FINAL
2022 SHELTER ISLAND YACHT BASIN
DISSOLVED COPPER TOTAL MAXIMUM DAILY LOAD
MONITORING AND PROGRESS REPORT

Submitted to:
California Regional Water Quality Control Board
San Diego Region

Prepared by:

WSP USA Environment & Infrastructure Inc.
9177 Sky Park Court
San Diego, CA 92123

Prepared for:

Port of San Diego
3165 Pacific Highway
San Diego, CA 92101

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ACRONYMS AND ABBREVIATIONS

303(d) list	Clean Water Act Section 303(d) list of water quality impaired segments
AB	Assembly Bill
AFP	antifoulant paint
Amec Foster Wheeler	Amec Foster Wheeler Environment & Infrastructure, Inc.
ASTM	ASTM International
Basin Plan	*Water Quality Control Plan for the San Diego Basin – Region 9*
BMP	best management practice
CCC	criterion continuous concentration
CCR	California Code of Regulations
CMC	criterion maximum concentration
COC	chain of custody
CTD	conductivity, temperature, and depth
CTR	California Toxics Rule
DO	dissolved oxygen
DOC	dissolved organic carbon
DPR	California Department of Pesticide Regulation
DPR Rule	Section 6190 of Title 3, California Code of Regulations
EC_{50}	median effective concentration
EDTA	ethylenediaminetetraacetic acid
ELAP	California Environmental Laboratory Accreditation Program
ER	equipment rinsate
FB	field blank
HPD	Harbor Police dock
Hull Cleaning Pause	8-week pause in in-water hull cleaning of copper-based AFPs in SIYB
Investigative Order	Investigative Order No. R9-2011-0036
ISO	International Organization for Standardization
J-flag	estimated value
JRMP	Jurisdictional Runoff Management Plan
LC_{50}	median lethal concentration
LID	low-impact development
LIMS	Laboratory Information Management System
MAR	marine habitat beneficial use
MIACC	Marina Inter-Agency Coordinating Committee
Monitoring Plan	SIYB Dissolved Copper TMDL Monitoring Plan
MP	management practice
MS4	Municipal Separate Storm Sewer System
N/A	not applicable
Named TMDL Parties	the parties named in the TMDL, namely the Port, marinas and yacht clubs, hull cleaners, boaters, and the City of San Diego
ND	non-detect
NELAP	National Environmental Laboratory Accreditation Program
NOEC	no observed effect concentration
NT	not tested
OAL	Office of Administrative Law
PDF	Portable Document Format
PDP	Priority Development Project
Port	San Diego Unified Port District
QA	quality assurance
QAPP	Quality Assurance Project Plan
QC	quality control
REF	reference

ACRONYMS AND ABBREVIATIONS (continued)

Regional Board	San Diego Regional Water Quality Control Board
RHMP	Regional Harbor Monitoring Program
SBE	Sea-Bird Electronics
SCCWRP	Southern California Coastal Water Research Project
SD	standard deviation
SE	standard error
SIML	Shelter Island Master Leaseholders
SIYB	Shelter Island Yacht Basin
SM	Standard Method
SOP	standard operating procedure
SWAMP	Surface Water Ambient Monitoring Program
SWRCB	State Water Resources Control Board
TAC	test acceptability criteria
TIE	toxicity identification evaluation
TMDL	Dissolved Copper Total Maximum Daily Load
TOC	total organic carbon
TSS	total suspended solids
TST	Test of Significant Toxicity
USEPA	United States Environmental Protection Agency
Weck	Weck Laboratories, Inc.
Weston	Weston Solutions, Inc.
WILD	wildlife habitat beneficial use
Wood	Wood Environment & Infrastructure Solutions, Inc.
WSP	WSP USA Environment & Infrastructure Inc.
WQO	water quality objective

UNITS OF MEASURE

~	approximately
%	percent
±	plus or minus
°C	degree(s) Celsius
>	greater than
<	less than
≤	less than or equal to
≥	greater than or equal to
μg/cm^2/day	microgram(s) per square centimeter per day
μg/L	microgram(s) per liter
μm	micrometer(s)
μS/cm	microSiemen(s) per centimeter
kg/yr	kilogram(s) per year
m^2	square meter(s)
mg/L	milligram(s) per liter
mL	milliliter(s)
ppt	part(s) per thousand

EXECUTIVE SUMMARY

This report is the annual Shelter Island Yacht Basin (SIYB) Dissolved Copper Total Maximum Daily Load (TMDL) Monitoring and Progress Report for 2022, which has been prepared by the San Diego Unified Port District (Port) in compliance with Investigative Order No. R9-2011-0036 (Investigative Order), issued to the Port by the San Diego Regional Water Quality Control Board (Regional Board) on March 11, 2011. Per the Investigative Order requirements, the report includes information on the following:

1. Best management practice (BMP) planning and implementation conducted by the Port. The report also includes information provided by the SIYB marinas and yacht clubs related to their BMP efforts.
2. The progress on the number of vessels that have converted from copper-based hull antifoulant paints (AFPs) to alternative AFPs (low- and non-copper). It should be noted that this effort relies primarily on third-party data provided by the SIYB marinas and yacht clubs from the annual vessel tracking census.
3. Water quality monitoring conducted by the Port to assess dissolved copper concentrations and toxicity in the water column.
4. An assessment of the trajectories of dissolved copper load and water quality measurements to evaluate progress toward attaining the SIYB TMDL and water quality objectives (WQOs).

The 2022 monitoring year was the final compliance year for the SIYB TMDL. The TMDL required a 76 percent (%) reduction in loading of dissolved copper into SIYB by the end of 2022. This report presents the findings from the last year of the TMDL and marks the final annual monitoring and progress report to fulfill the requirements of Investigative Order No. R9-2011-0036. The assessments of BMP implementation, loading, and water quality discussed in this report follow the approach described in the *SIYB Dissolved Copper TMDL Monitoring Plan* (Wood Environment & Infrastructure Solutions, Inc. [Wood], 2022a) in compliance with the Investigative Order.

It should be noted that the Port works collaboratively with the marinas and yacht clubs to review the vessel hull paint data used to assess dissolved copper load reductions and evaluate progress toward attaining the final SIYB TMDL load reduction target. While the vessel data collection is a collaborative effort, the findings, data interpretations, and conclusions in this report are those of the Port and are not intended to represent all TMDL parties. Other TMDL parties may identify alternative interpretations related to data included in the report or other data that were collected separately from this Investigative Order effort. In such instances, the other TMDL parties may choose to provide alternative data interpretations and conclusions independently to the Regional Board.

Best Management Practice Implementation

A variety of BMPs intended to reduce dissolved copper loading and improve water quality have been implemented in SIYB and throughout San Diego Bay. Highlights of the Port's copper reduction efforts in 2022 included the following:

- Continuing to keep all Port vessels copper-free by painting with non-copper hull paints, which contribute no load to SIYB

- Addressing data gaps related to effects of in-water hull cleaning on water quality through implementation of an 8-week pause in in-water hull cleaning (known as the Hull Cleaning Pause) of copper-based AFPs in SIYB and concurrent water quality monitoring
- Coordinating with the Regional Board and Port Marina Working Group on implementation of the Hull Cleaning Pause, discussion of TMDL strategies, and other copper-related items
- Engaging with paint manufacturers to discuss development of non-copper alternatives
- Providing ongoing education and outreach, such as regular meetings with stakeholders, up-to-date web content, and newspaper articles
- Collaborating with the California Department of Pesticide Regulation (DPR) and Los Angeles County Department of Beaches and Harbors to stay engaged on state and regional copper-related initiatives, TMDL issues, and progress

Vessel Conversions and Reduction of Dissolved Copper

Based on the vessel tracking assumptions presented in Section 2.2.3 of this report, the transition of a vessel from high-copper to non-copper hull paint was assumed to reduce annual loading by 0.9 kilogram per year (kg/yr), and the transition to DPR Category I or low-copper hull paints was assumed to reduce loading by 50% (i.e., 0.45 kg/yr). Vessel tracking indicates that, in 2022, there was a reduction of 44.9% (approximately 943 kg/yr) in annual dissolved copper loading to SIYB from vessels when compared with the SIYB TMDL assumed baseline load of 2,100 kg/yr[1].

Several notable points from the 2022 vessel tracking data are as follows:

- An 89% response rate was accomplished for the 2022 vessel tracking data set. This response rate may be attributed to continued invested efforts by marina and yacht club representatives in vessel tracking from year to year.
- The use of confirmed high-copper paints has decreased over the past 10 years, as high-copper paints can no longer be sold or applied to vessels in California under the DPR Rule.
- Of the remaining vessels classified with “high-copper” paints in 2022, 87% have either “unknown” or “unconfirmed” paints and consequently are conservatively assumed to have high-copper paints under the assumptions defined in the Monitoring Plan.
- Given the decreasing trend in high-copper paint use and the fact that it is no longer available at local boatyards, it is likely that some of the remaining unknown/unconfirmed paints are actually DPR Category I paints or aged-copper paints. This report provides alternative loading scenarios to evaluate the potential dissolved copper load contribution from unknown/unconfirmed paints.
- The number of vessels with non-copper alternatives has remained relatively consistent since the 2013 monitoring year.

[1] The total dissolved copper load per the SIYB TMDL equals 2,100 kilograms per year (kg/yr) from vessel paints (the total includes contributions from passive leaching and in-water hull cleaning). The estimated load contributions from background sources, urban runoff, and atmospheric deposition are not included in this total.

Water Quality Monitoring

Monitoring of water column dissolved copper and toxicity is required to track progress toward attainment of WQOs. In August 2022, water quality was sampled at six stations in SIYB and at two reference stations[2] (located adjacent to Shelter Island in the main San Diego Bay navigation channel) to determine dissolved copper concentrations, test for acute and chronic toxicity, and assess water quality trends.

Results from the August 2022 monitoring event showed that the basin-wide average dissolved copper level was 6.1 micrograms per liter (µg/L), which represents a 27% percent reduction in the basin-wide average relative to the 2005–2008 baseline (8.3 µg/L). However, dissolved copper concentrations at five of the six SIYB sampling stations still exceeded both the California Toxics Rule (CTR) criterion continuous concentration (CCC) WQO of 3.1 µg/L and the CTR acute criterion maximum concentration (CMC) WQO of 4.8 µg/L, as observed in previous years.

Chronic toxicity results indicated that ambient waters from one station (SIYB-1, the station farthest inside the basin) had statistically significant effects on developing mussel larvae. This finding is consistent with results from prior monitoring years. A Phase I toxicity identification evaluation suggested that the observed chronic toxicity at Station SIYB-1 was likely due to a cationic trace metal. Acute toxicity testing was performed using both topsmelt and inland silverside for the 2022 monitoring year. The combined results of both tests indicated that there were no acute toxic effects on these organisms from samples collected in SIYB in August 2022.

Water quality monitoring was also conducted at the same six SIYB stations and two reference locations during the winters of 2022 and 2023. This information was intended to supplement the summer compliance monitoring and evaluate seasonal variations in copper concentrations. Information on the two winter monitoring events is provided in Section 5.2 and Appendix H of this report.

Next Steps for the SIYB TMDL

Since the implementation of the SIYB TMDL and issuance of Investigative Order No. R9-2011-0036, the Port has assumed a leadership role and worked collaboratively with stakeholders and other Named TMDL Parties to plan, implement, and manage a suite of copper load reduction actions, initiatives, and studies in compliance with the aforementioned requirements. These efforts have enabled the Port to develop a comprehensive understanding of the SIYB TMDL and its complexity, and in many cases demonstrated work above and beyond the expectations set forth in the SIYB TMDL.

Based on the SIYB TMDL Monitoring Program findings since its initiation in 2011, there does not appear to be a clear and consistent link between copper load reduction and water quality improvement (as would be expected by the SIYB TMDL model predictions). Additionally, vessel tracking data have indicated that while copper AFPs remain legally available statewide, most boaters will continue to use and maintain these products. Further reductions in dissolved copper load are expected to continue beyond the TMDL timeline as the DPR Rule is fully realized and the remainder of vessels in SIYB transition to DPR Category I paints. However, without modifying

[2] To supplement the TMDL compliance monitoring, a second reference station (SIYB-REF-2) was added to the sampling locations starting in 2020 (further described in Section 2.3.1).

paint availability at the state level, achieving desired loading reductions and water quality standards may not be attainable, even beyond the existing SIYB TMDL timeline.

This report marks the final report for this SIYB TMDL and satisfactorily fulfills the requirements of Investigative Order No. R9-2011-0036. Moving forward, the Port will work collaboratively with the Regional Board and stakeholders to develop a more holistic approach to assess the ecological conditions in SIYB that is in line with the goals of the Strategic Water Quality Assessment Approach for San Diego Bay (Regional Board, 2022). The Port remains committed to working with the Regional Board, state agencies, and the other Named TMDL Parties to achieve our shared goals of protecting beneficial uses and improving water quality in SIYB and San Diego Bay.

1.0 INTRODUCTION

This report is the annual Shelter Island Yacht Basin (SIYB) Dissolved Copper Total Maximum Daily Load (TMDL) Monitoring and Progress Report for 2022, which has been prepared by the San Diego Unified Port District (Port) in compliance with Investigative Order No. R9-2011-0036 (Investigative Order), issued by the San Diego Regional Water Quality Control Board (Regional Board) to the Port on March 11, 2011 (Regional Board, 2011). The Investigative Order, issued under Section 13325 of the Porter-Cologne Water Quality Control Act, requires that the Port provide technical reports on the progress of implementation of the SIYB TMDL. To evaluate progress, the annual SIYB TMDL Monitoring Program is composed of three components: (1) best management practice (BMP) planning and implementation to reduce dissolved copper loading, (2) tracking of vessel hull paint use to assess the number of hull paint conversions from copper-based antifoulant paints (AFPs) to non-copper or low-copper alternatives, and (3) water quality monitoring to measure dissolved copper concentrations and toxicity in the water column. Data collected annually through the SIYB TMDL Monitoring Program are then used to assess trajectories of dissolved copper load and water quality measurements to evaluate progress toward attaining the SIYB TMDL and water quality objectives (WQOs).

The assessments of BMP implementation, loading, and water quality follow the Port's *SIYB Dissolved Copper TMDL Monitoring Plan* (Monitoring Plan) prepared in compliance with the Investigative Order. The Port works collaboratively with the marinas and yacht clubs to review the vessel hull paint data used to assess dissolved copper load reductions and evaluate progress toward attaining the final SIYB TMDL load reduction requirement. The annual vessel tracking is conducted both by the Port and the SIYB marinas and yacht clubs. However, the SIYB marinas and yacht clubs collect data independently from the Port and provide these data to the Port for review and inclusion in the annual report. Data from the SIYB marinas and yacht clubs are included, as received, in the appendices of this report. The loading analyses provided in this report incorporate these third-party vessel hull paint data with other Port data sets using the methodology identified in the Monitoring Plan.

It should be noted that this report is an annual requirement of the Investigative Order that was issued to the Port. While the vessel data collection is a collaborative effort, the findings, data interpretations, and conclusions in this report are those of the Port and are not intended to represent all TMDL parties. Other TMDL parties may identify alternative interpretations related to data included in the report or other data that were collected separately from this Investigative Order effort. In such instances, the other TMDL parties may choose to provide alternative data interpretations and conclusions independently to the Regional Board.

1.1 Background

Shelter Island Yacht Basin is a recreational yacht basin near the mouth of San Diego Bay, California, and comprises marinas and yacht clubs, an anchorage, a fuel dock, and other facilities that support recreational boating (Figure 1-1).

Copper is commonly used as a biocide in vessel AFPs because of its effectiveness in reducing fouling of vessel hulls. In California, the Department of Pesticide Regulation (DPR) regulates the use of copper in vessel paints; it is currently legal to use copper-based paints that are registered with and meet DPR registration requirements for pesticide usage. However, these paints leach copper into the water column. Copper is toxic not only to the targeted fouling organisms on vessel hulls, but possibly also to other non-targeted organisms that inhabit the basin.

SIYB waters contain dissolved copper concentrations that have exceeded numeric WQOs, as well as toxicity and pesticides narrative WQOs. These elevated dissolved copper concentrations may threaten and impair the wildlife habitat and marine habitat beneficial uses in the basin. Because of these exceedances, SIYB was placed on the list of impaired water bodies compiled pursuant to federal Clean Water Act Section 303(d) (303(d) list). The SIYB TMDL was developed to address and resolve this impairment by requiring reductions to the loading of dissolved copper into SIYB waters.

Figure 1-1. Location of Shelter Island Yacht Basin Within San Diego Bay

1.2 SIYB TMDL Compliance Schedule

Resolution No. R9-2005-0019 requires that the parties named in the SIYB TMDL, namely the Port, marinas and yacht clubs, hull cleaners, boaters, and the City of San Diego (Named TMDL Parties), reduce loading of dissolved copper into the water column by 76 percent (%), from 2,163 kilograms per year (kg/yr) to 567 kg/yr over a 17-year period (Regional Board, 2005). This period extended through 2022, based on the official SIYB TMDL approval date[3] of February 9, 2005. No reductions in dissolved copper loading were required during the initial two-year orientation period (2005–2007). The subsequent 15-year period required incremental reductions of dissolved copper loading by 10% within 7 years (2012); by 40% within 12 years (2017); and by 76% within 17 years (2022) (Table 1-1).

Table 1-1. Loading Targets for SIYB TMDL Attainment

Stage	Time Period	% Reduction from SIYB TMDL Estimated Loading	TMDL Compliance Year	Estimated Target Loading (kg/yr of Dissolved Copper)
1	2005–2007	0	N/A	N/A
2	2008–2012	10[a]	2012 (7 years)	1,900
3	2013–2017	40[b]	2017 (12 years)	1,300
4	2018–2022	76	2022 (17 years)	567

Notes:
a. Loading calculations presented in the *2012 SIYB Dissolved Copper TMDL Monitoring and Progress Report* showed that a 17% load reduction had been achieved. Compliance with the 2012 load reduction goal of 10% or greater was confirmed by the Regional Board in a letter to the Port dated July 26, 2013 (Appendix E).
b. Loading calculations presented in the *2017 SIYB Dissolved Copper TMDL Monitoring and Progress Report* showed that a 45% load reduction had been achieved. Compliance with the 2017 load reduction goal of 40% or greater was confirmed by the Regional Board October 10, 2018 Executive Officer's Report (Appendix E) as part of the monthly Regional Board meeting.
% = percent; kg/yr = kilogram(s) per year; N/A = not applicable; Port = San Diego Unified Port District; Regional Board = San Diego Regional Water Quality Control Board; SIYB = Shelter Island Yacht Basin; TMDL = Total Maximum Daily Load

For the first SIYB TMDL compliance year (2012), loading calculation estimates presented in the 2012 Monitoring Report (AMEC Environment & Infrastructure, Inc., 2013) indicated a 17% reduction in dissolved copper loading to SIYB, thus exceeding the 10% requirement. In a letter to the Port dated July 26, 2013, the Regional Board stated, "*Based on the data submitted and information provided in the Report [2012 SIYB TMDL Monitoring and Progress Report], the 10 percent reduction in dissolved copper loading required to demonstrate compliance with the SIYB TMDL by the December 1, 2012 compliance date was achieved*" (Regional Board, 2013). This letter is provided in Appendix E.

Similarly, loading calculation estimates presented in the 2017 Monitoring Report (Amec Foster Wheeler Environment & Infrastructure, Inc. [Amec Foster Wheeler], 2018a) indicated a 45% reduction in dissolved copper loading to SIYB, exceeding the 40% compliance requirement for the third stage of the SIYB TMDL (2017). In a letter to the Port dated September 11, 2018, the Regional Board stated, *"The Port District's 2017 Report marks the end of Stage 3 of the interim loading targets, and suggests that overall the Yacht Basin is meeting the 40 percent reduction target as a result of improved use of best management practices and vessel conversions to less*

[3] For a TMDL to be incorporated into the *Water Quality Control Plan for the San Diego Basin – Region 9* (Basin Plan; Regional Board,1994), it must be approved by the Regional Board, California State Water Resources Control Board, Office of Administrative Law (OAL), and United States Environmental Protection Agency (USEPA) Region 9. The official TMDL approval date is the OAL approval date.

toxic hull coatings" (Regional Board, 2018). At the October 10, 2018 Regional Board Monthly Meeting, the Executive Officer's Report confirmed and memorialized that the SIYB TMDL efforts had successfully achieved the 2017 compliance requirement. The letter from the Regional Board and the October 2018 Executive Officer's Report are included in Appendix E.

The 2022 monitoring year was the final compliance year for the SIYB TMDL. The TMDL required a 76% reduction in loading of dissolved copper into SIYB by the end of 2022. This report presents the findings from the last year of the SIYB TMDL and marks the final annual monitoring and progress report to fulfill the requirements of Investigative Order No. R9-2011-0036. In a letter to the Interested Parties of the SIYB dated October 5, 2022, the Regional Board recognized efforts by the TMDL Parties to reduce copper loading and improve water quality in SIYB over the course of the TMDL implementation period. The letter also outlined the Regional Board's approach moving forward beyond the 2022 compliance date. This letter is provided in Appendix E.

1.3 Sources of Dissolved Copper

Based on the Regional Board's source analysis, the total mass load of dissolved copper to SIYB was estimated to be 2,163 kg/yr, of which 98% of the inputs were attributable to passive leaching of copper from copper-based hull paints on vessels and to hull cleaning activities (Table 1-2). The SIYB TMDL identifies the Port, marinas and yacht clubs, hull cleaners, and boaters as responsible for reducing loads in their respective areas, operations, and activities. The total copper load from the SIYB TMDL equals 2,100 kg/yr from vessel paints. The estimated load reduction resulting from background, urban runoff, and atmospheric deposition (approximately 63 kg/yr) is not included in this total. This report evaluates the dissolved copper loading based on the vessel-related contribution, totaling 2,100 kg/yr, originating from the Harbor Police dock, transient dock, and weekend anchorage, in addition to marinas and yacht clubs, where boats reside and hull cleaning activities occur.

Table 1-2. Sources of Dissolved Copper per the SIYB TMDL

Source	Estimated Mass Load to SIYB (kg/yr)	Contribution to SIYB (% Dissolved Copper)
Passive Leaching	2,000	93
Hull Cleaning	100	5
Urban Runoff	30	1
Background	30	1
Direct Atmospheric Deposition	3	<1
Sediment	0	0
Total	2,163	100

Notes:
< = less than; % = percent; kg/yr = kilogram(s) per year; SIYB = Shelter Island Yacht Basin; TMDL = Total Maximum Daily Load

1.4 Water Quality Objective Criteria

The WQO for dissolved copper in SIYB is equal to the National Recommended Water Quality Criteria for Aquatic Life of the United States Environmental Protection Agency (USEPA) and the California Toxics Rule (CTR) water quality criteria for dissolved copper in marine environments (USEPA, 2000). Continuous or chronic exposures may not exceed 3.1 micrograms per liter (µg/L) over a 4-day average; acute exposures may not exceed 4.8 µg/L over a 1-hour average. Furthermore, numeric WQOs must not be exceeded more than once every 3 years.

In addition to numeric WQOs, the *Water Quality Control Plan for the San Diego Basin – Region 9* (Basin Plan) established narrative WQOs for toxicity and pesticides (Regional Board, 1994) as follows:

Toxicity Objective – *All waters shall be maintained free of toxic substances in concentrations that are toxic to, or that produce detrimental physiological responses in human, plant, animal, or aquatic life. Compliance with this objective will be determined by use of indicator organisms, analyses of species diversity, population density, growth anomalies, bioassays of appropriate duration, or other appropriate methods as specified by the Regional Board.*

Pesticide Objective – *No individual pesticide or combination of pesticides shall be present in the water column, sediments or biota at concentration(s) that adversely affect beneficial uses. Pesticides shall not be present at levels which will bioaccumulate in aquatic organisms to levels which are harmful to human health, wildlife or aquatic organisms.*

Two beneficial uses within SIYB are threatened by elevated dissolved copper concentrations: marine habitat (MAR) and wildlife habitat (WILD). The Regional Board indicated that if numeric WQOs are met for dissolved copper, then narrative WQOs would be considered met as well.

1.5 Monitoring Purpose

The Investigative Order required the Port to complete an annual evaluation, interpretation, and tabulation of BMPs, vessel hull paint information, and water quality sampling results. Because of the proportional contribution of copper loading to SIYB from copper-based hull paints, tracking of vessel conversions from copper to non-copper or lower-copper hull paints was the primary method used to assess compliance with SIYB TMDL load reduction targets. Water quality monitoring was required to assess long-term trends in the basin and provide comparisons with the numeric and narrative WQOs, by way of measuring surface water dissolved copper concentrations and evaluating toxicity. Monitoring was a necessary component to evaluate whether the trajectory of water quality measurements will meet WQOs. By conducting both vessel tracking and water quality monitoring on an annual basis, the relationship between load reductions and water quality could be evaluated. Additionally, this approach provided the data needed to assess the overall effectiveness of the SIYB TMDL implementation in attaining loading reduction targets and meeting numeric WQOs to protect the basin’s MAR and WILD beneficial uses.

1.6 Revision of the Monitoring Plan

The Monitoring Plan (Revision 8) (Wood Environment & Infrastructure Solutions, Inc. [Wood][4], 2022a; Appendix A) was updated for the 2022 monitoring year to reflect the 2022 monitoring period dates.

[4] The Environment & Infrastructure branch of Wood was acquired by WSP in September 2022 and is now known as “WSP USA Environment & Infrastructure Inc.”

In addition, the following updates were made to the SIYB TMDL water quality monitoring program, as described further in Section 2.0:

- Addition of acute toxicity testing using the inland silverside (*Menidia beryllina*) conducted concurrently with the routine compliance tests using Pacific topsmelt (*Atherinops affinis*) (see Section 2.3.6.1)
- Addition of a toxicity identification evaluation (TIE) for surface water samples collected from Station SIYB-1 conducted concurrently with compliance chronic toxicity tests using the Mediterranean mussel (*Mytilus galloprovincialis*) (see Section 2.3.6.4)

1.7 Implementation of Best Management Practices

The Port has developed a comprehensive Copper Reduction Program and is implementing BMPs to reduce copper loads at the Harbor Police dock, transient dock, and weekend anchorage, as well as supporting the other Named TMDL Parties with their load reduction and BMP implementation efforts in SIYB and throughout San Diego Bay. The five primary elements of the Port's Copper Reduction Program are as follows:

- Testing and research
- Transition to non-copper hull paints and DPR Category I paints (i.e., paints with leach rates less than or equal to (≤) 9.5 micrograms per square centimeter per day [μg/cm²/day])
- Policy development and legislation
- Education and outreach to boaters
- Monitoring and data assessment

The marinas and yacht clubs in SIYB also implement BMPs and compile vessel information from boat owners to assist in the preparation of this report.

Over the course of the SIYB TMDL program, multiple quality control measures have been integrated to build on previous knowledge and to help effectively implement the program, including the following:

- Meetings between the Port and other stakeholders in SIYB about the SIYB TMDL
- Increased scrutiny of water quality data and analytical methods
- Ongoing reassessment of field sampling techniques, including additional oversight of field procedures
- Review of methods used to track the types of hull paints used on vessels in SIYB
- Updates and improvements to modeling of copper loads, including assessments of in-water hull cleaning

These measures have been implemented to collect relevant useful data and to enhance communication among the marinas and yacht clubs and other Named TMDL Parties. The intent of this iterative and collaborative process is to provide transparency and to provide a scientifically defensible data set to support the SIYB TMDL compliance requirements.

1.8 New Initiatives and Adaptive Management

The following new program initiatives were implemented during the 2022 monitoring year:

1. A recommendation was made in the *2020 SIYB Dissolved Copper TMDL Monitoring and Progress Report* (Wood, 2021) to fill data gaps associated with the effects of in-water hull cleaning on water quality. To address this recommendation, the Port partnered with the Regional Board and SIYB stakeholders to evaluate how dissolved copper concentrations changed throughout SIYB before, during, and after an 8-week pause in in-water hull cleaning from December 19, 2021 through February 9, 2022 (referred to throughout the document as the "Hull Cleaning Pause"). The findings from the Hull Cleaning Pause study are summarized in Section 4.0 and presented in full in Appendix G.
2. The Port continued efforts to perform winter monitoring events to supplement the annual compliance monitoring, which occurs in the summer. These sampling efforts were conducted in March 2022 and January 2023. Water quality monitoring was conducted using the same sampling and analysis methodologies employed for the summer compliance monitoring, as discussed in Section 2.3. The purpose of the winter monitoring was to understand the potential seasonal variability of dissolved copper levels in SIYB and at the reference stations during a period of cooler water temperatures and lower frequencies of hull cleaning and vessel usage relative to the summer months. The findings from the winter monitoring events are discussed in Section 5.2 and presented in full in Appendix H.
3. Due to the many challenges experienced using Pacific topsmelt for toxicity testing in the current and previous monitoring years (e.g., limited organism supply and availability, poor organism health and sensitivity), the Port made a written request to the Regional Board on August 8, 2022 (Appendix E) to perform the acute bioassay test using the inland silverside (*Menidia beryllina*) concurrently with the routine topsmelt test for the 2022 SIYB TMDL summer monitoring event. This request was approved by the Regional Board via email on August 11, 2022 (Appendix E). The inland silverside is a USEPA-approved alternative test species for Pacific topsmelt that is commonly used in environmental compliance testing nationwide. To evaluate the inland silverside as a potential alternative test species for future toxicity testing in SIYB, the acute toxicity testing for the 2022 summer monitoring event was conducted using both Pacific topsmelt and the inland silverside. Acute toxicity testing results for both species are presented in Section 3.3.2.1.
4. The Port added a Phase I TIE component to the 2022 chronic toxicity testing program. Previously, in 2005, an initial Phase I TIE conducted by Southern California Coastal Water Research Project (SCCWRP) indicated that the toxicity observed in samples collected from SIYB was largely due to trace metals. The study identified copper as the most likely cause of toxicity because increasing dissolved copper concentrations correlated with increasing toxicity, and copper concentrations were high enough to account for virtually all the observed toxicity (Schiff et al., 2007). From 2011 through 2020, the SIYB TMDL Monitoring Program consistently observed a toxic effect on bivalve larvae at the innermost station in SIYB (Station SIYB-1).

   To evaluate whether the effect observed in recent toxicity testing in SIYB is still due to trace metals, or some other toxicant, a Phase I TIE was initiated concurrently with the summer toxicity testing on water collected from Station SIYB-1 to re-evaluate the likely class(es) of contaminants causing toxicity (if observed). Because there were no toxic effects on bivalve larvae observed at SIYB-1 during the 2021 summer monitoring event, the Phase I TIE approach was repeated during the 2022 summer monitoring event. Results of the Phase I TIE are presented in Section 3.3.2.2 and Appendix F.

Additional toxicant identification and confirmation (Phase II/III TIE) procedures were also conducted on the SIYB-1 sample collected during the 2023 winter monitoring event (see Section 5.2 and Appendix H).

1.9 Content of Report

This SIYB TMDL Monitoring and Progress Report presents the results for the 2022 monitoring year, as well as a summary of the findings from the entire TMDL implementation period (2011 through 2022), including the following:

- BMP implementation, including those BMPs implemented by the Port in SIYB and throughout San Diego Bay, as well as those implemented by the Shelter Island Master Leaseholders (SIML) TMDL Group, marinas, and yacht clubs in SIYB
- Methods used to estimate dissolved copper load and assess water quality in SIYB
- Tabulation, evaluation, and interpretation of data collected by the Port, marinas, and yacht clubs on vessel tracking and hull paint conversions
- Water quality monitoring data, including results from chemical and toxicological evaluations of surface water samples collected in August 2022
- A summary of findings from the Hull Cleaning Pause study
- Discussion of trends in copper loading and water quality in SIYB over time
- Programmatic analysis and lessons learned throughout the SIYB TMDL Monitoring Program
- Conclusions and recommendations for next steps

The report also includes several appendices with additional supporting information and data. Appendix A is the *2022 SIYB Dissolved Copper TMDL Monitoring Plan* (Wood, 2022a). Appendix B contains BMP plans for the Port, as well as marinas and yacht clubs. Appendix C includes vessel tracking data (including information for each available slip) for the entire SIYB. Appendix D contains the water quality monitoring results for the August 2022 monitoring event, including field-collected data, the analytical chemistry report, and the toxicity testing report. Appendix E includes SIYB-related correspondence between the Port and other agencies and other pertinent information. Appendix F is a technical memorandum summarizing the results of the Phase I TIE conducted to evaluate potential causes of chronic toxicity at Station SIYB-1. Appendix G is a technical report summarizing the methods and findings from the SIYB Hull Cleaning Pause study. Appendix H presents the results from the winter monitoring events conducted in SIYB in March 2022 and January 2023.

2.0 METHODS

This section describes the BMP plans in place to reduce copper loads, methods used to estimate load reductions, sampling methods to assess dissolved copper levels and toxicity in SIYB, and associated project-specific quality assurance (QA) and quality control (QC) procedures.

2.1 Implementation of Best Management Practices in SIYB and San Diego Bay

The Port has developed a Copper Reduction Program and maintains a cumulative list of its copper reduction BMPs implemented in SIYB in support of the SIYB TMDL (Appendix B). The report also describes BMPs or other actions implemented by the Port to reduce dissolved copper discharges from vessel hulls into other harbors and marinas within San Diego Bay and beyond, including actions with statewide or national applicability (Appendix B).

In addition, the marinas and yacht clubs submit specific BMP plans to the Port annually to detail the BMPs and actions that marinas and yacht clubs have implemented to reduce dissolved copper loads to SIYB. The marina and yacht club BMP plans are also provided in Appendix B.

2.2 Dissolved Copper Load Analysis

This section describes the methods and procedures used to track vessel hull paint use and estimate dissolved copper loading into SIYB during the 2022 monitoring period.

2.2.1 Tracking Hull Paint Use: DPR Product/Label Database

The DPR Rule (3 California Code of Regulations [CCR] section 6190) went into effect on July 1, 2018, establishing a maximum leach rate for copper AFPs that is protective of aquatic environments. Under this regulation, paint manufacturers are no longer allowed to import or sell copper-based paints with leach rates greater than 9.5 µg/cm^2/day for use on recreational vessels in California. Note that any existing stock could be sold until June 30, 2021.

Since implementation of the DPR Rule in July 2018, many copper-based AFPs have been reformulated to meet maximum allowable copper leach rate requirements. To assist with vessel tracking efforts, the DPR California Product/Label Database Application[5] was used to determine whether copper-based AFP products are actively registered (i.e., DPR Category I paints with leach rates ≤9.5 µg/cm^2/day). This database identifies the registration status of AFP products and relevant product information such as paint name, copper content, and DPR registration number. Copper-based AFP products that exceed the maximum copper leach rate of 9.5 µg/cm^2/day (i.e., non-DPR Category I paints) can no longer be registered through the DPR and are classified as "Inactive" in the DPR Product/Label Database product status.

In addition to copper-based AFPs, the DPR Product/Label Database was used to track other non-copper biocide AFPs (e.g., zinc, Irgarol, etc.) that are registered through the DPR. Non-biocide paints and products (which do not require registration through the DPR) were tracked using information obtained from the product manufacturers' websites.

[5] The DPR California Product/Label Database can be accessed at: https://apps.cdpr.ca.gov/docs/label/labelque.cfm

2.2.2 Vessel Tracking

Annual reduction of copper loading was assessed by tracking conversions of hull paints from copper to non-copper or lower-copper products (i.e., either by leach rate or copper content) for vessels moored in SIYB. The annual vessel tracking is conducted both by the Port (for the Harbor Police dock, transient dock, and weekend anchorage) and the SIYB marinas and yacht clubs. SIYB marinas and yacht clubs collected data independently from the Port and provided these data to the Port for review and inclusion in this report, as described in this section.

Yacht club and marina operators collect vessel data by surveying their boaters for the vessel-related information listed in Table 2-1. A standard survey form has been made available to all marinas and yacht clubs in SIYB and is included in Appendix A.

Table 2-1. Vessel Survey Data Collected in 2022

Vessel Tracking Data Fields	
1.	Name of Marina or Yacht Club
2.	Slip/Mooring Reference Number
3.	Slip/Mooring Occupation (percentage of time occupied)
4.	Vessel Type (power or sail)
5.	Vessel Length
6.	Vessel Beam Width
7.	Paint Type (copper, DPR category I, low-copper, or non-copper)
8.	Paint Product Name
9.	Paint Product Number
10.	Registration Number (when applicable)
11.	Boatyard Name or Purchase Date
12.	Painting Date (month)
13.	Painting Date (year)[a]
14.	Copper Content

Notes:
a. Aged-copper paints are determined by the painting date. To be considered an aged paint for the 2022 hull paint census, the vessel would have had to be painted on or prior to December 31, 2019.
DPR = Department of Pesticide Regulation; USEPA = United States Environmental Protection Agency

If no response was received initially, or if the vessel tracking survey form lacked pertinent information, yacht clubs and marina operators made follow-up efforts to obtain missing or incomplete records. Vessel information was then submitted to the Port in mid-January 2023 for review and inclusion in this report. Data from the SIYB marinas and yacht clubs are included, as received, in Appendix C.

Since 2018, the Port has also required all marinas and yacht clubs as Named TMDL Parties to provide a self-certification statement to the Port with their vessel tracking data submittals. For each facility, the signed self-certification statement declares that the data were prepared under the signatories' knowledge and direction, and that the data represented truthful, accurate, and complete information. Self-certification letters are provided in Appendix E.

Once the census results were received by the Port, annual hull census data from marinas and yacht clubs were reviewed to confirm paint types. Hull paint types were confirmed if the required supporting data that were provided for a given paint (e.g., product name and/or DPR registration number) were consistent with the DPR Product/Label Database (biocide paints) or the product manufacturer's website (non-biocide paints or products). Vessels stored out of the water (e.g., on HydroHoists®) or in slip liners, or reported to have no bottom paint, were also confirmed to have non-copper paint. If the vessel owner did not know the paint's DPR registration number or product name, or if information provided was inconsistent with the DPR Product/Label Database (biocide paints) or the product manufacturer's website (non-biocide paints or products) (e.g., paint name and/or DPR registration number provided were for different paints), hull paint types could not be confirmed and were conservatively assumed to be copper-based. For vessels to be considered to have hulls with aged-copper paints, the painting date submitted must have been on or before December 31, 2019 for the 2022 monitoring year. Following vessel tracking data review and confirmation, vessels were classified into the paint type categories outlined in Table 2-2.

Vessel tracking data from SIYB also included the percentage of time that slips were unoccupied or were occupied by vessels with copper, lower-copper (DPR Category I and low-copper paints), aged-copper, non-copper, or unknown hull paints, as required by the Investigative Order. The annual percentage of time that the slip was occupied was determined by dividing the total number of days occupied by 365 days. Hull paint data and percent occupancy information were compiled for each paint type and used to estimate the annual dissolved copper load to SIYB.

Table 2-2. Vessel Tracking Data Reported for 2022

Vessel Tracking Data Fields	
1.	Total number of slips or buoys in facility available to be occupied by vessels
2.	Number of unoccupied slips or buoys and length of time unoccupied during each year
3.	Number of vessels confirmed with copper-based hull paints and approximate length of time occupying a slip or buoy in facility each year
4.	Number of vessels confirmed with aged-copper-based hull paints[a] and approximate length of time occupying a slip or buoy in facility each year
5.	Number of vessels confirmed with DPR Category I or low-copper paints[b] and approximate length of time occupying a slip or buoy in facility each year
6.	Number of vessels confirmed with alternative hull paints, by hull paint type, and approximate length of time occupying a slip or buoy in facility each year
7.	Number of vessels with unconfirmed information regarding hull paints and approximate length of time occupying a slip or buoy in facility each year
8.	Estimate of the dissolved copper load reduction achieved for the year (kg/yr and percent)

Notes:
a. Per Regional Board letter dated July 26, 2013 (Appendix E).
b. Per Regional Board email dated November 9, 2015 (Appendix E).
DPR = Department of Pesticide Regulation; kg/yr = kilogram(s) per year

2.2.3 Annual Dissolved Copper Load

To estimate dissolved copper loads attributed to vessels for the SIYB TMDL Monitoring Program, the in-water hull cleaning load (100 kg/yr) and passive leaching load (2,000 kg/yr) identified in Appendix 2 of the SIYB TMDL were combined to form a total vessel-related load of 2,100 kg/yr. This vessel-related baseline load was divided by the total vessel population identified in the TMDL (2,363 vessels), which resulted in an annual per-vessel load of 0.89 kg/yr (rounded to 0.9 kg/yr).

The dissolved copper load attributed to in-water hull cleaning was identified in Appendix 2 of the SIYB TMDL (Regional Board, 2005) as approximately 100 kg/yr. As part of the Regional Board's load estimation, it was assumed that all SIYB vessel hulls were painted with copper paint, all hulls were cleaned approximately monthly, and in-water hull cleaning BMPs were used during half of the cleaning events. The remaining dissolved copper load identified in the TMDL (2,000 kg/yr) was attributed to passive leaching. Based on these assumptions, the total annual per-vessel load of 0.9 kg/yr is composed of the load from in-water hull cleaning (approximately 0.04 kg/yr) and passive leaching (approximately 0.86 kg/yr). Note that in-water hull cleaning of copper-based AFPs was not permitted in SIYB during the Hull Cleaning Pause from December 19, 2021 through February 9, 2022 (see Section 4.0). It was assumed that there was no dissolved copper loading to SIYB from in-water hull cleaning during the Hull Cleaning Pause. Therefore, dissolved copper load estimates presented herein account for the load reduction resulting from the portion of the Hull Cleaning Pause that occurred during the 2022 monitoring period (i.e., January 1 through February 9, 2022).

The following assumptions were used by the Regional Board to derive the baseline copper loading identified in Appendix 2 of the SIYB TMDL (Regional Board, 2005). Calculations of loading reductions were based on comparisons with these baseline conditions:

- All 2,363 SIYB slips or buoys were occupied by a number of vessels (N_v).
- All 2,363 vessels moored within SIYB have copper-based paints 100% of the time.
- Annual loading from passive leaching basin wide (L_p) equals 2,000 kg/yr.
- Annual loading from hull cleaning (L_h) equals 100 kg/yr.
- Average annual loading per vessel (L_v) with copper hull paint equals 0.9 kg/yr, where $L_v = (L_p + L_h)/N_v$.

The SIYB TMDL copper load reduction is assessed by tracking the number of vessel hulls with copper paint, lower-copper paint (DPR Category I or low-copper), aged-copper paint, or non-copper paint, and by counting the number of vacant slips in SIYB. In accordance with the SIYB TMDL, this loading reduction analysis assumed a loading reduction of approximately 0.9 kg/yr for every vessel in SIYB that converted from copper-based (i.e., non-DPR Category I) to non-copper-based paints. The use of lower-copper hull paints was also recognized in the TMDL as a viable means of reducing copper loading to the basin. Lower-copper paints are identified as DPR Category I paints and paints with a copper content of less than 40% (i.e., low-copper). This loading reduction analysis assumed that each vessel that transitioned to lower-copper hull paints reduced annual dissolved copper loading by 50% (0.45 kg/yr). Aged-copper paints were also considered to contribute a half-load if they were applied on or prior to December 31, 2019.

The vessel tracking program estimates loading reductions conservatively. If the most recent painting date is unknown, the vessel is assumed to be painted recently, and if the occupancy rate of a slip or mooring is not reported, the slip or mooring is assumed to be occupied 100% of the time (i.e., 365 days per year). In addition, if the hull paint name and type are unknown or cannot be confirmed, the paint is assumed to be copper-based. The DPR Rule went into effect on July 1, 2018, establishing a maximum leach rate of 9.5 $\mu g/cm^2/day$ for copper-based AFPs registered through the DPR and sold in California. As a result of the implementation of the DPR Rule, a majority of vessels painted since July 2018 should have DPR Category I paints. However, it should be noted that the existing stock of paints with leach rates exceeding the DPR maximum leach rate criterion were approved by the DPR for sale until June 30, 2021. As such, these high-copper (i.e., non-DPR Category I paints) will not be completely phased out in California until 3 years following the end of the DPR Rule transition period (i.e., June 30, 2024), when remaining high-copper paints would be considered “aged.” To account for the potential remaining non-DPR

Category I paints, estimated dissolved copper loading for any unknown or unconfirmed paints was calculated using two different approaches:

1. Original Conservative Approach: Any vessels painted with unknown or unconfirmed paints are conservatively assumed to have high-copper paint (0.9 kg/yr/vessel; Scenario 1 in Section 5.1.3).
2. Loading Approach Assuming Unknown or Unconfirmed Paints are DPR Category I: Any vessels painted with unknown or unconfirmed paints are assumed to have low-leach copper paint (0.45 kg/yr/vessel) as a result of the implementation of the DPR Rule (Scenario 3 in Section 5.1.3).

Annual loading was calculated for each slip by multiplying the reported dissolved copper annual loading for a given hull paint category by the percentage of time a slip was reported to be occupied (e.g., the product of 0.9 kg/yr for copper hull paints and 90% occupancy results in an annual loading of 0.81 kg/yr). In the case of the weekend anchorage and transient dock, data on the length of stay indicated by each permit issued were used to calculate annual occupancy and loading. Because no hull paint data were available, all vessels at the weekend anchorage and transient dock were conservatively assumed to have copper-based paints. All assumptions used to calculate annual dissolved copper loading are summarized in Table 2-3.

Table 2-3. Dissolved Copper Loading Calculation Assumptions

Dissolved Copper Loading Assumptions	
1.	All vessels moored in SIYB at the enactment of the TMDL had copper hull paints.
2.	Average annual dissolved copper load from a vessel with copper paint equals 0.9 kg/yr.
	a. The passive leaching load from a vessel with copper paint equals 0.86 kg/yr.
	b. The cleaning load from a vessel with copper paint equals 0.04 kg/yr.[a]
3.	Annual dissolved copper load for vessels with unknown or unconfirmed hull paints is calculated using two different approaches:
	a. Original Conservative Approach: Any vessels painted with unknown or unconfirmed paints are conservatively assumed to have high-copper paint (0.9 kg/yr/vessel; Scenario 1 in Section 5.1.3).
	b. Loading Approach Assuming Unknown or Unconfirmed Paints are DPR Category I: Any vessels painted with unknown or unconfirmed paints are assumed to have low-leach copper paint (0.45 kg/yr/vessel) as a result of the implementation of the DPR Rule (Scenario 3 in Section 5.1.3).
4.	Slips/moorings for which occupancy data are not provided are considered to be 100% occupied.
5.	Annual dissolved copper load from a vessel with non-copper hull paint equals 0 kg/yr.
6.	DPR Category I paints are paints with leach rates ≤9.5 µg/cm²/day. These paints are considered as lower copper.
7.	Low-copper hull paints are paints with less than 40% copper. These paints are also considered as lower copper.
8.	Average annual dissolved copper load from a vessel with lower-copper paint equals 0.45 kg/yr
	a. The passive leaching load from a vessel with lower-copper paint equals 0.43 kg/yr.
	b. The cleaning load from a vessel with lower-copper paint equals 0.02 kg/yr.[a]
9	A vessel determined to have aged-copper paint (i.e., copper paint applied to a vessel hull prior to December 31, 2019) contributes an annual dissolved copper load of 0.45 kg/yr.
10.	Annual loads will be normalized by the percentage of time vessels are docked in SIYB.

Notes:
a. Dissolved copper load estimates presented herein account for the load reduction resulting from the portion of the Hull Cleaning Pause that occurred during the 2022 monitoring period (i.e., January 1 through February 9, 2022). The annual dissolved copper load from in-water hull cleaning assuming no loading occurred during the Pause was determined to be approximately 0.0356 kg/yr/vessel for vessels with high-copper paint and 0.0178 kg/yr/vessel for vessels with lower-copper paint.
≤ = less than or equal to; µg/cm²/day = microgram(s) per square centimeter per day; % = percent; DPR = Department of Pesticide Regulation; kg/yr = kilogram(s) per year; SIYB = Shelter Island Yacht Basin; TMDL = total maximum daily load

2.3 Water Quality Monitoring

Water quality samples were collected to assess levels of dissolved copper and toxicity in the basin. The monitoring methods used were consistent with those of prior studies conducted by the Regional Board in SIYB, as reported in Appendix 6 of the SIYB TMDL Technical Report (Regional Board, 2005).

2.3.1 Sampling Station Locations

From 2011 through 2019, the annual compliance monitoring was conducted at six stations within SIYB and one reference station (SIYB-REF-1[6]) in the main channel of San Diego Bay. These station locations were similar to those sampled by the Regional Board in prior studies and met the Investigative Order requirement of spatially representing dissolved copper concentrations in SIYB, as described in the original Monitoring Plan and most recent update (Weston Solutions, Inc. [Weston], 2011; Wood, 2022a). Starting in 2020, a second reference station (SIYB-REF-2), located farther from the mouth of SIYB, was added as a sampling station to provide a better understanding of the gradient of dissolved copper levels in San Diego Bay moving away from the mouth of SIYB and the background conditions within San Diego Bay outside SIYB. Station locations are provided in Table 2-4 and Figure 2-1. To the greatest extent possible, samples were collected within approximately plus or minus (±) 3 meters of the target coordinates.

Table 2-4. Sampling Station Coordinates

Station	Target Coordinates		Actual Coordinates	
	Latitude	Longitude	Latitude	Longitude
SIYB-1	32.71821	-117.22601	32.71811	-117.22605
SIYB-2	32.71412	-117.22921	32.71422	-117.22916
SIYB-3	32.71550	-117.22989	32.71552	-117.22984
SIYB-4	32.71683	-117.23203	32.71690	-117.23204
SIYB-5	32.71217	-117.23297	32.71214	-117.23295
SIYB-6	32.70858	-117.23514	32.70875	-117.23507
SIYB-REF-1 [a]	32.70406	-117.23232	32.70418	-117.23220
SIYB-REF-2 [b]	32.70926	-117.22544	32.70930	-117.22551

Notes:
a. SIYB-REF-1 was identified as SIYB-REF in prior reports.
b. SIYB-REF-2 was added as a second reference station beginning in 2020 to supplement the SIYB TMDL compliance monitoring.
REF = reference; SIYB = Shelter Island Yacht Basin

6 Previously identified as "SIYB-REF."

Figure 2-1. Shelter Island Yacht Basin TMDL Sampling Stations

2.3.2 Sampling Date

Surface water at the eight sampling stations (six SIYB stations and two San Diego Bay reference stations) was sampled on August 16, 2022. In accordance with the Monitoring Plan (Appendix A), water sampling bracketed slack high tide during the summer[7], as depicted in Figure 2-2.

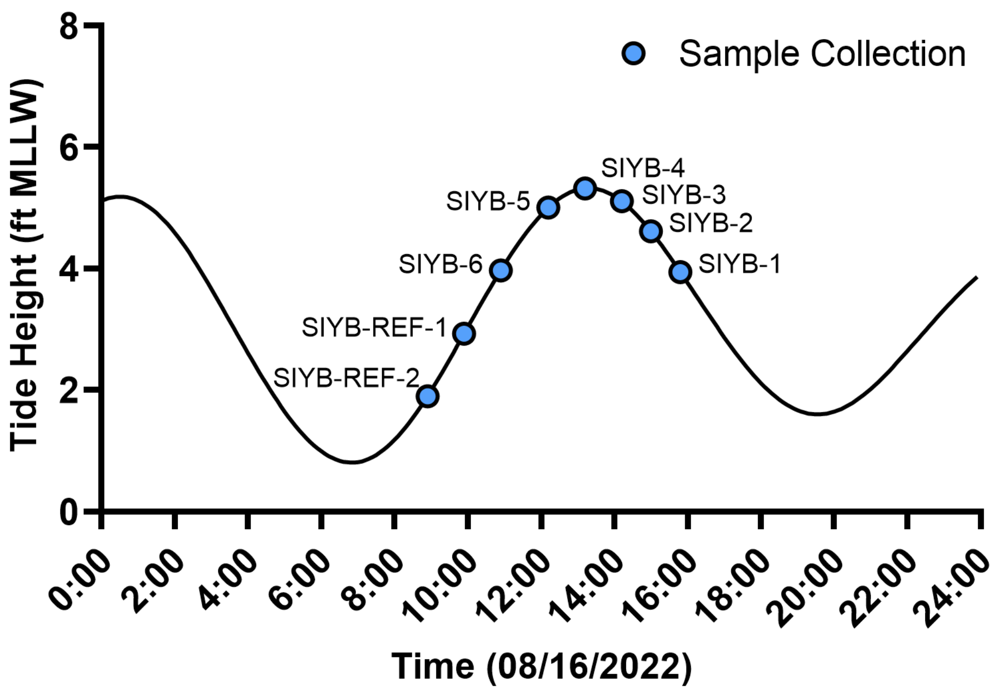

Figure 2-2. August 16, 2022 Sample Collection Times Over Tidal Cycle

Note: High tide on 08/16/2022 was +5.71 feet at 13:18 (https://tidesandcurrents.noaa.gov/waterlevels.html?id=9410170)

2.3.3 Sample Collection

Discrete surface water samples were collected from each station at a depth of 1 meter using a Niskin bottle deployed from a research vessel. Surface Water Ambient Monitoring Program (SWAMP)-defined "clean hands" techniques (California State Water Resources Control Board [SWRCB], 2014) were used, consistent with the project-specific and approved SIYB TMDL Quality Assurance Project Plan (QAPP) (Wood, 2022b). After collection, water samples were transferred to labeled containers for analysis of total and dissolved copper and zinc, total organic carbon (TOC), dissolved organic carbon (DOC), total suspended solids (TSS), and toxicity[8].

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[7] To supplement the annual TMDL compliance monitoring, additional water quality monitoring events were conducted in March 2022 and January 2023 using the same sampling and analysis methodologies used during the compliance monitoring event in the summer. Findings from these events are summarized in Section 5.2 and presented in full in Appendix H. The goal of the supplemental winter monitoring was to assess the basin-wide dissolved copper levels during a second seasonal index period. While the summer compliance monitoring is conducted at a peak time of higher water temperatures, vessel usage, and hull cleaning, the winter monitoring events were completed when these site characteristics were presumed to be lower compared with those during the summer. This information is useful when evaluating potential seasonal effects on the dissolved copper levels in SIYB.

[8] Because the sample from SIYB-REF-2 was collected only to assess variability in dissolved copper levels at the reference stations, this sample was not tested for toxicity.

Field water quality measurements of temperature, conductivity, salinity, pH, dissolved oxygen (DO), and light transmittance were also taken at each station, including surface readings and top-to-bottom profiles[9]. In situ analytical methods and detection limits are listed in Table 2-5.

Table 2-5. In Situ Analytical Methods and Detection Limits

Water Quality Measurement	Method	Instrument Sensitivity
Temperature	SBE CTD and YSI ProDSS	± 0.1 °C
Specific Conductance	SBE CTD and YSI ProDSS	± 1 µS/cm
Salinity	SBE CTD and YSI ProDSS	± 0.1 ppt
pH	SBE CTD and YSI ProDSS	± 0.1 pH unit
Dissolved Oxygen	SBE CTD and YSI ProDSS	± 0.1 mg/L
Light Transmittance	SBE CTD	± 0.1%

Notes:
°C = degree(s) Celsius; µS/cm = microSiemen(s) per centimeter; % = percent; ± = plus or minus; CTD = conductivity, temperature, and depth; mg/L = milligram(s) per liter; ppt = part(s) per thousand; SBE = Sea-Bird Electronics

Detailed field notes (Appendix D) and photographs (Figure 2-3) were taken during sample collection at each station. All samples were logged on chain-of-custody (COC) forms and then placed in coolers on ice. Samples were stored at 4 degrees Celsius (°C) in the dark until delivered to the appropriate laboratory for analysis. Water chemistry analyses were conducted by Weck Laboratories, Inc. (Weck) in City of Industry, California; toxicity tests were conducted by WSP USA Environment & Infrastructure Inc. (WSP) Environmental Toxicology Laboratory in San Diego, California.

2.3.4 Equipment Decontamination

The Niskin bottle was cleaned prior to sampling with Alconox and thoroughly rinsed with deionized water. Upon deployment, the Niskin bottle received a thorough site water rinse at each station prior to sample collection. After collection, water samples were transferred using SWAMP “clean hands” techniques (SWRCB, 2014) from the Niskin bottle to laboratory-certified, contaminant-free sample bottles.

[9] Due to field collection schedule limitations, no CTD water quality profile was captured at station SIYB-REF-2.

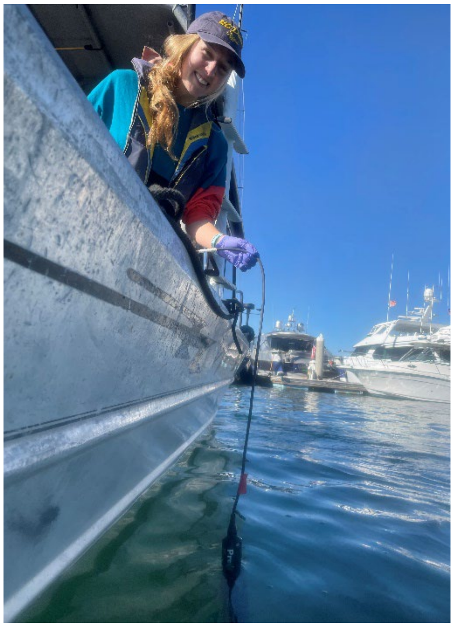

Photo A. Water quality readings of temperature, conductivity, salinity, pH, and dissolved oxygen were taken before, during, and after sampling using a YSI water quality meter.

Photo B. Recording of weather conditions, activities such as boat cleaning, and any other observations that may have an impact on water quality was an important component of the field monitoring program.

Photo C. Water samples were collected using a Niskin bottle and following SWAMP "clean hands" sampling techniques.

Photo D. Water samples were filtered in the field immediately after collection for analysis of dissolved metals.

Figure 2-3. Field Sampling Photographs

2.3.5 Chemical Analyses

After collection was completed, samples were transported to the laboratory under customary COC protocols. Samples were analyzed for total and dissolved copper, total and dissolved zinc, TOC, DOC, and TSS, following certified USEPA or Standard Method (SM) test methods.

The laboratory analytical methods and target detection and reporting limits are specified in Table 2-6. Actual method detection and reporting limits are provided in Appendix D.

Table 2-6. Laboratory Analytical Methods

Water Quality Measurement	Method	Target Method Detection Limit	Target Reporting Limit
Total Copper	USEPA 1640	0.0038 µg/L	0.010 µg/L
Dissolved Copper	USEPA 1640	0.0038 µg/L	0.010 µg/L
Total Zinc	USEPA 1640	0.036 µg/L	0.20 µg/L
Dissolved Zinc	USEPA 1640	0.036 µg/L	0.20 µg/L
TOC	SM 5310B	0.19 mg/L	0.30 mg/L
DOC	SM 5310B	0.15 mg/L	0.30 mg/L
TSS	SM 2540D	N/A	5.0 mg/L

Notes:
µg/L = microgram(s) per liter; DOC = dissolved organic carbon; mg/L = milligram(s) per liter; N/A = not applicable; SM = Standard Method; TOC = total organic carbon; TSS = total suspended solids; USEPA = United States Environmental Protection Agency

Analysis of water quality data included comparison of dissolved copper levels with numeric WQOs. In addition, basin-wide average dissolved copper concentrations were compared with the surface water baseline level of 8.3 $\pm$ 1.4 µg/L (mean plus or minus standard error). This baseline value was calculated using surface water quality data collected from 2005 through 2008 from stations in the vicinity of the Regional Board monitoring station network (Weston, 2011).

2.3.6 Toxicological Analyses

To assess compliance with the narrative toxicity objective, toxicity testing was performed on samples collected from within SIYB and a reference site (SIYB-REF-1). Routine toxicity testing included a 96-hour acute bioassay test using Pacific topsmelt (*Atherinops affinis*) and a 48-hour chronic bioassay test using mussel larvae (*Mytilus galloprovincialis*). Due to challenges experienced using Pacific topsmelt for toxicity testing in the current and previous monitoring years (e.g., limited organism supply and availability, poor organism health and sensitivity upon arrival to the laboratory), the Port made a written request to the Regional Board on August 8, 2022 to perform the acute bioassay test using the inland silverside (*Menidia beryllina*) concurrently with the routine topsmelt test for the 2022 summer monitoring event.[10] This request was approved by the Regional Board via email on August 11, 2022 (Appendix E).

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[10] In prior years, there have been many challenges with using Pacific topsmelt for toxicity testing, including limited test organism supply and availability, as well as poor organism health and sensitivity upon arrival at the laboratory, due to difficulties culturing these organisms in a laboratory setting. The SIYB TMDL Monitoring Program does not currently include an alternative test species to use if issues are encountered with the primary test species (i.e., Pacific topsmelt). However, the inland silverside (*Menidia beryllina*) is a USEPA-approved alternative test species for Pacific topsmelt that is commonly used in environmental compliance testing nationwide. To evaluate inland silverside as a potential alternative test species for future toxicity testing in SIYB, the acute toxicity testing for the 2022 summer monitoring event was conducted using both topsmelt and inland silverside.

2.3.6.1 96-Hour Acute Bioassays Using Topsmelt and Inland Silverside

Both topsmelt and inland silverside acute toxicity tests were initiated on August 17, 2022, following the procedures in *Methods for Measuring the Acute Toxicity of Effluents and Receiving Waters to Freshwater and Marine Organisms* (USEPA, 2002). For the August 2022 toxicity testing program, an insufficient number of topsmelt were available from the test organism supplier to perform topsmelt tests on the full dilution series. Therefore, topsmelt tests were only performed on the laboratory control and undiluted compliance samples (i.e., 100% sample concentration) for each site. Inland silverside tests were performed on the full dilution series (0, 25, 50, and 100% sample concentrations).

Juvenile fish from each species were exposed for 96 hours to each sample concentration (or laboratory control). Each concentration was tested with six replicates and five fish per replicate. Water quality measurements of DO, temperature, pH, and salinity were conducted daily. Test conditions are summarized in Table 2-7. After 96 hours, percent survival for each species was calculated. The test was considered acceptable if mean survival was greater than or equal to 90% in the controls.

Table 2-7. Conditions for the 96-Hour Acute Bioassay: Pacific Topsmelt and Inland Silverside

96-Hour Acute Fish Survival Bioassay Conditions	
Samples Tested [a]	SIYB-1, SIYB-2, SIYB-3, SIYB-4, SIYB-5, SIYB-6, SIYB-REF-1
Date Sampled	August 16, 2022
Test Dates	August 17–21, 2022
Test Species	Pacific topsmelt *(Atherinops affinis)* Inland silverside (*Menidia beryllina*)
Test Protocol	USEPA Acute Manual, 2002 (EPA/821/R-02/012)
Test Acceptability Criterion	≥90% mean survival in the laboratory control
Test Type and Duration	Acute survival/96-hour static-renewal (48-hour water renewal)
Organism Supplier	Aquatic BioSystems, Fort Collins, Colorado
Control Water Source	Scripps Pier seawater
Acclimation Time [b]	Pacific topsmelt: 1 day Inland silverside: 1 day
Age at Test Initiation [c]	Pacific topsmelt: 10 days old Inland silverside: 12 days old
Test Concentrations	Pacific topsmelt: 0 (laboratory control) and 100% sample [d] Inland silverside: 0, 25, 50, and 100% sample
Replicates per Sample	6
Organisms Exposed per Replicate	5
Exposure Volume	250 mL

Notes:
a. Because the sample from SIYB-REF-2 was collected only to assess variability in dissolved copper levels at the reference stations, this sample was not tested for toxicity.
b. There is no USEPA method requirement for acclimation time (USEPA, 2002). However, the toxicity laboratory recommends a minimum 1- to 2-day acclimation time prior to testing. Both the topsmelt and inland silversides used for testing were acclimated for at least 1 day, as recommended by the laboratory.
c. The USEPA method requires topsmelt and inland silversides to be 7 to 15 days old at test initiation (USEPA, 2002). The topsmelt and inland silverside batches used for testing were within this age range.
d. An insufficient number of topsmelt were available from the test organism supplier to perform topsmelt tests on the full dilution series. Therefore, topsmelt tests were only performed on the laboratory control and undiluted compliance samples (i.e., 100% sample concentration) for each site.
≥ = greater than or equal to; µm = micrometer(s); % = percent; mL = milliliter(s); REF = reference; SIYB = Shelter Island Yacht Basin; USEPA = United States Environmental Protection Agency

In addition, 96-hour reference toxicant tests using copper chloride were conducted using both topsmelt and inland silversides to evaluate the relative sensitivity of the test organisms to a single known chemical, as well as the laboratory's proficiency with the test procedure. The reference toxicant tests were conducted with copper concentrations of 0, 25, 50, 100, 200, and 400 µg/L. The reference toxicant tests were conducted concurrently with the SIYB acute toxicity tests and used test organisms from the same batches. Following test termination, the median lethal concentration (LC_{50}) was calculated and compared with historical laboratory reference toxicant test data for each species. Test organisms were considered appropriately sensitive if the test LC_{50} was within two standard deviations of the historical laboratory mean for a given species.

2.3.6.2 48-Hour Chronic Bioassay Using the Mediterranean Mussel

The 48-hour bivalve larvae tests were initiated on August 17, 2022 and followed the procedures in *Short-term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to West Coast Marine and Estuarine Organisms* (USEPA, 1995b). Bivalves were exposed to five sample concentrations and a control. Each concentration was tested with five replicates, and approximately 200 larvae were targeted for inoculation into each replicate. Daily water quality measurements included DO, temperature, pH, and salinity. Test conditions are summarized in Table 2-8.

Table 2-8. Conditions for the 48-Hour Chronic Mussel Development Bioassay

48-Hour Chronic Bivalve Survival and Shell Development Bioassay Conditions	
Samples Tested [a]	SIYB-1, SIYB-2, SIYB-3, SIYB-4, SIYB-5, SIYB-6, SIYB-REF-1
Date Sampled	August 16, 2022
Test Dates	August 17–19, 2022
Test Species	Mediterranean mussel *(Mytilus galloprovincialis)*
Test Protocol	USEPA 1995 West Coast Manual (EPA/600/R-95/136); ASTM, 1998 (E 724-98)
Test Acceptability Criteria	USEPA Criteria: ≥50% survival in the laboratory control; ≥90% proportion normal development in the surviving embryos; and <25% minimum significant difference ASTM Criteria: ≥70% combined survival/proportion normal in the laboratory control
Test Type/Duration	Bivalve larvae survival and development (endpoint reported as normal development of surviving embryos) – Static/48 hours
Organism Source	Mission Bay, San Diego, California
Control Water Source	Scripps Pier seawater, 20-µm filtered
Age Class of Mussels Exposed	<4 hour-old embryos
Test Concentrations	0 (laboratory control), 6.25, 12.5, 25, 50, and 100% sample
Replicates/Sample	5
Initial Density of Organisms Exposed per Replicate	~200
Exposure Volume	10 mL

Notes:
a. Because the sample from SIYB-REF-2 was collected only to assess variability in dissolved copper levels at the reference stations, this sample was not tested for toxicity.
~ = approximately; ≥ = greater than or equal to; < = less than; µm = micrometer(s); % = percent; ASTM = ASTM International; mL = milliliter(s); REF = reference; SIYB = Shelter Island Yacht Basin; USEPA = United States Environmental Protection Agency

After test termination, the percentage of surviving embryos with normal development was calculated to determine whether normality had been significantly reduced. The test was considered acceptable if (1) at least 50% of larvae survived in the controls, and (2) an average of 90% of surviving larvae developed normally in the controls. In addition, the percent minimum significant difference in the test must be less than 25%. A combined endpoint of normal surviving embryos was reported.

A 48-hour reference toxicant test using copper chloride was conducted concurrently with the SIYB chronic toxicity tests to evaluate the relative sensitivity of test organisms and the laboratory's proficiency with the test procedure. The bivalve reference toxicant test was conducted with copper concentrations of 0, 2.5, 5.0, 10, 20, and 40 µg/L. The same batch of test organisms was used for both the reference toxicant test and the project samples. At test termination, the median effective concentration (EC_{50}) was calculated and compared with historical laboratory reference toxicant test data for this species. Test organisms were considered to be responsive and appropriately sensitive if the test EC_{50} was within two standard deviations of the respective historical laboratory mean.

2.3.6.3 Toxicity Statistical Analyses

Determinations of toxicity using the 96-hour acute and 48-hour chronic bioassays were statistically assessed using the Comprehensive Environmental Toxicity Information System™, Tidepool Scientific Software. Survival of topsmelt and inland silversides and normal development of surviving mussel embryos in each test dilution from SIYB were compared with organism performance observed in control exposures to filtered clean seawater collected from the end of the pier at Scripps Institution of Oceanography in La Jolla, California. Results were used to determine LC_{50} and EC_{50} values. If fish survival and normal embryo development in the controls did not differ significantly from those of the treatments, then conditions were considered nontoxic at the station. The Test of Significant Toxicity (TST) method was used to identify any samples that exhibited a statistically significant difference from the control (USEPA, 2010).

2.3.6.4 Toxicity Identification Evaluation

The SIYB TMDL Monitoring Program has consistently[11] observed a toxic effect on bivalve larvae at the innermost station in SIYB (Station SIYB-1). As discussed in Section 1.8, a study performed by SCCWRP in 2005 indicated that the toxicity observed in samples collected in SIYB was largely due to trace metals (Schiff et al., 2007).

To determine whether the effect observed during recent toxicity testing in SIYB is still due to trace metals or some other toxicant, a Phase I TIE was initiated concurrently with the compliance chronic toxicity testing on water collected from Station SIYB-1 during the 2022 summer monitoring event to re-evaluate the likely class(es) of contaminants causing toxicity (if observed). The site-specific TIE approach is outlined in the Monitoring Plan (Wood, 2022a; Appendix A) and in the technical memorandum in Appendix F.

[11] No chronic toxicity was observed at Station SIYB-1 during the 2021 summer monitoring event. Therefore, the Phase I TIE treatments performed were unable to determine a potential cause of toxicity.

2.4 Quality Assurance and Quality Control

This section describes the QA/QC procedures for all field activities and laboratory analyses. Specific QA/QC procedures are provided in detail in the SIYB TMDL QAPP (Wood, 2022b).

2.4.1 Field QA/QC

Sampling process QA/QC included preparation prior to, during, and after sample collection to minimize the possibility of compromising sample integrity. The sample collection team was trained in and followed field sampling standard operating procedures (SOPs), as described in the SIYB QAPP (Wood, 2022b). The WSP Field QA Officer and a Port representative were onboard the sampling vessel at all times to review each step of the sample and data collection processes. Additionally, Port-approved field checklists were used throughout the monitoring event to ensure that all sample collection procedures were consistent at each station and all required field data were recorded properly (see Appendix D).

Field water quality meters were checked and calibrated in accordance with the manufacturer's specifications prior to monitoring. During sample collection, field team members wore powder-free nitrile gloves and avoided contamination of samples at all times by using SWAMP-defined "clean hands" techniques (SWRCB, 2014). All samples were collected in laboratory-supplied, laboratory-certified, contaminant-free sample bottles.

As required by SWAMP protocols, a field replicate was collected at one station (SIYB-1) to assess variability in sampling procedures and ambient conditions. The field replicate sample was analyzed for the same suite of chemical parameters (no toxicity) as the primary test samples. One equipment rinse (ER) blank and one field blank (FB) were also collected.

Chemistry and toxicity samples were uniquely identified on sample labels with the project title, appropriate sample identification, date and time of sample collection, analysis type, and preservation method. Sample labels were inspected by a QA reviewer before and after bottles were filled at each station to ensure that every sample was labeled correctly. All samples were kept on ice from the time of sample collection until delivery to the analytical laboratories for analysis within method-specified holding times. Both Weck and WSP Environmental Toxicology Laboratory are accredited by the National Environmental Laboratory Accreditation Program (NELAP) and/or California Environmental Accreditation Program (ELAP) for the specific tests that were performed at the time they were conducted.

Customary COC procedures were used for all samples throughout the collection, transport, and analytical processes, as detailed in the QAPP (Wood, 2022b). Completed COC forms are provided in the laboratory reports in Appendix D.

2.4.2 Laboratory Analytical QA/QC

The QA objectives for chemical analysis conducted by the participating analytical laboratories are provided in their individual laboratory QA manuals. The objectives for accuracy and precision involved all aspects of the testing process, including:

- Methods and SOPs
- Calibration methods and frequency

- Data analysis, validation, and reporting
- Internal QC
- Preventive maintenance
- Procedures to ensure data accuracy and completeness

Results of all laboratory QA/QC analyses are reported in the laboratory reports in Appendix D. Any QC samples that failed to meet the specified QA/QC criteria in the methodology or QAPP were identified, and the corresponding data were qualified appropriately. Furthermore, in cases where laboratory data were not within control limits, follow-up testing was performed by the laboratory to verify results wherever applicable. All QA/QC records are kept on file for review.

2.5 Data Review and Management

After the monitoring event, field data sheets were checked for completeness and accuracy by the field staff and the QA reviewer. In addition, all COC forms were checked against sample labels at the end of the day prior to sample transport to the laboratories.

In the laboratory, technicians documented sample receipt in laboratory logbooks, and samples were logged into the electronic Laboratory Information Management System (LIMS) for sample tracking purposes to ensure that holding times were met and samples were efficiently analyzed. Logbooks were maintained at each instrument to provide hardcopy documentation of analytical runs, and data generated by each instrument were directly uploaded to the LIMS for data review and processing. Data validation was performed within the LIMS and included application of both performance-based and project-specific QC criteria to reject or accept specific data. Data for laboratory analyses were entered directly onto data sheets. The technician who generated the data had primary responsibility for the accuracy and completeness of the sample description, analysis information, results, and documentation.

All data were subsequently reviewed and verified by each section supervisor and released to the laboratory project manager to determine whether data quality objectives had been met for final reporting, and whether appropriate corrective actions had been taken when necessary. Any necessary corrective actions were coordinated with the laboratory project manager, the laboratory QA/QC director, and the WSP project manager for resolution.

After completion of the data review by the laboratories, laboratory results were forwarded to WSP as Portable Document Format (PDF) files for review and reporting. All laboratory records and data received are maintained in the project files and included in Appendix D.

3.0 RESULTS

This section provides details on the Port's dissolved copper BMP implementation activities; the marinas' and yacht clubs' dissolved copper BMP implementation activities; results of the vessel tracking census; estimates of dissolved copper load reduction; and results of the ambient water quality and toxicity monitoring performed in SIYB in 2022.

3.1 BMP Implementation

All Named TMDL Parties have obligations to implement BMPs and meet the copper loading reduction requirements outlined in the SIYB TMDL. The Port continues to address copper loading at the Harbor Police dock, the transient dock, and the weekend anchorage, and to support the load reduction efforts of the other Named TMDL Parties. The Port has implemented or is in the process of planning and implementing several categories of BMPs and other actions to reduce dissolved copper loads to SIYB, including:

- Hull paint transition
- Hull cleaning BMPs
- Education and outreach
- Grant funding and incentives
- Alternative hull paint studies
- Agency-wide activities
- Monitoring
- Reporting
- Policy/regulation
- Testing and research
- Structural and mechanical BMPs

Marinas and yacht clubs have also indicated to the Port that they are implementing BMPs. Sections 3.1.1 and 3.1.2 describe specific BMPs used during the 2022 monitoring year. Section 3.1.1 was provided directly by the Port. Section 3.1.2 was provided directly by individual marinas and yacht clubs and the SIML TMDL Group.

3.1.1 Port of San Diego BMPs to Reduce Copper Loading

The Port has planned, initiated, and implemented BMPs and other actions to reduce discharges of dissolved copper into harbors and marinas within SIYB, throughout San Diego Bay, and statewide as part of its Copper Reduction Program. The program focuses on source contributions of copper, identifies a strategic approach for implementing projects over the short and long term aimed at copper reduction, and seeks to effectively achieve regulatory compliance for loading and improved water quality while balancing economic and public interests.

The projects implemented by the Port since the Regional Board adopted the SIYB TMDL have reduced dissolved copper discharges to SIYB and San Diego Bay and have supported the load reduction efforts of the other Named TMDL Parties, including the SIYB marinas and yacht clubs, hull cleaners, and boaters. The Port's Copper Reduction Program began in 2007 and identified more than 30 key initiatives, many of which enabled the Port and the other Named TMDL Parties to comply with the SIYB TMDL interim targets.

Lastly, the Port continued to support and encourage the other Named TMDL Parties (i.e., boaters, in-water hull cleaners, and SIYB marinas and yacht clubs) in copper reduction efforts within their leaseholds and operations/activities.

The Port made progress across all focused areas of the Copper Reduction Program:

Policies and Regulation: A variety of separate initiatives were completed, including partnering with the Regional Board to implement a temporary pause to in-water hull cleaning of copper-based AFPs in SIYB, as well as the continued implementation of hull cleaning permits.

Testing and Research: Port staff met several times with representatives from four alternative coating companies to discuss product development and better understand when products would be available to recreational boaters.

Implementation and Facilitation of Hull Paint Transitions: All Port vessels continued to be painted with non-copper hull paints, contributing no dissolved copper load to SIYB.

Education and Outreach: The Port engaged with stakeholders about water quality and Copper Reduction Program activities via outreach efforts such as SIYB TMDL status updates to stakeholder groups, information dissemination through digital efforts, workgroup meeting presentations, newspaper articles, and other outreach initiatives.

Companion Programs: Construction site inspections, commercial business inspections, and Priority Development Project (PDP) regulation implementation continued.

Monitoring and Reporting: In addition to annual SIYB TMDL monitoring, the Port also conducted water quality sampling during the Hull Cleaning Pause. Data were analyzed and reported under separate cover in September 2022 (see Appendix G). Supplemental winter water quality monitoring events were also completed in March 2022 and January 2023. Data from those events are summarized in Section 5.2 of the report and provided in Appendix H. Planning for the 2023 Regional Harbor Monitoring Program (RHMP) also began, with Port staff attending Bight Regional Monitoring scoping meetings held by SCCWRP.

The main elements of the Port’s 2022 Copper Reduction Program efforts are described in this section. A complete list of the Port’s BMPs, the status of each, and brief effectiveness assessments are in Appendix B.

3.1.1.1 Policies and Regulation to Reduce Copper Loading

Policies, regulations, and legislative efforts to reduce copper loading are instrumental to the Port’s Copper Reduction Program. These initiatives not only help to meet regulatory compliance requirements, but also to work toward reducing copper throughout San Diego Bay.

When the Port adopted Resolution 2009-230 in 2009, the objective was to specifically detail strategies for reducing copper throughout San Diego Bay, including the following:

- Complying with the provisions of regulatory requirements and achieving reductions in copper levels within or in advance of the time frames specified in the SIYB TMDL
- Identifying viable options for reducing copper levels in San Diego Bay
- Supporting regulations on hull paints at a state or federal level
- Developing, as necessary, policies, ordinances, procedures, and/or programs to achieve load reductions

- Working with tenants and stakeholders to identify and implement copper reduction strategies
- Maintaining the Port vessel fleet paint as 100% non-copper

Strategies outlined in Resolution 2009-230 have resulted in the Port's approach toward implementing policy, regulation, and legislative efforts to date, all of which are in place to assist in copper reduction throughout San Diego Bay.

DPR Copper Paint Rule: Implementation and Coordination

The DPR Rule (3 CCR section 6190) went into effect on July 1, 2018, establishing a maximum leach rate for copper AFPs. This regulation is the result of joint efforts by the Port and state legislators with the passing of Assembly Bill (AB) 425, requiring the DPR to adopt a leach rate protective of aquatic environments. Starting on July 1, 2018, paint manufacturers were no longer allowed to import or sell paints in the state of California with leach rates greater than 9.5 µg/cm^2/day. Existing stock could be sold until June 30, 2021, after which time the recreational use of all paints with leach rates above 9.5 µg/cm^2/day were prohibited.

The 2022 reporting year was the first full calendar year that high-copper paints were not available for sale in the state of California. It is expected that that any recreational vessels painted with copper-based AFPs in California after June 30, 2021 are painted with the lower-leach rate paints.

The Port continued collaboration with the DPR on their statewide special study to evaluate whether Category I paints are improving water quality in impaired basins over time. The study is anticipated to be conducted on a biannual basis for the next several years, if DPR funding is available. The first sampling event was conducted in 2019, and in 2021, the DPR published a report titled *Study 319 Report: Monitoring of Dissolved Copper in California Coastal Waterbodies* (Burant et al., 2021). The DPR report included sites in SIYB and other California coastal waterbodies and found that dissolved copper concentrations in all eight waterbodies were higher than their respective reference sites. The DPR report also confirmed that copper-based AFPs on vessel hulls are the source of dissolved copper in marinas and boat basins. The 2019 data serve as the DPR's baseline to evaluate future trends in dissolved copper levels. **DPR repeated biannual sampling in 2022. The Port provided logistical support and a sampling vessel for the DPR's 2022 sampling event in SIYB.**

Correspondence with State and Federal Agencies

Regular communications with state and federal agencies, policy makers, and legislators promote consistency in requirements being developed across the state. They also provide a valuable networking mechanism to discuss strategies for implementation of activities and lessons learned and to build upon successful activity models. During 2022, the following correspondences occurred:

San Diego Regional Water Quality Control Board

In January 2023, the Port provided a letter to the Regional Board discussing the Port's continued commitment to implementing the SIYB TMDL beyond the final deadline of December 2022. The letter highlighted key accomplishments from the TMDL implementation period, challenges in reducing copper inputs to SIYB, and considerations for the next phase of the program (see Appendix E).

Department of Pesticide Regulation

Port and DPR staff held several conference calls, continuing their ongoing collaborative partnership that promotes consistency in copper paint-related regulations across the state. This partnership enables long-term copper reduction planning to align with state efforts.

Marina Inter-Agency Coordinating Committee

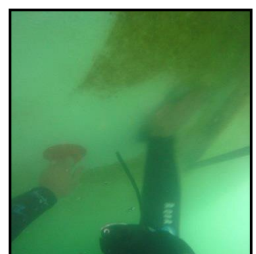
Three Marina Inter-Agency Coordinating Committee (MIACC) meetings occurred during the 2022 reporting year, on January 27, July 28, and December 6, 2022. Topics of discussion for the meetings included a presentation evaluating the efficacy and environmental impact from proactive in-water hull cleaning of commercial vessels, the SIYB TMDL and results of the Hull Cleaning Pause (presented by Port staff, see below for more information), and an informational presentation on Clean Marine. **The Port's participation in this working group remains valuable as it serves as a venue for the discussion of copper impairment issues across the state, acting as a conduit to address these issues at the state level.**

Coordination with Other Regions on Copper TMDLs and Impairments

In 2022, Port staff continued to hold regularly scheduled "Copper Catch Up" calls with the Los Angeles County Department of Beaches and Harbors to discuss both agencies' TMDL programs and share lessons learned for copper reduction efforts. Staff from both agencies discussed alignment in regional approaches to copper reduction, where applicable, that greatly strengthen both programs, such as discussing special studies and findings that each agency is currently pursuing. **Six meetings were held in 2022.**

<u>In-Water Hull Cleaning: Ordinance and Permit</u>

Since October 2011, the Port's in-water hull cleaning regulations have been in place requiring hull cleaning businesses to obtain Port-issued permits to conduct hull cleaning on tidelands, develop BMP plans and implement BMPs during all cleaning activities, and ensure that all hull cleaners are trained on the BMPs. The regulations also require marinas to check each hull cleaner for proof of a valid permit and to prohibit non-permitted divers from working in their facilities. At the end of 2012, the Port began issuing identification cards to all permitted hull cleaners to facilitate check-in at the marinas, a process that continued into 2022. **For 2022, a major focus of the Copper Reduction Program remained on regulations for in-water hull cleaning, as the Port addressed the data gap between in-water hull cleaning and water quality via the Hull Cleaning Pause study.**



Diver cleaning vessel hull

Validation of the permits continued in 2022 via collaborative efforts by the Port, marinas, and yacht clubs to continue implementing the check-in process. Port staff conducted inspections of the Harbor Police and transient docks, marinas, yacht clubs, and the hull cleaners that were conducting business in these areas. ***The Port conducted 225 inspections for in-water hull cleaning activities (including those conducted as part of the Hull Cleaning Pause study) and 36 marina and yacht club inspections bay-wide in 2022.***

In-Water Hull Cleaning Permit

For the 2022 reporting period, all permit requirements remained in place, and new permits were issued on a conditional basis. Key permitting statistics are as follows:

- 113 permits have been issued since the onset of the regulation.
- 61 hull cleaning permits are active (as of December 31, 2022).
- 5 hull cleaning permits were issued in 2022.

Vessel hull before and after cleaning

To date, the regulations helped to reduce copper loads from in-water hull cleaning by requiring the use of diver BMPs.

In-Water Hull Cleaning Ordinance Update and Related Activities

Temporary Pause to In-Water Hull Cleaning in SIYB

In October 2021, the Port adopted an amendment to its hull cleaning Ordinance, Article 4.14 of the District Code, requiring that in-water hull cleaning of boats with copper-based AFPs be temporarily paused in SIYB. The Port partnered with the Regional Board to implement the Hull Cleaning Pause, which aimed to reduce copper inputs into the basin and thereby improve water quality and to assess the relationship between in-water hull cleaning activities and water quality conditions in SIYB. The Ordinance amendment included prohibitions for the cleaning of copper-based AFPs and set a minimum penalty of $1,000 for any party found cleaning a copper-based AFP in SIYB during the Hull Cleaning Pause. More than 200 in-water hull cleaning inspections were conducted during the Pause, and no enforcement actions were taken.

3.1.1.2 Testing and Research

The Testing and Research component of the Copper Reduction Program was developed to assist the Named TMDL Parties in finding solutions to reduce their copper loads, facilitate the transition to alternative non-copper paints, conduct detailed assessments of water quality, and identify new or innovative solutions that may result in water quality improvements. Testing and research strategies evaluated in 2022 included the following:

Hull Paint Transitions

The transition from copper AFPs to non-copper alternatives is one of the most direct approaches to reduce copper loading. By transitioning to the available non-copper alternatives, load reduction is achieved by removing both the loading associated with in-water hull cleaning and passive leaching. The Port remains active in researching and coordinating with manufacturers of alternative non-copper paint technologies. **In 2022, Port staff met with representatives from four alternative hull coating companies (SeaCoat, CeRam-Kote, Imperion Coatings, and Coval) to learn about their respective non-copper paint products and discuss ways to bring these products to the recreational boating market.**

Conversion of Port Fleet

The Port completed the transition of its fleet of boats to non-copper paints in 2012. Boats were painted with various alternatives, largely depending on their use patterns. The Port continues to maintain a copper-free fleet, therefore eliminating any copper loading contributions from both in-water hull cleaning and passive leaching from its fleet of vessels.

In 2022, all 15 of the Port's boats continued to use non-copper paints, resulting in a 13.5-kg/yr copper load reduction and zero copper loading to SIYB.

3.1.1.3 Education and Outreach

The Port has developed an extensive education and outreach program geared toward educating Named TMDL Parties and other stakeholders on the use of alternative hull paints and increasing their awareness of the environmental impacts of copper paints. The education and outreach program also serves to engage stakeholders in the SIYB TMDL issues at the local, regional, state, and federal level.

Audiences Reached in 2022

The Port continued to ensure information was delivered through multiple media avenues. Outreach efforts continued via email and phone-call responses to public inquiries, regular meetings with marinas and yacht clubs, "one-on-one" meetings with SIYB marina and yacht club managers upon request, and continued hosting of web-access to brochures and information.

The efforts under the Education and Outreach component of the Copper Reduction Program were designed to reach different stakeholders and audiences, depending on the outreach mechanism (Table 3-1). While each component was designed for a primary audience, secondary audiences may also benefit from the information.

Table 3-1. Target Audiences Reached by Outreach Events

Outreach Component	Audience Reached							
	Regulators	Academics	Government Agencies	Boaters	Marinas	Boatyards	Paint Manufacturers	General Public
Booths at Events [1]	-	-	-	-	-	-	-	-
Conference Attendance	P	P	P	S	S	S	S	S
Guest Speaking Engagements	P	P	P	P	P	P	S	S
Workshops [1]	-	-	-	-	-	-	-	-
Printed Outreach Material	S	S	S	P	P	S	S	P
Dedicated Web Address to Copper Reduction Program	P	P	P	P	P	P	P	P
Peer-Based Testimonials	S	S	S	P	P	S	S	P
Newspaper Articles	P	S	P	P	P	P	P	P
"One-on-One" Meetings	-	-	-	P	P	-	-	-
Public Engagement Sessions [1]	-	-	-	-	-	-	-	-

Notes:
P = Primary Audience, indicating the most likely audience reached with the associated outreach effort.
S = Secondary Audience, indicating audiences that could be potentially reached with the associated outreach effort.
1. Efforts under these initiative topics did not occur in 2022 due to COVID-19.

A significant effort in the 2022 reporting year included the continued messaging of Hull Cleaning Pause requirements, including information regarding the public comment period for the draft Hull Cleaning Pause study report. In 2022, the Education and Outreach component of the Copper Reduction Program continued to be affected by the COVID-19 pandemic in terms of audiences reached; however, several efforts were still undertaken, with most continuing to occur on virtual platforms. The 2022 outreach efforts are summarized as follows:

SIYB TMDL Stakeholder Meetings

Port staff held one-on-one meetings with marina and yacht club managers to personalize outreach efforts and to foster collaborative relationships. In 2022, the one-on-one meetings with marina and yacht club managers focused on inspections and discussed the Hull Cleaning Pause efforts and observations, as well as SIYB TMDL updates.

Workshops, Seminars, Guest Speaking Opportunities, and Public Engagement Sessions

Ongoing public education and outreach can occur in the form of conference attendance and invited speaker opportunities. In addition to providing information on the Port's Copper Reduction Program and SIYB TMDL status, staff in attendance may also gain valuable insight from other presentations that discuss regulatory framework and project examples. Further, seminars and workshops allow for more focused topics to be discussed in depth and at length, providing the opportunity to disseminate information and provide additional learning experiences for Port staff.

Guest Speaker Invitations

In 2022, Port staff were invited to present at one speaking engagement at the state level:

- *MIACC* – Port staff gave an overview of the Hull Cleaning Pause study and discussed copper reduction efforts, as well as next steps for the SIYB TMDL from a regulated party's perspective (July 28, 2022). Approximately 46 people attended.

Dedicated Web Address

The Port has developed a dedicated web address, www.sandiegobaycopperreduction.org, that links viewers to all elements of its Copper Reduction Program. The link, implemented in 2010, provides information on hull paint conversion efforts such as the 319(h) grant project, hull cleaning regulations, and general paint research information. The site also contains downloadable materials such as frequently asked questions, documents related to the hull cleaning permit, data relevant to copper impairment, and recent press releases relevant to copper reduction. Monitoring studies are also available on the website.

In 2022, the Copper Reduction Program website was routinely updated with information pertaining to current Copper Reduction Program initiatives (e.g., documents and information updates associated with the Hull Cleaning Pause), as well as updated lists of permitted hull cleaners as new information became available. In addition, a dedicated email address, hullcleaning@portofsandiego.org, continued to remain available to facilitate information transfer among interested parties. Staff also ensured that the website was readily available and that information remained current and easy to find. **In 2022, the Port's dedicated website had 2,010 page views. The average time a user spent on the page was 3 minutes 54 seconds**.

Peer-Based Testimonials

Another media tool is peer-based marketing, with local boaters discussing their experiences using alternative paint products. In 2012, video testimonials were developed and displayed at the 2012 expo. In 2013, the video was posted on the Port's website. Additional written testimonials were also included so that readers could learn about other local boaters' experiences***. As of December 31, 2022, the video had been viewed 1,184 times.***

Newspaper Articles

The Log newspaper has a 52,000-person readership in southern California and is available at more than 500 boating-related locations throughout the region. **The Log publication has served as an important vehicle for informing the public about the Port's efforts regarding copper reduction in San Diego Bay. In 2022, one article appeared in The Log related to the Port's Copper Reduction Program, and specifically SIYB.**

- July 21, 2022: "Sixteen-week Water Quality Survey Shows No Difference in Copper Reduction Following Eight-Week Pause on In-Water Hull Cleaning" – This article discussed water quality results from both annual monitoring and the Hull Cleaning Pause study.

Internal Education

Increasing Port-wide awareness about the Copper Reduction Program, alternative paint use, and status of water quality regulations is vital to a successful program. A solid understanding of the program attracts support by the Port's decision makers, such as the Board of Port Commissioners and executive team, and so enables projects and policy decisions to move forward. An informed executive team can also ensure that adequate funding is available to implement the program. As such, Port staff continually seek opportunities to provide information on key items of the Copper Reduction Program. The following information was provided to the Port Board and executives in 2022:

- April 14, 2022: A Port Board memorandum provided notification of the submittal of the 2021 SIYB TMDL Monitoring and Progress Report to the Regional Board.
- July 12, 2022: Port staff appeared before the Board of Port Commissioners to provide a status update on the SIYB TMDL and provide a summary of the Hull Cleaning Pause study.

Long-Term Vessel Planning Committee

In September 2020, the Harbor Police department created a committee to strategically plan for long-term vessel acquisitions for the Harbor Police fleet. **In 2022, Port staff who work with the Copper Reduction Program continued to participate in the committee to ensure vessels added to the fleet remain copper free.**

Partnerships and Collaboration

Since the inception of the SIYB TMDL, the Port has been working to identify opportunities with other Named TMDL Parties, academia, and other agencies to develop and provide outreach, testing opportunities, funding opportunities, and policies**. In 2022, the Port continued to participate in multiple collaborative opportunities with groups within San Diego and throughout the California boating and regulatory communities, including**:

- Coordination with the SIML TMDL Group and other SIYB marinas on SIYB TMDL annual reporting
- Regular participation in state-led MIACC meetings for antifouling and marina-related topics
- Collaborative discussions with Los Angeles County Department of Beaches and Harbors to discuss Copper Reduction Program efforts and lessons learned from the SIYB TMDL to date
- In October 2022, a series of meetings organized by the Port with SIYB tenants, Port staff, and Regional Board staff to discuss SIYB TMDL progress and source control

3.1.1.4 Additional Efforts (Companion Programs)

Several other Port programs directly or indirectly support Copper Reduction Program efforts. The Blue Economy Incubator continues to be instrumental in identifying potential pilot studies that may assist in continued efforts to reduce copper concentrations and improve water quality throughout San Diego Bay.

The Port's Stormwater Program incorporates BMPs to decrease copper loading from landside activities bay-wide and specifically into SIYB. These efforts, described in this section, are primarily related to compliance requirements set forth in the Municipal Separate Storm Sewer System (MS4) Permit. Information related to the implementation efforts for these programs can be found in the Port Jurisdictional Runoff Management Plan (JRMP) Annual Report at: **https://pantheon storage.blob.core.windows.net/environment/JRMP-2021-2022-Annual-Report.pdf**

Construction Site Inspections

Construction inspections ensure that sites undergoing development or redevelopment implement measures to control pollution and prevent discharges. For construction sites and facilities that do not comply, the Port takes enforcement action.

Commercial Business Inspection Program

Per the requirements of the MS4 Permit, the Port inspects commercial facilities in SIYB and bay-wide. One component, the Port's marina inspection program, provides opportunities to educate boat owners about pollution prevention, focusing on visual observations to identify sources of pollution and the pollution prevention practices implemented at the marinas and yacht clubs, including over-water work and boat maintenance. The goal of the inspections is to help implement behavior changes that will help reduce pollution (including copper) in bay waters.

Priority Development Project Regulations

The Port incorporates PDP requirements on applicable development and redevelopment projects bay-wide. Depending on the type and size of the projects, PDP requirements could include site design, source controls, and treatment controls such as low-impact development (LID). All efforts help reduce copper loading into San Diego Bay. Since 2009, 34 bay-wide projects overall with metals as priority pollutants have been implemented, treating a total of 114.25 acres. In SIYB, there have been five existing projects overall with metals as priority pollutants, treating a total of 9.19 acres.

3.1.1.5 Monitoring and Reporting

The main goal of the Monitoring and Reporting component of the Copper Reduction Program is to assess long-term improvements in water quality. Over the course of the SIYB TMDL, several special studies have been implemented to address data gaps in basin water quality dynamics and copper loading. The data collected for the annual monitoring program and through various special studies have all contributed to a better understanding of basin water quality dynamics in SIYB.

In-Water Hull Cleaning Pause Study

The Hull Cleaning Pause began December 19, 2021 and continued through February 9, 2022. Weekly water quality monitoring was conducted as a companion program for 4 weeks prior to the Pause, weekly during the Pause, and continued for 4 weeks after the Pause. To ensure compliance with the Ordinance, Port staff conducted frequent inspections in SIYB during the Pause period. Water quality results were reported in a standalone technical report that includes water quality data and observations related to the Hull Cleaning Pause period. Additional details are provided in Section 4.0 and Appendix G.

Winter Monitoring Event

The Port also completed winter monitoring events in 2022 and 2023 to evaluate seasonal variations in copper levels in SIYB. This monitoring was in addition to the required summer monitoring and was conducted at the same stations that are monitored each summer. Additional details are provided in Section 5.2 and Appendix H.

Regional Harbor Monitoring Program

This bay-wide monitoring program is conducted every 5 years in coordination with the SCCWRP Bight Regional Monitoring Program to assess the ambient conditions in San Diego Bay and other southern California harbors on the basis of comparisons with historical data and comparisons of contaminant concentrations with known surface water and sediment thresholds. The program samples water, sediment, benthic infauna, and a variety of fish and invertebrate species in San Diego Bay. Upon completion of the study, a comprehensive report is generated. The Port is the lead agency on this project.

Planning for the next core monitoring event began in 2022. Port staff attended all Bight planning committee meetings to represent the RHMP.

3.1.2 Marina, Yacht Club, and SIML TMDL Group BMPs to Reduce Copper Loading

The SIYB marinas and yacht clubs implement BMPs annually to reduce copper loading from their respective facilities and operations. A summary of the marinas' and yacht clubs' BMPs was provided to the Port and is included in Appendix B. This section has been provided directly by individual marinas and yacht clubs and the SIML TMDL Group. This information is being included by the Port to comply with the requirements of the Investigative Order. Questions pertaining to the BMP selection or descriptions of information within this section should be directed to the Named TMDL Parties, as applicable.

SIML TMDL Group BMPs to Reduce Copper Loading

The Shelter Island Master Leaseholder Group is committed to adopting and implementing best management practices (BMPs) to effect copper load reduction. The group represents the majority of the marinas and yacht clubs in Shelter Island Yacht Basin/. Monthly meetings are scheduled during which BMPs, have been developed, applied, modified and assessed for effectiveness.

We measure the success of these BMPs by estimated load reductions; extensive tracking of load reductions is used as feedback to effectiveness of instituted programs. Additionally we weigh strive the effect of regulatory developments, and product choices as effectors of programmatic construct.

Accordingly, we have as in improvement of the process; we have reviewed the method by which load reductions are estimated.

1. Profound changes in the types of paints available have been made.
    a. With recent regulatory actions altering the formulation of paints, all paints applied in California are destined to become low copper paints. This development alters the categorization of older paints because the recognized reduction applied only to high copper paints, which are no longer legally applicable. The off shot is that deferring recoating of hulls is no longer considered a load reduction stratagem.
2. Recognizing the number of boat hulls with paints exhausted of copper may lead to BMPs programmatic developments.
    a. More than 25% of hulls have not been painted in the last five years. Maintaining these hulls free of growth is accomplished by in-water cleaning; a cleaning process does not liberate copper because these paints are exhausted of copper content.

We are encouraged that additional load reductions can be accomplished by refining both the BMPs and the methods to evaluate BMP effectiveness.

Retaining achieved load reductions is accomplished through a continuous program of education and outreach. Ad hoc group meetings, meetings with Port Staff, meetings with technical and regulatory professionals, complement monthly meetings of group members in an effort educate and outreach. A wok group inclusive of Port Staff was assembled this year to explore additional measures to ward address TMDL compliance.

These and additional BMP actions are described in more detail in Appendix B.

Program Improvement

- **Assess and Improve**- Adapt to scientific findings and adopt independent model for load calculation
- **Collaboration**– Participate in meetings and coordination with Port staff and Port consultants on new and ongoing scientific studies
- **BMP Subcommittee** –conducted 5 meetings in 2022
- **Consultancy and Guidance –** retained an environmental professional
- **Seek Alternative Methods -** Facilitation of dry storage on land and support of inter-club sailing regattas using dry storage boats reduce copper load

Technical Improvement

- Fish and wildlife Consults
- Developed advisory groups with scientists and experts in field

Outreach

- **Hull Surveys**– 95% of boaters holding slips in member organizations were contacted about antifouling paint usage.
- **Communication –** email blasts and were sent to boat owners with information on TMDL

  Across Companies- Reached out to boatyards and paint manufacturers

Education

- **Meetings** – Participation and attendance at SIYB TMDL Group meetings since 2005 including 11 group meetings in 2022
- **Training** - Ongoing staff trainings for existing and new marina employees
- **Procedures** – Ongoing procedures for verifying and monitoring Port Diver Permit
- **Signage**-Posting diver BMP signs at marinas and yacht club entrances

Posted sign informing hull cleaners and boat owners about BMPs

Bay Club Marina BMPs to Reduce Copper Loading

In addition to the BMP information mentioned above, the Bay Club Marina revised its wharfage agreement in 2019 to include a number of environmental conditions, including those related to copper loading and the TMDL. These facility-specific BMPs are included as part of the Bay Club Marina contract for private wharfage that is signed by the owners that berth their vessels at this facility. The portions of the Bay Club Marina Hotel contract with its vessel-owner tenants that specifically address copper reduction are summarized below.

- Bay Club Marina gives "front of the line" wait list priority to non-copper vessels.
- Posted sign informing hull cleaners and boat owners about BMPs.
- “Owner also understands that he/she will be required to provide an annual bottom paint questionnaire to the marina office by November 15 each year that includes the following information: paint name, color, product number, brand, copper percentage, boatyard name, and date of paint was applied.”
- “Marina recommends the use of non-toxic, biocide free bottom paints.”
- “Hull cleaning must utilize Best Management Practices to minimize discharge of bottom paint into the water.”
- “Vessel Owners are required to use environmentally friendly hull cleaning companies who are licensed by the Port of San Diego and use Best Management Practices and monitor their divers.”

3.2 SIYB TMDL Vessel Tracking

Vessel tracking data collected in 2022 are presented in this section. Through continued efforts by marina and yacht club managers to survey boaters, approximately 89% of boat owners responded and reported information regarding their hull paints in 2022. Figure 3-1 illustrates the changes in response rate over previous surveys.

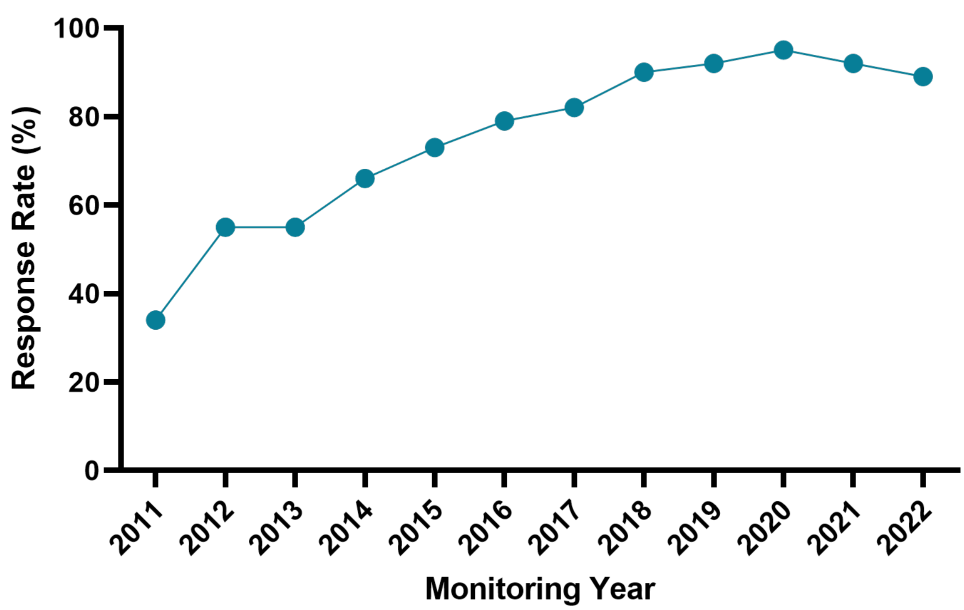


Figure 3-1. Vessel Census Response Rate by Monitoring Year

3.2.1 Vessel Counts by Hull Paint Type

Hull paint conversion calculations were based on data provided by SIYB marinas and yacht clubs, in addition to data from the Harbor Police dock, transient dock, and weekend anchorage.

The 2022 census of the hull paint types reported by all SIYB marinas and yacht clubs is as follows:

- A total of 2,163 vessels were included in the 2022 census of hull paint types in marinas and yacht clubs.
- 606 vessels have copper or unknown/unconfirmed (assumed to be copper) hull paint. This includes:
  - 77 vessels with confirmed copper paints (i.e., non-DPR Category I paints).
  - 529 vessels with unconfirmed or unknown paints that are conservatively assumed to be copper.
- 1,022 vessels have paints confirmed to be lower copper. These vessels consist of the following:
  - 1,013 vessels with DPR Category I (low-leach) paints.
  - 9 vessels with low-copper paint (non-Category I with less than 40% copper content).
- 434 vessels have aged-copper hull paint applied more than 3 years ago.
- 101 vessels have either confirmed non-copper paints, no bottom paint, or are stored in slip liners or HydroHoists®.

The 2022 census of the hull paint types reported from the Harbor Police dock, transient dock, and weekend anchorage is as follows:

- 15 Port vessels berthed at the Harbor Police dock have non-copper paints or no paint.
- There are 66 spaces in SIYB where transient vessels can be berthed (26 slips at the transient dock and 40 mooring locations at the weekend anchorage). All vessels that were berthed at these two locations in 2022 are considered to have unknown (assumed to be copper) hull paint.

3.2.2 Slip Count and Occupancy

Based on the 2022 hull paint census, 2,296 slips were available to be occupied by vessels in SIYB, including 40 moorings at the weekend anchorage, 26 transient dock slips, and 17 slips at the Harbor Police dock. This slip count is slightly lower than the average number of slips observed in SIYB in the past 5 years (2,311 slips). In addition, there was a decrease of 67 slips in 2022 compared with the baseline of 2,363 slips and moorings identified in the SIYB TMDL.

Of the 2,296 available slips and moorings in SIYB in 2022, 52 slips (50 slips in the marinas and yacht clubs and 2 slips at the Harbor Police dock) were reported to be vacant year-round, leaving 2,244 slips that were occupied for at least a portion of time in 2022. Slip occupancy rates for each hull paint type are shown in Tables 3-3 through Table 3-6. On average, slips and moorings in SIYB were occupied 93% of the time.

3.2.3 Vessel Dimensions

Based on reported hull lengths and beam widths, the average vessel in SIYB in 2022 was 11.6 meters (38.2 feet) long by 3.7 meters (12.1 feet) wide (Appendix C). The average wetted hull surface area was 36.5 square meters (m^2), which is slightly larger than the size identified in the SIYB TMDL assumptions (35.2 m^2).

3.2.4 Estimated Copper Load and Load Reduction

Estimates of the dissolved copper load and load reduction for 2022 are presented in this section first as a total combined load and then parsed out to show loads attributed to passive leaching and in-water hull cleaning separately.

The total 2022 dissolved copper load estimates from passive leaching and in-water hull cleaning sources combined are summarized in Table 3-2 and as follows:

- Vessels with copper (or assumed copper) paints contributed a load of 542 kg/yr. This total includes 518 kg/yr from vessels in marinas and yacht clubs and hull cleaning activities occurring in those facilities, roughly 96% of the loading from this paint type category, and 23.8 kg/yr from vessels at the transient dock and weekend anchorage and hull cleaning activities occurring in those locations, roughly 4% of the loading from this paint category.
- DPR Category I paints in marinas and yacht clubs contributed a dissolved copper load of approximately 430 kg/yr.
- Low-copper hull paints in marinas and yacht clubs contributed a dissolved copper load of 3.79 kg/yr.
- Aged-copper paints in marinas and yacht clubs contributed an annual dissolved copper load of 181 kg/yr.
- No dissolved copper load was contributed to SIYB by 116 vessels with either confirmed non-copper paint, vessels in slip liners or HydroHoists®, or vessels that were unpainted. This includes 101 vessels in marinas and yacht clubs and all 15 Port vessels berthed at the Harbor Police dock.
- A total of 50 slips within the SIYB marinas and yacht clubs and 2 slips at the Harbor Police dock were reported to be vacant year-round, and therefore did not contribute a dissolved copper load into the basin.

In summary, vessels painted with copper-based paints contributed a combined passive leaching and in-water hull cleaning load of 1,157 kg/yr of dissolved copper to SIYB in 2022. This total dissolved copper load is composed of approximately 1,133 kg/yr (98%) for vessels in marinas and yacht clubs and hull cleaning activities occurring in those facilities plus approximately 23.8 kg/yr (2%) for vessels at the transient dock and weekend anchorage and hull cleaning activities occurring in those locations.

Table 3-2. 2022 Estimated Copper Load and Load Reduction from SIYB TMDL Baseline

Copper Loading Category	Total Copper Load (kg/yr)
Marinas and Yacht Clubs	
Vessels with Confirmed Copper Paint	64.9
Vessels with Unknown or Unconfirmed Paint (Assumed Copper)	430
Vessels with DPR Category I (Low-Leach Paint)	430
Vessels with Confirmed Low-Copper Paint	3.79
Vessels with Unconfirmed Low-Copper Paint	20.6
Vessels with Aged-Copper Paint	181
Vessels with Confirmed Non-Copper Paint, No Paint, Hydrohoists®, or Slip Liners	0
Vessels with Unconfirmed Non-Copper Paint	2.82
Year-Round Vacancies in Marinas and Yacht Clubs	0 [a]
Harbor Police Dock, Transient Dock, and Weekend Anchorage	
Port Harbor Police Fleet with Confirmed Non-Copper Paint or No Paint	0
Transient Dock and Weekend Anchorage Guest Vessels with Unknown Paint (Assumed Copper)	23.8
Year-Round Vacancies at Port Harbor Police Dock	0 [b]
Grand Total Load	1,157
***Load Reduction from SIYB TMDL Baseline* [c]**	***943 (44.9%)***

Notes:
a. 50 slips within the SIYB marinas and yacht clubs were reported to be vacant year-round and therefore contributed no dissolved copper load to SIYB.
b. 2 slips at the Harbor Police dock were reported to be vacant year-round and therefore contributed no dissolved copper load to SIYB.
c. The total copper load from the SIYB TMDL equals 2,100 kg/yr from vessel paints (passive leaching and in-water hull cleaning, combined). The estimated load due to background, urban runoff, and atmospheric deposition is not included in this total.
% = percent; DPR = Department of Pesticide Regulation; kg/yr = kilogram(s) per year; SIYB = Shelter Island Yacht Basin; TMDL = Total Maximum Daily Load

In addition to combined dissolved copper load estimates presented in Table 3-2, load estimates are presented separately for passive leaching and in-water hull cleaning for the 2022 monitoring year. Estimated dissolved copper loads in 2022 attributed to the SIYB TMDL-derived passive leaching load allocation are shown in Table 3-3 (marinas and yacht clubs) and Table 3-4 (Harbor Police dock, transient dock, and weekend anchorage). Estimated dissolved copper loads in 2022 attributed to the SIYB TMDL-derived in-water hull cleaning load allocation are shown in Table 3-5 (marinas and yacht clubs) and Table 3-6 (Harbor Police dock, transient dock, and weekend anchorage). As discussed in Section 2.2.3, hull cleaning load allocations presented in Tables 3-5 and 3-6 were adjusted to account for the load reduction resulting from the portion of the Hull Cleaning Pause that occurred during the 2022 monitoring period (i.e., January 1 through February 9, 2022).

Based on the estimated total dissolved copper load from passive leaching and in-water hull cleaning combined (1,157 kg/yr), the load reduction for 2022 was calculated (Table 3-2). Load reduction is determined by subtracting the estimated dissolved copper load from the 2,100-kg/yr baseline load attributed to vessels identified in the SIYB TMDL Technical Report (passive leaching = 2,000 kg/yr and in-water hull cleaning = 100 kg/yr). Based upon these calculations, the 2022 estimated copper load reduction is 943 kg/yr (i.e., 2,100 kg/yr minus 1,157 kg/yr = 943 kg/yr), which is a 44.9% reduction from the baseline load identified in the SIYB TMDL.

Table 3-3. 2022 Copper Load as a Result of Passive Leaching Using SIYB TMDL Assumptions for Each Vessel Hull Paint Type in SIYB Marina and Yacht Clubs

Vessel Hull Paint Category	Number per Category	Average Time Occupied [c]	Copper Load per Vessel (kg/yr) [d]	Total Copper Load (kg/yr)
Copper (Confirmed)	77	94.1%	0.86	62.3
Copper (Unknown/Unconfirmed – Assumed Copper) [a]	500	96.0%	0.86	413
DPR Category I (Low-Leach)	1,013	94.7%	0.43	413
Low-Copper (Confirmed)	9	94.0%	0.43	3.64
Low-Copper (Unconfirmed) [a]	25	91.8%	0.86	19.7
Aged-Copper Paint [b]	434	93.1%	0.43	174
Non-Copper (Confirmed)	101	94.6%	0	0
Non-Copper (Unconfirmed) [a]	4	78.8%	0.86	2.71
Vacant Slips (Marinas and Yacht Clubs)	50	N/A	N/A	0
Total ***(Marinas and Yacht Clubs)***	***2,163*** [e]	***N/A***	***N/A***	***1088***

Notes:
a. Unknown or unconfirmed paints are conservatively assumed to be high-copper paint, per the Monitoring Plan assumptions.
b. Copper paints applied on or before December 31, 2019 are considered aged and assigned a half-load.
c. The average time occupied represents the average percentage of time in 2022 that vessels in each paint category occupied slips.
d. Based on per-vessel load identified for passive leaching in Appendix 2 of the SIYB TMDL.
e. Vacant slips are not included in this total.
% = percent; DPR = Department of Pesticide Regulation; kg/yr = kilogram(s) per year; N/A = not applicable; SIYB = Shelter Island Yacht Basin; TMDL = Total Maximum Daily Load

Table 3-4. 2022 Copper Load as a Result of Passive Leaching Using SIYB TMDL Assumptions for Each Vessel Hull Paint Type at the Harbor Police Dock, Transient Dock, and Weekend Anchorage

Vessel Hull Paint Category	Number per Category	Average Time Occupied [b]	Copper Load per Vessel (kg/yr) [c]	Total Copper Load (kg/yr)
Port Harbor Police Fleet (Confirmed Non-Copper)	15	93.3%	0	0
Transient Dock (Unknown – Assumed Copper) [a]	26	53.6%	0.86	12.0
Weekend Anchorage (Unknown – Assumed Copper) [a]	40	31.4%	0.86	10.8
Vacant Slips (Port Harbor Police Dock)	2	N/A	N/A	0
Total ***(HPD, Transient Dock, and Weekend Anchorage)***	***81*** [d]	***N/A***	***N/A***	***22.8***

Notes:
a. Unknown or unconfirmed paints are conservatively assumed to be high-copper paint, per the Monitoring Plan assumptions.
b. The average time occupied represents the average percentage of time in 2022 that vessels in each paint category occupied slips in SIYB. Calculations for the transient dock and weekend anchorage were based on the total number of days a slip or mooring was occupied by a guest vessel.
c. Based upon per vessel load identified for passive leaching in Appendix 2 of the SIYB TMDL.
d. Vacant slips are not included in this total.
% = percent; HPD = Harbor Police dock; kg/yr = kilogram(s) per year; N/A = not applicable; SIYB = Shelter Island Yacht Basin; TMDL = Total Maximum Daily Load

Table 3-5. 2022 Copper Load as a Result of In-Water Hull Cleaning Using SIYB TMDL Assumptions for Each Vessel Hull Paint Type in SIYB Marina and Yacht Clubs

Vessel Hull Paint Category	Number per Category	Average Time Occupied [c]	Copper Load per Vessel (kg/yr) [d]	Total Copper Load (kg/yr)
Copper (Confirmed)	77	94.1%	0.0356	2.58
Copper (Unknown/Unconfirmed – Assumed Copper) [a]	500	96.0%	0.0356	17.1
DPR Category I (Low-Leach)	1,013	94.7%	0.0178	17.1
Low-Copper (Confirmed)	9	94.0%	0.0178	0.15
Low-Copper (Unconfirmed) [a]	25	91.8%	0.0356	0.82
Aged-Copper Paint [b]	434	93.1%	0.0178	7.19
Non-Copper (Confirmed)	101	94.6%	0	0
Non-Copper (Unconfirmed) [a]	4	78.8%	0.0356	0.11
Vacant Slips (Marinas and Yacht Clubs)	50	N/A	N/A	0
Total (Marinas and Yacht Clubs)	***2163 [e]***	***N/A***	***N/A***	***45.0***

Notes:
a. Unknown or unconfirmed paints are conservatively assumed to be high-copper paint, per the Monitoring Plan assumptions.
b. Copper paints applied on or before December 31, 2019 are considered aged and assigned a half-load.
c. The average time occupied represents the average percentage of time in 2022 that vessels in each paint category occupied slips.
d. The per-vessel load identified for in-water hull cleaning in Appendix 2 of the SIYB TMDL (0.04 kg/yr) was adjusted to account for the portion of the Hull Cleaning Pause that occurred during the 2022 monitoring period (i.e., January 1 through February 9, 2022).
e. Vacant slips are not included in this total.
% = percent; DPR = Department of Pesticide Regulation; kg/yr = kilogram(s) per year; N/A = not applicable; SIYB = Shelter Island Yacht Basin; TMDL = Total Maximum Daily Load

Table 3-6. 2022 Copper Load as a Result of In-Water Hull Cleaning Using SIYB TMDL Assumptions for Each Vessel Hull Paint Type at the Harbor Police Dock, Transient Dock, and Weekend Anchorage

Vessel Hull Paint Category	Number per Category	Average Time Occupied [b]	Copper Load per Vessel (kg/yr) [c]	Total Copper Load (kg/yr)
Port Harbor Police Fleet (Confirmed Non-Copper)	15	93.3%	0	0
Transient Dock (Unknown – Assumed Copper) [a]	26	53.6%	0.0356	0.50
Weekend Anchorage (Unknown – Assumed Copper) [a]	40	31.4%	0.0356	0.45
Vacant Slips (Port Harbor Police Dock)	2	N/A	N/A	0
Total (HPD, Transient Dock, and Weekend Anchorage)	***81 [d]***	***N/A***	***N/A***	***0.95***

Notes:
a. Unknown or unconfirmed paints are conservatively assumed to be high-copper paint, per the Monitoring Plan assumptions.
b. The average time occupied represents the average percentage of time in 2022 that vessels in each paint category occupied slips in SIYB. Calculations for the transient dock and weekend anchorage were based on the total number of days a slip or mooring was occupied by a guest vessel.
c. The per-vessel load identified for in-water hull cleaning in Appendix 2 of the SIYB TMDL (0.04 kg/yr) was adjusted to account for the portion of the Hull Cleaning Pause that occurred during the 2022 monitoring period (i.e., January 1 through February 9, 2022).
d. Vacant slips are not included in this total.
% = percent; HPD = Harbor Police dock; kg/yr = kilogram(s) per year; N/A = not applicable; SIYB = Shelter Island Yacht Basin; TMDL = Total Maximum Daily Load

3.3 SIYB TMDL Water Quality Monitoring

This section summarizes the analytical chemistry and toxicity results from the 2022 SIYB TMDL summer monitoring event conducted by the Port on August 16, 2022.

3.3.1 Surface Water Chemistry

Surface water samples were tested for dissolved and total copper and zinc, DOC, TOC, and TSS. Results for analytical testing performed by Weck are summarized in Table 3-7 and presented in the laboratory report in Appendix D.

Table 3-7. Chemistry Results for SIYB Surface Waters, August 2022 Event

Station	Dissolved Copper (µg/L)	Total Copper (µg/L)	Dissolved Zinc (µg/L)	Total Zinc (µg/L)	DOC (mg/L)	TOC (mg/L)	TSS (mg/L)
SIYB-1	**11**	12	27	27	1.4	1.6	2 J
SIYB-2	**7.7**	8.1	19	19	1.4	1.4	8
SIYB-3	**5.4**	6.0	13	14	1.3	1.4	3 J
SIYB-4	**5.3**	5.6	14	13	1.3	1.5	4 J
SIYB-5	**5.0**	5.6	13	14	1.3	1.3	4 J
SIYB-6	2.1	2.6	6.4	7.2	1.2	1.3	4 J
SIYB-REF-1	0.78	1.2	2.3	4.1	1.3	1.4	4 J
SIYB-REF-2	1.2	1.6	4.9	5.6	1.4	1.3	5

Notes:
Values in **bold** are above the USEPA National Recommended Water Quality CCC for dissolved copper of 3.1 µg/L in marine waters.
No values were above the CCC for dissolved zinc of 81 µg/L.
High tide on 08/16/2022 was +5.71 feet at 13:18; (https://tidesandcurrents.noaa.gov/waterlevels.html?id=9410170)
µg/L = microgram(s) per liter; CCC = criterion continuous concentration; DOC = dissolved organic carbon; J = estimated value; mg/L = milligram(s) per liter; REF = reference; SIYB = Shelter Island Yacht Basin; TOC = total organic carbon; TSS = total suspended solids; USEPA = United States Environmental Protection Agency

Dissolved Copper – Dissolved copper levels within SIYB ranged from 2.1 µg/L at the outermost station (SIYB-6) to 11 µg/L at the innermost station (SIYB-1). Dissolved copper concentrations at five of the six SIYB stations exceeded the dissolved copper CTR criterion continuous concentration (CCC) WQO of 3.1 µg/L and criterion maximum concentration (CMC) WQO of 4.8 µg/L. The concentrations of dissolved copper at the outermost station in SIYB (SIYB-6) and the reference stations outside SIYB were below both WQOs.

Total Copper – Total copper concentrations measured in SIYB followed a similar spatial pattern, ranging from 2.6 µg/L at the outermost station (SIYB-6) to 12 µg/L at the innermost station (SIYB-1). The total copper concentrations at the reference stations (SIYB-REF-1 and SIYB-REF-2) were 1.2 µg/L and 1.6 µg/L, respectively.

Dissolved Zinc – Dissolved zinc concentrations in SIYB increased moving from the mouth to the head of the basin, ranging from 6.4 to 27 µg/L. Dissolved zinc levels in SIYB and at the reference stations were well below the USEPA CCC of 81 µg/L.

Total Zinc – Total zinc concentrations followed a similar spatial pattern, with values ranging from 7.2 µg/L at Station SIYB-6 to 27 µg/L at Station SIYB-1. The total zinc concentrations at the reference stations (SIYB-REF-1 and SIYB-REF-2) were 4.1 µg/L and 5.6 µg/L, respectively.

DOC – DOC concentrations in the water column, which have been shown to affect the bioavailability of free copper (Delgadillo-Hinojosa et al., 2008; Rosen et al., 2005; Zirino et al., 2002), were relatively consistent within SIYB and at the reference stations, ranging from 1.2 to 1.4 milligrams per liter (mg/L).

TOC – Similarly, measured concentrations of TOC were relatively consistent for all samples in SIYB and the reference stations, ranging from 1.3 to 1.6 mg/L.

TSS – Measured concentrations of TSS were variable for all samples in SIYB and the reference stations, ranging from 2 (J) mg/L to 8 mg/L.

3.3.1.1 Analytical Chemistry QA/QC

All samples were submitted to the analytical chemistry laboratory on the day after they were collected (August 17, 2022). The samples were received in good condition at Weck at 1.6°C and on ice. The samples for dissolved metals analyses were field-filtered by WSP field personnel and preserved by the laboratory immediately upon receipt. All samples met holding time requirements for analysis.

Analytical chemistry results underwent a thorough QA/QC evaluation; they were determined to meet the data quality objectives in the QAPP and were deemed acceptable for reporting purposes, with any qualifications noted in the QA section of the laboratory report (Appendix D).

Results from a review of data quality indicators and evaluation of potential data impact associated with the 2022 SIYB TMDL summer monitoring analytical chemistry results are as follows:

- Similar to results in previous events, low-level detections of copper and zinc were measured in the ER blank and FB.
  - Ideally, levels of metals in these QA samples should be very low or non-detect (ND). Trace levels of copper and zinc measured in the FB may indicate trace field and/or laboratory contamination. Concentrations of copper and zinc were measured in the ER blank at concentrations greater than those detected in the FB, indicating that the low-level detections reported in the ER sample may be due to potential trace contamination of the Niskin sampler. However, the concentrations of copper and zinc in the ER blank and FB were negligible relative to sample concentrations measured within SIYB and therefore are not considered a significant data bias.
- Low-level detections of DOC, TOC, and TSS were measured in the ER blank and the FB.
  - Trace detections of DOC, TOC, and TSS measured in the ER blank and FB are of a range similar to those of previous events and may be representative of trace field and/or laboratory contamination. Because similar low-level detections have been observed in previous events, extra care is taken in the field to ensure that sampling equipment is thoroughly cleaned and rinsed prior to collection of each sample. However, due to the ubiquitous nature of these constituents, some combined low-level contamination from the field and analytical testing is expected, even under clean room conditions. These low-level detections are not considered significant enough to warrant retesting or recollection of samples and testing. All results are considered usable for their intended data purposes and are reported as provided by the laboratory.

- Low-level detections of dissolved copper, dissolved zinc, and TSS were measured in the method blanks.
    - Concentrations of dissolved copper, dissolved zinc, and TSS measured in the method blanks were estimated between the method detection limit and reporting limit and were orders of magnitude below SIYB sample concentrations. These ultra-low-level detections are expected due to the low method detection limits. This trace-level laboratory contamination is considered to be negligible, and there is no impact on data usability.
- The dissolved zinc concentration was slightly higher (1 µg/L) than the corresponding total zinc concentration in one sample (SIYB-4).
    - As discussed above, trace levels of dissolved and total zinc were measured in the ER blank, FB, and/or method blank indicating potential trace levels of field and/or laboratory contamination. This slight deviation is not considered significant enough to warrant resampling or retesting. The results were reported within acceptance criteria determined by the test method and SOP and therefore are considered usable for their intended purposes and reported as provided by the laboratory.
- The DOC value in one sample (SIYB-REF-2) was slightly higher (0.1 mg/L) than the TOC value reported for the same sample.
    - Water samples for TOC and DOC analyses are dispensed to separate sample vials in the field, and laboratory analyses are conducted separately. This sample collection and testing approach can sometimes result in TOC levels reported slightly lower than DOC levels. The magnitude of this minor difference (0.1 mg/L) is similar to results from previous events. Corresponding laboratory QA/QC samples met all QAPP limits. Additionally, concentrations measured in the associated laboratory blanks were ND. Therefore, the results are considered usable for their intended purposes and are reported as provided by the laboratory.

3.3.2 Toxicity

In addition to water chemistry analyses, the samples were tested for toxicity using an acute 96-hour survival exposure with marine larval fish (Pacific topsmelt and inland silversides) and a chronic 48-hour survival and development test using bivalve embryos (Mediterranean mussel). Results for the toxicity testing performed by WSP Environmental Toxicology Laboratory are summarized in this section and presented in the laboratory report in Appendix D.

3.3.2.1 Pacific Topsmelt and Inland Silverside 96-Hour Acute Bioassays

Due to limited availability of topsmelt from the test organism supplier, acute topsmelt toxicity tests for the 2022 summer monitoring event were only conducted on the laboratory controls and undiluted compliance samples (i.e., 100% sample concentration) for each site. Pacific topsmelt survival in the laboratory controls ranged from 76.7% to 83.3%, which did not meet the test acceptability criteria (TAC) of at least 90% mean survival in the controls. Similar topsmelt survival rates were also observed in the undiluted samples collected from SIYB and the reference site (SIYB REF-1; Table 3-8). The reduction in topsmelt survival observed in all test samples, including laboratory controls and the reference site sample, indicated an issue with the health of the batch of organisms received from the organism supplier, rather than a toxic response.

Because of the many challenges experienced using Pacific topsmelt for toxicity testing in the current and previous monitoring years (e.g., limited organism supply and availability, poor organism health and sensitivity), the acute bioassay test was also performed using the inland silverside (*Menidia beryllina*) for the 2022 summer monitoring event.

Inland silverside survival in the laboratory controls ranged from 93.3% to 96.7%, which met the TAC of at least 90% mean survival in the controls. Survival rates in all SIYB samples and concentrations tested were greater than or equal to 90% (Table 3-9). No statistically significant effects on inland silverside survival were observed in any samples tested, indicating that surface water samples collected in SIYB and at the reference station (SIYB-REF-1) were not acutely toxic to inland silverside.

Overall, the results of acute toxicity tests performed using both topsmelt and inland silversides indicated that there were no acute toxic effects on these organisms from samples collected in SIYB during the August 2022 monitoring event. Results of the acute topsmelt and inland silverside survival tests conducted on SIYB surface water samples are summarized in Tables 3-8 and 3-9, respectively, and reported in full in Appendix D.

Table 3-8. Results of the 96-Hour Pacific Topsmelt (*Atherinops Affinis*) Acute Bioassay

Concentration (% Sample)	Station/Mean Survival (%)						
	SIYB-1	SIYB-2	SIYB-3	SIYB-4	SIYB-5	SIYB-6	SIYB-REF-1
Laboratory Control [a]	83.3	83.3	83.3	83.3	76.7	76.7	76.7
25	NT [b]	NT [b]	NT [b]	NT [b]	NT [b]	NT [b]	NT [b]
50	NT [b]	NT [b]	NT [b]	NT [b]	NT [b]	NT [b]	NT [b]
100	83.3	70.0	80.0	86.7	70.0	76.7	83.3
Test Results							
NOEC (%) [c]	100	100	100	100	100	100	100
LC_{50} [c]	>100	>100	>100	>100	>100	>100	>100
% Effect [c]	0.0	16.0	4.0	-4.0	8.7	0.0	-8.7
TST Result [c]	Pass	Fail	Pass	Pass	Pass	Pass	Pass

Notes:

a. Topsmelt tests failed to meet the minimum test acceptability criteria requiring greater than or equal to 90% mean survival in the laboratory controls. Therefore, the test results were deemed invalid. However, a thorough evaluation of the test results suggests that the observed effects in both the control and test samples were not due to a toxic response but rather were attributable to test organism health. To supplement the topsmelt test results, tests were also performed with inland silversides (see Table 3-9).

b. An insufficient number of topsmelt were available from the test organism supplier to perform topsmelt tests on the full dilution series. Therefore, topsmelt tests were only performed on the laboratory control and undiluted compliance samples (i.e., 100% sample concentration) for each site.

c. Because the minimum test acceptability criterion of 90% mean survival was not met in the laboratory controls, the test was considered invalid, and statistics are provided for informational purposes only.

> = greater than; % = percent; % effect = the percent effect in the 100% sample compared with the laboratory control (a negative % effect value represents a positive effect); LC_{50} = concentration estimated to be lethal to 50% of the organisms; NOEC = no observed effect concentration; NT = not tested; REF = reference; SIYB = Shelter Island Yacht Basin; TST (Pass/Fail) = Test of Significant Toxicity; TST Pass = sample is nontoxic according to the TST calculation; TST Fail = sample is toxic according to the TST calculation

Table 3-9. Results of the 96-Hour Inland Silverside (*Menidia beryllina*) Acute Bioassay

Concentration (% Sample)	Station/Mean Survival (%)						
	SIYB-1	SIYB-2	SIYB-3	SIYB-4	SIYB-5	SIYB-6	SIYB-REF-1
Laboratory Control	93.3	93.3	96.7	96.7	96.7	96.7	96.7
25	100	93.3	96.7	93.3	96.7	100	100
50	96.7	96.7	96.7	96.7	96.7	93.3	90.0
100	96.7	90.0	96.7	93.3	93.3	93.3	100
Test Results							
NOEC (%)	100	100	100	100	100	100	100
LC_{50}	>100	>100	>100	>100	>100	>100	>100
% Effect	-3.6	3.6	0.0	3.5	3.5	3.5	-3.5
TST Result	Pass	Pass	Pass	Pass	Pass	Pass	Pass

Notes:

There were no statistically significant effects on inland silverside survival from SIYB samples collected on August 16, 2022 compared with the laboratory controls using the TST or the USEPA 2002 acute method guidance flowchart statistical methods.

> = greater than; % = percent; % effect = the percent effect in the 100% sample compared with the laboratory control (a negative % effect value represents a positive effect); LC_{50} = concentration estimated to be lethal to 50% of the organisms; NOEC = no observed effect concentration; REF = reference; SIYB = Shelter Island Yacht Basin; TST = Test of Significant Toxicity; TST Pass = sample is nontoxic according to the TST calculation; USEPA = United States Environmental Protection Agency

3.3.2.2 Bivalve Larvae 48-Hour Chronic Bioassay

Bivalve tests were conducted on both filtered and unfiltered samples (for the 100% treatments only). Filtration of the 100% concentration samples was conducted to safeguard against potential effects from resident organisms in the raw water samples. Results for both unfiltered and filtered samples are presented as a combined endpoint of survival and development per the USEPA (1995b) protocol.

A statistically significant decrease in the combined survival and development endpoint using the TST test was observed in one of the six samples tested (SIYB-1) from within the basin. Exposure of bivalve larvae to the undiluted and unfiltered SIYB-1 sample (i.e., 100% concentration) resulted in 52.9% combined survival and normal development compared with results for the laboratory control (85.3%); these effects were statistically significant using both the USEPA (1995b) statistical approach and the TST analysis, indicating that surface waters collected from Station SIYB-1 were toxic to bivalve larvae. A statistically significant decrease in the combined survival and normal development endpoint was also observed in the undiluted filtered SIYB-1 sample (35.5% combined survival and normal development). Bivalve larvae toxicity was not observed in samples collected from any of the other stations in SIYB or the reference station (SIYB-REF-1). Results of the bivalve larvae development tests conducted on SIYB surface water samples are summarized in Table 3-10 and Appendix D.

Table 3-10. Results of the 48-Hour Mussel Larval Development Chronic Bioassay

Concentration (% Sample)	Station/Combined Survival and Normal Development (%)						
	SIYB-1	**SIYB-2**	**SIYB-3**	**SIYB-4**	**SIYB-5**	**SIYB-6**	**SIYB-REF-1**
Laboratory Control	85.3	83.7	85.7	91.0	86.0	85.1	85.9
6.25	89.4	89.9	85.1	89.2	91.1	84.5	84.8
12.5	85.5	85.9	87.7	88.6	89.8	83.6	88.5
25	86.8	89.8	91.9	87.4	82.5	87.5	80.6
50	88.5	89.1	91.0	89.2	86.2	87.0	91.3
100	**52.9***	87.1	90.5	89.2	88.6	86.9	92.0
Filter Control	86.3	84.0	88.8	89.4	86.7	88.7	89.4
100 (1.2-µm filtered) [a]	**35.5***	77.8	90.1	83.8	82.5	81.7	86.6
Test Results – Unfiltered Sample							
NOEC (%)	50	100	100	100	100	100	100
EC_{50}	>100	>100	>100	>100	>100	>100	>100
% Effect	37.9	-4.0	-5.5	2.0	-3.0	-2.1	-7.1
TST Result	Fail	Pass	Pass	Pass	Pass	Pass	Pass
Test Results – Filtered Sample							
NOEC (%)	<100	100	100	100	100	100	100
% Effect	58.9	7.3	-1.4	6.2	4.9	7.9	3.1
TST Result	Fail	Pass	Pass	Pass	Pass	Pass	Pass

Notes:
Bold* indicates a statistically significant decrease compared to control using both the traditional USEPA flow-chart statistical methods and the TST approach.
a. Tests were also performed on undiluted samples that were filtered through a 1.2-µm filter to remove potentially harmful native algae that might interfere with test organism performance.
> = greater than; < = less than; µm = micrometer(s); % = percent; % effect = the percent effect in the 100% sample compared to the laboratory control (a negative % effect value represents a positive effect); EC_{50} = concentration estimated to cause an adverse effect on 50% of the organisms; NOEC = no observed effect concentration; REF = reference; SIYB = Shelter Island Yacht Basin; TST (Pass/Fail) = Test of Significant Toxicity; TST Pass = sample is nontoxic according to the TST calculation; TST Fail = sample is toxic according to the TST calculation; USEPA = United States Environmental Protection Agency

Toxicity Identification Evaluation

Because chronic toxicity has been observed at Station SIYB-1 during all prior SIYB TMDL monitoring events (except the August 2021 event), a Phase I TIE was conducted on water from Station SIYB-1 concurrently with the compliance testing to identify the likely class(es) of contaminants causing toxicity.

As discussed previously, chronic toxicity was observed in the sample collected from Station SIYB-1 during the 2022 summer monitoring event (52.9% combined survival and normal development). Toxicity in the SIYB-1 sample was removed using ethylenediaminetetraacetic acid (EDTA), which is a targeted treatment that preferentially binds with divalent cationic metals (e.g., copper, lead, zinc). Given the specificity of the EDTA treatment and supporting results from the other Phase I TIE treatments (Appendix F), the observed toxicity at Station SIYB-1 was likely due to a cationic trace metal.

Detailed methods and results from the Phase I TIE conducted in August 2022 are presented in a technical memorandum in Appendix F.

3.3.2.3 Toxicity QA/QC

This section summarizes the QA/QC findings associated with the 2022 SIYB TMDL compliance toxicity testing. The QA/QC summary provided by WSP Environmental Toxicology Laboratory is included in Appendix D.

Field Observations

On August 12, 2022, as well as the day prior to sample collection (August 15, 2022), reconnaissance surveys were conducted in SIYB to evaluate the study area for the presence of algal blooms and general water clarity. In addition to these visual assessments, the reconnaissance surveys also included collection of water samples that were sent to the laboratory to be analyzed for the presence of harmful algal species. The analyses showed that the water clarity in SIYB was acceptable, and the water samples analyzed did not contain an abundance of harmful algae species. Based upon these findings, it was determined that the sample collection should proceed as planned.

Sample Receipt

Samples were received in good condition on the same day that they were collected (August 16, 2022). All tests were initiated on August 17, 2022, within the 36-hour holding time requirement.

Toxicity Test Validity

<u>96-Hour Acute Bioassay Tests Using Pacific Topsmelt and Inland Silversides</u>

The topsmelt test organisms were received by a commercial supplier (Aquatic BioSystems) 1 day before testing. The fish were held in the laboratory and allowed to acclimate to test conditions for 24 hours prior to test initiation. While there was limited topsmelt mortality observed during holding (less than 10%), the laboratory had concerns regarding the health and quality of the topsmelt because limited topsmelt were available for testing, and the fish received were from the supplier's last remaining stocks. Due to the limited number of topsmelt available for testing, the acute topsmelt tests could only be performed on the laboratory controls and undiluted samples from SIYB (i.e., 100% sample concentration).

Pacific topsmelt survival in the laboratory controls for the 96-hour acute toxicity test ranged from 76.7% to 83.3%, which did not meet the TAC of at least 90% mean survival in the controls. Therefore, the test results were considered invalid. The reduction in survival across sample concentrations from all sites in SIYB and the reference site in San Diego Bay, as well as in the laboratory controls, indicates that the batch of fish used to initiate the topsmelt test was suboptimal. Therefore, based upon review of the topsmelt test results, the reduced and variable survival observed was determined to not be a toxic response, but rather attributable to overall organism health.

For the past several years, there have been many challenges with using Pacific topsmelt for toxicity testing, including limited test organism supply and availability, as well as poor organism health and sensitivity due to difficulties culturing these organisms in a laboratory setting. Because of these challenges, the acute bioassay test was also performed using the inland silverside (a USEPA-approved alternative marine fish test species) for the 2022 summer monitoring event.

The inland silverside test organisms were received by a commercial supplier (Aquatic BioSystems) 1 day prior to testing. The fish were held in the laboratory and allowed to acclimate to test conditions. There was less than 10% mortality with the fish during holding, which is considered typical, and the inland silversides appeared to be of good quality for test initiation. Acute toxicity tests using the inland silverside were conducted concurrently with the topsmelt tests on the same set of samples.

Inland silverside survival ranged from 93.3% to 96.7% in all laboratory controls, which met the minimum TAC of 90% mean survival in the controls. The inland silverside acute bioassay test met all TAC set by the USEPA, as well as internal laboratory QA program requirements. All inland silverside survival test results were therefore considered valid and acceptable for reporting purposes.

48-Hour Chronic Bioassay Test Using Bivalve Larvae

Control survival for the 2022 summer monitoring bivalve larvae tests ranged from 88.8% to 96.6%, which met the USEPA TAC of 50% or greater survival. Bivalve larvae normality in the controls ranged from 93.9% to 94.3%, which met the USEPA TAC of 90% or greater proportion normal. Further, all laboratory controls met the ASTM International (ASTM) TAC of 70% or greater for the combined survival and proportion normal endpoint. All bivalve larvae development test results were therefore considered valid and acceptable for reporting purposes.

Reference Toxicant Tests

Concurrent reference toxicant test results for the Pacific topsmelt, inland silverside, and bivalve larvae tests are summarized in Tables 3-11, 3-12, and 3-13, respectively. The laboratory controls for the acute reference toxicant test using topsmelt did not meet the TAC, and therefore the test was deemed invalid. Reference toxicant tests using both inland silversides and bivalve larvae met the corresponding minimum TAC and were deemed valid. The calculated LC_{50} for the inland silverside test and EC_{50} for the bivalve test were within the acceptable range (i.e., within two standard deviations of the laboratory historical mean), indicating that the test organisms used during this round of testing were healthy and exhibited typical sensitivity to copper.

Table 3-11. Summary of Copper Chloride Reference Toxicant Test Results for Pacific Topsmelt

Concentration (µg/L Copper)	Mean Survival (%)	LC_{50} (µg/L Copper)	Historical LC_{50} ± 2SD Range (µg/L Copper)
Laboratory Control [a]	85	210	65.0 – 304
25	100		
50	95		
100	85		
200	55		
400	5		

Notes:
a. Topsmelt reference toxicant tests failed to meet the minimum test acceptability criteria requiring greater than or equal to 90% mean survival in the laboratory controls. Therefore, the test results were deemed invalid.
µg/L = microgram(s) per liter; % = percent; LC_{50} = concentration estimated to be lethal to 50% of the organisms; SD = standard deviation

Table 3-12. Summary of Copper Chloride Reference Toxicant Test Results for Inland Silversides

Concentration (µg/L Copper)	Mean Survival (%)	LC_{50} (µg/L Copper)	Historical LC_{50} ± 2SD Range (µg/L Copper)
Laboratory Control	95	225	102 – 371
25	100		
50	95		
100	100		
200	65		
400	0		

Notes:
µg/L = microgram(s) per liter; % = percent; LC_{50} = concentration estimated to be lethal to 50% of the organisms; SD = standard deviation

Table 3-13. Summary of Copper Chloride Reference Toxicant Test Results for Bivalve Larvae

Concentration (µg/L Copper)	Mean Combined Survival and Normal Development (%)	EC_{50} (µg/L Copper)	Historical EC_{50} ± 2SD Range (µg/L Copper)
Laboratory Control	85.2	9.55	4.63 – 18.1
2.5	82.4		
5.0	85.3		
10	37.8		
20	0		
40	0		

Notes:
µg/L = microgram(s) per liter; % = percent; EC_{50} = concentration estimated to cause an adverse effect on 50% of the organisms; SD =standard deviation

Curved Hinged Larvae

During the 2014 monitoring, it was noted that some of the larvae (approximately 70%) were enumerated as “abnormal” because they had a slightly curve-hinged shell (i.e., bean-shaped) rather than a straight-hinged D-shaped shell (AMEC Environment & Infrastructure, Inc., 2015). To evaluate the recurrence of this observation for future SIYB TMDL bivalve larvae tests, the laboratory scored the larvae as (1) larvae with a fully developed shell with a straight-hinged D-shape, (2) partially developed larvae with a concave or curved hinge, and (3) larvae that fail to develop a shell or display severe morphological defects (see photographs in the toxicity report in Appendix D).

During the 2022 summer monitoring event, the greatest percentages of curved hinges were observed in the undiluted (unfiltered and filtered) samples from Stations SIYB-1 and SIYB-2 (1.6 to 2.0%). The percentage of curved hinges observed in the remaining samples was less than 0.5%. The factor(s) that contributed to the elevated number of curved hinges observed in the SIYB-1 sample in 2014 (greater than 70%) did not recur during the summer 2022 monitoring event.

4.0 IN-WATER HULL CLEANING PAUSE WATER QUALITY MONITORING

To address data gaps associated with the relationship between in-water hull cleaning and water quality, the Port implemented an 8-week Hull Cleaning Pause and conducted water quality monitoring before, during, and after the Pause to evaluate dissolved copper levels throughout SIYB over time. The Hull Cleaning Pause applied to all vessels with copper-based AFPs in SIYB from December 19, 2021 through February 9, 2022.

The 16-week monitoring program was planned and implemented in partnership with the Regional Board and included the following components:

1. Hull cleaning inspections and visual observations: To ensure compliance with the Hull Cleaning Ordinance amendment, Port staff conducted frequent inspections throughout SIYB during the Hull Cleaning Pause to look for hull cleaning activity and document visual observations of hull fouling and water conditions in the basin.
2. Weekly water quality monitoring: Surface water quality sampling was performed weekly for the duration of the monitoring program to evaluate concentrations of dissolved copper in SIYB for 4 weeks leading up to the Hull Cleaning Pause, 8 weeks during the Pause, and 4 weeks following the Pause. Thirteen core monitoring stations and two reference stations were sampled weekly over the 16-week monitoring program. Seven additional enhanced stations were sampled biweekly to provide supplemental data at a higher resolution and in closer proximity to vessels than the stations on the outer edges of the marinas along and within the main channel.
3. Storm monitoring event: Stormwater and surface water quality sampling was performed before and after one storm event during the monitoring program to evaluate potential effects of stormwater discharge on copper levels in SIYB and on the Hull Cleaning Pause monitoring results.

A detailed technical report was completed and includes the findings of the Hull Cleaning Pause study. The report is included as Appendix G. Key findings from each component of the monitoring program are as follows:

- Weekly average dissolved copper concentrations for the core and enhanced stations over the 16-week monitoring program are shown in Figure 4-1, along with results from the two reference stations.

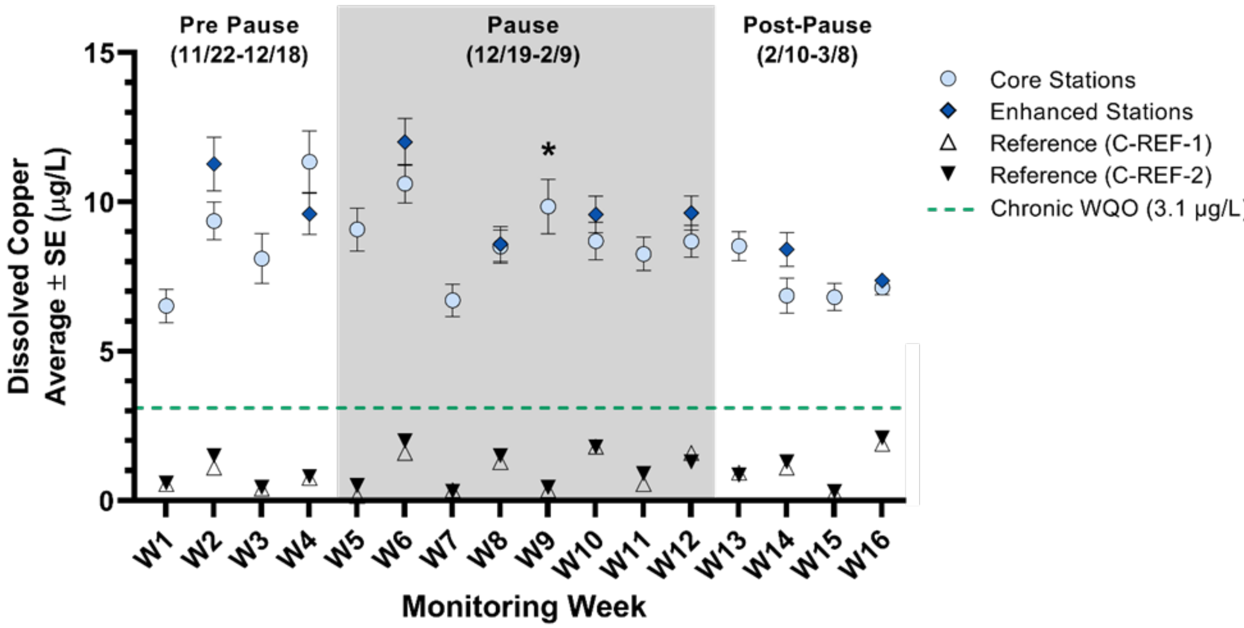


Figure 4-1. Weekly Average Dissolved Copper Concentrations at Core and Enhanced Stations Over Monitoring Program

Notes: μg/L = microgram(s) per liter; REF = reference; SE = standard error; W = week; WQO = water quality objective
* The Week 9 monitoring event occurred 4 days after a tsunami event.
SE bars for Week 16 are smaller than the size of the symbol and therefore are not visible.

- There was an apparent increase in the dissolved copper levels throughout the basin during the Pre-Pause period and extending through the first two weeks of the Pause, particularly at the inner basin stations and the stations in closer proximity to vessels (i.e., enhanced stations)[12]. There was also a noticeable increase in hull cleaning activities in the last 2 weeks of the Pre-Pause period as boaters and hull cleaners prepared for the Hull Cleaning Pause. Under the assumption that dissolved copper leach rates spike following cleaning events, the increase in dissolved copper concentrations observed during the Pre-Pause period and beginning of the Pause period, particularly in the inner basin, may be attributed to an increase in hull cleaning activities.
- After the first 2 weeks of the Pause, dissolved copper concentrations began to gradually trend downward over the remainder of the Pause period. This trend continued through the Post-Pause period. This finding was consistent with that presented in Earley et al. (2013), with the expected spike in dissolved copper concentrations from hull cleaning activities gradually diminishing as concentrations returned to “pseudo steady state” after the first 30 days of the Pause.
- The hull cleaning inspections conducted throughout the 8-week Hull Cleaning Pause did not find any instances where divers were cleaning or had cleaned (via dive tag observations) vessels with copper-based AFPs. This finding was further supported by the notable increase in marine growth (fouling) on vessel hulls throughout the basin over the course of the Pause.

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[12] It should be noted that a tsunami occurred 4 days before the Week 9 monitoring event. Dissolved copper concentrations measured in Week 9 were slightly elevated compared with concentrations in previous weeks; however, by the following week (Week 10), dissolved copper concentrations returned to levels similar to those measured before the tsunami (Week 8).

- Following the Pause, it was assumed that hull cleaning frequency would increase to Pre-Pause levels as cleaning activities resumed. However, observations during dock walks conducted in the Post-Pause period did not indicate a notable increase in hull cleaning, suggesting that there may have been a delay in resuming routine hull cleaning activities following the Pause. This may have contributed to the continued slight downward trend in dissolved copper concentrations following the Pause.
- The results of the pre- and post-storm weekly monitoring events suggested that stormwater discharge did not contribute a substantial amount of copper loading to SIYB. While the storm did appear to have an overall mixing effect on the spatial distribution of dissolved copper in SIYB (i.e., more uniform concentrations throughout the basin after the storm), the basin-wide average dissolved copper concentrations remained the same before and after the storm (11 µg/L). As such, storm events and associated stormwater runoff are not expected to have had any significant impact on dissolved copper levels or conclusions related to the effects of hull cleaning on dissolved copper concentrations throughout the monitoring program.
- While there was an observed decrease in basin-wide dissolved copper levels during the Pause and Post-Pause periods, it should be noted that the basin-wide average measured during the final week of the monitoring program (7.2 µg/L in Week 16) was similar to that measured during Week 1 (6.5 µg/L). These basin-wide average dissolved copper concentrations were also consistent with those measured during previous SIYB TMDL monitoring events.
- The original SIYB TMDL model assumes that in-water hull cleaning accounts for 5% of the annual dissolved copper loading from copper-based paints to SIYB. Under this assumption, the 8-week Hull Cleaning Pause would result in an estimated 7.5 kg/yr reduction in loading to SIYB using the 2022 vessel tracking data. Of this load reduction, 5.7 kg/yr occurred during the 2022 monitoring year (see Section 5.1.1).
- While a pause in the hull cleaning of vessels with copper-based AFPs does decrease the load of dissolved copper into the basin, leading to subsequent reductions in dissolved copper concentrations, it appears that changes to the basin-wide dissolved copper concentrations are minimal when compared with the passive leaching of copper-based AFPs, which is the predominant source of copper loading to the basin. Further, the total cessation of hull cleaning during the monitoring program was insufficient to reduce the basin-wide dissolved copper levels to a level that would achieve the current water quality standard (3.1 µg/L).

5.0 DISCUSSION

This section discusses trends in copper loading and water quality based on data and information collected over the course of the SIYB TMDL Monitoring Program.

5.1 Dissolved Copper Load

Based on the 2022 vessel census data, there was an estimated annual dissolved copper load to SIYB of 1,157 kg/yr from passive leaching and in-water hull cleaning. This total is composed of 1,133 kg/yr (98%) from vessels in marinas and yacht clubs and 23.8 kg/yr (2%) from vessels located at the transient dock and weekend anchorage. Figure 5-1 presents dissolved copper loads from 2012 to 2022 compared with the SIYB TMDL baseline load (2,100 kg/yr) and load reduction targets. Since achieving the 2012 and 2017 interim TMDL loading targets, the estimated dissolved copper load to SIYB has leveled off and remained relatively consistent over the past 6 years (Figure 5-1).

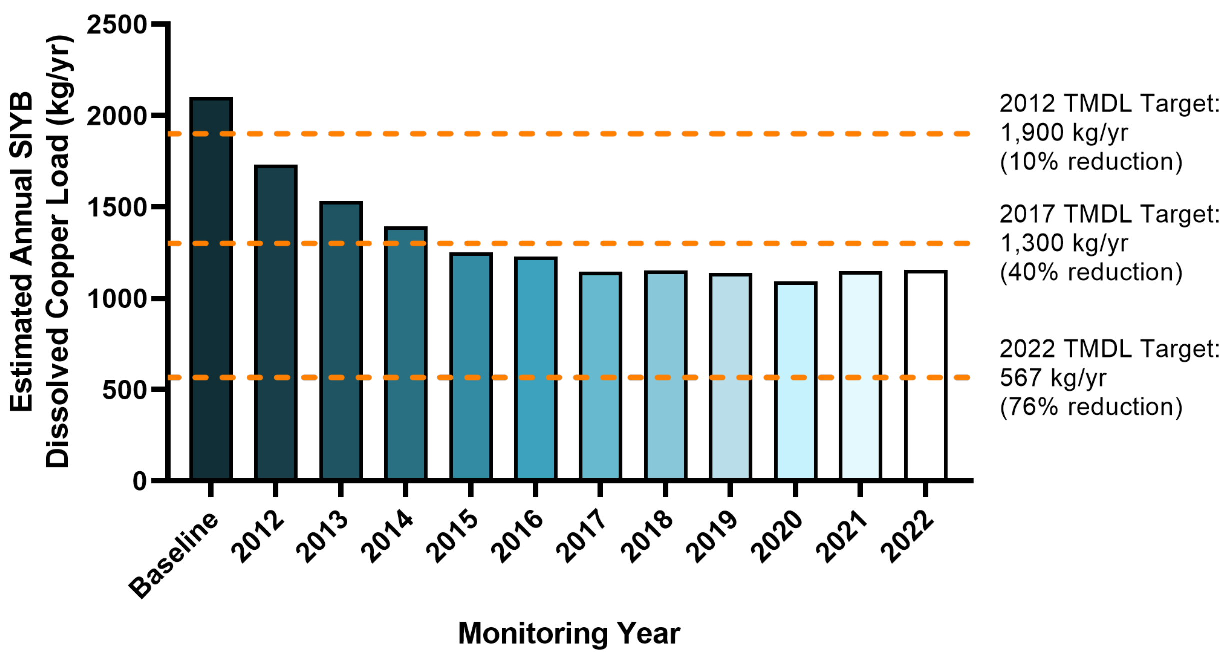

Figure 5-1. Annual SIYB Dissolved Copper Load During Each Monitoring Year

5.1.1 Dissolved Copper Load Reduction Sources

The results of the vessel tracking efforts were used to estimate the dissolved copper load reduction of 44.9% (943 kg/yr) for 2022 compared with the SIYB TMDL baseline load (2,100 kg/yr). Load reduction sources include use of lower-copper paints, aged-copper paints, non-copper alternatives, vacant slips, decreased slip occupancy rate, and elimination of loading from in-water hull cleaning during the Hull Cleaning Pause. The relative input from each load reduction strategy contributing to the total load reduction in 2022 is shown in Figure 5-2.

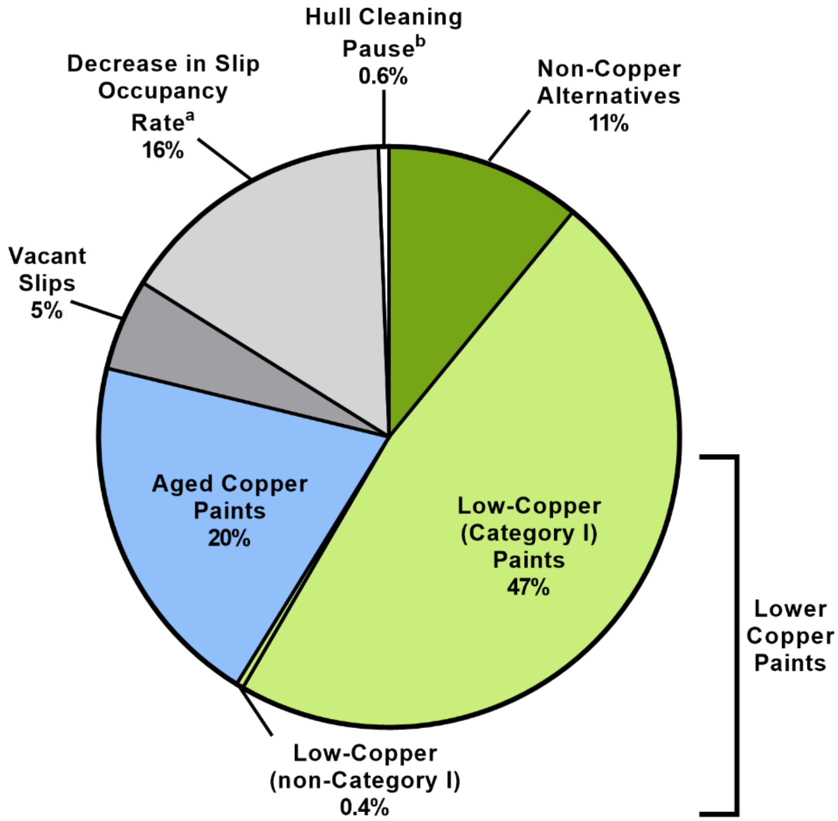

Figure 5-2. Relative Contribution of Different Load Reduction Strategies to the Overall Load Reduction in 2022

Notes:

a. Decrease in average slip occupancy represents the load reduction due to an average occupancy rate of 93% for all vessels in SIYB.

b. Note that the 8-week Hull Cleaning Pause occurred from December 19, 2021 through February 9, 2022. However, the load reduction presented above only accounts for the portion of the Pause that occurred during the 2022 monitoring year (i.e., January 1, 2022 through February 9, 2022).

Overall, the data from 2022 indicate that low-copper paints (specifically DPR Category I paints) and aged-copper paints accounted for approximately 67% of the copper load reduction. Decreases in slip use and occupancy (i.e., 93% average occupancy rate for vessels in 2022 relative to the 100% occupancy rate used for the SIYB TMDL assumptions), as well as full vacancies (i.e., slips that were vacant for the entire 2022 monitoring year), accounted for the second largest copper load reduction. Non-copper paints, slip liners, and HydroHoists® are all considered non-copper alternatives, which do not contribute a copper load to SIYB. Notably, the use of non-copper alternatives, which can provide the greatest load reduction benefit, accounted for only 11% of the copper reduction in 2022, consistent with results from previous years. It should be noted that the entire Port fleet was converted to non-copper paints in 2012 and has not contributed to copper loading in SIYB since that time.

In 2022, additional load reduction resulted from the Hull Cleaning Pause, which eliminated loading from in-water hull cleaning of copper-based AFPs in SIYB for 8 weeks. Figure 5-2 presents the load reduction resulting from the portion of the Pause that occurred during the 2022 monitoring year (i.e., January 1, 2022 through February 9, 2022).

5.1.2 Annual Variation in Dissolved Copper Load Categories

The annual vessel tracking program has been a part of the Monitoring Plan since 2012, which allows for documentation of changes in paint type use and slip occupancy over time. Figure 5-3 presents the distribution of paint load categories from 2012 to 2022.

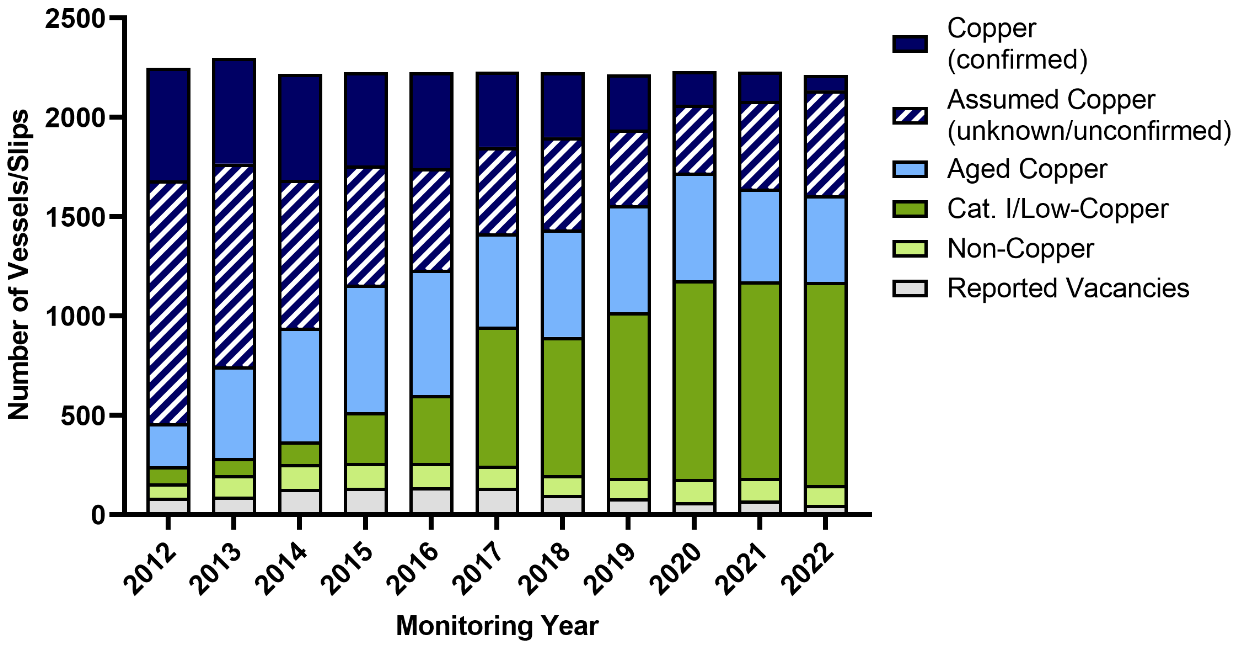

Figure 5-3. Load Categories per SIYB TMDL Year, 2012–2022

Since the implementation of the SIYB TMDL Monitoring Program, there has been a notable shift from the use of high-copper paints to DPR Category I/low-copper paints. However, as discussed in Section 5.1, the annual dissolved copper load has leveled off since 2017 as a result of the following trends in vessel tracking and paint use (depicted in Figure 5-3):

- The use of confirmed high-copper paints has decreased over the past 10 years, as high-copper paints can no longer be sold or applied to vessels in California under the DPR Rule.
- Of the remaining vessels classified with "high-copper" paints in 2022, 87% have either "unknown" or "unconfirmed" paints and consequently are conservatively assumed to have high-copper paints under the assumptions defined in the Monitoring Plan.
- Given the decreasing trend in high-copper paint use and the fact that it is no longer available at local boatyards, it is likely that a portion of the remaining unknown/unconfirmed paints are DPR Category I paints or aged-copper paints (see Section 5.1.3).
- The number of vessels with non-copper alternatives has remained relatively consistent since the 2013 monitoring year.
- Only 50 vacancies were observed in marinas and yacht clubs in 2022, which is the lowest vacancy rate observed since the monitoring program began.

5.1.3 Alternative Load Reduction Scenarios: Category I Paint Tracking Efforts During and Following the DPR Rule Transition Period

Following DPR Rule implementation in July 2018, the transition to Category I low-leach paints became evident in paint use trends, as the majority of newly painted vessels were confirmed to be painted with DPR Category I paints (see Figure 5-4). However, the DPR Rule allowed for existing stock of high-copper paints (those exceeding the maximum leach rate requirement of 9.5 µg/cm^2/day) to be sold until June 30, 2021. During this transitional period, it became increasingly challenging to track paint use and distinguish between original paint formulations with leach rates exceeding 9.5 µg/cm^2/day and ones that were reformulated to meet the DPR maximum leach rate requirements. In many cases, a particular paint name could be associated with both a high-copper and DPR Category I paint. For example, a high-copper paint "Ultra-Kote" was reformulated to meet DPR Rule maximum leach rate requirements; however, its name has not changed, and only the DPR registration number (which is not always known or provided) can be used to distinguish between the DPR Category I and high-copper formulations. In addition, some uncertainty exists with paint classification due to inconsistent product information obtained from different sources. For example, Coppercoat® is classified as "non-leaching" on the manufacturer's website[13], but is a registered copper paint pesticide with the DPR.

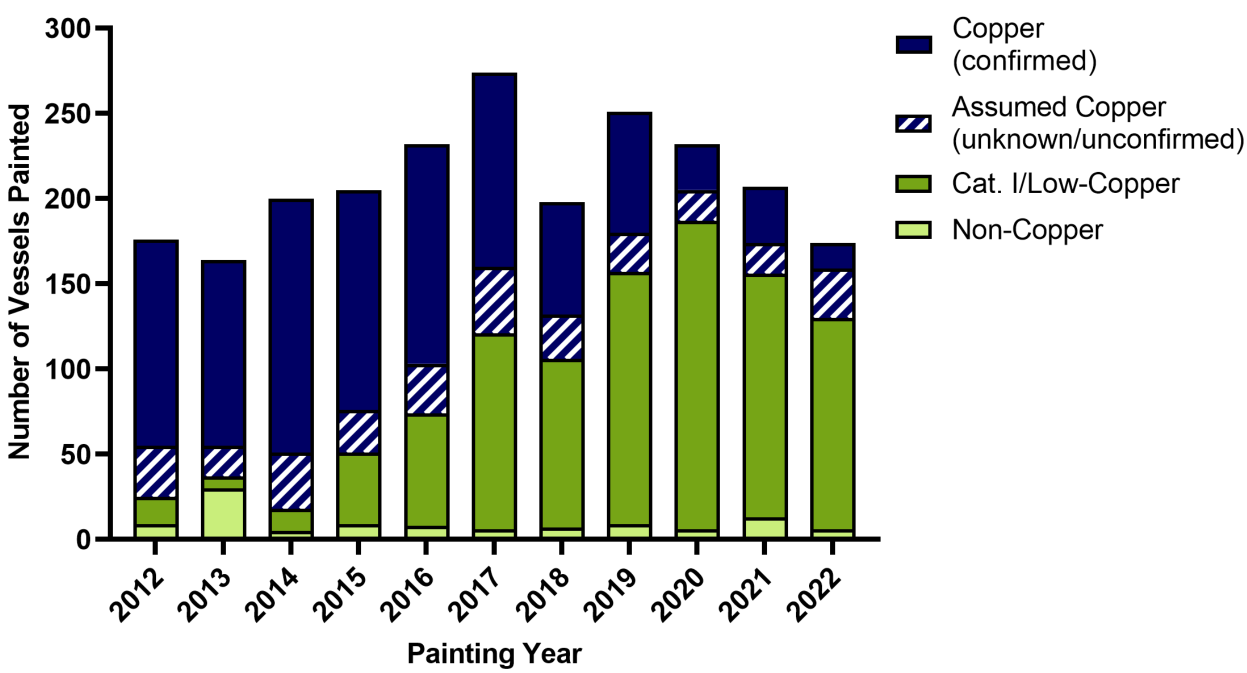

Figure 5-4. Hull Paint Types for Newly Painted Vessels Over Time
Note: Only vessels with painting dates reported in the vessel tracking data were used for this analysis.

The DPR maintains a database of paints that is continually updated as products are reformulated. As such, the accuracy and knowledge of specific vessel paint data, particularly the DPR registration number, become critical to understanding the specific product that was applied and whether that product is high-copper or DPR Category I. However, the paint information may be updated or modified over the course of the reporting period, and as a result, the paints applied to

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13 https://www.coppercoatusa.com/faq.php

vessels and reported via vessel tracking may differ from the information in the DPR database. Given that this process is overseen by the DPR, and high-copper paints are no longer available, the ongoing value of vessel tracking for all paints is limited.

The vessel tracking approach defined in the Monitoring Plan estimates loads conservatively. If a vessel's paint is unknown or cannot be confirmed to be low-copper or non-copper based upon the product information supplied, the paint is assumed to be high-copper and is assigned a full load of 0.9 kg/yr. Therefore, the 2022 dissolved copper load estimate of 1,157 kg/yr presented in this report (Section 3.2.4) was calculated using these more conservative assumptions.

Notably, 529 of the remaining 606 vessels (87%) in marinas and yacht clubs classified as high-copper in 2022 had unknown or unconfirmed hull paint types and were conservatively assumed to be high-copper. However, it is possible and quite likely that vessels with unknown or unconfirmed paints are actually DPR Category I paints as a result of the DPR Rule implementation and paint availability in the boatyards or are aged-copper paints. In particular, vessels painted after the DPR Rule transition period (i.e., after June 30, 2021) are likely to have DPR Category I paints because the majority of vessels in SIYB are painted in California.

In addition, annual vessel tracking has identified that a subset of the "aged-paint" vessels have not been painted for a considerable period of time (i.e., more than 5 years). The average life cycle of a copper hull paint is 3 years. Currently, copper hull paints that are older than 3 years old are assumed to contribute a half-load of dissolved copper (i.e., 0.45 kg/yr), which is based on studies indicating that a majority of the copper biocide leaches out of the paints within the first 2 to 3 years after application. It is also likely that a paint's ability to leach copper continues to diminish after 3 years. Modeling of biocide release rates by mass-balance calculation using International Organization for Standardization (ISO) Method 10890:2010 projects that copper levels are depleted in copper-based AFPs after 5 years (ISO, 2010). Therefore, copper-based paints older than 5 years old would be expected to contribute no load.[14]

To account for additional load reductions that may result from the DPR Rule implementation and depletion of copper from aged paints, multiple load estimates were calculated for five possible scenarios, each using different assumptions related to known/unknown or aged paint types, as follows:

- Scenario 1 – Original Conservative Loading Approach: This scenario represents the dissolved copper load estimate using the original Monitoring Plan assumptions presented in Table 2-3 in Section 2.2.3. Any vessels painted after December 31, 2019 (or with an unknown painting date) with unknown or unconfirmed paints were conservatively assumed to have high-copper paint (0.9 kg/yr/vessel).
- Scenario 2 – Loading Approach Assuming All Paints Applied After the DPR Rule Transition Period (June 30, 2021) are DPR Category I: This scenario represents the dissolved copper load estimate assuming that any vessels painted after June 30, 2021 have DPR Category I paint (0.45 kg/yr/vessel), as existing stock of high-copper paints could no longer be sold or applied in California.

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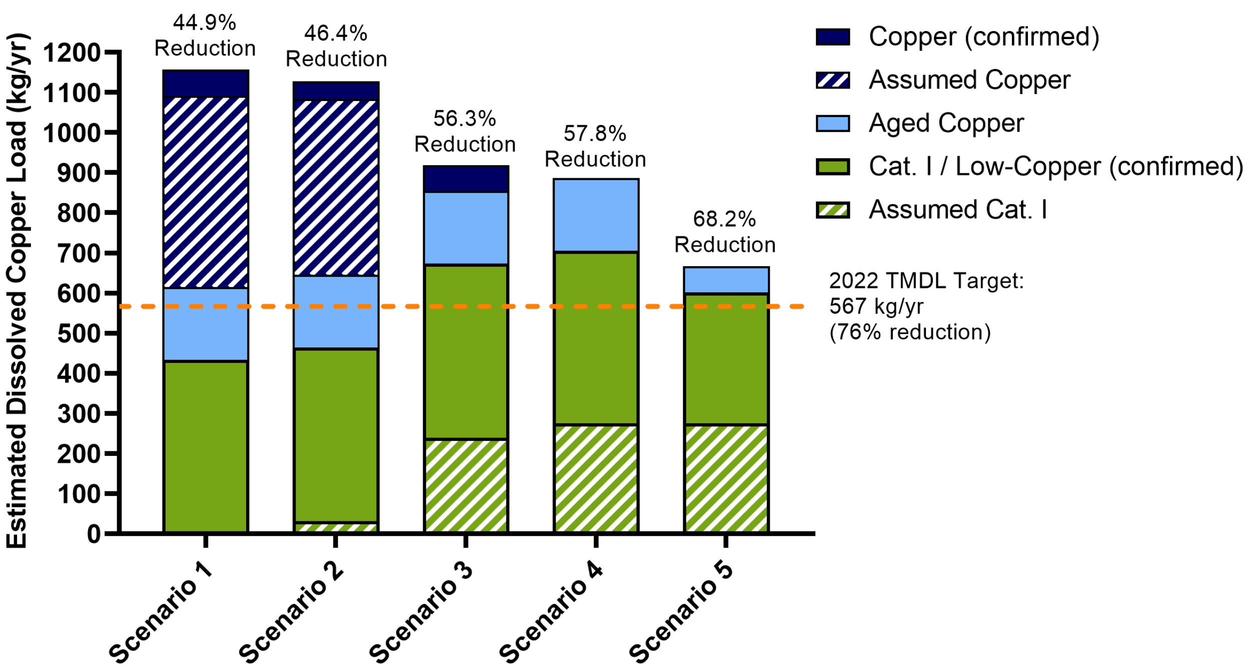
14 Information regarding loading from paints older than 5 years old was provided to the Port by the SIML TMDL Group on March 30, 2023 (see Appendix B).

- Scenario 3 – Loading Approach Assuming All Unknown or Unconfirmed Paints are DPR Category I: This scenario represents the dissolved copper load estimate assuming that any vessels painted after December 31, 2019 (or with an unknown painting date) with unknown or unconfirmed paints have DPR Category I paint (0.45 kg/yr/vessel) as a result of the implementation of the DPR Rule.
- Scenario 4 – Loading Approach Assuming No High-Copper Paints were Applied After DPR Rule Implementation: This scenario represents the dissolved copper load estimate assuming that all vessels painted after the original DPR Rule implementation date, July 1, 2018, have DPR Category I paint (0.45 kg/yr/vessel). This scenario assumes that boatyards did not apply surplus high-copper paints to any vessels that were berthed in SIYB.
- Scenario 5 – Loading Approach Assuming No High-Copper Paints were Applied After DPR Rule Implementation and Copper-Based Paints Applied Over 5 Years Ago Contribute No Load: As presented in Scenario 4, this scenario shows the dissolved copper load estimate assuming that all vessels painted after the DPR Rule implementation have DPR Category I paint (0.45 kg/yr/vessel). In addition, this scenario assumes that copper-based paints that were applied more than 5 years ago (i.e., on or before December 31, 2017) contribute no load to SIYB. This is based on the assumption that copper levels in copper-based AFPs are depleted after 5 years (ISO, 2010).

Loading estimates for each scenario are presented in Figure 5-5.



Notes:
Scenario 1: Original assumptions
Scenario 2: Assume all vessels painted after June 30, 2021 are Category I
Scenario 3: Assume vessels with unknown or unconfirmed paints are Category I
Scenario 4: Assume all vessels painted on/after July 1, 2018 are Category I
Scenario 5: Assumes all vessels painted on/after July 1, 2018 are Category I & all vessels painted before December 31, 2017 contribute no load

Figure 5-5. 2022 Dissolved Copper Loading Estimate Scenarios

Dissolved copper load estimates calculated for Scenarios 2 through 5 indicate a reduced load relative to that calculated using the original SIYB TMDL assumptions. As shown in Scenario 1, data from the 2022 hull paint census suggest that there are still some vessels (n=77) confirmed to have non-DPR Category I paints, based on the paint information provided by the boaters. The remaining vessels classified as "high-copper" and assigned a full load (0.9 kg/yr) were either unknown or unconfirmed paints that were conservatively assumed to be high-copper based on the Monitoring Plan assumptions (Scenario 1). However, as discussed above, it is likely that a portion of these unknown/unconfirmed paints assumed to be high-copper are DPR Category I paints (Scenarios 2 and 3). High-copper (i.e., non-DPR Category I paints) will not be completely phased out in California until 3 years following the end of the DPR Rule transition period (June 30, 2024). At that time, all copper paints, if painted and/or purchased in California, will be either DPR Category I paints or aged paints. The complete phase-out of high-copper paints is reflected in Scenario 4 using the 2022 vessel census data. Scenario 5 also takes into account the load reduction projected to result from the depletion of copper from aged paints more than 5 years old. Based on the scenarios presented above and the real-world uncertainties related to paint use, loading from aged paint, etc., the dissolved copper load reduction to SIYB is estimated to range between 45% and 68% (Figure 5-5).

5.2 Water Quality Monitoring

This section discusses the findings from the water quality monitoring conducted in SIYB over the course of the program's history since the issuance of the Investigative Order in 2011. It includes a discussion of dissolved copper and toxicity results from the 2022 summer monitoring compliance event, as well as trends in water quality over time.

Dissolved Copper Levels

Figures 5-6 and 5-7 present the dissolved copper concentrations measured in SIYB during each monitoring event as a basin-wide average and by individual monitoring station, respectively. These figures include results from both the compliance monitoring events conducted in the summer and the supplemental monitoring events conducted in the winters of 2021 through 2023 for comparison.

The basin-wide average dissolved copper level during the 2022 summer monitoring event was 6.1 µg/L. This value represents a 27% percent reduction in the basin-wide average relative to the 2005–2008 baseline (8.3 µg/L; Figure 5-6). As in previous years, a gradient in dissolved copper levels was observed in SIYB in August 2022, with higher concentrations near the head (Station SIYB-1) that decreased moving toward the mouth (i.e., Station SIYB-6). Dissolved copper levels at the five innermost stations in SIYB (SIYB-1 through SIYB-5) remained above the CTR chronic CCC WQO of 3.1 µg/L and acute CMC WQO of 4.8 µg/L during the 2022 summer monitoring event (Figure 5-7), which is consistent with results from previous monitoring years. In most years, copper levels at SIYB-6 have been below both WQOs and close to or below the acute WQO at SIYB-5.

In addition to the annual summer compliance monitoring, supplemental winter monitoring events were conducted in February 2021, March 2022, and January 2023. The purpose of this winter monitoring was to provide a better understanding of the potential seasonal variability of dissolved copper levels in SIYB and at the reference locations during a period of cooler water temperatures and lower frequency of hull cleaning and vessel usage relative to the summer months. Detailed results from the winter monitoring events are included in the 2021 annual report (February 2021 event; Wood, 2022d) and Appendix H herein (March 2022 and January 2023 events).

Beginning in winter 2021, basin-wide dissolved copper concentrations in SIYB began trending downward, decreasing from a maximum of 8.5 µg/L in August 2019 to a minimum of 4.9 µg/L in August 2021. Despite cooler water temperatures observed during the winter monitoring events, basin-wide average dissolved copper concentrations measured since August 2021 have been similar regardless of the season (4.9 µg/L to 6.1 µg/L; Figure 5-6).

Similar concentrations and spatial trends in dissolved copper have also been observed at individual monitoring locations during the winter monitoring events (Figure 5-7). The greatest variability in dissolved copper concentrations in recent monitoring years has been observed near the head of the basin at Station SIYB-1. However, this variability does not appear to be directly attributable to seasonality, with similar ranges of dissolved copper concentrations measured at Station SIYB-1 during both the summer (6.7 µg/L to 15 µg/L) and winter monitoring events (7.7 to 11 µg/L).

Overall, there were no substantial differences in dissolved copper concentrations in SIYB between the summer and winter monitoring events.

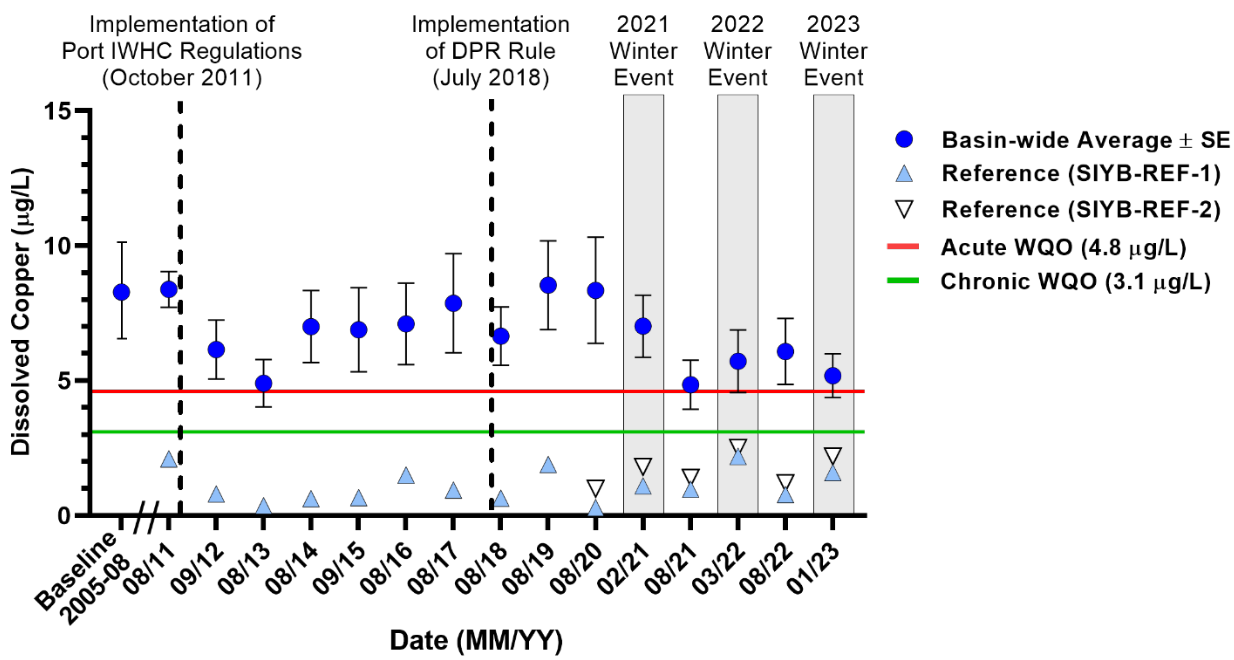


Figure 5-6. SIYB Dissolved Copper Levels Over Time and Key Load Reduction Initiatives

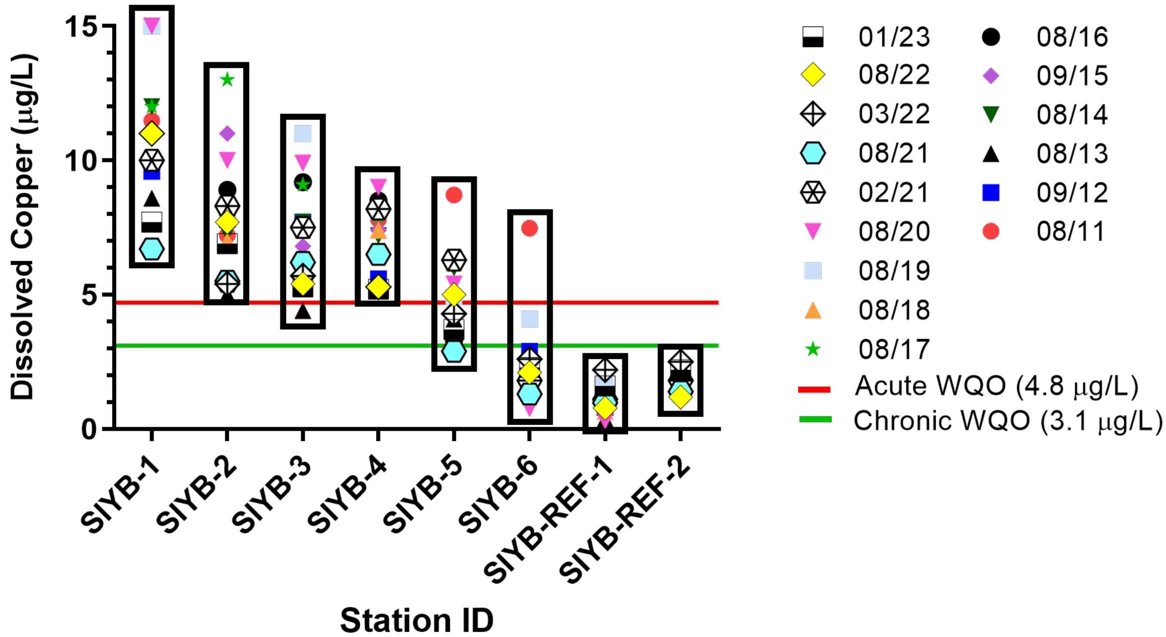


Figure 5-7. Dissolved Copper Comparison by Sampling Station

Acute Toxicity

Acute toxicity tests were performed using both Pacific topsmelt and inland silversides during the 2022 summer monitoring event. As discussed in Section 3.3.2, there were issues with the health of the batch of topsmelt received from the organism supplier similar to issues experienced in recent years. However, overall, the combined results of the topsmelt and inland silverside tests indicated that there were no acute toxic effects on these organisms from samples collected in SIYB in August 2022.

Since the beginning of the SIYB TMDL Monitoring Program, a toxic response in topsmelt has only been observed at one station (SIYB-4) in the summers of 2018 and 2019; however, the cause of this toxicity is unknown. In accordance with the Monitoring Plan[15], samples were re-collected at this site for confirmation testing in 2019, and acute toxicity was no longer present; therefore, no additional evaluation (i.e., TIE) was warranted. Similarly, no acute toxic response was observed at Station SIYB-4 (or other stations in SIYB) in the past 3 years during the summer or winter monitoring events (see Appendix H).

Chronic Toxicity

Bivalve larvae chronic survival and development are considered primary indicators of copper toxicity, because the mussel species *Mytilus galloprovincialis* is considered one of the most sensitive test organisms used in the calculation of the water quality criterion for copper in marine environments (USEPA, 1995a). Despite dissolved copper levels exceeding WQOs in a majority of the basin, chronic toxicity was only observed at the innermost station (SIYB-1) during the 2022 summer monitoring event, which is consistent with results from prior monitoring years.

[15] Due to unexplained toxicity observed during the 2018 monitoring year, toxicity testing methods in the Monitoring Plan were updated in 2019 to include conditions that may necessitate a TIE.

Since 2011, chronic toxicity of bivalve larvae has only been observed at the two innermost sampling stations in the basin (SIYB-1 and SIYB-2). A toxic response was observed at Station SIYB-1 during all monitoring events from 2011–2020 and at Station SIYB-2 periodically throughout the SIYB TMDL Monitoring Program (5 of 15 events; Figure 5-8). The head of the basin, where Stations SIYB-1 and SIYB-2 are located, has the highest concentration of vessels within the immediate vicinity, as well as the highest copper concentrations, compared with stations in the middle and near the mouth of the basin.

Notably, no chronic toxicity was observed at Station SIYB-1 during the 2021 summer monitoring event; this corresponded with the lowest dissolved copper level measured at Station SIYB-1 (6.7 µg/L) over the course of the SIYB TMDL Monitoring Program. In addition, lower levels of chronic toxicity were observed at Station SIYB-1 in the two most recent winter monitoring events (12% effect relative to the control in March 2022 and 9.7% effect in January 2023; Appendix H). These effects on mussel embryo development were statistically significant using the USEPA 1995 traditional flow-chart statistical methods (i.e., Dunnett multiple comparison test); however, the effects were not significant using the TST approach (USEPA, 2010).

Figure 5-8 depicts the dissolved copper levels measured at Stations SIYB-1 and SIYB-2 and indicates whether chronic toxicity was observed during each monitoring event. In general, from the initiation of the toxicity monitoring in SIYB in 2011 through 2023, chronic toxicity was almost always observed at dissolved copper concentrations above approximately 8 µg/L, and rarely observed at levels below 8 µg/L (only in 2012 and 2023).

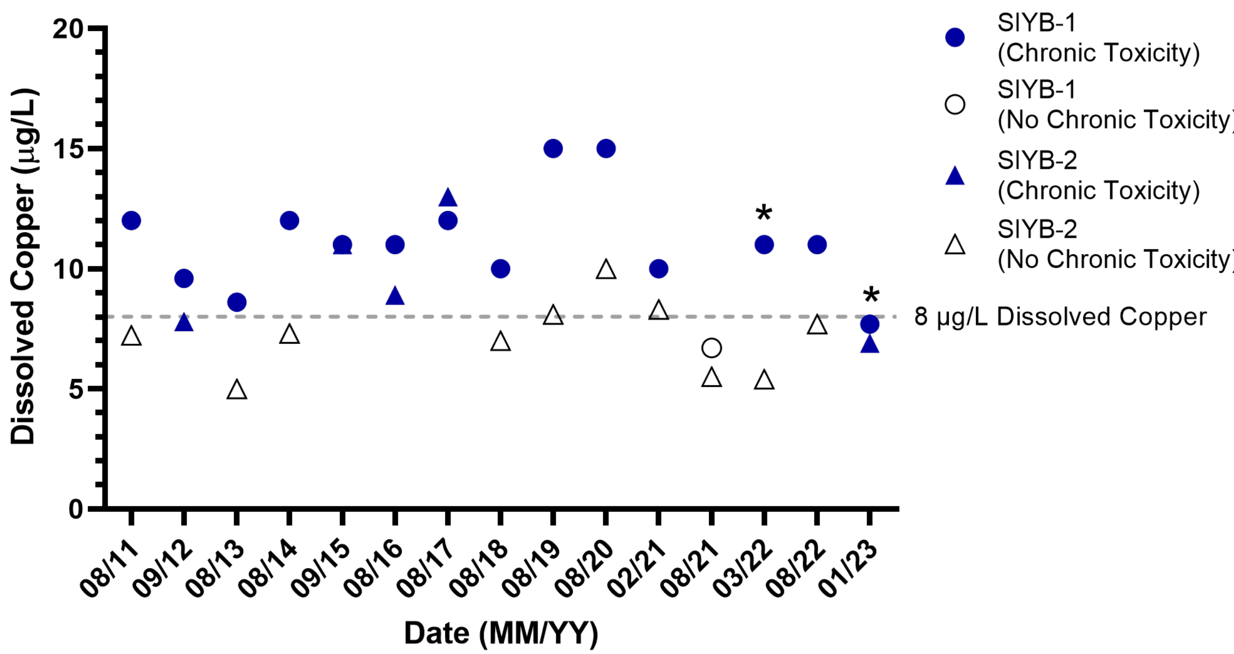


Figure 5-8. SIYB Dissolved Copper Levels and Chronic Toxicity Over Time

* Note that effects on mussel embryo development observed at Station SIYB-1 in March 2022 and at Stations SIYB-1 and SIYB-2 in January 2023 were statistically significant using the traditional USEPA flow-chart statistical methods (i.e., Dunnett multiple comparison test). However, effects were not significant using the TST approach.

Toxicity Identification Evaluation

Because chronic toxicity has been observed at Station SIYB-1 during almost every monitoring event, a Phase I TIE was conducted during the August 2022 event in an attempt to identify the likely class(es) of contaminants causing toxicity (if observed). As discussed in Section 3.3.2.2, results of the Phase I TIE indicated that the observed toxicity was likely due to a cationic trace metal. Measured concentrations of dissolved copper typically measured at Station SIYB-1 (11 µg/L on average over the SIYB TMDL Monitoring Program) would be expected to result in toxicity to mussel embryos based on estimated effects concentrations (e.g., EC_{50}) reported in the literature. In addition, chronic toxicity test results over the course of the SIYB TMDL Monitoring Program indicate that chronic toxicity is generally observed in SIYB at copper concentrations above approximately 8 µg/L (Figure 5-8). This suggests that copper is likely the specific cationic trace metal responsible for observed toxic effects at Station SIYB-1. These results are consistent with findings from the TIE conducted in SIYB by SCCWRP in 2005 (Schiff et al., 2007).

Additional toxicant identification and confirmation (Phase II/III TIE) procedures, including a copper spiking study, were conducted on the SIYB-1 sample collected during the 2023 winter monitoring event. Based on the results of the TIEs conducted in August 2022 and January 2023, multiple lines of evidence indicate that dissolved copper is a principal cause of toxicity to mussel embryos exposed to samples from Station SIYB-1. Key observations supporting this conclusion are as follows:

1. The addition of EDTA during both the summer 2022 and winter 2023 monitoring events successfully removed toxicity in water from Station SIYB-1. This treatment is highly specific at chelating and thus reducing the toxicity of cationic trace metals, including copper.
2. Concentrations of dissolved copper are consistently elevated at Station SIYB-1 above values found to cause toxicity to mussel embryos as reported in the literature and based on results from the SIYB TMDL Monitoring Program (Figure 5-8).
3. Addition of copper to clean laboratory water and site water from Station SIYB-1 (Phase II/III TIE) resulted in comparable dose response curves and EC_{50} values. If another toxicant were present, these curves and EC_{50} values would be expected to diverge from each other.
4. Toxicity of water from SIYB is consistently observed above a threshold of approximately 8 µg/L. The dissolved copper measurement of 7.7 µg/L at Station SIYB-1 during the winter 2023 monitoring event was just below this threshold, thus likely explaining why only subtle chronic toxicity was observed during this event.
5. The statistical correlation between dissolved copper and percent effect on mussel embryo development over time is also strong and statistically significant.

Detailed methods and results from the TIE efforts conducted in August 2022 and January 2023 are included in Appendix F and Appendix H, respectively.

6.0 PROGRAMMATIC ANALYSIS AND LESSONS LEARNED

Since the implementation of the SIYB TMDL and the issuance of Investigative Order No. R9-2011-0036, the Port has assumed the leadership role and worked collaboratively with stakeholders and other Named TMDL Parties to plan, implement, and manage a suite of copper load reduction actions, initiatives, and studies in compliance with the aforementioned requirements. Efforts include development of a multi-faceted Copper Reduction Program composed of hull paint research, voluntary and policy-based copper reduction initiatives, water quality studies, as well as outreach events that educate the boating community on copper water quality issues, hull cleaning strategies, and non-copper paint alternatives (see Section 3.1 and Appendix B). These copper load reduction strategies have enabled the Port to develop a comprehensive understanding of the SIYB TMDL and its complexity, and in many cases demonstrated work above and beyond the expectations set forth in the SIYB TMDL.

This section includes an analysis of the overall SIYB TMDL Monitoring Program findings, including a discussion of the relationship between dissolved copper load and water quality, as well as a summary of findings related to dissolved copper sources in SIYB. It also summarizes each component of the SIYB TMDL Monitoring Program, including lessons learned and next steps.

6.1 Comparison of Achieved Load Reduction to Monitored Water Column Dissolved Copper Concentrations

The Investigative Order required the Port to "assess vessel conversions from copper-based AFPs to alternative AFPs" and to provide "an estimate of the dissolved copper load reduction achieved" based on annual vessel tracking data. In addition to vessel tracking, annual water quality monitoring of dissolved copper levels in SIYB waters was required to make "interpretations and conclusions, as to whether the 'trajectory' of the measured water quality values points toward attainment of the dissolved copper water quality objectives" (Regional Board, 2011).

Using the results of the 2022 SIYB hull census, the estimated dissolved copper load into the basin has decreased between 45% and 68%[16] from the baseline since implementation of the SIYB TMDL in 2011 (depending on the loading assumptions used; see Section 5.1.3; Figure 5-5). Load reductions can be attributed primarily to these factors: (1) continued improvement in the accuracy of the hull census; (2) a more accurate accounting of the vessels with aged- and lower-copper paint; and (3) transitions to DPR Category I paints following implementation of the DPR Rule. The load reduction attributable to the conversion of vessels from copper to non-copper paints is negligible (although the Port's fleet of vessels berthed in SIYB continued to be copper-free).

While there was a more pronounced reduction in the estimated copper load in the basin in the earlier years following SIYB TMDL implementation (the first two TMDL copper load reduction targets were achieved), the rate of load reduction has leveled off since 2017 and appears to be in a relatively steady state. Conceptually, the observed concentrations of dissolved copper in the water column should be positively correlated to the calculated copper loading in SIYB. The primary goal of copper load reduction efforts is to decrease water column copper concentrations

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16 While the vessel tracking approach in the Monitoring Plan estimates loads conservatively, there are limitations to the assumptions particularly related to unknown, unconfirmed, and aged paints over 5 years old, as discussed in Section 5.1.3 and presented in the alternative loading scenarios.

to meet the CTR regulatory criterion target of 3.1 µg/L. A comparison of the annual copper load reduction estimate with ambient dissolved copper levels in SIYB determined during the annual SIYB TMDL Monitoring Program shows that there is a disconnect between these two metrics (i.e., estimated load reductions did not result in a corresponding decrease in ambient dissolved copper levels in the water column).

As shown in Figure 6-1, although there appeared to be agreement in load reduction and water column dissolved copper levels early in the program (2012–2013), this apparent agreement was not replicated for the following 7 years (i.e., load estimates continued downward and leveled off in 2017, while water column copper levels, in general, increased until the 2021 and 2022 monitoring years when a reduction was observed). It is possible that the 2021 and 2022 observations may be related to the more prevalent use of DPR Category I paints by SIYB boaters; however, with just 2 years of data, it is too early to identify this decrease as a trend. As such, the observed disconnect between dissolved copper loading and copper levels in the water column present challenges in predicting at what point copper load reduction would result in measurable and sustainable improvements in water quality in SIYB.

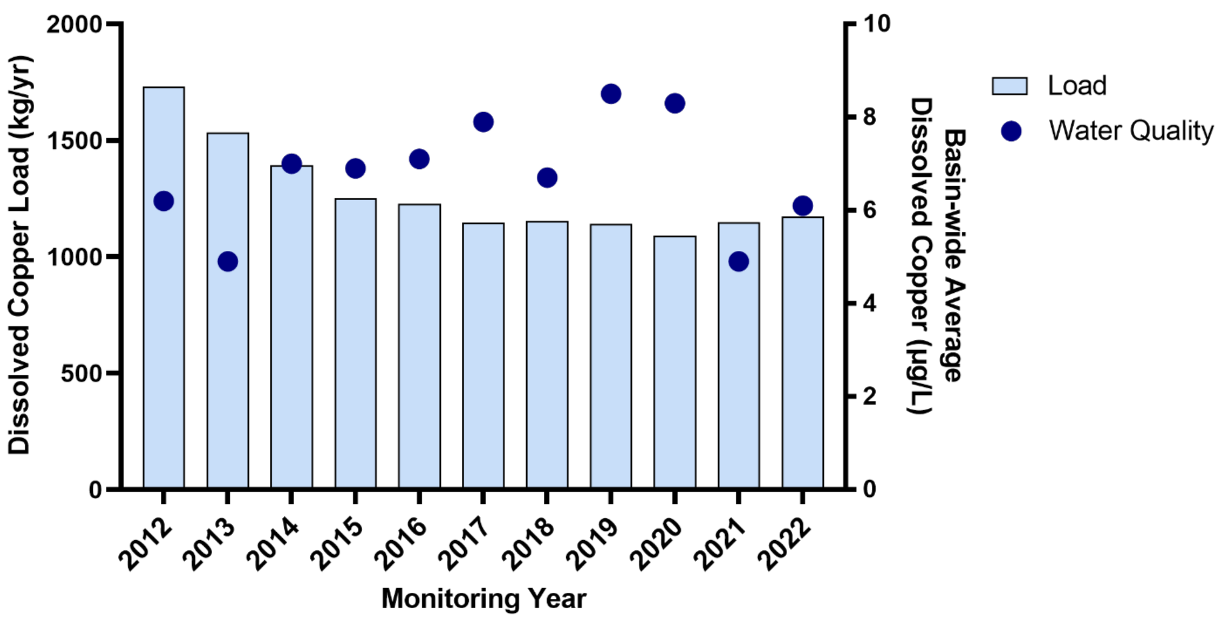

Figure 6-1. Comparison of Loading to Dissolved Copper Concentrations in SIYB

6.2 Dissolved Copper Source Analysis Summary

The SIYB TMDL stated that, "Reductions from passive leaching and hull cleaning are expected to be achieved through implementation of Management Practices (MPs), such as the use of nontoxic or less toxic antifouling paints in place of copper-based paints" (Regional Board, 2005). As such, the Port has focused efforts on understanding paint use and in-water hull cleaning practices in SIYB and addressing loading associated with these sources through a variety of initiatives in line with the strategies presented in the TMDL.

Consistent with the SIYB TMDL model assumptions, findings from the TMDL Monitoring Program and associated special studies indicated that passive leaching and in-water hull cleaning of copper-based AFPs are the primary sources of dissolved copper to the basin. Program findings related to these sources are presented in this section.

Vessel Paint: The SIYB TMDL Implementation Plan and Copper Reduction Program placed a primary focus on transitioning vessels from high-copper to low- or non-copper paint. Modifications to paint formulations required a lengthy legislative process and coordination with the DPR in their regulation of paint use. Nonetheless, the number of vessels that have transitioned to low-leach copper DPR Category I paints has increased by 48% since implementation of the DPR Rule in 2018. By the end of the TMDL implementation period in 2022, approximately 70% of vessels moored in SIYB were confirmed to have low- (46%), aged- (19%), or non-copper paints (5%).

Further reductions in dissolved copper loads are expected to occur beyond the SIYB TMDL timeline under the assumption that all or most vessels in SIYB will have DPR Category I, aged-, or non-copper paints by June 30, 2024, as a result of the DPR Rule (Figure 6-2). This assumption is based on the vessel tracking data supplied by the SIYB marinas and yacht clubs, which indicate that the majority of vessels are painted in California boatyards.

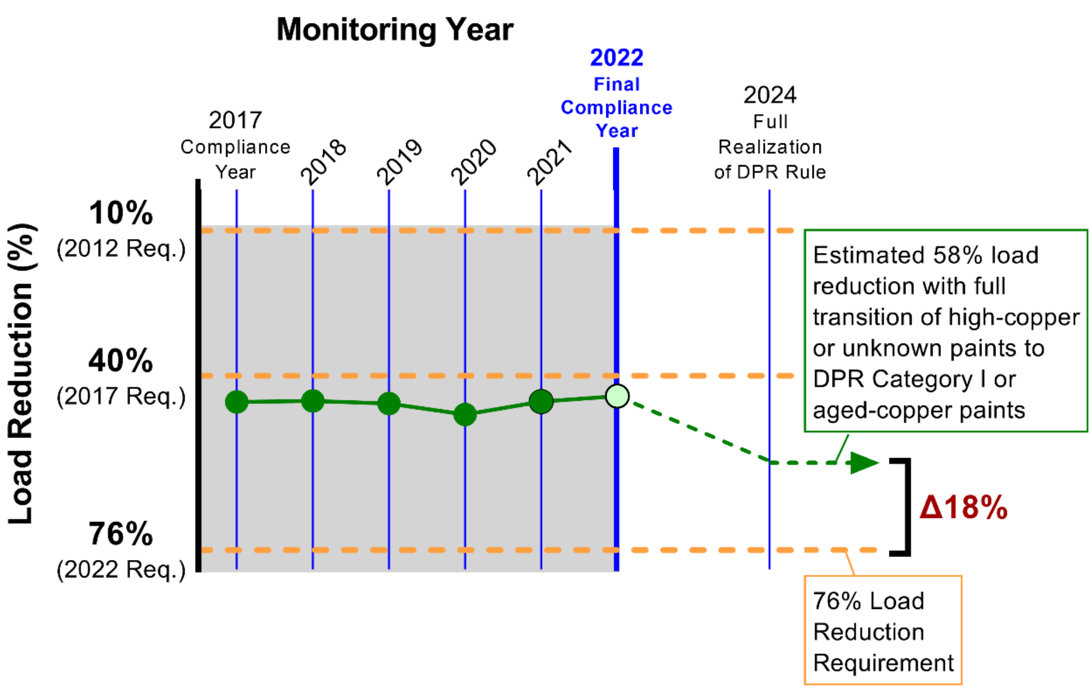

Figure 6-2. Trajectory of Estimated Dissolved Copper Load Reduction with Fully Realized DPR Rule

Another notable paint use behavior observed over the past 10 years is the limited use of non-copper paints in SIYB. Despite longstanding education efforts and grant initiatives to supplement paint application, the number of vessels with non-copper alternatives has remained relatively consistent since 2013. Port paint studies and discussions with boatyards, paint manufacturers, and boaters identify higher upfront application costs, difficulty in cleaning, and product unfamiliarity as some reasons for continued use of copper-based AFPs. In addition, the adoption of the DPR Rule demonstrates that copper AFPs will likely remain a legally available product on the market, which may ultimately be an unintended consequence limiting the transition to non-copper alternatives. Vessel conversions to non-copper paints may become a realistic copper load reduction approach once additional non-copper alternatives are on the market in the future.

Lessons learned regarding copper-based AFPs as a source of dissolved copper to SIYB include the following:

- Based on the SIYB TMDL conceptual model assumptions, a 76% load reduction was assumed to be the target at which basin water quality would meet the WQOs for dissolved copper; however, based on data collected to date in SIYB, this may not be the case.
- While vessel transitions have been successful, the full effects of DPR Category I paints on water quality are unclear, and the use of non-copper paints remains limited. These issues are significant limitations to further reducing copper loads into SIYB and changing the water quality patterns observed in SIYB.

In-Water Hull Cleaning: In-water hull cleaning of copper-based AFPs was identified in the SIYB TMDL as the second largest source of copper to SIYB after load contributions from passive leaching. However, due to differences in loading models in the literature, there has been uncertainty regarding the proportion of dissolved copper loading attributable to in-water hull cleaning. As such, the Port and the SIYB stakeholders invested a significant amount of resources over the course of the TMDL to better understand in-water hull cleaning as a source of dissolved copper to SIYB.

Model predictions presented in the original SIYB TMDL model (Regional Board, 2005) and Earley et al. (2013) indicated that the loading attributable to in-water hull cleaning could range from 5% to 40% of the total dissolved copper loading to SIYB. To better understand the relationship between in-water hull cleaning and water quality in SIYB, the Port implemented an 8-week Hull Cleaning Pause and conducted water quality monitoring of dissolved copper levels in SIYB before, during, and after the Pause. Findings from the monitoring program indicated that while the pause in hull cleaning effectively eliminated the load of dissolved copper into basin waters from this activity, the corresponding decrease in surface water dissolved copper concentrations in SIYB was minimal and insufficient to achieve WQOs in SIYB.

Lessons learned regarding in-water hull cleaning as a source of dissolved copper to SIYB include the following:

- Based on the findings of the Hull Cleaning Pause study, changes to existing hull cleaning practices (including the current use of BMPs) are not likely to result in substantial improvements in water quality in SIYB, as passive leaching is the predominant source of dissolved copper to the basin.
- Additional water quality improvements would likely require further reductions in loading associated with passive leaching from copper-based AFPs (i.e., lower leach rates) and/or increased use of non-copper paints.

6.3 SIYB TMDL Monitoring Program Summary (2011–2022)

The Port's Copper Reduction Program was developed and implemented in compliance with Investigative Order No. R9-2011-0036. It was initiated in 2007, and over the course of the SIYB TMDL, numerous initiatives have been completed, enabling the Port and the other Named TMDL Parties to achieve the SIYB TMDL interim targets. The program focused on source contributions of copper; identified a strategic approach for implementing projects over the short and long term aimed at copper reduction; and aimed to effectively achieve regulatory compliance for loading and improved water quality. This section discusses each component of the SIYB TMDL Monitoring Program, including overall findings, lessons learned, and next steps.

6.3.1 BMP Implementation

The Port has planned, initiated, and implemented a suite of BMP strategies to reduce discharges of dissolved copper into harbors and marinas within SIYB, throughout San Diego Bay, and statewide. BMPs implemented by the Port through the Copper Reduction Program have included hull paint research, voluntary and policy-based copper reduction initiatives, water quality studies, as well as hosting outreach events that educate the boating community on copper water quality issues, cleaning of copper AFPs, and non-copper paint alternatives. The following are highlights of some of the key initiatives:

- The Port developed Board policies and ordinances and worked closely with regulators to implement copper reduction actions at a state and local level (see Section 6.3.4).
- The Port advanced the knowledge of non-copper alternatives by conducting testing and research on alternative paints and securing grants to assist in paint transitions.
    - The Port was awarded a $190,000 grant from USEPA to evaluate viable alternatives to copper AFPs (2008).
    - The Port was awarded a $600,000 grant from the SWRCB 319(h) Non-Point Source program to convert recreational boats from copper AFPs to non-biocide paints (2011).
    - The Port awarded $360,000 in grant funding to three companies to assist the development of innovative new non-biocide paints (2013).
- Notably, the entire Port fleet was converted to non-copper alternative paints in 2012 and remains copper free.
- The Port has furthered the understanding of water quality, source loading, and basin hydrodynamics by conducting numerous special studies to better understand the water quality in the basin (see Section 6.3.3).
- The Port has conducted a significant amount of outreach over the years, including hosting hull paint expos, developing paint brochures, and conducting various workshops and public engagement events to educate boaters on proper hull maintenance and encourage the use of non-copper alternatives.
- Annual monitoring in SIYB since 2011 has resulted in a basin-wide data set of vessel paint use and water quality data that is spatially and temporally robust (see Sections 6.3.2 and 6.3.3).

Overall, the BMPs implemented by the Port since the Regional Board adopted the SIYB TMDL have reduced dissolved copper discharges to SIYB and San Diego Bay and have supported the load reduction efforts of the other Named TMDL Parties, including the SIYB marinas and yacht clubs, hull cleaners, and boaters.

6.3.2 Paint Transition and Vessel Tracking

The basis of any TMDL is load reduction. For the SIYB TMDL, load reduction was determined by tracking the annual dissolved copper load from multiple sources (primarily from passive leaching from copper AFPs) and comparing this annual load with the baseline load identified in the SIYB TMDL Implementation Plan. The TMDL identified the "transition to nontoxic and less toxic hull coatings" as "the most reasonable foreseeable strategy to promote compliance with the required load reductions for copper in SIYB." Therefore, the Port's Copper Reduction Program included several initiatives to encourage transitions to non-copper and low-copper alternatives such as hosting outreach events to educate the boating community on the effects of copper AFPs on water quality and non-copper alternatives, securing grants to assist in paint transitions, conducting testing and research on alternative paints, and working with paint manufacturers to develop alternative paints (see Section 6.3.1).

To track load reduction resulting from these efforts, Investigative Order No. R9-2011-0036 required annual tracking of vessel conversions from copper-based AFPs to alternative AFPs in SIYB. In accordance with the Investigative Order and Monitoring Plan, the SIYB vessel tracking program was developed and implemented on an annual basis by the individual marinas and yacht clubs and by the Port for the Port-operated Harbor Police Dock, transient dock, and weekend anchorage. Throughout the SIYB TMDL implementation period, the vessel tracking program was refined as needed to enhance the efficiency of data collection methods and increase the accuracy of the data used to calculate annual loading estimates. This included development of a rigorous QA/QC program to review hull census data, as well as the re-evaluation of loading assumptions based on best available science (e.g., DPR Category I paints and aged paints).

Implementation of the vessel tracking program required a considerable number of person-hours to collect, compile, and review vessel information from more than 2,000 vessels each year. As a result of continued efforts by the marinas and yacht clubs, the annual hull paint survey response rate increased from 34% in 2011 to approximately 90% by the end of the program. Vessel tracking efforts by the Port, marinas, and yacht clubs were a successful and critical part of tracking paint use and dissolved copper load reductions over the course of the SIYB TMDL.

However, based on the data collected to date, paint use and dissolved copper loading to SIYB has reached steady state. Following full realization of the DPR Rule in June 2024, all or most vessels in SIYB are expected to have DPR Category I, aged-copper, or non-copper paints.

The key findings and lessons learned from paint transitions and vessel tracking include the following:

- The Port and other Named TMDL Parties were successful in transitioning away from high-copper AFPs. Approximately 70% of vessels in SIYB in 2022 were confirmed to be painted with low-, aged-, or non-copper paints (Figure 5-3). As presented in Section 5.1.3, it is quite likely that this percentage is even higher (73–100%) because vessels with unknown or unconfirmed paints are likely actually painted with DPR Category I paints or aged-copper paints based on paint availability following the implementation of the DPR Rule.

- The load reduction estimate of 45% calculated using the Monitoring Plan assumptions is likely an underestimate. This is due to the conservative vessel tracking approach which assumes that, for example, (1) unknown or unconfirmed paints[17] are “high-copper” and contribute a full load of 0.9 kg/yr, and (2) aged paints over 5 years old contribute a half-load even though they likely contribute a diminishing copper load as they age.
- Because copper paint remains legal to use and is the preferred paint type among vessel owners in SIYB, the dissolved copper load is not expected to decrease substantially until, and if, the use of non-copper paints becomes more prevalent among SIYB boat owners.
- At this point, continued annual vessel tracking appears to be of limited value (especially because the loading estimates from the annual hull census have reached an apparent steady state under the current paint use scenario) and will not be of additional value until there is considerable movement of boaters toward non-copper alternatives.

6.3.3 Water Quality Monitoring

In addition to tracking the annual load of copper to the basin, the Investigative Order also directed the planning and implementation of an annual monitoring program to assess the dissolved copper levels in the surface water of SIYB. The annual SIYB TMDL Monitoring Program was initiated in 2011 and continued through the entire SIYB TMDL implementation ending in 2022. The results of the annual water quality monitoring were used to determine the average basin-wide level of dissolved copper in the water column. Toxicity tests were also conducted at each basin station through the entire program. When deemed necessary, the Port supplemented the annual water quality monitoring with special studies. These special studies were designed to address additional study questions and data gaps that arose during the TMDL implementation period as needed.

Throughout the SIYB TMDL Monitoring Program, efforts were made to standardize and reduce variability in the monitoring approach. This included efforts such as (1) standardizing the field collection methods and processes; (2) developing a robust QA/QC program to maintain integrity of the data from the field collection through data analysis and reporting; (3) using a field QA officer and QA checklists to ensure the same sampling procedures were followed at each station during each monitoring event; and (4) using the same analytical laboratory that specializes in analysis of low-level metals in seawater. Consistency in sampling and analysis methods and associated QA/QC procedures was important to ensure that the data collected were accurate and representative of the ambient conditions in the basin. It also allowed for comparison of results and analysis of the trajectory of dissolved copper levels over time, as required by the Investigative Order.

The Port was successful in evaluating the water quality conditions in the basin through implementation of a robust monitoring and QA/QC program. The consistency in the QA program and sampling and analysis approaches provided a high degree of confidence that the annual monitoring results (supplemented by the special studies) provided an accurate depiction of the dissolved copper levels in the basin and that the yearly monitoring results were sufficient to assess the status and trends of dissolved copper in SIYB over the TMDL implementation period. While the 12 years of basin-wide dissolved copper levels have fluctuated slightly from year to year,

[17] Often times, hull paints are classified as unknown or unconfirmed because no survey response was received or the response was incomplete.

spatial trends in dissolved copper throughout the basin have, in general, shown a consistent pattern (i.e., gradient of increasing dissolved copper concentrations from the mouth to the head of the basin). Further, dissolved copper levels in surface water have consistently been above WQOs in a majority of the basin area. Toxicity results were also very consistent throughout the program, with chronic toxicity limited to the head of the basin (primarily at Station SIYB-1 farthest from San Diego Bay proper) and no acute toxicity identified in a majority of monitoring events.

As discussed above, the only substantial change in paint use during the 12-year implementation period was limited to transitions to DPR Category I paints as a result of the DPR Rule. This change, while substantial, was instituted toward the end of the SIYB TMDL implementation period and will not be fully realized until 2024. While the transition to DPR Category I paints resulted in a reduced copper load into the basin, it is unclear the degree to which the full realization of the DPR Rule would have affected the dissolved copper levels in SIYB if the Rule had been instituted earlier in the implementation program, or how the full transition to DPR Category I is likely to affect future ambient dissolved copper levels in SIYB. As high-copper paints continue to be phased out in favor of DPR Category I paints, it will be important to assess future changes in water quality in SIYB. The Port will support DPR with its ongoing program to monitor the long-term benefits of the DPR Rule implementation on water quality in SIYB (and other vessel berthing locations throughout the state of California).

<u>Special Studies</u>

In addition to annual water quality monitoring, the Port went above and beyond the requirements of the SIYB TMDL to design and implement several special studies to fill data gaps identified during the TMDL implementation period. These special studies included the following:

- In-water hull cleaning studies were completed to (1) evaluate particulate loading from various cleaning methods (AMEC Earth & Environmental, Inc., 2006), and (2) assess changes in SIYB copper concentrations when cleaning was paused (Wood, 2022c).
- A hydrodynamic modeling exercise was performed to determine whether engineering solutions could increase water circulation and reduce dissolved copper levels (Weston, 2013).
- A basin-wide water column study was completed to evaluate copper levels at different depths and locations throughout the basin (Amec Foster Wheeler, 2017).
- A tidal time-series study was completed to evaluate the influence of tidal fluctuations on copper levels in SIYB (Amec Foster Wheeler, 2018b).
- The Port provided SIYB TMDL Conceptual Model updates (2015 and 2019) to the Regional Board that incorporated newly available information related to copper sources and loading scenarios.

The development and implementation of special studies over the course of the SIYB TMDL implementation period were critical to provide further understanding of dissolved copper levels and loading sources in the basin. Findings from these studies supported the original TMDL model by confirming that passive leaching of copper-based paints is the primary source of dissolved copper to the basin. Findings also validated that the annual water quality monitoring approach provided an accurate representation of water quality conditions in SIYB.

The key findings and lessons learned from water quality monitoring in SIYB include the following:

- The Port successfully implemented a long-term (more than 10 years) TMDL water quality monitoring program to evaluate annual trends in dissolved copper and toxicity in SIYB surface waters.
- The long-term trends in dissolved copper levels (i.e., above WQOs in a majority of the basin) and toxicity (i.e., limited to only the head of the basin) have been relatively consistent over the course of the SIYB TMDL Monitoring Program. Consequently, continued annual water quality monitoring would likely be of limited value.
- While the monitoring to date has generated a wealth of status and trends information, the health of the biological resources is much less understood. At this point in time, shifting the SIYB TMDL Monitoring Program toward a more holistic assessment of the ecological health of the basin is the next logical step to complement the 10+ years of water quality and toxicity data gathered.
- In addition to an ecological assessment of the basin, the Port will continue to partner with the DPR in its efforts to assess the long-term benefits on water quality associated with the implementation of the DPR Rule.

6.3.4 Regulatory Activities

Since 2005, the Port has actively championed the regulation of copper AFPs at both a state and federal level. The Port sponsored AB 425, which required the DPR to lower copper leach rates. These efforts resulted in the adoption of AB 425, setting a statewide maximum leach rate of 9.5 µg/cm^2/day for copper AFPs, which became effective on July 1, 2018.

At the local level, in 2009, the Port adopted Board Resolution 2009-230 codifying the Port's commitment to develop and implement copper reduction initiatives. In 2011, the Port adopted an ordinance regulating in-water hull cleaning activities throughout San Diego Bay and continues to implement an In-Water Hull Cleaning permit program.

Given that regulations are a mechanism that require compliance, it is likely that the implementation of the DPR Rule, the Port's implementation of copper reduction initiatives (such as upholding a copper-free fleet), and the BMP requirements that are part of the In-Water Hull Cleaning permit program have all aided in water quality improvement both within SIYB and throughout San Diego Bay.

7.0 CONCLUSIONS AND RECOMMENDATIONS

This report marks the final annual monitoring and progress report and therefore fulfills the requirements of Investigative Order No. R9-2011-0036. Since implementation of the SIYB TMDL, the Port has, in a collaborative manner, planned and implemented all requirements of the Investigative Order per the SIYB TMDL and associated model. The Port's multifaceted copper reduction efforts have included implementing the annual monitoring program according to the SIYB TMDL, Investigative Order, and approved Monitoring Plan; conducting numerous special studies to better understand the water quality in the basin; and evaluating copper loading sources to determine where programmatic adjustments most impactfully and directly address water quality. These efforts were in addition to the Port's boater outreach and education efforts and legislative activities (e.g., support for AB 425) and continued collaboration with the Named TMDL Parties, the Regional Board, California DPR, and others. In combination, the goal of these activities has been to realize copper load reductions into SIYB that would then result in measurable improvements in water quality (and attainment of beneficial uses).

The robust vessel paint tracking and water quality data sets have enabled the Port to evaluate how the aforementioned efforts have translated to loading reductions and water quality changes. Vessel tracking data have indicated that while copper AFPs remain legally available statewide, most boaters will continue to use and maintain these products. Further reductions in dissolved copper load are expected to continue beyond the SIYB TMDL timeline as the DPR Rule is fully realized, and the remainder of vessels in SIYB transition to DPR Category I paints. Without modifying paint availability at the state level, achieving desired loading reductions and water quality standards may not be attainable, even beyond the existing SIYB TMDL timeline.

Based on the data collected in SIYB to date, there has been no clear and consistent link between copper load reduction and water quality improvement (as would be expected by the SIYB TMDL model predictions). However, the SIYB TMDL Monitoring Program and associated special studies have yielded a wealth of information regarding the paint use and hull cleaning practices in SIYB, as well as the relatively consistent dissolved copper characteristics and limited toxicity in the basin. In recognizing the disconnect between dissolved copper loading and water quality, as well as the challenges associated with reducing copper inputs from a widely used, legally available paint product, it would be beneficial to focus future efforts in SIYB on understanding the overall ecological health of the basin.

Moving forward, the Port remains committed to working with the Regional Board, state agencies, and the other Named TMDL Parties to achieve our shared goals of protecting beneficial uses and improving water quality in SIYB and San Diego Bay. Recommendations and next steps for efforts beyond the SIYB TMDL are as follows:

1. Work collaboratively with the Regional Board and stakeholders to develop a more holistic approach to assess the ecological conditions in SIYB that is in line with the goals of the Strategic Water Quality Assessment Approach for San Diego Bay (Regional Board, 2022).
2. Adjust monitoring and reporting efforts to focus on evaluations of ecological health within the basin rather than an annual focus on vessel tracking and water quality monitoring.
3. Continue implementation of the Port's Copper Reduction Program in SIYB and San Diego Bay.

4. Continue conversations with DPR and the Regional Board regarding hull paint regulations and strategies to improve water quality in SIYB, San Diego Bay, and across the state.
5. Continue engaging with paint manufacturers and stakeholders to encourage development and use of non-copper alternatives.

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APPENDIX A

SIYB DISSOLVED COPPER TMDL MONITORING PLAN (REVISION 8)

APPENDIX B

BEST MANAGEMENT PRACTICE PLANS

APPENDIX C

VESSEL TRACKING DATA

APPENDIX D

WATER QUALITY RESULTS

APPENDIX E

CORRESPONDENCE AND AGENCY MEMORANDA

APPENDIX F

MUSSEL EMBRYO TIE RESULTS FOR 2022 SIYB DISSOLVED COPPER TMDL ANNUAL SUMMER COMPLIANCE MONITORING – SITE SIYB-1

APPENDIX G

IN-WATER HULL CLEANING PAUSE WATER QUALITY MONITORING TECHNICAL REPORT

APPENDIX H

2022–2023 WINTER MONITORING RESULTS TECHNICAL MEMORANDUM