Shelter Island Yacht Basin TMDL
Final Monitoring Plan

Prepared for:
California Regional Water Quality Control Board,
San Diego Region

Prepared by:
Weston Solutions, Inc.

In Coordination with:
Port of San Diego

May 2011

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including
QAPP & Conceptual Model

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ACRONYMS AND ABBREVIATIONS

APHA	American Public Health Association
ASTM	American Society for Testing and Materials
Basin Plan	*Water Quality Control Plan for the San Diego Basin – Region 9*
BMPs	best management practices
COC	chain-of-custody
CTR	California Toxics Rule
Cu^{2+}	free copper
dGPS	differential global positioning system
DO	dissolved oxygen
DOC	dissolved organic carbon
ELAP	California Environmental Laboratory Accreditation Program
HDPE	high-density polyethylene
Implementation Plan	SIYB Dissolved Copper TMDL Implementation Plan
Investigative Order	Investigative Order No. R9-2011-0036
L_h	hull cleaning annual loading
L_p	passive leaching annual loading
LC_{50}	median lethal concentration
LOEC	lowest observed effect concentration
MAR	marine habitat
Monitoring Plan	SIYB Dissolved Copper TMDL Monitoring Plan
N_v	number of vessels
NOEC	no observed effect concentration
OAL	Office of Administrative Law
pH	hydrogen ion concentration
Port	Port of San Diego
QA	quality assurance
QA/QC	quality assurance/quality control
QAPP	Quality Assurance Project Plan
QC	quality control
RHMP	Regional Harbor Monitoring Program
Regional Board	San Diego Regional Water Quality Control Board
SIYB	Shelter Island Yacht Basin
SM	Standard Methods
SOPs	Standard Operating Procedures
SWAMP	Surface Water Ambient Monitoring Program
State Board	State Water Resources Control Board
TMDL	Total Maximum Daily Load
TOC	total organic carbon
TDS	total dissolved solids
USEPA	U.S. Environmental Protection Agency
WESTON	Weston Solutions, Inc.
WGS 84	World Geodetic System 1984
WILD	wildlife habitat
WQO	water quality objective

UNITS OF MEASURE

cm	centimeter
°C	degrees Celsius
ft	feet or foot
kg/yr	kilogram per year
µg/L	microgram per liter
µm	micrometer
m	meter
m^2	square meter
mm	millimeter
mg/L	milligram per liter
mL	milliliter
ppt	parts per thousand
psu	practical salinity unit
yr	year
%	percent

1.0 INTRODUCTION

The Shelter Island Yacht Basin (SIYB) Dissolved Copper Total Maximum Daily Load (TMDL) Monitoring Plan (Monitoring Plan) describes the approach to assessing loading reductions through tracking conversion of vessels from copper to non-copper hull paints for the purpose of determining compliance with TMDL criteria. The Monitoring Plan also details the annual water quality monitoring that will be performed to quantify long-term reductions in dissolved copper concentrations and toxicity. Results of the tracking program will be used to assess both interim and final compliance with the TMDL loading reduction requirements for dissolved copper into SIYB. Water quality monitoring will be used to assess annual improvements in dissolved copper concentrations and toxicity levels, while also determining progress towards final TMDL compliance numeric and narrative objectives. The Monitoring Plan was prepared in response to Resolution No. R9-2005-0019 in which the San Diego Regional Water Quality Control Board (Regional Board) incorporated the dissolved copper TMDL into the *Water Quality Control Plan for the San Diego Basin – Region 9* (Regional Board, 2005).

The Monitoring Plan meets the requirements of Investigative Order No. R9-2011-0036 (Investigative Order), which directs the Port of San Diego (Port) to develop and submit a Monitoring Plan to track the progress of implementing the TMDL. The Monitoring Plan includes a Quality Assurance Project Plan (QAPP) and Conceptual Model, which are provided as separate documents. The QAPP defines the project objectives and organization, functional activities, and quality assurance/quality control (QA/QC) protocols in compliance with Surface Water Ambient Monitoring Program (SWAMP) protocols. The Conceptual Model identifies the physical and chemical factors that control the fate and transport of copper in SIYB, and identifies the biological receptors that could be exposed to pollutants in the water and sediments. The Conceptual Model also identifies potential future studies that may be implemented to provide refinements to the model. In compliance with the Investigative Order, the Monitoring Plan includes a monitoring station network that is both consistent with prior Regional Board studies and is spatially representative of water quality conditions in SIYB. Lastly, the Monitoring Plan considers existing data on surface water dissolved copper concentrations to characterize baseline conditions.

1.1 Compliance Schedule

Under Resolution R9-2005-0019, the SIYB dissolved copper TMDL (hereafter referred to as SIYB TMDL) requires that loading of dissolved copper into the water column be reduced by 76% to 567 kilograms per year (kg/yr) over a 17-yr period (Regional Board, 2005). Based on the official TMDL approval date[1], this time period is set to end in 2022. No reductions in dissolved copper loading were required during the initial two-year orientation period (2005-2007). The subsequent 15-yr period requires incremental loading reductions. A 10% reduction in dissolved copper loading is required within seven years, a 40% reduction in loading is required within 12 years, and a 76% reduction within 17 years (Table 1-1).

[1] For a TMDL to be incorporated into the Basin Plan, it must be approved by the Regional Board, State Water Resources Control Board (State Board), Office of Administrative Law (OAL), and USEPA Region 9. The official TMDL approval date is when the OAL approves the document.

Table 1-1. Loading Targets for TMDL Attainment

Stage	Time Period	Percent Reduction from Current Estimated Loading	Reduction to be Attained by end of Year	Estimated Interim & Final Target Loading (kg/yr of Dissolved Copper)
1	2005-2007	0%	N/A	N/A
2	2007-2012	10%	7	1,900
3	2012-2017	40%	12	1,300
4	2017-2022	76%	17	567

1.2 TMDL Implementation Plan

The SIYB TMDL Implementation Plan (Implementation Plan) represents the Named Parties' implementation strategy for achieving a reduction in the loading of copper into the water column of SIYB, as directed by the SIYB TMDL and Investigative Order. The Implementation Plan describes the approach to achieving reductions in copper loading into SIYB in order to preserve and restore water quality and associated marine habitat (MAR) and wildlife habitat (WILD) beneficial uses. The Implementation Plan takes a solutions-oriented approach of establishing and implementing best management practices (BMPs) that directly and indirectly facilitate reductions in copper loading into the basin to meet the SIYB TMDL interim and final dissolved copper loading compliance thresholds. Key measures to monitor progress toward Implementation Plan objectives include:

- Establishing a tracking program for boats moored in SIYB to quantify loading reductions achieved through the conversion of vessels to non-copper and low-copper (i.e., less than 40% cuprous oxide) antifouling hull paints.
- Establishing a monitoring program to provide long-term trend analysis of water quality.

Because the primary source of dissolved copper to the water column is copper-based antifouling hull paints of recreational vessels (Section 1.3), interim and final targets for loading reductions will be assessed through the tracking of the conversion of vessel hull paints from copper-based to non-copper and low-copper (less than 40% cuprous oxide) products (Section 2.0). Annual water quality monitoring will be used to assess long-term improvements in dissolved copper concentrations and toxicity (Section 3.0).

1.3 Sources of Dissolved Copper

Based on the Regional Board's source analysis, the total mass load of dissolved copper to SIYB was determined to be 2,163 kg/yr, of which 98% of inputs were attributable to copper-based hull paints of recreational vessels (Regional Board, 2005). Copper is released from hull paints to the water column through two sources: passive leaching and underwater hull cleaning. Passive leaching is the single largest source of dissolved copper to SIYB resulting in the mass loading of 2,000 kg/yr and representing 93% of the total contribution (Table 1-2). Antifouling paints are an effective control for marine fouling; however, organisms still build up over time, requiring underwater hull cleaning by divers. Underwater hull cleaning is a routine maintenance in which the hull is cleaned in the water versus out of the water at a boatyard, resulting in the release of

dissolved copper into the water column. Underwater hull cleaning is the second largest source of dissolved copper, resulting in the mass loading of 100 kg/yr and representing 5% of the total contribution.

Table 1-2. Sources of Dissolved Copper to SIYB

Source	Mass Load (kg/yr)	Contribution (% 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**

Inputs of dissolved copper from upland sources appear to be much less pronounced according to the Regional Board's source analysis. Urban runoff, consisting of wet and dry weather flows, was determined to contribute 1% (30 kg/yr) of dissolved copper loading to SIYB (Regional Board, 2005). Other sources of dissolved copper to the SIYB include background inputs from San Diego Bay, direct atmospheric deposition, and sediments. Water from the San Diego Bay flushes SIYB and contributes to the loading of dissolved copper. The copper concentration of ambient seawater within San Diego Bay was used to calculate the contribution of natural background sources (i.e., 1% or 30 kg/yr). Direct atmospheric deposition, including wet and dry deposition to SIYB, contributes less than 1% (3 kg/yr) of dissolved copper loading to SIYB. Indirect deposition is not included here, because it is a component of urban runoff. According to the TMDL source analysis, sediments were considered to be a net sink for copper in SIYB, and, therefore were considered to provide zero annual loading of dissolved copper to the basin.

1.4 Water Quality Objective Criteria

The numeric water quality objectives (WQOs) for dissolved copper in SIYB are equal to the California Toxics Rule (CTR) water quality values for dissolved copper within seawater (U.S. Environmental Protection Agency [USEPA], 2000). Continuous or chronic exposures may not exceed 3.1 µg/L over a 4-day average, while acute exposures should not exceed 4.8 µg/L over a 1-hour average. In addition, numeric water quality objectives must not be exceeded more than once every three years. Based on these numeric targets and existing monitoring data at the enactment of the TMDL, the final waste load allocation was determined to be 567 kg/yr. This includes a 10% margin of safety calculated to be 57 kg/yr. In addition to numeric WQOs, the Basin Plan establishes narrative WQOs for toxicity and pesticides (Regional Board, 1994):

Beneficial uses within SIYB threatened by elevated dissolved copper concentrations include MAR and WILD. The Regional Board indicated that if numeric WQOs are met for dissolved copper, then narrative water quality objectives will also be met. However, since numeric WQOs are not site specific, direct assessments of toxicity as well as SIYB biota will provide direct indications of basin-wide attainment of beneficial uses and narrative WQOs.

1.5 Monitoring Purpose

The Monitoring Plan includes annual tracking of vessel hull paint conversions to non-copper and low-copper paints and annual water quality assessments of copper levels and toxicity. Tracking of vessel conversions from copper to non-copper or low-copper hull paints will be used to assess compliance with interim and final TMDL loading-reduction targets on a basin-wide basis. Water quality monitoring will assess long-term improvements in water quality, as measured by surface-water dissolved copper concentrations and toxicity levels. Additionally, water quality monitoring will be used to determine final compliance with both numeric and narrative WQOs throughout the basin. By conducting both vessel tracking and water quality monitoring on an annual basis, the program will be able to evaluate the relationship between load reductions and water quality improvements. Additionally, this approach will provide the data needed to assess the overall TMDL implementation effectiveness and success in attaining both loading reductions and numeric WQOs that are protective of the basin's MAR and WILD beneficial uses.

2.0 TRACKING VESSEL CONVERSION

Based on the Regional Board's source analysis, the vast majority (i.e., 98%) of copper loading to SIYB was attributed to anti-fouling paints of vessels moored within the basin. Given the principal importance of anti-fouling paints to loading exceedances, annual dissolved copper loading reductions will be assessed through tracking of conversions of hull paints from copper to non-copper or low-copper products for vessels moored within SIYB.

2.1 Vessel Tracking

The primary assessment of loading reductions will be through tracking of conversions of hull paints from copper to non-copper or low-copper products for vessels moored in SIYB since transitions from copper paints result in simultaneous reductions in copper inputs from both passive leaching and hull cleaning. This approach will provide a direct, cost-effective measure of annual loading reductions. Named Parties operating facilities that aggregate vessels in SIYB (i.e., marina and yacht club owners and operators) will be responsible for collecting vessel tracking data between January 1 and December 31 annually. The marina and yacht club owners and operators will be responsible for submitting the following vessel tracking information to the Port on an annual basis no later than January 15 (Table 2-1).

Table 2-1. Required Vessel Tracking Data

Element	Vessel Tracking Data
1	Name of marina or yacht club
2	Date of report
3	Total number of slips or buoys in facility available to be occupied by vessels
4	Slip/mooring occupation data
4a	Percent of time unoccupied
4b	Percent of time occupied by vessel(s) with known copper hull paint
4c	Percent of time occupied by vessel(s) with documented low-copper hull paint
4d	Percent of time occupied by vessel(s) with documented non-copper hull paint
5	Vessel-specific information
5a	Document or registration numbers of vessels moored in slips/moorings
5b	Vessel type (sail, power, multi-hull, etc.)
5c	Vessel length
5d	Vessel beam width

As a data quality assurance/quality control and confirmation check, additional information on paint type and application will be required for vessels reported to have low-copper (less than 40% copper) or non-copper hull paints (Table 2-2).

Table 2-2. Required Low-Copper and Non-Copper Hull Paint Vessel Data

Element	Low-Copper and Non-Copper Vessel Hull Paint Confirmation Data
1	Vessel document or registration number
2	Hull paint name
3	Product number
4	Name of boatyard that applied paint
5	Painting date
6	Percent copper if low-copper hull paint is indicated

The Port will compile the vessel tracking data from SIYB marinas and yacht clubs to report on the percent of time that slips are unoccupied or are occupied by vessels with copper, low-copper, non-copper, or unknown hull paints as required by the Investigative Order (Table 2-3). This data will be used to calculate the annual dissolved copper load to SIYB from vessels, the number of vessels converted from copper to low-copper or non-copper hull paints, and the reduction in dissolved copper loading achieved annually, as described in Section 2.2.

Table 2-3. Investigative Order Required Vessel Tracking Data to be Reported Annually

Element	Vessel Tracking Data
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 alternative hull paints, by hull paint type, and approximate length of time occupying a slip or buoy in facility each year
5	Number of vessels with unconfirmed information about hull paints and approximate length of time occupying a slip or buoy in facility each year
6	Estimate of the dissolved copper load reduction achieved for the year (kg/yr and %)

2.1.1 Tracking Approach

Marina and yacht club owners and operators will be responsible for instituting tracking programs to record the number of slips and buoys in facilities, the number of vessels in their facilities with non-copper, copper, and low-copper hull paints, and the amount of time that vessels occupy slips and buoys. Operators and owners of vessels moored within SIYB will be required to report vessel registration information (e.g., documentation or registration number), dimensions (length and beam width), and paint type (if known) to marina and yacht club owners/operators. Marina and yacht club owners/operators will compile this information in a standardized format, inclusive of the total number of occupied and unoccupied slips and moorings within their facilities from January 1 to December 31. Marina and yacht club owners/operators then will provide annual reports to the Port no later than the January 15. Boatyards may also contribute information to the database, providing confirmation of the type of hull paint applied to vessels.

The tracking program takes a conservative approach to estimating loading reductions. If the hull paint name and type is unknown, the paint will be assumed to be copper-based. Named Parties will collect, maintain, and submit tracking information in a standardized format to the Port-maintained database for inclusion in annual tracking reports to the Regional Board. Annual reports will be used to determine basin-wide loading and annual loading reductions.

2.1.2 Tracking Database

A tracking database will be developed by the Port to document and track the number and paint types of all vessels moored within SIYB (if known and reported). The database will be capable of tracking pertinent boat information such as size (length and beam width), make/model, vessel document/registration number, power/sail, facility name & slip number, boatyard used for hull painting, and the type of paint last applied (product number), and approximate length of time occupying a slip or buoy in SIYB, among others. The vessel tracking database fields are provided in an MS Excel format as Appendix A.

It is the intention of the Named Parties to develop a web-based database. The database will be administered and maintained by the Port and will be designed for SIYB with the adaptability to move to a bay-wide tracking system over time. Boatyards, marinas, and yacht clubs will have the ability to access, input, and review data, both specific to their facilities and basin-wide. All users will have password protected rights to enter/edit data from their facility, and read-only rights for all basin-wide data.

2.2 Annual Dissolved Copper Load Analysis

Compliance with interim and final TMDL loading reduction goals will be assessed through basin-wide vessel tracking. Annual dissolved copper loading will be assessed through tracking the number of vessels with non-copper, copper, and low-copper hull paints, as well as the number of vacant slips in SIYB. This assessment will incorporate the following assumptions that were used by the Regional Board in determining loading allocations (Regional Board 2005, Appendix 2).

- All 2,363 SIYB slips or buoys were occupied by vessels (N_v).
- All 2,363 recreational vessels moored within SIYB have copper-based paints.
- Annual loading from passive leaching basin wide (L_p) equals 2000 kg/year.
- Annual loading from hull cleaning (L_h) equals100 kg/yr.
- Avg. annual loading (L_v) per vessel with copper hull paint equals 0.9 kg/yr. Where $L_v = (L_p + L_h)/N_v$.

Based on the Regional Board assumptions in determining dissolved copper loading via passive leaching and hull cleaning combined, there will be an average loading reduction of 0.9 kg/yr for every vessel in SIYB that converts from copper-based to non-copper-based paints. The use of low-copper hull paints (i.e., hull coatings with less than 40% copper) also was recognized in the TMDL as a viable means of reducing copper loading to the basin. This loading reduction analysis assumes that each vessel transitioned to low-copper hull paints on average will reduce annual dissolved copper loading by 0.45 kg/yr. Thus, calculations of annual dissolved copper loading will be based on the following assumptions (Table 2-4).

Table 2-4. 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.
3. Vessels with unknown hull paints will be assumed to have copper.
4. Annual dissolved copper load from a vessel with non-copper hull paint equals 0 kg/yr.
5. Low copper hull paints include paints with less than 40% copper.
6. Average annual dissolved copper load from a vessel with low-copper paint equals 0.45 kg/yr.
7. Annual loads will be normalized by the percent of time vessels are in SIYB.

The achievement of interim and final loading targets along with overall TMDL compliance will be dependent on reductions in the number of vessels with copper-based hull paints. In completing the source analysis, the Regional Board assumed that 100% of recreational boats in

SIYB used copper-based paints (Regional Board, 2005); therefore, any reported reduction in the number of boats with copper-based paints would equate to a nearly directly proportional decline in copper loading into the water column. The following schedule provides an estimate of the number vessels to be converted from copper-based to non-copper-based paints in order to meet interim and final loading targets (Table 2-5).

Table 2-5. Vessel Hull Paint Conversion Schedule to Meet Loading Targets

Stage	Time Period	Percent Reduction from Current Estimated Loading	Reduction to be Attained by End of Year	Estimated Interim Target Loading (kg/yr)	Annual Loading Reduction Target (kg/yr)	Reduction in Vessels with Copper Paints to Achieve Loading Target[1]
1	2005-2007	0%	N/A	2,163	0	0
2	2007-2012	10%	7	1,900	263	292
3	2012-2017	40%	12	1,300	863	959
4	2017-2022	76%	17	567	1,596	1,773

[1] Vessel reductions based on average-sized 40-ft vessel converted to non-copper hull paint (i.e., 0.9 kg/yr/vessel loading reduction), as assumed by SIYB TMDL Technical Report

3.0 WATER QUALITY MONITORING

Annual assessments of water quality will be performed to determine the average concentration of dissolved copper and toxicity levels in SIYB using a spatially-representative sampling design. Water quality monitoring will supplement tracking studies to assess long-term improvements in copper concentrations and toxicity levels, occurring as a consequence of loading reductions throughout the interim stages. Water quality monitoring will also be used to determine attainment of final WQOs.

3.1 Water Quality Sampling and Analyses

Water quality sampling will be conducted annually throughout SIYB to determine the average concentration of dissolved copper in the basin and assess water quality trends over time. The monitoring will be conducted using methods consistent with prior studies conducted by the Regional Board in SIYB, which were used to establish baseline copper levels and loading reduction requirements of the TMDL (Appendix 6; Regional Board, 2005). In 2000, the Regional Board surveyed six stations within SIYB to determine the average basin-wide concentration (5.45 µg/L) and maximum concentration (8.0 µg/L). By multiplying the chronic WQO (3.1 µg/L) by the ratio of the average concentration to the maximum concentration, the target basin-wide dissolved copper concentration (2.11 µg/L) was established. To be consistent with studies conducted by the Regional Board, this monitoring program will include annual sampling at six stations and one reference station in the main channel of San Diego Bay adjacent to SIYB. These station locations are similar to those sampled by the Regional Board and meet the Investigative Order requirement of being spatially representative of dissolved copper concentrations in SIYB, as described in Section 3.1.1.

3.1.1 SIYB Sample Locations

Based on an assessment of monitoring water quality data collected between 2005 and 2008 in SIYB from the RHMP Pilot Study (WESTON, 2008), RHMP 2008 (WESTON, 2010) and Neira et al., (2009) study, surface water dissolved copper concentrations ranged from 3.41-16.06 µg/L, with an average concentration of 9.09 ± 0.29 µg/L (mean ± standard error) (Figure 3-1). The original Regional Board monitoring network comprised of six stations within SIYB and one station in the main channel of San Diego is presented in Figure 3-2 and Table 3-1. Using the recent surface water dissolved copper monitoring data collected from six stations in the immediate vicinity of the sampling stations that comprise the monitoring network, dissolved copper concentrations ranged from 3.4-13.5 µg/L with an average concentration of 8.28 ± 1.36 µg/L. Based on a comparison of both the ranges and basin-wide average concentrations, the monitoring network is representative of dissolved copper water quality conditions in SIYB. Additionally, the recent monitoring data provide a reasonable assessment of baseline dissolved copper concentrations within SIYB.

Table 3-1. Sampling Station Coordinates

Station	Latitude	Longitude
SIYB-1	32.71821	-117.22601
SIYB-2	32.71412	-117.22921
SIYB-3	32.71550	-117.22989
SIYB-4	32.71683	-117.23203
SIYB-5	32.71217	-117.23297
SIYB-6	32.70858	-117.23514
SIYB-ref	32.70406	-117.23232

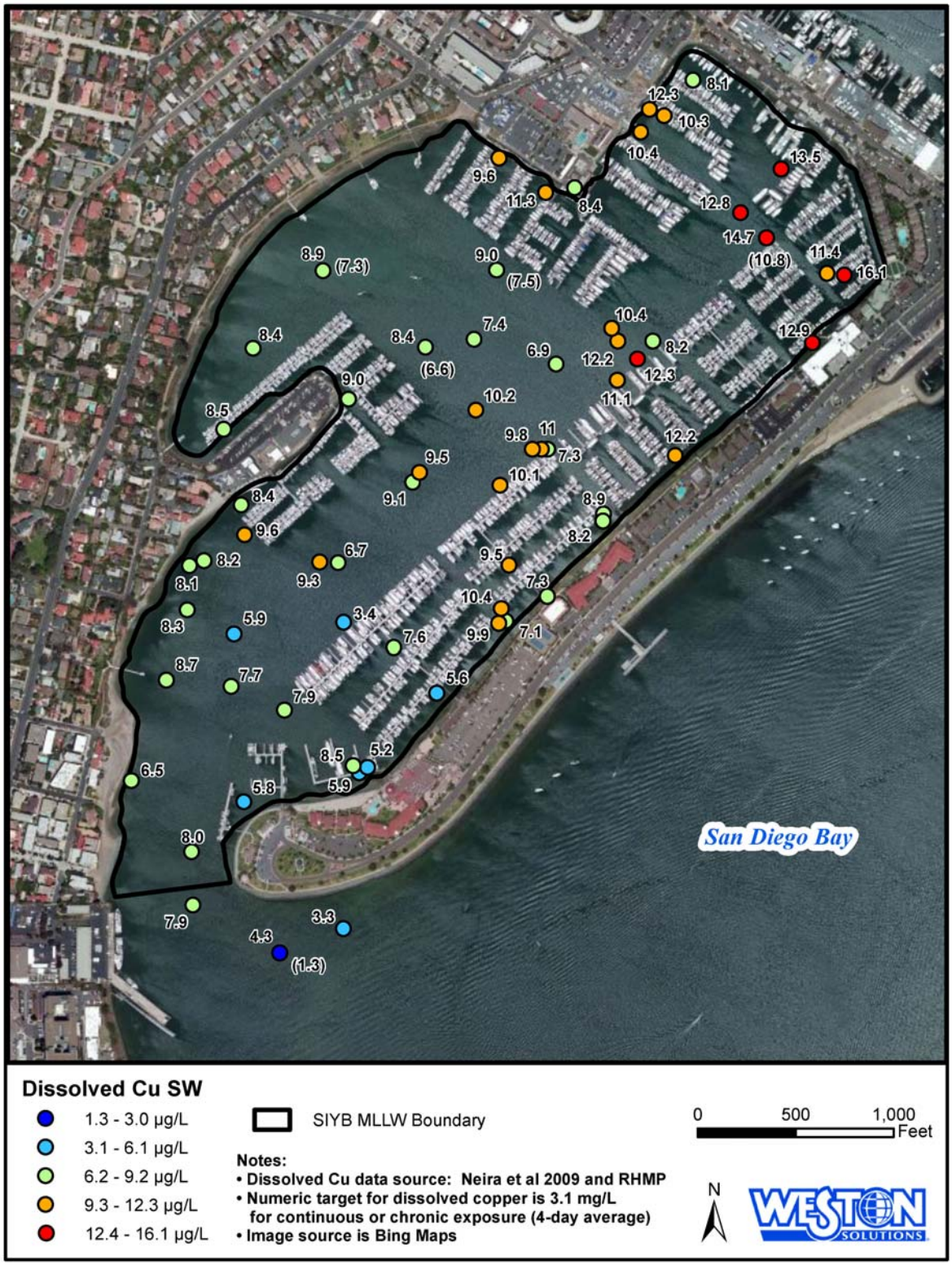

Figure 3-1. Dissolved Copper Levels in Shelter Island Yacht Basin Surface Waters

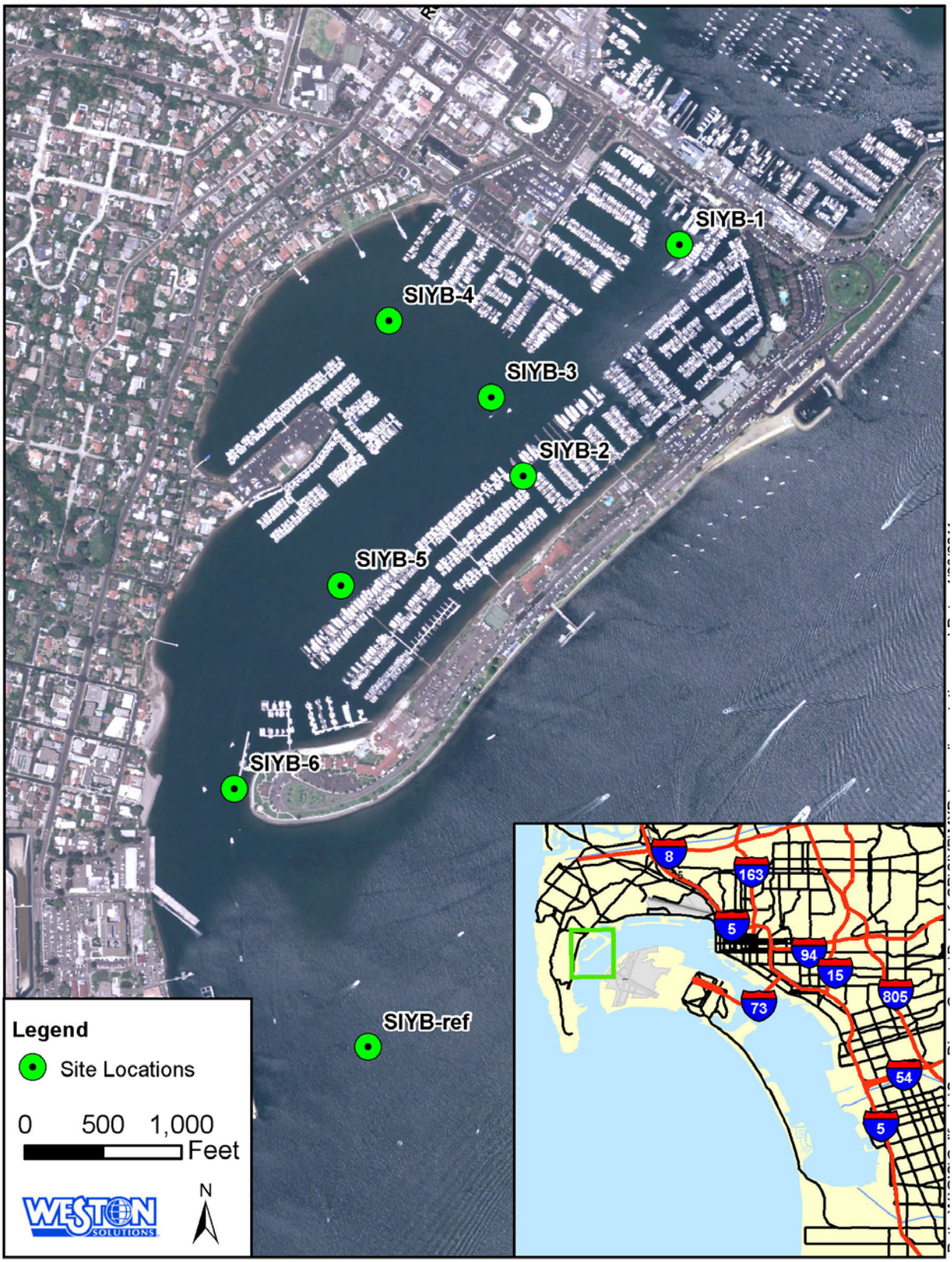

Figure 3-2. Shelter Island Yacht Basin Spatially-Representative Monitoring Network

3.1.2 Frequency of Sampling

Sampling will be conducted at the seven water quality stations at slack high tide once per year during the summer (i.e., August). By conducting sampling in the summer, dissolved copper concentrations are likely to be at the highest level in the water column due to higher release rates of copper from antifouling paints at higher sea surface temperatures and greater frequency of hull cleaning. As a consequence, this sampling design will provide the most conservative estimate for dissolved copper concentrations for SIYB. In addition, annual monitoring during the summer will facilitate integration with the Regional Harbor Monitoring Program (RHMP), which includes sampling of a broader range of chemical and biological parameters once every five years during the summer.

Performing annual sampling at the same station locations during the summer will allow for repeated measures and temporal trend analyses to determine changes in dissolved copper concentrations with time. Revisiting the same spatially-representative stations allows for basin-wide assessments of water quality, while limiting spatial variability and facilitating better detection of temporal trends. Additionally, correlation analyses can be used to assess relationships between estimated loading reductions from vessel conversions with surface water dissolved copper concentrations to track progress of the TMDL.

3.1.3 Sample Collection

Discrete water samples will be collected at each station using "clean hands" techniques with a Niskin bottle deployed from a sampling vessel. All stations will be located using differential global positioning system (dGPS). Samples will be collected within one meter of the surface. Upon collection, water samples will be transferred to labeled containers for analysis of total and dissolved copper, total and dissolved zinc, total organic carbon (TOC), dissolved organic carbon (DOC), and toxicity testing.

In situ measurements of free copper, salinity, and hydrogen ion concentration (pH) will be performed at all stations. Field measurements of pH and salinity will be made using a YSI meter according to manufacturer's specifications. An Orion copper-ion selective electrode (Cu-ISE) will be used to measure concentrations of free copper (Cu^{2+}) in surface water (i.e., within 1 m of the surface). The Cu-ISE measures pCu, where $pCu = \log_{10}(Cu^{2+})$, when calibrated with glycine and ethylenediamine copper buffers (Belli and Zirino, 1993; DeMarco et al., 1997). The precision of the Cu-ISE is $\pm$ 0.06 pCu units (Zirino et al., 1998), and the electrode is effective at total copper concentrations < 3 nM (Zirino et al., 2002). A description of the method used to measure Cu^{2+} is provided by Delgadillo-Hinojosa et al. (2008).

All water samples will be logged on a chain-of-custody (COC) form (Appendix B) and placed in a cooler on ice. Samples will be stored at 4°C in the dark until shipped or delivered to the appropriate laboratory for analysis. All water samples will be shipped within 24 hours of collection.

3.1.4 Equipment Decontamination and Cleaning

The Niskin bottle will be cleaned prior to sampling using clean soapy water and thoroughly rinsing with deionized water. Upon deployment, the Niskin bottle will receive a site water rinse prior to sample collection. After collection, water samples will be transferred from the Niskin bottle to laboratory-certified contaminant-free high-density polyethylene (HDPE) bottles.

3.1.5 Chemical Analysis

Water samples will be analyzed for total and dissolved copper, total and dissolved zinc, TOC, DOC, salinity, and pH (Table 3-2). The measurement of associated indicators can be entered into the Biotic Ligand Model to estimate the bioavailable fraction of dissolved copper present in SIYB and predict toxicity. Zinc is commonly used as an alternative biocide in antifouling paints and therefore total and dissolved zinc will be measured to ensure other water quality problems are not encountered during the conversion from copper-based to non-copper based paints. All analytical methods will follow USEPA or Standard Methods (SM; American Public Health Association [APHA], 1998). Recommended methods are presented in Table 3-2.

Table 3-2. Laboratory Analytical Methods and Detection Limits

Water Quality Measurement	Method	Method Detection Limit	Reporting Limit
Total Copper	USEPA 1640	0.01 µg/L	0.02 µg/L
Dissolved Copper	USEPA 1640	0.01 µg/L	0.02 µg/L
Total Zinc	USEPA 1640	0.005 µg/L	0.01 µg/L
Dissolved Zinc	USEPA 1640	0.005 µg/L	0.01 µg/L
Total Organic Carbon	USEPA 9060	0.1 mg/L	0.2 mg/L
Dissolved Organic Carbon	USEPA 9060	0.1 mg/L	0.2 mg/L
Free Copper	Orion Cu-ISE	<3 n/M	<3 n/M
Salinity	YSI Sonde	N/A	PSU
pH	YSI Sonde	N/A	0.2 pH unit

3.1.6 Toxicity Testing

Toxicity will be assessed at the six SIYB sampling stations and reference station. Toxicity testing for this project will consist of a 96-hr acute bioassay test using topsmelt (*Atherinops affinis*) to be consistent with the TMDL guidance (Regional Board, 2005). Additionally, a 48-hr chronic bioassay test using the mussel (*Mytilus galloprovincialis*) will also be conducted since previous studies have generally used the 48-hour mussel chronic test as the primary indicator of toxicity. Both tests will be used to assess the narrative toxicity objective described in the Implementation Plan since both species have ecological relevance to the marina environment and previously have been found to be sensitive to copper.

The 96-hour acute bioassay with topsmelt will be conducted in accordance with procedures described in *Methods for Measuring the Acute Toxicity of Effluents and Receiving Waters to Freshwater and Marine Organisms* (USEPA, 2002). Testing will be initiated within 36 hours of

sample collection. Topsmelt will be exposed for 96 hours to five sample concentrations (0.5 dilution series) and a control. Each concentration will be run with four replicates and ten topsmelt per replicate. Water quality will be conducted daily and include dissolved oxygen (DO), temperature, pH, and salinity. Test conditions are summarized in Table 3-3. After 96 hours, percent survival will be calculated. The test will be considered acceptable if 90% or greater survive in the controls. A 96-hour reference toxicity test using copper sulfate will be conducted concurrently with the project sample to evaluate the relative sensitivity of test organisms. At test termination, the median lethal concentration (LC_{50}) will be calculated and compared to historical laboratory reference toxicant test data for this species.

Table 3-3. Conditions for the 96-Hour Bioassay with *Atherinops affinis*

Test Conditions 96-Hour Acute Bioassay		
	Test Species	***Atherinops affinis***
	Test Procedures	EPA-821-R-02-012 (USEPA, 2002)
	Age/Size Class	7-15 days
	Test Type/Duration	Acute static-renewal /96-hours
	Sample Storage Conditions	4°C, dark, minimal head space
	Holding Time	36-hours
	Control Water Source	Scripps Pier seawater, 3 µm filtered, UV sterilized
Recommended Water Quality Parameters	Temperature	21 ± 1°C
	Salinity	10-30 ± 2 ppt
	Dissolved Oxygen	> 4.0 mg/L
	pH	Monitor for pH drift
	Photoperiod	16 hours light, 8 hours dark
	Test Chamber	500 mL
	Concentrations	5 and a control with a 0.5 dilution series (recommended)
	Replicates/Sample	4
	No. of Organisms/Replicate	10
	Exposure Volume	250 mL
	Aeration	None, unless DO falls below 4.0 mg/L
	Feeding	2 hours prior to renewal (recommended)
	Water Renewal	After 48 hours (minimum)

The 48-hour bivalve larvae test will be performed in accordance with procedures outlined in *Short Term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to West Coast Marine and Estuarine Organisms* (USEPA, 1995) and ASTM E724-98 (ASTM, 2006). Testing will be initiated within 36 hours of sample collection. The test will be run for 48 hours, or up to 54 hours if necessary, to ensure development of the bivalve larvae to the D-hinge stage in the control. Bivalves will be exposed to five sample concentrations and a control. Each concentration will be run with four replicates and 150-300 larvae will be targeted for inoculation into each replicate. Water quality will include DO, temperature, pH, and salinity at test initiation and termination. Test conditions are summarized in Table 3-4. A 48-hour reference toxicity test using copper sulfate will be conducted concurrently with the project sample to evaluate the

relative sensitivity of test organisms. At the termination of the study, survival will be compared between the control and test concentrations to determine if significant mortality or reduction in normality exists.

Table 3-4. Conditions for the 48-Hour Bioassay with *Mytilus galloprovincialis*

Test Conditions		
48-Hour Chronic Bioassay		
Test Species		***Mytilus galloprovincialis***
Test Procedures		EPA/600/R-95/136 (USEPA 1995), ASTM E724-98 (ASTM 2008b)
Age/Size Class		<4 hour old embryos
Test Type/Duration		Bivalve Larvae – Static / 48 hours
Sample Storage Conditions		4°C, dark, minimal head space
Holding Time		36 hours
Control Water Source		Scripps Pier seawater, 0.2 µm filtered, UV sterilized
Recommended Water Quality Parameters	Temperature	15 ± 1°C
	Salinity	30 ± 2 ppt
	Dissolved Oxygen	> 4.0 mg/L
	pH	6-9; Monitor for pH drift
Photoperiod		16 hours light, 8 hours dark
Test Chamber		20-mL glass shell vials
Concentrations		5 and a control
Replicates/Sample		4
No. of Organisms/Replicate		Recommended: 15–30/mL
Exposure Volume		10 mL
Feeding		None
Water Renewal		None

3.1.7 Water Quality Analysis

Analysis of water quality data will include calculations of average dissolved copper concentrations to determine basin-wide compliance with the CTR dissolved copper chronic target (3.1 µg/L) or a potential site-specific objective. Since the same station locations will be revisited annually, repeated measures analysis will be used to statistically determine significant reductions in copper levels with time. The first monitoring season's data will be compared to the 2005-2008 dissolved copper surface concentration data reported in Section 3.1 to determine whether conditions have improved or degraded over the intervening period. Although this data will be informative for long-term trend analysis, it will not be used to assess compliance with interim loading reduction targets, since interim TMDL compliance will be directly assessed by loading reductions rather than water quality improvements.

Determinations of toxicity using the 96-hour topsmelt bioassay will be statistically assessed using ToxCalc to compare survival of topsmelt exposed to the multi-concentration dilution series

of SIYB seawater (i.e., treatments) to topsmelt exposed to filtered seawater (i.e., controls). Results will be used to determine No Observed Effect Concentration (NOEC), Lowest Observed Effect Concentration (LOEC), and LC_{50} values. If survival of the control does not differ significantly from that of the treatments, then conditions within SIYB will be considered to nontoxic, indicating that the narrative water quality target has been met.

Determinations of toxicity using the 48-hour bivalve bioassay will be statistically assessed using ToxCalc to compare survival and normality of bivalve larvae exposed to the multi-concentration dilution series of SIYB seawater (i.e., treatments) to bivalve larvae exposed to filtered seawater (i.e., controls). Results will be used to determine NOEC, LOEC, and LC_{50} (for survival) and EC_{50} (for normality) values. If survival and normality of the control do not differ significantly from that of the treatments, then conditions within SIYB will be considered to be nontoxic, indicating that the narrative water quality target has been met.

3.2 QA/QC Procedures

Sampling process QA/QC will include proper collection of the samples in order to minimize the possibility of contamination. All samples will be collected in laboratory-supplied, laboratory-certified, contaminant-free sample bottles. Field staff will wear powder-free nitrile gloves (or similar) at all times during sample collection. The sampling team will provide field sampling standard operating procedures (SOPs) and ensure all sampling personnel are trained accordingly. Additionally, the field staff will be made aware of the significance of the project's detection limits and the requirement to avoid contamination of samples at all times. Duplicate samples will also be analyzed to assess variability in sampling and to remain compliant with SWAMP protocols. Each batch of samples that is submitted to the laboratories for analyses will be accompanied by an equipment rinse blank, field blank, and a duplicate sample, as specified under SWAMP.

Samples will be analyzed by a laboratory certified by the California Environmental Laboratory Accreditation Program (ELAP) for the analyses of inorganics, toxic chemical elements, and organics in wastewater. The QA objectives for chemical analysis conducted by the participating analytical laboratories are detailed in their Laboratory QA Manual(s). The objectives for accuracy and precision involve all aspects of the testing process, including the following:

- Methods and SOPs;
- Calibration methods and frequency;
- Data analysis, validation, and reporting;
- Internal QC;
- Preventive maintenance; and
- Procedures to ensure data accuracy and completeness.

Results of all laboratory QC analyses will be reported with the final data. Any QC samples that fail to meet the specified QC criteria in the methodology or QAPP will be identified, and the corresponding data will be appropriately qualified in the final report.

All QA/QC records for the various testing programs will be kept on file for review by regulatory agency personnel.

3.3 Chain-of-Custody Procedures

Chain-of-custody procedures will be used for all samples throughout the collection, transport, and analytical process. Samples will be considered to be in custody if they are (1) in the custodian's possession or view, (2) retained in a secured place (under lock) with restricted access, or (3) placed in a container and secured with an official seal such that the sample could not be reached without breaking the seal. The principal documents used to identify samples and to document possession will be COC records, field logbooks, and field tracking forms.

Chain-of-custody procedures will be initiated during sample collection. A COC record will be provided with each sample or group of samples (Attachment 2). Each person who had custody of the samples will sign the form and ensure that the samples were not left unattended unless properly secured. Documentation of sample handling and custody will include the following:

- Sample identifier;
- Sample collection date and time;
- Any special notations on sample characteristics or analysis;
- Initials of the person collecting the sample;
- Date the sample was sent to the analytical laboratory; and
- Shipping company and waybill information.

Completed COC forms will be placed into a plastic envelope and kept inside the cooler containing the samples. Upon delivery to the analytical laboratory, the COC form will be signed by the person receiving the samples. Chain-of-custody records will be included in the final reports prepared by the analytical laboratories and will be considered an integral part of the report.

3.4 Health and Safety

Since sampling will be conducted from a boat, dangerous situations have the potential to arise. Field personnel need to be aware of safety hazards and take appropriate precautions. A health and safety tailgate meeting will be held prior to the occurrence of any on-site activity. During this meeting, site specific hazards will be discussed and addressed appropriately.

3.4.1 Use of Boats and Working over Water

Work will be conducted from a boat over and around SIYB; therefore, special considerations are required. All crafts will be operated according to the applicable navigational rules and regulations. The boat will be operated by a certified captain with U.S. Coast Guard small vessel training. Personnel working on the boat will be trained according to internal SOPs. The hazards associated with the operation and use of boats includes drowning, heat stress, and injuries from falling. An approved personal flotation device must be available for each person onboard. Wet conditions increase the chances of slipping; therefore, engineering controls such as guardrails will be used. Sampling will be conducted in the summer and therefore increase the risk of heat

stress. Plenty of water will be made available to field staff and wearing short pants is acceptable to reduce this risk. A Float Plan will be prepared for each trip and submitted to the Safety Officer or Project Manager. At a minimum, it will include destination, expected time of return, personnel on board, and description of vessel. The Float Plan will be used if the field crew does not return or notify the shore contact at a specified time and a rescue is needed. Weather forecast will be reviewed prior to field sampling. High winds may pose potential hazardous conditions within the harbor.

4.0 DATA REVIEW AND MANAGEMENT

4.1 Data Review

All data will be reviewed and verified by participating team laboratories to determine whether data quality objectives have been met, and that appropriate corrective actions have been taken, when necessary, as detailed in the QAPP.

4.2 Data Management

All laboratories will supply analytical results in both hard copy and electronic formats. Laboratories will have the responsibility of ensuring that both forms are accurate. After completion of the data review by participating team laboratories, hard copy results will be placed in the project file at WESTON and the results in electronic format will be imported into WESTON's database system. Additional details on data management are provided in the QAPP.

4.3 Quality Assurance/Quality Control

Analytical laboratories will provide a QA/QC narrative that describes the results of the standard QA/QC protocols that accompany analysis of field samples. All hard copies of results will be maintained in the project files. In addition, back-up copies of results generated by each laboratory will be maintained at their respective facilities. At a minimum, the laboratory reports will contain results of the laboratory analysis, QA/QC results, all protocols and any deviations from the project Monitoring Plan, and a case narrative of COC details.

5.0 REPORTING

Reporting under the SIYB TMDL will include annual Monitoring and Progress Reports to be submitted to the Regional Board by the Port no later than March 31 of each year, beginning on March 31, 2012. The purpose of the Monitoring Plan annual reporting is to document the methods and results of annual vessel tracking surveys and water quality monitoring. Reports will detail the number of vessels converted to non-copper or low-copper paints within SIYB to calculate loading reductions. Additionally, annual progress reports will describe water quality conditions, specifically focused on the concentrations of dissolved copper within the basin and observed toxicity levels.

At a minimum, the following information will be included in annual Monitoring and Progress Reports.

SIYB TMDL Implementation. An evaluation, interpretation and tabulation of data and information on SIYB Dissolved Copper TMDL activities undertaken by the Named Parties including:

1. *Vessel Conversions*. Assess vessel conversions from copper-based antifouling hull paint to non-copper and low-copper hull paints, including:
    a. Total number of slips or buoys in SIYB available to be occupied by vessels;
    b. Number of unoccupied slips or buoys and length of time unoccupied during each year;
    c. Number of vessels confirmed with copper-based hull paint and approximate length of time occupying a slip or buoy in SIYB during each year;
    d. Number of vessels confirmed with alternative hull paints, by alternative hull paint type, and approximate length of time occupying a slip or buoy in SIYB during each year;
    e. Number of vessels with unconfirmed information about hull paint and approximate length of time occupying a slip or buoy in SIYB during each year;
    f. An estimate of the dissolved copper load reduction achieved, in terms of kilograms and percent, for the year;
    g. Any other data or information relevant to annual tracking of vessels in SIYB occupying slips or buoys and conversions from copper-based hull paints to alternative (i.e., non-copper or low-copper) hull paints.
2. *SIYB BMP Implementation.* Describe BMPs or other actions that have been implemented by the Named Parties to reduce dissolved copper discharges from boat hulls into SIYB. BMPs and other actions implemented and required to be implemented by underwater hull cleaners must be described.

San Diego Bay-wide BMP Implementation. Describe BMPs or other actions that can be, will be, or have been implemented by the Port to reduce dissolved copper discharges from boat hulls into harbors or marinas, other than SIYB, within San Diego Bay.

SIYB TMDL Monitoring. An evaluation, interpretation, and tabulation of water quality sampling and analysis data, including:

1. *Sample Locations and Numbers*. The locations, type, and number of samples must be identified and shown on a site map.
2. *Sample Analyses*. The sample collection and laboratory analytical methods, QA/QC results, time and date of sample collection and other pertinent information must be described.
3. *Conceptual Model Update.* Refinements and updates to the Conceptual Model based on available data must be described. The description must include identification of monitoring data needed to verify or refine assumptions, resolve uncertainties, and improve the scientific foundation of the TMDL.
4. *Water Quality Trends.* Interpretations and conclusions, as to whether the "trajectory" of the measured water quality values points toward attainment of the dissolved copper water quality objectives, must be provided.

6.0 REFERENCES

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ATTACHMENT 1

Tracking Database Fields

Provided as an Excel File

SIYB TMDL Hull Tracking Agreement
Exhibit A

Guidance Document for Vessel Hull Tracking Transfer Data Template

Field Name	Date	Facility	Slip/Mooring Number	Percent of Time Occupied	Vessel Document or Registration #	Vessel Type	Vessel Length	Vessel Beam	Paint Type	Paint Name	Product Number	Boatyard	Painting Date	% Copper
Field Description	Provide date information is added to this template. If updating an existing entry, provide date information was updated.	Identify the facility where the vessel is moored - yacht club, marina, etc.	Identify specific slip or mooring where the vessel is docked/moored. Entry can include both letters and numbers.	Report the percent of time vessels are in slips or moored to buoys in SIYB	The CF # and/or Vessel Documentation # are used to identify a vessel with a state or federal registration-based identification that is transferrable if the boat is sold or relocated. **Entry is mandatory for this field (use either CF# or Vessel Documentation #)**	This field is necessary to identify whether vessel is a power, sailboat, multi-hull, or electric. Use valid code list provided below.	Report the **Registered Vessel Length** in feet. Identify length increments in decimals, **NOT** inches. For Example: Length of 10 1/2 feet would be 10.5, NOT 10ft 6in	Report beam width of the vessel in feet - the widest point on the vessel. Identify length increments in decimals, **NOT** inches. For Example: Length of 10 1/2 feet would be 10.5, NOT 10ft 6in	Identify whether the current hull paint is copper based or non-copper based. This is a mandatory entry field. **If information is not available identifying the coating as "Cu" "Zn", "NON", or "ORG", the default MUST be "UKN" until supporting information can be provided.**	Identify the product name of the hull paint used. This information will assist in determining paint composition. A list of the more commonly used paints is included below, but is not intended to be comprehensive.	List the product number of the current hull paint, if known. This field is a **required entry if being completed by applicator,** but voluntary if provided by boater or marina.	Identify the boatyard used for most current hull paint application. If form is being completed by applicator, enter your boatyard code below. If using a boatyard outside of San Diego Bay, enter "OTH".	Report date of most recent hull painting. If form is being completed by boatyard, report current painting date.	Report the percentage of copper in the paint
Required Field Type	Date Entry	Text - use only the BOLD codes listed below	Text	Numeric Entry (%), w/ decimal increments	Text	Text - use only the BOLD codes listed below	Numeric Entry (ft), w/ decimal increments	Numeric Entry (ft), w/ decimal increments	Text - use only the BOLD codes listed below	Text	Text	Text - use only the BOLD codes listed below	Date entry - use format identified below	Numeric Entry
Valid Field Code*	**MM/DD/YY**	**BCM** - Bay Club Marina **CN** - Crows Nest Marina **GC -** Gold Coast Anchorage **HMM** - Half Moon Marina **HPD -** Harbor Police Dock **LPYC -** La Playa Yacht Club **KK** - Kona Kai Marina **PSN -** Pearson's Fuel Dock **SIM** - Shelter Island Marina **SDYC -** San Diego Yacht Club **SGYC** - Silver Gate Yachy Club **SWYC-** Southwestern Yacht Club **TON -** Tonga Landing				**P -** Power **S -** Sailboat **E-** Electric **H -** Houseboat **M -** Multi-hull			**Cu -** single active = copper **LCu** -Low Copper (≤ 40%) **NON -** non-biocide **Zn** - single active = zinc **ORG** -single active = organic **COMBO** - multiple active **UKN -** Unknown	**Examples below:** Interlux Ultra (67) Monterey (58) Seaguard (49) ABC 3 (48) Hydrocoat (40) Cukote (46) Seacoat (45) Trilux33 (33) Micron66 (40) Micron Extra (39) Jotun ( ) Petit Vivid (17) Trilux/Biolux (17) Micron Optima (28 Trinidad ( ) Trinidad SR (70) Trinidad VOC (65) Interlux Super KL Ultrakote (76) Tropicoat (76) Proline 1088 (67) Calif Bottomkote Sharkskin (45) Procoat (45) Mission Bay Pacifica Econea E-Paint Cerakote Intersleek Ceram-kote Microphase VC127 SeaHawk AF33 Bluewater Imron Interlux Silicone Interlux K91 PolarCrest VC Performance Epoxy EP-21 Sunwave		**DR** - Driscolls **KC** - Knight & Carver **KK** - Koehler Kraft **MG** - Marine Group **NB** - Nielsen Beaumont **SI** - Shelter Island **OTH** - Other Boatyard	**MM/YYYY**	

* Valid field codes for each field having a predetermined set of allowable values are identified in **BOLD** print. Each valid code is followed by a definition of the value.

Facilities will be required to provide information for each of the slips and moorings in their facility.

Green: Required Field

Yellow: Required if claiming non-copper or low-copper paint

Gray: Optional

SIYB TMDL Hull Tracking Agreement

Exhibit B

Vessel Hull Tracking Data Transfer Template

Date	Facility	Slip/Mooring Number	Percent of Time Occupied	Vessel Document # or Registration #	Vessel Type	Vessel Length	Vessel Beam	Paint Type	Paint Name	Product Number	Boatyard	Painting Date	% Copper

ATTACHMENT 2

Chain-of-Custody Form

WESTON SOLUTIONS

☐ 2433 Impala Drive • Carlsbad, CA 92010 • (760) 795-6900, FAX 931-1580
☐ 1440 Broadway, Ste. 910 • Oakland, CA 94612 • (510) 808-0302, FAX 891-9710

CHAIN OF CUSTODY
1760

DATE_____ PAGE_____ OF_____

PROJECT NAME / SURVEY / PROJECT NUMBER

PROJECT MANAGER / CONTACT

COMPANY / CLIENT

ADDRESS

PHONE / FAX / EMAIL

SITE ID (Location)	SAMPLE ID	DATE	TIME	MATRIX	CONTAINER TYPE / VOLUME	TOTAL NUMBER OF CONTAINER	ANALYSIS/TEST REQUESTED								PRESERVED HOW	FOR WESTON USE ONLY: SAMPLE TEMP. (°C) UPON RECEIPT	FOR WESTON USE ONLY: WESTON LAB ID

Sample Matrix Codes: FW= fresh water GW=ground water SLT=salt water SW=storm water WW=waste water SED=sediment A=air BIO=biologic SS=soil T=tissue O=other (specify) _____

Container Code: G=glass P=plastic B=bags ☐ O=other _____

Shipped By: ☐ Courier ☐ UPS ☐ FedEx ☐ USPS ☐ Client drop off ☐ Other _____

Turnaround Time: ☐ 2-day ☐ 5-day ☐ 7-day ☐ 10-day ☐ 14-day ☐ Standard ☐ Other _____

Reporting Requirements: ☐ PDF ☐ EDD ☐ Hard Copy ☐ Email ☐ Other _____

SAMPLED BY: PRINT SIGNATURE

COMMENTS / SPECIAL INSTRUCTIONS

RELINQUISHED BY				RECEIVED BY			
Print Name	Signature	Firm	Date/Time	Print Name	Signature	Firm	Date/Time
1.							
2.							
3.							
4.							
5.							
6.							

WHITE – return to originator • YELLOW – lab • PINK – retained by originator