Assessing Alternatives to Copper Antifouling Paint: Piloting the Interstate Chemicals Clearinghouse (IC2) Alternatives Assessment Guide

Prepared for:

Washington State Department of Ecology

Prepared by:

ToxServices LLC

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TOXSERVICES
TOXICOLOGY RISK ASSESSMENT CONSULTING
1367 Connecticut Ave., N.W., Suite 300
Washington, D.C. 20036

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FOREWORD AND ACKNOWLEDGEMENTS

In the late 16th century, the great French essayist Michel de Montaigne had a medallion inscribed with the words “Que sais-je” (“What do I know?”) above a pair of scales, which he wore as a reminder of the uncertainties and limitations associated with one’s current state of knowledge. Likewise, the selection of materials or chemicals during a product’s design process is usually based on incomplete knowledge, and often entails the assessment and subsequent reduction of human health or environmental risks, instead of avoiding hazards or promoting continuous improvement in a chemical, material, product, system, production process, or function.

The development and maturation of alternatives assessment frameworks such the Interstate Chemicals Clearinghouse’s Alternatives Assessment Guide (“the IC2 Guide”) provides assessors with an impartial, scientifically-based framework that empowers knowledge-based decision making, and ideally, reduces and avoids regrettable substitution. Widespread adoption of alternatives assessment methods will work to replace the phrase “Que sais-je” with a resounding “Je sais Alternatives Assessment!” (“I know Alternatives Assessment!”), securing the health of ourselves and the world in which we live.

EXECUTIVE SUMMARY

The Interstate Chemicals Clearinghouse (IC2) released Version 1.0 of its guide for conducting Alternatives Assessments ("the IC2 Guide") in 2014. The purpose of the current contract is to test the usability of the IC2 Guide while developing a basis for a future, detailed assessment of alternatives to copper antifouling paints. Copper contamination is a leading concern in the Puget Sound region, and a 2011 Washington State law (Chapter 70.300 RCW) requires copper antifouling paints to be phased out beginning in 2018 and completed by January 1, 2020.

This report is a compilation of the five major tasks that the ToxServices' Team completed for Washington State Department of Ecology (Ecology) under Contract # C1500007.

Under Task 1, ToxServices identified one copper antifouling paint and six soft nonbiocide alternative paints. The six alternatives were selected based on their performance in a previous alternatives assessment report conducted by the U.S. Environmental Protection Agency and California Environmental Protection Agency. ToxServices created a Uniform Data Set by assessing the human health, environmental, and physical hazards posed by individual chemicals in each of the formulations using a method based on the hazard assessment tool GreenScreen® for Safer Chemicals (GreenScreen®). Task 1 serves as the basis for the Hazard Module.

Under Tasks 2, 3, and 4, three independent groups of the ToxServices' Team completed an alternatives assessment using the three alternatives assessment frameworks described in the IC2 Guide: the Sequential, Simultaneous and Hybrid Frameworks, respectively. The three IC2 frameworks share four identical core modules: Hazard, Performance Evaluation, Cost and Availability, and Exposure Assessment. Three additional modules (Materials Management, Social Impacts, and Life Cycle) were implemented in the Hybrid Framework to determine if they significantly affected the results.

Under Task 5, the three independent groups met to share the results and challenges in completing the frameworks and worked collaboratively to summarize findings and offer recommendations for improving the usability of the IC2 Guide.

Preferred alternatives were identified under each of the three frameworks. In the Sequential Framework (Task 2), three paints, Intersleek 900 System, BottomSpeed TC Base Coat/Top Coat Clear, and Surface Coat Part A – Black, were identified as preferred alternatives. Under the Simultaneous Framework (Task 3), Surface Coat Part A – Black was the most preferable. Under the Hybrid Framework (Task 4), BottomSpeed TC Base Coat/Top Coat Clear was selected as the preferred alternative.

Although the assessors were each able to select preferred alternatives, the results indicate that no alternative is an ideal alternative to copper antifouling paint. Some paint formulations appear to be slightly preferable to the copper antifouling paint in terms of hazard, but all formulations contain hazardous chemicals that pose human health and/or environmental risks. In addition, data gaps due to minimal disclosure of chemicals introduces uncertainty in the selection of a preferred alternative. Further, the IC2 Guide contains limited decision-making guidance on differentiating alternatives, which compelled assessors to create their own decision rules. This adds variability in the choice of a preferred alternative. Therefore, the paint alternatives identified as preferable in this report do not constitute an endorsement because significant reservations and data gaps remain.

Based on experiences from completing Tasks 2, 3, and 4, the ToxServices' Team found that the IC2 Guide is sufficiently flexible to meet the needs of a wide range of users; however, some degree of technical expertise is needed to conduct the Hazard and Exposure Assessment Modules. Nevertheless, several challenges were encountered at both the framework and module level.

At the framework level, it is not clear whether additional work should be done at the end of a framework if multiple alternatives remain. Further, decision methodology is not always clearly presented in the IC2 Guide.

At the module level, various challenges were identified in all modules; however, the most significant challenges were encountered during completion of the Hazard Module. Specifically, the IC2 Guide provides no guidance on how to treat incomplete formulations or how to further differentiate alternatives if the hazard scores were non-differentiating. In the other modules, chemical specific guidance was provided; however, guidance on evaluating a product in each of the modules was lacking.

In order to resolve these challenges, the ToxServices' Team recommends a number of IC2 Guide revisions to improve the usability of the IC2 Guide. Specifically, the IC2 Guide would benefit from additional technical copyediting as well as improved organization and flow. Additionally, improvements should be made to ease navigation throughout the IC2 Guide.

Several technical revisions to the IC2 Guide are recommended, including modification of the scoping step and determining the availability of alternatives at the beginning of an alternatives assessment. This would allow the assessor to begin an alternatives assessment with a clear path and solid foundation. In addition, guidance on how to select a framework, and identifying the advantages and drawbacks of each, would help users select the appropriate framework to meet their needs.

The IC2 Guide could also be improved by expanding guidance on decision making by providing direction on how to create decision rules and prioritize trade-offs. This expansion should also be applicable to chemical and product-level assessments. Further, the effectiveness of the Hazard Module should be enhanced, and certain modules should be made more independent and stand-alone.

If these recommendations are implemented, the IC2 Guide will be a better document for its users and provide more guidance in performing an Alternatives Assessment. The ToxServices' Team considers the following three recommendations as the highest priorities:

1. **Enhance Effectiveness of Hazard Module** by providing guidance on how to use GreenScreen® Benchmark scores and the hazard data that support the scores to differentiate among alternatives. Opportunities for green chemistry innovation should be requested for scenarios where the design of safer alternatives is warranted.

2. **Expand Guidance on Decision-Making** by providing direction on how to create decision rules and prioritize trade-offs that is applicable to chemical and product-level assessments.

3. **Improve Organization and Flow of the Guide** by reorganizing and enhancing content based on the five distinct steps of an alternatives assessment.

INTRODUCTION

Background

On January 8, 2014, the Interstate Chemicals Clearinghouse (IC2) released Version 1.0 of its guide for conducting Alternatives Assessments, entitled the "Interstate Chemicals Clearinghouse Alternatives Assessment Guide" ("the IC2 Guide"). According to the IC2, the IC2 Guide is intended to be "a set of tools that manufacturers, product designers, businesses, governments, and other interested parties can use to make better, more informed decisions about the use of toxic chemicals in their products or processes" (IC2 2013).

The purpose of the current contract is to test the usability of the IC2 Guide while developing a basis for a future, detailed assessment of alternatives to copper antifouling paints. Copper contamination is a leading concern in the Puget Sound region, and a 2011 Washington State law (Chapter 70.300 RCW) requires copper antifouling paints to be phased out beginning in 2018 and completed by January 1, 2020 (State of Washington 2011).

Alternatives to copper antifouling paints include both zinc and organic biocide paints, as well as nonbiocide paints that create a slick surface, which prevents attachment of aquatic organisms to submerged surfaces. Compared to copper antifouling paints, nonbiocide paints are considered preferable from a human and environmental health standpoint, have a long lifespan, and perform well in research studies (CalEPA 2011).

This section of the report summarizes the five major tasks that the ToxServices' Team (made up of scientists and engineers from ToxServices LLC, Abt Associates, and the Massachusetts Toxics Use Reduction Institute) completed for Washington State Department of Ecology ("Ecology") under Contract # C1500007.

Overall Objectives of the Project

As outlined by Ecology, the primary objectives this Contract are to:

- Explore alternatives to copper antifouling paints for marine usage and provide a basis for a future, more detailed assessment of alternatives to copper antifouling paint.
- Evaluate the usability of the IC2 Guide

To meet these objectives, Ecology outlined the following steps:

- Create a Uniform Data Set to use during evaluation of the IC2 Guide that contains chemical hazard assessments of alternatives to copper antifouling paint
- Conduct Alternatives Assessments using the Uniform Data Set and the three frameworks (i.e., Sequential, Simultaneous, and Hybrid) outlined in the IC2 Guide
- Identify safer alternatives to copper antifouling paint based on the Alternatives Assessments
- Compare results of the three Alternatives Assessments to determine if the same conclusions were reached and, if not, provide input on possible reasons for the variability
- Evaluate the ability of new users to conduct an Alternatives Assessment

- Make recommendations to Ecology on any portions of the IC2 Guide that require further clarity to improve user friendliness.

Scope

The ToxServices' Team followed the process depicted in Figure 1.

Figure 1: Approach to Assessing the IC2 Alternatives Assessment Guide

<table>
<tr><td colspan="4">Road Map for Completing Alternative Analyses Using the IC2 Alternatives Assessment Guide</td></tr>
<tr><td colspan="3">Task 1: Conducting Hazards Analysis on a Uniform Data Set
ToxServices</td><td>August - October 2014</td></tr>
<tr><td colspan="3">Tasks 2 through 4: Draft Alternatives Assessments of Copper Boat Paint Using the Uniform Data Set and Three Frameworks</td><td rowspan="2">October – December 2014</td></tr>
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Abt Associates</td></tr>
<tr><td colspan="3">Task 5: Final Report
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Abt Associates
Massachusetts Toxics Use Reduction Institute</td><td>December 2014 – February 2015</td></tr>
</table>

Under Task 1 of the contract, ToxServices created a Uniform Data Set by assessing the human health, environmental, and physical hazards posed by individual chemicals in the copper antifouling paint (the control) and six alternative paint formulations[1].

- Control: Kop-Coat, Inc.'s Pettit Marine Paint Trinidad Pro Antifouling Bottom Paint 1082 Blue
- Alternative 1: Kop-Coat, Inc.'s Klear N' Klean Plus XP-A101 White Topcoat
- Alternative 2: International Paint LLC's Intersleek 900 System
- Alternative 3: International Paint LLC's XZM480 International
- Alternative 4: BottomSpeed Coating System's BottomSpeed TC Base Coat/Top Coat Clear
- Alternative 5: Hempel (USA), Inc.'s Hempasil XA278
- Alternative 6: FUJIFILM Hunt Smart Surfaces, LLC's Surface Coat Part A – Black

[1] The paints are referred to as "formulations" throughout this report; however, in the context of this report, that term is synonymous with the term "product," which is the term used in the IC2 Guide.

These paint formulations were evaluated in two previous reports:

- Safer Alternatives to Copper Antifouling Paints: Nonbiocide Paint Options (CalEPA 2011). Prepared by Institute for Research and Technical Assistance (IRTA) for CalEPA's Department of Toxic Substances Control.
- Safer Alternatives to Copper Antifouling Paints for Marine Vessels (U.S. EPA 2011). Prepared by IRTA and the Unified Port of San Diego for the U.S. EPA

In the U.S. EPA (2011) report, 46 paints, which included biocide paints based on copper and zinc and nonbiocide paints, were evaluated. From an overall health and environmental standpoint, the nonbiocide paints are the best alternatives to copper antifouling paint. A few nonbiocide paints from the U.S. EPA (2011) report were further evaluated on panels and boat hulls, and the results were documented in the CalEPA (2011) report. The six paints chosen by the ToxServices' Team as viable alternatives were those that had the best performance in the two reports above. These six alternatives were compared to the copper antifouling paint for a total of seven paints.

The IC2 Guide presents three different Alternatives Assessment Frameworks and leaves it to the discretion of the assessor to choose which Framework best fits the project at hand. The IC2 Sequential Framework evaluates the four required core modules (Hazard, Performance Evaluation, Cost and Availability, and Exposure Assessment) in a consecutive manner. The IC2 Simultaneous Framework reviews data from all four modules at the same time and then applies decision rules, as specified in the IC2 Guide, to help guide the work. The IC2 Hybrid Framework uses a combination of both. The ToxServices' Team was assigned to evaluate the usability of all three Framework available in the IC2 Guide.

Under Task 2, ToxServices conducted an Alternatives Assessment using the Sequential Framework.

Under Task 3, Abt Associates conducted an Alternatives Assessment using the Simultaneous Framework.

Under Task 4, Abt Associates (independent from those who conducted Task 3) conducted an Alternatives Assessment using the Hybrid Framework.

Stakeholder involvement was out of scope for this project, and the sections of the IC2 Guide pertaining to these steps were not evaluated.

While the three Alternatives Assessments completed under this project are valuable with respect to evaluating the alternatives to copper antifouling paint, the main intention of this project was to pilot each framework within the IC2 Guide and provide feedback on the usability of the Guide. We were also interested in evaluating how the three different frameworks could influence the identification of a preferred alternative. These Alternatives Assessments were not created with the intention of being used as standalone Alternatives Assessments for copper antifouling paint, and the results of each framework should not be interpreted as comprehensive Alternatives Assessments for copper antifouling paint.

Under Task 5, the three independent groups met to share the results and challenges in implementing the frameworks. The full ToxServices' Team (ToxServices, Abt Associates, and Massachusetts Toxics Use Reduction Institute) worked collaboratively to summarize findings and offer recommendations for improving the usability of the IC2 Guide.

SUMMARY OF APPROACH (TASKS 1 THROUGH 4)

This section summarizes the approach used to create the Uniform Data Set under Task 1 and the results of the Alternatives Assessments undertaken using the Sequential, Simultaneous, and Hybrid Frameworks under Tasks 2 through 4.

Method to Create Uniform Data Set

The Hazard Module in the IC2 Guide provides detailed methods on evaluating hazard. ToxServices performed a series of increasingly detailed hazard evaluations of all chemicals in the control and the selected alternative paint formulations to create the Uniform Data Set using the following steps:

- Step 1: Apply GreenScreen® List Translator (Initial Screen)
- Step 2: Perform hazard assessment based on GreenScreen® methodology (Level 2)
- Step 3: Expand hazard assessment based on GreenScreen® methodology (Level 3)

It should be noted that the Quick Chemical Assessment Tool (QCAT), the hazard screening tool recommended in Level 1 of the Hazard Module, was not used by ToxServices in creating the Uniform Data Set because it does not include chronic aquatic toxicity in its hazard endpoints evaluation (Stone 2012). Because the major concern associated with copper antifouling paints is aquatic toxicity, the assessors concluded that a tool which incorporated chronic toxicity (i.e., GreenScreen® List Translator) was a more appropriate hazard screening tool for this hazard evaluation.

The GreenScreen® List Translator methodology assigns List Translator scores using hazard scores from a list-based search. The possible List Translator scores are:

- List Translator 1 (LT-1): Equivalent to Benchmark 1
- Possible List Translator 1 (LT-P1): Possible Benchmark 1 (Further Evaluation Needed)
- List Translator Unassigned (LT-U): Insufficient information is available from the List Translator Evaluation (Further Evaluation Needed)

The GreenScreen® methodology assigns Benchmark scores based on a chemical's hazard profile. The possible Benchmark scores are:

- Benchmark 1: Avoid (Chemical of High Concern)
- Benchmark 2: Use (But Search for Safer Substitutes)
- Benchmark 3: Use (But Still Opportunity for Improvement)
- Benchmark 4: Prefer (Safer Chemical)

The compilation of chemical hazard evaluations for each paint formulation (along a brief overview of each paint and its corresponding physical characteristics) is the Uniform Data Set and is equivalent to the hazard evaluation piece of the Hazard Module. The results from ToxServices' hazard evaluation of each formulation can be seen in Tables D-1 through D-9 and were used as the basis for the decision-making portion of the Hazard Module for each of the three frameworks.

Method to Complete the Sequential, Simultaneous and Hybrid Frameworks

The three assessors evaluated the three frameworks using the four required core modules of the IC2 Guide: Hazard, Performance Evaluation, Cost and Availability, and Exposure Assessment. Three additional modules that exist in the IC2 Guide (Materials Management, Social Impacts, and Life Cycle) were applied in the Hybrid Framework to determine if they significantly affected the results.

Each assessor used the same three data sources to evaluate each framework:

- Uniform Data Set for Assessing Alternatives to Copper Boat Paint (ToxServices 2014a). Prepared by ToxServices LLC for Washington State Department of Ecology.
- Safer Alternatives to Copper Antifouling Paints: Nonbiocide Paint Options (CalEPA 2011). Prepared by Institute for Research and Technical Assistance (IRTA) for CalEPA's Department of Toxic Substances Control
- Safer Alternatives to Copper Antifouling Paints for Marine Vessels (U.S. EPA 2011). Prepared by IRTA and the Unified Port of San Diego for the U.S. EPA

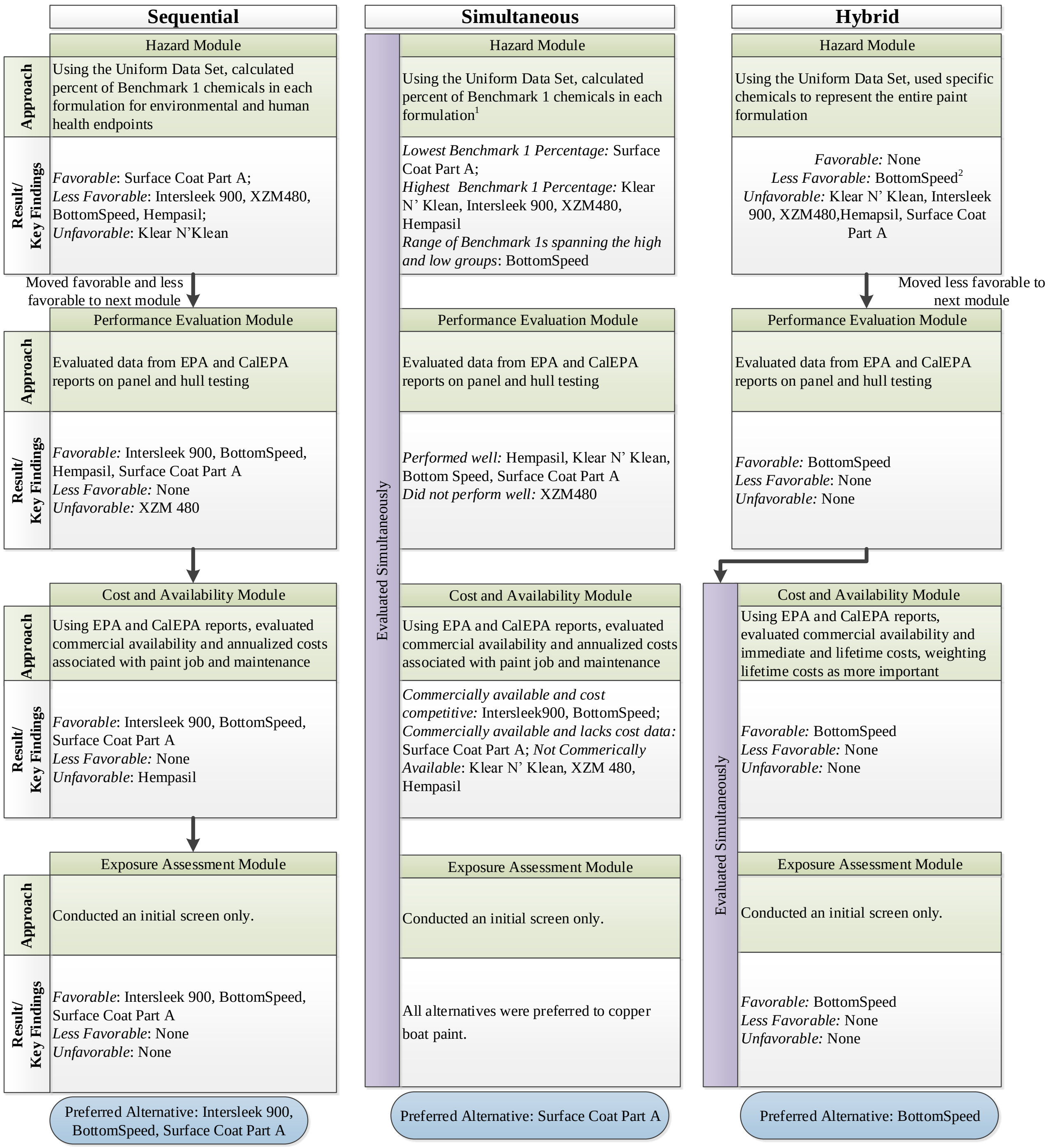
The hazard data in ToxServices' Uniform Data Set was used to evaluate hazard under the Hazard Module. Data from the CalEPA (2011) and U.S. EPA (2011) reports were used to evaluate performance and cost under the Performance Evaluation and Cost and Available Modules, respectively. The Exposure Assessment was qualitative and was completed using expertise of the assessors. Some guidance was provided on how to make decisions on prioritizing alternatives in each Module in the IC2 Guide. However, if sufficient guidance was not provided, it was up to each assessor to create and implement decisions on how to interpret this data as they worked through the requirements of the frameworks and the IC2 Guide. Additionally, per the terms of the Project, each Framework was completed independently. Therefore, common methods to interpret hazard, performance, cost and availability, and exposure were not established.

Results of the Sequential, Simultaneous, and Hybrid Frameworks

An overview of the approaches for decision-making and results of each framework is outlined in Figure 2[2]. The three additional modules are not included in Figure 2 because they were only evaluated in the Hybrid Framework. Based on the project scope, evaluation using the additional modules was only completed as part of the Hybrid frameworks analysis to better understand how these modules might influence the outcome of the assessment.

[2] Note that for legibility purposes the figures in this section refer to the paints by abbreviated names.

Figure 2: Summary of Approach and Findings of each IC2 Framework



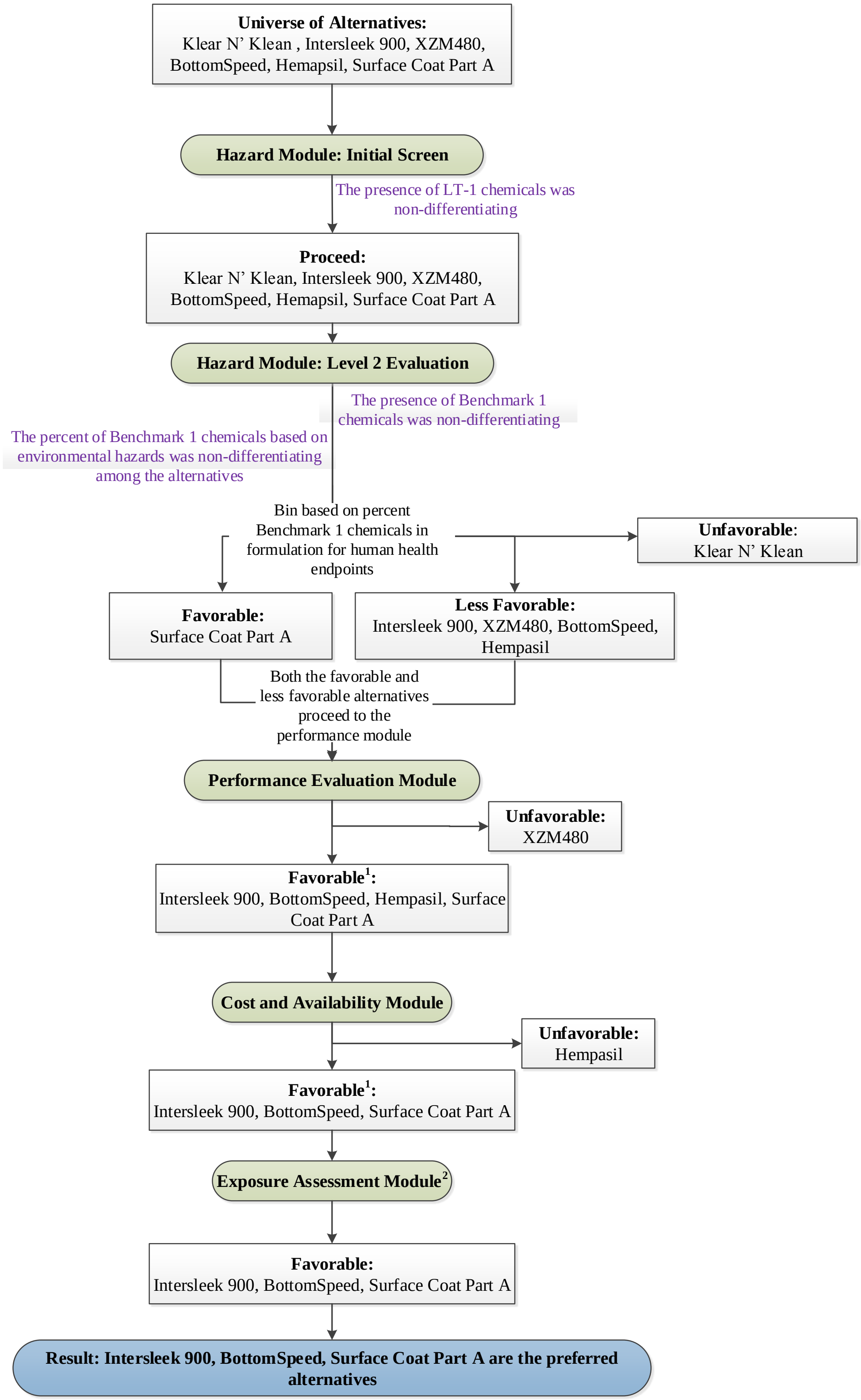
[1] Undisclosed ingredient was assumed to be Benchmark 1.

[2] The assessors of the Hybrid Framework had to iterate through the Hazard and Performance Evaluation Modules twice. They originally selected Klear N' Klean XP-A101 White Top Coat as the only alternative to pass through the Hazard Module but later found it to be no longer commercially available under the Cost and Availability Module. Upon the second iteration of the Hazard Module, BottomSpeed TC Base Coat/Top Coat Clear was binned as favorable when evaluating the silicon-based components of the alternative paints.

IC2 Sequential Framework

In the IC2 Sequential Framework, the four core modules were completed in a linear order, starting with the Hazard Module and moving on to Performance Evaluation, Cost and Availability, and Exposure Assessment Modules. Data were collected and alternatives were binned as favorable, less favorable or unfavorable relative to the copper antifouling paint. Favorable and less favorable alternatives advanced to subsequent modules, and unfavorable alternatives were eliminated from further review. The overall process and results are shown in Figure 3 and complete methodology and results can be found in Task 2.

Figure 3: Overview of Alternatives Assessment Using the IC2 Sequential Framework



[1] No alternatives were binned as less favorable; [2] Only an Initial Screen was conducted for this module.

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Hazard Module

Using the hazard evaluations in the Uniform Data Set, formulations were categorized as unfavorable if they contained any GreenScreen® Benchmark 1 chemicals[3]. This resulted in all alternatives being binned as unfavorable.

A second approach was to bin and eliminate the alternative formulations based on the percentage of Benchmark 1 chemicals driven by environmental endpoints. Alternatives were considered favorable if they did not appear to be as environmentally toxic as copper antifouling paint. The results revealed there was no difference among the alternatives based on Benchmark 1 chemicals driven by environmental toxicity endpoints.

Next, the alternatives were binned and unfavorable ones eliminated based on the percentage of Benchmark 1 chemicals driven by human health endpoints. This approach was considered to advance alternatives that were preferable in terms of human health. Additionally, alternatives that were not sufficiently disclosed and, therefore, could not be fully evaluated for toxicity were eliminated based on poor characterization.

Of the six alternatives, no alternatives were identified as unfavorable based on environmental toxicity, and only one formulation was identified as unfavorable based on human health hazards: Klear N' Klean XP-A101 White Top Coat. Four formulations were binned as less favorable due to their human health hazards and poor characterization: XZM480 International, Interlseek 900 System, BottomSpeed TC Base Coat/Top Coat Clear, and Hempasil XA278. One paint was binned as favorable, as it was well characterized and had relatively low human health toxicity: Surface Coat Part A – Black. The alternatives that were binned as less favorable and favorable were advanced to the next module.

Performance Evaluation Module

Data from the U.S. EPA (2011) and CalEPA (2011) reports were used to evaluate performance, specifically, results from Tier 1 panel testing and Tier 2 boat hull testing. XZM480 International peeled in the Tier 2 boat hull testing and was, therefore, binned as unfavorable. All of the other alternatives paints were considered favorable, as their performance was comparable both against the copper antifouling paint as well as in comparison to one another. The formulations binned as favorable moved on to the Cost and Availability Module.

Cost and Availability Module

An annualized cost of applying the paints and required maintenance data was obtained from the CalEPA (2011). Three alternatives were binned as favorable and moved on to the next module: Intersleek 900 System, BottomSpeed TC Base Coat/Top Coat Clear, and Surface Coat Part A – Black. Hempasil XA278 was binned as unfavorable as it was not commercially available.

[3] The assessors of the Sequential Framework treated the following scores as equivalent to Benchmark 1 scores: List Translator-1 (LT-1) chemicals and Benchmark 1_{TP}.

Exposure Assessment Module

Under the Exposure Assessment Module, a comparison was made between the alternatives and the copper antifouling paint with respect to exposure potential, environmental fate and transport, and release mechanism throughout the paints' life cycle. Although copper antifouling paints are reapplied more frequently than nonbiocide paints, the amount of paint needed for copper antifouling paints is less than the alternatives. A qualitative evaluation of environmental and human exposure potentials through various stages of its lifecycle was conducted and resulted in a determination that there are no substantive exposure differences between copper antifouling paint and soft nonbiocide paints. A quantitative comparison between copper antifouling paints and alternatives was not possible due to lack of information regarding the amount of paints required to cover a boat during each application.

Based on the results of the Level 1 exposure assessment, the assessors concluded there was no difference in exposure between the copper antifouling paint and the alternatives. Therefore, at the instruction of the IC2 Guide, a Level 1 exposure assessment was not completed. In conclusion, none of the paint formulations were eliminated in this module.

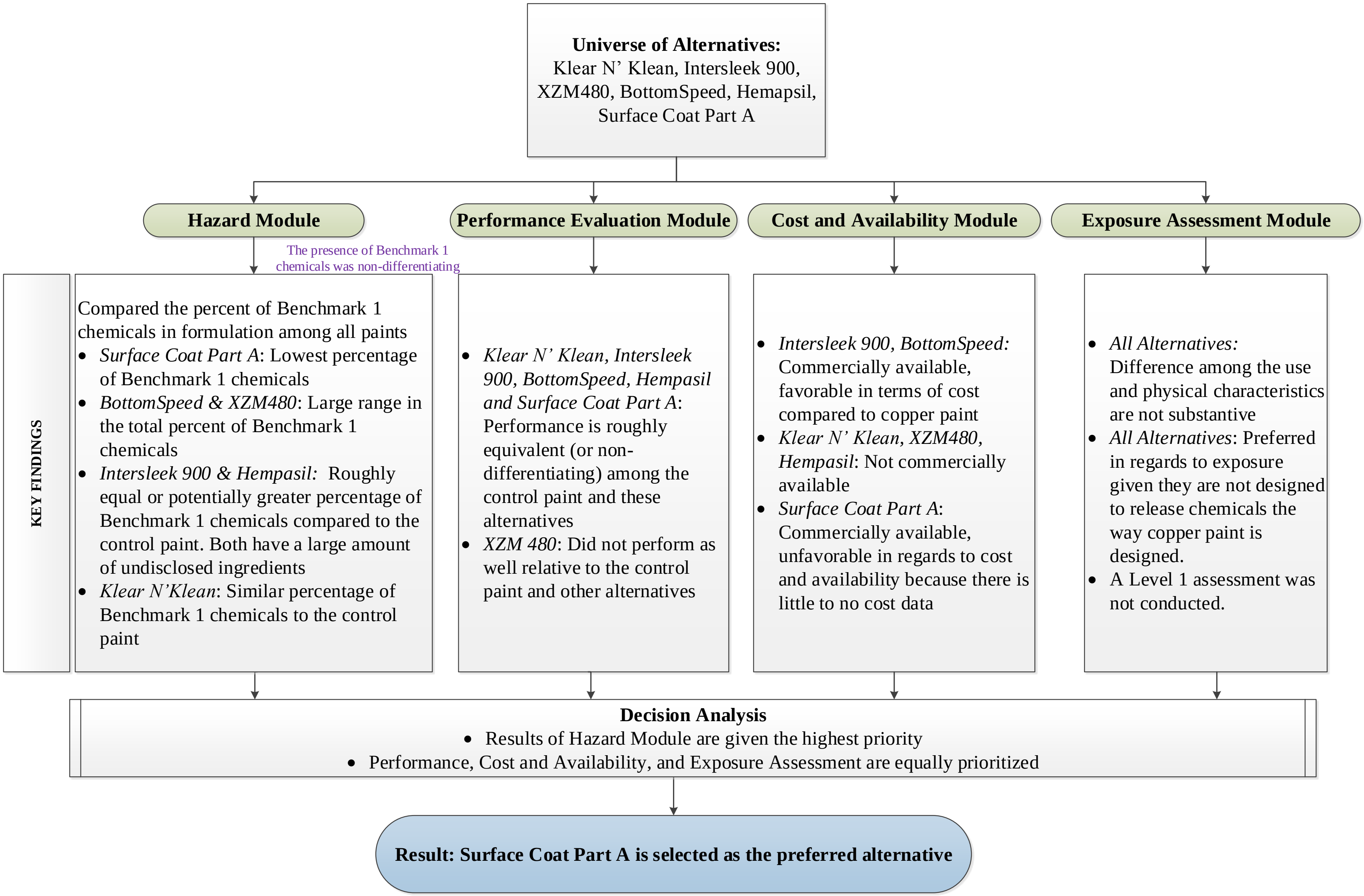
Overall Results of the Sequential Framework

Based on the Alternatives Assessment using the Sequential Framework, the Intersleek 900 System, BottomSpeed TC Base Coat/Top Coat Clear, and Surface Coat Part A – Black were all considered preferred alternatives. It should be noted that, although these formulations were considered preferable alternatives relative to copper antifouling paint, there was a great deal of uncertainty in recommending them due to their incomplete chemical and formulation disclosure.

IC2 Simultaneous Framework

In the IC2 Simultaneous Framework, data were collected on the paint formulations using each of the four core modules: Hazard, Performance Evaluation, Cost and Availability, and Exposure Assessment. Once data were collected, the assessors weighted the results of each module to select a preferred alternative—with the greatest weight given to the results of the Hazard Module and lesser but equal weights given to the results of the other three modules. An overview of the process and results are shown in Figure 4 and complete methodology and results can be found in Task 3.

Figure 4: Overview of Alternatives Assessment Using the IC2 Simultaneous Framework



Hazard Module

Using the hazard evaluations in the Uniform Data Set, the assessors eliminated any formulations containing at least one GreenScreen® Benchmark 1 chemical[4]. Because all the formulations contained GreenScreen® Benchmark 1 chemicals, no formulation was determined to be preferable. The next approach was to calculate the total percentage of Benchmark 1 chemicals in each formulation by weight, regardless of the hazard endpoint from which it was derived, and compare it to the control paint. Any undisclosed or Benchmark U chemicals in the formulation were assigned a Benchmark 1 score. Each hazard endpoint was weighted equally to prevent possible burden shifting and regrettable substitution.

Approximately 79-85% of the copper antifouling paint formulation was made up of Benchmark 1 chemicals. Approximately 76-95% of Klear N' Klean Plus XP-A101 White Top Coat contained Benchmark 1 chemicals. For the Intersleek 900 system and Hempasil XA278 alternative formulations, 100% of chemicals that were identified were determined to be Benchmark 1 chemicals. The percentage of Benchmark 1 chemicals ranged from approximately 13-88% in XZM480 International, 24-95% in BottomSpeed TC Base Coat/Top Coat Clear, and 18-43% in Surface Coat Part A – Black. These ranges in the total percentage of Benchmark 1 chemicals reflect incomplete formulation disclosure.

With the lowest and narrowest range of Benchmark 1 chemicals present in the formulation, Surface Coat Part A – Black had the most preferable hazard profile. It is possible that XZM480 International and BottomSpeed TC Base Coat/Top Coat Clear also have preferable profiles relative to the copper antifouling paint; however, because the percentages of the chemicals were provided in ranges, it could not be confirmed if these two paints had a lesser percentage of Benchmark 1 chemicals than the copper antifouling paint.

Performance Evaluation Module

Data from the U.S. EPA (2011) and CalEPA (2011) reports were used to gather data for performance. It was concluded that performance is not a differentiating factor among copper antifouling paint and alternatives with the exception of XZM480 International, which performed less well due to peeling in the full hull testing of the CalEPA (2011) report.

Cost and Availability Module

Data from the U.S. EPA (2011) and CalEPA (2011) reports were used to determine that Klear N' Klean Plus XP-A101, XZM480 International, and Hempasil XA278, were not commercially available. The remaining paints, Intersleek 900 System and BottomSpeed TC Base Coat/Top Coat Clear, were comparable with regard to annualized cost of paint jobs. The U.S. EPA (2011) and CalEPA (2011) reports did not include any cost data for Surface Coat Part A – Black, nor could comparable annualized cost information be found online. After repeated requests for information from the paint manufacturers, the team had to resort to gathering publicly available data. A press release from the manufacturer's website states that Surface Coat Part A – Black is

[4] The assessors of the Simultaneous Framework treated the following scores as equivalent to Benchmark 1 scores: LT-1 (List Translator 1), Benchmark 1_{TP}, and Benchmark U (hazards unassignable)

a “cost-effective method” of providing biofouling protection (Sherwin-Williams 2009). For purposes of completing this module, the assessors determined that this level of cost information was sufficient.

Exposure Assessment Module

An Initial Screen found that there were not substantial differences between the copper antifouling paint and the six alternatives with respect to use and physical/chemical properties. Differences between the copper antifouling paint and the six alternatives were apparent when release mechanisms were compared, and it was concluded that the alternatives have a preferable exposure profile compared to copper antifouling paint. Based on the results of the Initial Screen, a Level 1 evaluation was deemed not necessary.

Decision Analysis

Decision Methods are presented in Appendix A of the IC2 Guide to assist with the analysis of all of the data collected in each module. The assessors decided not to use any of the Decision Methods because a direct comparison of the results of each module provided a more straightforward, streamlined approach. Specifically, the assessors assigned the highest priority to the results of the Hazard Module to reflect the IC2 Guide’s “Golden Rule” and accompanying principle that hazard must be emphasized relative to other modules, and equal, but lesser, priority to the results of the Performance Evaluation, Cost and Availability, and Exposure Assessment Modules. A weighting system where percentage weights are assigned to the results of each module (as described in Appendix A) was not needed to assist in identifying preferable alternatives.

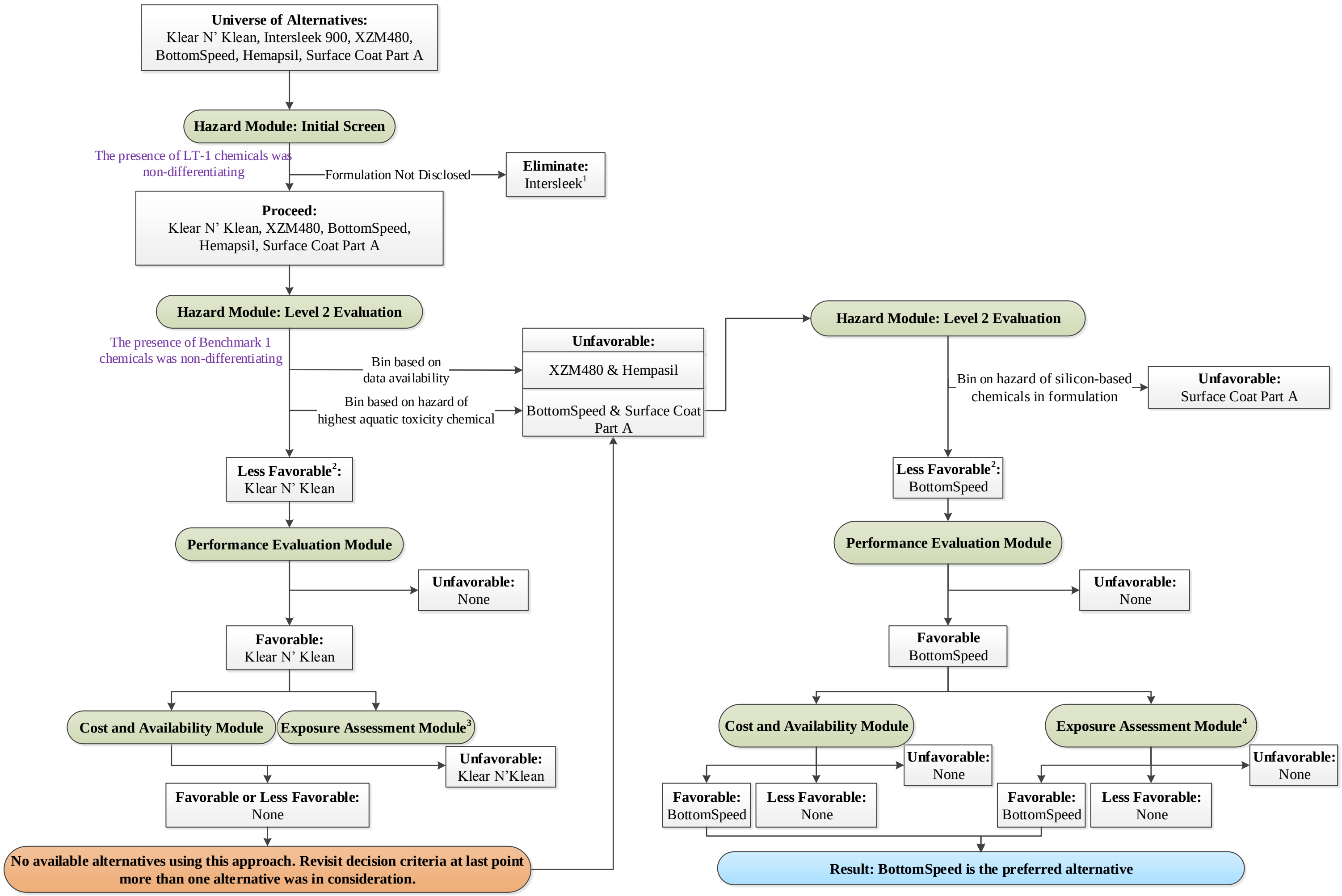
Overall Results of the Simultaneous Framework

Surface Coat Part A – Black was the most preferable alternative overall; however, this recommendation was made with several caveats. The first is that this formulation still poses significant hazard concerns, as shown in the chemical hazard summary table in Appendix D. Secondly, there are significant gaps in formulation data for the alternatives, which leads to uncertainty in the overall results.

IC2 Hybrid Framework

The IC2 Hybrid Framework combines elements from both the Sequential and Simultaneous Frameworks. Hazard and Performance Evaluation Modules were performed sequentially, and the Cost and Availability and Exposure Assessment Modules were performed simultaneously. The overall process and results are summarized in Figure 5 and complete methodology and results can be found in Task 4.

Figure 5: Overview of Alternatives Assessment Using the IC2 Hybrid Framework



[1] The Intersleek 900 System did not have any formulation data for the primer; [2] No alternatives were binned favorable, therefore only the less favorable alternatives proceeded; [3] Given that Klear N' Klean Plus XP-A101 White Top Coat was not commercially available an exposure assessment was not conducted in the first iteration of the framework; [4] Only an Initial Screen was conducted for this module.

Hazard Module

At the discretion of the assessor, a conservative approach was taken and those alternatives whose formulations were not accompanied by MSDS were eliminated before the Hazard Module was implemented. The Intersleek 900 System formulation did not have data or an available MSDS on the primer and, therefore, was excluded from further evaluation.

Using the hazard data from the Uniform Data Set, the first step was to use the Initial Screen to eliminate formulations with LT-1 chemicals, as this step is specified by the IC2 Guide. However, all of the formulations had at least one LT-1 chemical; therefore, all remaining paint formulations, proceeded for further assessment. After progressing through the Cost and Availability Module no alternatives remained. Therefore, a second iteration of the Hazard Module had to be performed. Both iterations are described below.

First Iteration

Additional decision criteria were developed to assess hazard for decision making. To further include the uncertainty coupled with incomplete disclosure in the decision-making process, the assessors binned formulations based on their level of disclosure. Any formulation with less than 50 percent of its chemicals disclosed (i.e., XZM480 International and Hempasil XA278) was binned as unfavorable. Klear N' Klean Plus XP-A101 White Top Coat, BottomSpeed TC Base Coat/Top Coat Clear, and Surface Coat Part A – Black proceeded for further assessment.

The second decision criterion was to eliminate any formulation containing Benchmark 1 chemicals; per the IC2 Guide. However, this was not a distinguishing factor because all the formulations contained Benchmark 1 chemicals. Therefore, the assessor developed additional criteria in order to assess the hazards for decision making.

The third decision criterion was to select a chemical from each formulation to serve as representative of the entire formulation, and then compare the hazard profiles of each representative chemical. Specifically, the chemical in each formulation with the highest aquatic toxicity profile was selected as the representative chemical for that formulation. Both BottomSpeed TC Base Coat/Top Coat Clear and Surface Coat Part A – Black contained chemicals with equivalent aquatic toxicity hazard as cuprous oxide and were, therefore, binned as unfavorable. Klear N' Klean Plus XP-A101 White Top Coat was binned as less favorable because there are very high chronic aquatic toxicity concerns due to the presence of alumina hydrate in the formulation. The acute aquatic toxicity hazard ranking of high is lower than cuprous oxide's acute aquatic toxicity ranking of very high.

Based on the above described first iteration approach, Klear N' Klean Plus XP-A101 White Top Coat progressed to the subsequent modules of Performance Evaluation and Cost and Availability; however, when completing the Cost and Availability Module, it was determined that this paint formulation is no longer commercially available. As a result, the assessors needed to iterate again through the Hazard Module in order to select an alternative formulation that is available for use.

Second Iteration

In the second iteration of the Hazard Module, the assessors began at the point in the process where more than one alternative was still being considered. Specifically, BottomSpeed TC Base Coat/Top Coat Clear and Surface Coat Part A – Black were again evaluated (these formulations had originally been binned as unfavorable when using the chemical with the highest aquatic toxicity profile as the representative chemical). All other paint formulations had previously been eliminated due to either availability on the market or lack of disclosure for the paint formulation.

The assessors used the silicon-based chemicals as the representative chemicals, given these are thought to be the functional chemicals in the alternative formulations. The functional or representative chemical for the copper antifouling paint was cuprous oxide. The silicon-based chemicals all had preferable hazard scores in regard to aquatic toxicity except for octamethylcyclotetrasiloxane, a chemical in Surface Coat Part A – Black, which received a Benchmark 1 score using the GreenScreen® approach (i.e., this chemical has very high chronic aquatic toxicity and is highly bioaccumulative and persistent). Therefore, Surface Coat Part A – Black was binned as unfavorable. All of the silicon-based chemicals in the BottomSpeed TC Base Coat/Top Coat Clear formulation had lower aquatic and chronic aquatic toxicity compared to cuprous oxide and, therefore, this formulation moved onto the Performance Evaluation Module. This was done while recognizing other chemicals in the paint formulation may assist in its fouling release property and that none of the formulations appear to be preferable in terms of hazard when compared to the copper control paint.

Performance Evaluation Module

A flow chart was developed from the questions in the IC2 Guide to help bin the alternatives (see Figure 15). Using the data provided in the CalEPA (2011) report, BottomSpeed TC Base Coat/Top Coat Clear was binned as favorable and moved onto the simultaneous portion of the framework.

Cost and Availability Module

A flow chart was developed based on questions in the IC2 Guide (see Figure 17). Decision criteria were provided to assess cost and bin the paint formulations accordingly. Both immediate and lifetime costs were evaluated, with lifetime costs weighted more heavily. Based on data provided in the CalEPA (2011) report in regard to the application techniques and costs, BottomSpeed TC Base Coat/Top Coat Clear was binned as favorable.

Exposure Assessment Module

Only an Initial Screen was implemented for this module. An evaluation was done based on the physical-chemical properties of the representative chemicals in the formulation, the amount of paint deemed necessary for use and the mechanism by which the paints function. The main distinguishing factor between the copper antifouling paint and BottomSpeed TC Base Coat/Top Coat Clear is their mechanism of action. Copper-antifouling paints are designed to release copper into the environment which serves as an antifoulant, while nonbiocide paints create a slick surface to which aquatic biota cannot attach. As a result, the exposure potential to the chemicals from alternative paint formulations was determined to be less than the exposure potential to copper antifouling paint. Therefore, a Level 1 evaluation was not conducted. The BottomSpeed TC Base Coat/Top Coat Clear formulation was binned as favorable.

Decision Analysis

The Simultaneous Decision Method was chosen to compare the results across the Cost and Availability and Exposure Assessment Modules. The BottomSpeed TC Base Coat/Top Coat Clear formulation was binned as favorable for both modules; therefore, the simultaneous comparison of the results was simple. The BottomSpeed TC Base Coat/Top Coat Clear formulation was preferable for each module and was selected as the preferred alternative using the Hybrid Framework.

Results of the Four Core Modules

BottomSpeed TC Base Coat/Top Coat Clear was selected as the preferred alternative. However, strong reservations were outlined with this selection. There are serious concerns with the human health implications, especially through the inhalation route of exposure, associated with the silicon-based chemicals in this alternative paint formulation compared to cuprous oxide. These concerns are outlined in detail in Task 4.

Optional Modules

In addition to the four core modules in the IC2 Guide, Level 1 assessments for the three optional modules in the IC2 Guide were conducted as part of the Hybrid Framework: Materials Management Module, Social Impact Module, and Life Cycle Module. Readily available resources were used (i.e., a few hours of internet searching for each module) to gather data and answer the questions outlined in the IC2 Guide.

Materials Management Module

Several completed life cycle and eco-efficiency analyses were found on-line which helped evaluate alternatives. An alternative formulation was binned as favorable if there was a benefit for the alternative paint when compared to the control paint based on the raw materials used, the amount of waste generated and the recyclability of the paint. BottomSpeed TC Base Coat/Top Coat Clear was binned as favorable because it uses fewer raw materials and generates less waste with negative impacts. However, the assessors noted that the copper-based paint is more recyclable at end of life than the silicon-based paint. This was given less weight in the binning process because the raw material inputs were determined to have a greater impact for the copper antifouling paint compared to the amount of waste for recycling for the BottomSpeed TC Base Coat/Top Coat Clear. In addition, strategies can be implemented to mitigate impacts from silicon-based paints.

Social Impact Module

This module evaluates the social impact of an alternative by evaluating the impacts on workers, communities and societies associated with the alternative's manufacture, transport, use and disposal compared to the copper antifouling control paint. A Level 1 assessment was performed, which requires impacts at the local level to be considered. Data were evaluated from the location of the manufacturing plants for both paints, and no distinguishing characteristics were found when comparing New Jersey, U.S.A. and Auckland, New Zealand. Workplace fatality rates are similar between the two countries. The main notable difference between the two paints is in raw material selection. Silica extraction, associated with BottomSpeed TC Base Coat/Top Coat Clear, has been linked to silicosis, and silicon is the functional chemical for the nonbiocide formulation. An analogous disease does not exist with copper extraction. All of the alternatives in the report are silicon based and therefore this less favorable aspect of BottomSpeed TC Base Coat/Top Coat Clear applies to all alternatives under consideration in this assessment. In regard to the community and global impacts the assessors noted concerns with potential impacts of salmon populations as a result of copper antifouling paint production and the greater global warming potential in the production and use of the copper antifouling paint. The assessors weighted the occupational hazard of mining silicon higher than the impacts to fish or global warming potential resulting in BottomSpeed TC Base Coat/Top Coat Clear being binned as slightly less favorable when compared to the copper antifouling paint for this module.

Life Cycle Module

It was determined that a Level 1 assessment was not necessary because the distinguishing differences in answering the preliminary questions had been discussed in Hazard, Social Impact, and Materials Management Modules. Specifically, based on evaluation of readily available data, increased impact in worker exposure to silica compounds and the increased risk of silicosis are expected. This was discussed in the Social Impact Module. Additionally, as discussed in the Hazard Module, the silica-based chemicals have less aquatic toxicity concerns associated with them; however, there are greater concerns related to human health effects when compared to cuprous oxide. As for other considerations, the data evaluated indicate that silicon-based chemicals will result in lower global warming potential during manufacture, application and use. This was discussed in the Materials Management Module. Therefore, all the distinguishing differences between the copper based control paint and BottomSpeed TC Base Coat/Top Coat Clear were evaluated prior to conducting the Life Cycle module, making a Level 1 assessment unnecessary.

Overall Results of the Hybrid Framework

BottomSpeed TC Base Coat/Top Coat Clear was selected as the preferred alternative under the Hybrid Framework. Implementing the three additional modules did not change this result. Again, it should be noted that, although this chemical was the preferred alternative, the adverse human health effects for several of the chemicals in this formulation, as well as the incomplete disclosure of chemicals, lowered the confidence of the selection of this formulation as the preferred alternative.

Comparison of Results Across the Three IC2 Frameworks

This section compares the findings of the preferred alternatives across the Sequential, Simultaneous, and Hybrid Frameworks.

Similarities in the Results

Similarities in the results were observed across the frameworks. Each assessor applied the same initial decision rule for assessing hazard for decision-making in the Hazard Module, which was to eliminate any alternative paint formulation with one or more Benchmark 1 chemicals. Because all the paints contained at least one Benchmark 1 chemical, this method was determined to be non-differentiating by all three assessors. Therefore, additional decision rules were identified by each assessor to further differentiate hazards. These additional approaches differed among all assessors and were the main source of variability in results, which are further discussed below. Assessors noted that preferred alternative(s) under the Hazard Module were selected with limited confidence, based on lack of formulation disclosure and lack of guidance in the IC2 Guide on how to assess hazard at the formulation-level.

Similar results were obtained in all three frameworks for the Performance Evaluation, Cost and Availability, and Exposure Assessment Modules. Performance was non-differentiating factor among all paint formulations with the exception of one alternative due to peeling. Cost was roughly equivalent for all paint formulations when considering annualized costs. Exposure potential was also non-differentiating among the alternatives.

Table 1 shows the preferred alternatives. These were selected with limited confidence under each framework due primarily to the uncertainty associated with the Hazard Module.

Table 1: Preferred Alternative(s) Selections by IC2 Framework

Framework	Preferred Alternative(s)
Sequential	• Intersleek 900 System • BottomSpeed TC Base Coat/Top Coat Clear • Surface Coat Part A – Black
Simultaneous	• Surface Coat Part A – Black
Hybrid	• BottomSpeed TC Base Coat/Top Coat Clear

Differences in the Results

While each assessor used the Uniform Data Set when completing the Hazard Module, they used different approaches to assess hazard for decision-making. As noted in the previous section, since all alternatives contained Benchmark 1 chemicals, assessors could not use Benchmark 1 chemicals as a way to differentiate alternatives. Assessors of the Sequential and Simultaneous Frameworks calculated and compared the total percentage of Benchmark 1 chemicals by weight as the primary way to differentiate hazard, but they used different approaches in applying these percentages. Specifically, assessors of the Sequential Framework considered the drivers behind the Benchmark 1 score. First, chemicals with Benchmark 1 scores driven by environmental toxicity and fate were considered, followed by Benchmark 1 scores driven by human health. The assessors of the Simultaneous Framework considered the total percentage of Benchmark 1 chemicals of the alternatives relative to the percentage of Benchmark 1 chemicals in the copper antifouling paint, regardless of the basis for the Benchmark 1 score. Assessors of the Hybrid Framework opted not to consider the percentage of Benchmark 1 chemicals in formulation. Instead, alternatives were first eliminated if the formulation was not disclosed. Next, representative chemicals were selected from each formulation to represent the hazard for the entire alternative formulation. Based on the representative chemical's hazard profile, alternatives were eliminated if the representative chemical had a higher aquatic toxicity than the copper antifouling paint's representative chemical, cuprous oxide.

Additionally, data gaps were handled differently, which is the primary reason for the difference in results between the Sequential and Simultaneous Frameworks. Under the Sequential Framework, data gaps were noted, but alternatives were not penalized if they lacked complete information. Under the Simultaneous Framework, unidentified chemicals and Benchmark U chemicals in each formulation were assigned Benchmark 1 scores. The assessors of the Hybrid Framework implemented their own method as a first step in the Hazard Module to remove any formulations with no data.

Based on the above, the differences in the results of each framework are not a consequence of inherent differences in the frameworks, but, rather, differences in decision-making approaches in the Hazard Module.

Summary of Alternatives to Copper Boat Paint

Although the assessors were able to select preferred alternatives, results indicated that none of them was a good alternative to copper antifouling paint. Some appeared to be slightly preferable to the copper antifouling paint in terms of hazard, but they all contained chemicals that posed human health and environmental concerns. Therefore, the selection of preferred alternatives does not constitute an endorsement because significant reservations remain. Data gaps due to minimal disclosure of chemicals coupled with the difference in decision rules resulted in uncertainty.

When the State of Washington conducts an actual Alternatives Assessments to find a replacement to copper antifouling paint, the assessors believe the paint manufacturers will be more forthcoming with disclosing their formulations under a non-disclosure agreement (NDA). This should minimize the data gap issue and provide a more robust Uniform Data Set, which will result in higher confidence to find a safer alternative to copper antifouling paint.

The results of the three frameworks raised a very important question: what constitutes a preferable alternative? Should a chemical or product that is slightly less hazardous be recommended if it still poses significant human health or environmental concerns? The answers will invariably depend on the organization conducting the Alternatives Assessment and its primary needs and goals. Transparency will be critical throughout the entire Alternatives Assessment, particularly if the results will inform decision-making.

Overall Effectiveness of IC2 Guide

The IC2 Guide is a valuable resource, and the ToxServices' Team concluded that it is sufficiently flexible to meet the needs of a range of users. Some degree of technical expertise is required to perform the Modules, specifically, Hazard and Exposure Assessment, even when performing Level 1 assessments. To apply Level 2 and Level 3 assessments, additional technical expertise will be required. To further increase the value of the IC2 Guide, the ToxServices' Team identified areas where the usability can be improved so that individuals without a scientific background can conduct an Alternatives Assessment without significant challenges. These findings and recommendations are presented in the next section and are based on the collective experiences of the ToxServices' Team as they implemented the three frameworks.

Challenges in Implementing the IC2 Guide

During the implementation of the frameworks, both framework and module level challenges were encountered. These challenges are summarized in Table 2.

Several framework-level challenges were identified. For example, in the Sequential Framework, it was difficult to determine if the assessors should revisit each module if multiple alternatives remained at the end of the assessment, or if all remaining alternatives should be considered preferred alternatives. The assessors of the Simultaneous and Hybrid Frameworks experienced difficulty implementing the Decision Methods (found in Appendix A of the Frameworks Module). Specifically, the Decision Methods outline a large number of questions aimed to guide the decision-making process when a more simple approach would have sufficed. Additionally, in the Simultaneous Framework, it was unclear if the alternatives should be binned/ranked at the end of each module for further evaluation at the end of the framework, or if the binning/ranking should only be performed at the end of the framework.

Additionally, a number of module-level challenges were identified. The greatest number of challenges was associated with the Hazard Module. It consists of two parts: hazard evaluation and assessing hazard for decision-making. Guidance is provided in the Hazard Module on assigning GreenScreen® Benchmark scores (i.e., the hazard evaluation portion of the Module) and eliminating Benchmark 1 chemicals (i.e., the assessing hazard for decision-making portion of the Module). However, no additional guidance is provided on assessing hazard for decision-making if all chemicals are Benchmark 1 (or, in the case of this Project, how to differentiate among alternatives if all formulations contain Benchmark 1 chemicals). Additionally, the Hazard Module does not provide guidance on how to handle incomplete formulation disclosure. Finally, all assessors cited the lack of guidance in all core modules with respect to conducting formulated product-level Alternatives Assessments. Recommendations on how to address these framework-level and module-level challenges are further described in the section called "Recommended improvements to the IC2 Guide."

Table 2: Summary of Challenges Implementing Three IC2 Guide Frameworks	
Type of Challenge	**Description of Challenge**
Framework-Level Challenges	
Sequential	• Unclear whether a user can go back to previous modules to use more stringent criteria if left with multiple alternatives at the end of the assessment
Simultaneous	• Difficult to implement Decision Methods as written in Appendix A of the IC2 Guide • Unclear what is meant by "multi-parameter" analysis in Figure 13 of the IC2 Guide • Unclear if ranking/binning should occur at the module level or at the framework level
Hybrid	• Difficult to implement Decision Methods as written in Appendix A of the IC2 Guide • Unclear what is meant by "multi-parameter" analysis in Figure 14 of the IC2 Guide • Challenging to follow areas where text appears to have been copied and pasted from other frameworks – e.g., the simultaneous portion of the Hybrid Framework refers to assessing human health effects, but hazard is considered under the sequential portion
Module-Level Challenges[5]	
Hazard	• Lacks direct guidance for formulated product-level Alternatives Assessments. Written for chemical assessments • Unclear how to handle incomplete formulation disclosure • Unclear on decision-making approaches to use after GreenScreen® Benchmark scores are established, particularly for scenarios where no clear-cut preferred alternatives exist
Performance Evaluation	• Lacks direct guidance for product-level Alternatives Assessments • Unclear why availability is considered in this module (versus in Cost and Availability Module) • Unclear in Question 2 if alternatives no longer commercially available should continue through the module
Cost and Availability	• Lacks direct guidance for product-level Alternatives Assessments • Unclear on how to address gaps in cost and availability data
Exposure Assessment	• Lacks direct guidance for product-level Alternatives Assessments • Unclear in Question 1 in Initial Screen on which criteria to include and from where to gather the necessary information • Unclear in Questions 2 and 3 in Initial Screen on what is meant by "manufacturing criteria" – Assessors are told to refer to the Performance Evaluation Module but this term is not used or defined there
Materials Management	• Unclear on how to integrate and assess data obtained through the process of answering the questions
Social Impact	• Incorrect table numbers are referenced in the text • Unclear on the scope of the Level 1 assessment. The Level 1 assessment fluctuates from the "area surrounding the factory or facility producing the product" to "across the product life cycle"

[5] Data used to evaluate the Performance Evaluation and Cost and Availability Modules were readily available in the CalEPA (2011) and U.S. EPA (2011) reports. There may be situations where data are not readily available; therefore, additional challenges may exist for the Performance Evaluation and Cost and Availability Modules that were not encountered in this Project.

Table 2: Summary of Challenges Implementing Three IC2 Guide Frameworks	
	• Difficult to understand concerns associated with all items listed in tables (e.g., demographics)
Life Cycle	• Duplicative in content of other optional modules – e.g., assessing climate change-related impacts which are included in the Materials Management Module • Difficult to complete as standalone module since questions often refer to other modules • Unclear when to exit the module

Recommended Improvements to the IC2 Guide

The ToxServices' Team has compiled two sets of recommendations to improve the overall effectiveness of the IC2 Guide. The first set aims to improve overall usability, while the second set focuses on changes in technical content.

Usability Recommendations

Technical Edits to IC2 Guide

The IC2 Guide would benefit from additional technical copyediting to focus the text, reduce repetition, and improve readability. The result should be a clear document with easy to understand text and more consistent terminology and flow of information. The addition of flow charts or lists of key considerations across modules would provide clarity. Some pages are incorrectly numbered in the Table of Contents, and table references in the text will need to be reviewed and corrected.

The IC2 Guide fluctuates between reading like a "resource" document that provides suggested approaches and a "how-to" guide that is prescriptive, making it difficult to know if certain steps are optional or required. One example of this inconsistency is how the IC2 Guide references the Decision Methods in Appendix A; it is difficult to determine whether the assessor is required to implement one of the Decision Methods or if it is provided as a resource.

The technical copyedit should address and correct inconsistent terminology. Different terminology is often used to describe the same thing. Examples include the use of "framework" versus "method," "decision method" versus "decision criteria" versus "multi-parameter analysis." "Multi-parameter analysis" is used within Figure 13: Simultaneous Framework and Figure 14: Hybrid Framework on pages 45 and 47 but is not referenced in the text that describes the methodology for these two frameworks.

In some cases, the same terminology is used to describe different things. For example, the use of the term "favorable" in relation to the binning of alternatives across modules implies equivalence in some cases and superiority in others when compared to the control. Another example is the use of the word "module," which is used in reference to the different attributes that can be assessed as part of an Alternatives Assessment (Hazard Module, Performance Evaluation Module, etc.). However, "module" is also used to describe some of the essential steps needed to conduct an Alternatives Assessment (i.e., the Initial Evaluation Module, Stakeholder Involvement Module, Frameworks Module, and Identification of Alternatives Module). We suggest "module" only be used to refer to independent parts of an Alternatives Assessment and not the essential decision-making steps.

In addition to making the terminology more concise throughout the IC2 Guide, it is recommended that the existing glossary be expanded. For example, terms such as chemical substance and ingredient as well as product and formulation are used interchangeably. This ambiguity makes it difficult to know whether the term refers to an individual chemical at the CAS level, or if it refers to an assembled product.

Improved Organization and Flow of IC2 Guide

Given the size and complexity of the IC2 Guide, a logical flow of content will increase its adoption and understanding by a range of users with different levels of expertise. Currently, it is difficult to know what sections to read, and in what order.

The proposed organization of the IC2 Guide is presented in Figure 6, where the main headings of the Table of Contents, both current and recommended, are shown. Changes to, or the addition of subsections, are shown under the recommended column.

Figure 6: Recommended Organization of the IC2 Guide

Current:

Overview
How to Implement the IC2 Guide
Initial Evaluation
Stakeholder Involvement Module
Frameworks Module
Identification of Alternatives
Hazard Module
Performance Evaluation Module
Cost and Availability Module
Exposure Assessment Module
Materials Management Module
Social Impact Module
Life Cycle Module
Glossary

Recommended:

I. Overview
II. How to Implement the IC2 Guide
III. Conduct Initial Evaluation
IV. Scope the Assessment *(new section)*
  a. Define the Issue *(new section)*
  b. Determine Stakeholder Involvement *(former Stakeholder Involvement Module)*
V. Identification of Alternatives
VI. Choose Framework *(former Frameworks Module)*
  a. Guidance on Selecting a Framework *(new section)*
  b. Data Analysis and Transparent Decision-Making *(new section)*
VII. Evaluate Alternatives
  a. Hazard Module
  b. Performance Evaluation Module
  c. Cost and Availability Module
  d. Exposure Assessment Module
  e. Life Cycle Thinking Module
VIII. Glossary

The section "How to Implement the IC2 Guide" needs to be simple, straightforward and frame the rest of the document.

On page 6 of the IC2 Guide, five distinct steps are presented:

1. Identify chemicals of concern

2. Initial evaluation
3. Scoping
4. Identification of alternatives
5. Evaluate alternatives

We recommend these steps drive the organization of the IC2 Guide. Currently, the Table of Contents is organized around a combination of the five steps and the modules, which is confusing. For example, Scoping is not found in the Table of Contents. Instead the Table of Contents goes from Step 2 (Initial Evaluation) to two elements of the Scoping step: the Stakeholder Involvement Module and Frameworks Module. We recommend that major headings of the Table of Contents be presented in outline format and numbered or lettered to better convey the step-wise nature of an Alternatives Assessment.

The Scoping step should have its own section titled "Scope the Assessment," and the Frameworks Module should have its own section titled, "Choose Framework," rather than keeping it under the Scoping step. Currently, the Scoping step helps decide if, and to what level, stakeholder involvement is necessary, and which of the three frameworks is appropriate. This ultimately means one chooses a framework before identifying alternatives. Given the obvious constraints on time and resources, this step would be more practical after alternatives have been identified. For example, in many cases, the number of alternatives will influence the choice of framework. If faced with 20 alternatives, an assessor may not have the time or resources to implement the Simultaneous Framework, which requires the evaluation of all alternatives across each module. A new step called "Define the Issue" should be included in the recommended new "Scope the Assessment" section, as discussed further on.

We recommend the appendices be removed from the body of the document and either be placed at the end or integrated into the body of the text. For example, an Appendix A resides on page 31 of the Stakeholder Involvement Module, and a second Appendix A on Decision Methods is found on page 48 of the Frameworks Module. The presence of multiple appendices with the same name is confusing, and it is not clear which is being referred to within the document.

Further, the content found in Appendix A: Decision Methods and Appendix B: Initial Screen should be streamlined and moved into a new section called "Data Analysis and Transparent Decision-Making" under "Evaluation of Alternatives." This new section is discussed in further detail in a subsequent recommendation.

Navigation Improvements of IC2 Guide

Improving the navigation of the IC2 Guide will make it easier to use and understand. Two possible approaches are offered below.

The first approach is to create a user-friendly PDF format through the addition of bookmarks and internal links. Bookmarks make it easier to quickly look at the contents of the document and click on links that lead to specific sections. The hierarchy of the bookmarks should align with the Table of Contents. Currently, users must scroll through the document page-by-page which is time-consuming.

A second approach is to build a web-based version of the IC2 Guide as a complement to the PDF. The key benefit is that the same content will be presented in a streamlined, interactive way. For example, the main organizing sections of the IC2 Guide would be presented as a drop-down navigation menu, allowing users to easily move from one area to the next. Flow charts, appendices, and figures would be interactive (e.g., with hyperlinks to each module within the framework flow charts) and presented as call-out boxes that can be enlarged, which would shorten the main text of the IC2 Guide. Another key benefit is the IC2 Guide would be made into a richer, more comprehensive resource by pointing users to external resources, such as tools and methods for conducting Alternatives Assessments and completed case studies using the IC2 Guide.

Technical Recommendations for IC2 Guide

Modify Scoping Step to Include Additional Guidance on Chemical or Product of Concern

Currently, the section on Scoping focuses on stakeholder involvement and choosing a framework, but not on defining the problem. As a result, the section reads more like a project scoping step and not a problem-scoping step. We recommend including a new step titled "Define the Issue" is as part of the "Scope the Assessment" section.

One of the key challenges shared by the assessors of each framework was the establishment of decision rules to guide the assessments, particularly in the Hazard Module. Each assessor had to define the issue and establish assessment boundaries in order to create decision rules for differentiating hazard. This was done to help determine an approach to proceed through the Hazard Module, not as an early, deliberate scoping step. The problem definition step is very important because it influences the decisions made throughout the rest of the alternatives assessment process. Each assessor took a different approach in defining the problem and establishing assessment boundaries, which led to variability in the overall results. This variability was not unexpected; however, it speaks to the need for more discussion of the importance of problem scoping and transparency around all decision points early in the alternatives assessment process.

To make "Scope the Assessment" section more effective, this new section should provide general discussion around the need and importance of defining the issue and delineating goals, principles, and decision rules in a transparent manner that will guide the rest of the alternatives assessment process. The National Academy of Sciences (NAS) report, "A Framework to Guide Selection of Chemical Alternatives," published in 2014 (NAS 2014), could inform the content of this new section, particularly Chapter 4 of the NAS report on scoping, problem formulation, and identifying alternatives. The NAS Committee reviewed how existing frameworks handle these steps, and the Committee's framework is based on this evaluation.

Add 'Availability' to Initial Screen on Identification of Alternatives

In each framework, alternatives were assessed but later eliminated from consideration because they were not commercially available.
The Identification of Alternatives Initial Screen on page 58 of the IC2 Guide states that the

assessor can focus the list of potential alternatives by conducting an Initial Screen using the lowest levels of the Hazard and Performance Evaluation Modules. The ToxServices' Team recommends adding availability as an optional Initial Screen, so assessors can determine whether it makes sense to evaluate alternatives that are not commercially available (e.g., those that are in the R&D phase or in a green chemistry design challenge) or eliminate them from consideration. Availability should be included when the Identification of Alternatives Initial Screen is introduced on page 8 and page 58.

Provide Additional Guidance on Selecting a Framework

Currently, the IC2 Guide explains the frameworks effectively and includes helpful flowcharts for each. To increase the effectiveness of this section, the ToxServices' Team recommends additional guidance on how to select a framework based on user needs, goals, and resources. After careful consideration and discussion, the ToxServices' Team recommends eliminating the Simultaneous Framework. The Sequential and Hybrid Frameworks are more practical and straightforward in application. While the Simultaneous Framework allows assessors to apply their own weights to the results of each module, the Team concluded that this framework does not seem feasible for real-word scenarios when time and/or resources are limited. We recommend a new section called "Guidance on Selecting a Framework" be added under "Choose Framework" (currently referred to as the Frameworks Module) to assist users in selecting between the Sequential and Hybrid Frameworks.

Expand Guidance on Decision-Making

The IC2 Guide provides direction on how to collect data but less direction on how to differentiate alternatives based on that data. This was most pronounced in the Hazard Module, where each assessor had to create their own decision rules to differentiate among alternatives with respect to hazard. For this Project, differentiation among alternatives was relatively easy in other modules. However, it is important to note that the ease of the other modules may be due to the fact that the two EPA reports provided a valuable body of work and a set of results on performance and cost the assessors could easily use, interpret and apply. The availability of such a resource may not exist for every alternatives assessment and more effort may be needed to determine the criteria to evaluate performance and cost.

As mentioned in the "Challenges in Implementing the IC2 Guide" section, the implementation of the Decision Methods found in Appendix A of the Frameworks Module was not useful as they require a large number of questions to be answered in order to choose preferable alternatives. However, in some instances, it may be more useful to perform a straightforward comparison. The inclusion of three Decision Methods (Simple Comparison Method, Iterative Comparison Method, and Simultaneous Comparison Method) also added complexity. If there is a clearly favorable alternative, implementation of one of these Decision Methods is likely unnecessary. Therefore we recommend that the decision process be incorporated into the Guide as described below.

A new section called "Data Analysis and Transparent Decision-Making" should be added under "Choose Framework" (currently referred to as the Frameworks Module). This section should provide guidance on how to create decision rules and prioritize trade-offs that are relevant to each framework. We also recommend that the guidance on prioritizing trade-offs in the three Decision Methods in Appendix A be collapsed into one Decision Method and presented in a format that is easier to follow. For the Sequential Framework, guidance is needed on how to proceed if left with multiple alternatives at the end of the assessment. A good model for this type of guidance and general discussion on transparent decision-making is Chapter 9 from the NAS (2014) report titled "Integration of Information to Identify Safer Alternatives."

Ensure Modules are Applicable to Chemical and Product-Level Assessments

The beginning of the IC2 Guide refers to Alternatives Assessments being applied to chemicals, processes, or products. In reality, the four core modules are written from the perspective of a chemical alternatives assessment, not a product or process-level assessment. In Tasks 2 through 4, the lack of guidance for product level assessments presented a significant challenge when completing the Hazard and Exposure Assessment Modules. For example, the first question of the Initial Screen in the Exposure Assessment Module instructs the assessor to compare chemical properties for the chemical of concern and its alternatives. For a product-level assessment, it is unclear if chemical properties of each chemical in the product should be compared or if only chemical properties relevant to the overall product should be compared. The ToxServices' Team recommends making each module more applicable to product-level alternatives assessments. Expanding the scope of the IC2 Guide to pertain to process-level assessments is not recommended. The scope of the IC2 Guide should explicitly state what types of assessments it does and does not address.

Enhance Effectiveness of Hazard Module

The Hazard Module was the most difficult module to conduct. It effectively describes different levels of hazard assessment, including the establishment of GreenScreen® Benchmark scores; however, it lacks sufficient guidance on how to use Benchmark scores and the hazard data that support the scores to differentiate among alternatives. For example, the IC2 Guide suggests eliminating chemicals that receive a Benchmark 1 score. However, if the Alternatives Assessment is at the product level, as was the case for this Project, there is no guidance on how to proceed when Benchmark scores are non-differentiating or when all products contain Benchmark 1 chemicals. We recommend that the Hazard Module provide additional guidance, such as consideration of the most relevant hazard endpoints based on the end-use or likely exposure scenarios, to assist in eliminating alternatives. We also recommend illustrative examples on how to consider the trade-offs between human health and environmental hazards and/or weighting hazard endpoints within the human health or environmental domains. These same concepts would apply to a chemical level Alternatives Assessment as well.

Opportunities for green chemistry innovation should also be explicitly called out in the Hazard Module for scenarios where the design of safer alternatives is warranted. The hazard evaluation section of the NAS (2014) report addresses green chemistry innovation and continuous improvement and could serve as a model.

The ToxServices' Team also recommends that the Hazard Module provide further discussion on how to handle data gaps. Illustrative examples of how to establish decision rules for handling incomplete chemical and product-level data would benefit the user while still leaving room for flexibility. The IC2 Guide should emphasize the need for transparency across all decision points.

Ensure Modules are Sufficiently Independent

It is our understanding the four core and three optional modules in the IC2 Guide are intended to stand alone as independent documents. Because the goal of the IC2 Guide is to harmonize Alternatives Assessment approaches across IC2 member states, a modular approach is logical. For example, if an Alternatives Assessment is completed using the four core modules, other users within the member states should be able to implement additional modules on the same assessment without needing to repeat the four core modules.

The four core modules are sufficiently independent in nature, with the exception of availability being assessed in the Performance Evaluation Module. The ToxServices' Team recommends that availability be eliminated from this module to avoid duplicative steps, especially in light of our recommendation to add availability to the Identification of Alternatives Initial Screen.

The three optional modules are not sufficiently independent. There is repetition in the Life Cycle Module, which frequently refers the assessor back to the Cost and Availability, the Social Impact, and the Materials Management Modules. It is not practical to reference optional modules within any module. If the assessor has not completed those optional modules, then it becomes difficult to implement the Life Cycle Module as currently written in the IC2 Guide. In addition, much of the content in the Social Impact and Materials Management Modules overlaps with the Life Cycle Module, causing redundant work. For example, in Hybrid Framework Alternatives Assessment, which included evaluation of the three optional modules, the assessor found that once the Social Impact and Materials Management Modules were completed, the Life Cycle Module seemed largely repetitive.

To make the three optional modules more independent in nature, two approaches could be considered. The first approach would involve revisiting each of the optional modules to eliminate repetition and make them more independent. This could be done through an upfront paragraph in each module explaining how each of the optional modules is unique and different from the Life Cycle Module, recognizing that life cycle assessments typically include an evaluation of materials management and social impacts. Additionally, it would be useful to include clear points of exit in the Life Cycle Module's Preliminary Steps – specifically, under the second sub-bullet of question 1 and question 3 – if all discriminating differences in alternatives have been assessed in other modules.

The second approach would involve combining the Materials Management and Social Impacts Modules into the Life Cycle Module, renaming it as the Life Cycle Thinking Module, and streamlining the content. It could be structured in a way that offers a menu of considerations, or sub-modules (e.g., impacts on communities, materials use, energy and environmental impacts) to provide sufficient flexibility in implementation.

SUMMARY OF FINDINGS AND RECOMMENDATIONS (TASK 5)

The Project consisted of two main objectives. The first objective was to use the three Alternatives Assessment Frameworks in the IC2 Guide to explore alternatives to copper antifouling paints and provide a basis for a future, more detailed assessment of alternatives to copper antifouling paint, and the second was to evaluate the usability of the IC2 Guide.

Existing reports from CalEPA and U.S. EPA harmonized the data for performance and cost for each alternative. Without these reports, it would have been challenging to perform the Alternatives Assessments due to a high degree of variability in the way manufacturers assess performance and cost.

While a substantial amount of data was available to assess each alternative, we were not able to recommend with confidence any of the alternatives as a result of incomplete formulation disclosure. Due to concerns regarding confidential business information, many manufacturers were not willing to disclose formulations for this Project. In order to perform a thorough Alternatives Assessment, manufacturers must be willing to disclose more information than what is typically available on the Safety Data Sheets. Confidence was also low because all formulations contained at least one Benchmark 1 chemical, and guidance beyond elimination of Benchmark 1 chemicals was not provided in the IC2 Guide. Therefore, decision-making approaches were created independently, which resulted in variability in the ultimate choice of preferred alternative.

After completing the Alternatives Assessments, we concluded that the IC2 Guide is a valuable resource that could benefit from clarification and improved organization to increase its overall effectiveness. It was also concluded that some degree of technical expertise is required to perform the modules, specifically, Hazard and Exposure Assessment. We present several recommendations to further improve the usability of the IC2 Guide that, if implemented, will make the IC2 Guide a better document for its users and provide more guidance in performing an Alternatives Assessment. The ToxServices' Team considers the following three recommendations as the highest priorities:

1. **Enhance Effectiveness of Hazard Module** by providing guidance on how to use GreenScreen® Benchmark scores and the hazard data that support the scores to differentiate among alternatives. Opportunities for green chemistry innovation should be requested for scenarios where the design of safer alternatives is warranted.
2. **Expand Guidance on Decision-Making** by providing direction on how to create decision rules and prioritize trade-offs that is applicable to chemical and product-level assessments.
3. **Improve Organization and Flow of the Guide** by reorganizing and enhancing content based on the five distinct steps of an alternatives assessment.

CREATION OF A UNIFORM DATA SET (TASK 1)

Identification of Control and Alternative Paints

In Task 1 of the Project, ToxServices performed hazard assessments of chemicals in the seven paint formulations (one control paint and six alternative paints):

- Control: Kop-Coat, Inc.'s Pettit Marine Paint Trinidad Pro Antifouling Bottom Paint 1082 Blue
- Alternative 1: Kop-Coat, Inc.'s Klear N' Klean Plus XP-A101 White Topcoat
- Alternative 2: International Paint LLC's Intersleek 900 System
- Alternative 3: International Paint LLC's XZM480 International
- Alternative 4: BottomSpeed Coating System's BottomSpeed TC Base Coat/Top Coat Clear
- Alternative 5: Hempel (USA), Inc.'s Hempasil XA278
- Alternative 6: FUJIFILM Hunt Smart Surfaces, LLC's Surface Coat Part A – Black

These paint formulations were evaluated in two previous reports:

- Safer Alternatives to Copper Antifouling Paints: Nonbiocide Paint Options (CalEPA 2011). Prepared by Institute for Research and Technical Assistance (IRTA) for CalEPA's Department of Toxic Substances Control.
- Safer Alternatives to Copper Antifouling Paints for Marine Vessels (U.S. EPA 2011). Prepared by IRTA and the Unified Port of San Diego for the U.S. EPA

In the U.S. EPA (2011) report, 46 paints, which included biocide paints based on copper and zinc and nonbiocide paints, were evaluated. From an overall health and environmental standpoint, the nonbiocide paints are the best alternatives to copper antifouling paint. A few nonbiocide paints from the U.S. EPA (2011) report were further evaluated on panels and boat hulls, and the results were documented in the CalEPA (2011) report. Of the nonbiocides that were further evaluated, only the soft nonbiocide paints performed well. Due to the favorable health and environmental profiles of biocide paints when compared to copper antifouling paints in addition to the soft nonbiocides performing better than hard biocides, the six paints chosen by the ToxServices' Team as viable alternatives were all soft nonbiocide formulations. These six paints were compared to the copper antifouling paint, which resulted in the evaluation of seven paints in total.

Identification of Paint Formulation Chemicals

In order to obtain formulation-specific disclosure from boat paint formulators, ToxServices made a reasonable effort to contact manufacturers of nonbiocide paints identified in California EPA's Department of Toxic Substances Control's review of alternatives to copper antifouling paints (CalEPA 2011) report to obtain full formulation information. ToxServices' Project manager Amanda Cattermole successfully established contact with Kop-Coat, Inc. and was able to obtain the full formulation for two formulations: Pettit Marine Paint Trinidad Pro Antifouling Bottom Paint 1082 Blue and Klear N' Klean Plus XP-A101 White Topcoat. One chemical, [REDACTED], which is an ingredient in Pettit Marine Paint Trinidad Pro Antifouling Bottom

Paint 1082 Blue, was not evaluated in the Uniform Data Set due to the late date[6] of disclosure for this ingredient.

Ingredients in five other paint formulations were disclosed through Material Safety Data Sheets (MSDS) found in Appendix B of CalEPA's (2011) report. For those formulations, ToxServices included in the Uniform Data Set only those ingredients disclosed on product level MSDS, as no additional formulation details were disclosed or identified in a literature search. It should be noted that a chemical stripper, Klean-Strip Aircraft Remover (manufactured by W.M. Barr), was also identified in the CalEPA (2011) report. This chemical stripper is a stripping formulation commonly used in boatyards to remove surface paints. Because this chemical stripper does not serve as an alternative to copper antifouling paint, it was not assessed as part of the Uniform Data Set.

ToxServices' Uniform Data Set comprises descriptions and chemical hazard assessments of the seven paint formulations, and those formulations are identified in Table 3, below.

Table 3: Seven Paint Formulations Comprising ToxServices' Uniform Data Set

Formulation Name	Manufacturer	Contains Copper?	% of Formulation Disclosed
Pettit Marine Paint Trinidad Pro Antifouling Bottom Paint 1082 Blue	Kop-Coat, Inc.	Yes	[REDACTED]
Klear N' Klean Plus XP-A101 White Topcoat	Kop-Coat, Inc.	No	[REDACTED]
Intersleek 900 System	International Paint LLC's	No	12-45%
XZM480 International	International Paint LLC's	No	16.5-<46%
TC Base Coat/Top Coat Clear	BottomSpeed Coating System's	No	39.3-<146%
Hempasil XA278	Hempel (USA), Inc.	No	14.5-21%
Surface Coat Part A – Black	FUJIFILM Hunt Smart Surfaces, LLC	No	75-131%

Description of Seven Paint Formulations

As part of creating a Uniform Data Set, ToxServices evaluated paint use instructions and specific conditions that may affect hazards posed by the paint formulations[7]. Copper antifouling paints are used routinely to protect the hulls of marine vessels to slow the growth of organisms that attach to the hull and can affect a vessel's durability and performance. Nonbiocide paints are available as alternatives to copper-based antifouling paints. Nonbiocide paints fall into one of two categories: soft nonbiocide or hard nonbiocide. A soft nonbiocide is described as a silicon or fluoropolymer containing product, whereas a hard nonbiocide is defined as a product that is of either the ceramic or epoxy type (California Coastal Commission 2011). A brief description of each alternative paint is provided below, and the detailed formulations of each of these paints are presented in Appendix A.

[6] The formulation of this ingredient was obtained on 10/15/14 and, therefore, was not included in the evaluation.
[7] Due to limited time and resources as well as unresponsiveness of suppliers, it was not possible to determine particle size of some chemicals. Therefore, effects as a result of exposure to nano sized materials were not included in this review. If an official Alternatives Assessment on copper antifouling paint were performed, the physical size of particulate matter and its health and environmental effects would be evaluated.

Pettit Marine Paint Trinidad Pro Antifouling Bottom Paint 1082 Blue (Proprietary Formulation)

The Trinidad Pro Antifouling Bottom Paint 1082 Blue[8], manufactured by Pettit Marine Paints, is a commercially available antifouling paint which provides resistance to barnacles, algae, slime, and other marine and fresh-water fouling organisms. It is a copper based formulated paint whose hard modified epoxy finish is designed for applications on boat materials such as bare fiberglass, blistered fiberglass, bare wood, bare steel, and lead and steel keels. The product has been on the market since 2008 and is one of Pettit Marine Paints' best sellers. The Trinidad antifouling product can be applied with a brush, roller, airless or conventional spray. Two coats are recommended on the product's technical data sheet, with a dry film thickness per coat of 2 mils (3.6 wet mils) at an application temperature range of 40°F to 90°F. The dry time is relevant to the ambient temperature at application and ranges from 3-6 minutes to recoat, and 8-24 minutes to launch (Pettit Marine Paints 2013).

Klear N' Klean Plus XP-A101 White Topcoat (Proprietary Formulation)

Klear N' Klean Plus XP-A101 White Topcoat[9] is no longer manufactured by Pettit Marine Paints and is no longer commercially available, as stated by a Pettit Marine Paints in a phone conversation on October 18, 2014 (ToxServices 2014b). No additional information on the product's application methodology was available.

Intersleek 900 System

The Intersleek 900 antifouling paint system[10] consists of a primer and top coat called Intersleek 970 White Part A and Veridian Tie Coat, respectively. The Veridian Tie Coat is applied first and provides a substrate for application of the InterSleek 970 top coat. Intersleek 970 White Part A is a fluoropolymer foul release coating with no added biocides manufactured by International and is available currently on the commercial market. The Intersleek 970 is applied as a finish coat for the Intersleek 900 foul release system. The Intersleek 970 is soft nonbiocide paint, based on silicon and fluoropolymer compounds. The Intersleek 970 can be applied with a brush or airless spray at a typical film thickness range of 150 - 200 microns dry (203-270 microns wet) at an application temperature range of 0°C-35°C. The dry time (either to touch dry, hard dry, before flooding, or pot life) is relevant to the ambient temperature at application and ranges from 30 minutes to 7 hours dependent on the type of dry is desired (International Paint 2013).

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[8] This formulation was disclosed under a Non-Disclosure Agreement and is considered Confidential Business Information.

[9] This formulation was disclosed under a Non-Disclosure Agreement and is considered Confidential Business Information.

[10] Upon a search for additional information on this paint system, ToxServices found that the Intersleek 900 paint system has changed in formulation slightly. According to the company website for International, this paint system now consists of Intersleek 970 White Part A and Intersleek 737. Intersleek 737 appears to have replaced the Veridian Tie coat; however, this replacement could not be confirmed. Additionally, it is not clear whether Intersleek 737 is the same formulation as Veridian Tie Coat or even of similar chemical class. For the purposes of this Project, only the data on the Intersleek 900 paint system formulated with the Intersleek 970 White Part A and Veridian Tie Coat were used.

XZM480 International

XZM480 International is no longer manufactured by International Paint and is not commercially available, as determined in a phone conversation with Roy Snow of International Paint (ToxServices 2014c). No additional information on the product's application methodology was available.

BottomSpeed TC Base Coat/Top Clear Coat

The BottomSpeed TC Base Coat and TC Top Coat Clear[11] is a versatile coating system that can be applied over a hull substrate or existing paint. The BottomSpeed is 100% metal free and is applied only with a roller (Brunetti 2012). No formulation-specific application instructions were identified for this formulation. No additional information on the application methodology was available.

Hempasil XA278

Hempasil XA278 is no longer manufactured by Hempel and is not commercially available, as determined by an email communication with Al Pliodzinskas of Hempel (ToxServices 2014d). No additional information on the product's application methodology was available.

Surface Coat Part A – Black

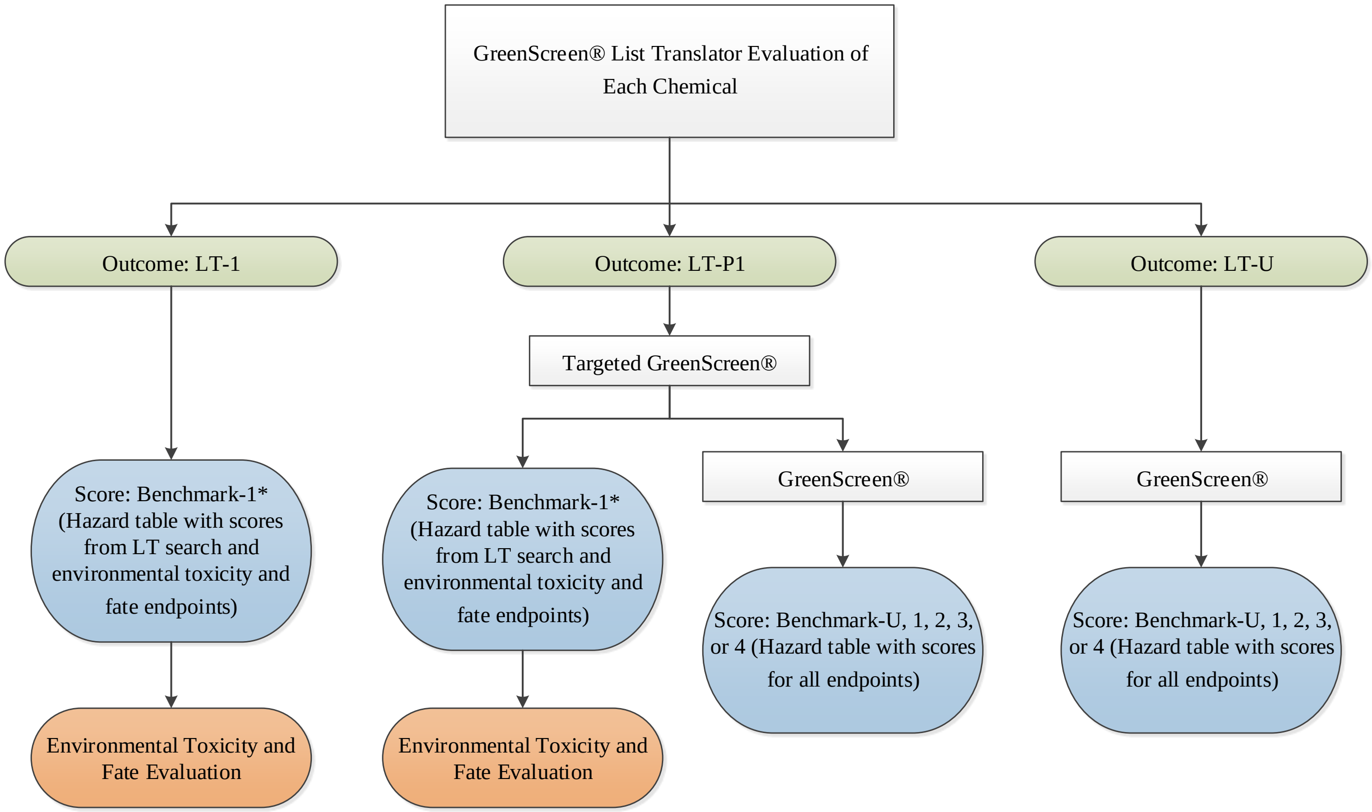
The Surface Coat Part A – Black is manufactured by Fuji Film Hunt under their Smart Surfaces Division and is a soft nonbiocide fouling release coating. The Surface Coat Part A – Black can be applied to a clean and dry Tie Coat[12] with a brush, roller, or airless spray with a 6 mils (152 microns) dry film thickness. The dry time is relevant to the ambient temperature at application and ranges from 48 hours at 40°F to 24 hours at 75°F (FujiFilm 2007).

Chemical Hazard Assessment Procedure Used to Create the Uniform Data Set

ToxServices assessed human health, environmental, and physical hazards posed by each of the chemicals in each paint formulation following procedures outlined in ToxServices' Standard Operating Procedure 1.69 (GreenScreen® Hazard Assessment) (ToxServices 2013). These assessments (along with a general description of each paint) compose the Uniform Data Set, which was used to assess the hazard of the paints in the Hazard Module of the Project.
As part of a GreenScreen® chemical hazard assessment, a chemical is first screened against Clean Production Action's GreenScreen® List Translator (CPA 2012a). The hazard assessment may be considered complete after a GreenScreen® List Translator evaluation, depending on the degree of hazards identified. Alternatively, the List Translator results may be inconclusive, requiring the preparation of a targeted or full GreenScreen®. An overview of the process for evaluating hazard using the GreenScreen® List Translator and GreenScreen® methodology is seen in Figure 7.

[11] The only reference to this product available on the internet is by Brunetti (2012). It is possible this paint is now called PropSpeed®; however, this could not be confirmed.
[12] A Tie Coat is defined as a coat of paint applied to a previous coat to improve the adhesion of subsequent coats or to prevent other surface defects (e.g., bubbling of a subsequent coating) (Encyclo.CO.UK 2014)

Figure 7: ToxServices' Hazard Assessment Approach for Chemicals in the Uniform Data Set



*Note a GreenScreen® was performed on LT-1 chemicals based only on inhalation exposure hazards.

LT-1: List Translator 1 (equivalent to a GreenScreen® Benchmark 1)
LT-P1: List Translator Possible GreenScreen® Benchmark 1
Benchmark-1: GreenScreen® Benchmark 1 (Avoid- Chemical of High Concern)
Benchmark-2: GreenScreen® Benchmark 2 (Use but Search for Safer Substitutes)
Benchmark-3: GreenScreen® Benchmark 3 (Use but Sill Opportunity for Improvement)
Benchmark-4: GreenScreen® Benchmark 4 (Prefer- Safer Chemical)

GreenScreen® List Translator

The first step in assessing hazard in the Uniform Data Set was to perform a GreenScreen® List Translator search. The GreenScreen® List Translator comprises over 850 lists from 36 primary authoritative and screening sources that include national and international regulatory and hazard lists, influential NGO lists of chemicals of concern (screening lists), authoritative scientific bodies, European Risk and Hazard Phrases, and chemical hazard classifications by countries using the Globally Harmonized System of Classification and Labeling System.

Pharos developed the GreenScreen® List Translator software to automate the GreenScreen® List Translator (Pharos 2014). The purpose of the GreenScreen® List Translator is to screen for chemicals that would achieve a Benchmark 1 score if a full GreenScreen® chemical hazard assessment was performed; therefore, the scope of the LT tool is limited to capturing Benchmark 1 chemicals only. Full GreenScreen® Assessments are required to determine if the final GreenScreen® Benchmark score is greater than 1.

ToxServices utilized the Pharos Chemical and Materials Library (Pharos 2014) online tool to quickly perform an automated List Translator search. The Pharos output displays authoritative and screening lists in which the chemical appears and indicates a benchmark or possible benchmark score according to GreenScreen® Criteria (CPA 2012b). List Translator scores for individual chemicals are reported by Pharos as List Translator Benchmark 1 (LT-1), List Translator Possible Benchmark 1 (LT-P1), and List Translator Unspecified Benchmark (LT-U), which are defined in Table 4, below. A Pharos print-out is shown in Appendix B, Figure B-1.

Table 4: GreenScreen® List Translator Scores

GS LT Score	GreenScreen® Benchmark Equivalency	Definition
LT-1	Benchmark 1	An LT-1 chemical score is based on lists that identify the chemical as a Chemical of High Concern and may be considered equivalent to a Benchmark 1 chemical using the full GreenScreen® method.
LT-P1	Possible Benchmark 1	An LT-P1 chemical score translates to Possible Benchmark 1 and reflects the presence of the chemical on Screening A or B lists and some uncertainty about the classification for key endpoints. Further research is needed on the flagged endpoint to determine if the chemical is indeed a GreenScreen® Benchmark 1.
LT-U	Unspecified Benchmark	An LT-U chemical score indicates that there is insufficient information to apply the GreenScreen® Benchmark Scoring algorithm to the chemical. That can be a good sign. Typically, only hazardous chemicals are found on hazard lists. However, lack of presence on hazard lists can also mean that the chemical has not investigated for safety. Therefore, the resulting conclusion using the List Translator is that the Benchmark U score is unspecified pending full GreenScreen® assessment. A full GreenScreen® assessment will need to be performed to determine if a chemical is a Benchmark 1, 2, 3, or 4.

GS LT: GreenScreen® List Translator
Clean Production Action (2013)

ToxServices screened all paint components against Clean Production Action's List Translator. Chemicals reported as LT-1 chemicals have been identified as carcinogens, mutagens, reproductive and developmental toxicants, endocrine active compounds, or persistent, bioaccumulative, and toxic (PBT) compounds; this score is considered equivalent to a GreenScreen® Benchmark 1 score. Initially, those chemicals that were identified as LT-1 did not undergo a full GreenScreen® evaluation to save time and resources, and only those hazard scores determined by authoritative listings in the List Translator search were to be reported. However, per the terms of the scope of work, ToxServices stated that, using expert judgment, expansion of the hazard assessment for the LT-1 chemicals may be performed if a need for additional data to inform the Alternatives Assessment was anticipated. Upon inspection of the dataset, two conditions resulted in the expansion of an LT-1 chemical hazard assessment:

1. Chemicals for which an LT-1 score was driven by the inhalation route of exposure, and
2. Chemicals for which an LT-1 score did not initially evaluate the environmental toxicity and fate hazard endpoints.

To address item 1 (above), ToxServices identified several chemicals that were classified as LT-1 chemicals based on hazard concerns regarding inhalation of respirable forms of the compound. ToxServices elected to perform a full GreenScreen® chemical hazard assessment for these chemicals with hazard scores stratified by route of exposure. This approach was used in order to better illustrate the hazards associated with each chemical so that the Exposure Assessment Module could be accurately and fully utilized. To address item 2 (above), ToxServices expanded the assessments[13] for all LT-1 chemicals to include the evaluation of the aquatic toxicity and environmental fate endpoints as these endpoints are highly relevant to the Alternatives Assessment of nonbiocide boat paints. As a result, the hazard tables for these evaluations present both hazard scores assigned based on authoritative listings from the List Translator output as well as hazard scores assigned based on an abbreviated literature search or modeling for aquatic toxicity and environmental fate.

Targeted GreenScreen® Chemical Hazard Assessment

For chemicals that were identified as LT-P1, a targeted GreenScreen® chemical hazard assessment was completed by first focusing on hazard endpoints that contributed to the LT-P1 score. If a chemical was confirmed to be a Benchmark 1 chemical based on an evaluation of data for the endpoints of concern, no further hazard information was obtained, and hazard scores were only assigned for endpoints determined based on authoritative listings and for the endpoints of concern.

Finally, for chemicals that were identified as LT-P1 chemicals and were not confirmed to be Benchmark 1 chemicals, as well as all chemicals identified as LT-U chemicals, were evaluated in a GreenScreen® chemical hazard assessment (all endpoints). These assessments focused on data obtained from high quality data sources including U.S. EPA's High Production Volume Information System (HPVIS), UNEP OECD Screening Information Datasets (SIDS), OECD Existing Chemicals Database, European Chemical Substances Information System IUCLID Chemical Data Sheets, National Toxicology Program (NTP), International Agency for the

[13] Under the GreenScreen® paradigm, there are four environmental toxicity and fate endpoints. If a chemical received an LT-1 score based on environmental toxicity and/or fate endpoints, no additional effort was made to evaluate the environmental toxicity and/or fate endpoints, even if data were not available for all four endpoints after the LT evaluation. This was due to the fact that the score would not have changed with additional data.

Research on Cancer (IARC), Human and Environmental Risk Assessment on ingredients of household cleaning products (HERA), and European Chemicals Agency (ECHA).

GreenScreen® Chemical Hazard Assessment

The GreenScreen® for Safer Chemicals, commonly known as the GreenScreen®, is a chemical screening method designed to identify less hazardous chemicals using a standardized approach that considers both human health endpoints and environmental fate and toxicity endpoints (CPA 2012b). A GreenScreen® chemical hazard assessment can identify substances that are inherently less hazardous for humans and the environment and effectively manages chemical risk by reducing hazard rather than controlling exposure to potentially toxic chemicals.

ToxServices evaluated chemicals against endpoints relating to human health effects, aquatic toxicity, and environmental effects, and each endpoint was given a score of very Low hazard (vL), Low hazard (L), Moderate hazard (M), High hazard (H) or very High hazard (H). Hazard scores were evaluated under GreenScreen® Version 1.2 to assign one of four different benchmark scores, as illustrated in Appendix B, Figure B-1 (from CPA 2011):

- Benchmark 1: Avoid (Chemical of High Concern)
- Benchmark 2: Use (But Search for Safer Substitutes)
- Benchmark 3: Use (But Still Opportunity for Improvement)
- Benchmark 4: Prefer (Safer Chemical)

In addition, chemicals with insufficient data or data gaps for specific hazard endpoints were assigned a Benchmark score of Unassigned ("U").

The hazard classifications for each endpoint noted on the List Translator are the product of evaluations of toxicity data by toxicologists in government and regulatory bodies; and review of additional data is not likely to negate LT-1 classifications obtained using the List Translator. GreenScreen® chemical hazard assessment based on a limited set of high quality and comprehensive literature sources. These include studies that are performed according to Good Laboratory Practice (GLP) standards and those performed according to Organization for the Economic Cooperation and Development (OECD) Guidelines, as well as those performed by authoritative bodies including the U.S. EPA and National Toxicology Program (NTP). The data sources that are searched in the GreenScreen® chemical hazard assessment include:

- U.S. EPA High Production Volume Information System (HPVIS): http://www.epa.gov/hpvis/index.html
- UNEP OECD Screening Information Datasets (SIDS): http://www.chem.unep.ch/irptc/sids/OECDSIDS/sidspub.html
- OECD Existing Chemicals Database: http://webnet.oecd.org/hpv/ui/SponsoredChemicals.aspx
- European Chemical Substances Information System IUCLID Chemical Data Sheets (ESIS 2014): http://esis.jrc.ec.europa.eu/index.php?PGM=dat
- National Toxicology Program: http://ntp.niehs.nih.gov/
- International Agency for the Research on Cancer: http://monographs.iarc.fr/ENG/Classification/index.php

- Human and Environmental Risk Assessment on ingredients of household cleaning products: http://www.heraproject.com/RiskAssessment.cfm
- European Chemicals Agency: http://echa.europa.eu/

The GreenScreen® chemical hazard assessment portion of ToxServices' Uniform Data Set Hazard Assessment procedures is meant to be an efficient assessment of a chemical's hazards; therefore, structural analogs were not always used to characterize the endpoints with data gaps. However, for certain endpoints (carcinogenicity, aquatic toxicity, persistence, bioaccumulation, and skin sensitization) that can be rapidly assessed using modeling software, the following software programs are used to estimate the hazard for these endpoints when data gaps are present:

- Oncologic (Carcinogenicity): http://www.epa.gov/oppt/sf/pubs/oncologic.htm
- EPI Suite (Persistence, Bioaccumulation): http://www.epa.gov/oppt/exposure/pubs/episuite.htm
- ECOSAR (Aquatic Toxicity): http://www.epa.gov/oppt/newchems/tools/21ecosar.htm
- ToxTree (Toxic Hazard Estimation) (skin sensitization): http://toxtree.sourceforge.net/
- OECD Toolbox (skin sensitization): http://www.oecd.org/env/ehs/risk-assessment/theoecdqsartoolbox.htm
- Vega (skin sensitization): http://www.vega-qsar.eu/

Once data are collected, a hazard classification (such as Low, Medium, High) is assigned for each of the 18 hazard endpoints using the hazard guidance table (CPA 2012b), and a hazard summary table is created (see Table 5, which is an example of a hazard summary table). The 18 hazard endpoints are identified in Appendix C. In cases where no data are identified for a hazard endpoint in the above resources, a data gap (DG) is identified for that endpoint.

Table 5: Example of Hazard Ratings for Chemical A Based on Results of GreenScreen® Chemical Hazard Assessment

Group I Human					Group II and II* Human									Ecotox		Fate		Physical	
C	M	R	D	E	AT	ST		N		SnS*	SnR*	IrS	IrE	AA	CA	P	B	Rx	F
						single	repeated*	single	repeated*										
H	H	L	L	DG	L	M	M	L	L	L	DG	M	H	*M*	*M*	*vL*	*L*	L	L

(See Appendix C for hazard acronyms)

For all levels of assessment performed, each chemical hazard assessment resulted in the assignment of a benchmark score to the chemical (i.e., LT-1, or Benchmark 1, 2, 3, 4, or U) (see Appendix B). The benchmark score is calculated by analyzing specific combinations of hazard classifications and is useful for broad comparisons between chemicals. The Benchmark Score outcomes in the Uniform Data Set are presented in Table 6.

Table 6: Possible Benchmark Outcomes	
Benchmark Score	**Definition**
Benchmark 1	GreenScreen® Benchmark 1 (Avoid-Chemical of High Concern)
Benchmark 1_{TP}	GreenScreen® Benchmark 1 – Based on hazards of a chemical's transformation product (equivalent to a GreenScreen® Benchmark 1)
Benchmark 2	GreenScreen® Benchmark 2 (Use but Search for Safer Substitutes)
Benchmark 3	GreenScreen® Benchmark 3 (Use but Still Opportunity for Improvement)
Benchmark 3_{DG}	GreenScreen® Benchmark3 – Based on data gaps (equivalent to a GreenScreen® Benchmark 3)
Benchmark 4	GreenScreen® Benchmark 4 (Prefer-Safer Chemical)
Benchmark U	Benchmark Unspecified

Results of Chemical Hazard Assessments of Seven Paint Formulations

ToxServices applied the stepped-wise screening approach to screen chemical ingredients of the seven paint formulations. Ingredient disclosure among the seven paint formulations was quite variable, and ranged from a low of 12% of ingredients disclosed to >100% formulation disclosure. Some of the formulations exceeded 100% disclosure because the individual ingredient percentages were provided in ranges. MSDS that disclosed at least 100% were considered to have complete disclosure, even if their individual ingredients were not fully disclosed/identified. In the United States, thresholds for chemicals requiring disclosure on MSDS are generally 1% for non-carcinogens that are health hazards and 0.1% for carcinogens[14].

Of the seven paint formulations assessed, the formulation disclosed on the product level MSDS was incomplete for three paints:

- Intersleek 900 System
- XZM480 International
- Hempasil XA278

In some cases, even ingredients that were disclosed could not be assessed due to lack of chemical identity. Examples of incomplete chemical identity include lack of a Chemical Abstract Service

[14] Under the U.S. Occupational Safety and Health Administration (OSHA)'s Hazard Communication Standard (29 CFR1910.1200), an MSDS in the U.S. must identify chemical and common name(s) of all ingredients which have been determined to be health hazards, and which comprise 1% or greater of the composition, except that chemicals identified as carcinogens shall be listed if the concentrations are 0.1% or greater; and, the chemical and common name(s) of all ingredients which have been determined to be health hazards, and which comprise less than 1% (0.1% for carcinogens) of the mixture, if there is evidence that the ingredient(s) could be released from the mixture in concentrations which would exceed an established OSHA Permissible Exposure Limit or ACGIH Threshold Limit Value, or could present a health risk to employees.

(CAS) Registry Number or an ingredient that was identified as a mixture with no additional information on the individual components of that ingredient. In some cases, incomplete chemical identity was due to the fact that an ingredient was identified as a chemical class; however, the class was too general to perform even a class-based assessment. The following paint formulations contained ingredients that were disclosed but not assessed due to incomplete chemical identity:

- Trinidad Pro Antifouling Bottom Paint
- Intersleek 900 System
- BottomSpeed TC Base Coat/Top Clear Coat
- Hempasil XA278

Results from the chemical hazard screening process are summarized in Table 7 and complete results can be found in Appendix D. The Benchmark distribution was diverse; however, each paint formulation contained at least one Benchmark 1 (equivalent to Avoid – Chemical of High Concern) chemical, regardless of route of exposure. However, the route of exposure (i.e., inhalation, oral, or dermal routes of exposure) played a major role in driving the Benchmark distribution of some of the paint formulations; therefore, the hazards of those chemicals were stratified by route of exposure so that those concerns could be addressed in the Exposure Assessment Module, if necessary.

Table 7: Chemical Hazard Summaries for Seven Assessed Paint Formulations

Paint Formulation	No. of Chemicals[a]	% of Formula ID'd[b,c]	Route of Exposure	Benchmark Distribution of Chemicals						
				LT-1	BM-U	BM-1	BM-2	BM-3	BM-4	Incomp. Data[d]
Pettit Marine Paint Trinidad Pro Antifouling Bottom Paint 1082 Blue	[REDACTED]	[REDACTED]	Inhalation	*	*	*	*	*	*	*
			Oral	*	*	*	*	*	*	*
			Dermal	*	*	*	*	*	*	*
Klear N' Klean Plus XP-A101 White Topcoat	[REDACTED]	[REDACTED]	Inhalation	*	*	*	*	*	*	*
			Oral	*	*	*	*	*	*	*
			Dermal	*	*	*	*	*	*	*
Intersleek 900 System[e]	>5	12-45%	Inhalation	1	0	2	0	0	0	2
			Oral	1	0	1	0	1	0	2
			Dermal	1	1	1	0	0	0	2
XZM480 International[f]	7	16.5-<46%	Inhalation	2	1	2	2	0	0	0
			Oral							
			Dermal							
TC Base Coat/Top Coat Clear[e]	>13	39.3-<146%	Inhalation	2	0	7	2	0	0	2
			Oral	2	0	4	4	1	0	2
			Dermal	2	3	4	2	0	0	2
Hempasil XA278[f]	>3	14.5-21%	Inhalation	1	0	1	0	0	0	1
			Oral							
			Dermal							
Surface Coat Part A – Black	8	75-131%	Inhalation	1	0	5	2	0	0	0
			Oral	1	0	3	3	1	0	0
			Dermal	1	2	3	2	0	0	0

*Indicates Benchmark or List Translator Score has been redacted to protect confidential business information.
LT-1: List Translator 1 (equivalent to a GreenScreen® Benchmark 1)
LT-P1: List Translator Possible GreenScreen® Benchmark 1

Table 7: Chemical Hazard Summaries for Seven Assessed Paint Formulations
Benchmark-1: GreenScreen® Benchmark 1 (Avoid-Chemical of High Concern) Benchmark-2: GreenScreen® Benchmark 2 (Use but Search for Safer Substitutes) Benchmark-3: GreenScreen® Benchmark 3 (Use but Still Opportunity for Improvement) Benchmark-4: GreenScreen® Benchmark 4 (Prefer-Safer Chemical) Benchmark-U: Benchmark Unspecified Inc. Data: Incomplete formulation disclosure [a] This column identifies the number of chemicals in each paint formulation. Some of the MSDS did not identify all components; therefore, the exact number of chemicals may not be identified in this column. [b] MSDS for each of the seven assessed formulations was used to determine the chemical composition of the ingredient. The percentages identified in this column are provided as ranges because the percentages provided on the MSDS were provided as ranges. The range is the sum of the lowest percentage of each chemical/ingredient in the formulation to the sum of the highest percentage of each chemical/ingredient in the formulation for each chemical/ingredient listed on the MSDS. [c] Not all chemicals/ingredients were identified on the MSDS, so the total percentages may not reach 100%. [d] Incomp. Data: Incomplete data. This column represents the number of chemicals/ingredients that, although identified on the product level MSDS, could not be screened for hazards due to incomplete disclosure. Incomplete disclosure could represent any of the following: the CAS Number was not provided, the ingredient was identified as a mixture, the ingredient was identified as proprietary and only described as a chemical class that was too general to perform even a class-based hazard assessment, or a chemical/ingredient had additional disclosure; however, the disclosure was provided too late in the hazard evaluation to incorporate. [e] This formulation contains two paints that work as a System. [f] This formulation was not stratified by route of exposure because it did not contain any chemicals whose hazards were clearly driven by route of exposure.

The compilation of chemical hazard assessments and overviews of each paint formulation is the Uniform Data Set (ToxServices 2014a). The hazard data from the Uniform Data Set is equivalent to the hazard evaluation piece of the Hazard Module in each of the Alternatives Assessments, which are described in the following sections. The results from ToxServices' hazard evaluation of each formulation can be seen in Table D-1 through Table D-9 and were used as the basis for the decision-making portion of the Hazard Module for each of the three frameworks.

OVERVIEW OF SEQUENTIAL, SIMULTANEOUS AND HYBRID ALTERNATIVES ASSESSMENTS

Tasks 2, 3, and 4 are Alternatives Assessment of copper antifouling paint alternatives using the Sequential, Simultaneous, and Hybrid Frameworks, respectively. Below is the proposed process for implementation of an Alternatives Assessments according to the IC2 Guide.

1. Define the Issue

Copper contamination is a leading concern in the Puget Sound region, and a 2011 Washington State law (Chapter 70.300 RCW) requires copper antifouling paints to be phased out beginning in 2018 and completed by January 1, 2020 (State of Washington 2011). Copper antifouling paint achieves foul control by leaching copper, a biocide, into the surrounding waters. These antifouling, or biocidal, capabilities result in very high aquatic toxicity (U.S. EPA (2011), CalEPA (2011)).

There are four types of alternatives to copper antifouling paint, Nonbiocide coatings, zinc-oxide[15] only coatings, organic-biocide coatings, and zinc-biocide[16] coatings. CalEPA (2011) stated nonbiocide paints were the best option to pursue in regard to switching away from copper antifouling paint. Therefore, this assessment compares Nonbiocide paint formulations to a selected copper control boat paint.

2. Identify the Decision-Making Framework

Under Task 2, ToxServices applied the Sequential Framework.

Under Task 3, Abt Associates applied the Simultaneous Framework.

Under Task 4, Abt Associates (independent from those who conducted Task 3) applied the Hybrid Framework.

When performing an Alternatives Assessment under the IC2 Guide, only one Framework needs to be implemented. The scope of this project required all three to be performed in order to evaluate each Framework's usability.

3. Identify the Decision Criteria

The three assessors implemented and evaluated the three frameworks using the four core modules of the IC2 Guide: Hazard, Performance Evaluation, Cost and Availability, and Exposure Assessment. Three additional modules (Materials Management, Social Impacts, and Life Cycle) were implemented in the Hybrid Framework to determine if they significantly affected the results.

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[15] U.S. EPA (2011) states these formulations do not contain a zinc biocide chemical, zinc just aids in the function of the rest of the paint formulation.
[16] These paint formulations generally contain zinc pyrithione (U.S. EPA 2011).

The decision making criteria for all three Frameworks included conducting an Initial Screen and Level 2 evaluation for the Hazard Module and a Level 1 evaluation for the Performance Evaluation and Cost and Availability Modules. An Initial Screen was conducted for the Exposure Assessment Module, and a Level 1 evaluation was to be conducted if needed.

4. Collect Information Regarding Criteria

Three main data sources were used for this assessment:

- Safer Alternatives to copper antifouling paints: Nonbiocide Paint Options (CalEPA 2011). Prepared by Institute for Research and Technical Assistance (IRTA) for CalEPA's Department of Toxic Substances Control;
- Safer Alternatives to copper antifouling paints for Marine Vessels (U.S. EPA 2011). Prepared by IRTA and the Unified Port of San Diego for the U.S. EPA; and
- Uniform Data Set for Assessing Alternatives to Copper antifouling paint (ToxServices 2014a). Prepared by ToxServices LLC for Washington State Department of Ecology.

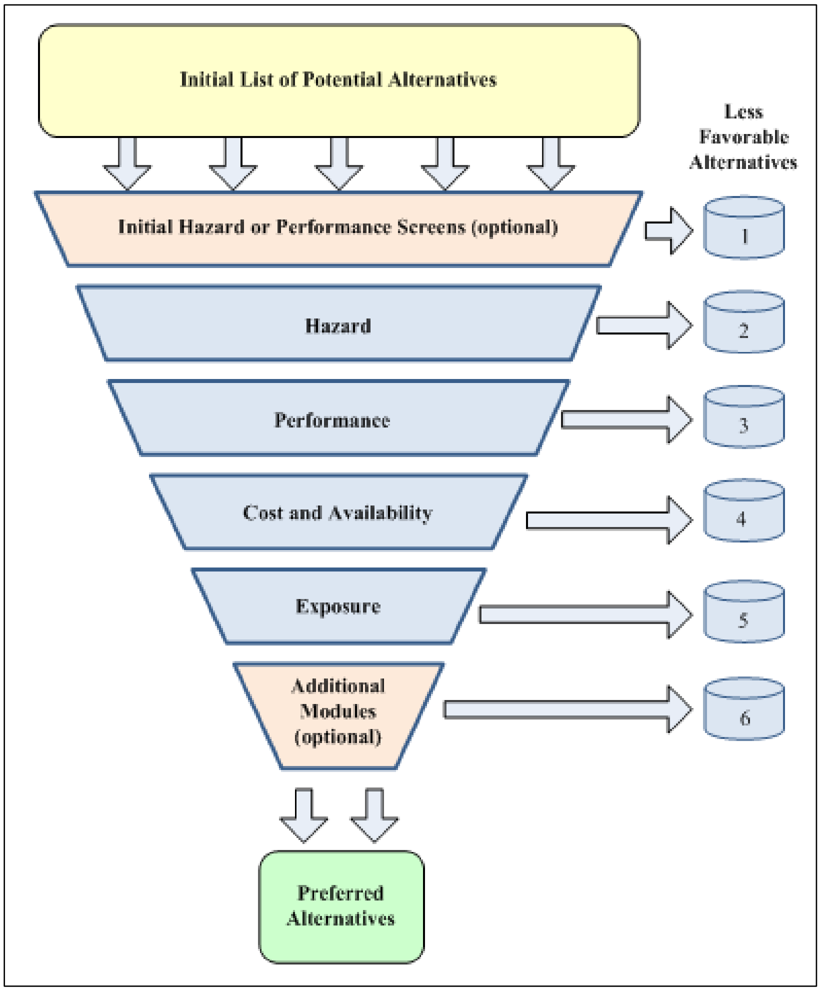
5. Compare the Alternatives to the Original Chemical of Concern

Using the information described above, we used the IC2 Guide to evaluate the alternatives. The methods and results of each Framework are described below. In the theme of transparency, the methodology and results have been described by each assessor. Therefore, there may be some repetition across Frameworks.

ALTERNATIVES ASSESSMENT USING THE IC2 SEQUENTIAL FRAMEWORK CONDUCTED BY TOXSERVICES (TASK 2)

In the Sequential Framework, the four core modules were completed in a linear order, starting with the Hazard Module and moving on to Performance Evaluation, Cost and Availability, and Exposure Assessment Modules. Data were collected and alternatives were binned as favorable, less favorable or unfavorable in comparison to the copper antifouling paint. Favorable and less favorable alternatives advanced to subsequent modules, and unfavorable alternatives were eliminated from further review. A flow chart of the Sequential Framework is presented in Figure 8.

Figure 8: Overview of IC2 Sequential Framework



Source: IC2 (2013)

Hazard Module

The purpose of the Hazard Module is to establish the hazard for each alternative, and, based on the established hazards, "bin" the alternatives into three categories: favorable, less favorable, and unfavorable. The unfavorable formulations are then eliminated from further analysis in subsequent modules.

In order to establish the hazards associated with an alternative, the IC2 Guide identifies four different approaches for establishing hazard: an Initial Screen and three levels of hazard assessment. Each of these approaches also provides a method to bin and eliminate alternatives that are more hazardous than the chemical, product or process of concern. The hazard screening portion of the Hazard Module was previously executed as part of the Uniform Data Set (see Creation of Uniform Data Set). The decision methods used to bin and eliminate alternatives is described below.

Hazard Module Results

According to the scope of work, ToxServices proposed that the Hazard Module be conducted using Levels 1 and 2. However, ToxServices also performed an Initial Screen, and, after reviewing the results of the Initial Screen, ToxServices determined it would be most informative to proceed directly to a Level 2 hazard assessment per scope of work. The Initial Screen using GreenScreen® List Translator revealed that all seven paint formulations contain LT-1 chemicals. Therefore, eliminating formulations that have LT-1 chemicals would result in the elimination of all formulations and was not a useful approach. The Level 1 hazard assessment was also deemed insufficient for the Alternatives Assessment of copper antifouling paints as a QCAT assessment (Level 1) does not examine chronic aquatic toxicity. Chronic aquatic toxicity is considered a critical endpoint for the Alternatives Assessment of copper antifouling paints, as the main reason a replacement for copper antifouling paints is sought is due to the acute and chronic aquatic toxicity associated with copper. Therefore, the Level 2 hazard assessment was performed. The results of the hazard assessment were included in the Uniform Data Set. Using the Uniform Data Set and the instructions in the IC2 Guide, the formulations were binned and, if necessary, eliminated based on hazard.

While all levels in the Hazard Module provide guidance on how to eliminate alternatives from further analysis, the guidance is only provided for situations when the target of concern is a chemical rather than a formulation. Specifically, the IC2 Guide suggests that chemical alternatives be eliminated if they are Benchmark 1 chemicals; however, the IC2 Guide does not provide guidance for how to bin and eliminate formulations or mixtures. This is likely due to the fact that, at this time, the hazard assessments suggested in Levels 1, 2, and 3 of the Hazard Module are only designed to provide quantitative results (e.g., Benchmark scores) at the chemical level, and the recommended tools do not offer an algorithm for quantifying the hazard of a formulation or mixture. As a result, ToxServices had to establish a procedure to bin and eliminate alternatives at the formulation level.

ToxServices' first approach to bin and eliminate formulations was similar to the method outlined for binning and eliminating individual chemical alternatives: if the formulations contained Benchmark 1 chemicals, they were to be binned as unfavorable and eliminated. An initial review of the GreenScreen® Benchmark scores of the individual chemicals in these formulations revealed that all formulations contained Benchmark 1 (or equivalent[17]) chemicals. Therefore, in this project, it is impossible to select an alternative by eliminating formulations based solely on the presence of high hazard chemicals (i.e., Benchmark 1 chemicals). As a next step,

[17] The following scores are equivalent to Benchmark 1 scores: List Translator-1 (LT-1) chemicals and Benchmark 1_{TP}.

ToxServices binned formulations based on total percent weight of Benchmark 1 chemicals and eliminated formulations containing the highest percentage, by weight, of unfavorable chemicals. ToxServices did not establish a cut-off value for elimination of formulations from further consideration, but, rather, compared all formulations and eliminated those that were clearly inferior to other alternatives in terms of percent weight of Benchmark 1 chemicals.

In addition, as the GreenScreen® criteria classify chemicals as Benchmark 1 by considering both environmental and human health hazards, ToxServices made a distinction between the two to aid the decision making process. Both human health and environmental hazards are important factors in any hazard assessment; however, one set of hazards may take priority when selecting an alternative. In this assessment, the main reason to search for alternatives to copper antifouling paints is environmental concern relating to the continuous release of copper, which is highly hazardous to aquatic organisms and is not degradable in the aquatic environment. However, there are also relevant human health concerns, especially for those applying the paints and cleaning the boat hulls. Therefore, in the first iteration of the sequential framework, ToxServices binned the six formulations by the percentage of Benchmark 1 chemicals based first on environmental hazard and then on human health endpoints.

According to the GreenScreen® paradigm, sub-benchmarks of Benchmark 1 include the following hazard combinations: PBT, vPvB, vPT, vBT, and T (High group I Human hazards). For the purpose of this assessment, ToxServices considered Benchmark 1 chemicals to be environmental hazards when they satisfy any one of the sub-benchmarks below:

- PBT = High P + High B + Very High Ecotoxicity
- vPvB = Very High P + Very High B
- vPT = Very High P + Very High Ecotoxicity
- vBT = Very High B + Very High Ecotoxicity

Benchmark 1 chemicals are considered to be human health hazards when they satisfy any one of the sub-benchmarks below:

- PBT = High P + High B + [Very High Group II Human or High Group I or II* Human]
- vPT = Very High P + [Very High Group II Human or High Group I or II* Human]
- vBT = Very High B + [Very High Group II Human or High Group I or II* Human]
- High T (Group I Human)

For Benchmark 1_{TP} chemicals, the hazards of the transformation products (for all Benchmark 1_{TP} chemicals, the hazardous transformation product is methanol) were evaluated in lieu of those of the parent compounds using the method above. This is due to the fact that the parent compound has a transformation product that is more hazardous than the parent compound itself. The chemicals which received a Benchmark score of Benchmark 1_{TP} were considered equivalent to Benchmark 1 or LT-1 chemicals throughout the Hazard Module assessment. Additionally, for human health hazards, the percentage of Benchmark 1 chemicals was also stratified based on exposure route when such information was available because the hazard of some chemicals is route dependent. Therefore, the stratification was included to provide additional information for the Exposure Assessment Module below, if necessary.

Another issue that was considered in the Hazard Module was the extent of ingredient disclosure. The level of ingredient disclosure for each paint formulation varies greatly among the paint formulations under evaluation, with certain paint formulations completely disclosed and other paint formulations only partially disclosed. To illustrate this point, ToxServices summarized the percentage of each paint formulation that was assessed in the Uniform Data Set and included the percentage of chemicals/ingredients that were disclosed in each formulation in Table 8, below. ToxServices identified the majority of ingredients composing the formulations from the product MSDS. Further disclosure was provided by the paint manufacturers upon ToxServices' request; however, the additional disclosure was only for two formulations, the copper antifouling paint and one alternative Nonbiocide paint.

According to the Occupational Safety and Health Administration's (OSHA) requirement, all "hazardous" components present at 1% and above and carcinogens at 0.1% and above should be disclosed on an MSDS. The OSHA Hazard Communication Standard (29 CFR 1910.1200) states that a chemical is deemed "non-hazardous" when it is not a carcinogen or a potential carcinogen, not corrosive, not toxic or highly toxic (rat LD_{50} < 500 mg/kg, dermal LD_{50} < 1,000 mg/kg, inhalation LC_{50} < 2,000 ppm), not an irritant, not a sensitizer, and does not have target organ effects (CSA 2005). Therefore, it is likely that the undisclosed ingredients are considered less hazardous in terms of human health than the disclosed ingredients by the manufacturers. However, it is not a requirement for environmentally hazardous ingredients to be identified on the MSDS. Additionally, the quality of MSDS preparation may vary across industries, and the definition of "hazardous" by OSHA does not completely align with GreenScreen® criteria (specifically, environmental hazards do not seem to be given the same consideration as human health hazards). As the IC2 Guide does not provide guidance on how to assess incompletely disclosed formulations, ToxServices did not eliminate the formulations simply due to incomplete formulation disclosure, and the Hazard Module was conducted based on hazards for known components. The results from the above evaluation are summarized in Table 8, below.

Table 8: Percentage of Benchmark 1 Chemicals in Seven Paint Formulations

Paint Formulation	% of Formula ID'd[1]	Route of Exposure	% LT-1/BM-1/BM-1TP Chemicals by Weight			
			Sum Total	Human Health Hazards Only	Environmental Hazards Only	Both
Pettit Marine Paint Trinidad Pro Antifouling Bottom Paint 1082 Blue	[REDACTED]	Inhalation	*	*	*	*
		Oral	*	*		
		Dermal	*	*		
Klear N' Klean Plus XP-A101 White Topcoat	[REDACTED]	Inhalation	*	*	*	*
		Oral	*	*		
		Dermal	*	*		
Intersleek 900 System	12-45% (paint)	Inhalation	45	45	0	0
		Oral	20	20		
		Dermal	20	20		
	0% (primer)	N/A	N/A	N/A	N/A	N/A
XZM480 International	16.5-<46%	All routes	31	31	0	0
BottomSpeed TC Base Coat/Top Coat Clear	39.3-<146% (base coat)	Inhalation	85	60	20	5
		Oral	45	20		
		Dermal	45	20		
	12.3-46%	Inhalation	42	42	0	0

Table 8: Percentage of Benchmark 1 Chemicals in Seven Paint Formulations						
	(top coat)	Oral	37	37		
		Dermal	37	37		
Hempasil XA278	14.5-21%	All routes	18	18	0	0
Surface Coat Part A – Black	75-131%	Inhalation	46	34	12	0
		Oral	26	14		
		Dermal	26	14		

*Indicates Benchmark or List Translator Score has been redacted to protect confidential business information.
[1]Some paints have a maximum percentage greater than 100%. This is due to the fact that percentage of some chemicals were provided in ranges on the product level MSDS.

The IC2 Guide does not specify which endpoints to consider when eliminating unfavorable alternatives (i.e., weighing environmental endpoints over human health or vice versa). ToxServices first considered the percentage of Benchmark 1 chemicals based on environmental hazards because the primary reason to search for alternatives to copper antifouling paints is its environmental toxicity and persistence. After eliminating the most environmentally hazardous formulation(s), ToxServices evaluated the human health hazards to further eliminate unfavorable formulations.

As shown in Table 8, the copper antifouling paint, Pettit Marine Paint Trinidad Pro Antifouling Bottom Paint 1082 Blue has the highest percentage, by weight, of environmentally hazardous Benchmark 1 chemicals. Specifically, chemicals classified as Benchmark 1 chemicals based on the environmental endpoints alone or in combination with the human health hazards are [REDACTED]% and [REDACTED]%, respectively, of the formulation for a total of [REDACTED]% of the formulation by weight. This was expected, as copper based boat paints are known to be toxic to the environment, which is the main reason why an alternative for copper antifouling paints is sought. The alternative formulations have much lower percentages (by weight) of environmentally driven Benchmark 1 chemicals, with the BottomSpeed TC Base Coat Clear containing the highest level at 25% (the sum of the percent weight of Benchmark 1 chemicals driven by environmental endpoints alone or together with human health endpoints) compared to the copper-based control. However, ToxServices did not consider the magnitude of the differences in the percentage of Benchmark 1 chemicals driven by environmental hazards of the six non-copper alternatives to be large enough to eliminate any paint formulations, especially considering that a number of the products disclosed less than 50% of their formulations. Eliminating BottomSpeed TC Base Coat/Top Coat Clear at this step may be overly conservative and penalizing for its relatively complete formulation disclosure.

In terms of human health hazards among the remaining formulations, Klear N' Klean Plus XP-A101 White Topcoat is the formulation containing the highest percent weight of Benchmark 1 chemicals driven by human health endpoints. With a relatively fully characterized ingredient composition ([REDACTED]%), this product contains up to [REDACTED]% of Benchmark 1 chemicals by the inhalation route of exposure and up to [REDACTED]% of Benchmark 1 chemicals by oral and dermal routes of exposure, all of which are driven by human health hazards. This formulation also contains [REDACTED]% Benchmark 1 or LT-1 chemicals due to environmental hazards. Therefore, ToxServices considered this paint to be unfavorable based on high human health hazards and excluded it from further analysis.

Intersleek 900 System contains, by weight, 45% Benchmark 1 chemicals by the inhalation route and 20% by oral and dermal routes of exposure. All of these chemicals were flagged due to high human health hazards. However, only up to 45% of the formulation is characterized, and the formulation of the primer that is required to be used in tandem with this product was not disclosed at all. Since environmental hazards are not given as much consideration compared to human health hazards in MSDS ingredient disclosures, it is unknown if the undisclosed ingredients in the formulation may be hazardous due to environmental concerns. Therefore, ToxServices considered this paint to be less favorable but included it for subsequent analysis.

Similar to Intersleek 900, XZM480 International is also poorly characterized, with only 46% of the formulation disclosed. A total of 31% by weight of the formulation consists of Benchmark 1 or LT-1 chemicals due to human health hazards; none were flagged due to environmental hazards. Since environmental hazards are not given as much consideration compared to human health hazards in MSDS ingredient disclosures, it is unknown if the remaining ingredients in the formulation may be hazardous due to environmental concerns. Therefore, ToxServices considered this paint to be less favorable but included it for subsequent analysis.

BottomSpeed TC Base Coat/Top Coat Clear are, as the name implies, a top coat and base coat and are used in tandem. The base coat formulation is relatively completely disclosed (39.3-146%) while the top coat formulation is less complete (44% disclosure). The base coat contains up to 60% by weight Benchmark 1 or LT-1 chemicals due to human health hazards by the inhalation route of exposure but only 20% by the oral and dermal routes of exposure. The base coat formulation also contains 20% of Benchmark 1 or LT-1 chemicals due to environmental hazards and 5% Benchmark 1 or LT-1 chemicals due to both human health (inhalation[18]) and environmental hazards. The top coat formulation contains 42% by weight Benchmark 1 chemicals by inhalation exposure and 37% by oral and dermal routes of exposure, based on human health hazards only. These levels are comparable to the percentage of Benchmark 1 chemicals in other less favorable paint formulations. Therefore, ToxServices also considered this paint to be less favorable but included it for subsequent analysis.

Hempasil XA278 is the least characterized paint formulation (only up to 21% of ingredients are disclosed). A total of 18% of the formulation by weight is Benchmark 1 chemicals due to human health hazards only. Because environmental hazards are not given as much consideration compared to human health hazards in MSDS ingredient disclosures, it is unknown if the remaining ingredients in the formulation may be hazardous due to environmental concerns. Therefore, ToxServices considered this paint to be less favorable but included it for subsequent analysis.

Surface Coat Part A – Black has a relatively completely characterized formulation (75-131%). It contains relatively lower percent by weight of Benchmark 1 chemicals due to human health hazards (34% by inhalation and 14% by oral and dermal routes). It also contains 12% by weight Benchmark 1 chemicals due to environmental hazards. It does not contain any chemicals that are classified based on both human and environmental hazards. Although many formulations

[18] The GreenScreen® chemical hazard assessment for this ingredient, which composes up to 5% of this formulation, is not stratified to have different Benchmark scores for oral, inhalation and dermal routes, but the data evaluated for this chemical suggest that the Benchmark 1 score is driven by repeated dose toxicity via inhalation.

discussed above don't contain any Benchmark 1 chemicals due to environmental hazards, their formulations are poorly disclosed and it is unknown if the undisclosed ingredients contain Benchmark 1 chemicals with environmental hazards. Based on the relatively lower percentage of Benchmark 1 chemicals by weight and complete formulation disclosure, ToxServices considered this paint to be most favorable and included it for subsequent analysis.

The binning of the paint formulations is summarized in Table 9 below. Compared to the copper antifouling paint, one alternative paint formulation was considered to be unfavorable, four were considered to be less favorable, and one was considered to be favorable with respect to hazard. The less favorable and favorable paint formulations were included for subsequent analysis.

Table 9: Categorization of Seven Paint Formulations by Hazard

AA Category	Paint Formulation	Rationale
Unfavorable	Klear N' Klean Plus XP-A101 White Topcoat	Highest human health hazards[1]
Less favorable	Intersleek 900 System	Less human health hazards, no known environmental hazards, poorly characterized formulation
	XZM480 International	Less human health hazards, no known environmental hazards, poorly characterized formulation
	BottomSpeed TC Base Coat/Top Coat Clear	Less human health hazards, less environmental hazards, poorly characterized formulation (top coat)
	Hempasil XA278	Less human health hazards, no known environmental hazards, poorly characterized formulation
Favorable	Surface Coat Part A – Black	Less human health hazards, less environmental hazards, relatively completely characterized

[1]Defined as having the highest percentage by weight of Benchmark 1 and/or LT-1 chemicals due to human health hazards.

One significant challenge to the Hazard Module is the incomplete disclosure of formulations. While some paints were considered more favorable compared to others based on the above evaluation in terms of the percent weight of GreenScreen® Benchmark 1 chemicals present, it is not clear if undisclosed chemicals in the favorable and less favorable formulations selected for further evaluation may be Benchmark 1 chemicals. For example, the formulation of the tie coat (i.e., primer) used for Intersleek 900 is not disclosed while only up to 45% of the top coat (i.e., paint) formulation is disclosed (Table A-3). Additionally, it is not clear if the formulation provided for XZM480 includes the primer/tie coat or other coatings required for its function, and only up to 46% of the formulation is disclosed (Table A-4). The MSDS for Hempasil XA278 also disclosed only three ingredients composing up to 21% of the formulation, and it is also not clear if the formulations for the primer/tie coat or other coatings are included (Table A-6). The formulation available for Surface Coat Part A – Black does not appear to include the formulation for the primer/tie coat or other coatings, and it is unknown if other coatings are necessary for application or are intended to be used in conjunction with one another (Table A-7). In addition to these incomplete disclosures, the ingredients disclosed were all listed in percentage ranges, which, in some cases, significantly affected the accuracy of this assessment, thus hampering a meaningful hazard comparison among formulations. The current hazard assessment was based on the percentage of Benchmark 1 chemicals present in the formulation by weight, and formulations with a higher level of disclosure may be penalized for this reason.

Performance Evaluation Module

The IC2 Guide (IC2 2013) described three levels of evaluation for the Performance Evaluation Module. According to the project proposal (ToxServices 2014e), ToxServices conducted the performance assessment at Level 1, the lowest level: "Basic performance evaluation: identifies a few, very basic questions about whether the alternative performs the required function in the product. This level uses qualitative information readily available from manufacturers and other sources to evaluate alternatives." The Level 1 evaluation involves consideration of the performance requirements at the chemical, product, and process level, and, if available, a review of existing use history and performance data for the alternatives. Based on available use and performance data, the alternatives are qualitatively compared to the chemical (or formulation) of concern as well as to the performance requirements to ensure that the alternatives are technically feasible. Recommendations from authoritative bodies are also considered in the Level 1 evaluation. Favorable alternatives should fulfill all performance requirements and perform comparably to the current chemical (or formulation). In comparison to the Level 1 assessment, the Level 2 performance assessment is a quantitative assessment of existing data, and Level 3, the highest level of assessment, is a quantitative assessment of specified and validated tests.

Antifouling paints are used to protect the hulls of marine vessels from excessive fouling, which can damage the hull, impact fuel efficiency, speed, and maneuverability, and create safety problems (CalEPA (2011), U.S. EPA (2011)). Current marine antifouling paints function by releasing a controlled amount of copper, which is toxic to aquatic organisms, in order to repel and control growth. In contrast, the potential nonbiocide alternatives are based on silicon compounds or fluoropolymers, and formulations are designed to function by creating a smooth surface to which organisms cannot attach. Regardless of the mechanism of action, favorable alternatives must adequately prevent marine fouling on boat hulls.

Though not commonly in use, several nonbiocide alternatives to copper paint have been developed in recent years. Their performance has been previously evaluated extensively by CalEPA and U.S. EPA in order to determine the feasibility of these formulations as alternatives to copper biocide paints (CalEPA (2011), U.S. EPA (2011)). ToxServices performed a Level 1 performance evaluation using this existing performance data. However, performance data are not available for the copper antifouling paint. This is likely due to the prior experience of study personnel with copper antifouling paints and cost considerations. Therefore, the alternatives could not be compared with respect to the existing copper formulations and were instead evaluated only against performance requirements of antifouling paints. As described in the IC2 Guide, ToxServices identified only those formulations that were viable alternatives based on performance (i.e., adequately prevented marine fouling) as favorable alternatives.

The performance of nonbiocide boat paints was evaluated using a tiered approach with a protocol developed by U.S. EPA and CalEPA. Tier 1 is panel test and tier 2 is boat hull test. Relevant data are briefly summarized below. ToxServices presented data from both the U.S. EPA and CalEPA reports for a more robust performance evaluation.

Tier 1 – Panel Test

Tier 1 is a panel test in which three fiberglass panels were installed side-by-side in a polyvinylchloride frame and submerged in the sea for 4 months or 1 year (two formulations were assessed for 4 months (tested by U.S. EPA (2011)) and the other formulations were assessed for 1 year using an extended protocol (tested by CalEPA (2011) to be more predictive of how the paints could perform on boats). The first panel served as the control, the rest two panels were painted with the product under evaluation. One of the test panels (middle panel) was cleaned every 3 weeks to mimic standard hull cleaning practices and the other test panel was cleaned from every 3 weeks to 8 weeks according to the paint manufacturer's instructions. The panels were evaluated at 3-week intervals and rated for fouling, cleaning and coating conditions (CalEPA 2011). An example of the panel setup and testing result is shown in Figure 9, below. Only best-performing paints were selected for tier 2 testing: boat testing (details described below).

Figure 9: Example of Panel Test Setup

All five paints that were considered as favorable or less favorable following the Hazard Module assessment performed well in the Tier 1 panel test, and they were selected to be further tested in boat hull tests. Intersleek 900 and BottomSpeed TC Base Coat/Top Coat Clear (referred to as BottomSpeed in the CalEPA (2011) report and PropSpeed in the U.S. EPA (2011) report[19]) were tested by the U.S. EPA (2011) for 4 months. Both products were rated "good" (the best rating) for performance with and without cleaning. They were the best-performing products in a total of 46 paints tested (U.S. EPA 2011). XZM480, Hempasil XA278, and Surface Coat Part A – Black (also referred to as SherRelease in the CalEPA (2011) report) were evaluated among 18 paints by the CalEPA for an extended period of 1 year at a later time. XZM480 is a modified version of Intersleek 900. It performed well except that the coating was very soft and easily scratched. The manufacturer developed a hardener later to improve the durability of the coating for Tier 2 testing. Hempasil XA278 was rated the best-performing paint in the panel testing conducted by CalEPA. Surface Coat Part A – Black also performed well in the panel testing (CalEPA 2011).

[19] In the U.S. EPA (2011) report, PropSpeed was tested. BottomSpeed is a slightly reformulated version of PropSpeed by the same manufacturer (CalEPA 2011).

Tier 2 – Boat Hull Test

The Tier 2 Boat Hull Test involved real-life testing of selected paints that performed well in the tier 1 test. In the study conducted by U.S. EPA (2011), volunteer boat owners were recruited and each paint was applied to one or two boats. Periodic inspections of the coatings included an underwater pre-cleaning assessment, underwater cleaning and a cleaning assessment, and an underwater post-cleaning assessment. Amount of fouling present, its location on the boat hull, the types of fouling, the level of cleaning effort, and the test coating condition were evaluated. This test lasted 16 to 20 months and included two summers. Of the five paints that were considered favorable or less favorable in the hazard assessment module, only two were tested in tier 2 in the U.S. EPA report. In the U.S. EPA report, Intersleek 900 was tested on two boats and inspected for 12 or 19 months. It was rated "good" for all parameters tested. PropSpeed (an earlier version of BottomSpeed TC Base Coat/Top Coat Clear) was removed from the study after only 2 months of testing due to delamination of the boat (U.S. EPA 2011).

All five paints were tested on the boats in the CalEPA report. CalEPA (2011) conducted boat hull tests using the protocol developed in the U.S. EPA (2011) report on all five of the less favorable and favorable boat paints: Intersleek 900 (2 boats), XZM480 International (1 boat without hardener and 1 boat with hardener), BottomSpeed TC Base Coat/Top Coat Clear (3 boats), Hempasil XA278 (1 boat), and Surface Coat Part A – Black (SherRelease, 1 boat). They were evaluated for 2-20 months. When the paints performed poorly, their boat tests were terminated early. The pre-application conditions/requirements and methods of application are summarized in Table 10 below.

Table 10: Boats and Application Methods in the Boat Hull Test

Paint Formulation	Pre-application Hull Treatment	Application Method
Intersleek 900 System	Stripped	Sprayed
	Over copper antifouling paint	Rolled
XZM480 International	Stripped	Rolled
XZM480 International with hardener	Over copper antifouling paint	Rolled
BottomSpeed TC Base Coat/Top Coat Clear	Half stripped, half over copper	Rolled
	Over copper	Rolled
	Unpainted	Rolled
Hempasil XA278	Stripped – sodium bicarbonate	Rolled
Surface Coat Part A – Black	Stripped – sodium bicarbonate	Sprayed

Intersleek 900 performed well with and without stripping and was expected to last 10 years before reapplication. XZM480 International performed well, but the paint was soft, which required a long time to cure in cold and damp weather. In addition, the coating was damaged by rubbing against the dock. The paint was tested with a hardener added and applied over copper antifouling paint on another boat. However, peeling of the paint was again observed, despite the good performance with antifouling. TC Base Coat /Top Coat Clear performed very well with and without stripping on all three boats. Hempasil XA278 and Surface Coat Part A – Black both performed well. The coating of Surface Coat Part A – Black was somewhat uneven due to the method of application (i.e., sprayed on rather than rolled on), but the performance was not affected. In conclusion, with the exception of XZM480, all other paints performed well. As summarized in Table 11, ToxServices removed the XZM480 International from further analysis due to poor performance because although the paint displayed good antifouling properties, a paint that peels from the boat surface will not ultimately be successful at preventing fouling. The other four formulations performed adequately in both panel and hull testing, and were considered to be technically feasible and thus favorable alternatives in terms of performance. As stated previously, the paint formulations could not be compared to the copper paint due to the lack of performance data for this formulation.

Table 11: Categorization of Five Paint Formulations by Performance

AA Category	Paint Formulation	Rationale
Unfavorable	XZM480 International	Peeling
Favorable	Intersleek 900 System	Performed well in panel testing and boat hull testing
	BottomSpeed TC Base Coat/Top Coat Clear	
	Hempasil XA278	
	Surface Coat Part A – Black	

Cost and Availability Module

The purpose of the Cost and Availability Module is to evaluate the cost and availability of potential alternatives. The IC2 Alternatives Assessment Guidance identifies four levels of evaluation and an advanced review (IC2 2013). According to the scope of work (ToxServices 2014e), ToxServices is to conduct a Level 1 (basic) assessment of cost and availability by asking "a few, very basic questions about whether the alternative is being used in cost competitive products. If yes, the alternative is considered feasible". The IC2 Guide provided the following two questions for consideration:

1. "Is the alternative currently used in the application of interest?"
2. "Is the alternative currently offered for sale for the application of interest? Is the price of the alternative close to the current?"

While the above questions seem to instruct the assessors to compare the cost of the alternatives (i.e., soft nonbiocide paints) to the current product/chemical (i.e., copper antifouling paint), ToxServices also made an attempt to compare the costs among the alternatives.

Of the four remaining paints under consideration, Hempasil XA278 is no longer commercially available (ToxServices 2014d). The other three boat paints appear to be currently in use and for sale[20]. The cost associated with Intersleek 900 and BottomSpeed TC Base Coat/Top Coat Clear were evaluated in comparison with copper antifouling paint (U.S. EPA (2011), CalEPA (2011)), but cost information on the other boat paint, Surface Coat Part A – Black is not available. There are two types of costs associated with boat paints: the paint job cost and the maintenance cost. They are discussed separately below.

[20] Determining whether the paints evaluated in this Project were still commercially available was a challenge. Therefore, if current availability could not be determined, a paint was considered available if it was commercially available at the time it was evaluated in the CalEPA (2011) and U.S. EPA (2011) reports. In an official Alternatives Assessment (versus a pilot, such as this), alternatives with unknown current commercial availability would be eliminated as viable alternatives.

Paint Job Cost

Copper paints are reapplied by rolling over previous coats of paint every 2-3 years and stripped after three or four paint jobs (sometimes up to 15 years). Alternative soft nonbiocide paints are more expensive than copper paint (~$575/gallon vs $150/gallon, respectively). Suppliers of nonbiocide paints recommend the copper paints be stripped initially and the nonbiocide paints can be applied over themselves in subsequent paint jobs. These paints can last 5 to 10 years before reapplication. Some of the suppliers recommend that the nonbiocide paints be sprayed on to the hull because a smooth surface prevents attachment of fouling (CalEPA 2011). Paint stripping is costly ($1,000-$1,800 for a 30 foot boat) and spray painting is more expensive than roll painting ($20 more per foot than rolling). Further, a tie coat is required between the primer and the topcoat for soft nonbiocide paints. Therefore, the paint job cost with nonbiocide paints is much higher than that with copper paints due to the higher cost of spray painting. However, all of the manufacturers of the three remaining paints evaluated in this report did not recommend spray painting. Intersleek 900 was recommended to be brushed or sprayed, BottomSpeed TC Base Coat/Top Coat Clear was recommended to be rolled or brushed, and Surface Coat Part A – Black was recommended to be brushed, rolled or sprayed. Further, in the previously mentioned boat hull testing, Intersleek 900 performed equally well with and without stripping, and stripped and rolled. Therefore, the cost of paint job may be reduced by rolling over copper paints, although it is not clear how long these coatings can last when applied this way. The CalEPA report estimated the annualized paint job cost of alternative nonbiocide boat paints and of copper paint, and the results can be found in Table 12, below (CalEPA 2011).

Table 12: Annualized Paint Job Costs (Rolled, no Stripping)

Paint Formulation	Paint Life[21]	Average Cost Per Year
Copper Paint	2 years	$540
BottomSpeed TC Base Coat/Top Coat Clear	5 years	$691
	10 years	$345
Intersleek 900	5 years	$472
	10 years	$236

The table above shows that if the nonbiocide paints are applied directly over copper paints by rolling, the annualized cost is comparable to, if not less than, that that for copper antifouling paint. The annualized paint job cost of Intersleek 900 is slightly lower than that for BottomSpeed TC Base Coat/Top Coat Clear. The cost associated with Surface Coat Part A – Black is unknown, but because it is also a soft nonbiocide paint, the methods of application and the associated cost may be similar to that of BottomSpeed TC Base Coat/Top Coat Clear and Intersleek 900.

Maintenance Cost

The second type of cost is maintenance (i.e., cleaning the hull). Nonbiocide alternatives to copper paint require more frequent cleaning. In CalEPA's analysis report (2011), only Intersleek

[21] The paint life of copper alternatives were estimated to be 5-10 years based on industries experiences and no paint-specific lives are available. Therefore, annualized costs were calculated both based on 5-year and 10-year paint lives (CalEPA 2011).

900 was evaluated in comparison with copper paint for maintenance, as summarized in Table 13, below (Table 4-2 from CalEPA (2011)). However, another soft nonbiocide paint not evaluated in this Alternatives Assessment was also included in the analysis and had exactly the same estimated maintenance cost as Intersleek 900. Therefore, ToxServices assumes that the maintenance cost of Surface Coat Part A – Black and BottomSpeed TC Base Coat/Top Coat Clear will have maintenance costs similar to Intersleek 900, which is roughly comparable to the cost of copper paint.

Table 13: Average Annual Maintenance Cost	
Paint Formulation	**Annual Maintenance Cost**
Copper Paint	\$593-\$930
Intersleek 900	\$653-\$990

In conclusion, comparison among Intersleek 900, Surface Coat Part A – Black and BottomSpeed TC Base Coat/Top Coat Clear cannot be performed because the cost information is only available for Intersleek 900 and partially available for BottomSpeed TC Base Coat/Top Coat Clear. However, information is available to compare the cost of these soft nonbiocide paints in general with that of copper antifouling paints. Soft nonbiocide paints are more expensive than copper paint per gallon; however, they last longer, and the maintenance costs are similar. If the soft nonbiocide paints are applied by spraying over stripped boat hull, as recommended by the paint manufacturers, the overall cost of these alternative paints is thousands of dollars higher than copper paints. Initial boat hull testing by CalEPA suggested that the soft nonbiocide paints performed equally well when applied using traditional methods (i.e., rolled on, no stripping). If the soft nonbiocide paints are directly rolled over copper paint, instead of sprayed on stripped boat hull, the overall costs are comparable to copper paints. Although more testing is needed to fully verify the performance of alternative paints applied using traditional approaches, this evaluation at least showed that there is a potential for alternative soft nonbiocide boat paint to be comparable to copper paints regarding overall cost. Therefore, with the exception of Hempasil XA278, which is no longer on the market, the rest of the three paints under evaluation are "favorable" when reviewed against the Cost and Availability Module and were included in subsequent analysis. The results of the cost and availability evaluation are summarized in Table 14, below.

Table 14: Level 1 Cost and Availability Analysis Results			
Paint Formulation	**Q1: Currently in Use?**	**Q2: Available for Sale and Comparable to Copper Paints in Price?**	**AA Category**
Hempasil XA278	N	N	Unfavorable
Intersleek 900 System	Y	Y (Potentially)	Favorable
BottomSpeed TC Base Coat/Top Coat Clear	Y	Y (Potentially)	
Surface Coat Part A – Black	Y	Y (Potentially)	

Exposure Assessment Module

The purpose of the Exposure Assessment Module is to identify alternatives with the lowest risk potential and remove those with serious exposure concerns from further consideration. The IC2 Guide (IC2 2013) introduced five levels of exposure assessment: Initial Screen, Level 1, Level 2, Level 3 and advanced approach. According to the scope of work, ToxServices is to conduct up to Level 1 exposure assessment (ToxServices 2014e). This includes an Initial Screen and Level 1 assessment (if necessary). The purpose of Initial Screen is to determine if exposure assessment is necessary by evaluating if there are sufficient similarities between the chemical (or product) of concern and potential alternatives. If exposure assessment is deemed necessary, Level 1 assessment will be performed, which is a qualitative assessment using readily available data to identify exposure concerns and potential solutions (IC2 2013).

Initial Screen

The Initial Screen step is performed to determine if an exposure assessment is necessary by comparing exposure pathways and potentials. First, exposure pathways are compared among alternatives based on their relevant physical-chemical properties, such as vapor pressure, molecular weight, partition coefficient, pH and use characteristics (binding properties) or synergistic effects. At the product level, specific physical-chemical properties of the three remaining soft nonbiocide paints and the copper antifouling paint (as a control for comparison) are not available. Nevertheless, general physical-chemical properties are known. For example, both the copper paint and the three soft nonbiocide paints contain considerable amounts of petroleum based solvents that are likely volatile. However, after the coatings are fully cured, no further volatilization is expected. Further, both copper paint and soft nonbiocide paints are hydrophobic by design to function effectively as boat antifouling coatings.

Next, manufacturing criteria are compared between the chemical of concern and alternative, including the functions performed, the relative amounts used and the manner of their uses (e.g., blended vs. chemically attached) (IC2 2013). The mechanisms of action of the copper antifouling paints and nonbiocide soft paints were considered to qualitatively determine the relative use amounts and manners. Copper antifouling paints control fouling by steadily releasing the biocide copper into the surrounding water by diffusion or by ablation. For this reason, copper paints are to be reapplied every two to three years. Soft nonbiocide paints do not contain any “active ingredients”. Commonly referred to as foul release coatings, they are typically formulated with silicon compounds that impart the hull surfaces too slippery for fouling organisms to attach. Therefore, these paints have a longer life (5-10 years) (U.S. EPA 2011). Based on the low frequency of reapplication, soft nonbiocide paints seem to have a lower environmental exposure potential (and occupational exposure potential for workers applying the paints) compared to copper paints.

Different from copper paints, soft nonbiocide coatings often require more layers of paint, such as primers, tie coats and topcoats (U.S. EPA 2011). Intersleek 900 consists of a primer, a top coat and a tie coat (International Paint 2013). Insufficient information is available for BottomSpeed TC Base Coat/Top Coat Clear, but the name and MSDS suggest that it has at least a base coat and a top coat. Limited information is available for Surface Coat Part A – Black, but it at least needs a tie coat before applying the top coat (FujiFilm 2007). The application thickness of copper paints is 3.6 mils (i.e., 91 microns, wet) or 2 mils (i.e., 50.8 microns, dry), while the thickness of soft nonbiocide paints is 3-4 times higher: 203-270 microns (wet) or 150-200 microns (dry) for Intersleek 900, and 200 microns (wet) or 152 microns (dry) for Surface Coat Part A – Black (Sherwin-Williams 2011, FujiFilm 2007). The thickness of BottomSpeed TC Base Coat/Top Coat Clear is not available. Therefore, although the soft nonbiocide paints are reapplied less frequently than copper paints as discussed above in step 1, these coatings are thicker, meaning that more paint is applied each time. Consequently, the total amount used over the life-time of a boat cannot be directly compared between copper paint and soft nonbiocide alternatives based on available information. Among the remaining three alternatives, the relative amount applied may be similar, based on the available data on Intersleek 900 and Surface Coat Part A – Black, as they are all silicon-based paints and have similar antifouling mechanisms, manners of application, and use patterns. There is insufficient information available to perform a detailed comparison of the exposure of the three soft nonbiocide paints Intersleek 900, BottomSpeed TC Base Coat/Top Coat Clear, and Surface Coat Part A – Black to the exposure of the copper based paint.

The third step is to compare the fate, transport and environmental partitioning of the chemical of concern and alternatives (IC2 2013). The IC2 Guide does not provide guidance on how to evaluate fate, transport, and partitioning of formulations. For example, it is unclear whether fate, transport, and partitioning characteristics should be evaluated for the formulation as a whole or for chemical components that may leach from the cured paint formulation. Copper, the active ingredient of copper antifouling paints, is expected to be slowly released into the water surrounding the boats. The solubility of cuprous oxide, the most commonly used active ingredient in copper paints that is highly toxic to aquatic organisms, is so low that it is often considered practically insoluble (HSDB 2003). Cuprous oxide is released from the boat by diffusion (U.S. EPA 2011), albeit at very low concentrations due to low water solubility. It can dissociate in saltwater, producing Cu^{2+} ions that may adsorb to dissolved molecules or particulate matter and tend to accumulate in sediment upon settling (Kiaune and Singhasemanon 2011).

The nonbiocide alternatives do not contain active ingredients and are not designed to be functional by leaching the coating components into the environment. While it is possible that leaching of some chemicals may occur over time, no studies have investigated this possibility. Therefore, ToxServices focused the fate, transport, and partitioning evaluation of the nonbiocide alternatives on the formulation as a whole. These silicon-based paint formulations are eventually worn off by water and through routine cleaning. The paints, in the form of cured paint flakes and particles, are expected to be hydrophobic and, hence, not soluble in water. Therefore, soft nonbiocide paints are expected to eventually, and mainly, partition to the sediment after fully curing on the surface of boat hulls based on their low solubility in water and low volatility.

Based on a qualitative assessment, neither copper (inorganic) nor silicon (inorganic or polymer) paint formulations are expected to be environmentally transformed in a manner that may affect their environmental exposure potential. Therefore, the fate, transport and environmental partitioning are expected to be comparable between copper paints and nonbiocide alternatives, and among the nonbiocide alternatives..

In the fourth step, the release mechanisms for the chemical of concern and the potential alternatives are compared during different stages of the life cycle (i.e., product use, manufacturing, transport and end-of-life) (IC2 2013).

- Manufacture and transport: No information could be identified regarding the method of manufacture and potential release mechanisms of these boat paints. The release potential during transportation is not expected to differ among the boat paints as transportation methods for all paints are expected to be similar.
- Product Use: Both copper-based and nonbiocide paints have the potential for release during application and during use. During the coating process, the copper paint can be applied with a brush, roller (Pettit Marine Paints 2013), airless or conventional spray, but the typical method of application is rolling due to low cost (U.S. EPA 2011). The Intersleek 900 system is recommended to be applied with a brush or airless spray (International Paint 2013), but performance tests indicated that it worked well when rolled on instead of sprayed on (U.S. EPA 2011). BottomSpeed TC Base Coat/Top Coat Clear can be applied with a roller (Brunetti 2012). Surface Coat Part A – Black is applied with a brush, roller or airless spray (FujiFilm 2007). Based on the information above, the method of application among the boat paints can be similar. Spraying (usually recommended for soft nonbiocide paints (CalEPA 2011)) is associated with higher occupational inhalation exposure compared to brushing and rolling (copper paints). Workers can wear personal protection equipment (gloves, uniform that covers skin, and masks) during the application process to reduce exposure, but this may not be the case in every boatyard, as shown in the photos in the CalEPA (2011) report. In addition, although boat yards cover/encapsulate the painting area where spray painting occurs to prevent the paints from being sprayed onto other boats (CalEPA 2011), it is not clear how the working area is cleaned afterwards and other workers and consumers in the boat yards may be exposed by inhalation and skin contact. As mentioned previously, more paint is needed to coat the same area for soft nonbiocide paints compared to copper paints, as the latter requires more layers (primer, tie coat, etc.) to obtain a thicker coating. However, these paints are applied less frequently compared to copper paints. Therefore, the overall occupational exposure potential during coating may not differ significantly between copper paint and soft nonbiocide paints, and among soft nonbiocide paints. Regarding release to the environmental during use, copper from copper paint is designed to be released into the surrounding environment and hence copper paints are reapplied every 2-3 years. Paint is also worn off into the water during routine cleaning. Soft nonbiocide paints under evaluation are not designed to be released from the boat hull. However, more paint is applied initially and it will eventually wear off requiring reapplication every 5-10 years. Therefore, it is not obvious that exposure associated with the copper antifouling paint and soft nonbiocide paints differ significantly, but available information is limited to draw a definitive conclusion.
- End-of-Life: As discussed previously, both copper antifouling paint and soft nonbiocide paints will eventually wear off from the boat hulls and most likely mainly partition to the sediment based on their low solubility. The release mechanism during end-of-life is expected to be similar among these paints due to comparable use patterns.

The fifth step involves determining if there are any substantive differences between the use and physical characteristics that could affect exposure, based on the above evaluation (IC2 2013).

Overall, although copper based paints are reapplied more frequently than nonbiocide paints, the amount of paint used each time is less compared to soft nonbiocide alternatives. A quantitative comparison between copper paints and alternatives is not possible due to lack of information regarding the amount of paints required to cover a boat during each application. A qualitative evaluation of environmental and human exposure potentials through various stages of the boat paints' life cycle above indicate that there are no clear substantive differences between copper based paints and soft nonbiocide paints, and among the three soft nonbiocide paints. Therefore, ToxServices considered the exposure assessment to be complete and the Level 1 exposure assessment was not performed. As the Level 1 exposure assessment was not performed, none of the paint formulations were eliminated in this assessment module.

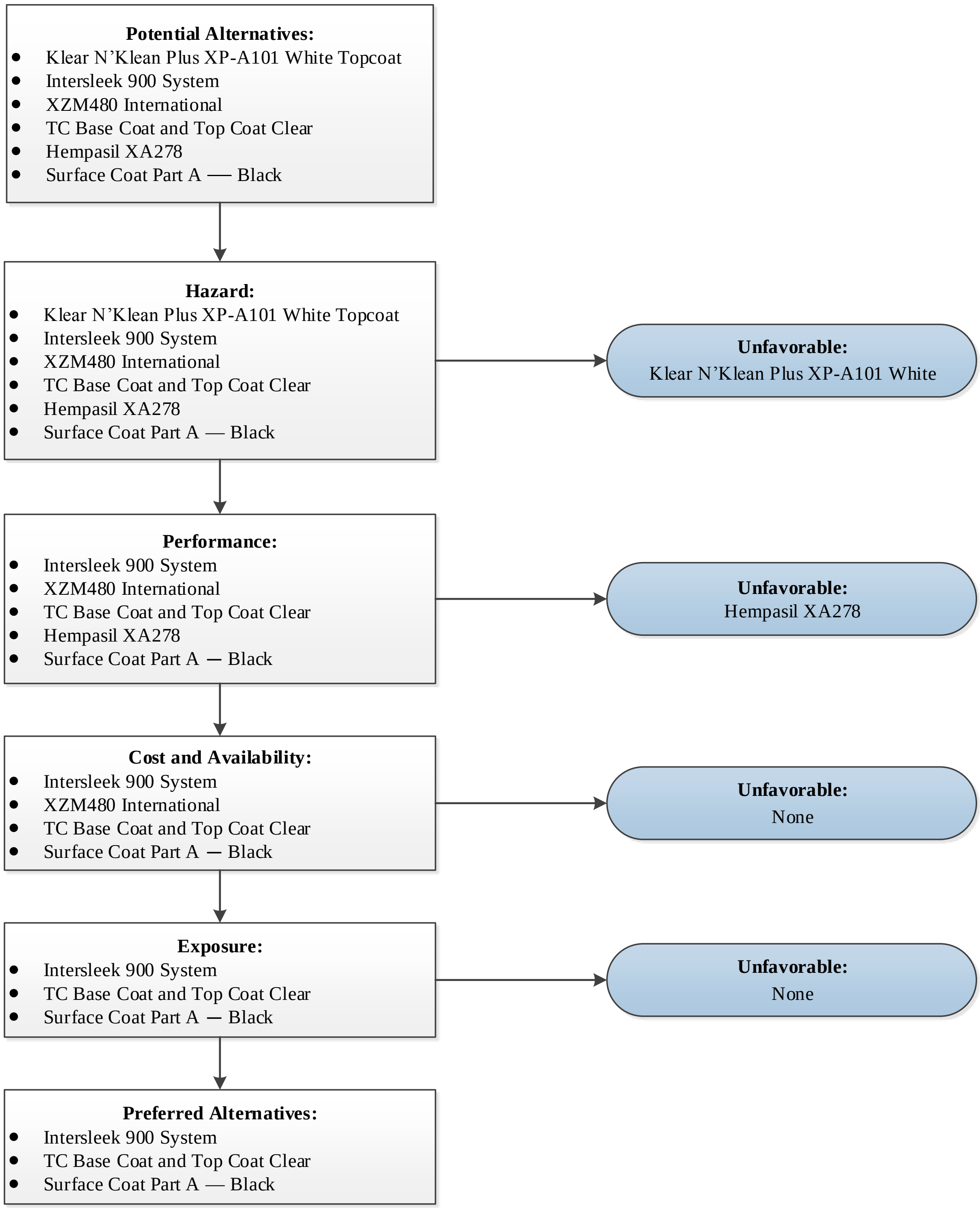
Level 1 Exposure Assessment

Overall, the Initial Screen of the exposure assessment screening revealed that, based on available information, there is not likely to be a substantive difference between the exposure potential of copper based paints and soft nonbiocide paints. Additionally, it is not likely that there will be a significant difference in exposure when comparing the three remaining soft nonbiocide alternative paints to one another. As a result, a Level 1 exposure evaluation was not performed.

Conclusion of Task 2

ToxServices evaluated seven paint formulations including one copper paint and six soft nonbiocide alternative paints using the Sequential Framework described in the IC2 Guide (IC2 2013) as summarized in Figure 10, below.

Figure 10: Summary of IC2 Sequential Framework Assessment Results



The copper antifouling paint that was used as a "control" was Pettit Marine Paint Trinidad Pro Antifouling Bottom Paint 1083 Blue, and the six alternatives were Klear N' Klean Plus XP-A101 White Topcoat, Intersleek 900 System, XZM480 International, BottomSpeed TC Base Coat/Top Coat Clear, Hempasil XA278, and Surface Coat Part A – Black.

Following the Hazard Module assessment, Klear N' Klean Plus XP-A101 White Topcoat was eliminated due to high human health hazard. The Performance Evaluation Module revealed that all paint alternatives generally performed comparably, both to the copper antifouling paint and among the alternatives; however, the XZM480 International Paint was eliminated from further evaluation due to peeling. When the remaining paints were evaluated under the Cost and Availability Module, the costs were comparable to the copper antifouling paint. Additionally, all paints except the Hempasil XA278 paint were available; therefore, the Hempasil XA278 was eliminated as a potential alternative following the application of the Cost and Availability Module. The final module implemented was the Exposure Assessment Module, and the results of that module indicated that the remaining alternatives are not expected to differ from the copper antifouling paint in terms of exposure. The results of each Module are summarized in Table 15.

Table 15: Task 2 Module Summary

Module	Paint Formulation	Recommendation	Rationale
Hazard	Klear N' Klean Plus XP-A101 White Topcoat	Unfavorable	Highest human health hazards
	Intersleek 900 System	Less Favorable	Less human health hazards, no known environmental hazards, poorly characterized formulation
	XZM480 International		
	Hempasil XA278		
	BottomSpeed TC Base Coat/Top Coat Clear		Less human health hazards, less environmental hazards, poorly characterized formulation (top coat)
	Surface Coat Part A – Black	Favorable	Less human health hazards, less environmental hazards, relatively completely characterized
Performance Evaluation	XZM480 International	Unfavorable	Peeling
	Intersleek 900 System	Favorable	Performed well in panel testing and boat hull testing
	BottomSpeed TC Base Coat/Top Coat Clear		
	Hempasil XA278		
	Surface Coat Part A – Black		
Cost and Availability	Hempasil XA278	Unfavorable	Not currently in use; not commercially available
	Intersleek 900 System	Favorable	Currently in use; commercially available; costs comparable (potentially) to copper antifouling paint
	BottomSpeed TC Base Coat/Top Coat Clear		
	Surface Coat Part A – Black		
Exposure Assessment	Intersleek 900 System	Favorable	Exposure expected to be similar to copper antifouling paint
	BottomSpeed TC Base Coat/Top Coat Clear		
	Surface Coat Part A – Black		

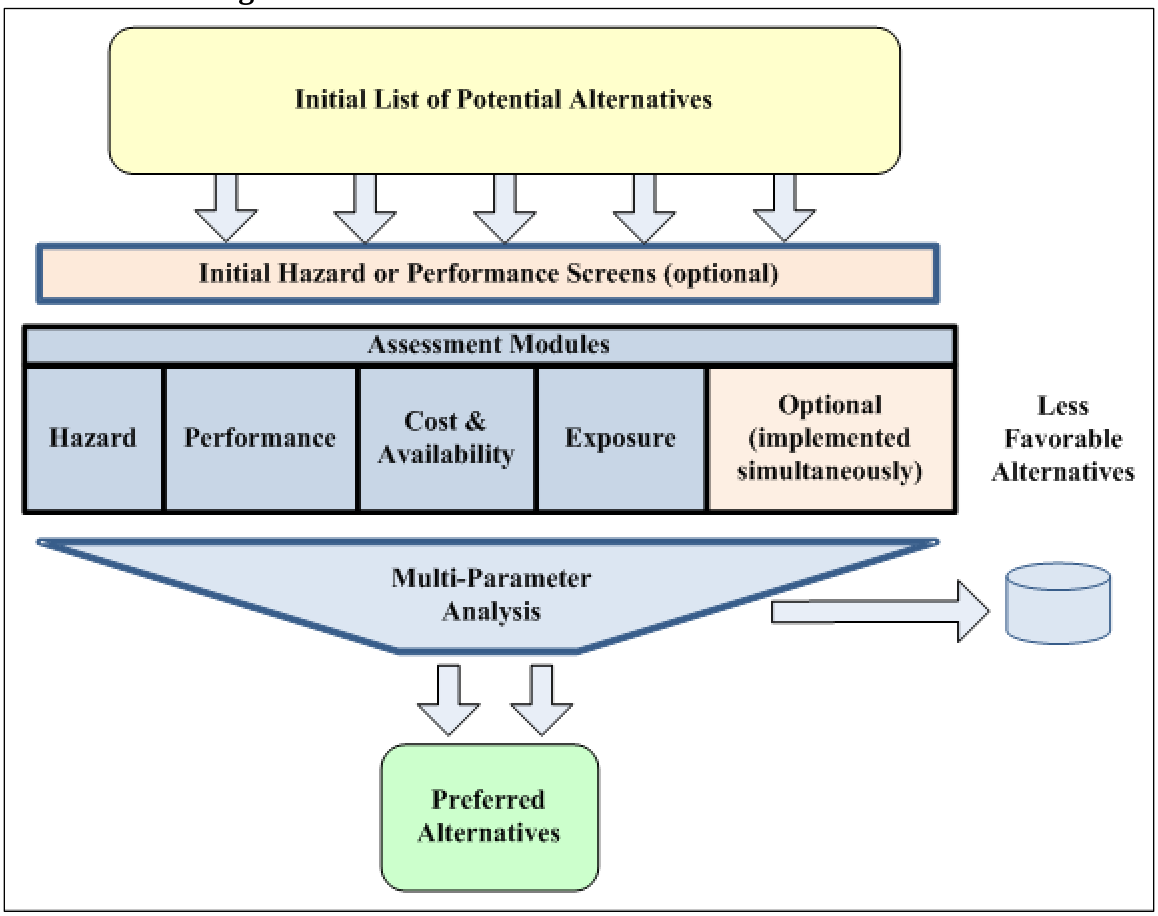
As a result of the Sequential Framework Alternatives Assessment performed under Task 2 of this Project, Intersleek 900, BottomSpeed TC Base Coat and TC Top Coat Clear and Surface Coat

Part A – Black are considered preferred alternatives based on their hazard profiles, performance, cost and availability, and exposure potential.

ALTERNATIVES ASSESSMENT USING THE IC2 SIMULTANEOUS FRAMEWORK CONDUCTED BY ABT ASSOCIATES (TASK 3)

In the Simultaneous Framework, data were collected on the paint formulations using each of the four core modules: Hazard, Performance Evaluation, Cost and Availability, and Exposure Assessment. Once data were collected, the assessors established and applied a weighting system to the data to select a preferred alternative. An overview of the process is shown in Figure 11.

Figure 11: Overview of IC2 Simultaneous Framework



Source: IC2 (2013)

Hazard Module

The main objective of the Hazard Module is to determine what hazard concerns exist for the control paint and the six soft nonbiocide alternatives.

Hazard Evaluations

The Hazard Module in the IC2 Guide provides detailed guidance on performing hazard evaluations. ToxServices conducted hazard evaluations on the seven paint formulations under Task 1 and presented results in the Uniform Data Set. ToxServices performed a series of increasingly detailed hazard analyses of all chemicals in the control and alternative paint formulations to create the Uniform Data Set using the following steps:

- Step 1: Apply GreenScreen® List Translator
- Step 2: Perform GreenScreen® Chemical hazard assessment based on GreenScreen® methodology
- Step 3: Expand hazard assessment based on GreenScreen® methodology

Results and Decision-Making within the Hazard Module

The IC2 Guide does not prescribe a decision-making approach within the Hazard Module after GreenScreen® Benchmark scores are established under Steps 1-3 described above. The example given on p.77 of the IC2 Guide assumes that two chemical alternatives receive Benchmark 4 scores, and therefore undergo further evaluation under the given framework being applied. This poses two key challenges for this assessment because:

- The IC2 Guide does not prescribe or address product-level assessments. It is written from the perspective of performing a single chemical hazard assessment.
- No guidance is provided for scenarios where there are no easily identified preferred alternatives. In the absence of alternatives with higher Benchmark scores, how should the hazards of alternatives with the same benchmark score be further differentiated?

For the purposes of this assessment, a series of decision rules were developed and applied by the assessor to determine a relative ranking of paint formulations. This assessor took the following step-wise approach to determine if preferred alternatives to the control paint exist.

<u>Decision Rule #1: Eliminate alternatives with one or more chemical substances with Benchmark 1 scores.</u>

This step is important to avoid a regrettable substitution to paint formulations containing chemicals with known chemical hazards.

This decision rule eliminates all six alternatives. While the decision analysis could stop here, with the conclusion that all alternatives contain at least one chemical with known hazards and should be avoided, this analysis applied additional decision rules as shown below in an effort to determine if any alternatives are "less hazardous" than the control paint.

Note: The subsequent decision rules are at the assessor's discretion. The IC2 Guide does not provide guidance on how to differentiate alternatives beyond the Benchmark scores provided by GreenScreen®.

<u>Decision Rule #2: Identify alternatives with a lesser percentage of Benchmark 1 chemicals in the overall paint when compared to the control paint, and determine whether any of these paints could be considered "less hazardous" than the control paint.</u>

This step is based on the logic that a paint formulation with a lesser percentage of Benchmark 1 chemicals is more preferable from a hazard standpoint (holding exposure and all other factors equal) than a paint formulation with higher percentage of Benchmark 1 chemicals as part of the overall formulation.

Additional assumptions within Decision Rule #2:

All routes of exposure (inhalation, dermal, and oral) identified in the Uniform Data Set for individual chemicals are important and will be considered. For chemicals with hazard stratified by exposure, any exposure route with a Benchmark 1 score will be included in the overall percentage of Benchmark 1 or equivalent scores in the formulation – even if other exposure routes have higher Benchmark scores. For example, in Table 16 for the control paint, since [REDACTED] is a Benchmark 1 via the inhalation route, its percentage in formulation ([REDACTED]%) will be included in the calculation of total percentage of Benchmark 1 or equivalent chemicals in formulation.

- For alternatives with undisclosed chemicals in the formulation, a "worst-case scenario" in terms of hazard will be assumed:
  - Unidentified chemicals in formulation will be assigned a Benchmark 1 score.
  - Chemicals with Benchmark U scores (hazards unassignable) will be assigned a Benchmark 1 score.
- The percentage of chemicals at the product level that are Benchmark 1 (or equivalent) for alternatives versus control paint will be calculated. Where percentages of any constituents are unknown, a note will be provided with the total calculation. For this approach, the following scores will be treated as equivalent to Benchmark 1 scores.
  - LT-1 (List Translator 1)
  - LT-P1 (List Translator Possible GreenScreen® Benchmark 1)
  - Benchmark 1_{TP} (based on hazards of a chemical's transformation product)
  - Benchmark U (hazards unassignable)
- Finally, the results will be analyzed to determine if one or more alternatives has a lesser percentage of Benchmark 1 chemicals at the product level than the control paint, and how they compare to each other on a hazard spectrum.

Caveat: This approach assumes that Benchmark 1 chemicals are equal in terms of hazard. It does not evaluate toxicity data behind the Benchmark 1 scores to further differentiate Benchmark 1 chemicals on the hazard spectrum, which would take additional time and resources. Given the well-documented environmental hazards of copper antifouling paint, this assessor considered an approach that would compare paint formulations based solely on their environmental hazards in order to identify preferable alternatives. However, this assessor did not adopt this approach believing that a preferable paint formulation should minimize both human health and environmental hazards relative to the control paint.

Table 16 through Table 22 present the chemicals and associated Benchmark scores for each evaluated paint and are compiled based on information presented in the Uniform Data Set. To facilitate the analysis, the chemicals are sorted by Benchmark score (lowest to highest), then percent of each chemical in the formulation (highest to lowest). The total percentage of chemicals with Benchmark 1 or equivalent scores in the formulation is presented at the bottom of each table. For chemicals with hazards stratified by exposure, the exposure route with the lowest Benchmark score (indicated in **bold**) is considered for the total percent calculations.

Table 16: Chemicals[1] and Benchmark Scores for Pettit Marine Paint Trinidad Pro Antifouling Bottom Paint 1082 Blue

CAS#	Chemical name	Percentage of chemical component at the product level	GreenScreen® Benchmark Scores
[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]

Table 17: Chemicals[1] and Benchmark Scores for Klear N' Klean Plus XP-A101 White Topcoat

CAS#	Chemical name	Percentage of chemical component at the product level	GreenScreen® Benchmark Scores
[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]

Table 18: Chemicals[1] and Benchmark Scores for Intersleek 900 System (Primer and Top Coat)

CAS#	Chemical name	Product name	Percentage of chemical component at the product level[2]	GreenScreen® Benchmark Scores	
Not provided	Unknown	Veridian Tie Coat (primer)	Unknown	**Assumed Benchmark 1**	
Not provided	Unknown		Unknown	**Assumed Benchmark 1**	
13463-67-7	Titanium dioxide	Intersleek 970 White Part A (top coat)	10-25%	**Inhalation**	**Benchmark 1**
				Oral	Benchmark 3
				Dermal	Benchmark U
1330-20-7	Xylenes(o-,m-,p-isomers)		1-10%	Benchmark 1	
100-41-4	Ethylbenzene		1-10%	LT-1	
Total percent of Benchmark 1 or equivalent in formulation			**100% of identified formulation is Benchmark 1; assumed that unidentified chemicals are Benchmark 1.**		

[1] 12-45% of formulation identified

[2] The MSDS for each ingredient was used to determine the chemical composition of the ingredient. Not all components of these ingredients were identified on the MSDS, so the percentages may not total 100%.

Table 19: Chemicals[1] and Benchmark Scores for XZM480 International			
CAS#	**Chemical name**	**Percentage of chemical component at the product level**	**GreenScreen® Benchmark Scores**
64742-95-6	Solvent naphtha (petroleum), light aromatic	10-<25%	LT-1
95-63-6	1,2,4-Trimethylbenzene	2.5-<10%	Benchmark 2
108-67-8	1,3,5-Trimethylbenzene	1-<2.5%	Benchmark 2
1185-55-3	Trimethoxy(methyl)silane	1-<2.5%	Benchmark 1_{TP}
2768-02-7	Vinyltrimethoxysilane	1-<2.5%	Benchmark 1_{TP}
128446-60-6	Silsesquioxane, 3-aminopropyl methyl, ethoxy-terminated	1-<2.5%	Benchmark U
67-56-1	Methanol	0-<1%	LT-1
Total percent of Benchmark 1 or equivalent in formulation		**13-87.5% of identified formulation is Benchmark 1; assumed that unidentified chemicals are Benchmark 1**	

[1] 16.5-<46% of formulation identified

<table>
<tr><th colspan="6">Table 20: Chemicals[1] and Benchmark Scores for BottomSpeed TC Base Coat/Top Coat Clear</th></tr>
<tr><th>CAS#</th><th>Chemical name</th><th>Product name</th><th>Percentage of chemical component at the product level[2]</th><th colspan="2">GreenScreen® Benchmark Scores</th></tr>
<tr><td rowspan="3">14807-96-6</td><td rowspan="3">Talc (powder)</td><td rowspan="10">BottomSpeed TC Base Coat</td><td rowspan="3">5-20%</td><td>Inhalation</td><td>Benchmark 1</td></tr>
<tr><td>Oral</td><td>Benchmark 3_{DG}</td></tr>
<tr><td>Dermal</td><td>Benchmark U</td></tr>
<tr><td rowspan="3">14808-60-7</td><td rowspan="3">Crystalline silica</td><td rowspan="3">5-20%</td><td>Inhalation</td><td>Benchmark 1</td></tr>
<tr><td>Oral</td><td>Benchmark 2</td></tr>
<tr><td>Dermal</td><td>Benchmark U</td></tr>
<tr><td>64742-95-6</td><td>Aromatic 100</td><td>5-20%</td><td colspan="2">LT-1</td></tr>
<tr><td>64742-48-9</td><td>Mineral spirits</td><td>5-20%</td><td colspan="2">Benchmark 1</td></tr>
<tr><td>Not provided</td><td>Polychlorinated alkanes</td><td>1-5%</td><td colspan="2">Assumed Benchmark 1</td></tr>
<tr><td>1314-13-2</td><td>Zinc oxide, as Zn (fume)</td><td>1-5%</td><td colspan="2">Benchmark 1</td></tr>
<tr><td>95-63-6</td><td>1,2,4-Trimethyl benzene</td><td></td><td>5-20%</td><td colspan="2">Benchmark 2</td></tr>
<tr><td>1330-20-7</td><td>Xylene</td><td rowspan="8">BottomSpeed Top Coat Clear</td><td>10-30%</td><td colspan="2">Benchmark 1</td></tr>
<tr><td>1185-55-3</td><td>Trimethoxy(methyl)silane</td><td>1-5%</td><td colspan="2">Benchmark 1_{TP}</td></tr>
<tr><td rowspan="3">68909-20-6</td><td rowspan="3">Trimethylated silica</td><td rowspan="3">1-5%</td><td>Inhalation</td><td>Benchmark 1</td></tr>
<tr><td>Oral</td><td>Benchmark 2</td></tr>
<tr><td>Dermal</td><td>Benchmark U</td></tr>
<tr><td>67-56-1</td><td>Methanol</td><td>0.1-2%</td><td colspan="2">LT-1</td></tr>
<tr><td>27858-32-8</td><td>Diisopropoxytitanium bis (ethylacetoacetate)</td><td>0.1-2%</td><td colspan="2">Benchmark 2</td></tr>
<tr><td>Not provided</td><td>Methoxy or monofunctional silane</td><td>0.1-2%</td><td colspan="2">Assumed Benchmark 1</td></tr>
</table>

Table 20: Chemicals[1] and Benchmark Scores for BottomSpeed TC Base Coat/Top Coat Clear				
CAS#	**Chemical name**	**Product name**	**Percentage of chemical component at the product level[2]**	**GreenScreen® Benchmark Scores**
Total percent of Benchmark 1 or equivalent in formulation[3]			**34.2-94.9%**	

[1] 39.3-<156% of formulation identified
[2] The MSDS for each ingredient was used to determine the chemical composition of the ingredient. Not all components of these ingredients were identified on the MSDS, so the percentages may not total 100%.
[3] Since the total percent of Benchmark 2 in formulation is at least 5.1%, the upper bound for the total percent of Benchmark 1 is 94.9%.

Table 21: Chemicals[1] and Benchmark Scores for Hempasil XA278			
CAS#	**Chemical name**	**Percentage of chemical component at the product level**	**GreenScreen® Benchmark Scores**
1330-20-7	Xylene	12.5-15%	Benchmark 1
100-41-4	Ethylbenzene	1-3%	LT-1
Not provided	Modified polysiloxane	1-3%	**Assumed Benchmark 1**
Total percent of Benchmark 1 or equivalent in formulation		**100% of identified formulation is Benchmark 1; assumed that unidentified chemicals are Benchmark 1.**	

[1] 14.5-21% of formulation identified

Table 22: Chemicals[1] and Benchmark Scores for Surface Coat Part A – Black				
CAS#	**Chemical name**	**Percentage of chemical component at the product level**	**GreenScreen® Benchmark Scores**	
7631-86-9	Silica	7-15%	**Inhalation**	**Benchmark 1**
			Oral	Benchmark 3_{DG}
			Dermal	Benchmark U
68083-19-2	Vinyl silicone polymer	3-7%	Benchmark 1	
64742-49-0	Naphtha (petroleum), hydrotreated light	3-7%	LT-1	
68186-94-7	Coating ferrite powder	3-7%	Benchmark 1	
556-67-2	Octamethycyclotetrasiloxane	1-5%	Benchmark 1	
68909-20-6	Amorphous silica (modified)	1-5%	**Inhalation**	**Benchmark 1**
			Oral	Benchmark 2
			Dermal	Benchmark U
70131-67-8	Siloxanes & silicones	50-70%	Benchmark 2	
68083-14-7	Methyl phenyl polysiloxane	7-15%	Benchmark 2	
Total percent of Benchmark 1 or equivalent in formulation[2]			**18-43%**	

[1] 75-131% of formulation identified
[2] Since the total percent of Benchmark 2 in formulation is at least 57%, the upper bound for the total percent of Benchmark 1 is 43%.

Summary of findings presented in Table 23:

- Surface Coat Part A – Black has the lowest percentage of Benchmark 1 chemicals in its formulation compared to the control paint and alternatives.
- BottomSpeed TC Base Coat/Top Clear Coat and XZM480 International could potentially have a lower percentage of Benchmark 1 chemicals than the control paint; however, due to the large ranges of Benchmark 1 chemicals in formulation, it could not be confirmed if these two paints had a lesser percentage of Benchmark 1 chemicals than the copper antifouling paint. Additionally, XZM480 International had undisclosed chemical ingredients, which this assessor assumed to be Benchmark 1 chemicals.
- Two alternatives – Intersleek 900 System and Hempasil XA278 – have roughly equal or potentially greater percentages of Benchmark 1 chemicals in their formulations compared to the control paint. Both alternatives had undisclosed chemical ingredients, which this assessor assumed to be Benchmark 1 chemicals.
- Klean N' Klean Plus XP-A101 White Top Coat has a similar percentage of Benchmark 1 chemicals in its formulation compared to the control paint.

Surface Coat Part A – Black appears to have the most preferable hazard profile on a relative hazard spectrum. However, it includes a significant percentage of Benchmark 1 chemicals as part of its overall formulations (18-43%) and should not be considered an ideal or optimal alternative in comparison to the control paint.

Table 23: Summary of Hazard Evaluation Results

Paint	Total percent of Benchmark 1 or equivalent in formulation
Pettit Marine Paint Trinidad Pro Antifouling Bottom Paint 1082 Blue	[REDACTED]%
Klear N' Klean Plus XP-A101 White Top Coat	[REDACTED]%
Intersleek 900 System (Primer and Top Coat)	100% of identified formulation[1] is Benchmark 1; assumed that unidentified chemicals are Benchmark 1
XZM480 International	13-87.5% of identified formulation[2] is Benchmark 1; assumed that unidentified chemicals are Benchmark 1
BottomSpeed TC Base Coat/Top Coat Clear	34.2-94.9%
Hempasil XA278	100% of identified formulation[3] is Benchmark 1; assumed that unidentified chemicals are Benchmark 1
Surface Coat Part A – Black	18-43%

[1] 12-45% of formulation identified
[2] 16.5-<46% of formulation identified
[3] 14.5-21% of formulation identified

As noted earlier, data gaps in the Uniform Data Set, and the assumptions needed to address them, introduce uncertainty into these results. For example, the Benchmark scores of unidentified chemicals in three paints (Intersleek 900 System, XZM480 International, and Hempasil XA278) are assumed to be Benchmark 1; however, it is possible that few or none of the unidentified chemicals are Benchmark 1, and therefore their hazards have been overestimated. If this information were made available, the above analysis should be revisited to better estimate the relative hazards of these paints.

Performance Evaluation Module

The Performance Evaluation Module is intended to ensure that the assessed alternatives are technically favorable for use as an antifouling boat paint and meet performance requirements. The primary data sources for evaluating the Performance Evaluation Module are the U.S. EPA (2011) report and CalEPA (2011).

The U.S.EPA project evaluated the performance of potential alternatives to copper antifouling paint. The research was conducted in the Port of San Diego over a four month period. The CalEPA project used the same protocol for panel and boat tests as the U.S. EPA project but extended the testing period to one year. Both projects evaluated performance through three types of assessments; fouling, coating, and cleaning.

Table 24 shows which of the paints in the Uniform Data Set were assessed for performance in the U.S. EPA (2011) and CalEPA (2011) reports. Table 24 also provides a comparison between the paint names in the Uniform Data Set and in the U.S. EPA (2011) and CalEPA (2011) reports. Although the names for several paints differ slightly, they are assumed to be the same paints[22].

Table 24: Comparison of Paints and Performance Data in Uniform Data Set, U.S. EPA (2011) Report, and CalEPA (2011) Report

Paints in Uniform Data Set	Performance assessed in U.S. EPA (2011) report?	Performance assessed in CalEPA (2011) report?	Name in U.S. EPA (2011) report	Name in CalEPA (2011) report
Pettit Marine Trinidad Pro Antifouling Bottom Paint	No	Yes	N/A	Trinidad Pro Blue
Klear N' Klean Plus XP-A101 White Topcoat	Yes	Yes	Klear N' Klean	Klear N' Klean Plus XP-A101
Intersleek 900 System	Yes	No	Intersleek 900	Intersleek 900
XZM480 International	No	Yes	N/A	XZM480
BottomSpeed TC Base Coat/Top Clear Coat	No	Yes	N/A	BottomSpeed Topcoat Clear; BottomSpeed TC BaseCoat
Hempasil XA278	No[1]	Yes	N/A	Hempasil XA278
Surface Coat Part A – Black	No	Yes	N/A	Surface Coat Part A – Black (Sher-Release)

[1] Hempasil XA278 is a modified version of Hempasil X3 (87500) which was tested in U.S. EPA (2011) project.

[22] Multiple attempts were made to contact the manufacturers of the paint to obtain formulations; however, the formulations were not disclosed. Therefore, for the purposes of this assessment, the assessors had to assume that the formulations were the same even if the name varied slightly between source documents.

A "No" entry in Table 24 for the U.S. EPA (2011) report is based on the following information:

- Pettit Marine Trinidad Pro Antifouling Bottom Paint 1082 Blue: Was used as the copper control in Uniform Data Set and the CalEPA (2011) report, but was not used as a reference paint in the U.S. EPA (2011) report as confirmed by Table 2-1.
- XZM480 International: Other paints manufactured by International were included in the U.S. EPA (2011) report, but XZM480 International was not. XZM480 International was referred to as an "emerging paint" in the CalEPA (2011) report.
- BottomSpeed TC Base Coat/Top Clear Coat: The U.S. EPA (2011) report includes a paint named PropSpeed. According to the CalEPA (2011) report, BottomSpeed TC Base Coat/Top Clear Coat is a modified version of PropSpeed. Therefore, the two paints are distinctly different.
- Hempasil XA278: The U.S. EPA (2011) report includes a paint named Hempasil X3 (87500). According to the CalEPA (2011) report, Hempasil XA278 is a modified version of Hempasil X3. Therefore, the two paints are distinctly different.
- Surface Coat Part A – Black: This paint is also known as Sher-Release. It is referred to as an "emerging paint" in the CalEPA (2011) report and neither name appears in the U.S. EPA (2011) report.

Upon review of the reports, the methodology and findings on performance appear to be valid and reliable. These two reports will serve as the basis for the Level 1 performance evaluation as described below.

Level 1: Basic Performance Evaluation

This Level 1 analysis is based upon the questions laid out in the IC2 Guide.

Note: Not all of the questions can be directly answered because they assume a chemical-level Alternatives Assessment. The questions are answered to the best of the assessor's ability for a product-level assessment of antifouling boat paints.

<u>Question 1: What are the performance needs for the application, process, or product that contains the chemical of concern (COC)? Why is the COC being used in this specific application?</u>

A comparison for the performance needs asks four main questions:

1. What are the performance requirements at the chemical level?
2. What are the performance requirements at the material level?
3. What are the performance requirements at the product level?
4. What are the performance requirements at the process level?

Because only one of the questions pertained to a product-level performance evaluation, the assessor assumed that it was only relevant to answer sub-question 3.

<u>Answer to Question 1:</u>

As described in the CalEPA (2011) report, Copper Antifouling Paints have been used for many years to protect the hulls of marine vessels from excessive fouling. Marine organisms are deterred from attaching to the boat hull because the copper in the paints acts as a biocide (CalEPA 2011). The typical life of a copper paint is two to three years before repainting is required. Soft nonbiocide paints use a different antifouling method that provides a slick surface to prevent marine fouling attachment. All the assessed alternatives were soft nonbiocide paints and these generally last longer than copper paints, ranging from five to more than 10 years before repainting is needed.

<u>Question 2: Has the alternative(s) already been identified as a favorable alternative with respect to performance?</u>

A comparison of whether or not the alternative has already been identified as a favorable alternative with respect to performance asks four main questions:

1. Is the alternative being used (i.e., by others) for the same or similar function?
2. Is the alternative used in similar products available on the commercial market?
3. Is the alternative marketed in promotional materials an option for providing the desired function for the specific application of interest?
4. Based upon answers to the above questions, does the alternative appear applicable to the product or process under evaluation?
    a. If yes, identify the alternative as favorable. Evaluation complete.
    b. If no, identify that the alternative is not technically favorable and document the information used to reach the conclusion. Continue evaluation.

<u>Answers to Question 2:</u>

Table 25 presents the answers to Question 2 of the basic performance evaluation.

Table 25: Summary of Functionality and Market Availability of Alternatives, Compared to Control Paint

Paints in Uniform Data Set	Used for same or similar function?	Available on commercial market?	Marketed as providing the same function?
Klear N' Klean Plus XP-A101 White Top Coat	Yes	No	n/a
Intersleek 900 System	Yes	Yes	Yes[1]
XZM480 International	Yes	No	n/a
BottomSpeed TC Base Coat/Top Clear Coat	Yes	Yes	Yes[2]
Hempasil XA278	Yes	No	n/a
Surface Coat Part A – Black	Yes	Yes	Yes[3]

[1] International Paint (undated)
[2] Promotional materials for this paint could not be located, but it is assumed that it is marketed as an antifouling paint.
[3] FujiFilm (undated)

Note: It is unclear from the questions above if the three alternative paints that are no longer commercially available should continue through the module. It is also unclear why availability is being considered in the Performance Evaluation Module since the IC2 Guide includes a Cost and Availability Module. For the purposes of evaluating the IC2 Guide, this assessor will continue to evaluate the performance of all six alternatives via the remaining questions in this module.

Question 3: Has an authoritative body demonstrated that the alternative functions adequately for both the process and product? Are there reports from an authoritative body that evaluates the alternative(s) for use in the specific or similar applications?

If the answer to these questions is yes, then the alternative is identified as a potential alternative. The assessor can either exit the Performance Evaluation Module or proceed to the next level of the assessment. If the answer to these questions is no, the assessor is to continue the evaluation.

Answers to Question 3:

The U.S. EPA (2011) and CalEPA (2011) reports serve as "authoritative" sources of performance data for the six alternatives paints found in the Uniform Data Set.

Results from the U.S. EPA project

One alternative paint was concluded to perform well:

- Intersleek 900 System

One paint's performance was rated as "fair":

- Klear N' Klean Plus XP-A101 White Top Coat

Results from the CalEPA project

The following four alternative paints performed well over the course of the panel and boat testing:

- Hempasil XA278
- Klear N' Klean Plus XP-A101 White Top Coat
- BottomSpeed TC Base Coat/Top Clear Coat
- Surface Coat Part A – Black (Sher-Release)

One paint was shown to not perform as well over the course of the panel and boat testing:

- XZM480 International

The CalEPA (2011) report states that by the end of the project, XZM480 International appeared to be peeling in several spots on two of the boats being tested.

Question 4: Is the proposed alternative(s) considered favorable but there are indications that it does not perform as well as the current chemical?

The IC2 Guide walks the assessor through a series of questions to answer if the proposed alternative(s) is considered favorable but there are indications that it does not perform as well as the current chemical:

- If yes, can the process or product be modified to accommodate the alternative and improve its performance?
  - If yes, continue evaluation.
  - If no, is the difference in performance critical to the product?
    - If yes, eliminate the alternative as a favorable alternative and document the information used to reach the conclusion.
    - If no, continue evaluation.
  - If no, continue evaluation.

Answers to Question 4:

As summarized above, XZM480 International was found by the end of the CalEPA (2011) project to not perform as well relative to other alternatives.

The performance of Klear N' Klean Plus XP-A101 White Top Coat was rated as "fair" in the U.S. EPA (2011) report, but it found to "perform well" in the CalEPA (2011) report. For purposes of this assessment, the results from the CalEPA (2011) report will be given precedence, since the methodology of this project built upon the methodology and findings in the U.S. EPA (2011) report.

No indications of poor performance in comparison to the copper control were found for the other four alternatives.

Question 5: Has the proposed alternative(s) been identified by expert sources as unfavorable, i.e., NOT a viable alternative based on performance?

The IC2 Guide walks the assessor through a series of questions to answer if the proposed alternative(s) has been identified by expert sources as unfavorable:

- If yes, how do the performance results compare to the desired function in the specific product or process?
  - Is the application of the alternative identical to the chemical of concern?
    - If yes the application is identical, the alternative is NOT technically feasible and document the information used to reach the conclusion.
    - If no, the application is not identical, can the product or process be modified to accommodate the alternative?
      - If yes, identify the alternative as favorable. Evaluation complete.
      - If no, identify that the alternative is not technically favorable and document the information used to reach the conclusion. Evaluation complete.
- If no, identify that the alternative is technically favorable and document the information used to reach the conclusion. Evaluation complete.

Answers to Question 5:

As summarized in Table 26, five of the six alternative paints were shown to perform well relative to copper antifouling paint. One of six alternative paints was shown to have performance issues in the CalEPA (2011) report. One paint was given a rating of "fair" in the U.S. EPA (2011) report, but as previously stated, the results of the CalEPA (2011) report, which showed the paint to perform well, are given precedence over those from the U.S. EPA (2011) report.

Table 26: Summary of Performance Evaluation Results			
Paints in Uniform Data Set	**Overall performance rating (with caveats noted with*)**	**Caveats / Notes**	**Source**
Pettit Marine Trinidad Pro Antifouling Bottom Paint	--	--	--
Klear N' Klean Plus XP-A101 White Top Coat	Performed well*	*Found to perform 'fairly' in U.S. EPA (2011); results from CalEPA (2011) given precedence. This raises uncertainty around the performance rating for this paint.	CalEPA (2011)
Intersleek 900 System	Performed well	--	U.S. EPA (2011)
XZM480 International	Did not perform as well	*Found to not perform as well (relative to control and alternatives) at the end of the CalEPA (2011) project	CalEPA (2011)
BottomSpeed TC Base Coat/Top Clear Coat	Performed well	--	CalEPA (2011)
Hempasil XA278	Performed well	--	CalEPA (2011)
Surface Coat Part A – Black	Performed well	--	CalEPA (2011)

Results and Decision-Making within the Performance Evaluation Module

Based on this series of questions and performance testing results from the U.S. EPA (2011) and CalEPA (2011) reports, this assessor concludes that performance is roughly equivalent (or non-differentiating) among the control paint and five alternatives (Klear N' Klean Plus XP-A101 White Top Coat, Intersleek 900 System, BottomSpeed TC Base Coat/Top Clear Coat, Hempasil XA278, and Surface Coat Part A – Black). XZM480 International did not perform as well relative to the control paint and these five alternatives.

Cost and Availability Module

The Cost and Availability Module is intended to evaluate the cost and availability of potential alternatives to copper antifouling paint. The primary data sources for evaluating the Cost and Availability Module are the U.S. EPA (2011) report and CalEPA (2011) report introduced in Section 1. The cost estimates used by the assessor are derived from the cost analysis presented in the U.S. EPA (2011) report. The U.S. EPA cost analysis includes:

- Baseline costs for copper paint: haulout, minimal prep work, single coat of copper paint, and annual cleaning costs
- Costs for alternative paints: haulout, minimal prep work, paint volume (takes into account multiple coats and recommended thickness), and annual cleaning costs
- Annualized costs: assumed that the application was considered to be paid off over the life of the paint, and the annualized application cost could then be added to the annual cleaning cost. Variations in paint lifespan were accounted for. Also took amortization into account.

Costs are influenced by stripping, spraying, longevity, and cleaning frequency (U.S. EPA 2011).

Table 27 shows which of the paints in the Uniform Data Set were assessed for performance in the U.S. EPA (2011) and CalEPA (2011) report. Table 27 also provides a comparison between the paint names in the Uniform Data Set and in the U.S. EPA (2011) and CalEPA (2011) reports. Although the names for several paints differ slightly, they are assumed to be the same paints. Upon review of the reports, the methodology and findings on cost and availability appear to be valid and reliable. These two reports will serve as the basis for the Level 1 performance evaluation as described below.

Table 27: Comparison of Paints and Cost and Availability Data in Uniform Data Set, U.S. EPA (2011) Report, and CalEPA (2011) Report

Paints in Uniform Data Set	Cost and availability assessed in U.S. EPA (2011) report?	Cost and availability assessed in CalEPA (2011) report?	Name in U.S. EPA (2011) report	Name in CalEPA (2011) report
Pettit Marine Trinidad Pro Antifouling Bottom Paint	No	Yes	N/A	Trinidad Pro Blue
Klear N' Klean Plus XP-A101 White Top Coat	Yes	Yes	Klear N' Klean	Klear N' Klean Plus XP-A101
Intersleek 900 System	Yes	No	Intersleek 900	Intersleek 900
XZM480 International	No	Yes	N/A	XZM480
BottomSpeed TC Base Coat/Top Clear Coat	No	Yes	N/A	BottomSpeed Topcoat Clear; BottomSpeed TC BaseCoat
Hempasil XA278	No	Yes	N/A	Hempasil XA278
Surface Coat Part A – Black	No	Yes	N/A	Surface Coat Part A – Black (Sher-Release)

A "No" entry in Table 27 for the U.S. EPA (2011) report is based on the following information:

- Pettit Marine Trinidad Pro Antifouling Bottom Paint 1082 Blue: Was used as the copper control in Uniform Data Set and the CalEPA (2011) report, but was not used as a reference paint in the U.S. EPA (2011) report as confirmed by Table 2-1.
- XZM480 International: Other paints manufactured by International were included in the U.S. EPA (2011) report, but XZM480 International was not. XZM480 International was referred to as an "emerging paint" in the CalEPA (2011) report.
- BottomSpeed TC Base Coat/Top Clear Coat: The U.S. EPA (2011) report includes a paint named PropSpeed. According to the CalEPA (2011) report, BottomSpeed TC Base Coat/Top Clear Coat is a modified version of PropSpeed. Therefore, the two paints are distinctly different.
- Hempasil XA278: The U.S. EPA (2011) report includes a paint named Hempasil X3 (87500). According to the CalEPA (2011) report, Hempasil XA278 is a modified version of Hempasil X3. Therefore, the two paints are distinctly different.
- Surface Coat Part A – Black: This paint is also known as Sher-Release. It is referred to as an "emerging paint" in the CalEPA (2011) report and neither name appears in the U.S. EPA (2011) report.

Typical cost of antifouling boat paint (both with and without copper)

In general, nonbiocide boat paints require more complex application methods than copper paint. For example, stripping the boat hull, using more paint and more paint systems, and using spray application techniques (U.S. EPA 2011). However, soft nonbiocide paints (all of the alternatives assessed in this report) are generally cleaned with the same frequency as copper paints (U.S. EPA 2011).

Availability of antifouling boat paint (both with and without copper)

Copper paints are widely available at boatyards, which is where most painting occurs. Regulatory agencies and stakeholders are encouraging a shift to non-copper alternatives due to environmental impacts of copper antifouling paints.

Level 1: Basic Cost and Availability Evaluation

This assessment is based on a Level 1 cost and availability evaluation, which asks a few basic questions about whether the alternative is being used in cost competitive products:

- Is the alternative currently used in the application of interest? Identify information sources used to reach the conclusion.
- Is the alternative currently[23] offered for sale for the application of interest? Is the price of the alternatives close to the current? Identify information sources used to reach the conclusion.

If the answer to either question is positive, the alternative is considered favorable for both cost and availability.

All of the alternatives included in this evaluation are used for the same function – as an antifouling agent to slow the growth of organisms that attach to the hulls of boats. Some of the alternatives are currently in use in the application, while others are not because they are no longer commercially available. The assessor believes that Question 2 above is more applicable for evaluating cost and availability in this case because it asks if the alternatives are offered for sale with a price close to that of copper antifouling paint.

Under the assumption described above, the assessor's evaluation of cost and availability of these paints is based solely on Question 2 asked in the Level 1 cost and availability evaluation. The Level 1 module indicated that alternatives that answer positive to either question are considered favorable for both cost and availability. However, Question 2 includes two sub-questions:

- Is the alternative currently offered for sale for the application of interest?
- Is the price of the alternatives close to the current?

[23] Determining whether the paints evaluated in this Project were still commercially available was a challenge. Therefore, if current availability could not be determined, a paint was considered available if it was commercially available at the time it was evaluated in the CalEPA (2011) and U.S. EPA (2011) reports. In an official Alternatives Assessment (versus a pilot, such as this), alternatives with unknown current commercial availability would be eliminated as viable alternatives.

Sub-question 1 addresses the availability of the alternative and sub-question 2 addresses cost. Because this review is only considering Question 2, the assessor assumes that the answer to both sub-questions must be positive in order for the alternative to be positive in terms of cost and availability. Therefore, the assessor did not research the price of an alternative and ruled out the alternative as unfavorable if it was not currently commercially available.

Pettit Marine Trinidad Pro Antifouling Bottom Paint 1082 Blue

<u>Availability</u>

According to the Uniform Data Set created in Task 1, Pettit Marine Trinidad Pro Antifouling Bottom Paint 1082 Blue is manufactured by Pettit Marine Paints and is commercially available as an antifouling paint that provides resistance to barnacles, algae, slime, and other marine and fresh-water fouling organisms. The product has been on the market since 2008 and is one of the manufacturer's bestselling paints.

<u>Cost</u>

The cost analysis provided in the U.S. EPA (2011) report is not specifically for Trinidad Pro Antifouling Bottom Paint 1082 Blue but for an unspecified copper paint. The costs provided in the report are general and serve as a baseline. The assessor assumes that these costs are reflective of the cost of Pettit Marine Trinidad Pro Antifouling Bottom Paint 1082 Blue. Table 28 presents the application costs and annualized total costs for copper antifouling paint in various scenarios (e.g., 30-foot vs. 40-foot boat; sailboat vs. powerboat). The cost estimates reveal that rolled and stripped copper antifouling paint with a 3-year lifespan is the cheaper option for Copper Antifouling Paints compared to rolled and not stripped with a 2-year lifespan. The total annualized total cost for copper antifouling paint ranges from $953 to $1,238 for a 30-foot boat, and from $1,306 to $1,704 for a 40-foot boat.

Table 28: Annualized Total Cost Over Life of Copper antifouling paint

Paint type	Average application cost	Life of paint	Annualized Capital Cost	Average Cleaning Cost – Sailboat	Annualized Total Cost – Sailboat	Average Cleaning Cost – Powerboat	Annualized Total Cost Powerboat
30-foot boat							
Not stripped, Rolled	$1,038	2	$540	$593	$1,133	$698	$1,238
Stripped, Rolled,	$1,038	3	$360	$593	$953	$698	$1,058
40-foot boat							
Not stripped, Rolled	$1,488	2	$774	$790	$1,564	$930	$1,704
Stripped, Rolled	$1,488	3	$516	$790	$1,306	$930	$1,446

Source: U.S. EPA (2011), Table 5-12 and Table 5-13

Klear N' Klean Plus XP-A101 White Top Coat

Availability

Klear N' Klean Plus XP-A101 White Top Coat is no longer manufactured by Pettit Marine Paints and thus no longer commercially available according to the Uniform Data Set created in Task 1. This information was confirmed by ToxServices on October 18, 2014 via phone conversation with a Pettit Marine sale representative (ToxServices 2014b).

Cost

Under the assumptions outlined in the beginning of this section stating that an alternative must fulfill both Question 2 sub-questions, the price of this alternative was not investigated because the product is not commercially available.

Intersleek 900 System

Availability

According to the Uniform Data Set, the Intersleek 900 System is manufactured by International Paint and is commercially available as an antifouling paint system that consists of a primer and a top coat.

Cost

A cost analysis for the Intersleek 900 System is available in the U.S. EPA (2011) report. The analysis evaluated multiple application scenarios and their associated costs, including:

- 30-foot vs. 40-foot boat
- Stripped vs. non-stripped
- Rolled vs. sprayed
- 5-year vs. 10-year lifespan
- Sailboat vs. powerboat

Table 29 presents the application costs and annualized total costs for the Intersleek 900 System in various scenarios. The total annualized cost for the Intersleek 900 System ranges from $891-$1,890 for a 30-foot boat, and from $1,226-$2,598 for a 40-foot boat. The application costs for the Intersleek 900 System are greater than for copper antifouling paint, but annualized total costs are lower for both 30 and 40-foot boats.

Table 29: Annualized Total Cost Over Life of the Intersleek 900 System							
Paint type	**Average application cost**	**Life of paint**	**Annualized Capital Cost**	**Average Cleaning Cost – Sailboat**	**Annualized Total Cost – Sailboat**	**Average Cleaning Cost – Powerboat**	**Annualized Total Cost Powerboat**
30-foot boat							
Stripped, Rolled	$4,556	5	$948	$653	$1,601	$743	$1,691
	$4,556	10	$474	$653	$1,127	$743	$1,217

Table 29: Annualized Total Cost Over Life of the Intersleek 900 System							
Paint type	**Average application cost**	**Life of paint**	**Annualized Capital Cost**	**Average Cleaning Cost – Sailboat**	**Annualized Total Cost – Sailboat**	**Average Cleaning Cost – Powerboat**	**Annualized Total Cost Powerboat**
Stripped, Sprayed	$5,512	5	$1,147	$653	$1,800	$743	$1,890
	$5,512	10	$573	$653	$1,226	$743	$1,316
Not stripped, Rolled	$2,286	5	$475	$653	$1,128	$743	$1,218
	$2,286	10	$238	$653	$891	$743	$981
Not stripped, Sprayed	$2,922	5	$608	$653	$1,261	$743	$1,351
	$2,922	10	$304	$653	$957	$743	$1,047
40-foot boat							
Stripped, Rolled	$6,713	5	$1,396	$870	$2,266	$990	$2,386
	$6,713	10	$698	$870	$1,568	$990	$1,688
Stripped, Sprayed	$7,733	5	$1,608	$870	$2,478	$990	$2,598
	$7,733	10	$804	$870	$1,674	$990	$1,794
Not stripped, Rolled	$3,413	5	$710	$870	$1,580	$990	$1,700
	$3,413	10	$355	$870	$1,225	$990	$1,345
Not stripped, Sprayed	$4,113	5	$856	$870	$1,726	$990	$1,846
	$4,113	10	$428	$870	$1,298	$990	$1,418

Source: U.S. EPA (2011)

XZM480 International Paint

Availability

According to the Uniform Data Set, XZM480 International is no longer manufactured by International Paint and thus no longer commercially available. This information was confirmed via phone conversation with an International Paint sales representative (ToxServices 2014c).

Cost

Under the assumptions outlined in the beginning of this section stating that an alternative must fulfill both Question 2 sub-questions, the price of this alternative was not investigated because the product is not commercially available.

BottomSpeed TC Base Coat/Top Clear Coat

Availability

BottomSpeed TC Base Coat/Top Clear Coat is a commercially available antifouling paint system that consists of a base coat and a top coat according to the Uniform Data Set. BottomSpeed was evaluated as an "emerging paint" in the CalEPA (2011) report.

Cost

Price information for BottomSpeed TC Base Coat/Top Clear Coat was not available in the U.S. EPA (2011) report but was available in the CalEPA (2011) report. Cost estimates for BottomSpeed TC Base Coat/Top Clear Coat on a 30-foot boat were provided in the CalEPA (2011) report. It is estimated that a BottomSpeed TC Base Coat/Top Clear Coat paint job with two coats of sealer/topcoat applied over copper paint is $3,324 compared to $1,038 for a new coat of copper paint (CalEPA 2011). However, BottomSpeed TC Base Coat/Top Clear Coat can have a lifespan of 10 years. The annualized paint job cost of BottomSpeed TC Base Coat/Top Clear Coat with a 5-year lifespan is $691 and is $345 with a 10-year lifespan (CalEPA 2011). These annualized total costs are in comparison to $540, which is the annualized paint job cost of copper paint with a 2-year lifespan (CalEPA 2011). The CalEPA (2011) report goes on further say that "if the life of the BottomSpeed TC Base Coat/Top Clear Coat paint job is even six years, the annualized total cost of the paint job is $576 which is close to the annualized total cost of the copper paint job." The CalEPA (2011) cost estimate does not account for cleaning costs, but the assessor assumes that these would be similar to the cleaning costs of the soft nonbiocide paints analyzed in the U.S. EPA (2011) report. Table 30 presents the annualized total cost over life of BottomSpeed TC Base Coat/Top Clear Coat based on the average application and annualized capital costs provided in the CalEPA (2011) report with the average cleaning costs provided in the U.S. EPA (2011) report. The CalEPA (2011) report rolled BottomSpeed TC Base Coat/Top Clear Coat over copper paints. Information on the performance of BottomSpeed TC Base Coat/Top Clear Coat when rolled over existing copper paint is provided in the Performance Evaluation Module of this report.

Table 30: Annualized Total Cost Over Life of BottomSpeed TC Base Coat/Top Coat Clear

Paint type	Average application cost[1]	Life of paint	Annualized Capital Cost[1]	Average Cleaning Cost – Sailboat[2]	Annualized Total Cost – Sailboat	Average Cleaning Cost – Powerboat[2]	Annualized Total Cost Powerboat
30-foot boat							
Not stripped, Rolled	$3,324	5	$691	$653	$1,344	$743	$1,434
	$3,324	10	$345	$653	$998	$743	$1,088

[1] CalEPA (2011)
[2] U.S. EPA (2011)

Hempasil XA278

Availability

According to the Uniform Data Set, Hempasil XA278 is no longer manufactured by Hempel and thus no longer commercially available. This information was confirmed via email communication with an environmental specialist at Hempel (ToxServices 2014d).

Cost

Under the assumptions outlined in the beginning of this section stating that an alternative must fulfill both Question 2 sub-questions, the price of this alternative was not investigated because the product is not commercially available.

Surface Coat Part A – Black

Availability

Surface Coat Part A – Black is manufactured by Fuji Film Hunt Smart Surfaces and is commercially available as an antifouling coating according to the Uniform Data Set.

Cost

Price information for Surface Coat Part A – Black is not available in the U.S. EPA (2011) or CalEPA (2011) reports. It could be assumed that the coating was not cost-effective as of 2011 because its use was not widespread, as reflected in the case example on p.92 of the IC2 Guide. However, the limited use of this alternative in 2011 is more likely due to its status as an emerging paint as deemed by the CalEPA (2011) report.

A Google search was conducted to find cost information on this alternative. Although not as "authoritative" as other sources used in this evaluation, a press released on Sher-Release claims that the alternative is a "cost-effective method of providing superior biofouling protection (Sherwin-Williams 2009)."

Results and Decision-Making within the Cost and Availability Module

Table 31 presents the results of the research for conducting this module. Three of the six alternatives are not commercially available, which makes Klear N' Klean Plus XP-A101 White Top Coat, XZM480 International, and Hempasil XA278 unfavorable alternatives to copper antifouling paint. The three remaining alternatives – Intersleek 900 System, BottomSpeed TC Base Coat/Top Clear Coat, and Surface Coat Part A – Black – are all commercially available. However, complete quantitative pricing information was only available for the Intersleek 900 System and BottomSpeed TC Base Coat/Top Clear Coat.

The cost estimates reveal that for a 30-foot boat, rolled Intersleek 900 with a 5-year lifespan and Intersleek 900 with a 10-year lifespan, regardless of application method, have lower annualized total costs than copper antifouling paint with a 2-year lifespan. Rolled Intersleek 900 with a 10-year lifespan was also found to have a lower annualized total cost than copper antifouling paint with a 3-year lifespan for a 30-foot boat. Based on these findings, the Intersleek 900 System is a favorable alternative to copper antifouling paint based on cost and availability.

The annualized total cost estimates for BottomSpeed TC Base Coat/Top Clear Coat, although based on different assumptions than the Intersleek 900 System (i.e., does not account for cleaning), appear to be cheaper for this alternative with a 10-year lifespan compared to copper antifouling paint with a 2-year lifespan. Based on this cost data, both the Intersleek 900 System and BottomSpeed TC Base Coat/Top Clear Coat appear to be favorable alternatives to copper antifouling paint in terms of cost and availability.

With limited cost information for Surface Coat Part A – Black, the assessor is required to decide if this alternative is favorable or unfavorable under the Level 1 evaluation. Under the assessor's assumptions, the alternative is deemed favorable if the answer to both Question 2 sub-questions is positive – that is 1) the alternative must be currently offered for sale for the application of interest and 2) the price of the alternative is close to the current. Surface Coat Part A – Black is a commercially available alternative. However, the absence of cost data for this alternative in the U.S. EPA (2011) and CalEPA (2011) reports limits the assessor's ability to determine if this alternative is cost-comparative to copper antifouling paint. This is a major data gap and the Level 1 cost and availability evaluation does not provide guidance on how to address data gaps. The assessor believes that because there is no evidence that Surface Coat Part A – Black is unfavorable, it should be considered as a potential alternative during the final decision analysis when the influence of data gaps will be evaluated and weighed against alternatives with adequate data for cost and availability.

Table 31: Summary of Annualized Total Cost and Availability Results

Paint name	Commercial availability	Annualized total cost for 30-foot boat (40-foot boat)
Pettit Marine Trinidad Pro Antifouling Bottom Paint	Yes	\$953-\$1,238 (\$1,306-\$1,704)
Klear N' Klean Plus XP-A101 White Top Coat	No	Not evaluated because alternative is not commercially available
Intersleek 900 System	Yes	\$891-\$1,890 (\$1,226-\$2,598)
XZM480 International	No	Not evaluated because alternative is not commercially available
BottomSpeed TC Base Coat/Top Clear Coat	Yes	\$1,088-\$1,434 [Cleaning costs are assumed to be comparable to those of other soft nonbiocide paints].
Hempasil XA278	No	Not evaluated because alternative is not commercially available
Surface Coat Part A – Black	Yes	Information not available in U.S. EPA or CalEPA (2011) reports. Deemed "cost-effective" in a manufacturer's press release.

Exposure Assessment Module

The Exposure Assessment Module is intended to provide a flexible framework that allows assessors to determine if exposure considerations can add weight to the selection of an alternative. The module consists of an Initial Screen, three levels, and an advanced approach to exposure assessment. An Initial Screen was conducted to determine if a Level 1 evaluation was necessary.

Near field exposure to antifouling boat paint can occur during application. Antifouling paint can be applied via roller, spray, or brush. As demonstrated in the CalEPA (2011) report, workers typically wear respiratory equipment and protective clothing during application to reduce inhalation and dermal exposure. Far field exposure to antifouling boat paints can occur during the product use phase. According to the U.S. EPA (2011) report, copper loading in marina basins generally comes from two major sources: 1) the passive leaching of copper from the antifouling coatings, and 2) hull cleaning of the vessels by divers using abrasive tools.

Initial Screen

The Exposure Assessment Module's Initial Screen identifies whether sufficient similarities exist between the copper antifouling boat paint and soft nonbiocide alternatives. The Initial Screen will indicate that an exposure assessment is not necessary if differences in exposure concerns among the seven paints are inconsequential to the Alternatives Assessment. The assessor has assumed that the same holds true if exposure concerns are inconsequential among the soft nonbiocide alternatives, yet more favorable than that of the copper control. The Initial Screen identifies potential exposure concerns along with how the concerns may be addressed. Decisions in this level are based upon a qualitative assessment using readily-available data.

The Initial Screen asks seven general questions of the assessor. The first five of these questions are:

1. Compare exposure pathways between the chemical of concern and alternative.
2. Compare the manufacturing criteria for the chemical of concern and alternative.
3. Compare the fate, transport, and partitioning in environmental media for the chemical of concern and alternative.
4. Compare the release mechanisms for the chemical of concern and the potential alternative.
5. Based upon the above evaluation, are there any substantive differences between the use and physical characteristics that could affect exposure?

If the answer to Question 5 is no, then the exposure evaluation is complete. If the answer to Question 5 is yes, the following two questions are asked within the Initial Screen:

6. Have you assessed the chemical options for hazard?
7. Could the alternative pose a risk based on its physical and biological hazard characteristics? To what extent is the product designed to avoid such risks?

<u>Question 1: Compare exposure pathways between the chemical of concern and alternative</u>

The module asks if the exposure pathways for copper antifouling paint and its alternatives are similar by having the assessor compare the chemical properties among the options. The decision of what criteria to evaluate is left up to the discretion of the assessor. As written, the question tailored for a chemical-level Alternatives Assessment (e.g., "compare exposure pathways between the chemical of concern and alternative") does not provide guidance on how to apply the questions in the module to a product-level assessment. Because this is a product-level assessment intended to use readily-available data, information on these criteria were pulled from the MSDS provided in Appendix B of the U.S. EPA (2011) report or those cited in the Uniform Data Set.

The IC2 Guide invites assessors to evaluate what they deem the pertinent criteria to answer Question 1. This assessment will consider criteria that are relevant at the product level as chosen by the assessor: product-level volatility/vapor pressure, product-level solubility, and product-level specific gravity. Criteria offered in the IC2 Guide that are not applicable at the product level (e.g., molecular weight and molecular size) will not be considered. As shown in Table 32, data on the three criteria of interest were not always available in the MSDS for each alternative.

Table 32 presents the relevant physical and chemical product-level properties of the copper control and alternatives assessed in this report. For alternatives that contain a separate topcoat and basecoat (i.e., Intersleek 900 System and BottomSpeed TC Base Coat/Top Clear Coat), the physicochemical data are separated for each component of the product. Although information for volatility and solubility were not available in the Intersleek 900 System Top Coat's MSDS, the solubility of the main chemical component in the Intersleek 900 System Top Coat – titanium dioxide – has a very low solubility according to the Uniform Data Set[24]. All of the alternatives to copper antifouling paint are immiscible in water. All alternatives have a lower VOC content than the copper control except for BottomSpeed TC Base Coat. However, this difference is not even an order of magnitude greater. Lastly, all of the alternatives with readily-available information have a similar specific gravity to one another.

Table 32: Physical/Chemical Properties of Copper antifouling paint and its Alternatives

Paint name	**Volatility/vapor pressure**	**Solubility – Log K_{ow}**	**Density/ specific gravity**
Pettit Marine Trinidad Pro Antifouling Bottom Paint	VOC content: 330 g/L	Negligible	SG > 1
Klear N' Klean Plus XP-A101 White Top Coat	VOC content: 308 g/L % volatile: 29.4 %w	Negligible	SG = 1.05
Intersleek 900 System – Top Coat	Not located	Not located	SG = 1.134
Intersleek 900 System – Bottom Coat	Not located	Not located	SG = 1.129
XZM480 International	Not located	Immiscible	SG = 1.090
BottomSpeed TC Base Coat	VOC content: 518.91-532.09 g/L % volatile: 61.90-63.77 %w	Not located	Not located
BottomSpeed Top Clear Coat	Not located	Insoluble in water, soluble in organic solvents	Not located
Hempasil XA278	VOC content: 159 g/L	Insoluble in water	Not located
Surface Coat Part A – Black	VOC content: 45 g/L % volatile: 4-5 %w	Insoluble in water	SG = 1.05

Sources: MSDS provided in Appendix B of U.S. EPA (2011), Pettit Marine Paints (2003), ToxServices (2014a)

<u>Question 2: Compare the manufacturing criteria for the chemical of concern and alternative</u>

A comparison for the manufacturing criteria asks three main questions:

1. Do the alternatives perform the same function in the product?
2. Are they used in the same relative amounts or is the alternative used in lesser amounts?
3. Are they used in the same manner?

All of the paints assessed serve the same function – they are all antifouling boat paints. However, copper antifouling paints and soft nonbiocide paints (all six of the alternatives) achieve the same

[24] 0.0034 mg/L at 21.9°C

results via different methods. Copper antifouling paints passively leach a controlled amount of copper into the water near the hull or they rely on ablation to inhibit fouling (CalEPA 2011). The soft nonbiocide paints, on the other hand, exhibit antifouling properties because the coatings are so smooth that fouling cannot adhere (CalEPA 2011).

Table 33 presents available information on amount and frequency of paint applied for the various alternatives. Although there is variation in the thickness of paint applied among the alternatives, the differences are less than one order of magnitude. Pettit Marine Trinidad Pro Antifouling Bottom Paint 1082 Blue uses less paint per application, but is applied more frequently than the soft nonbiocide alternatives. Additionally, when copper paint is reapplied, the amount of available copper that leaches into the water is restocked, thus perpetuating the environment's exposure.

Table 33: Manufacturing Criteria for Copper antifouling paint and its Alternatives

Paint name	Function performed	Amount applied	Layers needed	Frequency applied	Location applied
Pettit Marine Trinidad Pro Antifouling Bottom Paint	Antifouling agent	2 mils dry, 3.6 wet mils (50.8 microns dry, 91.44 microns wet)[1]	Not located	2-3 years[2]	Boat hull
Klear N' Klean Plus XP-A101 White Top Coat	Antifouling agent	Not located	Not located	5-10 years[2]	Boat hull
Intersleek 900 System	Antifouling agent	150-200 microns dry (203-270 microns wet)[1]	1 base coat and 1 top coat[3]	5-10 years[2]	Boat hull
XZM480 International	Antifouling agent	Not located	>1 coat[3]	5-10 years[2]	Boat hull
BottomSpeed TC Base Coat/Top Clear Coat	Antifouling agent	Not located	2 base coats and 1 top coat[3]	5-10 years[3]	Boat hull
Hempasil XA278	Antifouling agent	Not located	>1 coat[3]	5-10 years[2]	Boat hull
Surface Coat Part A – Black	Antifouling agent	6 mils (152 microns)[1]	1 coat[3]	5-10 years[2]	Boat hull

[1] ToxServices (2014a) [2] U.S. EPA (2011) report [3] CalEPA (2011) report

Variation exists in the ways in which these boat paints can be applied. As explained in the CalEPA (2011) report, all paints can be applied via brush, roller or spray which impacts human exposure to these paints. The cleaning schedules of copper and soft nonbiocide paints are generally the same, and the cleaning process releases paint into waterways. Similar to application method, stripping frequency is also highly variable and non-differentiating among the different paints. The assessor also does not evaluate stripping (e.g., if chemical strippers introduce hazard concerns) because it is more applicable in the Life Cycle Module of the IC2 Guide.

Question 3: Compare the fate, transport, and partitioning in environmental media for the chemical of concern and alternative

As discussed above, the alternatives are all expected to partition into the environment in a similar way because they are all immiscible and have the same use application.

Question 4: Compare the release mechanisms for the chemical of concern and the potential alternative

The assessor has limited readily-available data on lifecycle phases but can reasonably assume that both the product manufacturing process and product transport is similar for all alternatives. The assessor does however, have information on the use phase of both copper antifouling paint and its alternatives. As stated above, copper antifouling paints and soft nonbiocide paints achieve the same antifouling goal via different methods. The copper paints passively leach a controlled amount of copper into the water near the hull or they rely on ablation to inhibit fouling (CalEPA 2011). The soft nonbiocide paints do not ablate chemicals and exhibit antifouling properties because the coatings are so smooth that fouling cannot adhere (CalEPA 2011). In addition to the inherently ablative properties of this type of paint, more copper antifouling paint may be released compared to soft nonbiocide paints because more intense and frequent cleaning is expected (CalEPA 2011).

Question 5: Based upon the above evaluation, are there any substantive differences between the use and physical characteristics that could affect exposure?

Differences among the use and physical characteristics are also not substantive between copper paint and the six soft nonbiocide alternatives for Questions 1-3 asked above. However, differences among the copper paint and the group of six soft nonbiocide paints do become apparent when comparing release mechanisms as explored in Question 4. Among themselves, all six soft nonbiocide paints have no substantive difference in release mechanisms. However, the release mechanism of a soft nonbiocide paint is different, yet preferable to copper antifouling paint for the reasons described in Question 4 above. Since soft nonbiocide paints are found to be preferable to copper paint in terms of exposure, and exposure is found to be a non-differentiating factor among alternatives, this assessor concludes that Level 1 assessment is not necessary based on the Initial Screen results.

Decision Analysis

Decision-Making Process for Selecting Optimal Alternative(s)

As recommended in the IC2 Guide, once data have been collected on all of the alternatives for each module, a comparison should be made against all criteria (in this case, hazard, performance, cost and availability, and exposure) to identify optimal alternatives. This assessor established the following decision rules on how to weight criteria before performing the data analysis.

Weighting of Criteria

- The results of the Hazard Module will be given the highest weight (or priority) relative to the other modules. This reflects the "Golden Rule" and accompanying principle in the IC2 Guide that hazard must be emphasized relative to other criteria.
- Performance, cost and availability, and exposure will receive equal weighting to each other, but will be weighted less than hazard. If necessary, quantitative weights will be assigned to hazard, performance, cost and availability, and exposure to assist in selecting preferred alternative(s).
- If necessary to prioritize trade-offs and select preferable alternative(s), one of the decision methods included in Appendix A in the IC2 Guide will be used (i.e., simple, iterative, or simultaneous comparison method).

Data Analysis and Results

- The decision-making process for selecting preferred alternatives is relatively straightforward based on the results of the four modules conducted simultaneously.
- Performance is concluded to be non-differentiating criteria among all paints except for XZM480 International, which is concluded to not perform as well relative to the control paint and five alternatives. Exposure is concluded to be non-differentiating among the six alternatives, and differentiating yet preferable when comparing the six alternatives to the copper antifouling paint due to release mechanisms. Therefore, hazard and cost/availability are the main differentiating criteria for selecting preferable alternative(s).
- In cases where the selection of preferable alternative(s) conflicts upon review of the hazard and cost/availability results, hazard is given a higher weight than cost/availability, as explained under weighting of criteria above.

This assessor determined that selecting and implementing one of the decision methods found in Appendix A in the IC2 Guide (i.e., simple, comparison, and simultaneous comparison methods) is not necessary to identify a preferred alternative. The data analysis is straightforward given findings across the four modules.

Table 34 presents a summary matrix of findings, which includes rationale for whether or not each alternative paint is preferred relative to the control paint.

Conclusions

- Surface Coat Part A – Black appears to be a preferable alternative (with important caveats noted below) to copper antifouling paint since it has the lowest percentage of Benchmark 1 chemicals in the formulation of any of the paints evaluated. Compared to copper antifouling paint, Surface Coat Part A – Black is also preferable from an exposure perspective. However, no cost data were located for this paint, with the exception of its manufacturer deeming it as "cost-effective" in promotional materials.
- BottomSpeed TC Base Coat/Top Clear Coat appears to be the next most preferable alternative. BottomSpeed could potentially have a preferable hazard profile compared to copper antifouling paint, but given the large range of assumed Benchmark 1 chemicals in

its formulation (34.2-94.9%), its hazard may be worse than the copper control. It is preferable to copper antifouling paint in terms of exposure but is lacking complete cost data. Given the ambiguity in its hazard profile and lack of complete cost data, it is not recommended as a preferred alternative.

- XZM480 International is not recommended as a preferred alternative given the large range of assumed Benchmark 1 chemicals in its identified formulation; the unidentified chemicals in its formulation were assumed to be Benchmark 1. Additionally, XZM480 International is no longer commercially available and concluded to not perform as well relative to the control paint and five alternatives.
- Intersleek 900 System and Hempasil XA278 have roughly equal or worse hazard profiles than the control paint, and Hempasil XA278 is no longer commercially available. Therefore, these two formulations are not recommended as preferred alternatives.
- Klear N' Klean has a roughly equal or worse hazard profile than the control paint and is no longer commercially available; it is therefore not recommended as a preferred alternative.

Caveats

While Surface Coat Part A – Black appears to be the least hazardous alternative on a hazard continuum compared to the control paint and five alternatives, the formulation still poses serious hazard concerns as shown in chemical hazard summary tables in the Uniform Data Set.

- Based on the higher end of the range of Benchmark 1 chemicals in formulation, it is possible that nearly 50% of chemicals are Benchmark 1.
- **Human health concerns:** Two of its eight chemical components are rated as "High" for carcinogenicity, one is rated as "High" for mutagenicity, and one is rated as "Medium" for developmental effects.
    - In comparison, six of 27 chemical components in the control paint are rated as "High" for carcinogenicity, none is rated as "High" for mutagenicity, two are rated as "High" and six as "Medium" for developmental effects. Note that Surface Coat Part A – Black and the control paint both had gaps in hazard data across Group 1 human health effects.
- **Environmental concerns:** One of its eight chemical components is rated as "High" for acute aquatic toxicity. One is rated as "Very High" for chronic aquatic toxicity. Seven are rated as "Very High" and none as "High" for persistence, and two are rated as "Very High" and one is rated as "High" for bioaccumulation.
    - In comparison, three of 27 chemical components in the control paint are rated as "High" and seven as "Very High" for acute aquatic toxicity. Six are rated as "Very High" and three as "High" for chronic aquatic toxicity. Eleven (11) are rated as "Very High" and five as "High" for persistence. One is rated as "Very High" and none as "High" for bioaccumulation. Note that Surface Coat Part A – Black and the control paint both had gaps in hazard data across ecotoxicity and environmental fate endpoints.

The data gaps across the four modules, combined with the fact that many assumptions had to be made in order to differentiate the relative hazards of the paints, reduce the level of confidence in the results. For these reasons, it is concluded that Surface Coat Part A – Black is potentially a preferable alternative to copper antifouling paint but it should not be considered an optimal alternative. Ideally, more preferable alternatives are available (or soon to be available) on the markets that were not assessed as part of this project. If not, these findings point to the need for a green chemistry challenge to develop formulations that, at a minimum, contain no Benchmark 1 chemicals and are equivalent (if not preferable) to copper antifouling paint across the criteria of performance, cost and availability, and exposure.

<table>
<tr><th colspan="7">Table 34: Summary Matrix of Findings</th></tr>
<tr><th>PAINT</th><th>HAZARD</th><th>PERFORMANCE</th><th>COST & AVAILABILITY</th><th>EXPOSURE</th><th>PREFERRED?</th><th>RATIONALE</th></tr>
<tr><td></td><td>Total percent of Benchmark 1 or equivalent in formulation; based on data from Uniform Data Set (Task 1)</td><td>Findings based on data from U.S. EPA (2011) and DTSC 2011 reports</td><td>Findings based on data from U.S. EPA (2011) and DTSC 2011 reports. Annualized total costs included below.</td><td>Findings based on data from Uniform Data Set (Task 1), MSDS for paints, U.S. EPA (2011), and DTSC 2011 reports</td><td></td><td></td></tr>
<tr><td>Pettit Marine Paint Trinidad Pro Antifouling Bottom Paint 1082 Blue</td><td>79.07-85.2%</td><td rowspan="3">Concluded that performance is not a differentiating factor among all paints except for XZM480 International.</td><td>Commercially available; $953-$1,238 for a 30’ boat and $1,306-$1,704- for a 40’ boat.</td><td rowspan="5">Concluded that exposure is not a differentiating factor among the six alternative paints, and is differentiating yet preferable to the copper antifouling paint due to release mechanisms.</td><td></td><td></td></tr>
<tr><td>Klear N’ Klean Plus XP-A101 White Topcoat</td><td>76-95%</td><td>Not commercially available.</td><td>No</td><td>• Similar or worse hazard profile vs. control
• Not commercially available</td></tr>
<tr><td>Intersleek 900 System (Primer and Top Coat)</td><td>100% of identified formulation is Benchmark 1; assumed that unidentified chemicals are Benchmark 1</td><td>Commercially available; $891-$1,890 for a 30’ boat and $1,226-$2,598 for a 40’ boat.</td><td>No</td><td>• Similar or worse hazard profile vs. control
• Similar cost vs. control</td></tr>
<tr><td>XZM480 International</td><td>13-87.5% of identified formulation is Benchmark 1; assumed that unidentified chemicals are Benchmark 1</td><td>Did not perform well. Peeling was observed.</td><td>Not commercially available.</td><td>No</td><td>• Uncertain whether hazard profile is better or worse vs. control given large range of Benchmark 1 chemicals in formulation
• Not commercially available
• Poorer performance</td></tr>
<tr><td>BottomSpeed TC Base Coat/Top Coat Clear</td><td>34.2-94.9%</td><td>Concluded that performance is not a differentiating factor</td><td>Commercially available. $1,088-$1,434 [Cleaning costs are</td><td>No</td><td>• Uncertain whether hazard profile is better or worse vs. control</td></tr>
</table>

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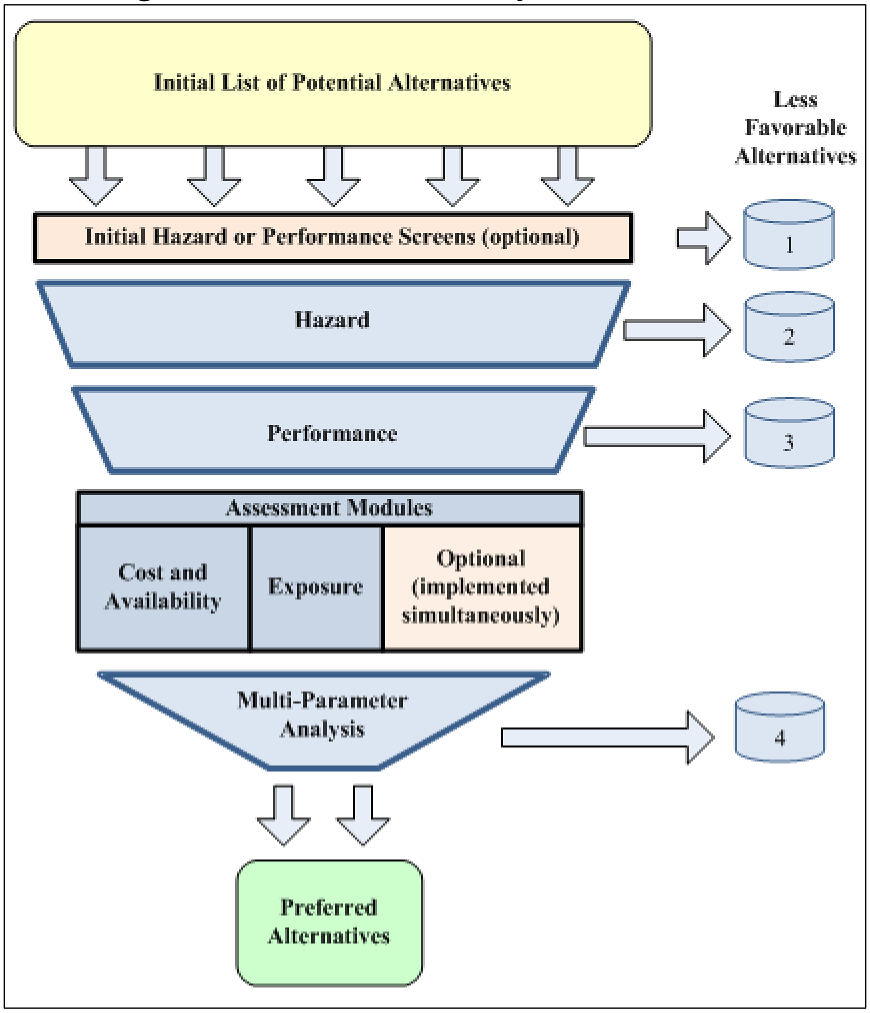
Table 34: Summary Matrix of Findings						
PAINT	**HAZARD**	**PERFORMANCE**	**COST & AVAILABILITY**	**EXPOSURE**	**PREFERRED?**	**RATIONALE**
		among all paints except for XZM480 International.	assumed to be comparable to those of other soft nonbiocide paints].			given large range of Benchmark 1 chemicals in formulation
Hempasil XA278	100% of identified formulation is Benchmark 1; assumed that unidentified chemicals are Benchmark 1		Not commercially available		No	• Similar or worse hazard profile vs. control • Not commercially available
Surface Coat Part A – Black	18-43%		Information not available in U.S. EPA or CalEPA (2011) reports. Deemed "cost-effective" in a manufacturer's press release.		Yes, with important caveats	• Lowest percentage of Benchmark 1 chemicals in formulation • Lacking cost data • Exposure is preferable vs. control

ALTERNATIVES ASSESSMENT USING THE IC2 HYBRID FRAMEWORK CONDUCTED BY ABT ASSOCIATES (TASK 4)

The Hybrid Framework combines elements from both the Sequential and Simultaneous Frameworks. Hazard and Performance Evaluation Modules were performed sequentially, and the Cost and Availability and Exposure Assessment Modules were performed simultaneously. In addition, the following optional modules were implemented: Materials Management, Social Impact, and Life Cycle. The overall process is summarized in Figure 12.

Figure 12: Overview of IC2 Hybrid Framework



Source: IC2 (2013)

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Sequential Portion of Hybrid Framework (Iteration 1)[25]

Hazard Module

Initial Screen

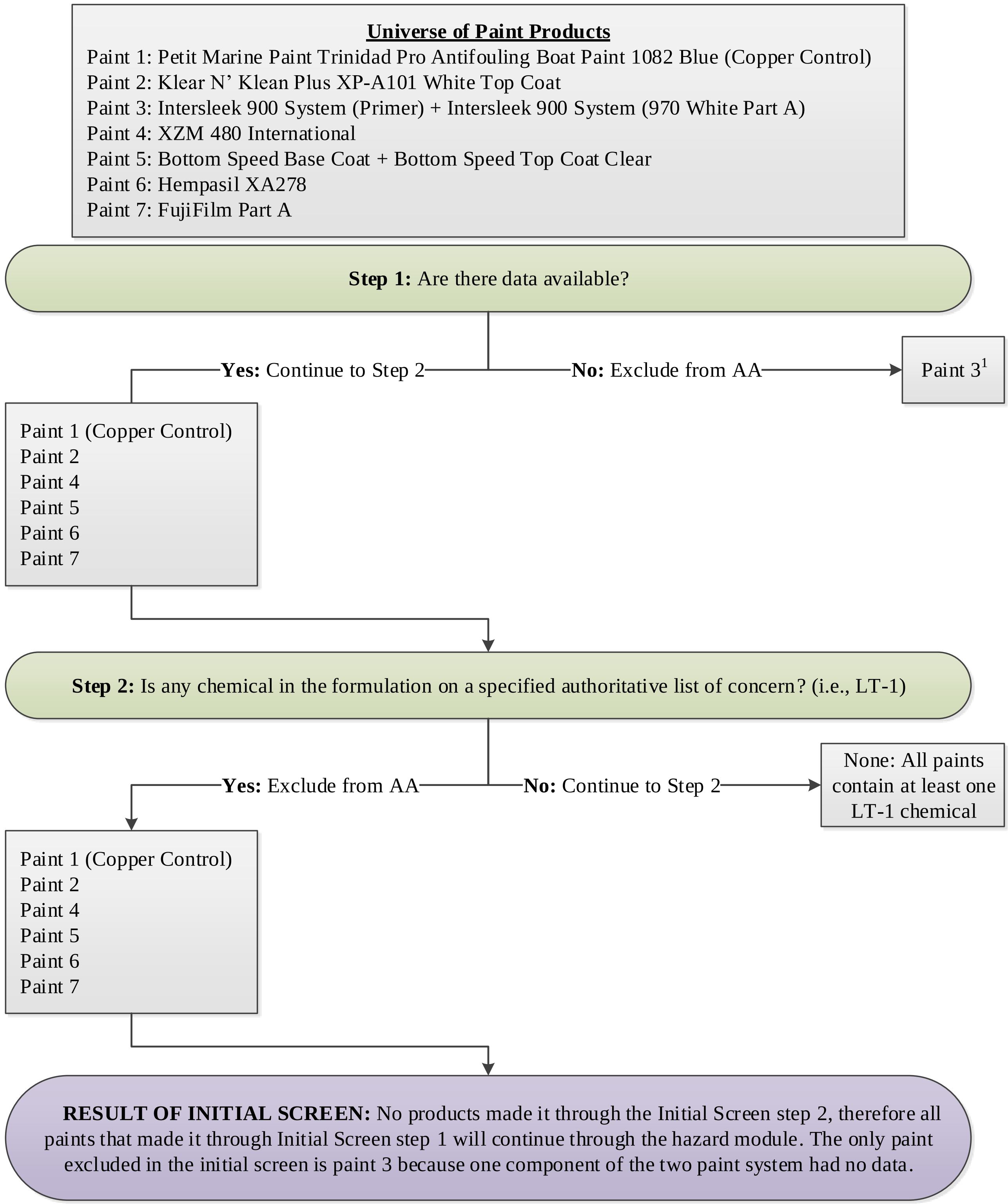
Before screening out paints based on their hazard classification as outlined in the IC2 Guide, we first screened out any alternatives for which no formulation data were available. Using the Uniform Data Set, we screened the alternatives to exclude any alternative formulations that contained chemicals on authoritative hazard lists – i.e., received a GreenScreen® score of LT-1[26]. This step is following the IC2 Guide's recommendation to screen out LT-1 chemicals from consideration. As is discussed in more detail in the next section, the IC2 Guide is primarily written assuming the screening out of individual chemicals but this assessment is at the formulation level. Therefore, we reviewed the entire paint formulations[27] and evaluated if they contained LT-1 chemicals. This was done with the goal of eliminating any paint formulation with an LT-1 chemical. The process for the Initial Screen is outlined in Figure 13.

[25] It should be noted that after progressing through the Cost and Availability Module no alternatives remained. Therefore, a second iteration of the Hazard Module was performed. Both iterations are described.

[26] The first step in the hazard assessment portion of the Uniform Data Set is to perform a List Translator search. The GreenScreen® List Translator (LT) comprises over 850 lists from 36 primary authoritative and screening sources that include national and international regulatory and hazard lists, influential NGO lists of chemicals of concern (screening lists), authoritative scientific bodies, European Risk and Hazard Phrases, and chemical hazard classifications by countries using the Globally Harmonized System of Classification and Labeling System.

[27] Two of the paints included in our evaluation (specifically Paint 3: Intersleek and Paint 5: BottomSpeed) are two-component systems, that is, they include a bottom coat/primer and a top coat. In these instances we assumed the two paints were integral to one another, and therefore, although they are two separate paints, they were viewed as one.

Figure 13: Overview of Initial Screen



[1] Paint 3 is a combination of two component paints, one of which had no data. Therefore, the entire formulation was excluded.

As Figure 13 notes, we excluded only one product from further evaluation with the Initial Screen – Paint 3: the Intersleek 900 System. No data were available on the primer and, because the primer and topcoat are used together, we excluded the system from evaluation.

As for screening out formulations that contain chemicals on authoritative lists, we did not exclude any of the paints because all of the paint formulations included at least one chemical that is on an authoritative list (see Table 35). Therefore, all of the paints, with the exception of Paint 3, moved on to the Level 2 Hazard Module. While undesirable, the presence of LT-1 chemicals is not a distinguishing factor among the paint formulations.

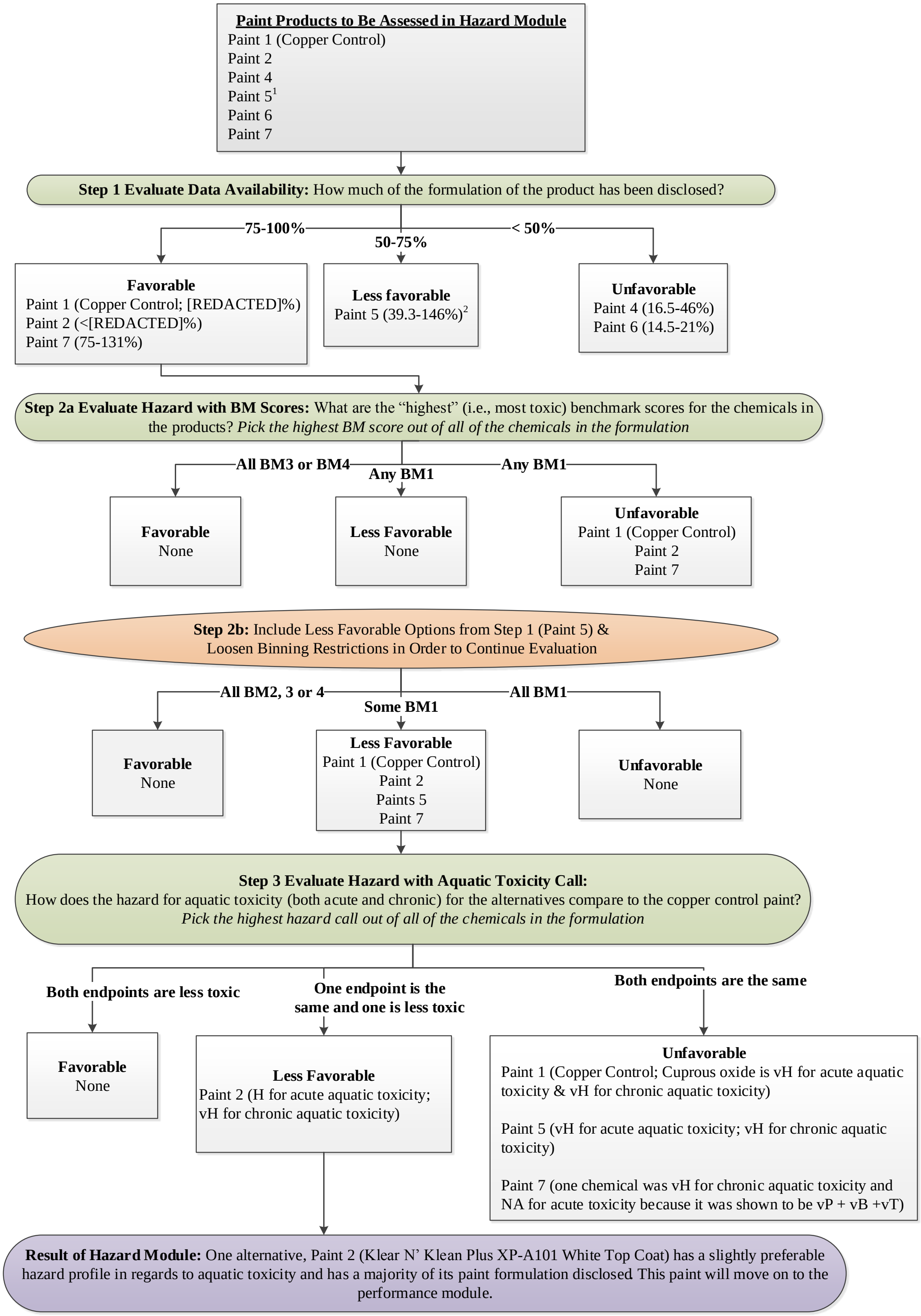
Table 35: List of LT-1 Chemicals for Each of the Paints Being Assessed in Step 2 of the Initial Screen

Paint Formulation	LT-1 Chemicals
Paint 1: Trinidad Pro	[REDACTED]
Paint 2: Klear N' Klean	[REDACTED]
Paint 4: XZM480	Solvent naphtha (petroleum) light aromatic; methanol
Paint 5: BottomSpeed	Aromatic 100; methanol
Paint 6: Hempasil	Ethylbenzene
Paint 7: FUJIFILM	Naphtha (petroleum); hydrotreated light

Level 2 Hazard Module

Before beginning the process of evaluating hazard, it should be noted that the IC2 Guide does not specifically address assessing hazard at the product level. It instead assumes the assessor is evaluating hazard on a chemical-by-chemical basis and that the assessor can select the chemicals with the highest Benchmark scores as less hazardous alternatives. However, the hazard evaluation is more complicated at the product level since a single Benchmark score is not provided for the formulation. Therefore, in the process of evaluating the alternative paint formulations, we brainstormed several approaches to evaluating hazard at the product level. We considered using the percentages provided in the Uniform Data Set on the proportion of the formulation in each Benchmark category, calculating Benchmark percentages based on the percentage of chemicals at each Benchmark score, or using specific chemicals to represent the entire formulation (e.g., the most toxic chemicals or the functional chemicals) and compare their hazard designations to that of the copper component of the control paint. We took a step-wise approach that first binned paints based on availability of formulation data, next on the Benchmark scores of the chemicals in formulation, and lastly on the acute and chronic toxicity of representative chemicals in the formulation, as shown in Figure 14 and described below.

Figure 14: Overview of Process and Results of Level 2 Hazard Module Implementation



[1] Paint 5 is a two-component formulation, but for the purposes of this evaluation, we viewed it as one system.
[2] Although the lower range of the disclosed formulation percentage for Paint 5 is in the unfavorable bin, the majority of the range is not.

Step 1: Evaluate Data Availability

To address uncertainty and data gaps into our hazard evaluation beyond Initial Screen, we developed criteria to bin chemicals as favorable (>75%) less favorable (50 to 75%), or unfavorable (<50%) based on the percentage of the paint formulation disclosed[28]. Because we want to avoid regrettable substitution, we do not want to assume an alternative with a lesser percentage of disclosure is safer than copper antifouling paint.

Paint 5 has a span of formulation disclosure that ranges from our unfavorable bin (39.3%) to our favorable bin (146%) (see Figure 14); therefore, we grouped it as less favorable. Paint 2 and Paint 7 were binned as favorable, Paint 5 was less favorable, and Paints 4 and 6 were unfavorable.

Step 2: Evaluate Hazard with Benchmark Scores

Next, we evaluated the hazards of the main copper based chemical in the control paint, cuprous oxide, compared to all of the hazards of the chemicals in Paints 2 and 7, the favorably binned alternatives from Step 1. Any paint which included a Benchmark 1 chemical was binned as unfavorable. The IC2 Guide assumes a chemical-to-chemical comparison of Benchmark scores and directs the user to select the chemical with the highest (least toxic) Benchmark score. However, since we conducted our evaluation at the product level, we opted to compare the Benchmark scores for all the chemicals in the paint formulation and select the lowest Benchmark score (i.e., the most toxic chemical) to represent the paint.

As noted in Figure 14, all of the alternative paint formulations contain Benchmark 1 chemicals and, therefore, we also evaluated Paint 5, which was initially binned as less favorable based on the percent of the paint formulation disclosed. However, Paint 5 also contains Benchmark 1 chemicals. Table 36 outlines the chemicals in the each of the paint formulations that received Benchmark 1 scores.

Table 36: Overview of Benchmark 1 Chemicals Included in Step 2 of the Hazard Module

Paint Included in Hazard Module	Benchmark 1 Chemicals in Paint Formulation
Paint 1: Trinidad Pro	[REDACTED]
Paint 2: Klear N' Klean	[REDACTED]
Paint 5: BottomSpeed	**Base Coat:** Talc (powder)[1], Crystalline silica[1], Mineral spirits, Zinc oxide **Top Coat:** Xylene, Trimethoxy(methyl)silane[1], Trimethylated silica
Paint 7: FUJIFILM	Silica[1], Vinyl silicone polymer, Coating ferrite powder, Octamethylcyclotetrasiloxane, Amorphous silica (modified)[1]

[1] This chemical is a Benchmark 1 for the inhalation route of exposure only
[2] Note this is the chemical of concern in this product
[3] These chemicals were not assessed in the Uniform Data Set due to late disclosure. However, it is assumed their hazard profiles are very similar to that of cuprous oxide.
[4] This is a Benchmark 1_{TP} which means the score is based on hazards of a chemical's transformation product (this is equivalent to a GreenScreen® Benchmark 1)

[28] These percentages are based on summing the percentage of chemical component at the product level as provided by the formulation material safety and data sheets (MSDS) and included in the Uniform Data Set (ToxServices 2014a). These are often reported as ranges (e.g., water may make up 50-60% of a formulation), which can result in percentages above 100%.

Given that all three of the alternative paints which made it to Step 2a (see Figure 14) of the Hazard Module were binned as unfavorable and that we did not feel comfortable including any paints for which <50% of the formulation was disclosed, the way to proceed with the assessment was to "loosen" the criteria for comparing the alternative paint formulations to the copper component of the control paint (see Step 2b in Figure 14). Therefore, paints which contained some but not all Benchmark 1 chemicals (Paints 1, 2, 5, and 7) were binned as less favorable and all four paints moved on to further evaluation of their hazards. The presence of Benchmark 1 chemicals is not a distinguishing trait between the paint formulations and therefore we opted to examine more closely the aquatic toxicity of the alternative paint formulations recognizing any paint formulation recommended will contain several chemicals of concern.

Step 3: Evaluate Hazard Concentrating on Aquatic Toxicity

Because the human and environmental hazards summarized by the Benchmark scores is non-differentiating based on our approach to evaluate hazard at the formulation level, we opted to further investigate aquatic toxicity related to cuprous oxide and the alternative paint formulations. We concentrated on aquatic toxicity given that the main concern with cuprous oxide within copper antifouling paint is its aquatic toxicity. We developed bins based on the two aquatic toxicity scores (acute and chronic) presented for cuprous oxide in the copper antifouling paint. Specifically, if any chemical within a paint formulation had the same or worse hazard designation as cuprous oxide in regard to chronic and acute aquatic toxicity, it was binned as unfavorable; if one, but not both, of the hazard designations was lower than cuprous oxide, it was binned as less favorable; and if both hazard designations were lower than cuprous oxide, the paint was binned as favorable.

Figure 14 demonstrates that none of the alternative paints were binned as favorable. None of the alternative paint formulations had strongly preferable aquatic hazards since all the paints contain at least one chemical that is very high for chronic aquatic toxicity and high for acute aquatic toxicity. The chemicals in the formulations that lead to these hazard designations are included in Table 37. The top coat for Paint 5 (BottomSpeed) appears to be the least toxic in regard to aquatic toxicity, but unfortunately it is used with a base coat that includes zinc oxide, which, as noted by U.S. EPA (2011), is not a biocide but acts similarly in that it is photoactive[29] and contains a heavy metal (zinc). However, it is possible that zinc oxide in this formulation is intended to help other components of the formulation function rather than act as an antifoulant. This is supported by the fact that zinc oxide is in the base coat and would not be directly exposed to the water.

[29] Photoactive means that when exposed to light, water and dissolved oxygen molecules combine to form a layer of hydrogen peroxide around a boat hull (U.S. EPA 2011).

Table 37: Overview of the Highest Aquatic Toxicity Hazard Designations from the Alternative Paint Formulations Which Made it to Step 3 of the Hazard Module Compared to the Copper Control				
Paint Included in Hazard Module	**Highest Hazard Designation for Acute Aquatic Toxicity**	**Chemical(s) Associated Acute Aquatic Toxicity Call**	**Highest Hazard Designation for Chronic Aquatic Toxicity**	**Chemical(s) Associated Chronic Aquatic Toxicity Call**
Paint 1: Trinidad Pro[1]	vH	Cuprous oxide	vH	Cuprous oxide
Paint 2: Klear N' Klean	H	[REDACTED]	vH	[REDACTED]
Paint 5: BottomSpeed	Top Coat: H	Xylene	M	Trimethylated silica; Xylene
	Bottom Coat: vH	Mineral spirits; Zinc oxide	vH	Zinc oxide
Paint 7: FUJIFILM	H, Not assessed[2]	H: Naphtha (petroleum), Hydrotreated light Not Assessed: Octamethylcyclotetrasiloxane	vH	Octamethylcyclotetrasiloxane

[1] Because the copper in this paint is the concern we compared the hazard designations for the alternative paint formulations to copper component (cuprous oxide) of the control paint.
[2] Octamethylcyclotetrasiloxane was not assessed because it was vH in regard to chronic aquatic toxicity, vH for persistence and vH for bioaccumulation. Through the targeted GreenScreen® this was given a Benchmark 1 and no other endpoints were assessed.

Paint 7 appears preferable since the highest acute aquatic toxicity rank for a chemical in its paint formulation is high; however, octamethylcyclotetrasiloxane, which has a very high hazard designation for chronic aquatic toxicity, was not assessed for acute aquatic toxicity because of the tailored GreenScreen® approach taken to develop hazard assessments in the Uniform Data Set. Octamethylcyclotetrasiloxane was rated very high for chronic aquatic toxicity, very high for persistence, and very high for bioaccumulation and was therefore given a score of Benchmark 1 with no additional hazard assessment based on the Targeted GreenScreen® approach taken. As such, no evaluation was done on the acute aquatic toxicity of this chemical. We are therefore uncomfortable moving this paint to the next round of assessment.

This leaves Paint 2 as the only preferable option to move on to the Performance Evaluation Module, although there are very high chronic aquatic toxicity concerns due to the presence of [REDACTED] in the formulation. The acute aquatic toxicity hazard ranking of high is lower than cuprous oxide's acute aquatic toxicity ranking of very high.

Results of Hazard Module

As outlined in Figure 14, based on the Level 2 Hazard Module results, we binned Paint 2, Klear N' Klean, as a less favorable alternative, and all other paints were binned as unfavorable. Given there are no favorable alternatives, Paint 2 continued to the next step of the framework to evaluate performance. It should be noted that all of the alternatives reviewed that potentially have more than 50% of their formulation disclosed (Paints 1, 2, 5, and 7) contain Benchmark 1 chemicals and chemicals which are on authoritative lists of concern (i.e., LT-1 chemicals). No alternative is clearly preferable based on hazard alone and therefore we concentrated mainly on the aquatic toxicity concerns related to the paint formulation, given the impetus for this assessment. However, it should be recognized that concentrating solely on aquatic toxicity concerns may overlook human health hazards associated with chemicals in the alternative paint formulations. This is supported by the data presented in Table 38 that outlines which human health or environmental attributes were ranked high or very high for the Benchmark 1 chemicals contained in the paint formulations.

Table 38: Summary of Endpoints Associated with Benchmark 1or LT-1 Chemicals for Cuprous Oxide and the Paint Formulations Binned as Favorable or Less Favorable based on Data Availability

Benchmark 1or LT-1 Chemical (CAS#)	**Endpoints with H or vH Hazard Rating[1]**
Paint 1: Trinidad Pro	
Cuprous Oxide[2] (1317-39-1)	Acute Aquatic, Chronic Aquatic, Persistence
Paint 2: Klear N' Klean	
[REDACTED]	[REDACTED]
Paint 5: BottomSpeed (Includes both Base Coat and Top Coat)	
Talc (14807-96-6)	Systemic Toxicity (repeated dose)[3], Persistence
Crystalline Silica (14808-60-7)	Carcinogenicity[3], Systemic Toxicity (repeated and single dose)[3], Persistence
Aromatic 100 (64742-95-6)	Carcinogenicity, Mutagenicity, Acute Aquatic,
Mineral Spirits (64742-48-9)	Acute Aquatic, Chronic Aquatic, Persistence, Bioaccumulation
Zinc Oxide (1314-13-2)	Systemic Toxicity, Acute Aquatic, Chronic Aquatic, Persistence
Xylene (1330-20-7)	Developmental, Systemic Toxicity (single dose), Skin Irritation,

Table 38: Summary of Endpoints Associated with Benchmark 1or LT-1 Chemicals for Cuprous Oxide and the Paint Formulations Binned as Favorable or Less Favorable based on Data Availability	
Benchmark 1or LT-1 Chemical (CAS#)	**Endpoints with H or vH Hazard Rating[1]**
	Eye Irritation, Acute Aquatic
Trimethoxy(methyl) silane[4] (1185-55-3)	Flammability
Trimethylated Silica (68909-20-6)	Acute Toxicity[3,6], Systemic Toxicity (repeated dose) [3] Persistence, Systemic Toxicity (single dose)[5], Neurotoxicity (single dose)[5]
Methanol (67-56-1)	Developmental, Acute Toxicity, Systemic Toxicity, Flammability
Paint 7: FUJIFILM	
Silica (7631-86-9)	Carcinogenicity[3], Systemic Toxicity (repeated dose)[3], Persistence
Vinyl Silicone Polymer (68083-19-2)	Persistence, Bioaccumulation
Naphtha (Petroleum), Hydrotreated Light (64742-49-0)	Carcinogenicity, Mutagenicity, Acute Aquatic, Bioaccumulation
Coating Ferrite Powder (68186-94-7)	Systemic Toxicity (repeated), Persistence
Octamethylcyclotetrasiloxane (556-67-2)	Chronic Aquatic, Persistence, Bioaccumulation
Amorphous Silica (modified) (68909-20-6)	Acute Toxicity[3,6], Systemic Toxicity (repeated dose)[3] Persistence, Systemic Toxicity (single dose)[5], Neurotoxicity (single dose)[5]

[1] Given the approach taken for the GreenScreen®, it is possible that not all endpoints were evaluated for all chemicals. Therefore, this column does not contain any chemical/endpoint combination which was not assessed.
[2] Given this is the chemical of concern this is the only chemical evaluated from Paint 1. There are many other LT-1 or Benchmark 1chemicals included in the Paint 1 formulation. Specifically, 14 Benchmark 1or LT-1 chemicals for the inhalation route of exposure, and 11 for the oral and dermal routes of exposure.
[3] For the inhalation route of exposure
[4] This is a Benchmark 1for its transformation product
[5] For the oral route of exposure
[6] For the dermal route of exposure

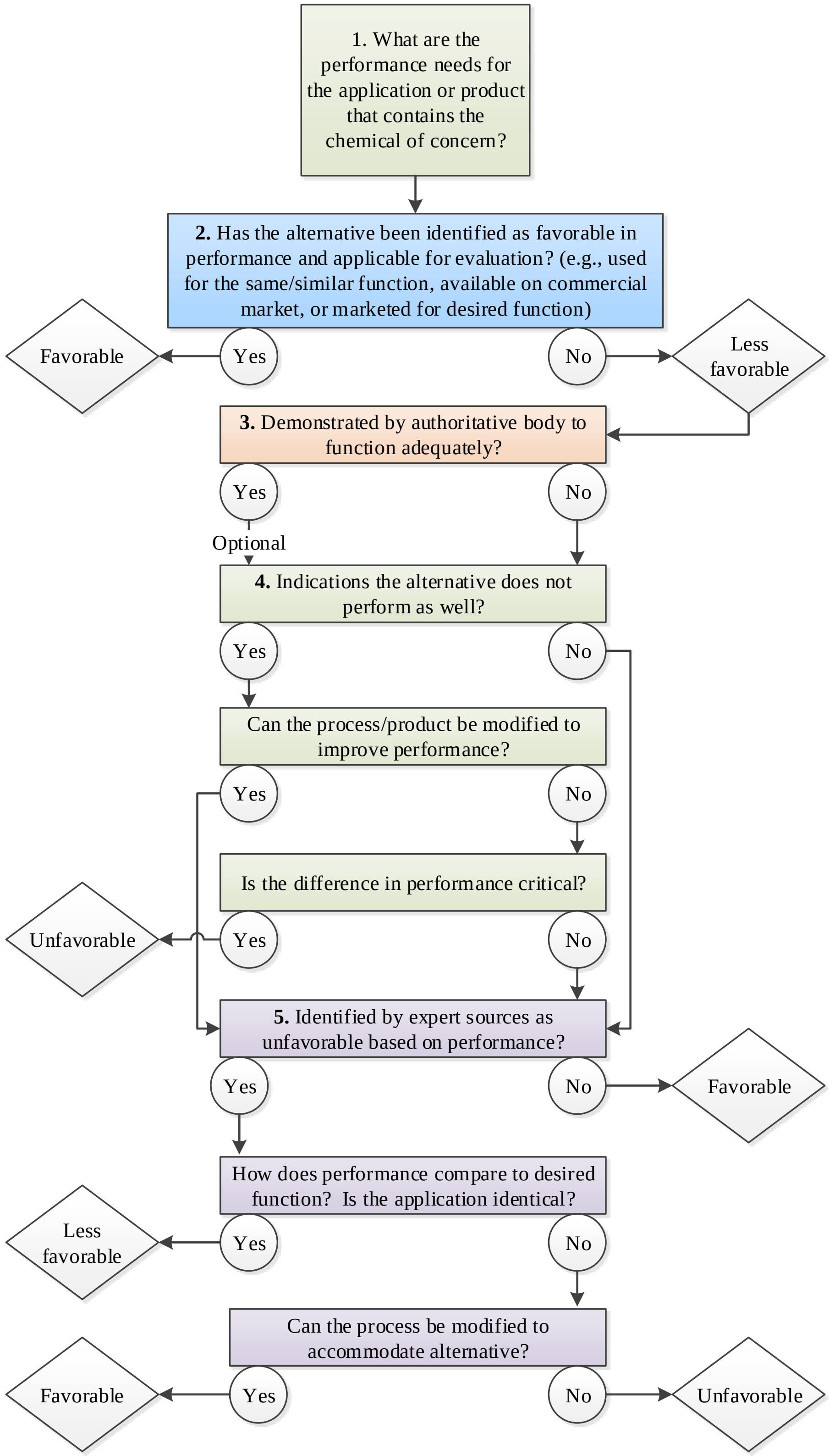
Given that all of the paint formulations we reviewed have Benchmark 1 or LT-1 chemicals, there are concerns about suggesting an alternative. At this phase in the process, an assessor may opt to switch over to the simultaneous framework to review exposure potential along with hazard, in order to select an alternative which poses less risk due to a reduction in exposure given that the hazard among these paint formulations are all high. However, given the goal to evaluate the Hybrid Framework, we next evaluated the Performance Evaluation Module to properly assess the usefulness of the IC2 Guide. We caution recommending Paint 2 as a preferred alternative to simply reduce aquatic toxicity concerns.

Performance Evaluation Module

We used existing data published by U.S. EPA and CalEPA in 2011 to execute the Performance Evaluation Module. As summarized previously, each report evaluated the relative performance of the Nonbiocide alternatives. This was done with both panel and full boat-hull testing.

We developed a decision flowchart based on the guidance provided by the IC2 Guide in the Level 1 Performance Evaluation Module. Figure 15 outlines how we opted to bin the alternatives based on the questions presented in the IC2 Guide. The following section will describe our decisions in this module with respect to the one alternative that made it through the Hazard Module – Paint 2: Klear N' Klean – and the data supporting those decisions.

Figure 15: Overview of the Performance Evaluation Module Process As Provided by the IC2 Guide



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Level 1 Performance Evaluation Module

Step 1: Determine Performance Needs

The first question of the Level 1 evaluation directs us to determine the performance needs for the copper antifouling paint alternatives. Copper antifouling paint is used as an antifouling agent to slow the growth of organisms that attach to the hulls of boats, which can affect boat durability and performance. Copper antifouling paint achieves this by serving as a biocide and leaching copper into the surrounding waters. Most antifouling paints are made with copper since the metal is undesirable for fouling organisms. Soft Nonbiocide paints, such as Paint 2 (Klear N' Klean), control the amount of fouling by creating slippery surfaces for which it is difficult for fouling organisms to attach[30]. For the purposes of this Performance Evaluation Module, we are looking at the efficacy of the foul release capabilities for the soft Nonbiocide alternatives.

Step 2: Has the alternative already been identified as a favorable alternative with respect to performance?

In order to answer this question, we aimed to answer three sub-questions provided in the IC2 Guide.

<u>Is the alternative being used for the same or similar function?</u>

CalEPA (2011) included Paint 2 in its evaluation of alternatives to copper antifouling paint as one of several soft Nonbiocides available. As a soft Nonbiocide, Paint 2 is used as a foul release paint in order to limit the amount of fouling on boats. CalEPA (2011) investigated Paint 2 as part of its one-year panel testing of alternatives to copper antifouling paint. The panel testing protocol was developed based on stakeholder input and is meant to mimic boat hull conditions. U.S. EPA (2011) also evaluated Paint 2 through panel and boat hull testing to test its antifouling efficacy[31]. This indicates that Paint 2 has been used for the same function as copper antifouling paint – to limit boat hull fouling – and can be considered an alternative in terms of performance and binned as favorable.

Although Paint 2 was binned as favorable based on providing the same function, there are indications of subpar performance when compared to copper antifouling paint. CalEPA (2011) found that panels treated with Paint 2 cleaned readily. However, while the Paint 2 coating condition was good for almost the entire duration of the study (1 year), CalEPA (2011) did note some scratches during the last inspection. CalEPA (2011) did not conduct hull testing on Paint 2 because it contains an ingredient that was removed from the market; disclosure of this ingredient's identity is not contained in the report.

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[30] There are two types of non-biocide paints, hard and soft. Hard non-biocide paints are usually composed of hard materials such as epoxy or ceramic that provides a hard slick surface. Soft non-biocide paints are formulated with silicon or fluoropolymer compounds. The CalEPA (2011) study did not evaluate any of the hard non-biocide paints since they were found to be less effective than soft non-biocide paints in the U.S. EPA (2011) report.

[31] It is possible that the Klear N' Klean product (Paint 2) evaluated by U.S. EPA is not Klear N' Klean Plus XP-A101 but instead Klear N' Klean XP-A100. In CalEPA's panel tests, Klear N' Klean Plus XP-A101 performed better than Klear N' Klean XP-A100. The U.S. EPA report does not specify which Klear N' Klean product they evaluated.

U.S. EPA (2011) evaluated Paint 2 in both panel and hull testing. In panel testing, Paint 2 performed poorly in terms of the overall amount of fouling, but good in terms of cleaning effort and cleaning performance. In boat hull testing, Paint 2 performed fair for the amount of fouling and cleaning effort, but poor in regard to overall performance. U.S. EPA (2011) noted this is because Paint 2 did not perform as well as copper hull paint standards for fouling performance, cleaning, and coating condition and longevity. Notably, U.S. EPA (2011) noted peeling or delamination along the waterline area about seven to eight months into the evaluation.

However, Paint 2 performs better than copper antifouling paint in certain areas. Copper antifouling paint is generally cleaned every three weeks during the summer and every four during the winter. The manufacturer's recommendation for Paint 2 is for it to be cleaned every six weeks. Furthermore, Paint 2 has a longer estimated lifespan (two to five years) compared to copper antifouling paint (two to three years), although due to the limited timespan of the testing conducted by CalEPA (2011) and U.S. EPA (2011), they are unable to fully verify those estimates. Paint 2 is also favorable in that in can be rolled on and does not require spraying. Spraying is a more complex process of paint application given it can result in increased cost (CalEPA 2011). This is discussed in more detail in the Cost and Availability Module.

Finally, it is important to keep in mind that the performance testing conducted by CalEPA (2011) and U.S. EPA (2011) both occurred in waters along the California coast. Therefore, the performance results may not be directly applicable to fouling conditions in other water conditions.

<u>Is the alternative used in similar products available on the commercial market? Is the alternative marketed in promotional materials as an option for providing the desired function?</u>

Neither report provides specific information about the availability on the commercial market or the promotional materials for Paint 2. We were unable to find any information online related to Paint 2's availability on the commercial market or its promotion as an antifouling paint.

Results of Performance Evaluation Module

The results to the three sub-questions provided in the IC2 Guide are summarized in Table 39.

Table 39: Overview of Step 2 of the Performance Evaluation Module for Paint 2: Klear N' Klean

Question	Result
Same/similar function	Yes
Used in similar products available on the commercial market	Unknown
Promotional materials	Not Available

Based on our answers to Step 2 of the Level 1 evaluation, Paint 2 has been shown to provide the same function as copper antifouling paint for boat hulls as documented by U.S. EPA (2011) and CalEPA (2011) and is the only alternative which made it through both the Hazard and Performance Evaluation Modules. Therefore, Paint 2 was binned as favorable and moved forward to the simultaneous portion of the Hybrid Framework.

Simultaneous Portion of Hybrid Framework (Iteration 1)

Following the direction in the IC2 Guide and after completion of the modules in the sequential portion of the Hybrid Framework, we gathered data for the Cost and Availability and Exposure Assessment Modules. These data are described in the subsequent sections.

Cost and Availability Module

Level 1 Cost and Availability Module

Similar to the Performance Evaluation Module, we focused on existing data on product costs from CalEPA (2011) and U.S. EPA (2011). Each report evaluated the short- and long-term costs of Nonbiocide alternative paints. Although we were to simultaneously evaluate the alternatives and the control, we first had to collect the data for each module. Below, we describe the process for collecting the data on the Paint 2 paint option for the Cost and Availability Module.

Step 1: Is the alternative currently used in the application of interest?

Based on the CalEPA (2011) and U.S. EPA (2011) reports, it appears that Paint 2 is currently used as an antifouling paint and moves to the next step in this module.

Step 2: Is the alternative currently offered for sale in the application of interest?

Based on a call with Pettit Marine Paints (ToxServices 2014b), Paint 2 is no longer being manufactured nor is it commercially available. As a result, Paint 2 is binned as unfavorable and removed from consideration.

Results of Cost and Availability Module

As described above, we determined that Paint 2 is no longer commercially available, nor is it being manufactured. Subsequently Paint 2 was binned as unfavorable and removed from consideration.

Exposure Assessment Module

Although the Exposure Assessment Module is part of the simultaneous portion of this framework, the Cost and Availability Module indicated that Paint 2 is no longer commercially available. As such, it is meaningless to evaluate Paint 2 in the Exposure Assessment Module and we therefore revisited the sequential portion of the Hybrid Framework.

Hybrid Framework Results (Iteration 1)

The decision-making employed in the first iteration of the Hybrid Framework resulted in no favorable alternatives to copper antifouling paint. Following the guidance provided in the IC2 Guide, "If…no favorable alternative remains, it may be necessary to return to previous decision points and evaluate alternatives that were binned as less favorable." However, we did not have any products which were binned as less favorable. To summarize, the reason for exclusion for each of the paints is summarized in Table 40.

Table 40: Summary of Process of Excluding Alternatives for Iteration 1 of Hybrid Framework

Paint	Module at Exclusion	Reason for Exclusion[1]
Paint 2: Klear N' Klean	Cost and Availability	Removed from market
Paint 3: Intersleek	Initial Screen	No data on formulation of primer
Paint 4: XZM480	Hazard	Less than 50% of formulation available
Paint 5: BottomSpeed	Hazard	Contains a chemical with equivalent aquatic toxicity concern as the copper control
Paint 6: Hempasil	Hazard	Less than 50% of formulation available
Paint 7: FUJIFILM	Hazard	Contains a chemical with equivalent aquatic toxicity concern as the copper control

[1] Note that all formulations contain LT-1 and Benchmark 1 chemicals.

In order to fully evaluate the IC2 Guide we had to revisit the decisions made at each step of the hazard evaluation and re-evaluate chemicals that were binned as unfavorable. Note that we did this in the spirit of evaluating the IC2 Guide recognizing we are evaluating formulations which contain chemicals which are ranked as the same toxicity as the cuprous oxide in regard to aquatic toxicity. We recommend the IC2 Guide outline clearly the approach for re-evaluating chemicals or products which were binned as unfavorable in previous iterations of the modules. Given that a chemical was binned as unfavorable, the potential for regrettable substitution does exist.

In an attempt to review all of the modules in the IC2 Guide we revisited our approach to evaluating hazard.

Hazard Module (Iteration 2)

In the second iteration of the Hazard Module, the assessors began at the point in the process where more than one alternative was still being considered.

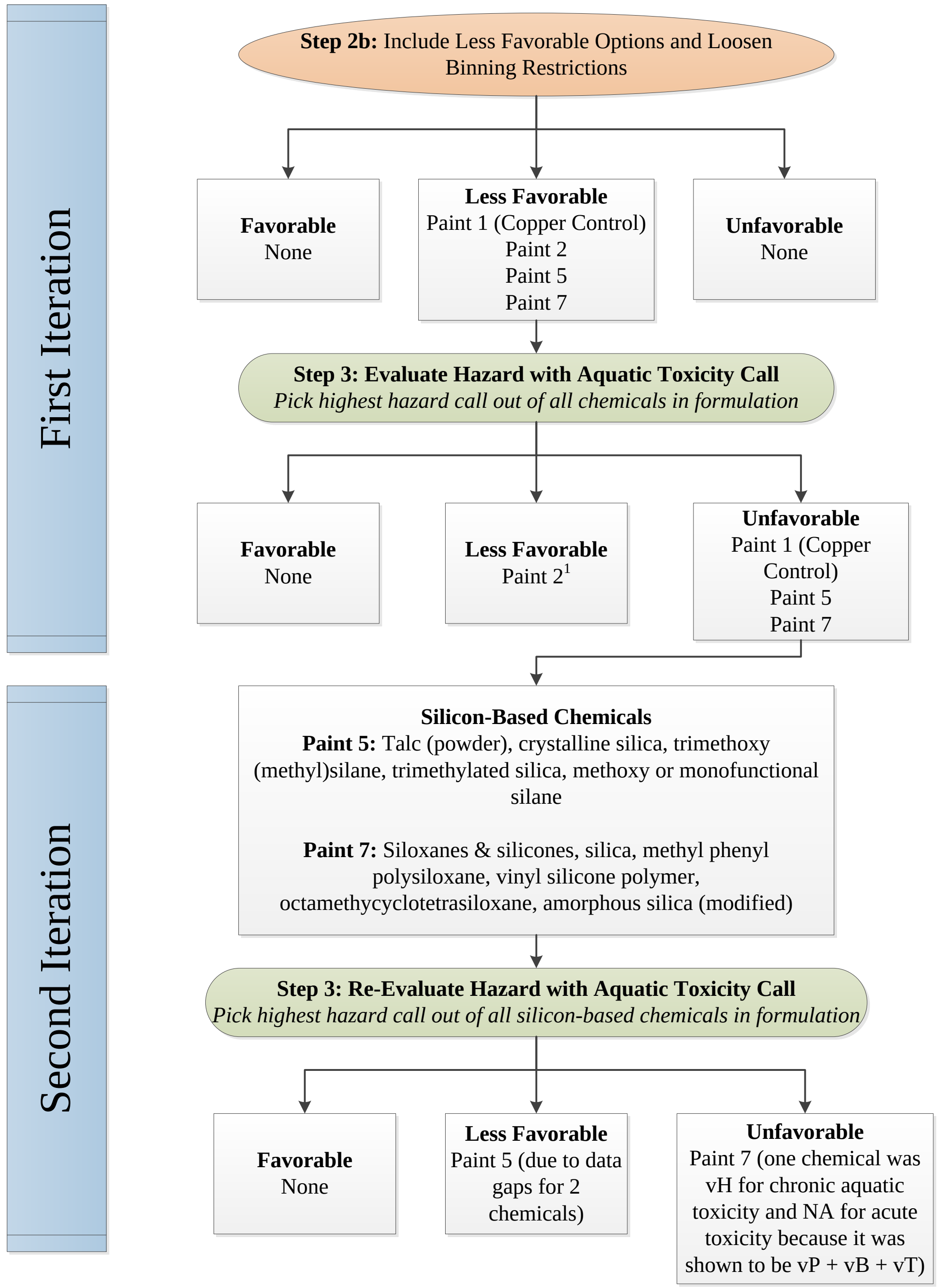
Level 2 Hazard Module (Iteration 2)

The last step in the assessment at which there was more than one alternative to copper antifouling paint in contention was at Step 2b of the Hazard Module (see Figure 14), when we binned paint formulations with some Benchmark 1 chemicals as less favorable. The criteria outlined in Step 3 of the first iteration of the Hazard Module, where we evaluated the hazard with the aquatic toxicity calls, resulted in no chemicals being binned as favorable, one being binned as less favorable (Paint 2), and the other two alternatives paints (Paint 5 and 7) being binned as unfavorable. Following the golden rule of the Alternatives Assessment process of reducing hazard through selecting a safer alternative, there is no feasible way Paint 5 or Paint 7 could be binned as less favorable or favorable when using the most aquatically toxic chemical to represent the entire formulation as we did in the first iteration of the assessment. This is because both of these paints contain chemicals that are equally hazardous as cuprous oxide when considering aquatic toxicity, with Paint 5 containing zinc oxide and Paint 7 containing octamethylcyclotetrasiloxane.

Given that the IC2 Guide does not dictate how to assess hazard at the product level, we decided to re-evaluate how we were reviewing the hazards of the chemicals within a paint formulation. Rather than identifying the chemical in each formulation with the highest aquatic toxicity (regardless of its function), we opted to evaluate the aquatic toxicity of the chemicals that function as the foul release agents in the alternative paints, and compare them to the aquatic toxicity of cuprous oxide which functions as the antifouling agent in copper antifouling paint. We are aware that Nonbiocide paints are usually based on silicon or fluoropolymers and therefore we made the assumption that the silicon or fluoropolymer-based chemicals in each of the formulations were the main functional components. We then reviewed the hazard data for any silicon or fluoropolymer-based chemicals in Paints 5 and 7, the only two paints remaining after Step 2 of the Hazard Module (Note: we did not re-evaluate Paint 2, which we determined is unfavorable given it is no longer available on the market). We did this while recognizing that there are other chemicals in the paint formulation which may assist in the fouling release property of the paints.

This approach could be informative to Nonbiocide paint formulators that would be interested in manufacturing a paint that has less toxic functional components. A flowchart depicting the new process is provided in Figure 16.

Figure 16: Overview of the Second Iteration of the Hazard Module



[1] We did not re-evaluate the Less Favorable paint from the First Iteration (Paint 2) since it is no longer commercially available.

Table 41 presents the data on the Benchmark scores and aquatic toxicity hazard designations of the silicon-based chemicals (there were no disclosed fluoropolymer-based chemicals present in the paint formulations evaluated) in comparison to cuprous oxide from Paints 5 and 7. Keep in mind Paint 5 is a two-component system with a primer and a top coat. We evaluated the silicon-based chemicals in each component of the system. It can be seen that both formulations contain Benchmark 1, silicon-based chemicals, and therefore, again the Benchmark scores are not distinguishing for these paint formulations even when just reviewing the silicon-based chemicals.

We used the same criteria as in the first round of implementing the Hazard Module to select a preferred alternative. That is, if a chemical within a paint formulation had the same hazard designations as cuprous oxide, it was binned as unfavorable, if one but not both of the hazard designations was lower than cuprous oxide, it was binned as less favorable and if both hazard designations were lower, the chemical was binned as favorable. Additionally, data gaps led to a less favorable binning. To roll up the individual chemical-level binning calls to the formulation level, we binned the paint based on the lowest graded chemical. For example, if there are three chemicals in a formulation and two were binned as favorable but one is unfavorable, we would bin the formulation as unfavorable.

Table 41: Aquatic Toxicity Calls of Silicon-Based Chemicals in Paints 5 and 7								
Chemical			**Percent in Product**	**GreenScreen® Benchmark (BM)**	**Acute Aquatic**	**Chronic Aquatic**	**Bin by chemical**	**Bin by Product**
Paint 5: BottomSpeed								
Base Coat								
Talc (powder) (14807-96-6)	Route of Exposure	Inhalation	5-20%	**BM 1**	**L**	L	Favorable	Less Favorable
		Oral		**BM 3_{DG}**				
		Dermal		**BM U**				
Crystalline silica (14808-60-7)	Route of Exposure	Inhalation	5-20%	**BM 1**	L	DG	Less Favorable*	
		Oral		**BM2**				
		Dermal		**BM U**				
Top Coat								
Trimethoxy(methyl)silane (1185-55-3)			1-5%	**BM 1_{TP}**	**L**	**L**	Favorable	
Trimethylated silica (68909-20-6)	Route of Exposure	Inhalation	1-5%	**BM 1**	**L**	**M**	Favorable	
		Oral		**BM 2**				
		Dermal		**BM U**				
Methoxy or monofunctional silane (CAS# not provided)			0.1-2%	--	--	--	Less Favorable*	
Paint 7: FUJIFILM								
Siloxanes & silicones (70131-67-8)			50-70%	**BM 2**	**L**	**L**	Favorable	Unfavorable
Silica (7631-86-9)	Route of Exposure	Inhalation	7-15%	**BM 1**	**L**	DG	Less Favorable*	
		Oral		**BM 3_{DG}**				
		Dermal		**BM U**				
Methyl phenyl polysiloxane (68083-14-7)			7-15%	**BM 2**	**L**	**L**	Favorable	
Vinyl silicone polymer (68083-19-2)			3-7%	**BM 1**	**L**	**L**	Favorable	
Octamethylcyclotetrasiloxane (556-67-2)			1-5%	**BM 1**	NA	**vH**	Unfavorable	
Amorphous silica (modified) (68909-20-6)	Route of Exposure	Inhalation	1-5%	**BM 1**	**L**	**M**	Favorable	
		Oral		**BM 2**				
		Dermal		**BM U**				
Note: * indicates that the chemical was classified as Less Favorable due to data gaps.								

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As presented in Table 41, the silicon-based chemicals in Paint 5 all have medium or low hazard designations in regard to aquatic toxicity. However, there is a data gap for crystalline silica in terms of chronic aquatic toxicity, and an evaluation was not feasible for methoxy or monofunctional silane given the lack of disclosure on the chemical's CAS number. This led to the paint formulation being binned as less favorable.

As for Paint 7, it contains octamethylcyclotetrasiloxane, which was described previously as unfavorable. This chemical was the reason for binning Paint 7 as unfavorable in the previous iteration of the Hazard Module. Octamethylcyclotetrasiloxane is rated very high for chronic aquatic toxicity, persistence and bioaccumulation. Therefore, it was given a score of Benchmark 1 and no further hazard evaluation was done on the acute aquatic toxicity of this chemical, given the Targeted GreenScreen® approach taken. We are therefore uncomfortable moving this paint to the next round of assessment.

Results of Hazard Module (Iteration 2)

Using the silicon-based chemicals to represent the formulation, Paint 5 was binned as less favorable due to data gaps, and moved on to the Performance Evaluation Module because no paints were binned as favorable in the second iteration of the Hazard Module. As noted in the first iteration of the Hazard Module, none of the alternative paint formulations are preferable based on their hazards (see Table 38), and we are hesitant to recommend any of these paints; at this point, an assessor could attempt to identify other paints which have been developed since 2011 or work with paint manufacturers to obtain additional formulation data for the paints which had less than 50% of their formulations disclosed. Additionally, the data provided in Table 41 does provide insights into developing safer paint formulations. Specifically, most of the silicon-based chemicals used in the paint formulations Benchmark 1chemicals, with the exceptions of siloxanes and silicones and methyl phenyl polysiloxane, which are both Benchmark 2 chemicals and are therefore inherently less toxic. Unfortunately, these Benchmark 2 paints are used in Paint 7 which also contains octamethylcyclotetrasiloxane, which has a very High hazard rating for chronic aquatic toxicity and was not assessed for acute aquatic toxicity given it was also found to be highly persistent and bioaccumulative, resulting in the assignment of a Benchmark 1 score. The presence of octamethylcyclotetrasiloxane resulted in Paint 7 being binned as unfavorable.

When comparing the aquatic toxicity of the silicon-based chemicals to the copper component of the control paint, it is clear they are less toxic with the exception of octamethylcyclotetrasiloxane. When using the silicon-based chemicals to represent the paint formulation, Paint 5 appears to be the best choice to move on to the Performance Evaluation Module given its lower aquatic toxicity concerns.

Performance Evaluation Module (Second Iteration)

Level 1 Performance Evaluation Module

To evaluate the performance of Paint 5, we utilized the decision-making framework depicted in Figure 15. Although we used the silicon-based components of Paint 5 to represent the entire formulation in the Hazard Module, in this module we will evaluate the entire formulation for performance. We recognize there is a disconnect between considering only the silicon-based chemicals in the Hazard Module and evaluating the entire paint formulation in the Performance Evaluation Module since it is possible some of the other chemicals in the formulation may enhance the performance of the paint. However, we only evaluated the hazard of cuprous oxide in both iterations of the Hazard Module and are assessing the performance of the entire copper paint formulation. Therefore, it is analogous to consider only the silicon-based components in the Hazard Module but review the performance of the entire formulation in this Performance Evaluation Module for the alternative paint formulation as well.

Step 1: Determine Performance Needs

This has already been addressed in the previous iteration of the Performance Evaluation Module. In summary, copper antifouling paint is used as an antifouling agent to slow the growth of organisms that attach to the hulls of boats that can affect boat durability and performance. Copper antifouling paint achieves this by serving as a biocide and leaching copper into the surrounding waters. For the Performance Evaluation Module, we are looking at the efficacy of the fouling release capabilities for the soft Nonbiocide alternatives.

Step 2: Evaluate if the alternative has been identified as a favorable alternative with respect to performance?

As a reminder, the IC2 Guide suggests its users answer the below three questions in assessing this question.

Is the alternative being used for the same or similar function?

Similar to Paint 2, CalEPA (2011) included Paint 5, also a soft Nonbiocide, in its evaluation of alternatives to copper antifouling paint. While CalEPA (2011) did not evaluate BottomSpeed in its panel testing, Paint 5 was tested on three different boat hulls. U.S. EPA (2011) did not evaluate Paint 5, although they did evaluate PropSpeed, a precursor to Paint 5 originally intended for use as a coating on propellers.

On the first boat CalEPA tested, Paint 5 was painted directly over copper paint on half of the boat and over a stripped hull on the other half. While the stripped portion was smoother and more cosmetically appealing, they did not notice any difference in boat performance or ease of cleaning.

On the second boat, Paint 5 was painted directly over the existing copper paint on the entire hull. In order to test the cleaning needs, the boat was left alone for six months without cleaning. When inspected after that period, there was about three to four inches of fouling on the boat hull. However, this fouling came off readily, and the Paint 5 coating appeared to be in excellent condition.

The third boat Paint 5 was tested on an inflatable rubber boat. The coating seemed to be flaking off from one small spot on the rubber, which CalEPA (2011) hypothesizes may be due to inflating and deflating of the rubber boat and the fact that it was launched before the coating was fully cured. However, they still found that the paint performed extremely well.

This testing shows that Paint 5 can be used either on a stripped hull or directly on copper antifouling paint. Furthermore, the testing conducted by CalEPA (2011) used rollers to apply the paint. This is significant because this is how copper paint is usually applied to boats. However, many Nonbiocide paint manufacturers recommend doing a spray application of their product but this is significantly more expensive. CalEPA (2011) demonstrated that Paint 5 can perform as well as copper antifouling paint, and can be considered a viable alternative in terms of performance, even when applied with a roller. Furthermore, testing showed that Paint 5 functioned well after six months with no cleaning, whereas copper antifouling paint is generally cleaned every three to four weeks. Finally, Paint 5 is projected to last five to ten years, while copper antifouling paint's lifespan is generally two to three years. As stated with Paint 2, the timespan of the testing is not sufficient to evaluate the full lifespan of Paint 5. Furthermore, since the testing was conducted along the California Coast, we are unaware if the results are applicable to boats in different aquatic environments.

In regard to product availability on the commercial market and use in promotional materials, we utilized the Google Search Engine to see if we could find a company website or any documentation related to the product. We were able to identify a Facebook page for Paint 5, although the company website provided on that page (www.bottomspeedusa.com) does not appear to be active. We were also able to locate a company website for PropSpeed (www.propspeedusa.com), which the Uniform Data Set hypothesizes may be the new name for BottomSpeed but the CalEPA document states was a precursor to Paint 5. While we were unable to corroborate that information, Paint 5 is mentioned in an article hosted on the PropSpeed website written by Brunetti (2012).

Is the alternative used in similar products available on the commercial market? Is the alternative marketed in promotional materials as an option for providing the desired function?

Based on this information, we determined that Paint 5 does perform the same function as copper antifouling paint and is described in some promotional-type materials. Unfortunately, we were unable to find clear information about its commercial availability. A summary of our evaluation is shown in Table 42.

Table 42: Summary of Step 2 of the Performance Evaluation Module for Paint 5: BottomSpeed

Question	Result
Same/similar function	Yes[1, 2]
Used in similar products available on the commercial market	Unclear[3]
Promotional materials	Yes[4]

Sources:
[1] CalEPA (2011)
[2] U.S. EPA (2011)
[3] BottomSpeed (undated)
[4] Brunetti (2012)

Result of Performance Evaluation Module

Based on this result, Paint 5 was binned as favorable and moved through to the simultaneous portion of the Hybrid Framework.

Simultaneous Portion of the Hybrid Framework

For the simultaneous portion of this Hybrid Framework, we evaluated Paint 5 which passed through the sequential portion of the framework. Based on the fact that only one alternative passed the sequential portion of the framework, we only need to determine if the alternative is preferred compared to the control copper antifouling paint.

A Level 1 evaluation was conducted for the Cost and Availability Module, through which we determined the alternative as favorable. An Initial Screen was conducted for the Exposure Assessment Module which resulted in the decision to not perform a Level 1 evaluation since the alternative will result in equal or less exposure potential compared to copper antifouling paint. The data and processes used to support these decisions are presented below along with a matrix at the end of this section that presents the relevant criteria for the simultaneous evaluation of copper antifouling paint and Paint 5 in order to come to the conclusion that Paint 5 can be recommended as a potential alternative.

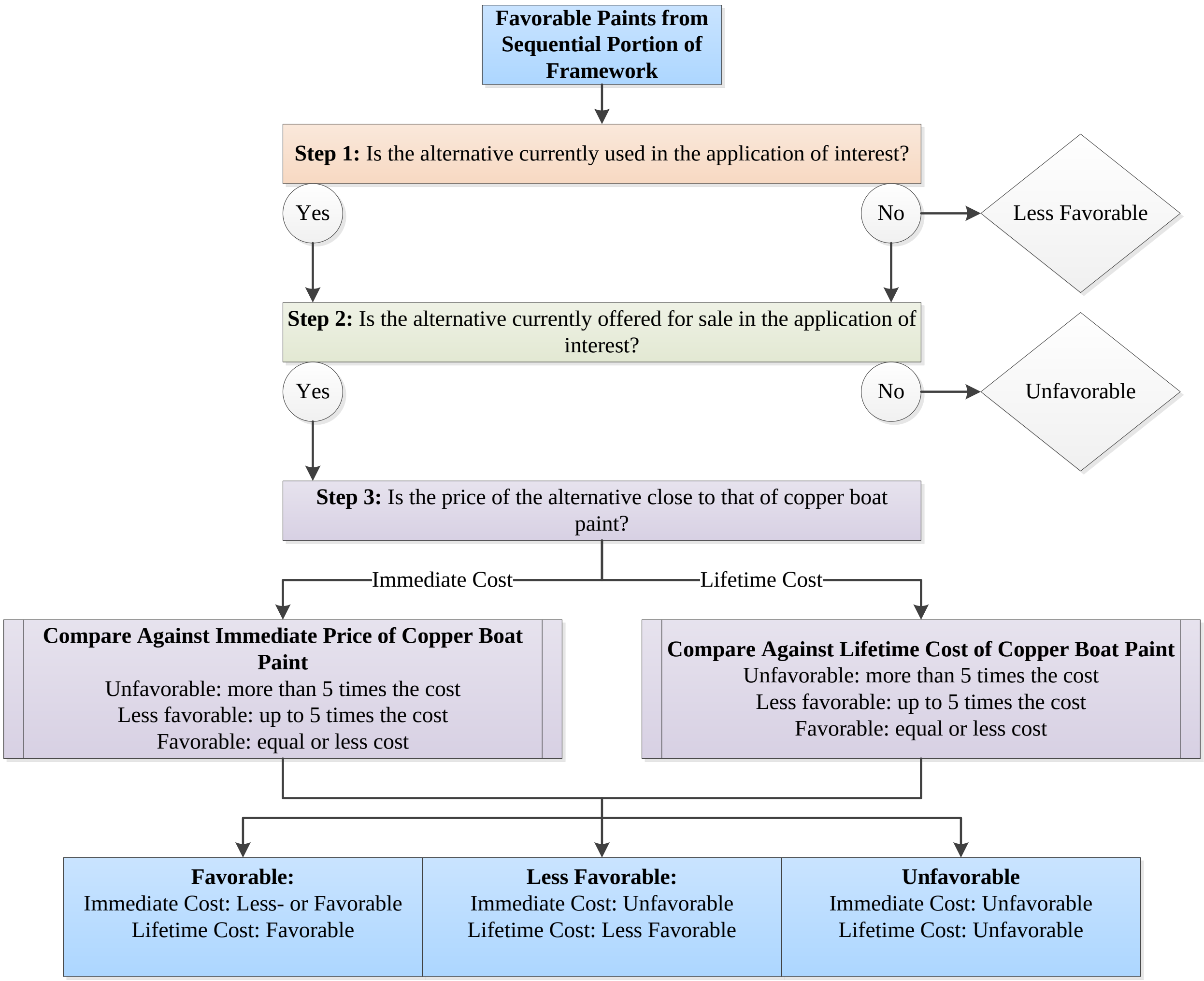
Cost and Availability Module

Level 1 Cost and Availability Module

As with the Performance Evaluation Module, we are comparing the data on the cost and availability of the entire Paint 5 formulation to that of the copper antifouling paint (Paint 1). A flowchart of the Cost and Availability Module is provided below in Figure 17. As displayed in this decision-making flowchart, the alternative's cost and availability was compared to that of copper and therefore copper antifouling paint is not binned in this module but is simply used as a comparison point.

This comparison was made for both the immediate cost and the lifetime cost of the paint, as described in the subsequent section. In the binning of the alternatives, we combined these two costs by placing more weight on the lifetime cost of the Paint. This was done by using the scheme outlined in the bottom three boxes of Figure 17.

Figure 17: Overview of Cost and Availability Module



The following section will describe the decision-making in this module with respect to Paint 5.

Step 1: Is the alternative currently used in the application of interest?

Paint 5 is described as an emerging paint in this application by CalEPA (2011) who indicates that its precursor, PropSpeed, was originally intended as a propeller coating paint but was found to work well as foul release paint during panel testing. Paint 5 is a slight reformulation intended more specifically for boat hull coatings. Based upon this information, it appears that Paint 5 is intended to be used as foul release paint and therefore moves to the next step in this module.

Step 2: Is the alternative currently offered for sale in the application of interest? Is the price of the alternative close to copper antifouling paint?

Paint 5 is commercially available[32] (CalEPA 2011, U.S. EPA 2011).

Immediate Cost

The immediate price includes the cost of preparing the necessary quantities of paint and the cost of labor involved in the paint job. It is unclear if the cost of labor includes personal protective equipment for applicators of the paints. However, we assume that it does given the costs were estimated by applicators themselves.

One of the biggest hindrances to the adoption of many soft Nonbiocide paints has been the relatively high paint job costs when compared to copper antifouling paint. Copper antifouling paint generally costs around $150 per gallon, and since boats generally have already been using copper antifouling paint and stripping is rarely conducted, there are fewer added costs when applying the paint using a roller directly over existing paint. For a 30 foot boat, copper antifouling paint jobs usually come out to $1,038.

According to CalEPA (2011) and U.S. EPA (2011), the base cost of a paint job for the Nonbiocide paint is $3,324. CalEPA (2011) calculated this cost by contacting three boatyards to obtain information about paint job costs for applying the Paint 5 two-component paint system (sealer and top coat) to a 30 foot boat without any stripping of existing copper paint, and taking the average of the three quotes. It was not stated in this report if the cost would vary based on boat type (e.g., power versus sail boat).

It a recommended practice to strip the boat hull of existing copper antifouling paint before applying soft Nonbiocide paints. Sodium bicarbonate blasting is the most common method for stripping paint and, for a 30 foot boat, has a range in cost from $1,075 to $1,276. This range reflects the cost of paying a service company to do the blasting and the cost of disposing of the resulting waste. Another option is to rent the equipment and conduct the blasting personally, but the resulting price range is $1,585 to $1,786. As a result, we determined that it would be more financially sensible to utilize a service company for stripping the copper antifouling paint and calculated the average from the range provided for professional stripping by sodium bicarbonate blasting which is $1,176. However, CalEPA (2011) tested Paint 5 applied directly over copper antifouling paint without any stripping and found it to perform comparably to when it was painted on a stripped hull. Therefore we calculated the cost of the paint with and without stripping the existing copper antifouling paint (see Table 43).

In addition, some soft Nonbiocide paints require spraying as the method of application rather than rolling the paint on. This can add $218 to $1,000 to the cost of a paint job for a 30-foot

[32] Determining whether the paints evaluated in this Project were still commercially available was a challenge. Therefore, if current availability could not be determined, a paint was considered available if it was commercially available at the time it was evaluated in the CalEPA (2011) and U.S. EPA (2011) reports. In an official Alternatives Assessment (versus a pilot, such as this), alternatives with unknown current commercial availability would be eliminated as viable alternatives.

boat, according to CalEPA (2011). However, CalEPA (2011) rolled Paint 5 onto boats in all of its testing, indicating that spraying may not be necessary. It is important to note however, that CalEPA (2011) was not able to determine the longevity of Paint 5 with these changes in application method. Since they only tested Paint 5 using rollers, we have not evaluated the cost of spraying for Paint 5.

The immediate prices for copper antifouling paint and Paint 5 for a 30-foot boat, with and without stripping are provided in Table 43 below.

Table 43: Immediate Price of Paint 1 and 5 for a 30 Foot Boat

Paint #	Formulations	Application	Stripping?	Paint Job[1]
1	Trinidad Pro	Rolled	No	$1,038
5	BottomSpeed	Rolled	Yes	$4,500[2]
			No	$3,324

[1] A paint job includes the cost of the paint and the cost of labor involved in applying the paint.
[2] This is calculated by adding the cost of a paint job without stripping to our calculated average cost of stripping copper antifouling paint using sodium bicarbonate blasting ($1,176).

Based on these numbers, Paint 5 is between 3.2 and 4.3 times more expensive than copper antifouling paint. As a result, Paint 5 is binned as less favorable in regard to immediate cost (see Figure 17 for binning criteria).

Lifetime Cost

While copper antifouling paint is generally considered a cheaper option due to its lower paint job costs, it also has a shorter lifespan when compared to soft Nonbiocides. Copper antifouling paint has a lifespan of two to three years, while Paint 5 is expected to have a lifespan of five to 10 years. The lifetime cost analysis evaluates the overall cost of an alternative and takes into account the lifespan of the alternative. The annualized costs reported by CalEPA (2011) are shown in Table 44. These values were calculated by adding a capital cost of 4% to the values shown in Table 43 and then dividing by the assumed paint lifespans.

Table 44: Annualized Cost of Paint 1 and 5 for a 30 Foot Boat

Paint #	Formulations	Lifespan (Years)	Annualized Cost
1	Trinidad Pro	2	$540
		3	$360[1]
5	BottomSpeed - Not Stripped	5	$691
		10	$345
	BottomSpeed - Stripped	5	$936[1]
		10	$468[1]

[1] These values were not provided from CalEPA (2011). Instead, CalEPA (2011) indicates that they assumed a capital cost of 4% when calculating the annualized costs. We extrapolated this calculation to our values for pricing scenarios not considered by CalEPA (2011).

Overall, the annualized cost for Paint 5 ranges between 0.6 and 2.6 times the cost of copper antifouling paint[33]. However, CalEPA (2011) indicates that copper antifouling paint is commonly projected to last for two years before requiring a new coat. Based on data proved in CalEPA which states that soft Nonbiocide paints have longer lifespans, "which may amount to at least 10 years" we assume Paint 5 is likely to last 10 years when applied to a stripped hull and five years when applied directly over copper antifouling paint. As a result, Paint 5 is between 0.87 and 1.28 times the lifetime cost of copper antifouling paint. Taking the midpoint of that range, Paint 5 can be binned as favorable for lifetime cost.

Final Cost and Availability Module Result

With a bin of less favorable for immediate costs and favorable for lifetime costs, we binned Paint 5 as favorable in regard to cost.

Exposure Assessment Module

Following the approach outlined in the IC2 Guide, we first implemented an Initial Screen to determine if a Level 1 exposure assessment would be useful or would provide additional information. No guidance is given in the IC2 Guide as to how to evaluate exposure at the product level, so we evaluated exposure differences between cuprous oxide and the silicon-based chemicals, making the assumption that the chemical's exposure profiles represent the entire formulation. This assumption was made based on data availability since the data we have for exposure are for chemical properties at the chemical level.

This section outlines our approach in implementing the Initial Screen which, as described below, determined a Level 1 assessment is not necessary. We therefore binned this product as favorable based on exposure.

Initial Screen

As described in the IC2 Guide, implementing the Exposure Assessment Module screen, "identifies whether sufficient similarities exist between the chemical of concern and potential alternatives(s) such that an exposure assessment is not necessary. If so, differences in exposure concerns between the chemical of concern and potential alternatives are inconsequential to the [Alternatives Assessment]." In addition, we also assumed that if there was less of a concern about exposure for the alternatives, a Level 1 assessment would also not be necessary. If the option between having a higher exposure to a more toxic chemical versus a lower exposure to a less toxic chemical, any assessor would opt to have the less exposure to less toxic chemical. Because we have already determined that Paint 5's silicon-based chemicals have lower aquatic toxicity profiles, if there is reason to believe equivalent or less exposure to the silicon-based

[33] It is important to note that our lifetime cost analysis did not include maintenance and cleaning costs. However, there are no indications, based on the performance evaluations contained in CalEPA (2011), that BottomSpeed requires additional care or maintenance when compared to copper boat paint. This is corroborated by U.S. EPA (2011) which reports hull cleaning costs for one hull cleaner that services boats with copper biocide paints and soft non-biocide paints. The cleaner estimates 15 cleanings per year for both, for an annual total of $742.50 for a 30-foot powerboat.

chemicals in Paint 5 would occur in the aquatic systems, Paint 5's silicon-based chemicals would be preferable to the copper antifouling paint. Given the screening level of this assessment and the initial concern with aquatic toxicity, we have concentrated mainly on aquatic exposure issues.

Question 1: Compare exposure pathways between the chemical of concern and alternatives.

In order to compare the exposure pathways, the IC2 Guide recommends comparing physical chemical properties for the chemical of concern and the alternatives for pertinent criteria. As seen in Table 45 there are data gaps related to physical chemical properties. However, given the original concern associated with the replacement of copper antifouling paint is the aquatic toxicity, the most relevant properties are the data on water solubility.

Based on the information provided in Table 45, the silicon-based chemicals in the Paint 5 formulation (note the paints listed are from both the base and top coat) are all insoluble, similar to cuprous oxide, with the exception of trimethoxy(methyl)silane. Trimethoxy(methyl)silane is very soluble in water, specifically the Uniform Data Set points out that trimethoxy(methyl)silane undergoes "rapid hydrolysis in the environment, producing methanol (3 moles) and methylsilanetriol (1 mole). Methanol is readily biodegradable in the environment. Therefore, methanol is likely to be rapidly released after the hydrolysis of the parent compound and then rapidly degraded, reducing the potential for human/environmental exposure" (ToxServices 2014a).

Table 45: Chemical Properties for Paints 1 and 5

Property	**Trinidad Pro**	**BottomSpeed Base Coat**		**BottomSpeed Top Coat**		
Chemical Substance	Cuprous oxide	Talc (powder)	Crystalline silica	Trimethoxy (methyl)sila ne	Trimethyl-ated silica	Methoxy or monofunctional silane
Percent of Formulation	[REDACTED]%	5-20%	5-20%	1-5%	1-5%	0.1-2%
Molecular weight (g/mol)	143.091	379.263	60.09	136.222	Not identified	No data
Molecular size		depends on process used to make powder				No data
Log K_{ow}				-0.67	Not identified	No data
Water Solubility	Insoluble in water (dissociates very slowly in saltwater)	Insoluble in water	Practically insoluble in water or acid; very slightly soluble in alkali	>10,000 mg/L (hydrolysis product)	Insoluble	No data
Boiling point						No data

Table 45: Chemical Properties for Paints 1 and 5						
Melting point (*C)	1235	900-1000	1710	< -77	Not identified	No data
Density/specific gravity (g/cm^3)	6	2.58-3.83	2.6	0.95 (at 25°C)	2 (at 20°C)	No data
pH						No data
Corrosivity						No data
Dissociation constant	N/A	N/A	N/A			No data

Question 2: Compare the manufacturing criteria for the chemical of concern and alternative. Do they perform the same function? Are they used in the same relative amounts or is the alternative used in lesser amounts? Are they used in the same manner?

As described previously, the silicon-based chemicals in Paint 5 perform the same function as copper in its paint formulation. That is to say they all prevent fouling on boat hulls. However, it is important to note that copper paint operates by releasing biocide (the reason it is of concern) while the Nonbiocide paints operate by creating a slick surface on the boat hull which prevents the fouling agents from attaching to the boat. Therefore cuprous oxide and the silicon-based chemicals have different mechanisms by which they function to achieve the same end results with very different exposure potential. Copper is designed to be released from the boat paint whereas the silicon-based chemicals are designed to create a slick surface on the boat hull to prevent attachment.

Additionally, the silicon-based chemicals in Paint 5 are used in substantially lower amounts compared to the copper-based chemical in the biocide paint. This would result in less of these chemicals with the potential for release. However, it should be noted that we are only concentrating on the silicon-based chemicals in this paint formulation and therefore only considering exposure to approximately 50% of the total formulation for the two-component paint system of Paint 5. Additionally, one of the silicon-based chemicals does not have any data associated with it.

Question 3: Compare the fate, transport and portioning in environmental media for the chemical of concern and alternative.

This question has been addressed in regard to the ability of the chemical to dissolve in water. The majority of the chemicals, including copper, are mostly insoluble with the exception of trimethoxy(methyl)silane which readily hydrolyzes. Therefore we are assuming the fate, transport and partitioning are similar for the majority of the chemicals, with the exception of trimethoxy(methyl)silane which has less exposure potential given how quickly it is expected to hydrolyze.

Question 4: Compare the release mechanisms for the chemical of concern and the potential alternatives.

This question evaluates if the release mechanisms are similar during the different life cycle phases. However, with the limited data we have based on the U.S. EPA (2011) and CalEPA (2011) reports we cannot readily evaluate the various life cycle phases. Fortunately, we do have some data on the use stage of the product and potential exposure pathways in an aquatic system. We know that copper antifouling paint releases copper by passive leaching and during hull cleaning. Compared to the Paint 5 alternative, copper is more likely to enter the aquatic environment because the copper paint is designed to release copper as a biocide. This is opposed to the Nonbiocide paints which are designed to make the hulls of boats slippery so that attachment by fouling agents is more difficult. Subsequently, less aggressive cleaning is needed for Nonbiocide paints because the fouling agents cannot strongly attach to the slippery surface. This is demonstrated in the CalEPA report (2011) which found that cleaning the boat hull of boats painted with Paint 5 was possible with non-aggressive tools and techniques.

Question 5: Based upon the above evaluation are there any substantive differences between the use or physical characteristics that could affect exposure?

Although there is a difference in regard to water solubility with one chemical in the alternative paint formulation compared to copper, we expect the exposure for this chemical to be less than that for copper. Therefore we believe that use, fate and transport, and potential exposure pathways for Paint 5 are similar or less concern compared to the copper antifouling paint and therefore we did not implement a Level 1 evaluation. We binned Paint 5 as favorable with respect to exposure.

Simultaneous Evaluation of Results from the Cost and Availability and Exposure Assessment Modules

The simple comparison decision method outlined in the IC2 Guide places a strong emphasis on comparing the human health and environmental hazards of the chemicals being assessed. However, in using the Hybrid Framework we only used a decision method to simultaneously evaluate the data from the Cost and Availability and Exposure Assessment Modules. This is because we already winnowed down the alternatives by conducting a comparative hazard assessment in the sequential portion of this framework. We therefore developed a matrix to compare the results of the Exposure Assessment and Cost and Availability Modules, as these are the modules we evaluated simultaneously[34]. Note that the costs presented in the below table are based on a boat which is not stripped of its copper antifouling paint given that CalEPA (2011) demonstrated stripping off old copper paint is not necessary.

[34] This is a noted issue in the IC2 Guide in that the write-ups are broad and seem to pertain more directly to the simultaneous or sequential frameworks with the assumption the hybrid framework will be the same. However, this is not the case. The IC2 Guide would benefit from specific directions for an assessor conducting the hybrid assessment or at least direction provided to skip to a specific step within the process when using the hybrid framework.

Table 46: Matrix of Relevant Criteria for the Cost and Exposure Assessment Modules				
	Paint 1: Copper Control	**Paint 5: BottomSpeed**	**Paint 5 Bin**	**Paint 5 Overall Cost Bin**
Immediate Cost	$1,038	$3,324	Less Favorable	Favorable
Lifetime Cost	3 years: $519/year 2 years: $346/year	10 years: $332/year 5 years: $665/year	Favorable[1]	
Exposure Potential[2]	N/A	The same or less than copper control	Favorable	N/A

[1] Based on data presented in CalEPA (2011), we assume the BottomSpeed paint will have a 10 year lifespan.
[2] Based on the Initial Screen.

Summary of Results for the Sequential Version of the Hybrid Framework

Given that both the Cost and Exposure Assessment Modules resulted in us binning Paint 5 as favorable, Paint 5 is the “preferred” alternative for this evaluation. However, there are several important caveats in regard to this result which are outlined in the next section.

Results of Hybrid Framework without Optional Modules

The silicon-based components of Paint 5 are less aquatically toxic and less likely to result in aquatic exposure than the copper-based components of the control paint. Additionally, when compared to copper antifouling paint, the entire formulation of Paint 5 performed well and was cost-effective when considering lifetime costs. Using the silicon-based chemicals to represent the entire formulation for the Hazard and Exposure Assessment Modules, Paint 5 successfully passed through all four core modules presented in the IC2 Guide. However, we cannot strongly recommend the entire paint formulation as the best alternative as it would be against the golden rule of recommending a product with less of a concern for toxicity when compared to the control. Therefore, we select Paint 5 as a potential alternative with strong reservations.

We initially binned Paint 5 as unfavorable due to the presence of zinc oxide in its base coat. The presence of zinc oxide could lead to an increase of zinc in waterways if there is a potential for zinc to be released from the paint. From a hazard standpoint, the presence of zinc oxide in the formulation is unfavorable. It should be noted that if hazard was assessed simultaneously with exposure, the overall risk to an aquatic system from zinc oxide in the paint formulation would likely be less than that from cuprous oxide. This is because it is in the base coat and there is substantially less zinc oxide in Paint 5 when compared to cuprous oxide in the copper antifouling paint. All of the commercially available paints with 50% or more of their formulation disclosed contain at least one chemical with equivalent aquatic toxicity concerns to the cuprous oxide.

We have strong reservations about the hazard profiles of a majority of the chemicals contained within Paint 5. These reservations exist not just for Paint 5, but all of the alternative paint formulations evaluated in this assessment since they all contain LT-1 and Benchmark 1 chemicals.

It is possible that switching from copper antifouling paint to silicon-based Nonbiocide paint can result in a regrettable substitution – i.e., toxicity concerns could shift from aquatic toxicity to human health toxicity. Table 47 demonstrates that many of the silicon-based chemicals in Paint 5 have greater human health concerns than cuprous oxide, which does not have high or very high hazard related to any of the human health endpoints evaluated with GreenScreen®. This is especially true when evaluating the inhalation route of exposure. This could have adverse implications for workers applying these paints. Most of the silicon-based chemicals used in the paint formulations are Benchmark 1 chemicals, with the exceptions of siloxanes and silicones and methyl phenyl polysiloxane, which are both Benchmark 2 chemicals and used in Paint 7.

Table 47: Summary of Endpoints Associated with Benchmark 1 or LT-1 Silicon-Based Chemicals

Benchmark 1or LT-1 Chemical (CAS #)	**Endpoints with H or vH Hazard Rating[1]**
Paint 1: Trinidad Pro	
Cuprous oxide[2] (1317-38-0)	Acute Aquatic, Chronic Aquatic, Persistence
Paint 2: Klear N' Klean	
Vinyltri(methylethylketoime)silane[4] (2224-33-1)	Systemic Toxicity (repeated dose), Eye Irritation
Amorphous silica (7631-86-9)	Carcinogenicty[3], Systemic Toxicity (repeated dose)[3], Persistence
Paint 5: BottomSpeed (Includes both Base Coat and Top Coat)	
Talc (14807-96-6)	Systemic Toxicity (repeated dose)[3], Persistence
Crystalline silica (14808-60-7)	Carcinogenicity[3], Systemic Toxicity (repeated and single dose)[3], Persistence
Trimethoxy(methyl)silane[4] (1185-55-3)	Flammability
Trimethylated silica (68909-20-6)	Acute Toxicity[3,6], Systemic Toxicity (repeated dose) [3] Persistence, Systemic Toxicity (single dose)[5], Neurotoxicity (single dose)[5]
Paint 7: FUJIFILM	
Silica (7631-86-9)	Carcinogenicity[3], Systemic Toxicity (repeated dose)[3], Persistence
Vinyl silicone polymer (68083-19-2)	Persistence, Bioaccumulation
Octamethylcyclotetrasiloxane (556-67-2)	Chronic Aquatic, Persistence, Bioaccumulation
Amorphous silica (modified) (68909-20-6)	Acute Toxicity[3,6], Systemic Toxicity (repeated dose) [3] Persistence, Systemic Toxicity (single dose)[5], Neurotoxicity (single dose)[5]

[1] Given the approach taken for the GreenScreen®, it is possible that not all endpoints were evaluated for all chemicals.
[2] Given this is the chemical of concern this is the only chemical evaluated from Paint 1. There are many other LT-1 or Benchmark 1chemicals included in the Paint 1 formulation. Specifically, 14 Benchmark 1or LT-1 chemicals for the inhalation route of exposure, and 11 for the oral and dermal routes of exposure.
[3] For the inhalation route of exposure
[4] This is a Benchmark 1for its transformation product
[5] For the oral route of exposure
[6] For the dermal route of exposure

An additional concern with Paint 5 is data availability. The range of the formulation disclosed is 39.3 to 146% meaning it is possible we are assessing less than 40% of the total formulation. Several of the other paint formulations were originally eliminated based on data availability, as shown in Table 48, which describes why we eliminated each of the paint formulations.

Table 48: Summary of Process of Excluding Alternatives		
Paint	**Module at Exclusion**	**Reason for Exclusion**
Paint 2: Klear N' Klean	Cost and Availability	Removed from market
Paint 3: Intersleek	Initial Screen	No data on formulation of primer
Paint 4: XZM480	Hazard	Less than 50% of formulation available
Paint 5: BottomSpeed	N/A – selected alternative[1]	
Paint 6: Hempasil	Hazard	Less than 50% of formulation available
Paint 7: FUJIFILM	Hazard	Contains a chemical with equivalent hazard concern as the copper control
[1] We may not have more than 50% of the formulation. See the first iteration of the Hazard Module for additional information.		

We strongly recommend the assessment of additional alternatives or a re-evaluation of the alternatives using the simultaneous comparison of hazard and exposure. This would allow a greater understanding of whether there would be regrettable substitution by moving away from a copper antifouling paint to a silicon-based paint given the presence of chemicals with high aquatic toxicity concerns and human health concerns in all of the paint formulations assessed.

Results of Hybrid Framework with Optional Modules

Paint 5 is the only paint which successfully passed through all four recommended modules. As described previously, we were tasked with evaluating if the inclusion of the three optional modules in the IC2 Guide (Materials Management, Social Impact, and Life Cycle) would result in a different alternative being selected as the preferred paint when using the Hybrid Framework. Our assessment with the additional three modules is described in the subsequent three sections. The results from these three modules were simultaneously assessed with the data from the Cost and Availability Module and the Exposure Assessment Module. Given that Paint 5 is the only paint that made it through the sequential portion of the Hybrid Framework, it is also the only paint considered in this section. Level 1 evaluations were conducted for the Materials Management and Social Impact Modules. The Preliminary Scoping process was implemented for the Life Cycle Module and we determined that all Life Cycle considerations had been evaluated in the other modules.

Materials Management Module

Level 1 Materials Management Module

According to the IC2 Guide, "the Materials Management Module is intended to help the assessor consider how different options can impact natural resources and waste generation, and to use the information to mitigate impacts to achieve sustainable materials management." Sustainable materials management shifts the focus from individual product attributes to examine the entire system of material flows and associated life cycle impacts.

The IC2 Guide states that the Materials Management Module is recommended primarily at the whole product level and for products containing materials derived from very different sources. It should be noted that the copper antifouling paint (Paint 1) and Paint 5 are solvent (oil)-based boat paints, which make them similar at the product level, although they do differ in the copper versus silicon elements. The Materials Management Module outlines five questions that we describe below and attempt to answer with readily available information. For the first three questions, if the answer to the question is yes, the IC2 Guide advises us to "document information used to reach the conclusion and identify alternative as favorable for those conditions. Continue evaluation." If the answer is no, the IC2 Guide advises us to "document the positives and negatives associated with the alternative along with information used to reach the conclusions. Continue evaluation." The last two questions for the Module's Level 1 evaluation direct the assessor to propose strategies to mitigate the negative impacts from the proposed alternative.

For this module, we supplemented our existing data from the Uniform Data Set (ToxServices 2014a), CalEPA (2011), and U.S. EPA (2011) reports with a variety of Google search strings to find relevant and readily available information on Paint 1 and Paint 5. A list of these search terms included items such as "life cycle," "copper antifouling paint manufacturing," "environmental footprint," "soft nonbiocide," and "foul release."

As described previously, copper is a biocide which kills biologic organisms that come into contact with it, whereas the silicon and silicone-based components of Paint 5 create a slick surface on the bottom of the boat inhibiting attachment. Given there is little to no data at the product level for either paint, we mainly examined the differences between the copper and silicon components of the paint systems and general differences in the literature between copper based paints and Nonbiocide based paints.

1. Identify the natural resources and raw materials used in the association with the baseline product and alternative product design.

Both of the products are solvent-based. For Paint 1, the main natural resource used is copper, and for Paint 5 it is silica/silicon[35] based elements.

<u>Does the alternative use more renewable raw materials?</u>

Based on readily available data, it is unclear if Paint 5 uses more or less renewable raw materials than Paint 1. As stated previously, both products are solvent (oil)-based boat paints, which are typically derived from petroleum, leading us to assume that neither paint is based on renewable raw materials.

In regard to copper versus silica and the availability to use renewable raw materials, both copper and silicon are mined and extracted and subsequently, not renewable. Copper, however can be recycled.

[35] Silicon is the chemical element, silica is silicon plus oxygen and is the form most often found in the natural environment, and silicone is a synthetic polymer that includes silicon, oxygen, carbon, and hydrogen.

Silicon is the second most abundant element in the earth and is often found in the form of silica, which is silicon plus oxygen (Nave 2014). The chemicals in Paint 5 consist of some natural silicates, such as crystalline silica and talc, which would be mined, but there are also some synthetic silicones as well. Given that silica is mined and extracted like copper, it is not renewable in this sense.

There is a body of research which is examining the extraction of pure silica and amorphous silica from renewable materials, including rice husk (Kamath and Proctor 1998, Polska and Radzki, 2008; Yalcin and Sevinc 2001, Sidheswaran and Bhat 1996), sugar cane Bagasse[36] (Affandi et al. 2009, Espindola-Gonzalez et al. 2010) coffee husk (Espindola-Gonzalez et al. 2010) and wheat husk (Javed et al. 2011). It is unclear where the silicon-based products are derived from for Paint 5, but there is potential for the use of a renewable waste product to be used as a raw material for a silicon-based paint such as Paint 5.

Although we do not have data to directly answer this question (i.e., the quantities of renewable resources used in each product) we are aware that both products are solvent-based and based on extracted minerals. It is therefore unlikely that Paint 5 uses more renewable raw materials. However Paint 5 has the future potential to use renewable resources in its production of its silica-based components, and the copper antifouling paint does not. Therefore Paint 5 is slightly more favorable in regard to renewable materials.

Does the alternative use less raw materials?

Exact data on the quantities of raw materials used to develop each product are not readily available. Therefore to answer this question, we used surrogate measures based on available data. Specifically, we evaluated if more or less paint is needed, making the assumption that using more paint per unit boat area would result in the need for more raw materials. Additionally, we used data based on a previously completed "eco-efficiency analysis" (Solomon 2011) that evaluated the potential for various activities associated with manufacturing, transporting and applying the Paints to be associated with an increase in the temperature of the planet. We made the assumption that an activity's potential to increase the temperature of the planet, termed the Global Warming Potential (GWP) by Solomon (2011), indicates the use of more raw materials and/or energy used to make the product[37].

Solomon's eco-efficiency analysis concluded that silicon-based paints require half the overall amount of paint for cargo ships compared to copper antifouling paints over a 15-year timeframe (See Figure 18). This is likely the result of the longer lifespan of silicon-based paints, which are projected to last between five and 10 years compared to the two to three year life span predicted for copper antifouling paints. As a result of the lower amount of paints needed, and the lower amounts of Volatile Organic Chemicals (VOCs) being emitted from the Nonbiocide paints (this is discussed more in the Section titled "Does the alternative generate fewer wastes with negative

[36] Bagasse is the fibrous remains after sugarcane is crushed to extract its juices.
[37] We recognize the difference between the definition of Global Warming Potential (GWP) presented in Solomon "the potential for the activity to increase the temperature of the planet" and the more common understanding of GWP which is how much heat the chemical traps when it is released to the air compared to how much heat CO_2 traps. In this instance we are deferring to the author's definition of GWP.

impacts?" Solomon concluded that silicon-based paint systems have a GWP approximately 70 tons of CO_2-equivalent lower than that of biocidal antifouling systems (220 versus 290 tons of CO_2-equivalent) (see Figure 19).

Figure 18: Comparing Amount of Paint Needed and Estimates of Waste Tins for Biocidal Antifouling Paints and Silicone Foul Release Paints (Solomon 2011)[38]

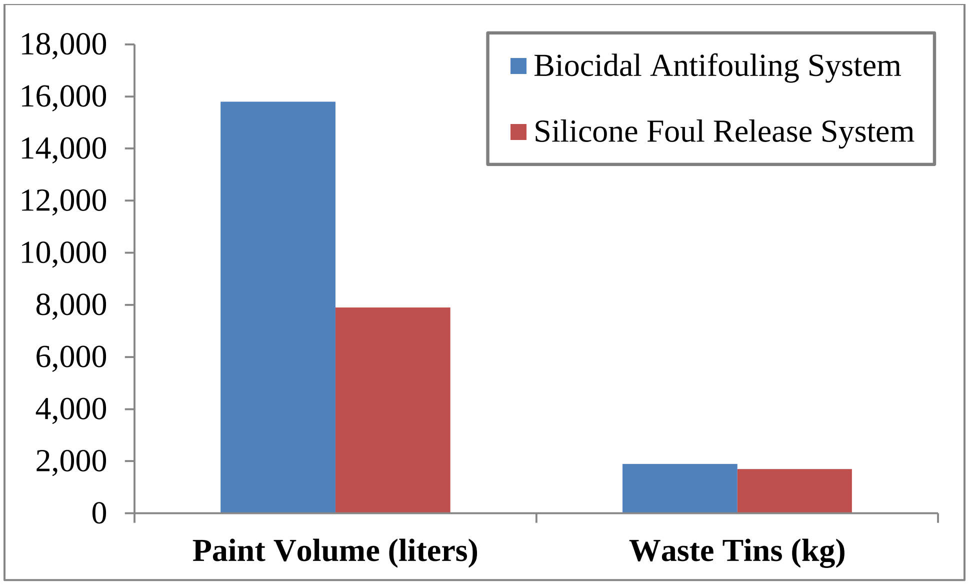
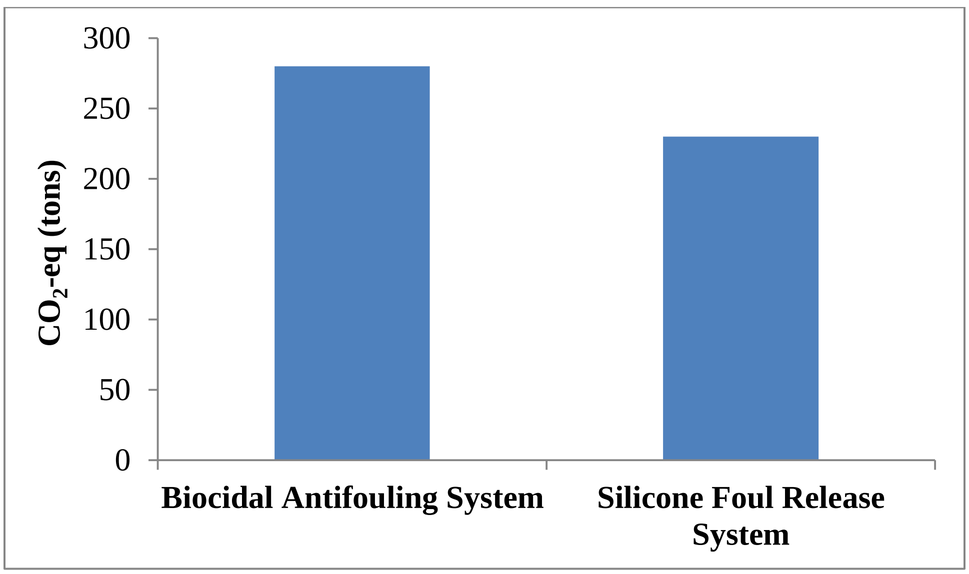


Figure 19: On-Site Global Warming Potential for Biocidal Antifouling Paints and Silicone-Based Foul Release Paints (Solomon 2011)[39]



[38] This figure was recreated from Solomon (2011) based on values estimated from figures contained within the report.
[39] This figure was recreated from Solomon (2011) based on values estimated from figures contained within the report.

It should be noted that the calculations in Solomon (2011) on the amount of paint needed are based on cargo ships and are not specific to Paint 5 or recreational boats. Therefore, we used numbers available in CalEPA (2011) and the Uniform Data Set to estimate the amount of paint needed for a 30 foot recreational boat for Paint 1 and Paint 5.

The CalEPA (2011) report explains that Paint 5 requires two base coats and one top coat. More specifically, CalEPA states that 1.5 gallons of the base paint are needed for one complete base coat and one gallon of paint is needed for the top coat for a 30 foot boat. This results in 4 total gallons of Paint 5 being needed (3 gallons of bottom coat and 1 gallon of top coat) for each complete application. Assuming Paint 5 has a 5-10 year lifespan, the boat will need to be repainted 2-3 times over the course of 15 years. This would result in 8-12 gallons of Paint 5 (base coat and top coat) being used over the course of 15 years for a 30 foot boat, given that 4 gallons of paint will be required at each repainting.

According to CalEPA (2011), Paint 1 requires two coats. Although data were not provided in the CalEPA (2011) report, we made the assumption that one-gallon of Paint 1 would be sufficient for one coat on a 30-foot boat[40]. Given the life span of Paint 1 is expected to be 2 to 3 years (CalEPA 2011), a boat would need to be repainted 5-8 times over the course of 15 years. If each paint job required 2 gallons of paint, over the course of 15 years, 10-16 gallons would be required. The range for the number of gallons of Paint 5 that will be required over a 15-year time frame (8-12 gallons) is slightly less, but does overlap with the estimate on the number of gallons of Paint 1 needed over the same time frame (10-16 gallons).

Additional evidence on the amount of raw materials used in the production of fouling control paints was presented in "Life cycle assessment of the use of marine biocides in antifouling paint" (Lin and Usino 2014), which found that the production of cuprous oxide is extremely resource intensive. While the purpose of this life-cycle assessment (LCA) was to compare a copper-based biocide paint to a paint using an organic biocide, Lin and Usino (2014) found that manufacturing copper antifouling paint has a significantly higher demand for non-renewable energy when compared to the organic biocide – a gap of almost 600 MJ in their five-year scenario. The authors concluded that the reason for this difference in energy demand is the burden of the production process for cuprous oxide (e.g., mining, smelting, refining), which accounts for 90% of the energy demand for copper antifouling paints. Although Lin and Usino (2014) did not examine silicon-based paints, their analysis still leads us to conclude that manufacturing copper antifouling paints is extremely resource intensive.

Although we have limited data on the amount of raw materials used for the paints, it is clear that the production of cuprous oxide is extremely resource intensive and there is some evidence that the amount of paint needed with Nonbiocide paints may be less compared to copper antifouling paint. This leads us to conclude that Paint 5 likely uses fewer raw materials than Paint 1.

[40] This assumption is corroborated by the fact that the estimated surface area for a 31 foot sailboat is 270 square feet (AkzoNobel 2003). As previously noted, two coats are recommended when Paint 1 is used (Pettit Marine Paints 2013, CalEPA (2011)). Therefore, enough paint to cover 540 square feet would be required. One can (or gallon) of Paint 1 covers 400 square feet, meaning that two cans would be required for each paint application (Pettit Marine Paints 2013).

Subsequently, we deemed Paint 5 slightly more favorable in regard to the amount of raw materials used.

Does the alternative use more recycled materials?

Quantitative data on the amount of recycled materials used in the development of the copper antifouling paint and Paint 5 are not readily available. Additionally, neither product's MSDS nor their promotional materials explicitly state the use of recycled materials in their formulations. However, according to a press release from AkzoNobel, the majority of copper used in antifouling paints are sourced from recycled copper wire and water pipes (AkzoNobel 2008). Copper antifouling paint can also be based on copper from boat paint which had been sand blasted off (CalEPA 2011). Therefore, it is possible the cuprous oxide in the control paint is based on recycled copper. It should be noted however, that once copper enters the waterways, as it is designed, it could never be retrieved in order to be recycled.

While some chemicals contained within Paint 5 (e.g., xylene) can be recycled, we were unable to find indications that those solvents or chemicals are generally from recycled sources. Additionally, the copper antifouling paint contains the same chemicals that may potentially be recyclable so this would not be differentiating between the two paints. However, in the future the silicon-based chemicals may be derived from renewable sources that would otherwise be considered waste, such as rice or wheat husks, if the processes outlined in the cited papers are further developed.

Although we do not have the exact quantities on the amount of recycled copper, the available information presented above leads us to conclude that copper paint is more likely to use recycled materials than a silicon-based paint. Therefore, Paint 5 is less favorable in regard to using recycled materials.

Summary of Conclusions in Regard to the Raw Materials Used in Paint 1 and Paint 5

Table 49 summarizes the results for the evaluation of the amount and type of raw materials used in the production of Paint 1 and Paint 5.

Table 49: Summary of Findings on Raw Materials Used in Evaluation of Alternative Boat Paints

Evaluation Metric	Evaluation Result	Summary of Justification
Renewable Raw Materials	Paint 5 slightly favorable.	There is the potential to use renewable raw materials to extract silicon-based chemicals.
Amount of Raw Materials	Paint 5 is slightly favorable.	Cuprous oxide is resource intensive to develop. Paint 5 may require less overall paint over the course of 15 years.
Recyclable Raw Materials	The copper antifouling paint is favorable.	Data source stated copper antifouling paint is often developed using recycled copper.

2. Identify the wastes generated in association with the baseline product and alternative product design(s).

Wastes can be generated from both the baseline (i.e., control) and alternative product during each stage of the lifecycle (i.e., extraction of raw materials, manufacture, use and end of life). Therefore we evaluated wastes generated at each lifecycle stage in the subsequent sections.

<u>Does the alternative generate less waste?</u>

In regard to raw material extraction, as stated previously, both Paint 1 and Paint 5 are based on non-renewable materials – copper and silica, respectively – that are extracted through mining operations. According to U.S. EPA (2012), the copper concentration in ores ranges from 0.5 to 1%. Ores containing 0.3% or less are typically rejected as waste rock. The acceptable ore must then go through multiple stages before becoming useable copper, including leaching, solvent extraction, milling, physical separation, and smelting. According to the Union Carbide Corporation, 1 pound of mined copper can generate 100 to 200 pounds of waste (Dailey undated). Additionally, a concern associated with copper mining waste is its naturally-elevated levels of radiation (U.S. EPA 2012).

In contrast, silica mining usually has a “limited environmental impact” (USGS 2014). Furthermore, a report about the Union Carbide Corporation Plant states that one pound of silicone product generates between one to three pounds of waste, which compares quite favorably to the 1:100 to 1:200 ratio for mined copper to waste generated (Dailey undated, U.S. EPA 2012). This data lead us to conclude that for the raw material extraction phase, Paint 5 will create less waste compared to the copper antifouling paint.

We were unable to locate waste generation data for the manufacturing processes for each paint formulation. However, since both paints are solvent-based, it is likely that the manufacturing process is similar. As such, we concluded there is likely little to no difference in regard to the amount of waste generated when comparing the manufacturing wastes of Paint 1 and Paint 5.

As for the use phase, during painting of the boat hull, one concern in regard to waste is leftover paint. Since Paint 5 is a two paint system, it has the potential to result in greater amounts of paint waste if the purchased paints are not completely used. An additional concern with waste during the use phase is the resulting empty paint containers. The findings in Solomon (2011), as depicted in Figure 18, show that silicon-based paints can result in slightly fewer paint canisters as compared to biocidal paint systems if less paint is used. If comparable amounts of paint are required (as shown in our calculations), Paint 5 would result in more empty paint containers given it is a two-component system.

However, there is an indirect benefit to using silicon based paints in regard to the amount of waste developed during the use phase. Specifically, there is a decrease in the amount of fuel needed for a power boat, resulting in less raw material waste with a reduction in fuel consumption. This results because foul release systems work by creating smoother surfaces, generally allowing boats to travel more efficiently and consume less fuel (Solomon 2011). This result is corroborated by Demirel et al. (2013), who reported a 2 to 4% fuel penalty for antifouling coatings compared to an unpainted hull due to resulting hull roughness.

In summary, for the use phase, we predict that Paint 5 will have a greater amount of waste related to paint canisters and left over paints, but generate less waste given the increased fuel efficiency and decreased boat drag compared to Paint 1. Therefore, we were unable to make a an overall determination if Paint 5 would generate more or less waste during the use phase compared to Paint 1.

In regard to waste generated at end of life, both products must be stripped off the hull. The amount of waste may vary depending on the stripping method (e.g., sandblasting or hand sanding) and the possibility of copper recycling from sandblasted paint (CalEPA 2011). At this time there is nothing indicating that a silicon-based paint which has been stripped off of a boat could be recycled. The copper antifouling paint therefore is considered preferable in regard to the amount of waste generated at end of life.

Overall, we predict Paint 5 would generate less waste during the raw material extraction phase and would generate more waste at end of life. We assumed the waste developed during paint manufacture was non-differentiating and we were unable to make a determination in regard to the use phase. Overall, we cannot make a determination about which paint will generate less waste throughout its life cycle.

<u>Does the alternative generate fewer wastes with negative impacts?</u>

As with the previous question, we considered wastes generated at each phase of the product's life cycle.

As previously noted, there is a concern with radioactivity of copper waste during mining and extraction. A similar concern is not noted for silicon waste at the raw material extraction phase. We could not determine any differences in wastes with negative impacts at the product manufacturing phase given that both paints are solvent based and likely have similar impacts. However, at the application phase, Solomon (2011) found that silicon-based nonbiocide paints result in three times fewer VOC emissions compared to the biocide systems.

We do not believe there is a difference in the wastes with negative impacts at end of life since both Paints 1 and 5 are solvent-based, and all solvent-based paints are handled as hazardous waste (Environmental Security Technology Certification Program 1999).

Overall, Paint 5 appears to generate fewer wastes with negative impacts at the raw material extraction and use phases based on the available data. Paint manufacturing and end of life do not seem to be differentiating. Subsequently we determined Paint 5 generates less wastes with negative impacts compared to Paint 1.

Is the alternative more recyclable or degradable?

While the copper in stripped paint waste can be recycled, there are no indications that silicon-based paints can be recycled once stripped off boat hulls. Additionally, both Paint 5 and the copper antifouling paint contain several chemicals with very high hazard designations for persistence. These chemicals are listed in Table 50 below.

Table 50: Chemicals in Paint 1 and Paint 5 with Very High Persistence	
Paint	**Very Persistent Chemicals in Formulation**
Paint 1: Trinidad Pro	[REDACTED]
Paint 5: BottomSpeed	Talc (powder); Crystalline silica; Zinc oxide, as Zn (fume); Trimethylated silica

Given we do not have data indicating components of Paint 5 can be recycled in the same way copper can, we believe Paint 5 is less recyclable than Paint 1.

3. Is the alternative more favorable from the perspective of sustainable materials management?

Based on our results for the previous questions, Paint 5 appears to be slightly more favorable for sustainable materials management. This is based on our conclusions in regard to the amount of raw materials needed, and amount of waste with negative impacts generated, by Paint 5 compared to Paint 1. However, the two paints cannot be differentiated based on which will generate less wastes overall and the copper antifouling paint appears to be more recyclable. This resulted in us determining that Paint 5 is only slightly more favorable than the copper antifouling paint from the perspective of sustainable materials management.

4. Develop a strategy to mitigate impacts from the choice of raw materials to support sustainable materials management

There are several changes that could be made to the raw materials for Paint 5 in order to support sustainable materials management. As mentioned previously, silica may be extracted from renewable sources (e.g., rice husks), many of which are typically considered waste materials. If this process becomes standardized and commercialized, silicon-based paints could be dependent on materials which were previously considered waste products. Additionally, while metal paint cans are currently accepted alongside other metals in recycling programs, paint manufacturers could potentially accept empty paint cans (metal or plastic) and reuse them after cleaning out any paint residue in order to use recycled materials for the paint canisters[41].

It is unclear to what extent Paint 5 utilizes recycled paint content in its manufacturing process. However, several states have leftover paint take-back systems which Paint 5's manufacturer,

[41] It should be noted that cleaning out the paint canisters for recycling or reuse may require the use of additional chemicals to remove the solvent based paints. However, since this would be necessary for both paints, and for recycling or reuse, we determined this to be non-differentiating.

Oceanmax, could take part[42]. Alternatively, Oceanmax could work with boatyards and paint distributors in other states to set up local take-back programs. While this may not be feasible with smaller, more isolated boatyards, states like Washington or Florida have large coasts that would allow Oceanmax to work with a larger coalition of boatyards. This would allow Oceanmax to incorporate leftover paint into their production of new paint, resulting in less waste and requiring less raw material input as well.

5. Develop a strategy to mitigate impacts after product use to support sustainable materials management

The take-back systems described in the previous section would also apply here in that these systems could help reduce the amount of waste generated from painting boats with foul release paints. Another mitigation strategy would be to implement paint swapping in communities with large boating populations. Similar to how many cities now have "trash to treasure" programs, boatyards could implement regularly scheduled paint swapping events so that boat owners with leftover paint could give them to other boat owners. This allows a recipient to utilize paint that would otherwise become waste.

Another strategy for mitigating the impacts of switching to Nonbiocide paints, as described in CalEPA (2011), is implementing copper recycling programs at boatyards. Although we determined stripping is not necessary for the alternative paints to function properly, if stripping is done, the resulting waste would contain recyclable copper material. CalEPA (2011) estimated that boatyards could save $2,400 per year from recycling that waste rather than paying for hazardous waste disposal. This recycling strategy would provide both environmental and financial benefits.

Result for the Materials Management Modules

Based on our findings for this module, Paint 5 appears to be slightly more favorable than Paint 1 for material management considerations. Paint 5 appears to use fewer raw materials and generate less waste with negative impacts. Additionally, there are strategies to mitigate impacts from silicon-based paints. However, it should be noted that the copper antifouling paint does appear to be more recyclable than the silicon-based paint.

Social Impact Module

Level 1 Social Impact Module

As stated in the IC2 Guide, "the Social Impact Module ensures that the [Alternatives Assessment] process does not result in unduly shifting a burden from one community of people to another. It requires the evaluation of impacts of an alternative upon the workers, communities, and societies involved in its extraction, manufacture, transport, use, and disposal." The goal of the Level 1 Social Impact Module is to identify potential differences in social impacts to local workers,

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[42] PaintCare, a non-profit organization established by the American Coatings Association, works with states that have passed paint stewardship laws. Currently eight states work with PaintCare: California, Colorado, Connecticut, Maine, Minnesota, Oregon, Rhode Island, and Vermont (Paintcare 2014).

affected communities and societies. The Level 1 module concentrates mainly on the local level, which is defined as the "area surrounding the factory or facility producing the product containing the chemical of concern." As stated in the IC2 Guide, this applies to alternative chemicals or products.

To determine the locations of each product's manufacturing facility, we consulted their materials safety data sheets' (MSDS) identification information. The MSDS for Paint 5 does not identify the product manufacturer, however, we were able to find an MSDS for a related product, PropSpeed. According to CalEPA (2011), Paint 5 is only a slight reformulation of PropSpeed. Based on PropSpeed's MSDS, PropSpeed's New Zealand supplier is in Edmonton in Auckland, New Zealand. This is corroborated by location information for PropSpeed's parent company, Oceanmax Manufacturing. While they do not specifically mention a facility in Edmonton, we made the assumption that Paint 5 is manufactured in Auckland.

For Paint 1, Trinidad Pro, the MSDS has an address listed for Kop-Coat Marine Group in Rockaway, New Jersey. The manufacturer for the copper antifouling paint is Pettit Marine Paint, whose website states specifically that their manufacturing plant is located in Rockaway, NJ. These locations were used to for the Level 1 module below when discussing manufacturing impacts. Additionally, we also examined local-level impacts associated with the end-use of the product.

The Social Impact Module walks the assessor through a set of seven questions which we attempted to answer below with readily available information. For the Social Impact Module, we supplemented our existing information from the Uniform Data Set and the CalEPA (2011) and U.S. EPA (2011) reports with a variety of search strings to pull up relevant information for Paint 1 and Paint 5. The search terms included items such as "copper antifouling paint," "paint manufacturing," and "worker safety."

The Social Impact Module provides a variety of characteristics to consider at the worker, community and global society levels across the product life cycle. These considerations include demographic, health, environment and financial considerations[43].

For the first six questions in the Social Impact Module the IC2 Guide states, if the answer is yes, to "document the information used to reach the conclusion(s) and how the concern(s) may impact the potential use of the alternative. Identify that the concern(s) may eliminate this alternative from consideration unless mitigation or control is feasible." If the answer is no we were to "document information used to reach the conclusion and continue the [Alternatives Assessment]." The seventh question asks if any steps can be taken to mitigate negative impacts associated with the alternatives. Our answers to the seven questions presented by the IC2 Guide are below.

[43] It should be noted that The IC2 Guide was not clear to us on what the focus of this module should be. There are references to "across the product life cycle" but the IC2 Guide also states that a Level 1 assessment focuses on "area surrounding the factory or facility producing the product" which sounds like the manufacturing stage only and not use or end-of-life. Clarification in this module would be beneficial for future users of the IC2 Guide.

1. Are there local worker health and safety issues that have not been addressed by other modules?

In order to understand if there are any local worker health and safety issues, we evaluated the manufacturing locations for Paints 1 and 5 to see if there were any concerns with their business practices or local economies. For each location, we used a Google News search for the location and the manufacturer (e.g., Edmonton and Oceanmax) to see if there were any negative news events. We did not find any information related to poor business practices by either company in these regions.

We also evaluated the worker safety legislation for New Zealand and the United States. In the United States, the Occupational Safety and Health Administration (OSHA) works "to assure safe and healthy working conditions… by setting and enforcing standards and by providing training, outreach, education and assistance[44]." In New Zealand, WorkSafe NZ functions in a similar role. Based on WorkSafe's "About us" page, however, they state that "New Zealand has unacceptably high rates of workplace fatalities, serious harm injuries and work-related disease and illness" (WorkSafe NZ 2014). However, in regard to work place fatalities, the 2013 work place fatality rates are very similar when comparing the number of deaths at the work place in New Zealand (51) to the number of deaths in the U.S. (4,405) to the size of the work force[45] (WorkSafe NZ 2014, OSHA 2014, CIA 2014). Both countries had work place fatality rates around 2-3 deaths per 100,000 workers in 2013.

Furthermore, we evaluated the permissible exposure limits for relevant compounds in New Zealand and the United States. New Zealand's permissible limits for copper fumes and [REDACTED] are 0.2 and [REDACTED] mg/m^3, respectively, while for the United States, those values are 0.1 and [REDACTED] mg/m^3. Based on this information, we are unable to make a determination if the U.S. or New Zealand standards provide greater worker protection for the chemicals in paint formulations being evaluated.

It should be noted, however, that there is an illness, silicosis, which only occurs in individuals which are exposed to silica dust for long periods of time or at very high volumes (MSHA undated). An analogous disease, which is specific to worker exposure to copper, does not exist. Silicosis leads to swelling in the lungs and can eventually result in lung scarring and the destruction of normal lung structures. Exposure to silica dust may occur during the raw material extraction phase for Paint 5.

There has been much work to mitigate the issue of silicosis for silica miners. In the United States, OSHA has developed permissible limits of exposure to silica and dust along with directives for personal protective equipment in order to mitigate the potential for silicosis for individuals exposed to silica dust (OSHA 2014). Similar standards exist in New Zealand, where Paint 5 is manufactured (MBIE 2013). However, we are unaware if Paint 5's raw materials are extracted from the same countries in which they are manufactured and therefore do not know if local workers are at a high risk of silicosis.

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[44] Additional information about OSHA's responsibilities is available here: https://www.osha.gov/about.html.
[45] There is approximately 2.4 million people in the labor force in New Zealand compared to approximately 155 million people in the U.S.

In an attempt to determine where worker concerns may be greatest in regard to silicosis, we evaluated where silica sand and gravel production is the greatest and also evaluated the production of these materials in the U.S. and New Zealand where Paint 1 and Paint 5 are manufactured. New Zealand is a relatively small source of industrial (silica) sand and gravel production. In 2004, New Zealand produced 47,000 metric tons of silica sand and gravel (Dolley 2004). This compared to the 29,700,000 metric tons produced in the United States in the same year. Other leading producers of silica are Slovenia, Germany, Austria, France, and Spain. We should note, however, that we were unable to find definitive instances of worker safety issues directly related to the production of Paint 5 or its manufacturer Oceanmax.

In regard to worker exposure during the use phase of the paints, it is possible that Paint 5 may result in less worker exposure overall in regard to the individuals that apply the paint for two reasons. The first is that Paint 5 may necessitate less cleaning than Paint 1 (discussed in the Performance Evaluation Module previously). This would result in lower amounts of potential exposure on the part of the boat cleaners. Similarly, Paint 5 has a longer lifespan, which may reduce the amount of exposure workers have to chemicals during the painting process.

2. Are there local community impacts that have not been addressed by other modules?

In evaluating the community, societal, and global impacts (questions 2 through 6 of this module), we identified economic impacts not previously discussed that could result from the substitution of Paint 5 for Paint 1. In addition, we examined environmental impacts at larger spatial scales.

During our evaluation of the two manufacturing locations, we attempted to determine if there are any environmental justice concerns associated with Paint 1 and Paint 5's manufacturing locations. We did not locate any data which led us to conclude there may be environmental justice concerns within the communities.

In regard to financial impacts which may be experienced at the local level, it should be noted that a reduction in cleaning and painting frequency, due to the longer life span of Paint 5, may reduce the amount of business for boatyards that do paint applications. However, it is possible boatyards may charge more per cleaning and painting with a reduction in the frequency to recoup the potential lost costs.

In addition to the financial issues the surrounding community may experience due to changes in the demand for the paint products, copper can impact a community's environment due to the biocidal properties of copper antifouling paint. Leached copper can result in significant aquatic impacts to fish. Furthermore, leached copper can pose health problems if ingested. Divers or recreational swimmers might accidentally ingest small quantities of water, which can lead to liver and kidney damage (U.S. EPA 2013).

Additionally, copper mining wastes can concentrate naturally-occurring radioactive materials, as stated previously. These wastes have the potential to leach into the surrounding environment and can seep into groundwater at copper mining sites (U.S. EPA 2012). In a U.S. EPA study of copper mining sites in Arizona, some of the copper mining wastes were found to have up to 100 times the background levels for almost all tested radio-chemicals (U.S. EPA 1999). However, several states, including Arizona, require groundwater monitoring for copper waste rock, making it less likely that the radioactivity would move outside the jurisdiction of the mining operations.

Finally, due to regulations in states such as California, there are already many alternatives available to the copper antifouling paint in the marketplace, so a switch away from it at this point may have already been anticipated by the manufacturer and by distributors. For example, Pettit has already developed an antifouling paint containing 6% ECONEA, a non-metal biocide, which they claim to be as effective as paints with 50% copper content (Pettit Paint undated).

3. Are there local societal impacts that have not been addressed by other modules?

Many of the societal impacts have been addressed in the previous modules. For example, there may be a concern with the increasing amount of waste copper resulting from stripping boat hulls painted with copper paint as discussed in the Materials Management Module. However, there is a system of recycling copper that was discussed previously, which would help to mitigate any costs associated with boat stripping if deemed necessary. Paint 5 was shown to perform effectively without stripping the existing copper antifouling paint, indicating that that step would not be required. Finally, the entire intent of this project is to decrease the loading of copper in marine systems which would occur with the switch to Paint 5.

The health and environmental impacts of the copper antifouling paint have already been discussed in the Hazard Module, but it is worth mentioning that the State of Washington has implemented a plan to phase out copper antifouling paints. In states like Washington that have implemented this type of phase out, boatyards are likely already moving away from copper antifouling paints. Manufacturers are most likely already anticipating a larger shift away from Copper Antifouling Paints and placing greater emphasis on their alternatives. Therefore it is unlikely there will be any significant societal impacts by affecting the business of local distributors.

4. Are there any other local concerns not addressed?

One potential concern for Paint 5 is the increased speed recreational boats can attain with fouling release paints, which could potentially result in worse results in the event of a collision. As stated in Demirel et al. (2013), copper antifouling paint often results in a 2 to 4% fuel penalty due to drag. Paint 5 may result in a two-knot gain in speed, although one user of Paint 5 indicated that he received as much as an eight-knot gain (Brunetti 2012). Customers should be educated about the different speed of their boats and cautioned against excessive speeds.

5. Are there any larger community concerns associated with this alternative?

We were not able to identify any larger community concerns for the alternative that we have not already addressed.

6. Are there any global societal concerns associated with this alternative?

As mentioned previously in the Materials Management Module, Paint 5 compares favorably to Paint 1 in terms of total VOC emissions and GWP. Furthermore, the reduced drag for boats and improved fuel efficiency when using Paint 5 commercially may increase the efficiency of freight shipping. However, since Paint 5 is manufactured in New Zealand, an increase in its use here in the United States would result in potentially higher transportation costs and emissions.

7. Can any steps be taken to mitigate negative impacts associated with the alternative?

The negative impacts identified in this module associated with Paint 5 are as follows:

- Less business for boatyards that do cleaning and paint applications
- Increase in stripped paint waste containing copper
- Increased collision risk
- Higher product transportation costs and emissions
- Silicosis

As stated previously, Paint 5 may result in fewer cleanings and paint jobs over time. This reduction may negatively impact local boatyard businesses. In order to mitigate this concern, boatyards may be able to charge higher individual prices for cleaning and painting for boats painted with Paint 5 to account for the lower frequency of jobs.

The increase in stripped paint waste containing copper can be mitigated in two ways. The first is that, as stated previously, Paint 5 can be applied directly over existing copper antifouling paint and functions adequately. This would eliminate the need for an initial stripping of the hull. Long-term however, boat hulls need to be stripped of paint[46] to prevent paint build up and thus, added weight. As such, moving to Paint 5 reduces the amount of copper waste created from stripping boat paint since it would only need to occur during the initial application.

In regard to concerns about increased boat speeds and collisions, marinas and boatyards that see upticks in the use of Paint 5 or similar foul release paints can educate their customers on their boat's increased efficiency or elect to increase their restrictions on speeds of recreational boats. Most likely many of boatyards or marinas have a maximum allowable speed, so this concern would only apply to areas that have not yet implemented any restrictions for safety.

Additionally, Oceanmax could elect to work with manufacturing plants in the United States to create their paint formulation, which would eliminate concerns regarding international transportation requirements.

Lastly, in regard to silicosis, Oceanmax and other manufacturers of silicon-based paints could work closely with their raw material suppliers to ensure the highest standards are met in regard to worker exposure to silica and the potential for silicosis. If there are concerns or evidence of poor

[46] CalEPA (2011) recommends stripping after every three to four paint jobs but notes that boats are usually stripped every seven to eight paint jobs.

worker safety practices at a raw material supplier silicon-based paint manufacturers should work with a different supplier.

Would selection of a different alternative reasonably satisfy the product/function needs while reducing impacts?

It is possible that other alternative antifouling or foul release paints would reduce some of these societal impacts. For example, foul release paints, such as those based on fluoropolymers, will not have the same concerns in regard to raw material extraction and silicosis. However, given all of the alternatives are silicon-based the silicosis issue cannot be negated by selecting a different alternative from our universe of alternatives.

Are there any other possibilities for mitigation?

We have discussed the possibilities to mitigate the negative impacts related to the alternative paint above.

Life Cycle Module

The Life Cycle Module is designed to assist us in addressing issues or impacts not included in other modules. That is, the "life cycle module identifies potential social, economic or environmental issues and then advises the assessor to either address those issues in the other module or continue with the [Life Cycle] Module to gather more information to assess and address outstanding impact."

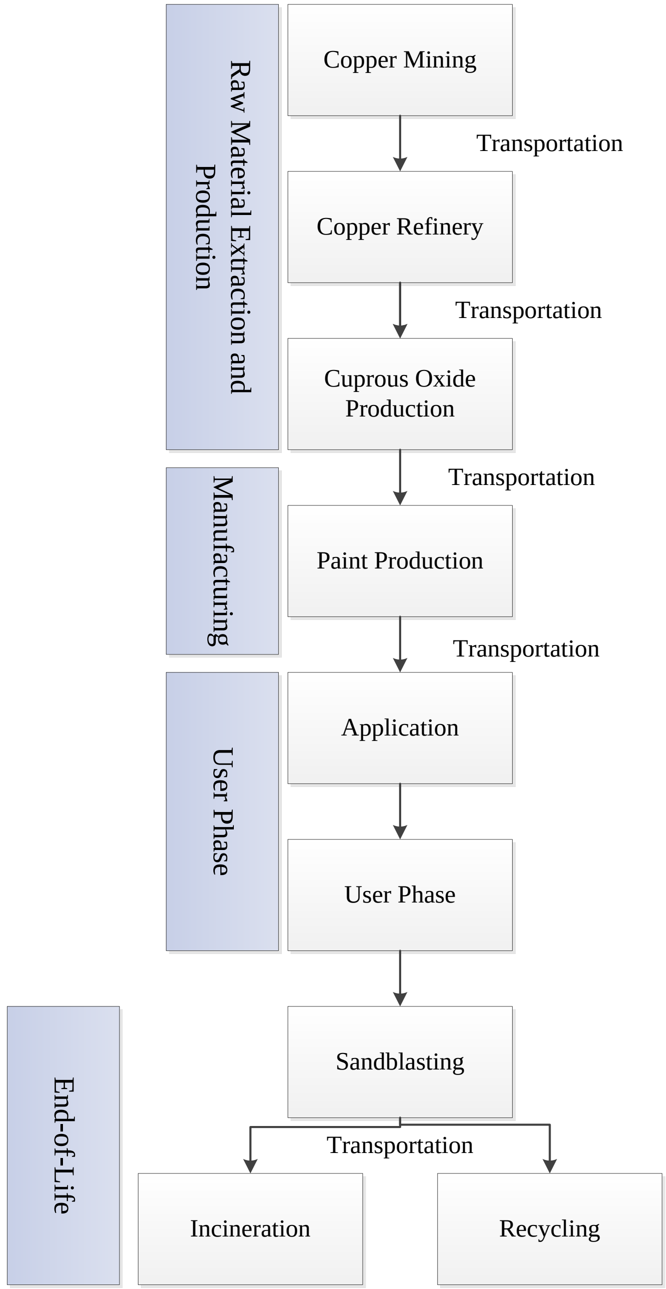
Instead of implementing a complete life cycle assessment as standardized through ISO 14040, the module guides us to use "life cycle thinking" to determine if adverse impacts from the use of a certain chemical or product would be greater, lesser, or similar to using the chemical of concern. In addition, the IC2 Guide points out that an assessment is not needed for every process at every life stage, but instead should be concentrated on processes that are different and discriminating. Therefore, to implement this module, the IC2 Guide first takes the assessor through preliminary steps to scope the assessment, and then directs the assessor to the Level 1 evaluation. It should be noted that based on the results of our preliminary steps, we determined a Level 1 assessment was not necessary because the phases where distinguishing differences occur have been assessed in other modules. The subsequent sections present the process and the data used to support this decision.

Preliminary Steps

The Preliminary Steps allow the assessor to identify potential differences between "unit process" at each life cycle stage to determine if there are discriminating differences between the baseline product and the alternatives. The IC2 Guide states that "unit processes" are the "material and energy inputs and outputs (including chemicals, materials, water, energy, etc…) associated with each stage in the life cycle, from the extraction of natural resources for raw materials to production, storage, and use of the product, to recycling, recovery, reuse, and/or disposal of wastes, and inclusive of transportation requirements along the way." Similar to the Initial Screen in the Exposure Assessment Module, the Preliminary Steps determine whether a deeper analysis is needed or if no further assessment is necessary. We feel that consistent terminology on the "Initial Screens" or "preliminary steps" would be useful for a user of the IC2 Guide.

The first step within the Preliminary Steps is to develop a diagram of the major processes that take place in each product's life cycle stages. Our flow diagram, shown in Figure 20, is a modified version of a flow diagram from Life Cycle Assessment for the Use of Marine Biocides in Antifouling Paint (Lin and Usino 2014).

Figure 20: Flow Diagram of Major Processes Involved in the Copper Antifouling Paint Life Cycle



The module then walks the assessor through a set of questions, which we outlined below with our answers and thought processes to assist in the scoping process.

1. How does the baseline product compare to the alternative(s) for material inputs and outputs and processes at each stage of the life cycle?

To answer this question and to guide us, the IC2 Guide asks two questions, presented below along with our answers.

<u>How does the baseline product compare the alternative(s) with respect to the source of raw materials, production processes and manufacturing, transportation, use and end of life management?</u>

- The source of raw materials: For Paint 5, the raw materials needed differ from Paint 1. Paint 5 is silicon-based. Therefore instead of copper extraction and processing, there will be silicon/silica extraction and silicone processing. This by definition results in different outputs at the raw material extraction level and likely also results in differences in the amount of energy needed to be input for raw material extraction.
- Production processes and manufacturing: Given that both Paint 1 and Paint 5 are solvent-based that are applied to the same substrate once the raw materials are extracted, we assumed the inputs and outputs of the production and manufacturing will be similar for the baseline and alternative products.
- Transportation: Transportation will be required for Paint 1 and Paint 5 at the same phases in the life cycle. Given the products are likely very similar in regard to how they are stored and contained, the transportation methods and subsequently the inputs and outputs are likely similar. The only difference may arise in the amount of energy needed, which is dependent on where the raw materials are extracted, where the product is manufactured, where it is eventually shipped, and where it is disposed.
- Use: The inputs at the use stage are likely very similar between Paint 1 and Paint 5 given that both can be applied with a roller. This indicates the same energy at this phase in regard to application. However, there may be a different amount of total product needed given the shorter life span of the copper antifouling paint. As for outputs, Paint 1 will leach copper into the marine systems, as it is designed to do, and Paint 5 will not. Additionally the paints may release different amounts of VOCs. Further, silicon-based paints may increase a boat's efficiency resulting in less fuel needs for the boats, i.e., reduced inputs for a boat user.
- End-of-life management: At their end of life, both products are sandblasted off the hull; therefore inputs here are likely to be similar. Outputs may vary given the different base products and the possibility of the copper in the copper antifouling paint can be recycled (CalEPA 2011). At this time, a silicon based paint which has been sandblasted off of a boat could not be recycled.

<u>Are any differences expected to be discriminating at the product level?</u>

Yes. The major discriminating differences in inputs and outputs will be at the raw material extraction phase and the use phase. These differences were discussed and evaluated in the Materials Management Module. It should be noted that if an assessor answers yes to this question, the IC2 Guide states "further consideration should be given to possible differences in social, economic or environmental impacts associated with those changes." If the assessor answers no, the IC2 Guide states, "further life cycle assessment may not be necessary." However, the IC2 Guide could be improved by addressing the situation where differences exist and they have already been evaluated in previous modules. In these cases, the life cycle assessment may not be necessary.

2. At which life cycle stages are the material inputs and outputs and/or process flows expected to be different between the baseline product and the alternative?

The IC2 Guide suggests answering four questions to address this broader question.

Are there differences in the raw materials used to produce the alternative chemical, or to produce new materials that must be used in the product?

Yes. As discussed previously, the baseline product is based on copper and the alternative is based on silicon. There are differences in the raw materials needed to produce the alternative product. This is discussed in the Materials Management Module.

What processes, if any will differ in the materials processing and manufacturing stages due to the use of the alternative chemical?

As discussed above, processing and manufacturing for Paint 1 and Paint 5 are expected to be similar.

Will the use of the alternative in the product result in additional or different chemical Releases/exposures to humans or the environment?

Yes. The purpose of examining alternatives to copper antifouling paint is to find a paint alternative that will reduce the amount of toxic chemicals (i.e., copper) entering marine systems. Additionally, the VOCs, which are generated during the application of the paint, may be different, as may the GWP, as discussed in the Materials Management Module. Additionally, there are differences in the mining practices for copper compared to silica and therefore there may be differences in the environmental impact from the extraction of the raw materials as well. These were discussed in the Materials Management and Social Modules. Further, as discussed in the Hazard Module, there are different toxicological profiles for the functional chemicals in the paints and the exposure potential for the functional chemicals in Paint 5 is expected to be similar or less.

Will the use of the alternative affect the generation of wastes and the way in which the product can be reused, recycled, or disposed?

The main waste stream for boat paint is paint which is stripped or sanded off of a boat before applying another coat. The CalEPA report found that waste copper paint may contain approximately 40 to 60% copper when it is hand-sanded off a boat and therefore can be recycled. There are other waste streams as a result of paint removal which include paint which is removed with a high pressure washer and the sludge of the paint that is put through a clarifier after pressure washing. These waste streams can technically also be recycled but they do not contain as much copper and therefore may not be financially feasible to recycle. Otherwise, the copper will need to be disposed of as hazardous waste. To our knowledge, there is no process by which silicon paint which is sanded or power washed off a ship would be recycled. However, we do not believe that the waste material will need to be handled as stringently as waste copper paint. This is based on data from the Naval Research Laboratory which states that one of the financial advantages of switching to silicon based paint is that the cost of disposal of hazardous wastes will be mitigated (Environmental Security and Technology Certification Program 1999).

3. What type of changes in the life cycle impacts, whether environmental, economic, or social might be associated with the differences noted above for the baseline product and the alternative(s)?

This question is presented in the IC2 Guide to ensure users are addressing all considerations of switching to an alternative chemical or product. In certain instances, it directs the assessor to other modules, which we have already conducted. This is noted below.

<u>For each of the differences noted, are increased cost impacts likely to result?</u>

Yes, the immediate cost of the alternative is expected to be greater than the baseline product. However, the lifetime cost of the alternative is expected to be less than the baseline. This difference is evaluated in the Cost and Availability Module.

<u>For each of the differences noted, are increased social impacts likely to result?</u>

There is concern for increased social impacts associated with the alternative in regard to worker's health for the extraction of silica. These have been addressed in the Social Impact Module.

<u>For each difference(s) noted, is it likely to increase use of raw materials and waste generation?</u>

It is unclear if there will be an increase in the use of raw materials but there will be a difference in the types of raw materials used. We have addressed this in the Materials Management Module.

<u>For each of the differences noted, are **increased** environmental impacts likely to result? These impacts may include but are not limited to climate change, acidification, eutrophication, photochemical ozone creation, releases toxic to humans and the environment, land use, or resource depletion.</u>

Through our evaluation of readily available data, we expect increased impact in worker exposure to silica compounds and the increased risk of silicosis. This was discussed in the Social Impact Module. Additionally, as discussed in the Hazard Module, the silica-based chemicals have less aquatic toxicity concerns associated with them; however, there are greater concerns related to human health effects when compared to the cuprous oxide. As for the other considerations, the data we evaluated (Solomon 2011, Lin and Usino 2014) indicate that silicon-based chemicals will result in lower GWP during manufacture, application and use. This was discussed in the Materials Management Module. Therefore, all the distinguishing differences between Paint 1 and Paint 5 have been evaluated, making a Level 1 assessment unnecessary.

It should be noted, if an assessor answers yes to this question, the IC2 Guide states “continue with the [Life Cycle Module]” and if the assessor answers no, the IC2 Guide states “document the information used to reach the conclusion. Continue with [the Life Cycle Module].” We believe the IC2 Guide can be improved here for two reasons. One is that, as with the second sub-question under Question 1 of this module, there is no guidance which states if the differences have all been evaluated, then a life cycle assessment is not necessary. This is critical for assessors with limited resources and time. Additionally, if an assessor answers no to this question and has completed all the previous modules, the Life Cycle Module should not be recommended.

4. What is the scope of the assessment?

We opted to not conduct a Level 1 assessment. The major differences between Paint 1 and Paint 5 are outlined in question 3 above and the differences have been evaluated in the other modules.

5. What type of information do I need to gather in order to conduct the analysis?

No data are needed. The reader is referred to the other modules to understand the differences in the paints at each stage of the life cycle.

Results with the Addition of the Three Optional Modules

Table 51 summarizes our results from the five modules we assessed simultaneously after the review of the three optional modules. The reader is reminded that we implemented the Hazard and Performance Evaluation Modules in the sequential portion of the Hybrid Framework and thus are not included in this matrix.

Table 51: Matrix of Relevant Criteria for the Cost and Exposure Assessment Modules			
	Paint 1: Copper Control	**Paint 5: BottomSpeed**	**Paint 5 Binning Result**
Cost			Favorable
Immediate Cost	$1,038	$3,324	Less Favorable
Lifetime Cost	3 years: $540/year 2 years: $360/year	10 years: $345/year 5 years: $691/year	Favorable[1]
Exposure Potential[2]	N/A	The same or less than copper control	Favorable
Materials Management			Favorable
Raw Materials Input	Copper	Silica	Slightly Favorable
Waste Generated	Mining waste Leftover paint Used paint cans Stripped paint waste	Leftover paint Used paint cans Stripped paint waste	Slightly Favorable
Social Considerations			
Workers	Potential exposure to waste with elevated radiation levels	Potential for silicosis	Less Favorable
Community	Affects local salmon populations	No data	Favorable
Society	High global warming potential	Increased fuel-use efficiency	Favorable
Life Cycle			Refer to other module results

[1] Based on data presented in CalEPA (2011) we assume the BottomSpeed paint will have a 10 year lifespan
[2] Based on the Initial Screen

Table 51 displays that Paint 5 is generally favorable when compared to Paint 1 in regard to the five modules we implemented simultaneously. This is caveated by the fact that Paint 5 was only able to pass through all the modules, including the Hazard and Performance Evaluation Modules, when focusing the hazard evaluation on the silicon-based chemicals. There are major concerns with the human health hazard profile of some of the chemicals in Paint 5 and these are outlined in the section titled, Results of Hybrid Framework without Optional Modules.

Additionally, it should be noted that the immediate cost for copper and the worker exposure issues in the Social Module do present less favorable situations for Paint 5 when compared to the copper antifouling paint. Regardless, the addition of the three additional modules did not change the result of our assessment. Paint 5 received a "Less Favorable" ranking for worker considerations in the Social Impact Module due to the potential for increased silicosis risk linked to an increase in demand for silicone-based paints. However, all the other modules resulted in favorable or slightly favorable rankings for Paint 5.

As a result, we selected Paint 5 as the "preferred" alternative to Paint 1, with the same strong reservations as presented in the Results of Hybrid Framework without Optional Modules section and an additional note about the silicosis concern. As stated previously, we strongly recommend the evaluation of additional alternatives. It would be advantageous to look at paint formulations that are not silica based, for example Nonbiocide paints that are fluoropolymer based instead. This would negate the concern of silicosis and potentially other health issues presented by chemicals in the Paint 5 formulation and outlined in the Hazard Module.

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APPENDIX A: FORMULATIONS FOR SEVEN PAINT FORMULATIONS

Table A-1: Kop-Coat, Inc.'s Pettit Marine Paint Trinidad Pro Antifouling Bottom Paint 1082 Blue (Paint #1)

CAS#	Chemical name	Trade name	Percentage of chemical in ingredient[47]	Percentage of ingredient in formulation	Percentage of chemical component at the product level
[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]

Table A-2: Kop-Coat, Inc.'s Klear N' Klean Plus XP-A101 White Topcoat (Paint #2)

CAS#	Chemical name	Trade name	Percentage of ingredient in formulation[48]
[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]

Table A-3: International Paint LLC's Intersleek 900 System (Primer and Top Coat) (Paint #3)

CAS#	Chemical name	Trade name	Product name	Percentage of ingredient in formulation[49]
Not provided	Unknown	Not provided	Veridian Tie Coat (primer)	Unknown
13463-67-7	Titanium dioxide	Not provided	Intersleek 970 White Part A (top coat)	10-25%
1330-20-7	Xylenes(o-,m-,p-isomers)	Not provided		1-10%
100-41-4	Ethylbenzene	Not provided		1-10%

[47] The MSDS for the individual trade name level ingredients were disclosed from the manufacturer at a very late date. As a result, an online search was performed for the individual ingredient MSDS at the trade name level. If the trade name/ingredient level MSDS was found online, the chemical(s) and percentage(s) disclosed on the publicly available MSDS were used. If they were not available online, the chemical(s) and percentage(s) were identified as "unknown." Not all chemicals of these ingredients were identified on the MSDS, so the percentages may not total 100%.

[48] The MSDS for each product was used to determine the ingredient composition of the paint. Not all ingredient of the paint were identified on the MSDS, so the percentages may not total 100%.

[49] The MSDS for each product was used to determine the ingredient composition of the paint. Not all ingredient of the paint were identified on the MSDS, so the percentages may not total 100%.

Table A-4: International Paint LLC's XZM480 International (Paint #4)

CAS#	Chemical name	Trade name	Percentage of ingredient in formulation[50]
64742-95-6	Solvent naphtha (petroleum), light aromatic	Not provided	10-<25%
95-63-6	1,2,4-Trimethylbenzene	Not provided	2.5-<10%
108-67-8	1,3,5-Trimethylbenzene	Not provided	1-<2.5%
1185-55-3	Trimethoxy(methyl)silane	Not provided	1-<2.5%
2768-02-7	Vinyltrimethoxysilane	Not provided	1-<2.5%
128446-60-6	Silsesquioxane, 3-aminopropyl methyl, ethoxy-terminated	Not provided	1-<2.5%
67-56-1	Methanol	Not provided	0-<1%

Table A-5: BottomSpeed Coating System's TC Base Coat/Top Coat Clear (Paint #5)

CAS#	Chemical name	Trade name	Product name	Percentage of ingredient in formulation[51]
14807-96-6	Talc (powder)	Not provided	BottomSpeed TC Base Coat	5-20%
14808-60-7	Crystalline silica	Not provided		5-20%
95-63-6	1,2,4-Trimethyl benzene	Not provided		5-20%
64742-95-6	Aromatic 100	Not provided		5-20%
64742-48-9	Mineral spirits	Not provided		5-20%
Not provided	Polychlorinated alkanes	Not provided		1-5%
1314-13-2	Zinc oxide, as Zn (fume)	Not provided		1-5%
1330-20-7	Xylene	Not provided	BottomSpeed Top Coat Clear	10-30%
1185-55-3	Trimethoxy(methyl)silane	Not provided		1-5%
68909-20-6	Trimethylated silica	Not provided		1-5%
67-56-1	Methanol	Not provided		0.1-2%
27858-32-8	Diisopropoxytitanium bis (ethylacetoacetate)	Not provided		0.1-2%
Not provided	Methoxy or monofunctional silane	Not provided		0.1-2%

[50] The MSDS for each product was used to determine the ingredient composition of the paint. Not all ingredient of the paint were identified on the MSDS, so the percentages may not total 100%.
[51] The MSDS for each product was used to determine the ingredient composition of the paint. Not all ingredient of the paint were identified on the MSDS, so the percentages may not total 100%.

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Table A-6: Hempel (USA), Inc.'s Hempasil XA278 (Paint #6)			
CAS#	**Chemical name**	**Trade name**	**Percentage of ingredient in formulation**[52]
1330-20-7	Xylene	Not provided	12.5-15%
100-41-4	Ethylbenzene	Not provided	1-3%
Not provided	Modified polysiloxane	Not provided	1-3%

Table A-7: FUJIFILM Hunt Smart Surfaces, LLC's Surface Coat Part A – Black (Paint #7)			
CAS#	**Chemical name**	**Trade name**	**Percentage of ingredient in formulation**[53]
70131-67-8	Siloxanes & silicones	Not provided	50-70%
7631-86-9	Silica	Not provided	7-15%
68083-14-7	Methyl phenyl polysiloxane	Not provided	7-15%
68083-19-2	Vinyl silicone polymer	Not provided	3-7%
64742-49-0	Naphtha (petroleum), hydrotreated light	Not provided	3-7%
68186-94-7	Coating ferrite powder	Not provided	3-7%
556-67-2	Octamethycyclotetrasiloxane	Not provided	1-5%
68909-20-6	Amorphous silica (modified)	Not provided	1-5%

[52] The MSDS for each product was used to determine the ingredient composition of the paint. Not all ingredient of the paint were identified on the MSDS, so the percentages may not total 100%.
[53] The MSDS for each product was used to determine the ingredient composition of the paint. Not all ingredient of the paint were identified on the MSDS, so the percentages may not total 100%.

APPENDIX B: GREENSCREEN® BENCHMARK SCORES

NOVEMBER 2014

GreenScreen® for Safer Chemicals v 1.2
GreenScreen Benchmarks™

ABBREVIATIONS
- **P** Persistence
- **B** Bioaccumulation
- **T** Human Toxicity and Ecotoxicity

Low P* + Low B + Low T (Ecotoxicity, Group I, II and II* Human) + Low Physical Hazards (Flammability and Reactivity) + Low (additional ecotoxicity endpoints when available)

Prefer—Safer Chemical

GS BENCHMARK 3

a. Moderate P or Moderate B
b. Moderate Ecotoxicity
c. Moderate T (Group II or II* Human)
d. Moderate Flammability or Moderate Reactivity

Use but Still Opportunity for Improvement

GS BENCHMARK 2

a. Moderate P + Moderate B + Moderate T (Ecotoxicity or Group I, II, or II* Human)
b. High P + High B
c. High P + Moderate T (Ecotoxicity or Group I, II, or II* Human)
d. High B + Moderate T (Ecotoxicity or Group I, II, or II* Human)
e. Moderate T (Group I Human)
f. Very High T (Ecotoxicity or Group II Human) or High T (Group II* Human)
g. High Flammability or High Reactivity

Use but Search for Safer Substitutes

GS BENCHMARK 1

a. PBT = High P + High B + [very High T (Ecotoxicity or Group II Human) or High T (Group I or II* Human)]
b. vPvB = very High P + very High B
c. vPT = very High P + [very High T (Ecotoxicity or Group II Human) or High T (Group I or II* Human)]
d. vBT = very High B + [very High T (Ecotoxicity or Group II Human) or High T (Group I or II* Human)]
e. High T (Group I Human)

Avoid—Chemical of High Concern

GS BENCHMARK U
Unspecified Due to Insufficient Data

See Guidance (GreenScreen for Safer Chemicals Hazard Assessment Procedure) at www.greenscreenchemicals.org for instructions.

Group I Human includes Carcinogenicity, Mutagenicity/Genotoxicity, Reproductive Toxicity, Developmental Toxicity (incl. Developmental Neurotoxicity), and Endocrine Activity. **Group II Human** includes Acute Mammalian Toxicity, Systemic Toxicity/Organ Effects-Single Exposure, Neurotoxicity-Single Exposure, Eye Irritation and Skin Irritation. **Group II* Human** includes Systemic Toxicity/Organ Effects-Repeated Exposure, Neurotoxicity-Repeated Exposure, Respiratory Sensitization, and Skin Sensitization. Immune System Effects are included in Systemic Toxicity/Organ Effects. **Ecotoxicity** includes Acute Aquatic Toxicity and Chronic Aquatic Toxicity.

* For inorganic chemicals persistence alone will not be deemed problematic. See Guidance.

APPENDIX C: GREENSCREEN® HAZARD ENDPOINTS AND ACRONYMS

(AA) **Acute Aquatic Toxicity**

(AT) **Acute Mammalian Toxicity**

(B) **Bioaccumulation**

(C) **Carcinogenicity**

(CA) **Chronic Aquatic Toxicity**

(D) **Developmental Toxicity**

(E) **Endocrine Activity**

(F) **Flammability**

(IrE) **Eye Irritation/Corrosivity**

(IrS) **Skin Irritation/Corrosivity**

(M) **Mutagenicity and Genotoxicity**

(N) **Neurotoxicity**

(P) **Persistence**

(R) **Reproductive Toxicity**

(Rx) **Reactivity**

(SnS) **Sensitization- Skin**

(SnR) **Sensitization- Respiratory**

(ST) **Systemic/Organ Toxicity**

APPENDIX D: INDIVIDUAL CHEMICAL HAZARD ASSESSMENT SUMMARIES FOR SEVEN PAINT FORMULATIONS

Table D-1: Chemical Hazard Summary Table for Kop-Coat, Inc.'s Pettit Marine Paint Trinidad Pro Antifouling Bottom Paint 1082 Blue (Paint #1)

Chemical	CAS #	% in Ingredient[54]	Group 1 Human Health					Group II and II* Human Health									Ecotox.		Fate		Physical		GreenScreen® Benchmark Score
			Carcinogenicity	Mutagenicity	Reproductive	Developmental	Endocrine Activity	Acute Toxicity	Systemic Toxicity		Neurotoxicity		Skin Sensitization*	Respiratory Sensitization*	Skin Irritation	Eye Irritation	Acute Aquatic	Chronic Aquatic	Persistence	Bioaccumulation	Reactivity	Flammability	
									s	r*	s	r*											

Table D-2: Chemical Hazard Summary Table for Kop-Coat, Inc.'s Klear N' Klean Plus XP-A101 White Topcoat (Paint #2)

Chemical	CAS #	% in Ingredient[55]	Group 1 Human Health					Group II and II* Human Health									Ecotox.		Fate		Physical		GreenScreen® Benchmark Score
			Carcinogenicity	Mutagenicity	Reproductive	Developmental	Endocrine Activity	Acute Toxicity	Systemic Toxicity		Neurotoxicity		Skin Sensitization*	Respiratory Sensitization*	Skin Irritation	Eye Irritation	Acute Aquatic	Chronic Aquatic	Persistence	Bioaccumulation	Reactivity	Flammability	
									s	r*	s	r*											
[REDACTED]	[REDACT-ED]	[REDACTED]	[REDACTED]																				[REDACTED]
[REDACTED]	[REDACT-ED]	[RE-DACTED]	[REDACTED]																				[REDACTED]

[54] Percentage of chemical component at the product level.

Table D-3: Chemical Hazard Summary Table for Chemicals used in International Paint LLC's Intersleek 900 System – Veridian Tie Coat (Primer) (Paint #3)

			Group 1 Human Health					Group II and II* Human Health									Ecotox.		Fate		Physical		
Chemical	CAS #	% in Ingredient	Carcinogenicity	Mutagenicity	Reproductive	Developmental	Endocrine Activity	Acute Toxicity	Systemic Toxicity		Neurotoxicity		Skin Sensitization*	Respiratory Sensitization*	Skin Irritation	Eye Irritation	Acute Aquatic	Chronic Aquatic	Persistence	Bioaccumulation	Reactivity	Flammability	GreenScreen® Benchmark Score
									s	r*	s	r*											
Unknown[56]	Not provided	Unk.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Unk.: Unknown
NA: Not Assessed

[55] Percentage of chemical component at the product level.
[56] ToxServices did not receive formulation information for the primer coat; however, as the primer is intended to be used as part of the Intersleek 970 System along with the top coat, it was necessary to include the Veridian Tie Coat primer in the assessment table.

Table D-4: Chemical Hazard Summary Table for International Paint LLC's Intersleek 900 System – Intersleek 970 White Part A (Top Coat) (Paint #3)

Chemical	Route of Exposure	CAS #	% in Ingredient[57]	Group 1 Human Health: Carcinogenicity	Mutagenicity	Reproductive	Developmental	Endocrine Activity	Group II and II* Human Health: Acute Toxicity	Systemic Toxicity (s)	Systemic Toxicity (r*)	Neurotoxicity (s)	Neurotoxicity (r*)	Skin Sensitization*	Respiratory Sensitization*	Skin Irritation	Eye Irritation	Ecotox.: Acute Aquatic	Chronic Aquatic	Fate: Persistence	Bioaccumulation	Physical: Reactivity	Flammability	GreenScreen® Benchmark Score
Titanium dioxide		13463-67-7	10-25%																					
	Inhalation			**H**							**H**													**BM 1**
	Oral			**L**	**L**	**L**	**L**	DG	**L**	*M*	**L**	DG	DG	**L**	DG	**L**	*M*	**L**	**L**	**vH**	**L**	*L*	*L*	**BM 3**
	Dermal			DG							DG													**BM U**
Xylenes(o-,m-,p-isomers)		1330-20-7	1-10%	**L**	**L**	**L**	*H*	*M*	**M**	*H*	**L**	**M**	**M**	*L*	DG	**H**	**H**	**H**	**M**	**L**	**vL**	*L*	**M**	**BM 1**
Ethylbenzene		100-41-4	1-10%	**H**	NA	NA	NA	NA	**M**	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	**H**	**LT-1**

Unk.: Unknown
NA: Not Assessed

[57] Percentage of chemical component at the product level.

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Table D-5: Chemical Hazard Summary Table for International Paint LLC's XZM480 International (Paint #4)																							
			Group 1 Human Health					Group II and II* Human Health									Ecotox.		Fate		Physical		
Chemical	CAS #	% in Ingredient[58]	Carcinogenicity	Mutagenicity	Reproductive	Developmental	Endocrine Activity	Acute Toxicity	Systemic Toxicity		Neurotoxicity		Skin Sensitization*	Respiratory Sensitization*	Skin Irritation	Eye Irritation	Acute Aquatic	Chronic Aquatic	Persistence	Bioaccumulation	Reactivity	Flammability	GreenScreen® Benchmark Score
Solvent naphtha (petroleum), light aromatic	64742-95-6	10-<25 %	**H**	**H**	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	**H**	**M**	**vL**	**L**	NA	NA	**LT-1**
1,2,4-Trimethylbenzene	95-63-6	2.5-<10 %	*L*	**M**	*M*	**L**	DG	**M**	**M**	**L**	**vH**	**H**	**L**	DG	**H**	**H**	**H**	**H**	*H*	**L**	*L*	**M**	**BM 2**
1,3,5-Trimethylbenzene	108-67-8	1-<2.5 %	*L*	**M**	*M*	**L**	DG	**M**	**M**	**L**	**vH**	**H**	**L**	DG	**H**	**H**	**H**	**H**	*H*	**L**	*L*	**M**	**BM 2**
Trimethoxy (methyl)silane	1185-55-3	1-<2.5 %	*L*	*M*	**L**	**L**	*M*	**L**	**L**	**M**	**M**	**L**	*M*	DG	**L**	**L**	**L**	**L**	*M*	*vL*	*L*	**H**	**BM 1_{TP}**
Vinyltrimethoxy silane	2768-02-7	1-<2.5 %	*L*	**L**	**M**	*M*	DG	**M**	**M**	*H*	**M**	DG	*M*	DG	*L*	**L**	**L**	**L**	*M*	*vL*	*L*	**H**	**BM 1_{TP}**
Silsesquioxane, 3-aminopropyl methyl, ethoxy-terminated	128446-60-6	1-<2.5 %	DG	DG	DG	DG	DG	DG	DG	DG	DG	DG	DG	DG	*H*	*H*	DG	DG	DG	DG	DG	*M*	**BM U**
Methanol	67-56-1	0-<1%	NA	NA	NA	**H**	NA	**H**	**vH**	NA	NA	NA	NA	NA	NA	NA	**L**	*L*	**vL**	*vL*	NA	**H**	**LT-1**

Unk.: Unknown
NA: Not Assessed

[58] Percentage of chemical component at the product level.

[REDACTED VERSION TO PROTECT SUPPLIER CONFIDENTIAL BUSINESS INFORMATION]

Chemical		CAS #	% in Ingredient[59]	Group 1 Human Health					Group II and II* Human Health										Ecotox.		Fate		Physical		GreenScreen® Benchmark Score
				Carcinogenicity	Mutagenicity	Reproductive	Developmental	Endocrine Activity	Acute Toxicity	Systemic Toxicity		Neurotoxicity		Skin Sensitization*	Respiratory Sensitization*	Skin Irritation	Eye Irritation	Acute Aquatic	Chronic Aquatic	Persistence	Bioaccumulation	Reactivity	Flammability	
Talc (powder)		14807-96-6	5-20%																					
	Route of Exposure: Inhalation			M				*M*	DG	DG	H													**BM 1**
	Route of Exposure: Oral			L	L	*L*	L	DG	L	DG	L	DG	DG	L	DG	L	L	L	*L*	vH	*L*	*L*	*L*	**BM 3$_{DG}$**
	Route of Exposure: Dermal			M				DG	DG	DG	L													**BM U**
Crystalline silica		14808-60-7	5-20%																					
	Route of Exposure: Inhalation			H					DG	*vH*	H													**BM 1**
	Route of Exposure: Oral			*L*	M	*L*	*L*	DG	M	*L*	*L*	DG	DG	*L*	DG	*L*	*M*	*L*	DG	*vH*	*vL*	*L*	*L*	**BM 2**
	Route of Exposure: Dermal			DG					*L*	*L*	DG													**BM U**
1,2,4-Trimethyl benzene		95-63-6	5-20%	*L*	M	*M*	L	DG	M	M	L	vH	H	L	DG	H	H	H	H	*H*	L	*L*	M	**BM 2**
Aromatic 100		64742-95-6	5-20%	H	H	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	H	M	vL	L	NA	NA	**LT-1**
Mineral spirits		64742-48-9	5-20%	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	vH	*H*	H	*vH*	NA	NA	**BM 1**
Polychlorinated alkanes		Not provided	1-5%	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Zinc oxide, as Zn (fume)		1314-13-2	1-5%	*L*	M	L	L	DG	L	L	H	DG	DG	L	*H*	L	L	vH	vH	vH	DG	L	L	**BM 1**

Unk.: Unknown
NA: Not Assessed

[59] Percentage of chemical component at the product level.

Table D-7: Chemical Hazard Summary Table for Chemicals used in BottomSpeed Coating System's TC Top Coat Clear (Paint #5)

Chemical		CAS #	% in Ingredient[60]	Group 1 Human Health					Group II and II* Human Health									Ecotox.		Fate		Physical		GreenScreen® Benchmark Score
				Carcinogenicity	Mutagenicity	Reproductive	Developmental	Endocrine Activity	Acute Toxicity	Systemic Toxicity		Neurotoxicity		Skin Sensitization*	Respiratory Sensitization*	Skin Irritation	Eye Irritation	Acute Aquatic	Chronic Aquatic	Persistence	Bioaccumulation	Reactivity	Flammability	
										s	r*	s	r*											
Xylene		1330-20-7	10-30%	**L**	**L**	**L**	*H*	*M*	**M**	*H*	**L**	**M**	**M**	*L*	DG	**H**	**H**	**H**	**M**	**L**	**vL**	*L*	**M**	**BM 1**
Trimethoxy (methyl)silane		1185-55-3	1-5%	*L*	*M*	**L**	**L**	*M*	**L**	**L**	**M**	**M**	**L**	*M*	DG	**L**	**L**	**L**	**L**	*M*	*vL*	*L*	**H**	**BM 1_{TP}**
Trimethylated silica		68909-20-6	1-5%																					
	Route of Exposure	Inhalation							**vH**	**L**	**H**	**L**	**L**											**BM 1**
		Oral		**L**	**L**	**L**	**L**	DG	**L**	**H**	**L**	**H**	DG	**L**	DG	**L**	**L**	**L**	**M**	*vH*	*vL*	*L*	**L**	**BM 2**
		Dermal							**H**	**L**	DG	**L**	DG											**BM U**
Methanol		67-56-1	0.1-2%	NA	NA	NA	**H**	NA	**H**	**vH**	NA	NA	NA	NA	NA	NA	NA	**L**	*L*	**vL**	*vL*	NA	**H**	**LT-1**
Diisopropoxy titanium bis (ethylacetoacetate)		27858-32-8	0.1-2%	*L*	**L**	*M*	*M*	DG	**L**	*vH*	**L**	*M*	*L*	*L*	DG	DG	*H*	**L**	**L**	*L*	*vL*	*L*	**M**	**BM 2**
Methoxy or monofunctional silane		Not provided	0.1-2%	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Unk.: Unknown
NA: Not Assessed

[60] Percentage of chemical component at the product level.

[REDACTED VERSION TO PROTECT SUPPLIER CONFIDENTIAL BUSINESS INFORMATION]

Table D-8: Chemical Hazard Summary Table for Hempel (USA), Inc.'s Hempasil XA278 (Paint #6)

			Group 1 Human Health					Group II and II* Human Health									Ecotox.		Fate		Physical		
Chemical	CAS #	% in Ingredient[61]	Carcinogenicity	Mutagenicity	Reproductive	Developmental	Endocrine Activity	Acute Toxicity	Systemic Toxicity		Neurotoxicity		Skin Sensitization*	Respiratory Sensitization*	Skin Irritation	Eye Irritation	Acute Aquatic	Chronic Aquatic	Persistence	Bioaccumulation	Reactivity	Flammability	GreenScreen® Benchmark Score
									s	r*	s	r*											
Xylene	1330-20-7	12.5 - 15%	**L**	**L**	**L**	*H*	*M*	**M**	*H*	**L**	**M**	**M**	*L*	DG	**H**	**H**	**H**	**M**	**L**	**vL**	*L*	**M**	**BM 1**
Ethylbenzene	100-41-4	1-3%	**H**	NA	NA	NA	NA	**M**	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	**H**	**LT-1**
Modified polysiloxane	Not provided	1-3%	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Unk.: Unknown
NA: Not Assessed

[61] Percentage of chemical component at the product level.

[REDACTED VERSION TO PROTECT SUPPLIER CONFIDENTIAL BUSINESS INFORMATION]

Table D-9: Chemical Hazard Summary Table for FUJIFILM Hunt Smart Surfaces, LLC's Surface Coat Part A – Black (Paint #7)																								
				Group 1 Human Health					Group II and II* Human Health									Ecotox.		Fate		Physical		
Chemical		CAS #	% in Ingredient[62]	Carcinogenicity	Mutagenicity	Reproductive	Developmental	Endocrine Activity	Acute Toxicity	Systemic Toxicity		Neurotoxicity		Skin Sensitization*	Respiratory Sensitization*	Skin Irritation	Eye Irritation	Acute Aquatic	Chronic Aquatic	Persistence	Bioaccumulation	Reactivity	Flammability	GreenScreen® Benchmark Score
										s	r*	s	r*											
Siloxanes & silicones		70131-67-8	50-70%	L	L	L	L	DG	L	L	L	L	L	L	DG	M	M	L	L	vH	vL	L	L	BM 2
Silica		7631-86-9	7-15%																					
	Route of Exposure	Inhalation		H					DG	DG	H													BM 1
		Oral		L	L	L	L	DG	L	L	L	DG	DG	L	DG	L	L	L	DG	*vH*	*vL*	*L*	*L*	BM 3$_{DG}$
		Dermal		DG					L	L	DG													BM U
Methyl phenyl polysiloxane		68083-14-7	7-15%	L	L	L	L	DG	L	L	L	L	L	L	DG	L	*M*	L	L	vH	L	*L*	L	BM 2
Vinyl silicone polymer		68083-19-2	3-7%	*L*	L	L	M	DG	L	L	*L*	DG	*L*	L	DG	L	L	L	L	vH	vH	*L*	L	BM 1
Naphtha (petroleum), hydrotreated light		64742-49-0	3-7%	H	H	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	H	*M*	vL	*H*	NA	NA	LT-1
Coating ferrite powder		68186-94-7	3-7%	*L*	*L*	DG	DG	DG	L	L	*H*	L	DG	DG	DG	L	L	L	DG	vH	*L*	*L*	L	BM 1
Octamethylcyclotetrasiloxane		556-67-2	1-5%	NA	NA	M	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	vH	vH	vH	NA	NA	BM 1
Amorphous silica (modified)		68909-20-6	1-5%																					
	Route of Exposure	Inhalation							vH	L	H	L	L											BM 1
		Oral		L	L	L	L	DG	L	H	L	H	DG	L	DG	L	L	L	M	*vH*	*vL*	*L*	L	BM 2
		Dermal							H	L	DG	L	DG											BM U

Unk.: Unknown
NA: Not Assessed

[62] Percentage of chemical component at the product level.