San Francisco Bay Area Receiving Water Trash Monitoring

Pilot-Testing of Qualitative and Quantitative Monitoring and Assessment Protocols

FINAL REPORT

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Bay Area Stormwater Management Agencies Association

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List of Acronyms

ACCWP	Alameda Countywide Clean Water Program
BASMAA	Bay Area Stormwater Management Agency Association
CCCWP	Contra Costa Clean Water Program
CEDEN	California Environmental Data Exchange Network
FSURMP	Fairfield Suisun Urban Runoff Management Program
MRP	Municipal Regional Permit
NPDES	National Pollution Discharge Elimination System
OVTA	On-land Visual Trash Assessments
OPC	California Ocean Protection Council
PMT	Project Management Team
QAPP	Quality Assurance Project Plan
QAPP	Quality Assurance Program Plan
QA/QC	Quality Assurance/Quality Control
RTA	Rapid Trash Assessment
RMC	Regional Monitoring Coalition
RMP	Regional Monitoring Program
SCCWRP	Southern California Coastal Water Research Project
SCVURPPP	Santa Clara Valley Urban Runoff Pollution Prevention Program
SFEI	San Francisco Estuary Institute
SFBRWQCB	San Francisco Bay Regional Water Quality Control Board
SMC	Southern California Monitoring Coalition
SMCWPPP	San Mateo County Water Pollution Prevention Program
SOP	Standard Operating Protocol
WY	Water Year

EXECUTIVE SUMMARY

Provision C.10.b.v of the Municipal Regional Stormwater NPDES Permit (MRP 2.0), issued by the San Francisco Bay Regional Water Quality Control Board to 76 cities, counties and flood control districts in the SF Bay Area, requires public agencies to develop, submit and test a Receiving Water Trash Monitoring Program Plan (Trash Monitoring Plan). Version 1.0 of the Trash Monitoring Plan includes a description of the monitoring design and monitoring/assessment protocols.

In July 2017, the Bay Area Stormwater Management Agencies Association (BASMAA) submitted the first iteration of the Trash Monitoring Plan to SF Bay Water Board staff for review and comment. The Final Trash Monitoring Plan that addressed all comments was submitted to the SF Bay Water Board staff in October 2017 (BASMAA 2017). Implementation of the Trash Monitoring Plan represents the "pilot-testing phase" of trash receiving water monitoring in the San Francisco Bay Area, during which the pilot protocols and methods were applied during the MRP 2.0-specified timeframe of October 2017 to July 2020.

The MRP requires that the results of the testing phase of the Trash Monitoring Plan be submitted to the SF Bay Regional Water Board as a Final Report by July 1, 2020. The Final Report provides analysis of all information/data collected from trash assessments and monitoring conducted between October 2017 and March 2020. Monitoring Plan objectives and scientific monitoring questions outlined in the Trash Monitoring Plan were used to guide the evaluation of trash monitoring and assessment data results presented in this Final Report.

Monitoring Questions

1. Are significantly strong correlations observed between qualitative and quantitative methods?
2. What is the current level of trash deposited in flowing waterbodies in the entire MRP area?
3. What is the range of trash levels observed at sites targeted for cleanup? How do these ranges compare to levels in all flowing waterbodies?
4. Do trash levels in flowing waterbodies differ significantly between wet and dry seasons?
5. What percentages of trash observed in receiving waters are attributable to wind/litter, illegal dumping, illegal encampments and other (stormwater/upstream sources)?
6. Do trash levels in flowing waterbodies strongly correlate to trash generation levels depicted on Permittee maps?

The Trash Monitoring Plan primarily focuses on two types of monitoring designs: 1) **probabilistic** (randomly) selected monitoring sites that are intended to represent the trash conditions in all creek, channel and riverine sites that flow through the urban Bay Area; and 2) **targeted** sites in urban creeks, channel and river segments and sites along San Francisco Bay shorelines where trash regularly deposits and is periodically removed by MRP Permittees. The design also includes a small number of targeted locations where trash booms are deployed to intercept trash prior to transport downstream to the San Francisco Bay.

Two trash assessment tools were developed and applied for the pilot testing phase of the Trash Monitoring Plan. **Qualitative** trash assessments are visual surveys of trash levels (i.e., conditions). Trained personnel assign a trash condition score from 1 to 12 (12 being the most trash) to a site based on the level of trash that is observed both within the water body and along its banks or shoreline within a defined assessment area. **Quantitative** trash monitoring entails removing, sorting and measuring the volume of trash that is found within the assessment area at a targeted site. Both quantitative trash

monitoring methods and the qualitative assessment methods were used at targeted sites to allow for the comparison of qualitative and quantitative approaches.

A total of 125 urban creek, channel and riverine probabilistic sites throughout the MRP Area were qualitatively assessed for trash. A total of 625 qualitative trash assessments were conducted over five sampling events (three during wet season and two during dry season) between October 2017 and March 2020. A total of 100 targeted sites were selected for both qualitative and quantitative trash assessments. A total of 200 trash assessments were conducted over two sampling events at targeted sites. Targeted monitoring was conducted at nine trash boom locations in Alameda, Santa Clara and San Mateo Counties.

Key Findings

1. Significant correlations were observed between qualitative trash condition scores and trash density (volume per unit area) at both regional and countywide scale. The visual assessment tool is recommended as a valid approach to assess conditions when using volume of trash as the indicator for trash conditions.
2. Regionwide, approximately 77% of the urban stream lengths in the MRP Area exhibit low to moderate levels of trash.
3. Trash condition scores at targeted sites were generally higher (more trash), compared to probabilistic sites.
4. Seasonality appears to have no effect on trash levels observed/measured at receiving water sites. Trash levels were highly similar between the dry and wet seasons. Storm intensity and frequency did not appear to have an influence on trash levels observed during the wet season.
5. Litter/Wind and Other/Stormwater trash pathways were the most frequent pathways reported at all monitoring sites, however, Illegal Encampments and Illegal Dumping trash pathways were associated with largest proportion of trash observed.

An evaluation of methods and monitoring design used during the pilot-testing phase of the Trash Monitoring Plan is provided in this report. This evaluation provides guidance for potential revisions to methods that may be used to monitor trash in receiving waters.

1 INTRODUCTION

The San Francisco Bay Regional Water Quality Control Board (Regional Water Board) has determined that trash is a pervasive problem near and in receiving waters, such as local creeks, rivers, and the San Francisco Bay Estuary (SFBRWQCB 2015). Trash can cause major impacts to beneficial uses, including recreation, aquatic life and habitat in those waters. Trash can originate on land or through individuals directly dumping/depositing trash into a receiving water or on its banks/shoreline. Eventually, trash present in local water bodies contributes to the global ocean ecosystem, where it can persist in the environment for hundreds of years, concentrate organic toxins, and be ingested by aquatic life. There are also physical impacts, as aquatic species can become entangled and ensnared, and can ingest trash that looks like prey, losing the ability to feed properly.

Between 2003 and 2005, trash levels and types deposited in local creeks and rivers were measured by the Regional Water Board using the Surface Water Ambient Monitoring Program's (SWAMP) Rapid Trash Assessment (RTA) Protocol. The Regional Water Board reported that data collected by SWAMP indicated that levels of trash in the waters of the San Francisco Bay region were very high (SFBRWQCB 2007). During 85 surveys conducted at 26 sites throughout the Bay Area, an average of almost three pieces of trash were observed per linear foot of creek. As a result of this new information, the Regional Water Board added 26 waterbodies in the region to the 303(d) list for the pollutant trash and concluded that this set of receiving waters was representative of the trash impacts present in all segments of local receiving waters that flow through urbanized watershed areas, and the shoreline of San Francisco Bay (Bay). Additionally, urban stormwater runoff was identified as an important pathway that transports trash from watersheds to these receiving waters. Identifying stormwater as an important pathway necessitated the inclusion of trash load reduction requirements in the Municipal Regional Stormwater NPDES Permit (MRP 2.0), Order No. R2-2015-0049.

MRP 2.0 was issued by the Regional Water Board on November 19, 2015 to 76 cities/towns, counties and special districts (Permittees). MRP 2.0 includes general stormwater management requirements, as well as those associated with specific pollutants. Provision C.10 of MRP 2.0 (Trash Load Reduction) requires Permittees to reduce trash discharged from their municipal separate storm sewer system (MS4) by demonstrable amounts in specific timeframes, install and maintain trash full capture systems, annually cleanup and assess trash hot spots in receiving waters, and conduct monitoring and assessment activities to address specific management questions regarding trash. Provision C.10.b.v entitled "Receiving Water Monitoring" requires Permittees to develop and test a receiving water trash monitoring program plan (Trash Monitoring Plan).

In July 2017, the Bay Area Stormwater Management Agencies Association (BASMAA) submitted the first iteration of the Trash Monitoring Plan to Regional Water Board staff for review and comment. The Final Trash Monitoring Plan that addressed all comments was submitted to the Regional Water Board staff in October 2017 (BASMAA 2017). Implementation of the Trash Monitoring Plan represents the "pilot-testing phase" of trash receiving water monitoring in the San Francisco Bay Area, during which the pilot protocols and methods were applied during the MRP 2.0-specified timeframe of October 2017 to July 2020.

The overall goal of the Trash Monitoring Program Plan, as described in the MRP 2.0 Fact Sheet, is to establish:

> *"…the least expensive and simplest to use monitoring methods and protocols that are applicable to the various discharge and receiving water scenarios that accounts for the various receiving waters and watershed, community, and drainage characteristics within*

> *Permittees' jurisdictions that affect the discharge of trash and its fate and effect in receiving water(s). These and other factors, such as feasibility, location logistics, types of trash, complexity, and costs provide a means to focus and limit the number of monitoring tools and protocols, and determine spatial and temporal representativeness of the tools and protocols, representativeness of scenarios that will be tested." (Emphasis added)*

The Fact Sheet also indicates that Permittees may include assessment methods based on the *Rapid Trash Assessment Method Applied to Waters of the San Francisco Bay Region: Trash Measurement in Streams* (SFBRWQCB 2007). Additionally, MRP 2.0 specifies that the development of receiving water monitoring tools and protocols and a monitoring program shall be designed, to the extent possible, to answer the following management questions:

1. Have a Permittee's trash control actions effectively prevented trash within a Permittee's jurisdiction from discharging into receiving water(s)?
2. Is trash present in receiving water(s), including transport from one receiving water to another, e.g., from a creek to a San Francisco Bay segment, at levels that may cause adverse water quality impacts?
3. Are trash discharges from a Permittee's jurisdiction causing or contributing to adverse trash impacts in receiving water(s)?
4. Are there sources outside of a Permittee's jurisdiction that are causing or contributing to adverse trash impacts in receiving water(s)?

Receiving water trash monitoring conducted through the Trash Monitoring Plan is intended to address these management questions by collecting initial information on the levels of trash in applicable receiving waters, the importance of site and watershed characteristics on trash levels observed/measured, and the relative contributions from important trash sources and pathways. Information and data collected during the testing phase of the Trash Monitoring Plan is not intended to address compliance issues associated with trash reduction requirements of the MRP. Compliance is achieved through other aspects of Provision C.10, including evaluations of the extent of certified trash full capture system implementation and the trash reduction effects of other management actions measured via On-land Visual Trash Assessments (OVTA) conducted on streets, sidewalks and other watershed land areas.

Provision C.10.b.v of the MRP requires that the results of the testing phase of the Trash Monitoring Plan be submitted to the Regional Water Board in two separate reports: 1) Preliminary Report by July 1, 2019; and 2) Final Report by July 1, 2020. This report serves as the Final Report for all MRP 2.0 Permittees and provides analysis of all information/data collected from trash assessments and monitoring conducted between October 2017 and March 2020. Trash assessment results, as well as the methods and approach used in the Trash Monitoring Plan, were evaluated by the BASMAA Project Management Team (PMT), regional stakeholders, and scientific peer reviewers.

2 BACKGROUND

2.1 TRASH MONITORING PLAN OVERVIEW

2.1.1 Monitoring Plan Development Process

The Trash Monitoring Plan was developed through a collaboration of the BASMAA Project Management Team (PMT), regional stakeholders and scientific peer reviewers. Permittees and SF Bay Regional Water Board staff developed a list of stakeholders who would be potentially interested in providing feedback on the Trash Monitoring Plan. Stakeholders included additional permittee representatives, and staff from environmental non-governmental organizations, USEPA, and Regional and State Water Boards.

BASMAA held three stakeholder meetings at key stages of the project to solicit input and share information. Additionally, stakeholders also had an opportunity to contribute information on existing monitoring tools and protocols. Stakeholders were provided the opportunity to review and provide comments on the Draft Trash Monitoring Plan. In some instances, follow-up discussions were necessary with individual stakeholders (e.g., Regional Water Board staff) to obtain clarification and guidance for moving forward with the project. A table of stakeholder comments received and BASMAA responses is provided as an attachment to the Trash Monitoring Plan (BASMAA 2017).

The development of the Trash Monitoring Plan utilized technical experts to review the monitoring tools, protocols and sample design. These peer reviewers were selected by the PMT based on their experience in designing and implementing trash receiving water monitoring programs and/or other types of water quality monitoring. Peer reviewers provided input on key topic areas, which assisted the PMT in developing an effective receiving water trash monitoring program.

2.1.2 Goals/Objectives of Monitoring Plan

The PMT developed specific goals of the Trash Monitoring Plan through the stakeholder engagement process to cost-effectively answer the MRP 2.0 management questions. These goals include:

- Informs management decisions;
- Accounts for the different stream and channel types, and considers temporal variability (e.g., to estimate baseline conditions and show change over time) and seasonality;
- Can assess trends over time;
- Helps to assess if the Permittees' trash reduction efforts are resulting in improvement;
- Allows for comparison of trash levels between sites (understand the range of levels of impact);
- Assists in determining relative contributions from different pathways (e.g., wind, illegal dumping, illegal encampments, MS4s);
- Leverages and exhibits consistency with existing monitoring efforts and other water quality monitoring programs, including direct discharge offset provisions (MRP Provision C.10.e); and
- Cost-effective, efficient and feasible (e.g., safe, access to sample locations, can be implemented by volunteer monitoring groups).

2.1.3 Trash Scientific Monitoring Questions

Project goals were used to guide the development of scientific monitoring questions that informed the study design and selection of methodologies used during the pilot-testing phase of the Trash Monitoring Plan. These scientific monitoring questions were developed to begin answering the broader

Management Questions listed in Table 2-1.

Table 2-1. Scientific monitoring questions developed to guide the design of the trash monitoring program and the methods used to monitor trash in receiving waters.

Management Question	Scientific Monitoring Question
1. Is trash present in receiving water(s) at levels that may cause adverse water quality impacts?	• What is the current level of trash deposited in flowing waterbodies in each MRP county; the entire MRP area? • Are significantly strong correlations observed between qualitative and quantitative methods? • What is the range of trash levels observed at sites targeted for cleanup? How do these ranges compare to levels in all flowing waterbodies?
2. Have a Permittee's trash control actions effectively prevented trash within a Permittee's jurisdiction from discharging into receiving water(s) (*over time*)?	• What is the current level of trash deposited in flowing waterbodies in each MRP county; the entire MRP area? • Are significantly strong correlations observed between qualitative and quantitative methods? • Do trash levels in flowing waterbodies strongly correlate to trash generation levels depicted on Permittee maps?
3. Are trash discharges from a Permittee's jurisdiction causing or contributing to adverse trash impacts in receiving water(s)?	• What is the current level of trash deposited in flowing waterbodies in each MRP county; the entire MRP area? • Are significantly strong correlations observed between qualitative and quantitative methods? • What is the range of trash levels observed at sites targeted for cleanup? How do these ranges compare to levels in all flowing waterbodies?
4. Are there sources outside of a Permittee's jurisdiction that are causing or contributing to adverse trash impacts in receiving water(s)?	• What percentages of trash observed in receiving waters are attributable to wind/litter, illegal dumping, illegal encampments and other (stormwater/upstream sources)?
5. Is trash (if present) being transported from one receiving water to another, at levels that may cause adverse water quality impacts?	• Do trash levels in flowing waterbodies differ significantly between wet and dry seasons?

2.2 Coordination with State Monitoring Project

In 2015, the State Water Resources Control Board (State Water Board) adopted an Amendment to the Water Quality Control Plan for the Ocean Waters of California (Ocean Plan) to Control Trash and Part 1 Trash Provision of the Water Quality Control Plan for Inland Surface Waters, Enclosed Bays, and Estuaries. Together these are referred to as the Trash Amendments. The Trash Amendments prohibit discharge of trash larger than 5 millimeters to state waters from stormwater systems.

The California Ocean Protection Council (OPC) sent a letter to the State Water Board supporting adoption of the Trash Amendments in 2015. The letter expressed the OPC's interest in the use of

scientific measures to track and verify program effectiveness. The OPC recognized that there is no agreed-upon scientific method to monitor for trash in receiving waters and that the lack of methods makes assessing progress on reducing trash in state waters difficult. In close partnership with the State Water Board, the OPC employed the Southern California Coastal Water Research Project (SCCWRP) and San Francisco Estuary Institute (SFEI) to begin evaluating and testing multiple trash monitoring methods with a goal of developing a library of methods with known levels of precision, accuracy, and cross-comparability of results. The methods tested would also be linked to specific management questions. The Trash Monitoring Methods Project sponsored by OPC is intended to provide the research needed to develop scientific measures to monitor macro (>5mm) trash in receiving waters.

The OPC/State Water Board Trash Monitoring Methods Project began subsequent to the finalization of the BASMAA Trash Monitoring Plan. As such, the methods developed via the BASMAA Trash Monitoring Plan were incorporated with other methods being used in Southern California and novel (e.g., aerial photography and machine-learning) methods developed as part of the OPC/State Water Board project. These three methods are currently being tested in coordination with MRP 2.0 permittee efforts described in this report. Additionally, MRP 2.0 Permittee staff participates on the OPC/State Water Board's Technical Advisory Committee (TAC) to provide further coordination on the testing of trash receiving water monitoring methods. This coordination is planned to continue throughout the term of both projects.

3 Data Collection and Analysis Methods

3.1 Study Area

The pilot-testing phase of the Trash Monitoring Plan focuses on initial evaluations of the extent, magnitude and pathways of trash present/deposited on the surface and banks of local creeks, channels, rivers and lakes/lagoons, and the shorelines of San Francisco Bay and the Pacific Ocean. The study area for the Trash Monitoring Program consists of receiving water bodies that are within the MRP Area, which includes portions of the five participating counties (San Mateo, Santa Clara, Alameda, Contra Costa, Solano) that are subject to MRP 2.0 requirements.

3.2 Monitoring Design

The Trash Monitoring Plan primarily focuses on two types of monitoring designs:

1) Probabilistic Assessment Sites – Randomly selected monitoring sites that were previously established for BASMAA's Regional Monitoring Coalition (RMC) Creek Status Monitoring Program. These sites are intended to represent the trash conditions in all creek, channel and riverine sites that flow through the urban Bay Area.

2) Targeted Monitoring Sites – Selected sites in urban creeks, channel and river segments and sites along San Francisco Bay shorelines where trash regularly deposits and is periodically removed by MRP Permittees. Includes a small number of targeted locations where trash booms are deployed to intercept trash prior to transport downstream to the San Francisco Bay.

Together, probabilistic and targeted sites are intended to represent the full range of trash conditions present in all water bodies flowing through the urban Bay Area that are subject to MRP 2.0 trash reduction requirements, and San Francisco Bay shorelines that may be impacted by contributions of trash from these flowing waters (e.g., creeks, channels and rivers). Brief descriptions of both types of

monitoring design and the associated sites are provided below, followed by descriptions of the types of monitoring methods deployed at each type of site.

3.2.1 Probabilistic Assessment Sites

Probabilistic trash assessment sites were chosen from the sample frame (i.e., stream network) developed by the RMC in 2012 for the Bay Area Regional Creek Status and Trends Monitoring Program (BASMAA 2012). The RMC sample frame includes all perennial and non-perennial creeks, channels and rivers that run through urban and non-urban areas within the five counties subject to MRP requirements. The sample frame was established using the United State Geological Survey (USGS) National Hydrography Dataset, which covers 3,567 miles of stream length in the five counties.

As part of the RMC's Regional Creek Monitoring Program, a pool of urban and non-urban probabilistic monitoring sites were previously established along the RMC sample frame at an average density of one site per 0.62 mile of stream length (i.e., total of 5,740 sites). Urban and non-urban probabilistic sites were previously selected (randomly) from this pool and monitored for physical, chemical and biological integrity as part of the Regional Creek Monitoring Program (2012-2019). The urban[1] sites previously monitored by the RMC formed the pool of sites for which probabilistic trash assessment sites were selected.[2] Additional details of the RMC sample frame and site selection process are summarized in the *BASMAA Regional Monitoring Coalition Five-Year Bioassessment Report Water Years 2012-2016* (BASMAA 2019).

A total of 125 probabilistic trash assessment sites[3] (approximately 7% of the urban sites in the RMC sample frame) representing urban creek, channel and river segments were initially selected for pilot-testing the Trash Monitoring Plan (Figure 3-1). Consistent with the Trash Monitoring Plan, Alameda, Contra Costa, San Mateo and Santa Clara Counties each selected 30 probabilistic assessment sites, and 5 sites were selected in Solano County. Trash assessments at these probabilistic sites focused on qualitatively observing and documenting trash levels and estimating the contributions of trash from different pathways. Because the vast majority of the trash assessment sites included in the Monitoring Program Plan were previously monitored by Permittees via RMC's Creeks Monitoring Program, these sites generally represent accessible locations where trash assessments could feasibly occur and permission to sample could be obtained. Probabilistic trash assessment sites were selected and evaluated in the order they appeared in the site pool to determine if each site met requirements outlined in the Trash Monitoring Plan and was physically accessible (including during higher flow conditions in the wet season). Evaluations of potential trash assessment sites were conducted following the methods presented in *Standard Operating Procedures for Ambient Creek Status Monitoring Site Evaluation* (BASMAA 2016).

3.2.2 Targeted Monitoring Sites

In addition to the 125 probabilistic sites, 100 targeted trash receiving water monitoring sites were selected and monitored (Figure 3-1). These targeted sites were generally known by MRP Permittees to accumulate trash. The vast majority of the sites were previously designated as "trash hot spots" and

[1] Probabilistic sites classified as urban are located within the boundaries of a city or a populated place.

[2] Non-wadeable and tidally influenced probabilistic sites that were originally removed from the site pool during creek status monitoring due to limitations in implementing standardized monitoring protocols at these sites, were added back into the pool of trash assessment sites due to interest in trash levels at these sites.

[3] During dry season sampling event in 2019, four of the sites were replaced due to issues related to physical access. As a result, a total of 129 probabilistic sites were assessed during the pilot testing phase of the project.

undergo periodic trash removal. These sites include segments of urban creeks, channels and rivers, and shoreline sites along the San Francisco Bay. To the extent possible, targeted trash monitoring sites were selected to represent a wide range of known trash levels in water bodies within a majority of MRP Permittee jurisdictions within each of the five MRP counties. The goal was to establish a pool of sites with a wide range of trash conditions as a basis to evaluate the relationship between qualitative and quantitative trash assessment tools. Consistent with the Trash Monitoring Plan, the following numbers of targeted sites were selected and monitored by Permittees in the following MRP counties: Alameda (29), Contra Costa (19), San Mateo (15), Santa Clara (32) and Solano (5).

It is important to note that each county used different criteria to select their targeted monitoring sites. Some counties selected targeted sites that contained illegal encampments with large quantities of trash. Other counties purposefully avoided selecting sites with illegal encampments for practical concerns and safety issues. Due to the discrepancy in the type of targeted sites and associated levels of trash, the quantitative assessment data collected at targeted sites were not compared between counties.

Targeted monitoring was conducted at nine trash boom locations in Alameda, Santa Clara and San Mateo Counties. Location description, agency/organization conducting maintenance, upstream drainage area and period of operation is presented in Table 3-1 and shown in Figure 3-2. Trash boom locations within the three counties include: (1) three booms along the shoreline of Lake Merritt in the City of Oakland, Alameda County; (2) two booms in the Lower Silver - Thompson Creek (tributary to Coyote Creek) and two booms at the bottom of the Adobe and Matadero Creek watersheds (both in Santa Clara County); and (3) two booms in the 16th Street and 19th Street Channels, located in San Mateo County.

Although trash boom monitoring was not identified as a required component of the Trash Monitoring Plan, MRP 2.0 Permittees agreed to conduct monitoring at these sites to better understand the utility of data from these locations and answer management questions outlined in MRP 2.0.

Table 3-1. Location description, drainage area, agency/organization conducting maintenance and period of operation for trash booms located in Alameda, Santa Clara and San Mateo Counties.

County	Jurisdiction	Maintenance	Location	Latitude	Longitude	Drainage Area (acres)	Period of Operation
Alameda	Oakland	Lake Merritt Institute	22nd and Harrison St (Outfall 56)	37.8102	-122.2623	35[1]	All Year
			Glen Echo Arm	37.8106	-122.2616	1609	
			Trestle Glen Arm	37.8081	-122.2500	1952	
Santa Clara	San José	Valley Water	Lower Silver Creek at King Rd	37.3604	-121.8642	12,056[2]	All Year
			Thompson Creek above Tully Rd	37.3292	-121.8106	14,205	
	Palo Alto	Palo Alto	Adobe Creek below Hwy 101	37.4324	-122.1050	8979	April - December
			Matadero Creek above Hwy 101	37.4397	-122.1142	7997	
San Mateo	City of San Mateo	City of San Mateo	16th Avenue Channel	37.5678	-122.2940	1218.3	All Year
			19th Avenue Channel	37.5526	-122.2901	1987	

[1] Total catchment area for storm drain is 138.4 acres; however full capture device at 22nd and Valley captures majority of trash; untreated drainage area upstream of the boom is 35 acres.

[2] Drainage area does not include area upstream Thompson Creek boom (assuming both booms are deployed at the same time). The total drainage area for Lower Silver Creek without Thompson Creek boom is 26,261 acres.

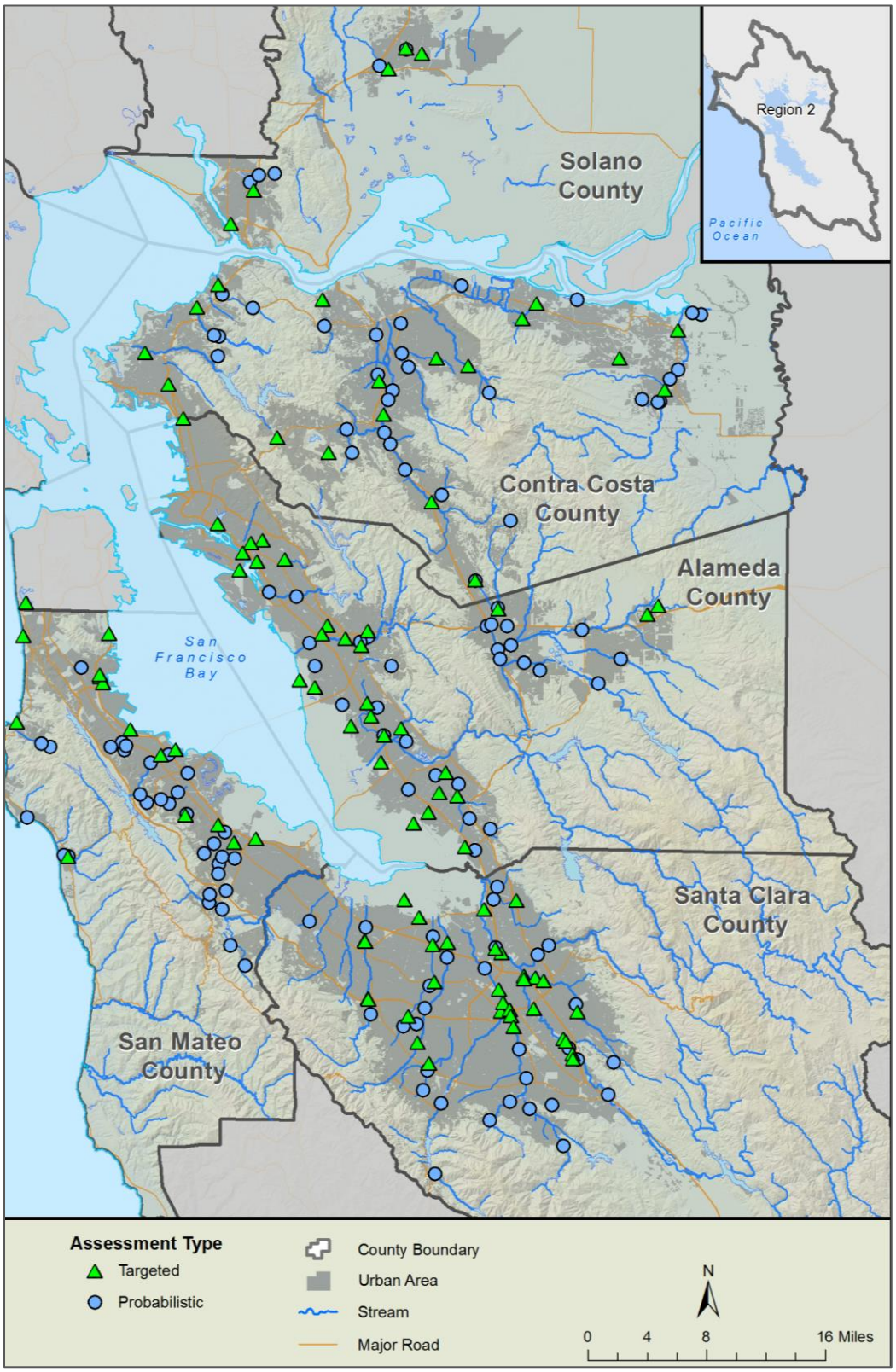

Figure 3-1. Locations of probabilistic and targeted receiving water trash monitoring and assessment sites included in the pilot-testing of the BASMAA Trash Monitoring Plan.

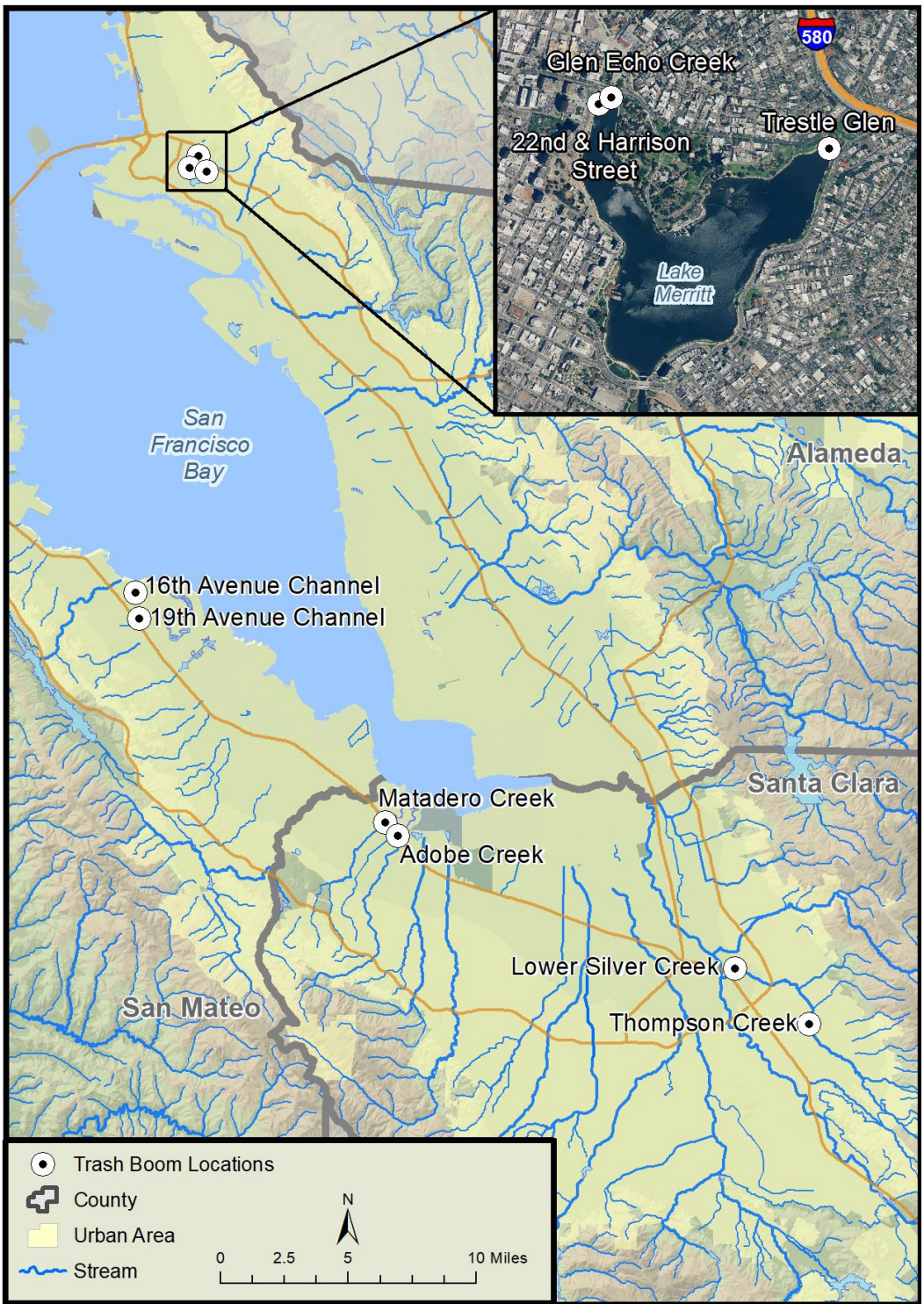

Figure 3-2. Locations of trash boom monitoring in the pilot-testing of the BASMAA Trash Monitoring Plan.

3.3 Monitoring Protocols and Data Collection

Standard Operating Procedures (SOPs) and associated field forms (Version 1.0) for conducting qualitative visual trash assessments and quantitative trash monitoring were developed as part of the Trash Monitoring Plan (BASMAA 2017). The SOPs and field forms were refined (Version 2.0) in July 2018 following recommendations by field staff after pre-monitoring calibration events, the initial assessment event at probabilistic sites, and the trainings conducted for field staff. Revisions of the SOPs primarily consisted of supplementing or modifying specific data fields that are associated with site characteristics. Summaries of qualitative and quantitative assessment methods are provided in Sections 3.3.1 and 3.3.2. Full descriptions of these methods are included in the Trash Monitoring Plan (BASMAA 2017).

3.3.1 Qualitative Visual Assessments

Qualitative trash assessments are visual surveys of trash levels (i.e., conditions) within a defined assessment area of a receiving water body. Trained personnel assign a **trash condition score** from 1 to 12 (12 being the most trash) to a site based on the level of trash that is observed both within the water body and along its banks or shoreline within a defined assessment area. Field personnel assign trash condition scores based on their first impression of the amount of trash that is visually observed within the entire assessment area.

Trash condition scores (1 to 12) are organized into four **trash condition categories** that include narrative descriptions of trash levels associated with the condition scores (Table 3-2). The four trash condition categories and associated condition scores are: Low (1-3), Moderate (4-6), High (7-9) and Very High (10-12). As part of the pilot testing phase of the Trash Monitoring Plan, trash condition scores were compared to trash volume data collected during the quantitative assessment (see Section 3.3.2) at targeted sites to validate the less intensive qualitative assessment method.

Qualitative visual assessments include documentation of site characteristics within the assessment area that may affect the transport and accumulation of trash. Site characteristic information includes predominant channel type (e.g., armored, levee, natural) and the proportion (%) of bank cover (e.g., grasses, shrubs, trees) and creek/channel cover (e.g., woody debris, aquatic vegetation, open/wet, dry) within the assessment area.

In addition to trash condition scoring, field crews estimated the relative contribution of trash associated with four different trash pathways: 1) Litter/Wind; 2) Illegal Encampments; 3) Illegal Dumping and 4) Other (Stormwater/Upstream Sources). The definition and characteristics for each of these four pathways are presented in Table 3-3.

During the testing of the Trash Assessment SOP, field crews determined that trash directly associated with stormwater and MS4s could not be accurately determined in the field. As a result, the “Other” category was created to include any trash that is transported by water to the assessment area from any upstream sources, including stormwater conveyances. Trash items identified as “Other” were typically small, transportable trash observed in the channel that appeared worn due to exposure from water (Table 3-3).

Because stormwater related trash is a component of the “Other” trash pathway, the amount or percentage of trash from stormwater could not be determined. However, the differences between the “Other” pathway and the remaining three trash pathways was investigated to provide information for identifying high priority pathways to inform management programs.

During qualitative assessments, the contribution of trash from each pathway was visually estimated and assigned a percentage between 0 and 100% (increments of 5%) of the total trash observed in the trash assessment area.

Table 3-2. Narrative descriptions of trash condition categories and scoring ranges for qualitative visual assessments in receiving waters.

Condition Category			
Low	**Moderate**	**High**	**Very High**
• Effectively no or very little trash • On first glance, little or no trash is visible • Little or no trash is evident when streambed and stream banks are closely examined for litter and debris • One individual could easily remove all trash observed within 30 minutes	• Predominantly free of trash except for a few littered areas • On first glance, trash is evident in low levels • After close inspection, small levels of trash are evident in stream bank and/or streambed • On average, all trash could be cleaned up by two individuals within 30 minutes to one hour • Approximately 2-3 times more trash than the low condition category	• Predominantly littered except for a few clean areas • Trash is evident upon first glance in moderate levels along streambed and banks • Evidence of site being used by people: scattered cans, bottles, food wrappers, plastic bags, etc. • On average, would take a more organized effort (more than 2 people, but fewer than 5) to remove all trash from the area. Removal of trash would take 30 mins to 2 hours • Approximately 2-6 times more trash than the moderate condition category	• Trash is continuously seen throughout the assessment area • Trash distracts the eye on first glance • Substantial levels of litter and debris in streambed and banks • Evidence of site being used frequently by people (e.g., many cans, bottles, food wrappers, plastic bags, clothing, piles of garbage and debris) • On average, would take a large number of people (more than 5) during an organized effort to remove all trash from the area. Removal of all trash would take more than 2 hours. • Approximately 2 or more times trash than the high condition category
1 2 3	4 5 6	7 8 9	10 11 12

Table 3-3. Characteristics of trash associated with each of the four transport pathways.

Pathway	Characteristics	Potential Location in Assessment Area
Litter/Wind	• Light weight • Distributed evenly, recent/not worn	• Adjacent to or under freeways and road crossings • Near roadways, bike or foot paths adjacent to the water body
Illegal Encampments	• Large items • Dense, multiple piles near current or abandoned camping site • No sign of water damage	• Adjacent to camps or trails • Banks, above and below high-water mark • Under bridges
Illegal Dumping	• Large items • Recent • Large piles, adjacent to roads	• Directly upstream or downstream of bridges • Near roadways
Other (Stormwater/ Upstream Sources)	• Small, persistent, transportable • Old, worn, water damaged • Integrated with vegetation, debris • Well distributed and mixed with debris	• Wetted channel • Banks below high-water line • Directly below outfalls

3.3.2 Quantitative Monitoring

Quantitative trash monitoring entails removing, sorting and measuring the volume of trash that is found within the assessment area at a targeted site. The collected trash is sorted into the four pathway categories (Table 3-2) and the volume of trash attributable to each pathway is quantified by using buckets or trash bags of known size. The quantified volume of trash for each trash pathway is then combined to establish the total volume of trash collected at each monitoring event. Materials that are too large to be placed in buckets or bags are stacked together (by pathway) and the volume of these materials is visually estimated using units of cubic feet or cubic yards. In addition, field crews identify the five most frequently observed types of trash (e.g., single use plastic grocery bags, beverage bottles) that are collected.

Both quantitative trash monitoring methods summarized above and the qualitative assessment methods described in the previous section were used at targeted sites to allow for the comparison of qualitative and quantitative approaches. At targeted sites, qualitative monitoring was conducted directly prior to (i.e., within 1-3 days) each corresponding quantitative monitoring event.

The removal of trash at a site via cleanup events that occur directly before or within a few weeks of assessment/monitoring events can potentially result in lower levels of trash observed at a site, in comparison with sites where recent cleanup events did not occur. Organized or informal cleanup activities that occurred prior to a trash assessment/monitoring event were documented at a small number of the targeted monitoring locations. However, most field crews did not document the last known trash cleanup event on data collection forms and therefore the data were not normalized to elapsed time between cleanup events.

Trash boom monitoring consisted of the removal and estimation of the total volume of trash that accumulated behind the booms during a known period of time. At some booms, trash was sorted and characterized; however, this information is not presented in this report.

3.3.3 Delineation of Assessment Areas

Trash assessments and monitoring was conducted within a defined assessment area within both probabilistic and targeted sites. A standard assessment length of 300-feet was used for sites located in creeks, channels and rivers. This is consistent with the length generally used by the RMC Creek Status and Trends Monitoring Program and for creek/channel trash hot spot cleanups required by MRP 2.0. For sites on creeks, channels and rivers, the width of the assessment area was specific to each site and extended to the upper portions of the banks where a majority of normal discharges and channel-forming activities take place. This creek/channel width is typically referred to as the “bankfull width” of the receiving water. The width of each trash assessment area on a creek or channel included the distance, as measured by the contour of the bank slope, between three equidistant bankfull locations at the middle and each end of each reach.

Trash assessments conducted at targeted sites along bay/ocean shorelines were typically 600 feet in length, which is consistent with the minimum length for trash hot spots, as described in MRP Provision C.10.c.i. For shoreline monitoring locations, the assessment area width was delineated as appropriate, based on a change in substrate material, presence of upland vegetation or the onset of development.

3.3.4 Field Staff Training and Calibration

Trash assessments were conducted by several entities representing MRP 2.0 Permittees (Table 3-4). For this reason, several field calibration events were conducted for field staff representing Permittees in Alameda, Contra Costa, Santa Clara, San Mateo and Solano Permittees to help standardize field data

collection methods. For Santa Clara and San Mateo, additional field training events were conducted to train permittee staff conducting both qualitative and quantitative trash assessments at targeted sites.

Table 3-4. Entities that conducted qualitative and/or quantitative trash assessment/monitoring at probabilistic and targeted receiving water monitoring sites in each county within the MRP Area.

County	Qualitative Assessments at Probabilistic Sites	Qualitative Assessments and Quantitative Monitoring at Targeted Sites
Alameda	Applied Marine Sciences (AMS)	SJ Conservation Corps & Charter School with AMS Supervision
Contra Costa	ADH Environmental	ADH Environmental
Santa Clara	EOA, Inc.	Municipal staff with EOA, Inc. supervision
San Mateo	EOA, Inc.	Municipal staff with EOA, Inc. supervision
Solano	Solano County Resource Conservation District	Solano County Resource Conservation District

3.4 Assessment/Monitoring Frequencies

Regionally, a total of 125 urban creek, channel and riverine probabilistic sites were initially selected and qualitatively assessed for trash. Qualitative visual trash assessments were conducted at a total of 30 probabilistic sites in Alameda, Contra Costa, Santa Clara and San Mateo Counties, and 5 sites in Solano County (Table 3-5). A total of five assessment events were planned at the probabilistic sites during the pilot testing phase of the Trash Monitoring Plan (October 2017 - March 2020). A total of 625 qualitative trash assessments were conducted over the five sampling events (three during wet season and two during dry season). During the 2019 dry season sampling event, four of the sites were replaced due to issues related to physical access. Thus there were 129 probabilistic sites that were assessed over the entire pilot study.

As described in the Trash Monitoring Plan, assessments are planned during three wet season events and two dry season events. Data collected during both seasons is intended to allow comparisons between dry and wet season trash conditions and accumulation rates in receiving waters. Dry season assessments are intended to provide information about non-stormwater sources and pathways, such as wind and illegal dumping. Wet season assessments provide information on the transport and deposition of trash resulting from stormwater runoff and transport from upstream locations.

In addition to the probabilistic sites, a total of 100 targeted sites were selected for qualitative and quantitative trash assessments. The total number of sites was determined based on population for each county: Santa Clara (32), Alameda (29), Contra Costa (19), San Mateo (15) and Solano (5). Targeted sites included 91 sites in urban creeks, channels, rivers and 9 sites along the shorelines of San Francisco Bay. Two quantitative monitoring events were planned at each targeted site during the pilot testing phase of the Trash Monitoring Plan; one during the dry season 2018 and one during dry season 2019. Trash monitoring at targeted sites coincided with Permittee's clean up events at known trash problem areas, which typically occur during the dry season each year. A total of 200 quantitative and qualitative assessments were conducted at 100 targeted sites.

Trash collected from trash booms was removed, bagged and measured (volume) during multiple monitoring events conducted at 9 locations (Table 3-5). The total number of monitoring events and the

period of trash accumulation at each boom were dependent on existing maintenance practices and thus varied among booms. Monitoring data were collected from each municipality/agency and compiled. The number of trash monitoring events ranged from 2 to 8 per boom, and the length of trash accumulation ranged from 6 to 230 days (refer to Table 4-10 for exact dates).

Table 3-5. Total number of sampling sites and events planned during pilot testing phase of Trash Monitoring Plan.

County	Probabilistic Sites (Qualitative Trash Assessments)			Targeted Sites (Qualitative and Quantitative Assessments)			Trash Boom		
	# Sites	Frequency	# Events	# Sites	Frequency	# Events	# Sites	Frequency	# Events
Alameda	30	5x	150	29	2x	58	3	2-4	8
Contra Costa	30	5x	150	19	2x	38	--		
San Mateo	30	5x	150	15	2x	30	2	3-8	11
Santa Clara	30	5x	150	32	2x	64	4	2-3	11
Solano (Vallejo, Suisun City and Fairfield)	5	5x	25	5	2x	10	--		
Total	**125**	**--**	**625**	**100**	**--**	**200**	**9**		**30**

3.5 Data Analysis Methods

All statistical, tabular, and graphical analyses were conducted using RStudio, running R version 3.5.0 (R Core Team 2018). The qualitative trash condition scores (1 to 12) defined in the Trash Monitoring Plan were used to evaluate all trash data collected at probabilistic and targeted sites. Four condition categories were used to distinguish these thresholds: "Low" (trash scores 1-3); "Moderate" (trash scores 4-6); "High" (trash scores 7-9); and "Very High" (trash scores 10-12).

To provide a standardized quantitative estimate of trash levels at targeted sites, trash volumes were converted to density (in units of gallons per square foot of assessment area) for all analyses, by dividing trash volumes (as a total and by pathway) by the site assessment area.

For all analyses of targeted data, multiple sampling events were kept separate when evaluating associations between qualitative and quantitative methods.

3.5.1 Estimating the Extent of Trash Levels in all Urban Streams

Cumulative distribution functions (CDFs) of qualitative trash condition scores were generated for probabilistic sites to estimate overall extent of trash levels within the urban portion of the sampling frame. The estimates were weighted based on total stream length of urban sites, divided by the total stream length in the urban area of the sample frame. Non-urban sites that were part of the original RMC creek status monitoring site selection process were excluded from the analyses of trash levels. Therefore, each urban trash monitoring site contributes an equal proportional amount of stream length to the extent estimates. The adjusted sample weights were used to estimate the proportion of stream length represented by trash condition scores regionwide. Condition estimates and 95% confidence intervals were calculated for all probabilistic results averaged across the five qualitative events, as well as for the trash condition scores generated from each seasonal sampling event individually. All calculations were conducted using the R-package *spsurvey* (Kincaid and Olsen 2016).

3.5.2 Boxplots and Descriptive Statistics

Boxplots and scatterplots were used to summarize the distributional characteristics of the data. In each boxplot, the horizontal line represents the median value, the bounds of the lower and upper box represent the interquartile range (IQR; representing the middle 50% of the data), and the lower and upper whiskers represent the 25th (Q1) and 75th (Q3) percentiles of the data plus 1.5 times the interquartile range (i.e. Q1 – 1.5*IQR or Q3 + 1.5*IQR), respectively. 'Outlier' values outside the whiskers are shown by points. Each set of seasonal assessment results was included (assessments performed at the same sites were not averaged).

Scatterplots are used to evaluate relationships between qualitative (trash condition scores) and quantitative (trash density) results. Linear regression lines were added for perspective only. Similarly, individual assessment results were included as is, and were not averaged.

3.5.3 Statistical Tests

Spearman rank correlation statistics (rho) were used to evaluate relationships between trash condition scores or densities and site characteristics (e.g., channel type, channel width, bank cover, channel cover), and pathways of trash. Each of the multiple trash condition scores collected at each site was used in analyses. For all analyses involving trash densities, only data for targeted sites were used. A p-value of < 0.05 was used to determine significance for all correlation analyses.

To test for statistical significance in trash densities among qualitative trash scores a Kruskal-Wallis rank sum test (a non-parametric analysis-of-variance) was performed, followed by pairwise comparison with adjustment for multiple comparisons. Non-parametric statistical testing was selected due to the non-normal distribution of trash densities that could not be corrected by transformation.

3.6 Data Quality

Field efforts associated with the Trash Monitoring Plan were covered under four Data Quality Objectives (DQOs) and Measurement Quality Objectives (MQOs) established within the Quality Assurance Project Plan (QAPP) to ensure that sound collection of data concerning trash loading was able to occur. Two qualitative DQO/MQOs of representativeness and comparability were put forth for the project, while two quantitative DQO/MQOs of completeness and precision were also established.

The quantification of trash loading is an inherently variable data type with respect to spatial and temporal characteristics, and the significant use of human judgment in associated trash data collection can increase the potential for bias. Given this, it was of importance to ensure effective training and consistent data collection principles so that the data quality goals encompassed within the four DQO/MQOs could be achieved.

A summary of data quality practices used for the project are provided in Appendix A.

4 Results and Discussion

The results and discussion presented in this section considers all data collected during the pilot phase of the Trash Monitoring Plan. The results are organized by the following sections and are intended to answer specific scientific monitoring questions outlined in the Trash Monitoring Plan:

4.1 Comparison of Qualitative Assessment and Quantitative Monitoring Results

- Are significantly strong correlations observed between qualitative and quantitative trash receiving water monitoring/assessment methods?

4.2 Levels of Trash in Urban Water Bodies in the MRP Area

- What is the current level of trash deposited in flowing waterbodies in each MRP county and the entire MRP urban area?
- Do trash levels in flowing waterbodies differ significantly between wet and dry seasons?
- Do other site and landscape variables correlate with trash levels in flowing waterbodies?
- What trash levels are observed at sites targeted for cleanup? How do these levels compare to levels in all flowing waterbodies?

4.3 Contributions of Trash from Different Pathways

- What percentages of trash observed in receiving waters are attributable to stormwater conveyance systems, direct dumping, wind, and encampments?

4.4 Levels of Trash Observed in Receiving Waters Compared to Trash Discharged by Stormwater Conveyances

- Do trash levels in flowing waterbodies strongly correlate to trash generation levels depicted on Permittee maps?

4.1 Comparison of Qualitative Assessment and Quantitative Monitoring Results

Both qualitative visual assessments and quantitative monitoring of trash volumes and densities were conducted at targeted sites (n=100) to evaluate the correlation between these two receiving water trash monitoring methods. Correlations between qualitative and quantitative results would serve as the basis for validating the qualitative assessment methodology and provide the foundation for its potential use as a surrogate method for quantitative trash monitoring in receiving waters. A strong association between these methodologies would provide a reliable estimate of the trash volumes via qualitative assessment results with a known level of variance, and provide the basis for using the less resource-intensive qualitative assessment tool for future trash receiving water monitoring efforts.

Significant correlations were observed between the qualitative trash condition scores (1-12) and trash density estimates (volumes per surface area) at both regional and countywide scales (Table 4-1). A comparison of trash condition scores and trash densities for the two assessment events conducted at targeted sites is presented in Figure 4-1. During both assessments, trash densities were significantly higher at sites with *High* or *Very High* trash condition scores (i.e. $\geq$ 7 condition score), compared to densities measured at sites with *Low* or *Moderate* scores (i.e. $\leq$ 6 condition score). When pooling both events, the Kruskal-Wallis non-parametric statistical test showed a significant difference in trash densities among the 12 trash condition scores. However, multiple-comparison tests revealed that trash densities were only significantly different with trash conditions scores that were separated by large differences in scores (e.g. 4 vs. 8 and 5 vs. 10; $p < 0.05$), compared to smaller differences in scores (e.g., 5 vs. 6 or 9 vs. 10; $p > 0.05$). These results suggest that reducing the scoring range (e.g., 1-8) may statistically increase the difference between the condition categories.

Table 4-1. Correlations between trash densities (volume per unit surface area) and qualitative trash condition scores (1-12) at targeted urban receiving water monitoring sites in the MRP area. Each of the targeted sites was assessed twice (dry season 2018 and dry season 2019).

Strata[1]	Targeted Sites[2]	Correlation Coefficient (rho)	p-value
Alameda	24	0.42	0.003
Contra Costa	19	0.70	< 0.001
San Mateo	12	0.75	< 0.001
Santa Clara	31	0.72	< 0.001
Solano	**5**	**NR**	**NR**
Regional	**91**	**0.60**	**< 0.001**

NR – Not reported due to the low number of samples

[1] Solano County (n=5 sites; n=10 sampling events) is included in the regional evaluation, but had low statistical power to evaluate correlations at the county scale.

[2] Shoreline sites (n = 9) were excluded due to their poor association between qualitative score and densities. Thus, for some counties, the number of sites shown in the table are lower than what was previously presented in Table 3-5.

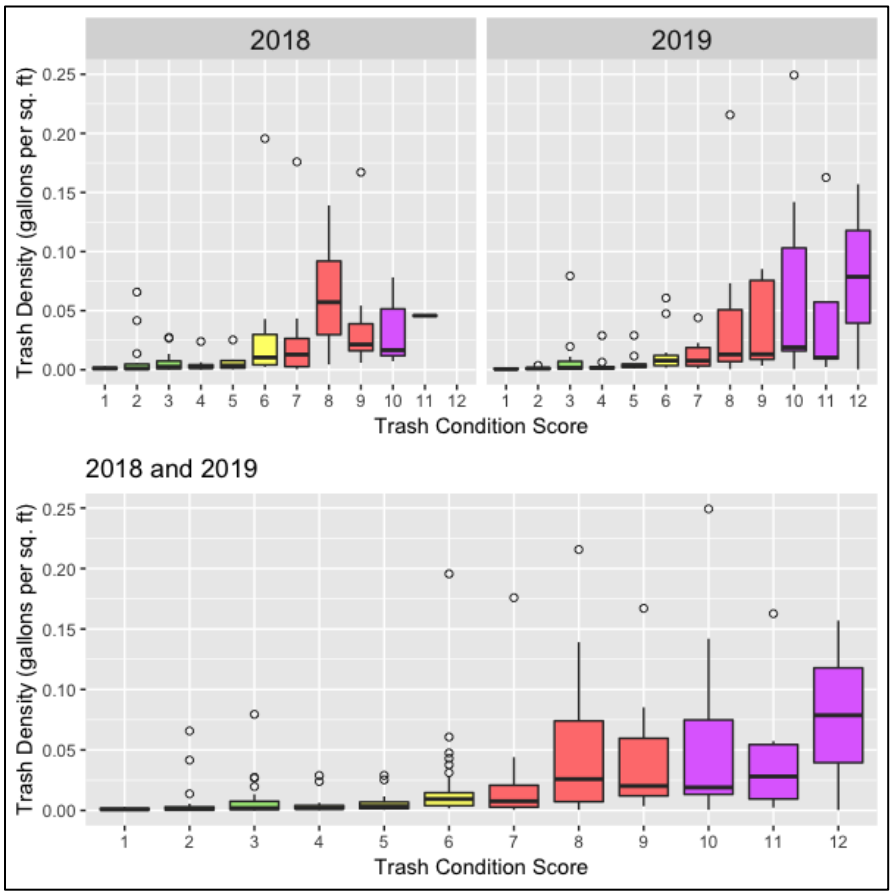

Figure 4-1. Comparison of trash densities (volume per unit surface area) and qualitative trash condition scores (1-12) at targeted receiving water monitoring sites (n=100) in the urban MRP area. Colors designate trash condition scores (Green = Low, Yellow = Moderate, Red = High, and Purple = Very High). Each of the targeted sites was assessed twice (dry season of 2018 and dry season 2019).

Organizing the trash condition scores presented in Figure 4-1 into the four broader trash condition categories shows a clear relationship with trash density (Figure 4-2), which visually confirms the positive correlations outlined in Table 4-1. Kruskal-Wallis non-parametric statistical testing showed that there was a significant difference in trash density among the four trash condition categories. A multiple-comparison test revealed that mean trash densities significantly differed between each of the condition categories, except for the *High* and *Very High* categories ($p = 0.30$). Trash densities between the Low and Moderate condition categories and the Moderate and High condition categories were significantly different ($p < 0.001$).

Based on the significant difference in trash densities between condition categories, descriptive statistics (mean density and quartiles) were calculated for the four condition categories during each of targeted assessments, as well as both targeted datasets pooled together (Table 4-2). During the 2018 assessment, mean trash density ranged from 0.0075 gal/ft^2 at sites corresponding to the *Low* condition category to 0.0439 gal/ft^2 for sites in the *High* condition category (i.e., approximately a factor of six). The mean density of the sites classed in the *Very High* condition category was slightly lower (0.0340 gal. per sq. ft)

than for the sites classed in *High* condition. This deviation is likely associated with the few number of sites (n=7) that represented the *Very High* condition and some sites having variable trash densities.

During the 2019 assessment, trash densities were lower than 2018, in each of the *Low* to *High* condition categories, ranging from 0.0058 to 0.0308 gal/ft^2. However, a significant number of targeted sites were classed in the *Very High* condition in 2019 (n = 18), which resulted in a notably higher mean density of 0.0619 gal/ft^2. Overall, combining the results from both assessments showed that the mean and median trash densities clearly increased with each successive trash condition category.

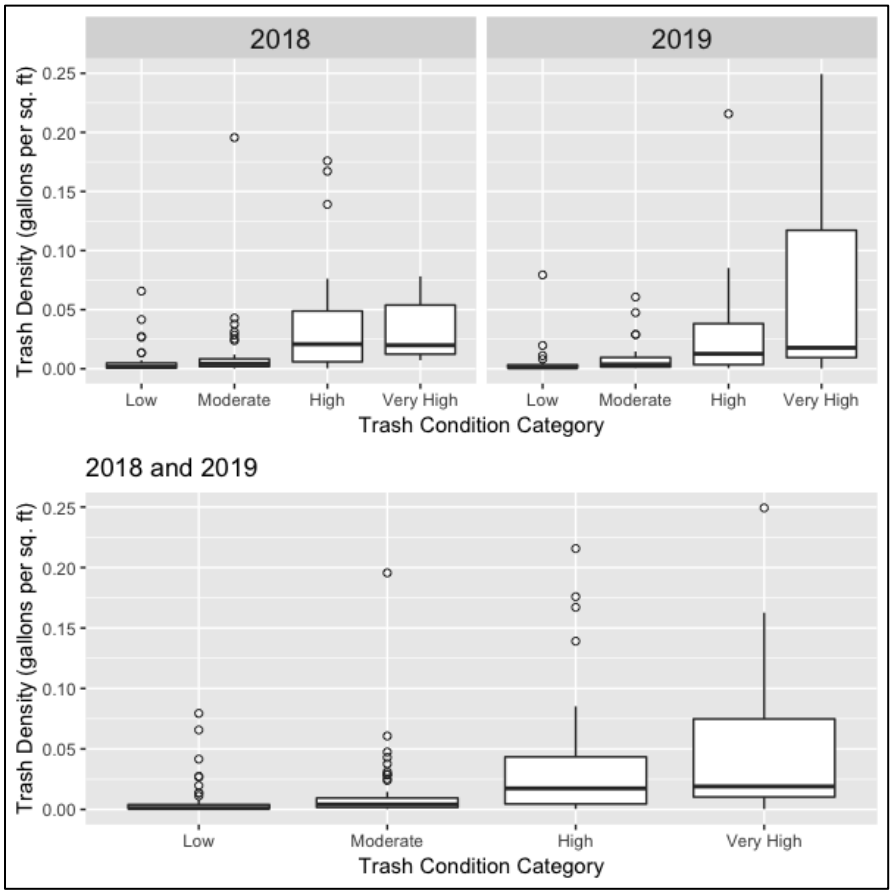

Figure 4-2. Comparison of trash densities (gallons per surface area unit) and qualitative trash condition categories at 100 targeted receiving water monitoring sites. Each of the targeted sites was assessed twice (dry season of 2018 and dry season 2019).

Table 4-2. Summary statistics for trash densities (gal/ft^2) and trash condition categories measured at 100 targeted sites in 2018, 2019, and combined.

Sampling Event	Condition Category	Number of Sites	Mean (gal. per sq. ft)	25th Percentile	50th Percentile	75th Percentile
2018	Low	31	**0.0075**	0.0006	0.0016	0.0048
	Moderate	43	**0.0124**	0.0018	0.0041	0.0083
	High	19	**0.0439**	0.0059	0.0208	0.0488
	Very High	7	**0.0340**	0.0123	0.0199	0.0539
2019	Low	26	**0.0058**	0.0007	0.0010	0.0033
	Moderate	24	**0.0089**	0.0015	0.0037	0.0095
	High	22	**0.0308**	0.0035	0.0126	0.0381
	Very High	18	**0.0619**	0.0095	0.0177	0.1171
2018 and 2019 Combined	Low	57	**0.0067**	0.0007	0.0011	0.0040
	Moderate	77	**0.0109**	0.0017	0.0041	0.0094
	High	41	**0.0368**	0.0045	0.0174	0.0434
	Very High	25	**0.0541**	0.0103	0.0190	0.0748

Outliers[4] shown (as open circles) in Figures 4-1 and 4-2 identify results where the trash density was higher than the 75th percentile + 1.5 times the interquartile range (an indicator of extreme values). There were outlier sites within each of the *Low, Moderate*, and *High* categories, suggesting that trash density can be highly variable among sites assigned a condition category. Closer examination of these outliers provides some insight into issues that may arise when applying both qualitative and quantitative assessment methods. These issues include:

- Trash was not visible in dense vegetation on the banks or under the water surface of the channel and was excluded from the qualitative assessment; however, this trash was removed and measured for the quantitative assessment.
- High volumes of trash occurred in a small proportion of the assessment area (e.g., under bridge), but the remaining area had low levels of trash; as a result, the overall site inappropriately received a low trash condition score during the qualitative assessment.
- High trash levels were observed at the site, but not all trash could be removed and measured due to access issues (e.g., deep water, muddy substrate) or safety issues related to illegal encampments. This example was often the case at shoreline sites, where trash was visible in mudflats which could not be safely accessed, removed and quantitatively measured.

These observations suggest that although correlations between qualitative and quantitative methods appear to be moderately strong, qualitative and quantitative results may not correlate well at every site due to the unique attributes of some sites.

[4] Data from outlier sites were included in the statistical analyses.

4.1.1 Effects of Channel Characteristics on Correlations between Qualitative and Quantitative Methods

Factors that may explain the relationship between qualitative trash condition scores or category and trash density were explored to inform the design of future receiving water trash monitoring. Figure 4-3 illustrates how channel type may affect this relationship. Although data are limited for certain types of sites (e.g., shorelines), trash condition scores correlate well with trash densities in different types of channels. Sites with concrete and natural channels had trash condition scores that spanned between 1 and 12, and exhibited similar relationships to trash density (i.e., slope of regression line ~ 0.008 gal/ft^2). Sites in earthen channels, however, had condition scores that ranged between 1 and 11 and exhibited a different relationship to trash density (i.e., slope of regression line ~0.002 gal/ft^2). Thus, for sites in natural and concrete channels, the trash density was higher for a given trash condition score, compared to earthen channels.

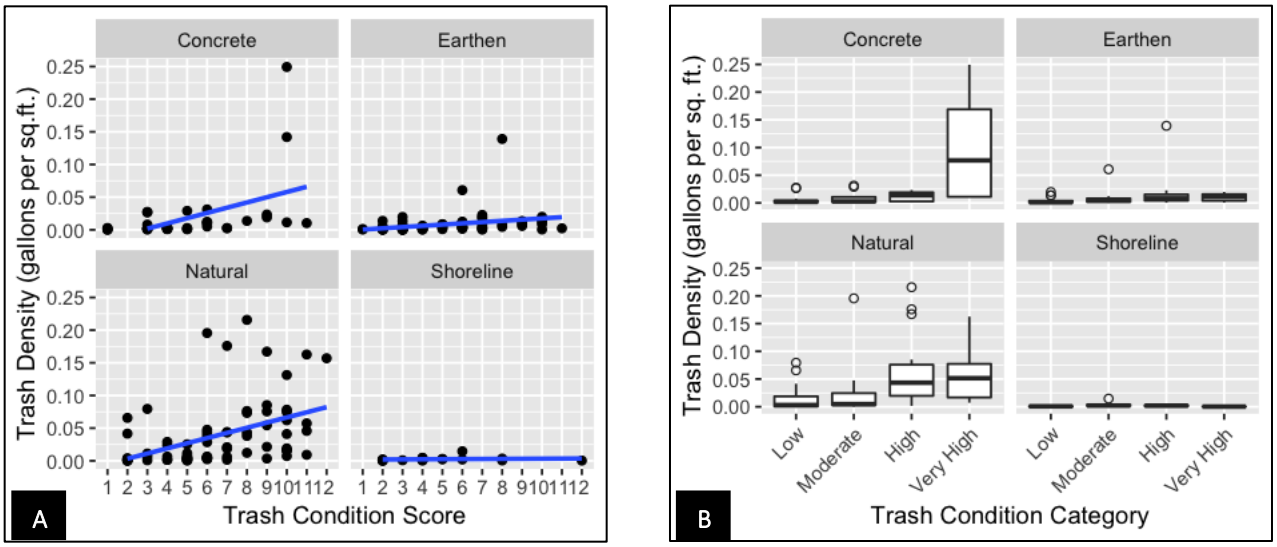

Figure 4-3. Comparison of trash densities and qualitative condition scores (A) and categories (B) observed at 100 targeted receiving water monitoring sites grouped by channel type. Each of the targeted sites was assessed twice (dry season 2018 and dry season 2019).

Although the dataset at shoreline sites is limited (n=18), trash condition scores did not tend to relate as well to trash densities as channels, presumably as a consequence of larger assessment areas where trash dispersion is less constrained that can occur farther away from the site than trash within stream channels. These observations suggest that not all channel types behave similarly in their mode of trash deposition. It should thus be considered in future monitoring that sites be selected or stratified according to different channel types, to ensure a full representation of receiving water conditions are assessed.

Overall, the comparison of qualitative assessments and quantitative monitoring indicates a strong association between the two methodologies. The results indicate potential regional differences in the relationships between the two methods, with Contra Costa, San Mateo, and Santa Clara Counties exhibiting higher correlations than Alameda County. Additionally, it appears that the relationship between qualitative and quantitative methods was weaker at the 1 to 12 scale, compared to categorical scale (i.e., *Low, Moderate, High, Very High*). There were less obvious delineations in trash levels between small incremental changes in condition scores, compared to the four categories. This pattern may suggest that refinements to the qualitative assessment SOP that reduces (or eliminates) the 1 to 12 scale may be

warranted. Alternatively, additional training and calibration of field crews to the current 1 to 12 scale may help improve the relationship to trash densities, along with additional training tools, such as video footage of trash deposition for each of the trash condition categories.

4.2 Levels of Trash in Urban Waterbodies in the MRP Area

4.2.1 Qualitative Visual Assessments at Probabilistic and Targeted Sites

Qualitative trash condition scores for the 129 probabilistic receiving water monitoring sites were used to conduct an evaluation of the extent and magnitude of trash in urban creeks and channels in the MRP area.[5] Table 4-3 illustrates the cumulative distribution results of trash condition scores (averaged over five events) for the regional probabilistic dataset. Condition scores at 40% of the urban probabilistic sites were in the *Low* condition category (i.e., condition score < 4) and 37% were in the *Moderate* category (condition score 4 to 6), indicating that approximately 77% (±13%) of the urban stream lengths in the MRP area exhibit low to moderate levels of trash. In contrast, 22% of the urban stream lengths in the MRP area had trash levels in the two highest condition categories, with only 2% in the *Very High* trash condition category. It is also notable that none of the sites assessed had an average trash condition score of 12.

The cumulative distribution results of the trash condition scores for each of the five monitoring events are shown in Appendix B - Table B1. The variability in trash condition scores for each probabilistic site is shown in Appendix B - Table B2 and for each targeted site in Appendix B – Table B3. Average trash condition scores at probabilistic and targeted stream sites in the region are illustrated in Figures 4-2 and 4-3. Trash condition scores for each site and event in each county are provided in Appendix C.

Table 4-3. Estimates of percent stream length (± 95% Confidence Interval) in the MRP urban area represented by average trash condition scores (1 to 12) and condition categories (Low, Moderate, High and Very High) based on observations at 129 sites within the 5 participating MRP counties.

Trash Condition Score	% of Stream Length (± 95% C.I.)	Trash Condition Category	% of Stream Length (± 95% C.I.)
1	5% (3%)	Low	40% (7%)
2	18% (6%)		
3	17% (6%)		
4	12% (6%)	Moderate	37% (6%)
5	16% (6%)		
6	9% (6%)		
7	12% (4%)	High	20% (2%)
8	6% (3%)		
9	2% (2%)		
10	1% (2%)	Very High	2% (0%)
11	2% (0%)		
12	0% (0%)		

[5] Condition scores from the 100 targeted sites were not used in this evaluation because of the uncertainty in the length of stream represented by these sites, beyond the length of the site. Targeted data were used, however, to compare to condition scores at probabilistic sites to evaluate whether the conditions observed at targeted sites (i.e., trash hot spots) were or were not represented in the probabilistic sample draw.

To estimate the total trash accumulation for urban streams in the MRP area, the trash density statistics from targeted sites was extrapolated to the extent of stream length represented by trash condition scores observed at probabilistic sites. In order to convert volumetric estimates to total accumulation, trash density (gal per sq. ft; Table 4-2) was first converted to linear distance by multiplying by the average assessment width of sites in each condition category. The trash accumulation (gal per ft) was then scaled to the entire MRP area (1,997 urban stream kilometers) by multiplying by the proportion of urban stream length represented by each condition category (Table 4-3). Table 4-4 presents the estimates of total trash accumulation for each condition category. The total accumulation of trash for all urban streams in the MRP area is estimated to be over 4 million gallons, based on trash density estimates from 2018 and 2019 combined. The majority of the trash accumulation is estimated to be derived from channels in the *High* condition category.

Table 4-4. Estimates of total trash accumulation represented by trash condition categories (Low, Moderate, High and Very High) based on observations at 129 probabilistic sites and 100 targeted sites within the 5 participating MRP counties.

Trash Condition Category	Length of Streams in the MRP Urban Area within each Category		Trash Accumulation Level in Streams within each Condition Category	
	km	%	gallons	%
Low	798.8	40%	568,382	14%
Moderate	738.9	37%	879,640	22%
High	399.4	20%	2,242,783	55%
Very High	39.9	2%	373,099	9%

The trash assessment scores from the targeted sites were compared to the results from probabilistic sites to determine if the range of conditions were similar between the two sample designs. The percentage of sites within each condition category was used to compare results. As presented in Table 4-5, 23% fewer targeted sites were in *Low* trash condition category, compared to the probabilistic sites, and more targeted sites were in the *Very High* condition categories than at probabilistic sites. A similar percentage of sites were observed in the *Moderate* and *High* condition categories between the two sampling designs. Targeted sites were selected by MRP Permittees as "trash hot-spots", thus higher trash scores would generally be expected at targeted sites compared to probabilistic sites. However, some of the targeted sites may have lower than expected trash conditions for several reasons, including recent cleanup activities (prior to assessment), exclusion of sites with illegal encampments, and overall low trash levels within some jurisdictional areas.

Table 4-5. Percentage of probabilistic and targeted sites in each trash condition category.

Trash Condition Category	Probabilistic Sites		Targeted Sites	
	% of Sites	# of Sites[1]	% of Sites	# of Sites
Low	40%	52	17%	17
Moderate	37%	48	47%	47
High	20%	26	26%	26
Very High	2%	3	10%	10
Totals		**129**		**100**

[1] Although 125 probabilistic sites were assessed during each event, 4 sites assessed during the first event were replaced with new sites before the subsequent monitoring events due to access issues.

Project results suggest that trash hot spot locations identified by MRP Permittees have higher levels of trash compared to the range of trash conditions observed at probabilistic sites. Additionally, these results may suggest that the probabilistic sites assessed via the Trash Monitoring Plan may not fully represent stream lengths with higher trash accumulation (i.e., trash hot spots).

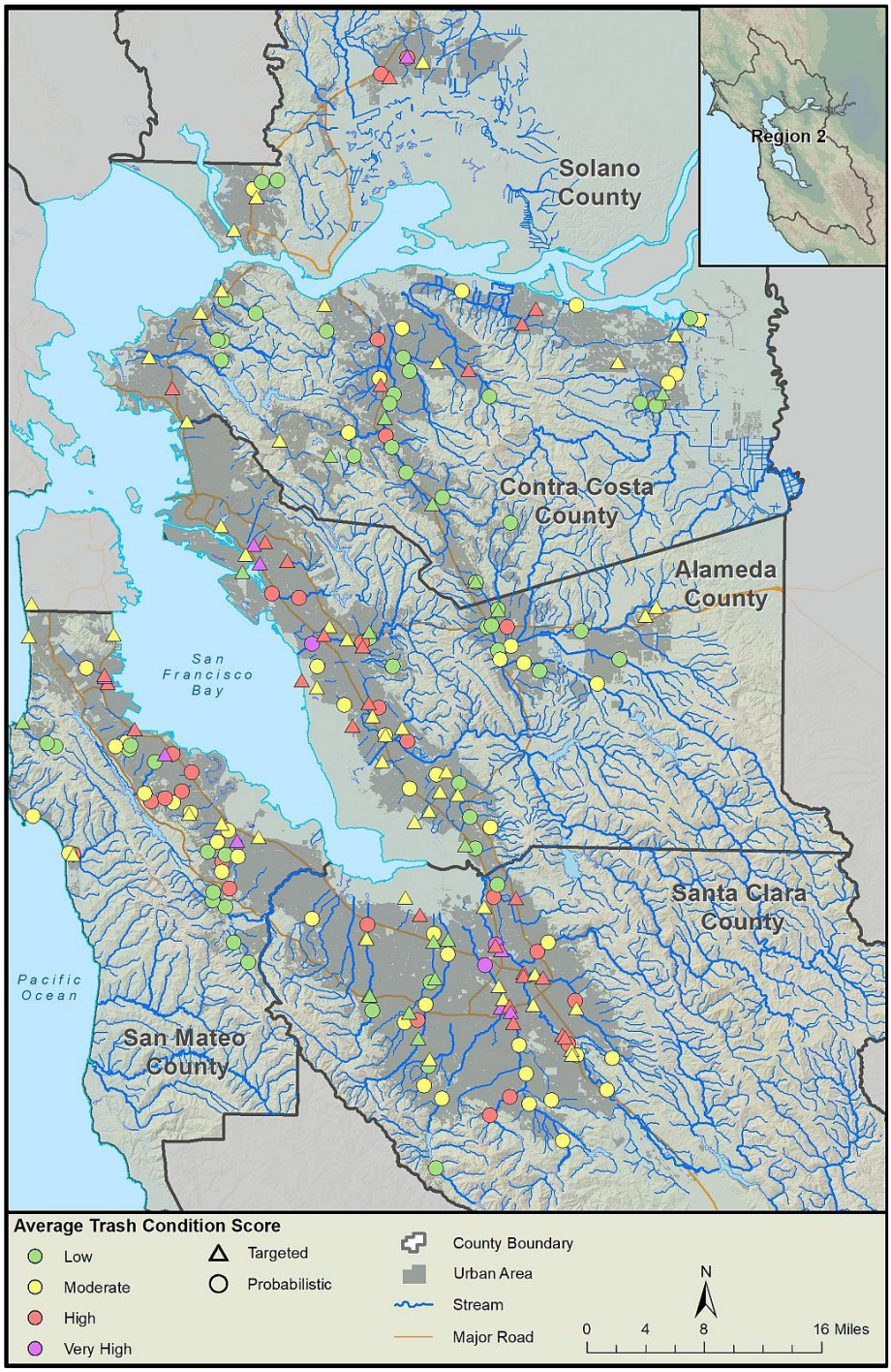

Figure 4-4. Average Trash Condition Scores for 129 probabilistic (average of 5 events) and 100 targeted (median of 2 events) sites in SF Bay Area urban streams and shorelines.

4.2.2 Associations with Site/Landscape Characteristics

To better understand patterns in the extent and magnitude of trash in receiving waters, all site characteristics (e.g., site width, bank cover, channel cover, and channel type) and descriptive site/landscape variables (e.g., range in flow, adjacent land use, number/size of storm drain outfalls, and evidence of public use) were evaluated for their potential association with trash condition scores and trash densities. Spearman correlation analysis, regression analysis, and data visualization were used to evaluate the relationship between site/landscape characteristics and qualitative trash condition scores at probabilistic and trash targeted sites combined, and between site/landscape characteristics and trash densities for targeted sites, where site/landscape characteristic data were available.

Bank and Channel Cover

Spearman correlation results for variables associated with the site width, and types of bank and channel cover are shown in Table 4-6. In general, site characteristic variables were weakly correlated or not correlated at all with qualitative trash condition scores. Higher assessment area widths (rho = 0.18), higher proportions of grasses (rho = 0.14), bushes (rho = 0.19), and trees (rho = 0.12) and lower proportions of armored banks (rho = - 0.21) were all significantly correlated ($p < 0.05$, indicating the correlation was non-zero) with trash condition scores. But there was no correlation with open/exposed banks. Similarly, trash conditions scores were not significantly correlated with the proportion of dry or open/wet channels, or aquatic vegetation/algae cover (i.e., $p > 0.05$). There was a very weak correlation of trash condition scores with woody debris (rho = 0.08, p = 0.02). The number of insignificant correlations and generally low correlation coefficients (rho < 0.2) suggests that size of assessment area, bank cover, and channel cover are ineffective groupings for stratification of sites by qualitative trash condition.

Table 4-6. Correlations between bank/channel cover variables and qualitative trash condition scores for all MRP urban sites (probabilistic and targeted). Variables with statistically significant correlations are bolded.

Site Characteristic	Variable	Correlation Coefficient (rho)	p-value
Width	**Contiguous Width**	**0.18**	**< 0.001**
Bank Cover	**% Grasses**	**0.14**	**< 0.001**
	% Bushes/Shrubs	**0.19**	**< 0.001**
	% Trees	**0.12**	**< 0.001**
	% Armored	**-0.16**	**< 0.001**
	% Open/Exposed	-0.01	0.88
Channel Cover	% Open/Wetted Channel	0.05	0.17
	% Woody Debris	0.08	0.02
	% Aquatic Veg/Algae	-0.04	0.30
	% Dry Channel	-0.06	0.06

Landscape Characteristics

Associations between descriptive landscape metrics, such as range in flow, adjacent land use, public use, and number/size of storm drain outfalls and trash condition (scores and densities) were evaluated. The degree of flow at a site was estimated during trash assessments by classification into a range of flow classes that varied from “dry” to “tidal”, as shown in Figure 4-5. There was no general pattern to flow and qualitative trash condition when all sites were combined. However, targeted sites with dry or with only isolated pools had lower trash density than sites in either the 0.1-1 cfs, 1-5 cfs, or 5-20 cfs flow

categories. In contrast, sites with higher runoff or those that were tidally influenced exhibited lower densities of trash that was relatively consistent amongst those sites. Presumably trash at these sites is more widely dispersed, leading to a lack of association with flow and trash density.

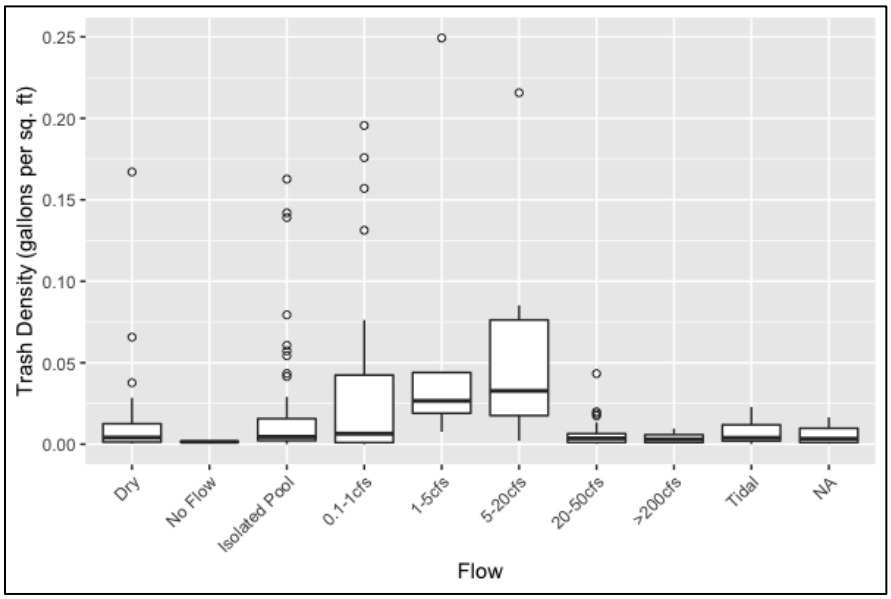

Figure 4-5. Comparison of estimated stream flow and trash density (gal/ft^2) at targeted sites (n=92) sampled during the two dry season assessments (2018 and 2019).

Adjacent land uses were characterized for each assessment site using broad land use categories. Each site was classified into two to four categories, including “residential”, “commercial”, “industrial”, “freeway”, “public”, and/or “open/park.” To assess associations among trash levels and adjacent land uses, the number of sites in each land use category was calculated. Six land use categories were found to be most frequently occurring, irrespective of trash condition category. Sites adjacent to “residential” (including single and multi-family) and “open/park” comprised at least half of all land use designations in the *Low* to *High* trash categories (Figure 4-6). In contrast, sites corresponding to the *High* and *Very High* trash condition were more frequently adjacent to higher proportions of “freeway” and “industrial” land use categories, compared to sites in either *Low* or *Moderate* condition categories. The proportion of commercial land use was relatively consistent between sites with different condition categories, comprising 12% to 22% of the adjacent land uses.

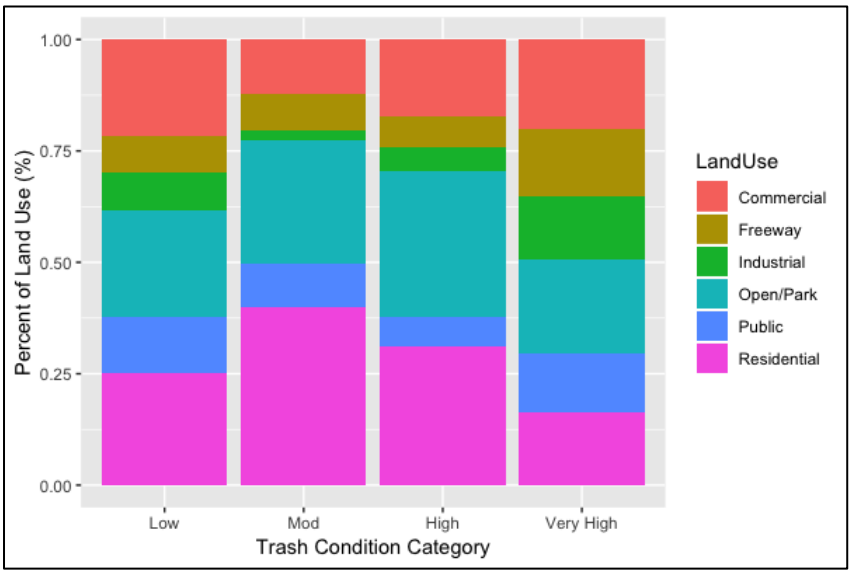

Figure 4-6. Comparison of trash condition categories observed at monitoring sites and the predominate land uses adjacent to these sites.

Evidence of public use was also recorded during surveys based on the categorical assessment scale of "None", "Low", "Moderate" or "High" observed during each assessment (Figure 4-7). As predicted, sites with higher levels of public use generally exhibited higher trash densities. A Kruskal-Wallis statistical test confirmed there was a significant difference in trash density by public use category, where sites classed in the "High" public use category had significantly higher mean trash density than sites in either the "Low" or "Moderate" public use classes.

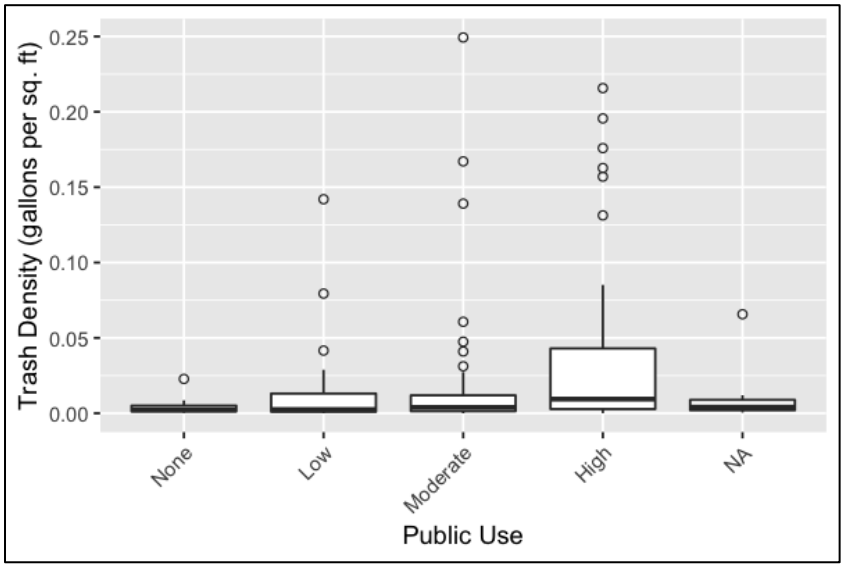

Figure 4-7. Comparison of public use levels and trash density at targeted sites sampled during two dry season assessments (2018 and 2019).

Correlations between the number and size of stormwater outfalls that were observed in the assessment area, and trash condition scores or trash densities were also examined. There was a weak correlation (rho = 0.09 – 0.14, $p < 0.05$) in trash condition scores and the number of outfalls in each of the size classes (18-

24", 24-36", 36-48", > 48"). Similarly, targeted sites showed a modest association between the abundance of stormwater outfalls and total trash density (Figure 4.8).

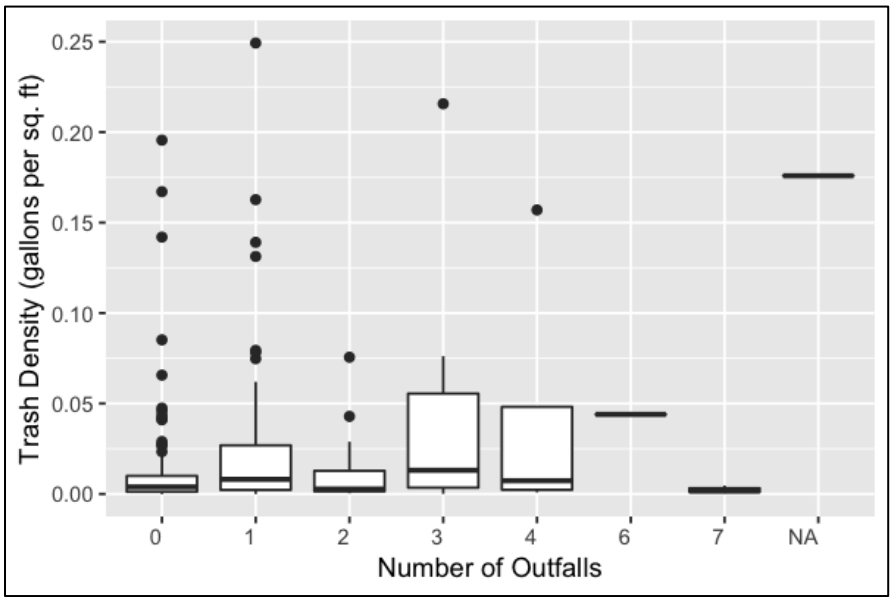

Figure 4-8. Total number of stormwater outfalls compared to the average trash density observed at targeted sites during two dry season assessments (2018 and 2019).

Overall, the comparison of site characteristics to trash densities and condition categories at receiving water monitoring sites suggests that neither bank and channel cover characteristics, magnitude of water flow at the time of the assessment/monitoring event, or the level of public use at the site can be used to fully explain the variations in trash conditions observed at probabilistic and targeted sites. The extent of natural vegetation along banks at a site appears to be somewhat positively correlated to trash condition scores, while the extent of armored banks is negatively correlated to scores. One hypothesis to explain these observations is that natural channels that have riparian vegetation and diverse instream substrate (both woody debris and varying sizes of substrate) "intercept" trash more effectively than channels with fewer obstructions. Similarly, sites with the largest flows observed or high levels of accessibility do not necessarily equate to higher trash densities, though at some sites this may occur. These observations suggest that the largest sources of variations in trash condition scores may be from other factors associated with the wide range of trash sources and pathways, in addition to the site-specific factors evaluated through this pilot project.

4.2.3 Contributions of Trash in Receiving Waters During Different Seasons

Between October 2017 and March 2020, three qualitative trash assessments were conducted during the wet season (October – March) and two assessments were conducted during the dry season (April – September) at the 125 probabilistic sites. Concurrent with the two dry season events, two assessments were conducted at an additional 100 targeted sites. As illustrated in Figure 4-9, the rainfall patterns during each of the three wet seasons differed substantially. During the wet season of 2017-18, storms were infrequent, short and had the highest intensity of the three water years. In 2018-19 wet season, storms were generally more frequent, longer, but less intense. The 2019-20 wet season (through March 2020) had very few storms that were of predominantly lower intensity than most storms occurring in either of the preceding two wet seasons. Despite the differences in rainfall, the distributions of trash

condition scores had minimal differences between wet seasons at probabilistic sites (Figure 4-10). The median of trash condition scores for all probabilistic sites monitored in each wet season (2017-18, 2018-19, 2019-20) was 4 (Moderate) on the 1 to 12 scale. In comparison, the median trash condition score (3) for all probabilistic sites during the 2018 dry season was slightly lower than the median score (4) for the 2019 dry season.

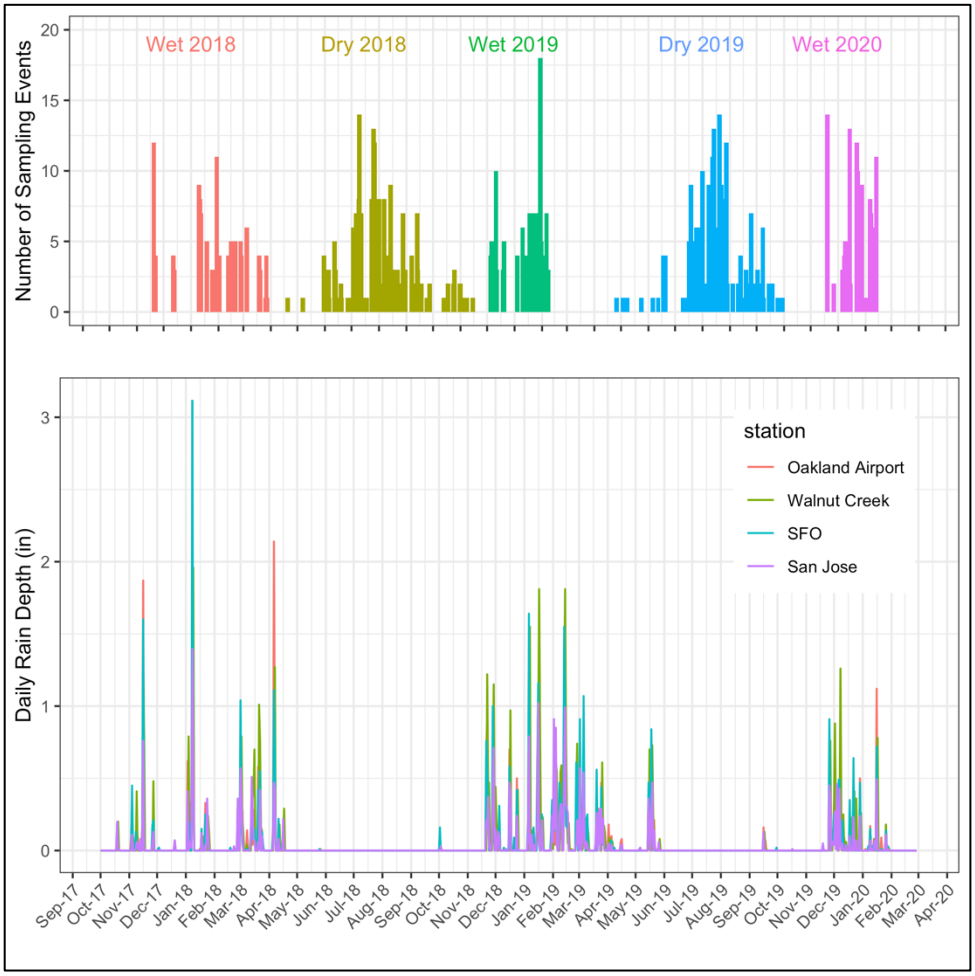

Figure 4-9. Daily precipitation (inches) recorded at four stations across the SF Bay Area from October 2017 through March 2020, and the number of probabilistic and targeted sampling events during that timeframe.

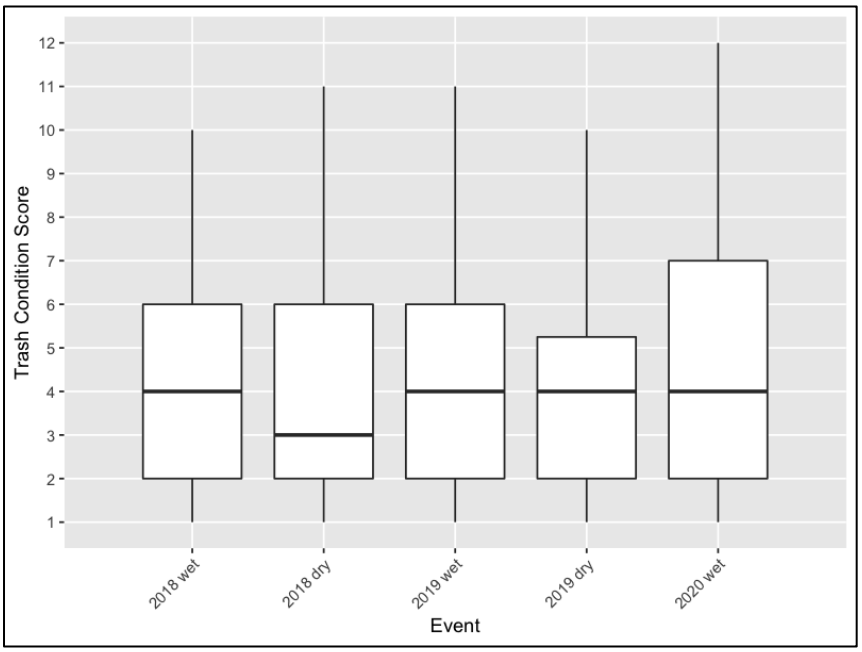

Figure 4-10. Ranges of trash condition scores at probabilistic sites during the 2018, 2019, and 2020 dry and wet season monitoring events.

The trash conditions observed at probabilistic sites indicated that slightly higher trash levels occurred during the wet season events compared to the dry season events. Figure 4-11 illustrates the proportion of probabilistic sites in each of the four trash condition categories for the five events. The proportion of sites in the *High* and *Very High* categories ranged between 22% and 25% for all wet season events, compared to 15% for both dry season events. The proportion of sites in the *Low* category was slightly higher in the dry season (48%-53%) relative to each of the wet season events (42% - 46%). Higher trash conditions during the wet season may be influenced by recent deposition of trash following storm events which mobilized trash to the site from either upstream in-stream sources (e.g., illegal encampments or dumping) or through the stormwater pathway. Additionally, trash is generally more visible during the wet season, when riparian vegetation is less dense, which could affect trash condition scores.

Anecdotal information from field crew experience indicates that dry season is a better time period to physically access the creek and visually observe trash in the channel and along the banks, when stream flows are reduced or creeks/channels are dry. In addition, trash from other pathways (e.g., litter/wind) may be more visible at some locations (e.g., bridges) when flows are lower and the transport of trash downstream is not actively occurring.

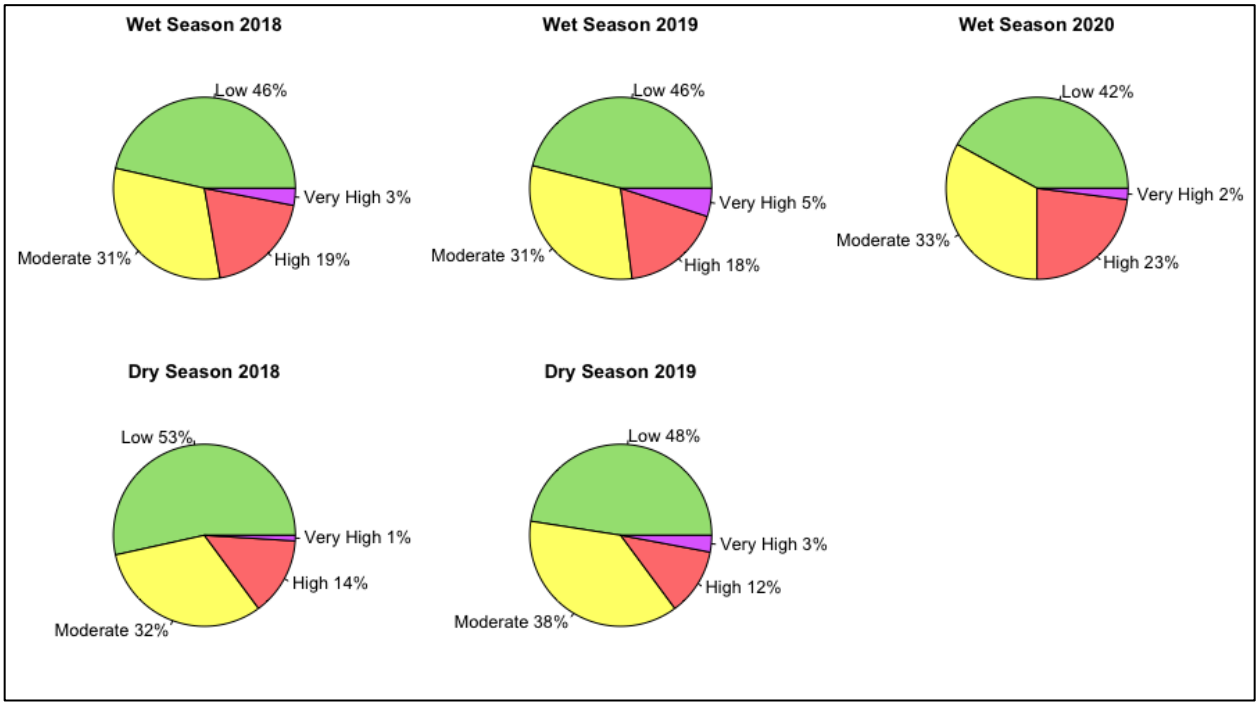

Figure 4-11. Comparison of trash conditions at probabilistic sites for wet and dry season (2018, 2019 & 2020) sampling events.

4.3 Contributions of Trash in Receiving Waters from Different Pathways

The BASMAA trash assessment qualitative and quantitative monitoring protocols include the identification of trash pathways. Field personnel qualitatively identified trash pathways at all sites (both probabilistic and targeted) and estimated the volume of trash from each pathway at targeted sites. Contributions from one or more of the following four pathways were documented: 1) litter/wind; 2) illegal dumping; 3) illegal encampments; and 4) other/stormwater. One of the goals for this project was to determine the relative contribution of trash observed at monitoring sites that is associated with the "Other/Stormwater" pathway.[6] The trash dataset was evaluated to answer the following questions:

- How well do qualitative and quantitative approaches to assessing contributions from different trash pathways compare?
- What are the prevalent pathways of trash observed in receiving waters?
- What are the relationships between trash pathways and trash levels?
- What are key factors that influence trash pathways?

4.3.1 Comparison of Qualitative and Quantitative Approaches

Prior to presenting the information collected on the relative contributions of trash to probabilistic and targeted sites from each of the four pathways, it is important to compare trash pathway contributions

[6] "Other/Stormwater" pathway includes trash that appears to be associated with stormwater and unknown upstream sources (i.e., trash transported by flow and deposited further downstream).

that were determined via two different approaches: 1) qualitative visual assessments and 2) volumetric measurements. Figure 4-12 presents the results of linear regression analyses conducted on data collected at targeted sites (n=100) on the relative (%) contributions by the four pathways using quantitative and qualitative approaches. Based on these analyses, it appears that the qualitative and quantitative approaches were well correlated ($r^2 > 0.7$) for two (i.e., litter/wind and homeless encampments) of the four pathways.

Multiple pathways were identified for the vast majority of the targeted sites using both the qualitative and quantitative approaches. Trash items associated with the litter/wind and other/stormwater pathways are typically light weight and smaller in size (e.g., single-use food ware, plastic bags, cigarettes), and therefore typically contribute smaller proportions of the overall trash volume at sites where the illegal dumping and/or illegal encampment pathways are also present. As a result, the estimates of trash from the litter/wind and other/stormwater pathways have lower regression slopes compared to the illegal encampment pathway, which is associated with larger items.

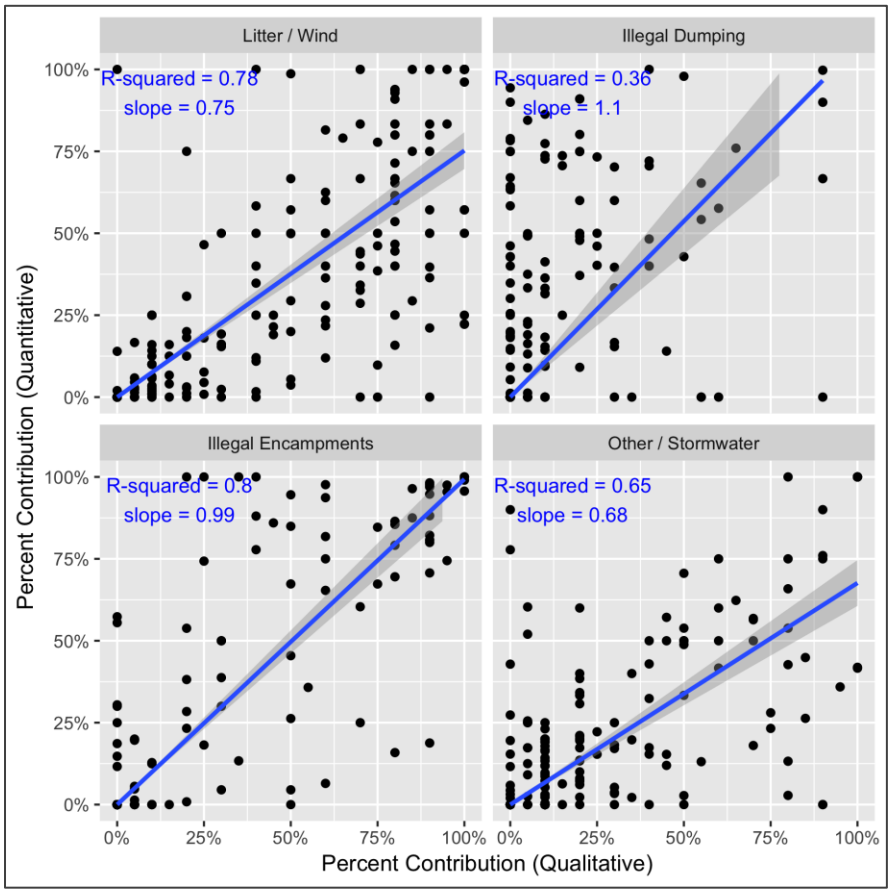

Figure 4-12. Comparisons of quantitative (volume measurements) and qualitative (visual estimate) approaches to relative contributions of trash from four trash pathways at 100 targeted monitoring sites sampled during two monitoring events (n = 200).

4.3.2 Prevalent Trash Pathways

The prevalence of each trash pathway was evaluated by qualitatively assessing whether the pathway was (or was not) identified as a contributor of trash to each site (Table 4-7). The two most common pathways identified as contributors were litter/wind (90% of events) and other/stormwater (78% of events). The

illegal encampment pathway was the least represented pathway (24% of events). These results indicate that trash from the wind/litter and other/stormwater pathways are most prevalent at all sites. Illegal dumping and illegal encampment pathways had higher relative contributions at the targeted sites, compared to the probabilistic sites. This result is expected since these sites were originally selected as trash hot spots, many of which included high trash areas that were associated with illegal encampments.

Table 4-7: Total number and percentage of events at probabilistic and targeted sites when trash from a given pathway was reported as contributing trash to the trash monitoring site.

Type of Site	# of events included in analysis[1]	# of Events where the Pathway was Identified (%)			
		Litter / Wind	Illegal Dumping	Illegal Encampments	Other / Stormwater)
Probabilistic	607	559 (92%)	160 (26%)	117 (19%)	483 (80%)
Targeted	198	166 (84%)	79 (40%)	79 (40%)	141 (71%)
Totals	**805**	**725 (90 %)**	**239 (30 %)**	**196 (24 %)**	**624 (78 %)**

[1] The number of sites included in this analysis are smaller than the total number of monitoring events because of data quality issues with 16 probabilistic sites and 3 targeted sites, as related to pathway determinations.

4.3.3 Relationships Between Trash Pathways and Trash Levels

Although illegal encampments and illegal dumping pathways were less prevalent at targeted and probabilistic sites compared to litter/wind and other/stormwater, these two pathways were associated with the largest volumes of trash observed at sites. During the two targeted monitoring events (dry season of 2018 and 2019), trash volumes were measured for each of the four pathways. In total, about 14,000 gallons of trash in 2018 and 21,000 gallons in 2019 were associated with illegal encampments and illegal dumping, while the litter/wind and other/stormwater pathways combined, accounted for about 3,000 gallons of trash in each event (Figure 4-13).

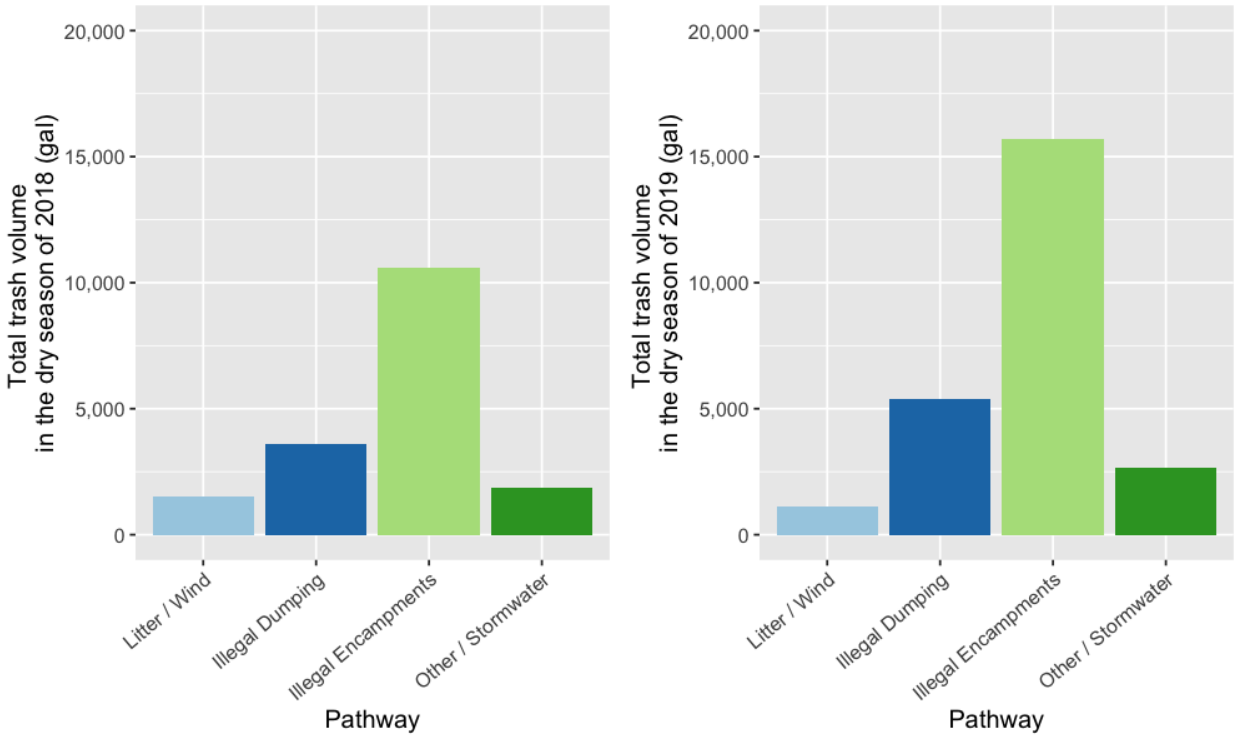

Figure 4-13. Total trash volume for each of the four pathways measured at targeted sites.

The positive association between illegal encampments and illegal dumping pathways, and trash condition scores and volumes, was confirmed using statistical correlation tests. The Spearman correlation analysis presented in Table 4-8 examined correlations between the relative contributions by each trash pathway and the trash condition score observed at the probabilistic and targeted sites. At probabilistic sites, higher trash condition scores were correlated to higher proportions of trash from the illegal encampment and illegal dumping pathways. In contrast, lower condition scores were correlated to proportions of trash from the litter/wind pathway. The contribution of trash from the other/stormwater pathway did not exhibit a correlation to trash condition scores at either targeted or probabilistic sites. That said, it should be noted that contribution estimates are relative percentages and a negative correlation does not indicate that there is less trash from the litter/wind pathway, but merely that this pathway is less dominant, compared to other pathways (i.e., Illegal dumping and Illegal encampments).

Table 4-8. Correlations between qualitative trash condition scores and the qualitative estimation of trash contributed from different pathways at probabilistic (n=129) and targeted (n=100) sites.

	Probabilistic		Targeted	
Pathway	Correlation Coeff. (rho)	p-value	Correlation Coeff. (rho)	p-value
% Litter / Wind	**-0.30**	**< 0.001**	**-0.42**	**< 0.001**
% Illegal Dumping	**0.48**	**< 0.001**	0.12	0.24
% Illegal Encampment	**0.50**	**< 0.001**	**0.53**	**< 0.001**
% Other / Stormwater	0.08	0.37	-0.15	0.15

The association between trash condition category and trash pathway contribution for probabilistic and targeted sites is represented visually in Figure 4-14. Consistent with the statistical analysis results presented in Table 4-7, poor trash conditions are associated with higher proportions of trash from illegal encampments and illegal dumping, and lower proportions of trash from litter/wind. There appears to be little or no change in the relative contribution of trash levels from the other/stormwater pathway.

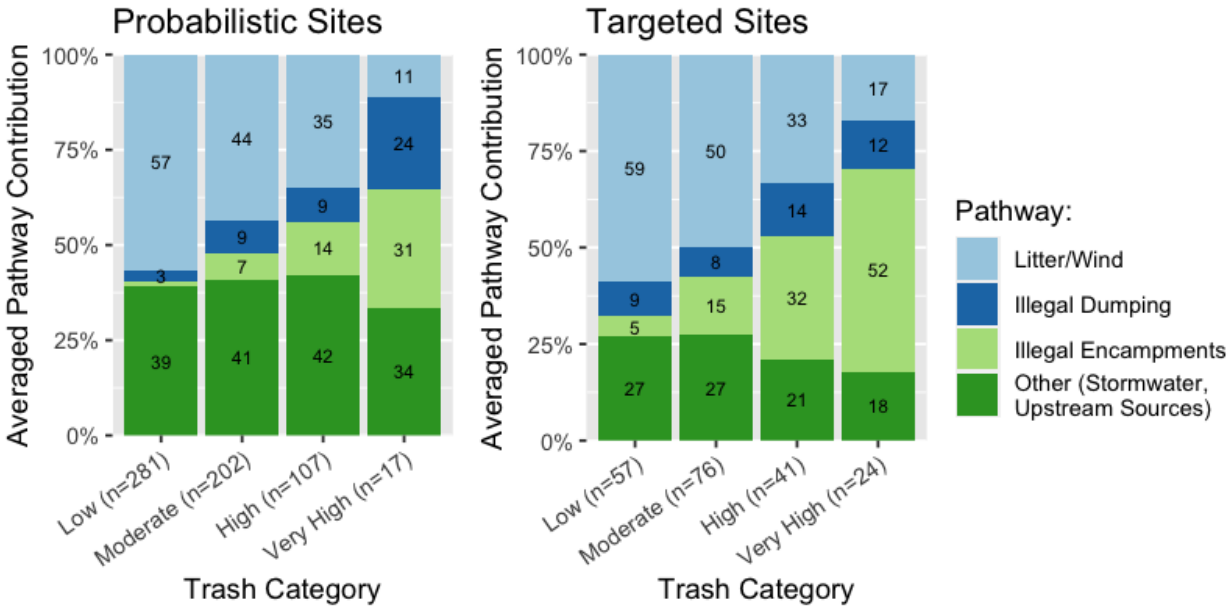

Figure 4-14. Average contributions of trash observed from each pathway to probabilistic and targeted receiving water monitoring sites during monitoring events. Monitoring events are grouped by trash condition categories.

4.3.4 Factors that Influence Trash Pathways

Seasonal differences in the relative contributions of trash from different pathways were also evaluated. Based on the data collected at probabilistic sites, the relative contributions of the four trash pathways remained relatively consistent across four of the five events (Figure 4-15). Trash associated with the litter/wind pathway was associated with the highest proportion of trash, except during the 2019 wet season, which showed a higher relative contribution from the other/stormwater pathway (i.e., > 50% of the trash) and a lower relative contribution from the litter/wind pathway. As discussed in Section 4.2.1, the 2019 wet season had more frequent storm events, compared to the 2018 and 2020 wet seasons, potentially resulting in more opportunities for trash to be transported and deposited across sites during the 2019 wet season. More frequent storm events may also have resulted in the transport of significantly more trash associated with the other/stormwater pathway, as illustrated in Figure 4-10. Notably, illegal encampments and illegal dumping consistently represented the lowest contribution to trash levels in each of the probabilistic monitoring events. Overall, the comparison of trash levels among seasons suggests that seasonal differences may have an impact on the relative contributions from different trash pathways. In particular, wet seasons with more frequent, runoff-inducing storm events might lead to higher contributions of trash from the other/stormwater pathway.

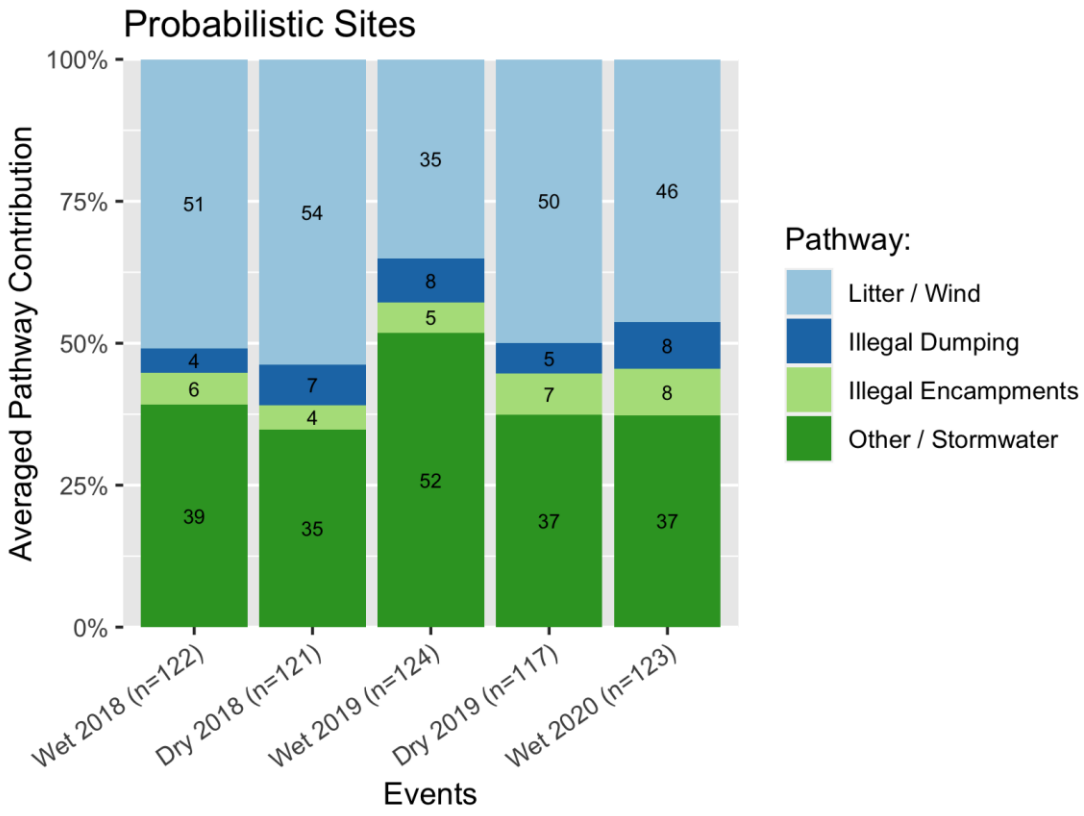

Figure 4-15. Average contributions of trash from each pathway identified during each receiving water trash monitoring event (n=5) at probabilistic sites.

4.4 Levels of Trash Observed in Receiving Waters Compared to Trash Discharged By Stormwater Conveyances

This section compares the amount of trash collected from targeted monitoring sites and trash booms to the amount of trash predicted to currently be generated from the upstream land areas (i.e., catchments) and transported via the stormwater conveyance system to these receiving water monitoring sites. The process used to predict trash generation in these catchments is described below.

Under MRP 2.0, each municipality subject to trash load reduction requirements was required to develop a *Baseline Trash Generation Map* that illustrates the 2009 levels of trash that is deposited on streets, sidewalks, landscaping, and other land areas, and available for transport to local receiving waters via the stormwater conveyance system pathway. These baseline maps serve as the starting point for demonstrating the attainment of stormwater trash load reduction requirements included in the MRP. Maps are color-coded using the color-scheme illustrated in Table 4-9, based on the observed levels of trash on different land areas within their jurisdictional boundaries. Baseline trash generation rates are then assigned to each trash generation category (Table 4-9) to estimate baseline trash generation levels (i.e., annual loads) from land areas, based on their baseline trash levels observed on-land. Annual baseline trash loads do not account for trash control measures that were implemented after 2009, the year the baseline maps depict.

Table 4-9. Average trash generation rates (gallons/acre/year) for each generation category. Rates are used to calculate annual trash loads from land areas within MRP Permittee jurisdictional boundaries.

Trash Generation Category	Low	Moderate	High	Very High
Annual Trash Generation Rate (gallons/acre/year)	0	7.5	30	90

Geographic Information System (GIS) data layers for creek network and stormwater conveyance systems were used to delineate the catchment area upstream of all targeted monitoring sites and trash booms. Annual baseline trash loads for each catchment were calculated by multiplying the rates shown in Table 4-9 by the acreage in each catchment that fall within each trash generation category.

To account for the significant trash control measures implemented by MRP Permittees since 2009, the baseline trash loads for each catchment were adjusted based on the extent of trash full capture systems installed to-date. Generation rates for land areas addressed by full capture systems were adjusted to low/green levels. Baseline loads were not adjusted to account for reductions associated with other types of control measures (e.g., street sweeping or on-land cleanup events) due to the challenges in the accounting methods described in MRP 2.0. The resulting adjusted baseline trash loads are intended to depict "current" trash loading from the stormwater pathway to the targeted monitoring sites and trash booms at the time receiving water trash monitoring was conducted (i.e., 2018-2019).

4.4.1 Comparison of Stormwater Trash Loads to Trash Volumes Removed from Trash Booms

Trash booms collect trash transported in receiving waters during dry and/or wet weather flow events. Data collected at all trash booms monitored during this project depict a combination of trash transported during wet and dry weather events. Annual rates of trash volumes captured by each boom monitored during the project were calculated by dividing total trash volume removed from the boom by the total number of days trash accumulated at the boom. Trash accumulation periods for all monitoring events ranged between 6 and 230 days during 2018 and 2019 (Table 4-10). These data should be interpreted with caution since for some booms, the annual rates were developed by extrapolating 1-2 weeks of trash accumulation for an entire year.[7] Trash accumulation rates were also standardized by area using the upstream catchment area associated with each boom.

Trash volumes collected at the 9 trash booms monitored during the project ranged from 0.1 to 2,020 gallons (Table 4-10). The annual rate of trash accumulation at the booms ranged from 177 to 5,163 gallons. The estimated annual trash volume standardized by area ranged two orders-of-magnitude (0.02 to 2.3 gallons/acre).

[7] For three trash booms in Alameda County, the annual estimate was based on the daily trash rate calculated for wet and dry event applied to number of days with rainfall (n=80) and no rainfall (n=285) during January 2019 through December 2019.

Table 4-10. Trash volumes removed from 9 booms and the estimated trash accumulation rates for each.

Trash Boom Location	Preceding Trash Removal Date	Trash Removal Date	Accumulation Period (days)	Trash Volume Removed (Gallons)	Annual Trash Rate (Gallons/ Year[1])	Annual Trash Rate per Area (Gallons/Acre/Year)
22nd and Harrison (Oakland)	3/27/2018	4/17/2018	21	5	322	2.3
	11/20/2019	11/26/2019	6	0.1		
	2/21/2019	2/28/2019	7	20		
	1/21/2020	1/28/2020	7	30		
Glen Echo (Oakland)	3/27/2018	4/17/2018	21	20.5	1444	0.9
	2/21/2019	2/28/2019	7	102		
Trestle Glen (Oakland)	11/20/2019	11/26/2019	6	30	2796	1.5
	1/21/2020	1/28/2020	7	120		
Lower Silver Creek (San José)	3/5/2019	5/30/2019	86	404	4096	0.34
	10/11/2018	11/20/2018	40	404		
	5/7/2018	8/23/2018	108	1818		
Thompson Creek (San José)	3/14/2019	4/29/2019	46	1010	5163	0.36
	12/18/2018	3/14/2019	86	2020		
	5/7/2018	12/18/2018	225	2020		
Adobe Creek (Palo Alto)	4/15/2019	5/18/2019	33	22	231	0.02
	10/3/2018	12/15/2018	73	45		
Matadero Creek (Palo Alto)	4/15/2019	5/18/2019	33	15	177	0.02
	10/3/2018	12/15/2018	73	60		
	5/19/2018	7/13/2018	55	3		
16th Ave Channel (San Mateo)	12/7/2018	5/28/2019	172	400	1380	1.4
	12/4/2018	12/7/2018	3	150		
	10/31/2018	12/4/2018	34	200		
	10/19/2018	10/31/2018	12	100		
	3/3/2018	10/19/2018	230	400		
	2/11/2018	3/3/2018	20	400		
	2/6/2018	2/11/2018	5	200		
	1/4/2018	2/6/2018	33	75		
19th Ave Channel (San Mateo)	6/6/2018	10/24/2018	140	300	623	0.31
	3/22/2018	6/6/2018	76	75		
	1/4/2018	3/22/2018	77	125		

[1] Annual trash rate was calculated by dividing combined trash volume for all events by total days of accumulation and standardizing to 365 days.

The annual rate of trash accumulation at each boom was compared to the estimated annual stormwater trash load generated from the catchment draining to each boom. As anticipated, the annual stormwater trash load was far greater than the annual volume of trash that accumulated at the booms. The booms accumulated between 4% and 42% of the estimated trash load from the catchment (Table 4-11).

Table 4-11. Estimated portion of the trash volume transported via stormwater from the catchment upstream of the trash boom that is accumulated in the trash boom.

Trash Boom Location	Trash Generation (gallons/year)	Annual Trash Removal (gallons/year)	Portion Accumulated in Trash Boom (%)
22nd and Harrison	2,908	322	11.1
Glen Echo	11,252	1,444	12.8
Trestle Glen	6,730	2,796	41.5
Lower Silver/Thompson (Combined)	65,773	9,259	14
16th Avenue Channel	10,529	1,380	13
19th Avenue Channel	14,340	623	4.3

4.4.2 Comparison of Stormwater Trash Loads to Trash Levels at Targeted Monitoring Sites

Similar to trash booms, stormwater trash loading estimates to each targeted monitoring site were developed and compared to quantitative monitoring results from targeted receiving water monitoring sites. The total estimated volume of trash annually generated in the catchments upstream of the targeted sites ranged from 40 to 162,295 gallons. The average volume of trash associated with the Other/stormwater pathway that was measured during two monitoring events at the non-shoreline targeted sites (n=91) ranged from 0 to 412 gallons. For 90 of the 91 sites, the amount of trash measured was between 0% and 4.5% of the estimated trash loading to the site. For the vast majority (91%) of these sites, the amount of trash measured at the site that was identified as originating from the Other (stormwater/upstream) pathway, was equivalent to less than 1% of the estimated trash load to the site. The volume of trash measured at one site was greater than the estimated trash load to the site.

Overall, the average volume of trash measured at each targeted site associated with the Other (stormwater/upstream) pathway was poorly correlated with the volume of stormwater-generated trash in the watershed (Figure 4-16). The poor association with these data is not surprising for a number of reasons. First, as described in the previous section, there are inherent challenges with accurately distinguishing the portion of trash at creek/channel sites that is associated with the Other (stormwater/upstream) pathway from other trash pathways. Additionally, there is a lack of information to determine what proportion of stormwater-related trash is deposited in assessment area of the channel and banks of a given site, and what portion is deposited upstream of the sites, accumulating at the site but above the assessment area, or is transported downstream of the site. Also, the timing of the trash transport process was not taken into account when making the comparison between trash loading and trash deposited at the site from stormwater. Loading estimates are annual, while the trash deposited in the creeks/channel occurs on a sub-annual basis, consistent with stormwater transport processes (i.e., stormwater flow events) and site-specific factors that were previously discussed as potentially being important for understanding deposition of trash (e.g., channel type and extent/type of vegetation).

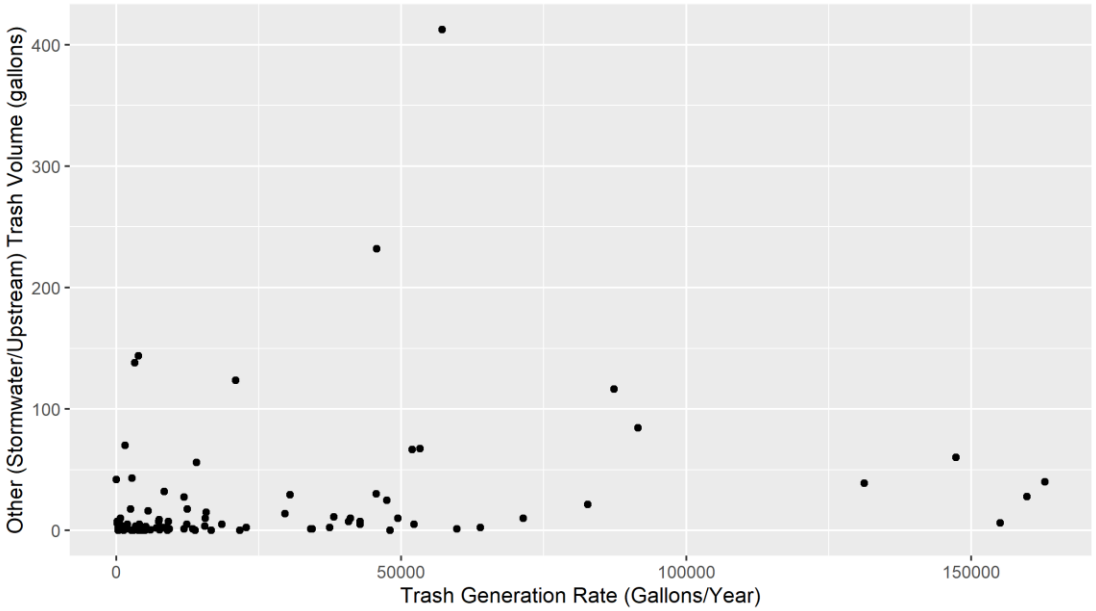

Figure 4-16. Comparison of the average trash volumes (gallons) for the Other (stormwater/upstream) pathway measured at 91 targeted monitoring sites with the predicted annual amount of trash generated in those drainage areas (gallons/year).

5 CONCLUSIONS

The following section presents conclusions for the data analyses presented in the Final Report. The conclusions are organized by specific scientific monitoring questions outlined in the Trash Monitoring Plan.

Comparison of Qualitative Assessment and Quantitative Monitoring Results

- *Are significantly strong correlations observed between qualitative and quantitative trash receiving water monitoring/assessment methods?* - Significant correlations are observed between qualitative trash condition scores (1-12) and trash density (volume per unit area) at both regional and countywide scales. Correspondence of qualitative scoring to trash density was better using the categorical scale for trash condition (i.e., Low, Moderate, High, Very High). Low correlation between methods at some sites indicates the assessment tools are less effective under certain types of conditions (e.g., shorelines).

Levels of Trash in Urban Water Bodies in the MRP Area

- *What is the current level of trash deposited in flowing waterbodies in the entire MRP urban area?*

  Trash levels were evaluated based on the qualitative trash condition scores/categories observed at probabilistic sites. For the probabilistic sites regionwide, 40% are in the Low condition category and 37% are in the Moderate category, indicating that approximately 77% of the urban stream lengths in the MRP area exhibit low to moderate levels of trash. In contrast, only 2% of the stream-lengths have trash levels in the Very High trash condition category. The total estimated amount of trash volume that was present in all urban streams in the MRP area during the study period was just over 4 million gallons. An estimated 64% was of this volume was associated with the 22% of the stream miles that fell into the High or Very High condition categories.

- *Do other site and landscape variables correlate with trash levels in flowing waterbodies?*

  Site and landscape characteristics for trash receiving water monitoring sites suggests that some bank and channel cover characteristics partially explain the variation in observed trash conditions. The extent of natural vegetation on banks at a site appear to be somewhat positively correlated to trash condition scores, while the extent of armored banks is negatively correlated to condition scores. This is likely because natural channels that have riparian vegetation and diverse instream substrate (both woody debris and varying sizes of substrate) "intercept" trash more effectively than channels with fewer obstructions. Public access was also found to be an important factor for the density of trash observed in streams.

- *Do trash levels in flowing waterbodies differ significantly between wet and dry seasons?*

  Seasonality appears to have little effect on trash levels observed/measured at receiving water sites. Trash condition categories observed at probabilistic sites indicate slightly greater trash levels during the wet season, compared to the dry season, but not statistically significant. Variations in trash levels between the three wet season events, however, also illustrates the effects that storm frequencies and intensities can have on trash levels observed at the same sites over time during the wet weather season.

- *What trash levels are observed at sites targeted for cleanup? How do these levels compare to levels in all flowing waterbodies?*

  The trash assessment results from the targeted (hot spot) sites were compared to the results from probabilistic sites to determine if the range of conditions were similar between the two

sample designs. Approximately 23% fewer targeted sites were in Low trash condition category, compared to the probabilistic sites, and more targeted sites were in the Moderate, High, and Very High condition categories than the probabilistic sites. Because targeted sites were selected by MRP Permittees as "trash hot-spots", higher trash scores would be expected at targeted, compared to probabilistic sites.

Contributions of Trash from Different Pathways

- *What percentages of trash observed in receiving waters are attributable to stormwater conveyance systems, direct dumping, wind, and encampments?*

  At targeted sites, illegal encampments and illegal dumping pathways were associated with much larger volumes of trash. In total, at targeted sites we estimate about 14,000 gallons and 21,000 gallons of trash were associated with illegal encampments and illegal dumping in 2018 and 2019, respectively. We also estimated that litter/wind and other/stormwater pathways together accounted for about 3,000 gallons of trash for both years. Based on comparisons between average pathway contribution and trash condition category, poor trash conditions are associated with higher proportions of trash from illegal encampments and illegal dumping. Although little to no association between trash conditions and the other/stormwater pathway have been observed, contributions of trash from this pathway appear to increase during the wet season, compared to the dry season.

Levels of Trash Observed in Receiving Waters Compared to Trash Discharged by Stormwater Conveyances

- *Do trash levels in flowing waterbodies strongly correlate to trash generation levels depicted on Permittee maps?*

  Trash monitoring data collected at 9 trash booms and 91 targeted sites were used to compare the amount of trash accumulation at a site to estimate annual trash loads transported via the stormwater pathway from watershed land areas to boom/targeted sites. A volume of trash equivalent to 4% to 42% of the estimated stormwater trash loads from the upstream catchments is captured by booms. For 90 of the 91 targeted sites, the amount of trash measured was a relatively small percent (between 0% and 4.5%) of the estimated trash loading to the site. For the vast majority (91%) of these sites, the amount of trash measured at the site that was identified as originating from the Other (stormwater/upstream) pathway, was equivalent to less than 1% of the estimated trash load to the site. Overall, the average volume of trash measured at each targeted site associated with the Other (stormwater/upstream) pathway was poorly correlated with the volume of stormwater-generated trash in the watershed. One of the major reasons for this poor correlation is the inherent challenges with accurately distinguishing the portion of trash at creek/channel sites that is associated with the Other (stormwater/upstream) pathway from other trash pathways.

6 EVALUATION OF TRASH MONITORING PROGRAM

An evaluation of methods and monitoring design used during the pilot-testing phase of the Trash Monitoring Plan is provided in the section below. This evaluation provides guidance for potential revisions to approach trash monitoring in receiving waters.

6.1 MONITORING DESIGN

6.1.1 Site Selection

The initial trash monitoring design utilized an existing RMC sample frame to select probabilistic sites for evaluating overall trash conditions within the MRP Area. Overall, 30 sites within each county and 125 sites at urban streams within the MRP area were sampled during the pilot study. The total of 125 sites provided a statistically significant number of samples to estimate probabilities of trash conditions (i.e., cumulative distribution frequencies) for all urban streams in the MRP area.

To evaluate monitoring questions related to seasonal differences, the monitoring design emphasized increased sampling effort at the same sites (i.e., five events at 125 sampling locations) over increased density of sampling sites (i.e., 1 event at 625 sampling locations). As a result, although the design provided adequate sampling to evaluate the seasonal variability of trash conditions in streams, trash conditions observed during the pilot study may under-represent trash conditions when the data are used to extrapolate to all creek/channel areas in the MRP area. This appears to be the case for creek segments with relatively high trash levels (i.e., *High* or *Very High* trash condition category). Overall, the probabilistic sites had low percentage of sites with high trash conditions. In contrast, a much higher percentage of the targeted sites of known trash problem areas had sites that scored in the *High* or *Very High* trash condition. The targeted sites with high trash levels appear to be clustered within certain creek segments, representing a small percentage of the urban creeks in the MRP area. There would have had to be a very large number of sites selected from the RMC sample frame for all of the targeted sites with high trash levels to be selected. Thus, sites of known trash problem areas should be targeted during monitoring designs for future receiving water trash monitoring.

Trash assessment results indicate that channel type may be an important factor influencing trash conditions. Much higher levels of trash were observed in natural channels, compared to concrete or earthen channels. Thus, to fully represent trash conditions, the influence of channel type should be considered in site selection or to stratify probabilistic sites for future sampling design.

6.1.2 Monitoring Frequency and Timing

Trash assessments were conducted during both dry and wet seasons (total of five events) at all probabilistic sites during the pilot study. The results suggest a slightly higher proportion of *High*/*Very High* trash conditions at sites sampled during wet season compared to the dry season. However, there was relatively no difference in median trash condition scores across all five sampling events.

It is important to have good physical access to visually observe the trash within the assessment area when conducting trash monitoring. Physical access in the channel is generally better during the dry season, when stream flows are reduced. However, increased vegetation growth in the dry season can create issues for observing trash. Trash pathways may also vary by season, depending on the type of site. For example, trash associated with illegal encampments may be more prevalent during the dry season. Thus, the timing of assessment may need to be determined based on the dominant pathway/sources of trash for any given site, and in consideration of flow and vegetation levels.

The trash monitoring conducted at probabilistic sites did not include removal of trash following the visual assessment, thus, it was not possible to evaluate changes in trash density over time at any of these sites. Although trash was removed at targeted sites, it was not possible to evaluate changes over time with any confidence as additional trash removal events occurred between assessments at many of the sites. As a result, the pilot study results do not provide insight into appropriate monitoring frequency of sites to determine trash conditions over time.

6.2 Assessment Area

The trash assessment protocol requires delineation of the assessment area to allow for comparison of trash conditions over time, as well as comparison of qualitative and quantitative assessment results. The upper edge of the assessment area for creek/channel sites was defined as bankfull width (or the high-water mark during a 1 – 2-year storm event). The goal was to specifically identify all trash that may impact "flowing waterbodies", with focus on the proportion of trash associated with the other/stormwater pathway.

There were several challenges with defining bankfull width. Channel features associated with bankfull (e.g., bank scour, breaks in type and size of vegetation) are not always present at every site (e.g., armored banks). There are also challenges to exclude the trash associated with less frequent storm events (5 - 10-year storm event) that can accumulate on the upper portions of the banks but is outside the bankfull definition. This trash may enter the channel at some point due to wind or stormwater runoff but was not included in the assessment.

Another major challenge in the assessment protocol was encountered for sites that had trash accumulation areas that could not be accessed (e.g. too deep or muddy, or with highly vegetated bank cover). In these cases, trash may be present in the channel, but the channel was not always accessible or visible from shore. This feature may be associated with some of the variation observed between wet and dry season events. Therefore, the scoring system needs to consider the level of effort involved in trash removal and the proportion of channel assessed.

The assessment protocol does not provide adequate guidelines on how to define shoreline sites. Important issues include when to conduct the assessment (i.e., high or low tide) and whether or not to include inaccessible mudflat areas during low tide. Furthermore, shoreline sites (standardized to 600 feet in length) could be extremely large depending on the distance between water edge and high tide line, which made the visual assessment of trash conditions more challenging. Additional guidance is needed for shoreline trash monitoring, should this occur in the future.

6.3 Assessment Method

The visual assessment tool is recommended as a valid approach to assess trash conditions for most creeks/channel sites for future monitoring design. The qualitative assessment method will provide a cost-effective approach to assess trash conditions at higher spatial density and frequency compared to the more resource intensive quantitative assessment method. The qualitative method has been shown to be a repeatable measure of relative trash condition that correlates with higher trash density.

It is critical that all field personnel are adequately trained to conduct the qualitative assessment method. This requires training and calibration activities to ensure that field crews are assigning the correct

category associated with observed trash conditions. This is especially important when municipal/agency staff may be used to evaluate the trash levels within their jurisdiction, which may bias the scoring towards the range of trash conditions in their region. Training should also ensure that practitioners are accurately assessing trash conditions that may be widely dispersed in a large area or clustered in portions of the site. Training materials should include better photo documentation for the low end and high end of each trash condition category.

Field collection of site characteristics data for the qualitative assessment was relatively time consuming and the data generated does not provide significant information to interpret results, compared to the resources expended. One exception is channel type (natural, earthen and concrete/armored), which had some correlation with trash conditions and therefore should be considered in selecting future sites for monitoring. Percent bank and channel cover estimates were very subjective and should be simplified in the future if used to evaluate channel roughness across a numeric scale (rather than percent for different categories). Identifying storm drain outfalls in the field is not recommended as a high priority information need, since this information is typically available in GIS. Other data types associated with site characteristics that do not appear to be useful for describing trash conditions include flow, water clarity, bank angle and sinuosity.

Assessment of trash pathways was the most subjective information collected during the visual assessments. The other/stormwater pathway was the most difficult pathway to discern, since much of the trash that appears to be worn and transported to receiving waters can be from sources other than stormwater conveyances, including illegal encampments or dumping upstream of the site. Additional guidance should be provided on how far upstream to consider illegal encampment and dumping influences, which would be helpful to standardize data collection in the future. Photographs and examples of trash from each pathway illustrated over time of decay (in addition to the guidance already developed for protocol) should be considered.

6.4 Utility of Boom Data

Trash booms are floating barriers placed in receiving water bodies to capture trash and other floating debris. Trash booms are considered partial capture devices since less buoyant trash can still be transported in the water column below the floating barrier, especially during storm events. However, much of the trash comprised of plastic and expanded polystyrene foam that enter receiving waters is primarily floatable material that is likely to get captured by trash booms. Trash data collected across the nine booms indicated that an amount of trash equivalent to 4% to 42% of the stormwater trash load was removed from the booms monitored. Thus, it appears these structures can effectively trap and remove trash that is likely associated with the stormwater pathway.

7 REFERENCES

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APPENDICES

A. Statement of Data Quality
B. Trash Condition Scores for Probabilistic sites over three sampling events (Tables B1-B2) and targeted sites over two sampling events (Table B3)
C. Trash Condition Scores for probabilistic and targeted sites for all counties (Figures C1-C5)
D. Trash densities at targeted sites (Table D1)

APPENDIX A: STATEMENT OF DATA QUALITY

A1 – Alameda County
A2 – Santa Clara and San Mateo Counties
A3 – Contra Costa County
A4 – Solano County (not included due to small number of samples)

A1 – Data Quality for Alameda County

As identified in BASMAA (2017), there are four main data quality objectives (DQOs) developed for the monitoring program to best ensure data quality: (1) representativeness, (2) comparability; (3) completeness; and (4) precision. ACCWP's activities relative to each of these four components are described briefly below:

Representativeness

Representativeness reflects the ability of data collected to represent the true condition of the sample sites. For the qualitative trash assessments, sample sites were identified through a probabilistic draw. AMS team members used site photos and GPS coordinates to return to the same basic reaches for each sampling event. In some cases, starting coordinates were shifted slightly, for example, due to difficulty in obtaining a precise GPS signal, but in each case reaches overlapped for the vast majority for each of the five sampling events. At the conclusion of each sampling day, the Monitoring Project Manager (MPM) reviewed all recorded site coordinates against targets to confirm reaches were appropriately located.

Overall assessments included three wet season events and two dry season events. All wet season sampling events were initiated only after the first significant rainfall of the year (>0.5" measured precipitation in a 24-hr period). All dry season events were targeted by ACCWP for the timeframe of July through September; due to staffing conflicts, the 2019 dry season effort extended into the first week of October 2019, but there was no significant precipitation experienced before conclusion of assessments.

Comparability

Comparability is the degree to which data can be compared both internally over time and externally to other relevant efforts. Sampling personnel assigned to conduct assessments for ACCWP were drawn from a pool of four individuals for all sampling events as a means of incorporating internal consistency across the five efforts.

Prior to conducting any assessments, ACCWP monitoring personnel participated in the BASMAA intercalibration and cross-training exercise in San José as a means of incorporating consistency with external assessors. ACCWP monitoring personnel also conducted an additional internal intercalibration exercise prior to initiation of WY2019 assessment activities.

Completeness

Completeness is defined as the percentage of valid data collected and assessed, compared to the total percentage of data expected to be obtained under normal operating conditions. The quantitative measurement quality objective (MQO) for assessing completeness of the trash monitoring effort was identified as 90%. Overall, completeness was very high, and well above the 90% threshold. The main exceptions to this were photographs inadvertently missed or that were corrupted before transferring from field cameras to long-term storage, and channel widths that were unable to be measured in the field due to non-wadeable conditions.

Precision

Precision assesses the consistency between individual measurements of a given parameter. Per BASMAA (2017), precision is assessed via replicate analyses of individual parameters at 10% of overall sampling sites. The defined MQO for precision is to achieve a relative percent difference (RPD) on individual metrics of ≤ 20%.

For ACCWP, the MPM assigned field duplicate sites prior to each sampling season. At each duplicate site, the members of the two-person field team worked together to assess the measurements and qualitative factors that required both members' participation (e.g., creek width). The two field team members then split apart and independently assessed the following factors:

- Trash condition
- Bank cover categories, by subcategory
- Channel cover categories, by subcategory
- Trash source categories, by subcategory

These FD assessments were performed at a total of 15 sites over the course of the five events. These encompass a total of 207 distinct datapoints for which replicate assessments were possible. Looking strictly at the MQO of 20% RPD, 62 of the pairs (30%) exceeded the MQO for precision. It should be noted that, due to the relatively small values reported as results for various metrics, even a small difference in reported results can generate a relatively large RPD. This suggests that an alternative MQO may be required to realistically assess precision going forward. Assessments of precision are discussed in more detail by category below.

Due to modifications made to data being collected that were put into effect between WY2018 and WY2019, the number of replicate pairs for each datapoint assessed may vary. For example, while replicate trash condition scores were recorded at all fifteen sites, the proportion of the channel containing algae was only assessed at six sites (consistent with the original WY2018 protocol and datasheets), and the proportion of armored bank cover was only assessed at nine sites (consistent with the revised protocol). For purposes of the following discussion, only categories assessed at a minimum of three events, consistent with current protocol, are described.

Trash Condition

Precision for trash condition score was assessed at a total of 15 replicate sites over the five events. Of the 15 replicate sites assessed, precision exceeded the 20% RPD MQO at 10 (67%). At 14 of the 15 sites, replicate trash condition scores represented a zero- or one-point differential, however, which would generally seem to indicate good agreement between the two assessments. In fact, scores at 9 of the 10 sites exceeding the MQO only differed by one point.

Additionally, it should be noted that in some cases a one-point differential achieves the MQO and in others it does not. For example, at ACCWP site 205R00279 visited in wet season 2020, assigned trash condition scores of 9 and 8 generated a 12% RPD, which achieved the MQO. In comparison, at site 204R00068 also assessed in wet season 2020, assigned trash condition scores of 3 and 2 generated a 40% RPD, which exceeded the MQO. With the current MQO, a one-point differential between scores of 5 or lower will automatically fail to meet the given MQO.

At the lone site that did not represent a zero- or one-point differential, 205R00686 assessed wet season 2020, the assessors' scores differed by three points. This difference appears to be a reflection of the differences in interpretation of characteristics descriptive of each trash condition category. At this site, a narrow concrete channel (approximately 6') with steep banks, fairly long stretches were mostly free of trash. However, there was one point within the reach where a hole had been cut in the surrounding chain link fence and illegal dumping had occurred, including a shopping cart and several smaller items (rope, wrappers, cans, etc.). So, the site reflected characteristics of both the moderate (i.e., all trash could be removed by two individuals within 30 minutes to one hour) and high (i.e., evidence of site being used by people) categories. This may suggest that additional thought needs to go into defining the trash condition categories to help navigate situations like this with conflicting evidence. This type of rethought could also be used to help normalize situations where two sites may reflect similar trash densities, but one would require much more cleanup effort due to larger areal extent.

Bank Cover

Assessments of bank cover are incorporated to help identify the trash capturing capability of the banks. Examining all subcategories of bank cover, 12 of 45 replicate analyses (27%) exceeded the MQO for precision (Table 1). Half of these exceedances represented a difference of ≤10% in the two measurements themselves, however.

Some of the difference between replicate assessments can be explained by uncertainty related to classification of dead and dying vegetation. Consistent with definitions used for bioassessment monitoring activities, this vegetation may be classified as exposed habitat. However, since it may serve a trash capturing function even while dead / desiccated, it may more appropriately be considered in the vegetation category. Additional clarification would likely serve to minimize this disagreement.

Table 1. Maximum Range Between Replicate Pairs and Percentage of Replicates Exceeding MQO for Individual Bank Cover Categories.

Metric	Max. Range (%)	%> MQO
Grasses	15	33
Bushes / Shrubs	35	33
Trees / Roots	0	0
Open / Exposed	45	44
Armored	5	22
Total	-	27

Channel Cover

Similar to bank cover, assessments of channel cover are incorporated to help identify the trash capturing capability within the channel itself. Examining all subcategories of bank cover, 10 of 36 replicate analyses (28%) exceeded the MQO for precision (Table 2). Similar to the case for bank cover replicates, eighty percent of these exceedances represented a difference of ≤10% in the two measurements themselves.

Table 2. Maximum Range Between Replicate Pairs and Percentage of Replicates Exceeding MQO for Individual Channel Cover Categories.

Metric	Max. Range (%)	%> MQO
Aquatic Veg	15	55
Dry Channel	15	33
Woody Debris	5	11
Open Wetted Channel	15	11
Total	-	28

Pathway Analysis

For pathway analysis, assessors are tasked with performing a subjective assessment of the trash present to evaluate its possible source based upon four identified categories. For this assessment, 15 of 60 replicate measurements (25%) exceeded the 20% MQO for precision (Table 3).

Table 3. Maximum Range Between Replicate Pairs and Percentage of Replicates Exceeding MQO for Individual Pathway Analysis Categories.

Metric	Max. Range (%)	%> MQO
Litter / Wind	90	53
Illegal Dumping	90	13
Illegal Encampment	25	13
Other / Stormwater	50	20
Total	-	25

The maximum ranges shown in Table 3 do not reflect the generally good agreement between replicate assessments of individual trash subcategories. For 50 of the 60 data pairs, the two replicate measurements fell within 5% of each other; it should be noted that for 6 of these measurements within 5% of each other, the replicate pair did not meet the MQO due to the relatively low percentages being compared. This again suggests a revised MQO may be required to assess precision effectively.

It should be noted that the 90% maximum ranges shown in Table 3 for the categories of Litter / Wind and Illegal Dumping may also be somewhat misleading. These 90% ranges were recorded at site 204R00068 in wet season 2020. At this site, the two assessors were in general agreement on trash condition (scores of 2 and 3) but differed on the source category associated with an accumulation of food-related waste within a short section of the concrete channel that appeared to originate from the adjacent commercial enterprise; one assessor associated this accumulation with litter / wind and the second assessor associated its origin was illegal dumping.

Discussion

Based on data gathered from the five ACCWP seasonal assessments completed to-date, some metrics exhibit good consistency between different observers (e.g., trash condition, encampment and dumping pathways). Other metrics do appear more difficult to assess in a consistent fashion (e.g., bank cover, litter pathway). As discussed previously, better guidance in how to characterize banks with dead or dying

vegetation may assist with removing some of the variability associated with the bank cover categories. Distinguishing between the pathway categories of litter / wind and other / stormwater may be more difficult and at this time with present guidance remains a judgment call as to what defines locally-generated litter.

Consistent among all of the precision analyses described above is that the current MQO based upon RPD between two replicate pairs is not a viable measurement of precision for this type of monitoring effort. An alternative MQO may need to be identified that incorporates ranges for each metric, for example ±1 (or similar) for trash category and ±15% (or similar) for bank cover, channel cover, and pathway.

A2 – Data Quality for Santa Clara and San Mateo Counties

Field efforts associated with the Pilot Receiving Water Trash Monitoring Program were covered under four Data Quality Objectives (DQOs) and Measurement Quality Objectives (MQOs) established within the Quality Assurance Project Plan (QAPP) to ensure that sound collection of data concerning trash loading was able to occur. Two qualitative DQO/MQOs of representativeness and comparability were put forth for the project, while two quantitative DQO/MQOs of completeness and precision were also established. The quantification of trash loading is an inherently variable data type with respect to spatial and temporal characteristics, and the significant use of human judgment in associated trash data collection can increase the potential for bias. Given this, it was of importance to ensure effective training and consistent data collection principles so that the data quality goals encompassed within the four DQO/MQOs could be achieved.

Before monitoring began in November of 2017, trainings were conducted for all staff involved in associated field efforts. This involved staff developing individual familiarity of the monitoring protocol and then rehearsing all components of the protocol in a routine field setting. The purpose of the trainings was to ensure that each member of a given field crew would be able to use the monitoring protocol to successfully collect all necessary data in the same manner as all other field crews and field crew members. The trainings also gave staff the opportunity to clarify any potential discrepancies within their or others' understanding of the protocol.

Throughout the monitoring period from November of 2017 to March of 2020, inter-calibration and field data duplication activities were orchestrated. These events allowed field staff to maintain consistency regarding execution of the protocol, discuss any questions pertaining to the protocol that had developed during previous project monitoring efforts, and generate field data based on each monitoring component to demonstrate achievement of the DQO/MQOs. Each scheduled inter-calibration and data duplication exercise involved two or more field crews that met at a series of receiving water sites to conduct the monitoring on an individual crew basis and compare the results between crews after finishing the monitoring for each site. During inter-calibration and duplication events, the members of each crew were interchanged on a site-by-site basis so that all possible crew member combinations were examined to ascertain bias or difficulty with protocol execution.

The following is a list of the training events that took place over the course of the monitoring period:

Date	Event Type	Agency
10/23/2017	Training	Santa Clara/San Mateo
1/25/2018	Training	Santa Clara/San Mateo
3/13/2018	Training	Santa Clara
3/28/2018	Training	San Mateo

Fifteen field inter-calibration and duplicate events in both Santa Clara and San Mateo County took place during the monitoring period, constituting 10% of the total sites sampled. The following table shows the calculated relative percent differences (RPDs) between the original and duplicate trash scores generated at the duplicate sites:

County	Site	Date	Orig. Num. Grade	Dup. Num. Grade	RPD (%)	Orig. Letter Grade	Dup. Letter Grade	RPD (%)
SC	282	7/23/2019	8	7	13	C	C	0
SC	346	7/23/2019	5	5	0	B	B	0
SC	659	7/23/2019	6	7	15	B	C	40
SC	90	7/23/2019	3	2	40	A	A	0
SC	154	7/23/2019	4	5	22	B	B	0
SC	538	7/30/2019	6	6	0	B	B	0
SC	26	7/30/2019	6	4	40	B	B	0
SC	586	7/30/2019	2	2	0	A	A	0
SC	714	7/30/2019	4	5	22	B	B	0
SC	67	2/13/2020	6	5	18	B	B	0
SC	234	2/13/2020	1	2	67	A	A	0
SC	259	2/13/2020	11	11	0	D	D	0
SC	355	2/13/2020	6	4	40	B	B	0
SC	554	2/13/2020	2	2	0	A	A	0
SC	627	2/13/2020	7	7	0	C	C	0
SM	180	7/25/2019	2	3	40	A	A	0
SM	436	7/25/2019	2	2	0	A	A	0
SM	807	7/25/2019	5	6	18	B	B	0
SM	884	7/25/2019	4	4	0	B	B	0
SM	1460	7/25/2019	1	2	67	A	A	0
SM	2228	7/25/2019	1	2	67	A	A	0
SM	232	8/1/2019	7	6	15	C	B	40
SM	520	8/1/2019	5	6	18	B	B	0
SM	1256	8/1/2019	2	2	0	A	A	0
SM	520	2/6/2020	5	5	0	B	B	0
SM	1288	2/6/2020	5	4	22	B	B	0
SM	1972	2/6/2020	4	4	0	B	B	0
SM	2056	2/6/2020	6	6	0	B	B	0
SM	2248	2/6/2020	8	8	0	C	C	0
SM	2548	2/6/2020	7	5	33	C	B	40

As shown in the table, the RPDs calculated from duplicate samples taken over the course of the monitoring period were generally low, with eight RPDs exceeding the commonly used threshold of 20% when calculated from numeric trash grades and three exceeding 20% when calculated from letter trash grades. The relatively low RPD values indicate that the DQO/MQO involving sample precision was achieved. The implementation of inter-calibration and data duplication activities in addition to the thorough trainings at the beginning of the program allowed for data representativeness, comparability, completeness, and precision to be maximized during the monitoring period as per the requirements of the DQO/MQOs.

A3 – Data Quality for Contra Costa County

Data Quality Objectives (DQOs) were established by the BASMAA Trash Monitoring Program Plan to ensure that data collected is sufficient and of adequate quality for the intended use. DQOs include both quantitative and qualitative assessment of the acceptability of data. The qualitative goals included representativeness and comparability, and the quantitative goals include completeness and precision. Measurement Quality Objectives (MQOs) are the acceptance thresholds or goals for the data (BASMAA, 2017).

Information and data collected on trash are quantified using personnel trained in the characterization and classification of trash data. DQOs have a strong emphasis on training and oversight, with inter-comparisons between performance of individual field team members participating in the various assessment and characterization efforts.

Table 1. CCCWP Training Events

Date	Event Type	Agency
9-13-18	Inter-Agency Training	ACCWP/CCCWP/SCVURPPP/SMCWPPP
1-26-18	Inter-Agency Calibration	ACCWP/CCCWP
7-12-18	Quantitative Training	CCCWP

The following DQOs and MQOs were established by the BASMAA Trash Monitoring Program Plan:

1. The representativeness of data is the ability of the sampling locations and the sampling procedures to adequately represent the true condition of the sample sites. Representativeness of the sampling event is ensured by sampling within the established assessment area and specified timeframe. The MQOs for sampling event representativeness are measured by proximity to the site location.

Trash surveys were conducted only within the defined assessment area as specified in the Program Plan and ensured by the Field Crew Supervisor. Wet and Dry season assessment requirements were met for all 30 Contra Costa County probabilistic/qualitative sites and 19 Dry season targeted qualitative and quantitative assessments.

2. Comparability is the degree to which data can be compared directly to other relevant studies. The MQOs will rely on training and oversight of the Monitoring Program Manager, Field Crew Supervisor, and Field Crew Members to follow field sampling protocols to ensure comparability with other studies that utilize similar protocols.

All field crew members were trained in methods, procedures and field sampling protocols (see Table 1).

3. Completeness is defined as the percentage of valid data collected and analyzed compared to the total expected to be obtained under normal operating conditions. For qualitative visual assessments, the objective is to conduct one assessment in each 300-foot segment in the assessment area for each site. An overall completeness of greater than 90% of the assessment area segments is considered acceptable for the Receiving Water Trash Monitoring Program. The Field Crew Supervisor should check both qualitative and quantitative data collection forms to make sure they are complete and accurately filled out, prior to leaving the site. Additionally, following quantitative monitoring events, the Field Crew Supervisor should

check the site to make sure that the vast majority of the trash present was removed from the assessment area. Photographs of the site after the cleanup has occurred should also be taken.

Field Crew Supervisors checked the completeness of all field logs and photo documented each site prior to departure. Before and after photos were taken at all 19 quantitative assessment sites, and the Field Crew Supervisor walked the length of the 300-foot reach following each assessment in order to determine completeness and remove any additional trash found within the assessment area.

4. For qualitative visual assessments, precision will be evaluated at 10% of the assessment events conducted by a Stormwater Program. The events should be randomly picked by the Monitoring Program Manager. Precision will be measured by comparing the assessment data collected by the Field Crew Supervisor overseeing the event and the data collected (in parallel) during the event by the Monitoring Program Manager or second Field Crew Supervisor.

For quantitative monitoring events, precision will also be evaluated at 10% of quantitative events conducted by each Stormwater Program. The events should be randomly picked by the Monitoring Program Manager. Monitoring data collected by the Field Crew Supervisor overseeing the quantitative event and the data collected (in parallel) during the event by the Monitoring Program Manager or second Field Crew Supervisor will be compared.

A target relative percent difference between qualitative data points or quantitative measurements (measured in parallel by separate individuals) is < 20%. Additionally, the accuracy in the reporting of crew members and Field Crew Supervisors on field data sheets is very important. All individuals present at the site and participating in the qualitative assessment of qualitative monitoring events should be recorded.

Field crews in Contra Costa County conducted 15 duplicate assessments in order to evaluate precision at a 10% frequency during the Trash Monitoring Program. Calculating Relative Percent Difference results in the magnitude of scores being compared; effecting the calculated RPDs. For continuous data, this is appropriate; for ordinal data, it is a different matter. For example, the RPD of 1 and 2 is 67% while that for 10 and 11 is 10%. Here, the example scores both differ by one unit yet one pair's RPD is less than "commonly used threshold of 25." To more accurately represent the level of precision at which blind duplicate scores are being assessed, a Percent Difference in score has been calculated based on the 12-point grading system, that is [(original score) – (duplicate score)/12] x (100).

Table 2. Duplicate Assessment Scores

County	Site	Date	Orig. Num. Grade	Dup. Num. Grade	Percent Difference (%)	Orig. Letter Grade	Dup. Letter Grade	RPD (%)
CC	388	1/23/2019	2	2	0.0	A	A	0
CC	727	1/24/2019	3	3	0.0	A	A	0
CC	919	1/24/2019	3	2	8.3	A	B	40
CC	880	6/19/2019	4	5	8.3	A	B	40
CC	631	7/17/2019	4	5	8.3	B	B	0
CC	281	7/18/2019	4	3	8.3	B	A	0
CC	395	7/31/2019	3	3	0.0	A	A	0
CC	388	8/28/2019	2	3	8.3	A	A	0
CC	891	8/28/2019	2	2	0.0	A	A	0
CC	27	1/14/2020	3	4	8.3	A	B	40
CC	247	1/14/2020	2	2	0.0	A	A	0
CC	503	1/14/2020	4	6	16.7	B	B	0
CC	843	1/22/2020	1	1	0.0	A	A	0
CC	395	1/22/2020	1	2	8.3	A	A	0
CC	567	1/22/2020	5	6	8.3	B	B	0

APPENDIX B: TRASH CONDITION SCORES AT PROBABILISTIC AND TARGETED SITES

Trash Condition Scores at Probabilistic Sites

Table B1 presents the cumulative distribution results of trash condition scores during each of five events for the entire regional dataset. Table B2 presents the trash condition scores observed at each site during each of the sampling events.

Across all five events, streams exhibited trash condition scores of 1 or 2 (27-38%) and 4 or 5 (20-28%). Less than 30% of the stream length had a condition score of 7 or higher during each of the 2018, 2019, or 2020 wet seasons (22%, 24%, 26%, respectively), and only 15% of the stream length had a score of 7 or higher during each of the dry events.

Table B1. Proportion of stream lengths with different average trash condition scores based on the five sets of observations at 125 sites within the five participating MRP counties. Condition categories are represented as follows: Low (green); Moderate (yellow); High (red) and Very High (purple).

Season	WY 2018 Wet Season	WY 2018 Dry Season	WY 2019 Wet Season	WY 2019 Dry Season	WY 2020 Wet Season
Event	1	2	3	4	5
Trash Condition Score	Percent of Stream Length (± 95% C.I.)				
1	18% (6%)	15% (5%)	15% (5%)	10% (5%)	15% (5%)
2	20% (7%)	22% (7%)	17% (7%)	24% (7%)	12% (7%)
3	9% (7%)	16% (7%)	14% (7%)	13% (6%)	14% (7%)
4	14% (7%)	10% (7%)	13% (7%)	11% (6%)	10% (6%)
5	11% (7%)	10% (7%)	11% (7%)	17% (6%)	18% (7%)
6	6% (6%)	11% (5%)	7% (6%)	11% (5%)	6% (6%)
7	10% (5%)	6% (4%)	8% (6%)	5% (4%)	10% (5%)
8	7% (3%)	6% (2%)	6% (5%)	7% (2%)	7% (4%)
9	2% (2%)	2% (1%)	5% (3%)	2% (1%)	6% (2%)
10	3% (0%)	1% (0%)	3% (2%)	1% (0%)	2% (1%)
11	0% (0%)	0% (0%)	2% (0%)	0% (0%)	1% (0%)
12	0% (0%)	0% (0%)	0% (0%)	0% (0%)	0% (0%)

Table B2. Trash condition scores at probabilistic sites over five sample events. Condition categories are represented as follows: Low (green); Moderate (yellow); High (red) and Very High (purple).

Site ID	Event 1	Event 2	Event 3	Event 4	Event 5
202R00284	2	5	4	5	5
202R01308	9	8	4	6	5
202R01356	1	1			
202R01612	1	1	1	1	1
202R02332			7	6	5
204R00020	4	4	2	2	1
204R00047	1	2	2	2	3
204R00068	3	3	2	3	3
204R00084	1	2	4	3	3
204R00100	5	2	3	3	3
204R00180	2	2	3	2	3
204R00191	7	5	3	5	1
204R00200	7	7	9	8	9
204R00232	6	8	5	7	7
204R00244	1	1	1	3	1
204R00292	3	2	2	2	2
204R00303	10	5	8	8	8
204R00327	6	6	6	4	6
204R00334	2	2	4	5	4
204R00340	2	2	4	3	4
204R00356	5	2	7	2	3
204R00367	1	2	2	2	2
204R00383	5	3	4	6	5
204R00388	2	3	2	2	2
204R00391	7	6	7	7	8
204R00436	2	4	3	2	5
204R00447	1	2	2	2	1
204R00473	1	2	2	1	2
204R00520	5	4	4	5	5
204R00575	7	4	5	8	8
204R00583	9	3	9	7	7
204R00596	8	3	9	5	6
204R00639	10	5	11	10	12
204R00680	7	9	9	8	9
204R00711	4	3	6	6	5

Site ID	Event 1	Event 2	Event 3	Event 4	Event 5
205R00259	10	11	10	10	11
205R00279	8	7	9	5	9
205R00282	4	3	9	8	7
205R00346	5	6	6	5	7
205R00355	5	5	6	6	6
205R00374	3	4			
205R00387	4	1	3	3	2
205R00419	2	2	2	3	2
205R00430	2	2	2	2	3
205R00451	10	9	11	11	11
205R00474	5	6	5	5	5
205R00535	5	3	3	5	6
205R00538	6	7	7	6	5
205R00547	1	3	1	2	1
205R00554	2	6	3	4	2
205R00586	1	2	2	2	1
205R00602	3	2	7	3	5
205R00622	3	3	2	2	3
205R00627	6	3	7	6	7
205R00659	7	5	7	6	9
205R00686	1	3	2	2	4
205R00707	4	5	4	6	5
205R00714			4	4	7
205R00872	1	1			
205R00878	5	5	4	5	4
205R00984	1	3	1	2	1
205R01704	2	2	3	2	3
205R01816	1	1	1	1	1
205R02408			1	1	1
206R00727			3		1
206R00919	3	1	3	4	3
206R00960	3	2	2	3	5
206R01024	4	2	3	2	2
206R01495	2	2		1	
207R00027	2	2	3	2	3

Site ID	Event 1	Event 2	Event 3	Event 4	Event 5
204R00712	8	8	8	7	7
204R00807	4	7	1	5	2
204R00831	7	6	7	5	7
204R00852	1	1	2	2	1
204R00884	6	4	5	4	5
204R01012	4	2	2	4	3
204R01256	6	4	6	2	6
204R01268	2	6	2	4	2
204R01288	4	2	6	5	5
204R01460	3	2	2	1	3
204R01972	4	4	3	5	4
204R02056	6	8	5	8	6
204R02228	1	2	1	1	2
204R02248	6	7	8	7	8
204R02312	8	7	8	6	8
204R02504	5	3	4	5	5
204R02548	7	6	4	6	7
205R00026	4	4	8	6	7
205R00035	5	7	7	8	7
205R00042	4	5	5	5	5
205R00067	5	6	5	5	6
205R00090	4	4	5	3	4
205R00099	4	6	5	3	4
205R00110	2	4	3	5	4
205R00115	7	6	8	8	8
205R00131	8	5	6	7	8
205R00154	7	3	6	4	8
205R00218	5	5	7	6	9
205R00227	2	6	4	4	5
205R00234	2	2	3	1	1
205R00241	2	3	5	4	5

Site ID	Event 1	Event 2	Event 3	Event 4	Event 5
207R00247	1	1	1	1	2
207R00395	5	5	4	3	4
207R00428	8	8	10		9
207R00476	8	7	10		5
207R00503	1	1	1	1	4
207R00567	2	3	5	5	5
207R00619	1	1	1	2	3
207R00631	7	5	5	4	7
207R00688	4	2	4		4
207R00823	2	1	1	5	1
207R00843	3	1	1	2	1
207R00880	4	3	5	3	9
207R00891	2	1	2	2	2
207R01163	9	8	10	3	5
207R01227	2	1	1	2	2
207R01271	1	1	1	1	1
207R01291	8	8	5	4	7
207R01447	2	2	3	2	4
207R02480	1	1	1		1
207R03504	2	1	1		1
543R00137	2	2	2	2	3
544R00025	2	3	1	2	3
544R00281	4	4	6	4	5
544R00342	8	6	4	1	3
544R00464	7	6	3	3	3
544R00598	3	1	3	2	1
544R01049	1	3	1	2	2
544R01305	3	4	8	3	8

Trash Condition Scores at Targeted Sites

Comparison of the trash condition scores for targeted sites by monitoring event suggests the majority of streams in the MRP urban area exhibit low to moderate levels of trash, with some sites in High and Very High condition. Table B3 presents the trash condition scores observed at each site during both of the sampling events. Of the 100 sites, 40% scored in the same condition category during both events, trash condition category increased in 40% of the sites between events, and 20% decreased in trash condition category between the two events.

Across both events, streams exhibited trash condition scores of 3 or 4 (24-28%) and 5 or 6 (25-27%). Less than 25% of the sites had a condition score of 9 or higher during each dry season (14% and 23%, respectively).

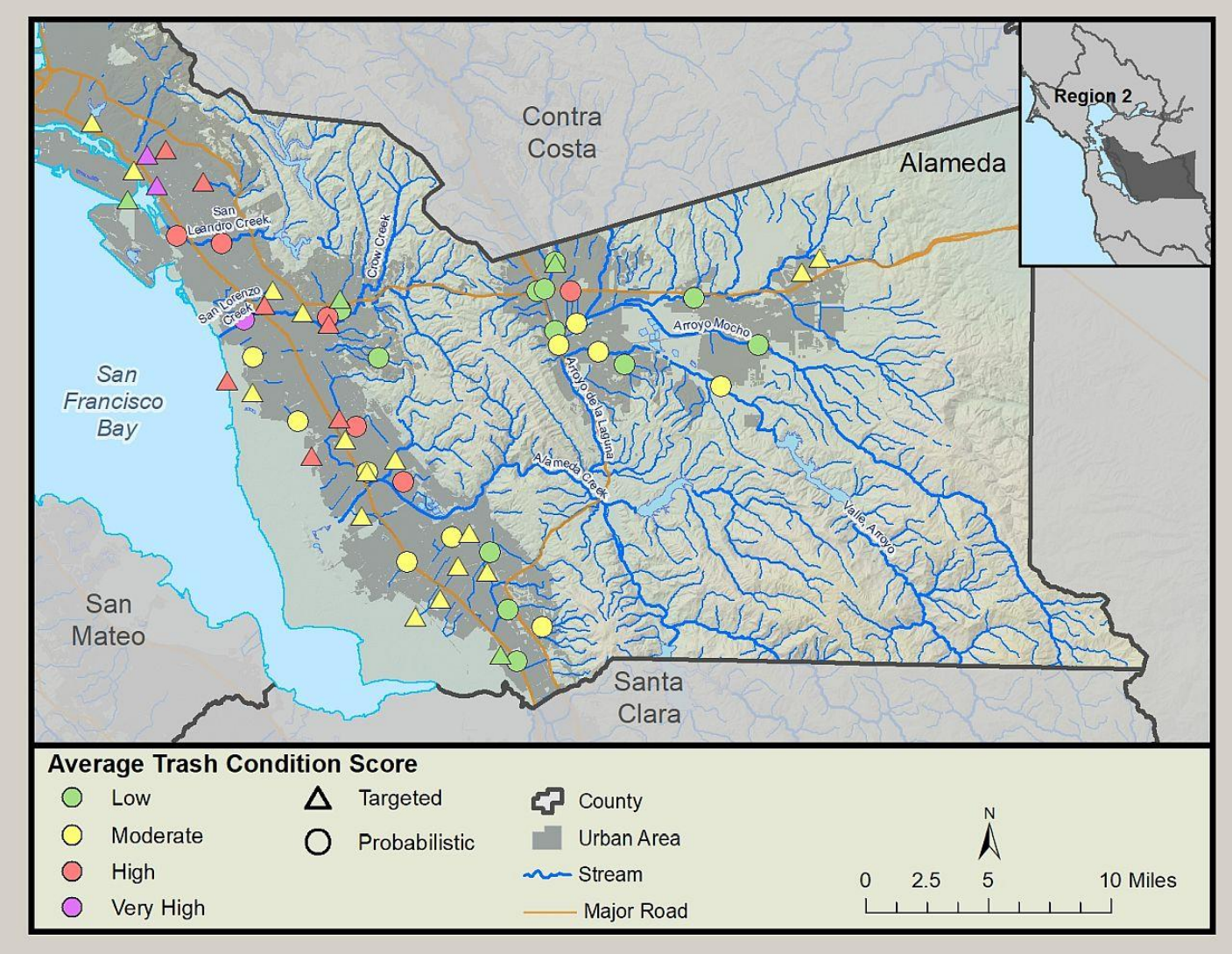
Table B3. Trash condition scores at targeted sites over two sample events. Condition categories are represented as follows: Low (green); Moderate (yellow); High (red) and Very High (purple).

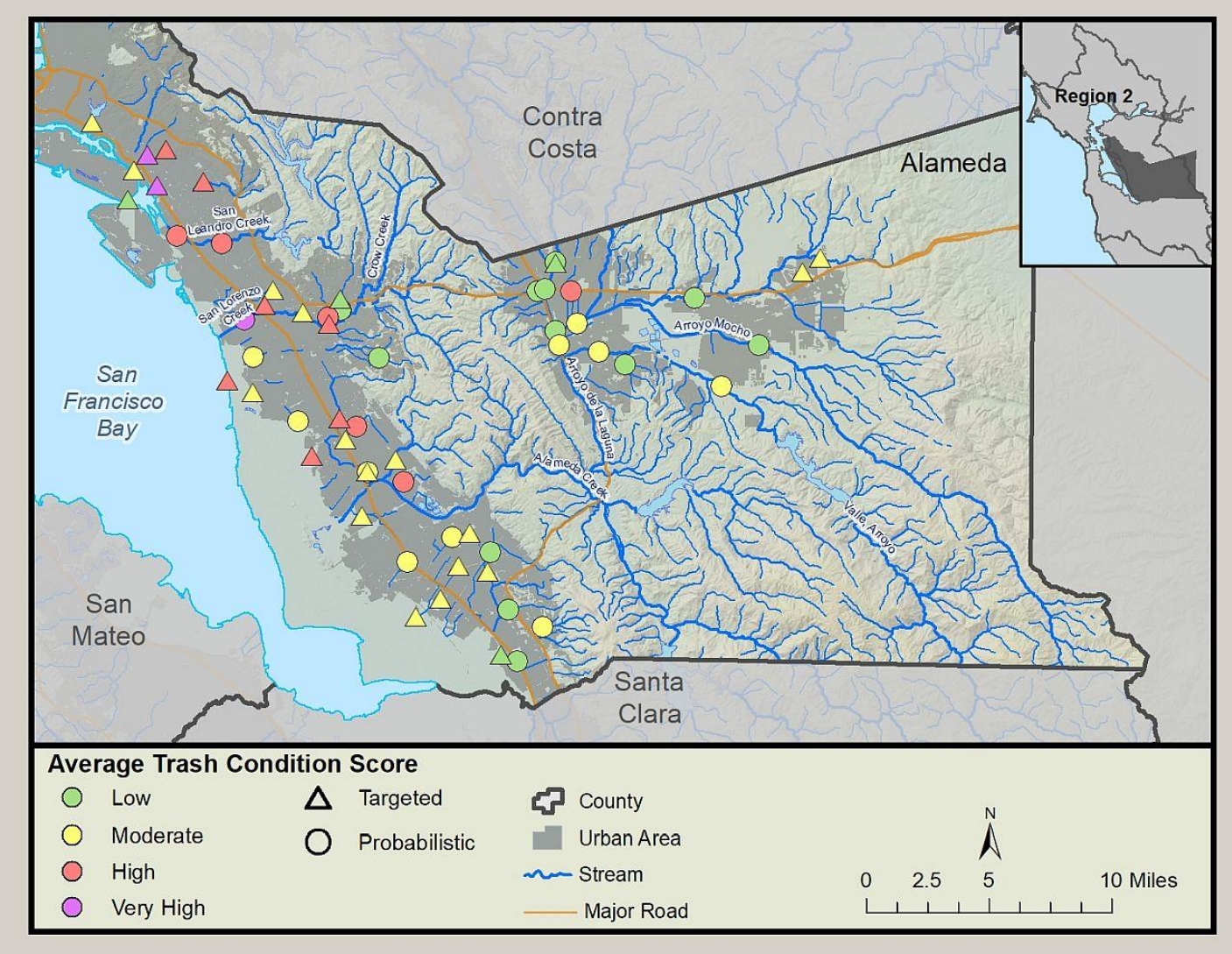
Site ID	Event 2	Event 4	Site ID	Event 2	Event 4
ACF_5C_1	6	6	ORI_01	4	5
ACF_5D_1	6	4	PAC01	2	2
ACF_CAL_1	2	3	PIN_01	3	4
ACF_WAR_1	7	9	PIT_01	6	7
ACF_WAR_2	3	10	PIT_04	10	8
ALA_CAS_1	2	2	PLH_01	6	8
ALA_CHA_1	6	8	RCY01	9	10
ALA_EST_1	6	3	RCY03	5	3
ALA_SAN_2	3	11	RIC_01	4	11
ALA_SAN_3	3	8	SCC02	5	5
ALA_SEM_2	9	10	SCC03	6	3
ALA_SITE3	2	4	SCF02	9	9
ANT_04	4	6	SCL01	4	2
BEL01	5	4	SCL02	1	1
BRE_02	2	3	SCL03	2	2
BRI02	3	5	SCP02	10	10
BUR01	5	8	SCS01	4	3
CCC_SF_2	8	3	SJC01A	10	10
CLA_01	7	7	SJC02	10	10
CON_01	5	4	SJC10	6	8
CUO01	3	1	SJC15A	4	7
CUO02	1	1	SJC18	8	11
DAN_01	1	3	SJC22A	7	4
DCY02	4	3	SJC23	10	8
DCY04	6	6	SJC25B	9	3
DUB_ALA_1	2	3	SJC29	6	9
ELC_01	3	5	SJC30	5	9
FF01	10	10	SJC31	8	12
FF03	4	6	SMO01	7	6
FF04	6	7	SMO03	9	10
FRE_CRAN_1	2	7	SNV_01	4	4
FRE_LAG_3	6	6	SNV_02	4	9
FRE_LAG_5	6	6	SPB_01	5	6
FRE_TULE_7	4	8	SRM_02	2	2
HAY_ACF_1	5	7	SSF01	7	7

Site ID	Event 2	Event 4
HAY_DEP_3	3	6
HAY_SFB_7	4	12
HMB01	7	5
LIV_ALP_1	3	5
LIV_ALT_1	2	5
LOA_01	2	3
MIP-01	9	3
MIP-05	8	7
MOR_01	4	2
MOV_01	4	5
MOV_02	3	4
MTZ_01	7	5
OAK_01	4	4
OAK_ARR_1	6	10
OAK_COU_1	5	11
OAK_LMC_1	2	6
OAK_PER_1	11	10
OAK_SAU_2	4	6

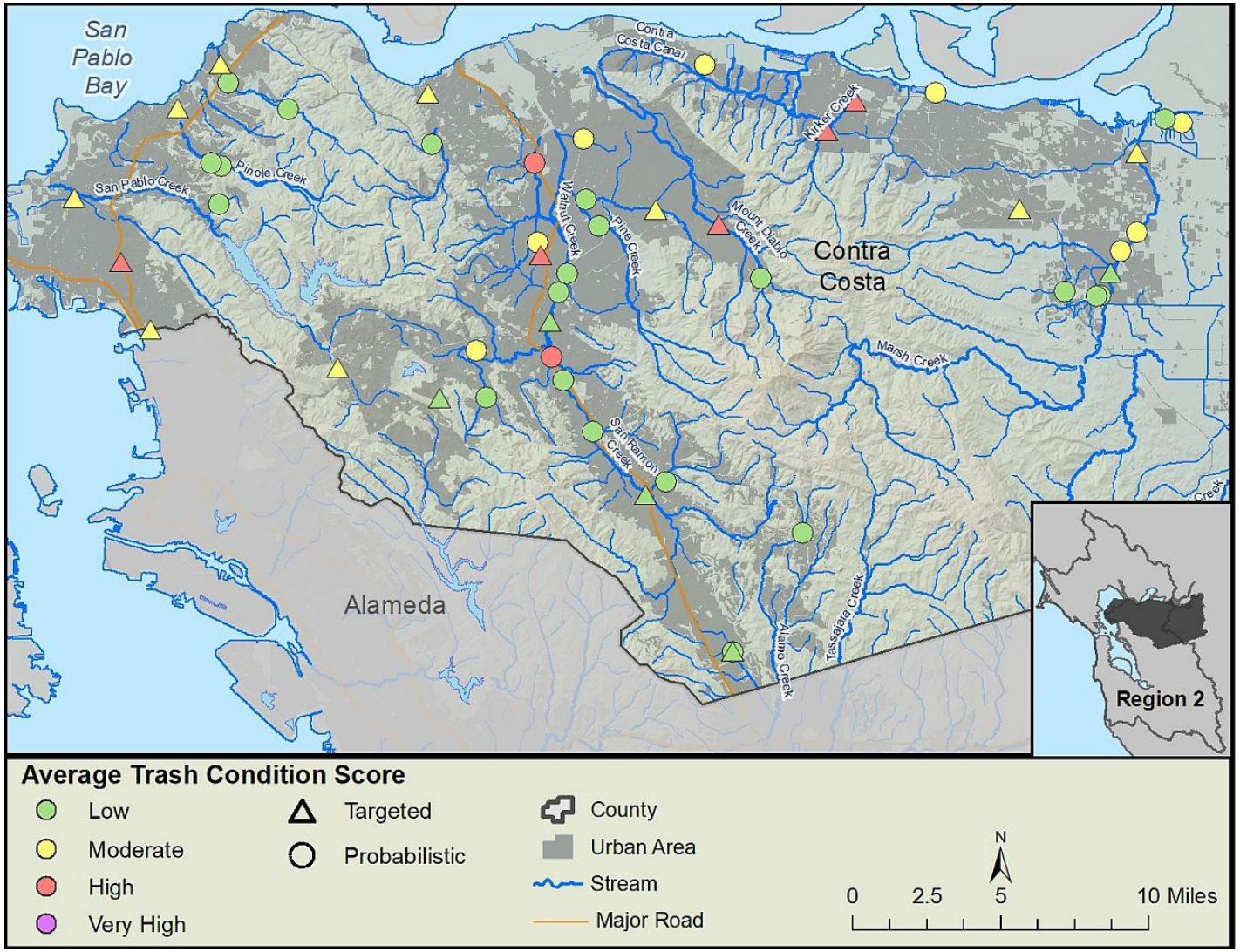
Site ID	Event 2	Event 4
SWD_06	7	11
SWD_07	6	5
SWD_08B	9	6
SWD_13	2	6
SWD_19	5	10
UNI_DRY_1	3	7
UNI_OAC_2	2	5
VA01	3	6
VA02	5	3
WCR_02	3	3
WVC02	5	2
WVC03	2	2

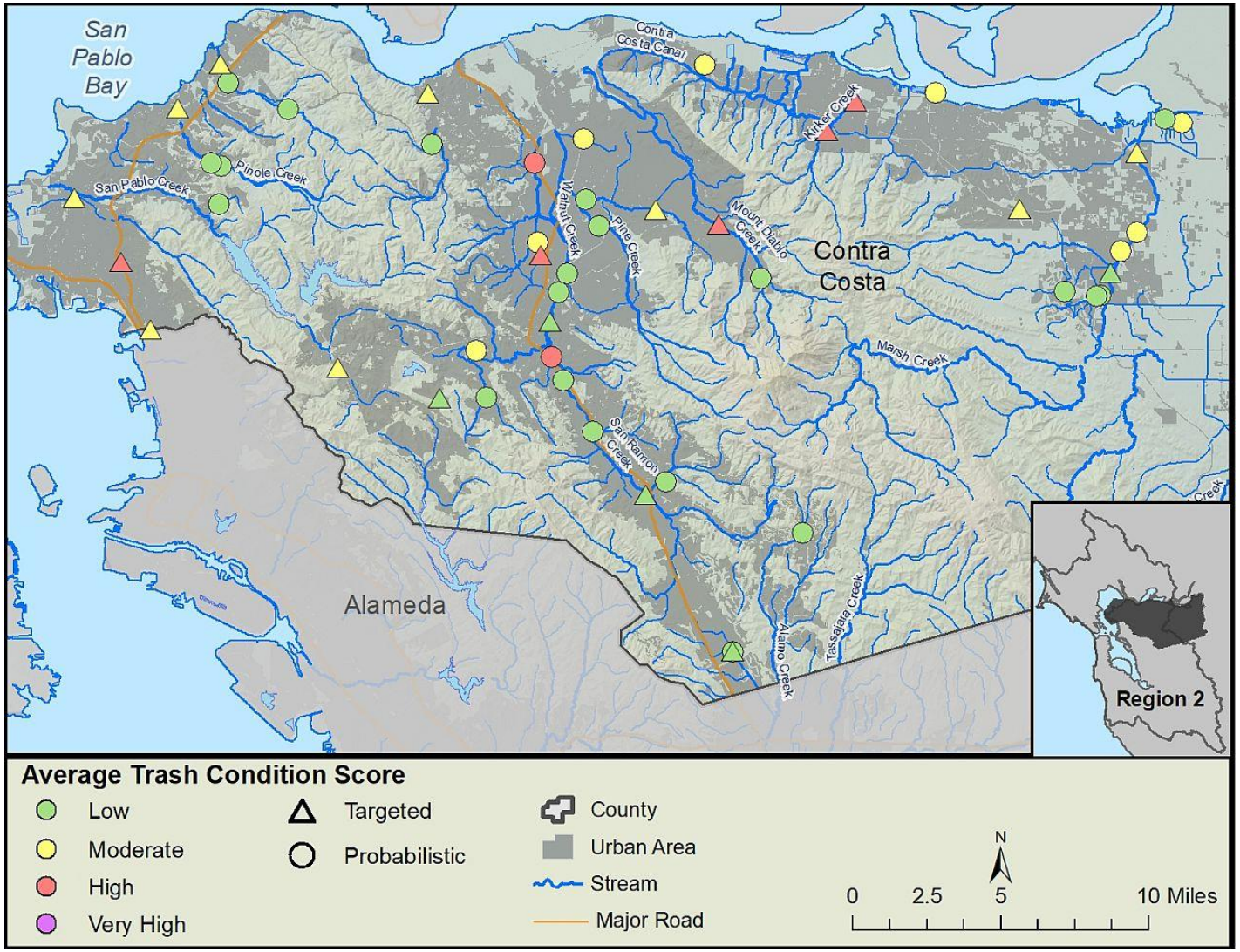
APPENDIX C: TRASH CONDITION CATEGORY FOR PROBABILISTIC AND TARGETED SITES FOR EACH COUNTY


Region 2
Contra Costa
Alameda
San Francisco Bay
San Mateo
Santa Clara
San Leandro Creek
San Lorenzo Creek
Crow Creek
Arroyo Mocho
Arroyo de la Laguna
Alameda Creek
Valle Arroyo
Average Trash Condition Score
Low
Moderate
High
Very High
Targeted
Probabilistic
County
Urban Area
Stream
Major Road
N
0 2.5 5 10 Miles

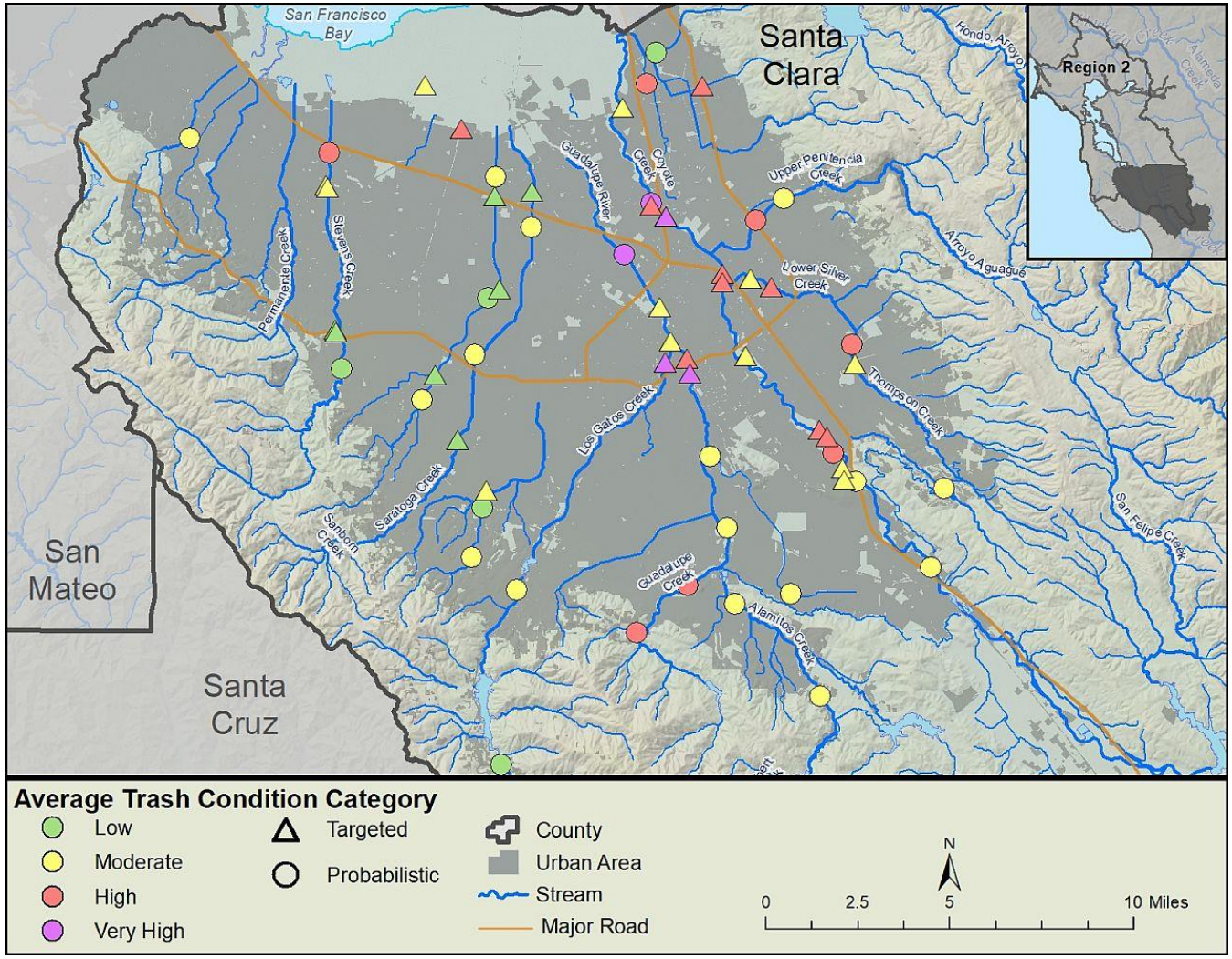


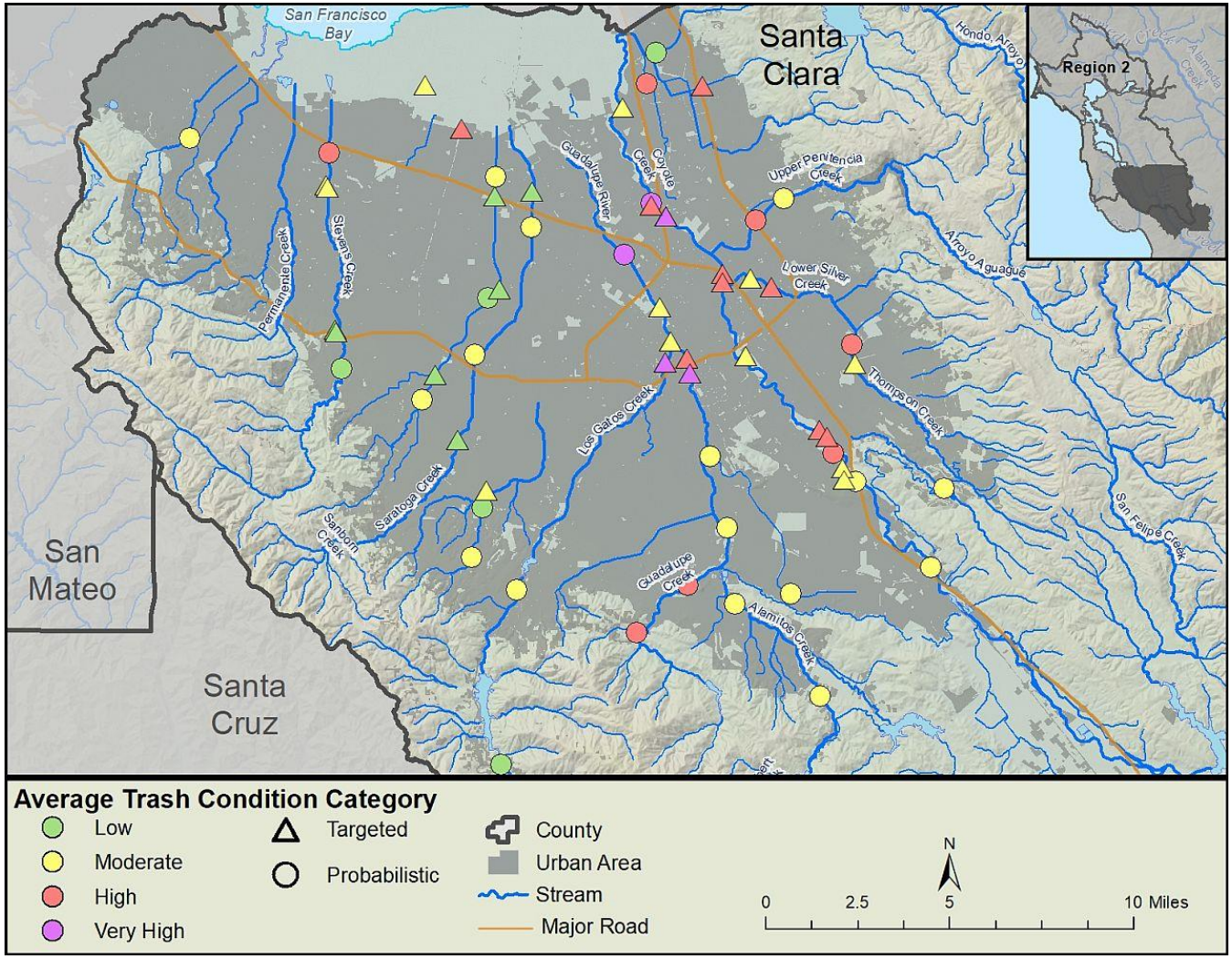
C.1 Average trash condition of probabilistic and targeted sites in Alameda County.


San Pablo Bay
Contra Costa Canal
Kirker Creek
Pinole Creek
San Pablo Creek
Walnut Creek
Pine Creek
Mount Diablo Creek
Contra Costa
Marsh Creek
San Ramon Creek
Alameda
Tassajara Creek
Alamo Creek
Region 2
Average Trash Condition Score
Low
Moderate
High
Very High
Targeted
Probabilistic
County
Urban Area
Stream
Major Road
N
0 2.5 5 10 Miles

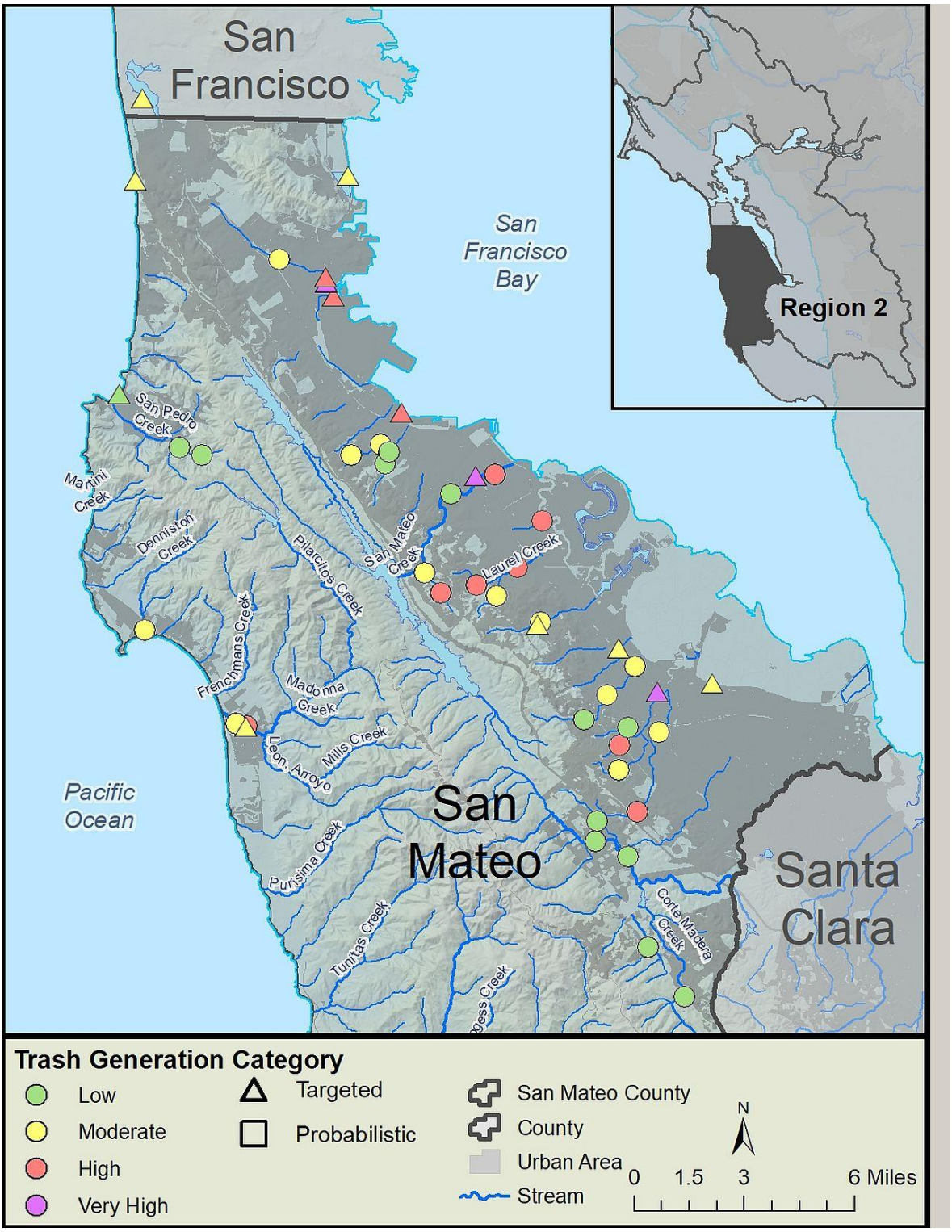


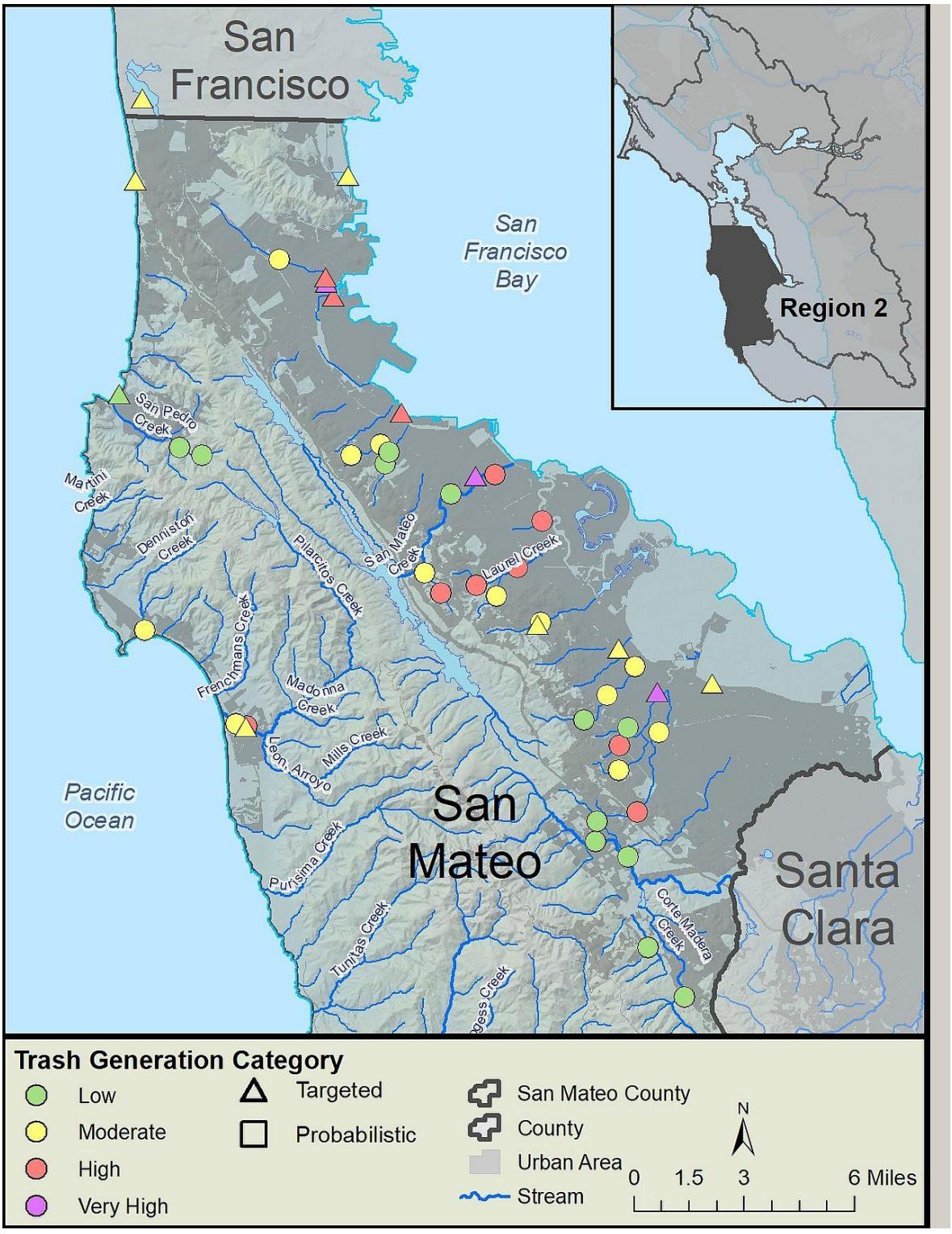
C.2 Average trash condition of probabilistic and targeted sites in Contra Costa County.


San Francisco Bay
Santa Clara
San Mateo
Santa Cruz
Region 2
Hondo Arroyo
Upper Penitencia Creek
Coyote Creek
Guadalupe River
Stevens Creek
Permanente Creek
Lower Silver Creek
Arroyo Aguague
Thompson Creek
Los Gatos Creek
Saratoga Creek
Sanborn Creek
Guadalupe Creek
Alamitos Creek
San Felipe Creek
Average Trash Condition Category
Low
Moderate
High
Very High
Targeted
Probabilistic
County
Urban Area
Stream
Major Road
N
0
2.5
5
10 Miles

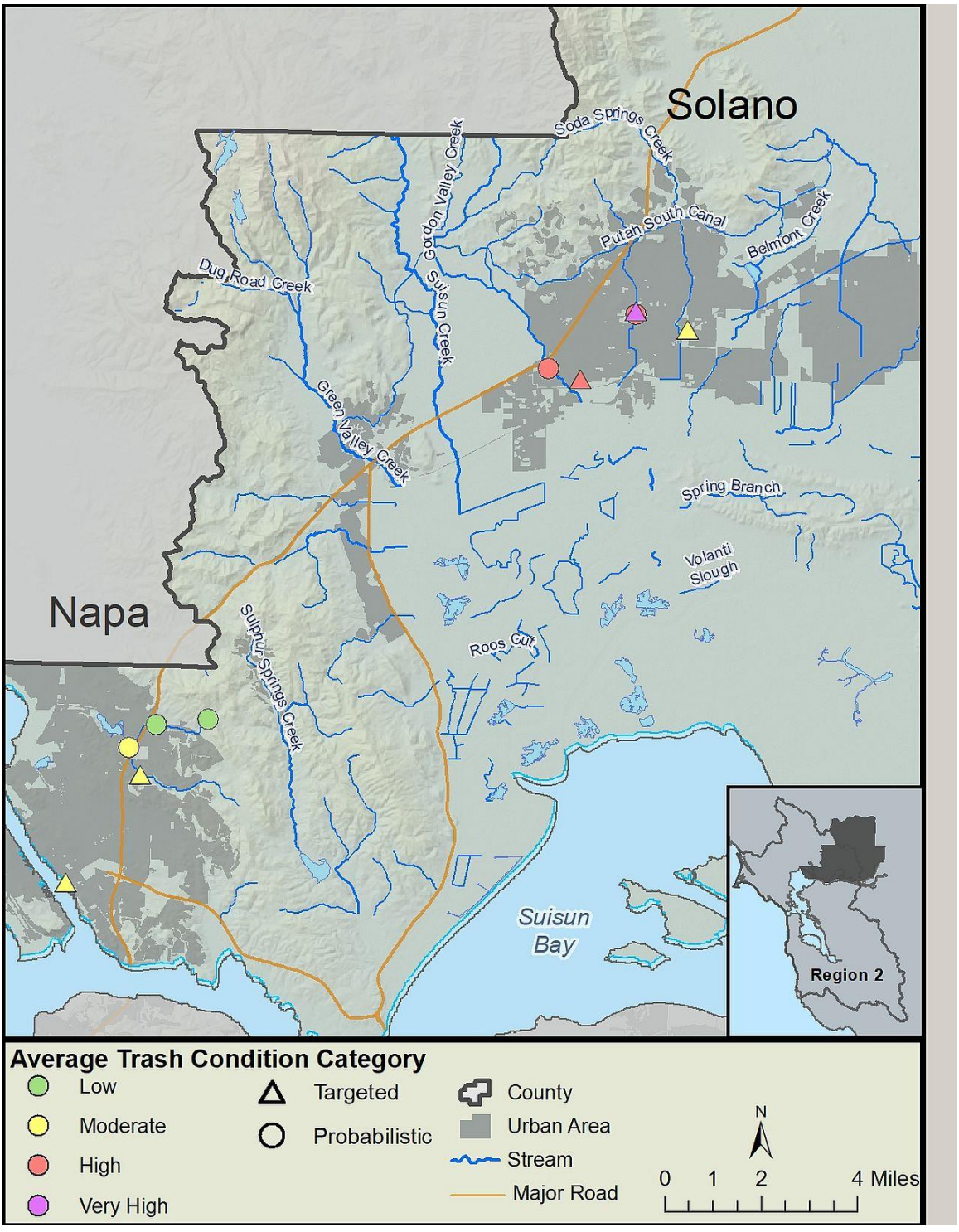


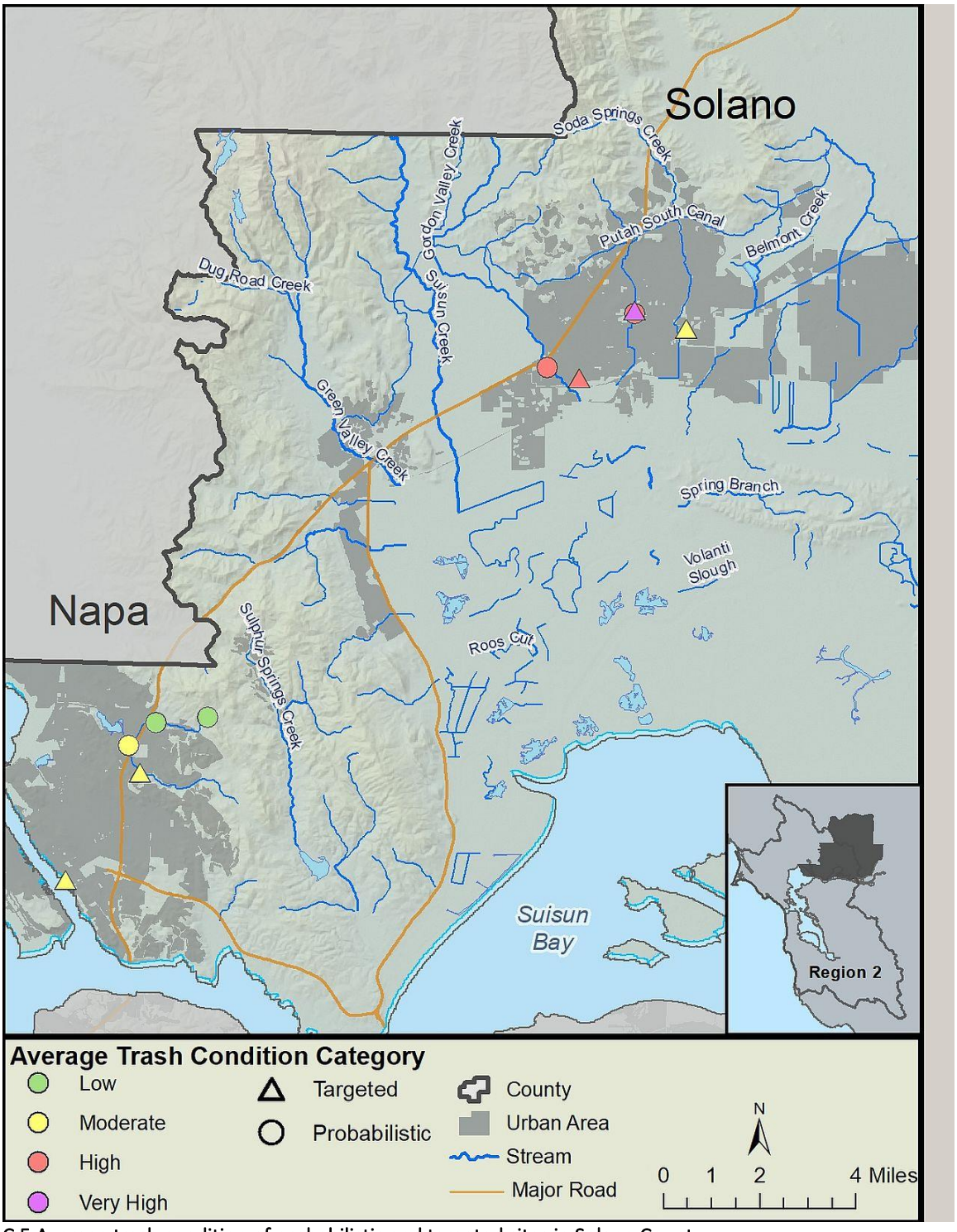
C.3 Average trash condition of probabilistic and targeted sites in Santa Clara County.


San Francisco
San Francisco Bay
Region 2
San Pedro Creek
Martini Creek
Denniston Creek
Pilarcitos Creek
San Mateo Creek
Laurel Creek
Frenchmans Creek
Madonna Creek
Mills Creek
Leon Arroyo
Pacific Ocean
San Mateo
Purisima Creek
Tunitas Creek
Corte Madera Creek
Santa Clara
Trash Generation Category
Low
Moderate
High
Very High
Targeted
Probabilistic
San Mateo County
County
Urban Area
Stream
N
0 1.5 3 6 Miles



C.4 Average trash condition of probabilistic and targeted sites in San Mateo County.


Solano
Napa
Soda Springs Creek
Gordon Valley Creek
Putah South Canal
Belmont Creek
Dug Road Creek
Suisun Creek
Green Valley Creek
Spring Branch
Volanti Slough
Roos Cut
Sulphur Springs Creek
Suisun Bay
Region 2
Average Trash Condition Category
Low
Moderate
High
Very High
Targeted
Probabilistic
County
Urban Area
Stream
Major Road
N
0 1 2 4 Miles



C.5 Average trash condition of probabilistic and targeted sites in Solano County.

APPENDIX D: TRASH VOLUME AT TARGETED SITES

Table D1. Trash volume and density at targeted sites during two sampling events. Qualitative assessment trash condition scores are provided for comparison.

SiteID	Event 1 (2018)			Event 2 (2019)			Site Average	
	Trash Volume (gallons)	Trash Density (gallons/ft2)	Condition Score	Trash Volume (gallons)	Trash Density (gallons/ft2)	Condition Score	Volume (gallons)	Density (gallons/ft2)
ACF_5C_1	20	0.0045	6	54.9	0.0122	6	37.45	0.017
ACF_5D_1	40	0.0035	4	15	0.0010	4	27.5	0.005
ACF_CAL_1	35	0.0056	2	3	0.0055	32.5	19	0.011
ACF_WAR_1	129.8	0.0197	7	62.4	0.0088	9	96.1	0.028
ACF_WAR_2	20	0.0004	3	30	0.0005	10	25	0.001
ALA_CAS_1	99.8	0.0416	2	5	0.0022	2	52.4	0.044
ALA_CHA_1	22.5	0.0044	6	57.5	0.0122	8	40	0.017
ALA_EST_1	119.8	0.0312	6	3.8	0.0009	3	61.8	0.032
ALA_SAN_2	79.8	0.0266	3	115	0.0103	11	97.4	0.037
ALA_SAN_3	82.3	0.0274	3	142.4	0.0137	8	112.35	0.041
ALA_SEM_2	70	0.0059	9	107.4	0.0087	10	88.7	0.015
ALA_SITE3	17.5	0.0011	2	12.5	0.0014	4	15	0.003
ANT_04	42.5	0.0047	4	25.3	0.0028	6	33.9	0.007
BEL01	1	0.0005	5	3	0.0015	4	2	0.002
BRE_02	12.5	0.0011	2	12.5	0.0011	3	12.5	0.002
BRI02	15	0.0008	3	55	0.0029	5	35	0.004
BUR01	75	0.0023	5	143	0.0034	8	109	0.006
CCC_SF_2	75	0.0045	8	15	0.0008	3	45	0.005
CLA_01	107.4	0.0060	7	332	0.0187	7	219.7	0.025
CON_01	40	0.0028	5	35	0.0024	4	37.5	0.005

SiteID	Event 1 (2018)			Event 2 (2019)			Site Average	
	Trash Volume (gallons)	Trash Density (gallons/ft2)	Condition Score	Trash Volume (gallons)	Trash Density (gallons/ft2)	Condition Score	Volume (gallons)	Density (gallons/ft2)
CUO01	6.5	0.0009	3	4	0.0005	1	5.25	0.001
CUO02	0.2	0.0000	1	4.3	0.0005	1	2.25	0.001
DAN_01	11.2	0.0011	1	7.5	0.0007	3	9.35	0.002
DCY02	32	0.0021	4	30.4	0.0020	3	31.2	0.004
DCY04	64	0.0119	6	64	0.0119	6	64	0.024
DUB_ALA_1	10	0.0016	2	5	0.0008	3	7.5	0.002
ELC_01	23.7	0.0025	3	15.5	0.0010	5	19.6	0.003
FF01	139.5	0.0114	10	1314.8	0.1420	10	727.15	0.153
FF03	112.4	0.0040	4	205	0.0094	6	158.7	0.013
FF04	205	0.0120	6	78	0.0228	6	141.5	0.035
FRE_CRAN_1	5	0.0006	2	37.5	0.0076	7	21.25	0.008
FRE_LAG_3	30	0.0104	6	30	0.0060	6	30	0.016
FRE_LAG_5	10	0.0039	6	21.3	0.0053	6	15.65	0.009
FRE_TULE_7	47.4	0.0017	4	17.5	0.0005	8	32.45	0.002
HAY_ACF_1	55	0.0044	5	64.9	0.0037	7	59.95	0.008
HAY_DEP_3	15	0.0010	3	25	0.0016	6	20	0.003
HAY_SFB_7	25	0.0003	4	15	0.0003	12	20	0.001
HMB01	1644.4	0.1759	7	33	0.0035	5	838.7	0.179
LIV_ALP_1	17.5	0.0040	3	10	0.0027	5	13.75	0.007
LIV_ALT_1	12.5	0.0040	2	17.5	0.0048	5	15	0.009
LOA_01	202.5	0.0657	2	71.3	0.0063	3	136.9	0.072
MIP-01	327.5	0.0234	9	122.2	0.0080	3	224.85	0.031
MIP-05	640	0.1391	8	21	0.0033	7	330.5	0.142
MOR_01	7.5	0.0017	4	5	0.0011	2	6.25	0.003
MOV_01	12.5	0.0014	4	10	0.0011	5	11.25	0.002
MOV_02	5	0.0005	3	10	0.0010	4	7.5	0.002

SiteID	Event 1 (2018)			Event 2 (2019)			Site Average	
	Trash Volume (gallons)	Trash Density (gallons/ft2)	Condition Score	Trash Volume (gallons)	Trash Density (gallons/ft2)	Condition Score	Volume (gallons)	Density (gallons/ft2)
MTZ_01	40	0.0027	7	423.9	0.0290	5	231.95	0.032
OAK_01	25	0.0019	4	10	0.0008	4	17.5	0.003
OAK_ARR_1	543.8	0.1956	5	25	0.0157	4	284.4	0.211
OAK_COU_1	5	0.0016	5	30	0.0092	11	17.5	0.011
OAK_LMC_1	7.5	0.0021	2	10	0.0020	6	8.75	0.004
OAK_PER_1	154.7	0.0458	11	74.9	0.0161	10	114.8	0.062
OAK_SAU_2	20	0.0046	4	69.9	0.0146	6	44.95	0.019
ORI_01	15	0.0015	4	15	0.0014	5	15	0.003
PAC01	3	0.0001	2	5	0.0001	2	4	0.000
PIN_01	22.5	0.0027	3	61.2	0.0064	4	41.85	0.009
PIT_01	44.9	0.0036	6	20	0.0016	7	32.45	0.005
PIT_04	319.9	0.0199	10	129.9	0.0081	8	224.9	0.028
PLH_01	68.7	0.0065	6	458.9	0.0433	8	263.8	0.050
RCY01	45	0.0214	9	40	0.0190	10	42.5	0.040
RCY03	46	0.0081	5	0	0.0000	3	23	0.008
RIC_01	52.4	0.0041	4	33.7	0.0023	11	43.05	0.006
SCC02	10	0.0008	5	19.5	0.0047	5	14.75	0.005
SCC03	21.5	0.0024	6	30.5	0.0111	3	26	0.014
SCF02	275	0.0131	9	275	0.0131	9	275	0.026
SCL01	2.5	0.0004	4	6.3	0.0014	2	4.4	0.002
SCL02	7.5	0.0028	1	5	0.0019	1	6.25	0.005
SCL03	10	0.0007	2	15	0.0011	2	12.5	0.002
SCP02	559	0.0133	10	691.9	0.0165	10	625.45	0.030
SCS01	11.7	0.0018	4	10	0.0016	3	10.85	0.003
SJC01A	100	0.0073	10	1030.9	0.0748	10	565.45	0.082
SJC02	760.9	0.0620	10	1609.9	0.1313	10	1185.4	0.193

SiteID	Event 1 (2018)			Event 2 (2019)			Site Average	
	Trash Volume (gallons)	Trash Density (gallons/ft2)	Condition Score	Trash Volume (gallons)	Trash Density (gallons/ft2)	Condition Score	Volume (gallons)	Density (gallons/ft2)
SJC10	517	0.0377	6	2955.8	0.2157	8	1736.4	0.253
SJC15A	247.5	0.0239	4	455.5	0.0440	7	351.5	0.068
SJC18	430	0.0381	8	1835.7	0.1627	11	1132.85	0.201
SJC22A	658	0.0434	7	438	0.0289	4	548	0.072
SJC23	758.9	0.0782	10	710.9	0.0733	8	734.9	0.152
SJC25B	755.9	0.0543	9	1247.9	0.0794	3	1001.9	0.134
SJC29	625	0.0429	6	1100.9	0.0756	9	862.95	0.119
SJC30	273	0.0253	5	921.5	0.0852	9	597.25	0.110
SJC31	980.5	0.0762	8	2020	0.1570	12	1500.25	0.233
SMO01	74.4	0.0025	7	36	0.0050	6	55.2	0.008
SMO03	219.8	0.0190	9	1446.1	0.2493	10	832.95	0.268
SNV_01	69.6	0.0041	4	25	0.0015	4	47.3	0.006
SNV_02	53.7	0.0064	4	28	0.0035	9	40.85	0.010
SPB_01	32.5	0.0062	5	55	0.0096	6	43.75	0.016
SRM_02	5	0.0003	2	7.5	0.0005	2	6.25	0.001
SSF01	20	0.0004	7	50	0.0011	7	35	0.002
SWD_06	277	0.0208	7	252	0.0573	11	264.5	0.078
SWD_07	272.5	0.0285	6	111	0.0116	5	191.75	0.040
SWD_08B	2548.6	0.1671	9	443.9	0.0475	6	1496.25	0.215
SWD_13	419.7	0.0137	2	136	0.0030	6	277.85	0.017
SWD_19	237	0.0076	5	1281.8	0.0410	10	759.4	0.049
UNI_DRY_1	79.8	0.0134	3	84.9	0.0174	7	82.35	0.031
UNI_OAC_2	1.3	0.0003	2	10	0.0039	5	5.65	0.004
VA01	67.4	0.0074	3	351	0.0607	6	209.2	0.068
VA02	115.3	0.0086	5	68.5	0.0197	3	91.9	0.028
WCR_02	20	0.0017	3	8.8	0.0007	3	14.4	0.002

SiteID	Event 1 (2018)			Event 2 (2019)			Site Average	
	Trash Volume (gallons)	Trash Density (gallons/ft2)	Condition Score	Trash Volume (gallons)	Trash Density (gallons/ft2)	Condition Score	Volume (gallons)	Density (gallons/ft2)
WVC02	7	0.0010	5	25	0.0037	2	16	0.005
WVC03	1	0.0002	2	2.5	0.0004	2	1.75	0.001

APPENDIX E: GUIDANCE FOR PEER REVIEWERS, PEER REVIEW COMMENTS, AND RESPONSES TO PEER REVIEWER COMMENTS

SF Bay Area Receiving Water Trash Monitoring Pilot-Testing of Qualitative and Quantitative Monitoring and Assessment Protocols

Guidance for Peer Reviewers
May 2020

Background

Provision C.10.b.v of the Municipal Regional Stormwater NPDES Permit (MRP 2.0), issued by the San Francisco Bay Regional Water Quality Control Board (SF Bay Regional Water Board) to 76 cities, counties and flood control districts in the SF Bay Area (collectively referred to as Permittees), requires the development, submittal and testing of a Receiving Water Trash Monitoring Program Plan (Trash Monitoring Plan). Version 1.0 of the Trash Monitoring Plan, which was submitted to the SF Bay Regional Water Board by the Bay Area Stormwater Management Agencies Association (BASMAA) on behalf of all Permittees, includes a description of the monitoring design and monitoring/assessment protocols.

Implementation of the Trash Monitoring Plan between October 2017 and July 2020 represents the "pilot-testing phase" of trash receiving water monitoring in the San Francisco Bay Area, during which pilot protocols and methods will be evaluated in the field. This evaluation is intended to provide cities, counties and flood control agencies subject to requirements in MRP 2.0 the opportunity to evaluate the validity of the pilot monitoring protocols and adapt the methodologies for future iterations of the monitoring program, should they occur, based on the information gained during the pilot-testing phase.

The MRP requires that the results of the pilot-testing phase of the Trash Monitoring Plan be submitted to the SF Bay Regional Water Board as a Final Report by July 1, 2020. The Final Report provides analysis of all information/data collected from trash assessments and monitoring during the pilot-testing phase. Monitoring Plan Objectives and scientific monitoring questions outlined in the Trash Monitoring Plan were used to guide the evaluation of trash monitoring and assessment data results presented in the Final Report. The monitoring objectives are listed below. The monitoring questions are included in the next section, along with the guiding questions that we request the peer reviewers answer during their review.

Monitoring Goals/Objectives

- Informs management decisions;
- Accounts for different stream and channel types, and considers temporal variability (e.g., to estimate baseline conditions and show change over time) and seasonality;
- Can assess trends over time;
- Helps to assess if the Permittees' trash reduction efforts are resulting in improvement;
- Allows for comparison of trash levels between sites (understand the range of levels of impact);
- Assists in determining relative contributions from different pathways (i.e., wind, illegal dumping, illegal encampments, MS4s);
- Leverages and exhibits consistency with existing monitoring efforts and other water quality monitoring programs, including direct discharge offset provisions (MRP Provision C.10.e); and
- Cost-effective, efficient and feasible (e.g., safe, access to sample locations, can be implemented by volunteer monitoring groups).

Scope of Peer Review

The Project Management Team (PMT) would like the Peer Reviewers to review and comment on the results and analyses of trash assessment data described in the Draft Final Report, to determine whether it adequately addresses the monitoring goals/objectives and questions developed by BASMAA. The following questions are provided to focus your review on specific areas on which we would appreciate your comments. Additional comments on other aspects of the Final Report are also welcome, but not required.

Guiding Questions for Peer Reviewers

1. Monitoring Question #1 - Are significantly strong correlations observed between qualitative and quantitative methods?
    - *Peer Review Question 1a - Does the correlation between qualitative and quantitative trash assessment methods described in the Final Report support the conclusion that qualitative (visual) trash assessment method is valid approach to assessing trash conditions of creeks in the MRP urban area?*
    - *Peer Review Question 1b - Could the visual assessment method also be an effective approach to address other potential monitoring objectives (e.g., trends, measure trash reduction efforts)? If not, what refinements in the method do you suggest?*
2. Monitoring Question #2 - What is the current level of trash deposited in flowing waterbodies in the entire MRP area?
    - *Peer Review Question 2a - Did the study adequately estimate the current level of trash deposited in flowing waterbodies in the entire MRP urban area?*
    - *Peer Review Question 2b - Is the protocol that was used to define an assessment area (i.e., where trash monitoring was conducted) clear, practical to implement, and repeatable? If not, what recommendations might you have to improve it.*
    - *Peer Review Question 2c - Would you suggest that other methods (e.g., design, sampling or analysis/interpretation) be employed to help answer Monitoring Question #2, should future trash monitoring occur in the MRP area?*
3. Monitoring Question #3 - What is the range of trash levels observed at sites targeted for cleanup? How do these ranges compare to levels in all flowing waterbodies?
    - *Peer Review Question 3a - Were the quantitative methods developed and employed by BASMAA to evaluate trash levels at targeted sites adequate to answer Monitoring Question #3?*
    - *Peer Review Question 3b - Should future trash monitoring occur to evaluate trash conditions in streams, would you recommend that a strictly probabilistic-based approach be used (with the goal that all stream types and trash conditions would be assessed over time) or should an approach that uses targeted sites at known trash problem areas be included?*
4. Monitoring Question #4 - Do trash levels in flowing waterbodies differ significantly between wet and dry seasons?
    - *Peer Review Question 4a - Did the study adequately assess if trash conditions are significantly different between wet and dry seasons in receiving waters?*
    - *Peer Review Question 4b - What additional data would you suggest should be collected or evaluated, should monitoring continue into the future, to identify optimal timing for trash assessments?*
5. Monitoring Question #5 - What percentages of trash observed in receiving waters are attributable to wind/litter, illegal dumping, illegal encampments and other (stormwater/upstream sources)?
    - *Peer Review Question 5a - Was the method developed and used adequate for estimating the relative contribution of trash from the four trash pathways (wind/litter, illegal dumping, illegal encampments, and other (stormwater/upstream sources))? If not, what refinements in the method are suggested?*
    - *Peer Review Question 5b - Are there suggested refinements to methods that could specifically improve the accuracy of estimating the contribution from the stormwater pathway?*

6. **Monitoring Question #6 -** Do trash levels in flowing waterbodies strongly correlate to trash generation levels depicted on Permittee maps?

    - *Peer Review Question 6 - Were the analysis methods employed in the study to compare trash levels observed in streams to trash generation levels depicted on Permittee maps adequate? If not, what improvements to the methods used would you recommend?*

Additional Questions for Peer Reviewers

7. *Peer Review Question 7 - Were the data quality objectives and measurement quality objectives developed for the study achieved? Do you have suggestions on how to improve quality assurance/controls for future data collection efforts, should they occur?*
8. *Peer Review Question 8 - What are your suggestions on how best to standardize qualitative assessment methods across sites that range in the levels of physical access to observe the site at a close distance?*
9. *Peer Review Question 9 - What are your recommendations on refinements to site characterization data (e.g., percent bank/channel cover) collection methods? Are there other factors that may be influencing trash conditions that should be considered if future data collection efforts were to move forward?*
10. *Peer Review Question 10 - What management or monitoring questions can be answered via data collected at trash booms in receiving waters?*

Peer Review Schedule

Please provide all responses to the questions above and any other comments on the Pilot-Testing of Qualitative and Quantitative Monitoring and Assessment Protocols Final Report to Chris Sommers (Project Manager) at csommers@eoainc.com **by Friday, May 22, 2020**. Chris can also be reached at 510-393-1549, should you have questions or if you would like to discuss the peer review process or the Study.

Comments from Peer Reviewers Shelly Moore and George Leonard on the Draft Trash Receiving Waters Monitoring Report and Responses from Project Consultants
June 2020

Comment #	Report Section	Peer Reviewer	Comment	Project Consultant's Response to Comments
1	Executive Summary	George Leonard	Why not keep it simple and make it a 1-10 scale?	No edit made. There are four condition categories so the number scale should be divisible by four (e.g., 8 or 12).
2	Executive Summary	George Leonard	Are you dealing with material and product types?	No edit made. We did not characterize the trash items during this study, as this level of detail was not needed to answer the management/monitoring questions.
3	Executive Summary	George Leonard	What was the statistical significance? What is the correlation coefficient?	No edit made (there were several statistical tests performed). Descriptions of these tests are provided in section 4.1
4	Executive Summary Key Findings	Shelly Moore	Re-word to indicate that visual tool is valid approach to assess trash conditions when using trash volume as the indicator for conditions (State Monitoring Project indicate that number of trash items does not show good correlation with trash conditions)	Edits were made to indicate conditions based on trash volume were correlated with visual assessment score.
5	Executive Summary Key Findings	Shelly Moore	Are trash levels higher or lower in a given season? You do not say how season effects trash levels. In Southern California, the storms tend to clean out storm drains; is it the opposite for highly vegetated Bay Area stormdrains (channels)?	Edits were made to clarify that study results did not show seasonality to significantly influence trash levels.
6	Executive Summary Key Findings	George Leonard	Key Finding #4 - This is an important observation and seems to go against the prevailing wisdom.	We agree. No edits necessary.
7	Executive Summary Key Findings	George Leonard	This is the first reference to plastic vs. trash. These categories should be defined early in this document.	No edit made. Specific trash types or materials were not an objective for this study.
8	Introduction	George Leonard	Management Questions - These are good management questions.	No edit necessary.
9	Table 2-1	George Leonard	Good questions but not sure they explicitly get at the question of does the level actually cause adverse water quality impacts (Management Question 1 and 3).	No edit made. Monitoring questions were identified through stakeholder process during development of the Trash Plan. Evaluating specific impacts of trash to water quality in creeks/channels was beyond the scope of this project. Total amount of trash deposition was used to indirectly evaluate the potential for water quality impacts.
10	Table 2-1	George Leonard	Not sure this question directly addresses the issue to the left in the table (Management Question 5).	See response above
11	Section 3.2.1	George Leonard	Regarding the use of the term "probabilistic" - this is really a stratified, random design.	We agree. We used the term probabilistic as a simpler term.
12	Figure 3-1	George Leonard	These are good, even coverage of sites throughout the watershed. This should provide a robust estimate of trash flows in the area of concern.	
13	Section 3.3.1	George Leonard	Are these relative to some number? Low is very subjective. Or are they are all simply relative measures?	These categories are relative. Field crews were trained and provided visual guidance of characteristics of each condition category. One of the goals of the project was to develop correlations between volumes and (visual) conditions, which would help give additional relevance to the condition scores/categories.
14	Section 3.3.1	Shelly Moore	(Regarding utility of Other/stormwater pathway) Not sure I would agree; there would be a lot of error associated with this kind of measurement as the uncertainty of source for many trash items is very high.	We agree with comment that determining pathway contributions is uncertain. Edits were made to clarify that we aimed to differentiate other / stormwater sources from other pathways.
15	Section 3.3.2	George Leonard	Ideally you want the weight of materials as the density of different products/items can vary a lot, making comparisons of volume erroneous. And if you want to quantify material flow, you'd like to keep it based on mass.	While we understand the point and agree that density is an important factor to consider when measure trash volumes, measurements of density are not practical at this scale of a program. We disagree that comparisons of volumes are erroneous in the absence of density. As evaluated and described in many previous documents regarding the measurement of trash, volume is the most practical and consistent measurement to make when assessing levels of trash in waterways. Ideally trash would be compacted, but again there are impracticalities in compacting all trash removed via a monitoring program of this size.
16	Section 3.3.2	George Leonard	Regarding documentation of the previous cleanup event - This is a major issue with all attempts to quantify material on land and in coastal habitats. It is not easily resolved without a level of resolution that is virtually impossible to guarantee.	We agree. No edits necessary.
17	Section 3.3.2	Shelly Moore	Are the booms all the same? Do they all collect trash to the same depth (some booms have skirts)	None of the trash booms monitored use skirts. Only trash on the surface is captured in the booms used for study.
18	Section 3.3.3	George Leonard	So, did you standardize the volume estimates to a density (per area) basis? Or were bankfuls always the same area? I don't quite understand the ultimate units of measurement you are using.	We standardized the lengths (300' or 600') and determined an average (of 3) width measurements for each assessment. This was used to calculate the area of the assessment (sq ft), and thus convert the trash volume to density (vol per square foot). This process is described in the methods section of the report and in the SOP.
19	Section 3.3.3	George Leonard	Why not use the metric system?	Preference. Standard lengths of 300 feet (stream) and 600 feet (shoreline) were already established by Programs at known trash problem areas (targeted sites).
20	Section 3.5.2	George Leonard	Scatter plots are not an "allowed" way to represent categorical data. A linear regression would be deemed invalid as the trash conditions scores are not a continuous variable.	We treated the condition scores as a discrete variable (i.e. numeric, ordered, countable) that was continuous for the purpose of correlation/regression. The discrete scores were separated into four categories (Low to Very High) that were not regressed/correlated.
21	Section 3.5.3	George Leonard	Regarding the statistical test used - Given the constraints, above, the statistical tests below are appropriate and valid.	Comment noted. No edits needed.
22	Section 4.1	George Leonard	What if you pool the data across the subcategories to roll up to the 4 main categories (i.e. low….to very high). Would those 4 categories be considered statistically significant? I would bet there would be little way to resolve differences within those categories given variability in the response variable.	We agree with this comment, this is presented in the Figure 4.2

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23	Section 4.1	George Leonard	Regarding the results of using the Kruskal-Wallis non-parametric statistical test - Yes, this is what I was asking about and suspected. Glad it worked out.	Comment noted. No edits needed.
24	Section 4.1, Figure 4-1	Shelly Moore	Include a description of box and whiskers	No edit made. Box and whiskers are defined in the methods, section 3.5.2
25	Section 4.1	George Leonard	Given these low absolute values, you could present the data as gal/100 sq feet, which would move the decimal point to the right 2 places. And the area (10 x10 feet) is essentially the area of small bedroom, so it is easy to get your head around.	No edit made. Will consider this unit of measure in the future.
26	Section 4.1	George Leonard	This means trash is patchy at scales SMALLER than your sampling unit. This poses an important challenge going forward.	Agree with comment. No edit necessary.
27	Section 4-1	Shelly Moore	Suggest providing some guidance on when you would recommend quantitative surveys over qualitative	Both have merits depending on goals and MQs of future monitoring. We'll add a statement in the last section to address your suggestion.
28	Section 4.1.1	George Leonard	It is statistically incorrect to use a linear regression unless both the dependent and independent variables are continuous variables. Here the x axis is categorical and thus violates that assumption.	See response to comment #18. Based on our significant experience in applying statistics to environmental data, we believe it is valid to treat a discrete variable as continuous, whereas the categorical variable was the four condition categories.
29	Section 4.1.1	George Leonard	Regarding the suggestion that in future monitoring, sites should be selected or stratified based on channel type - I believe this recommendation is warranted.	
30	Section 4.1.1	George Leonard	I agree that the data suggest that only resolution at the 4 category level is warranted. Actually, given the lack of difference between the high and very high categories, one could make the argument that only 3 categories are warranted.	We generally agree. However, given our extensive experience in conducting similar visual trash assessment approaches on land, it is likely that four categories are needed, but we just don't have enough sites in the very high category to substantiate this claim. Should additional data collection take place in the future, this hypothesis should be tested, and they number of categories adjusted accordingly.
31	Section 4.2.1	George Leonard	Comment on the footnote: it would NOT have been appropriate to analyze the targeted sites as they are non random and thus not representative. Only the probabilistic sites are.	We agree with this comment and was the reason we did not include.
32	Section 4.2.1	George Leonard	What percentage of the total trash is associated with the 22% of the reaches listed as high/very high? In short, from a total trash perspective, it looks like the high sites are where all the action is.	We agree, but did explicitly calculate this statistic. We do discuss that the worst sites (high and very high categories) are more associated with illegal dumping and encampments.
33	Section 4.2.1	George Leonard	I still think figuring out how to convert to mass would be more informative.	Weight of trash was not measured during the study. Estimating mass is not possible without significant assumptions and measurements would have had to occur in the field, which just wasn't practical. Additionally, Water Board staff have repeatedly stated that volume is the unit that they'd like us to measure.
34	Section 4.2.2, Figure 4-8	George Leonard	I don't see an obvious relationship here. Are you saying there is a statistically significant one?	There was a very weak statistically significant correlation between # outfalls and trash density for targeted sites.
35	Section 4.2.2	George Leonard	Could you do a multivariate analysis that would show if a group of characteristics explains a significant amount of the variation?	No edit made. Although not reported, a multi-variate analysis was done and did not reveal any site characteristics that helped explained variation. Therefore, it was not included in the report.
36	Section 4.3.2	George Leonard	What is the total proportion of all trash associated with encampments vs. litter? That seems especially relevant from a policy perspective.	We agree. This is presented in Figure 4.13
37	Section 4.3.3	George Leonard	How do you really know the differences in these categories from looking at the trash itself?	The factors used to categorize trash into different pathways is included in the SOP that was forwarded to the commenter. In summary, best professional judgment was used to categorize based on trash size, condition and location as indicators of trash pathways. Training of field personal was important for the consistent assessment of trash pathways.
38	Section 4.4.1, Table 4-11	George Leonard	Would you consider these values to represent the effectiveness of the trash booms. Or do they not collect all the trash because booms don't cover 100% of the flow?	These values provide a (low/floor) estimate of how much of the trash is generated upstream of the boom and passes to the boom site.
39	Section 4.4.2	George Leonard	Statement is not clear (at least to the reader) "Lack of relationship between annual trash loading associated with the stormwater pathway at a particular site and the amount of trash associated with this pathway that is measured at the same site".	Agree. Deleted the sentence.
40	Section 5 (Conclusions)	George Leonard	Yes, but doesn't this amount to the vast majority of trash? What is the total percent of trash in those high categories?	See Table 4-4. Based on the data collected at the probabilistic sites, we estimated that 64% of the trash in urban Bay Area creeks is located at sites with high or very conditions.
41			By my math, 92% of the trash is associated with encampments and illegal dumping. (= 35/38). This is an important finding with significant public policy ramifications.	Correct. Based on the data collected, we estimate that between 80-95% of the trash observed in urban Bay Area creeks is associated with illegal dumping and encampments when measuring by volume.
42	Section 5 (Conclusions)	George Leonard	My read of the data suggests seasonality has little effect.	Agree, edit made
43	Section 5 (Conclusions)	George Leonard	I'm surprised that any targeted sites were in the lowish categories given they were intentionally chosen to be hot spots. Can you explain that? Are they trashy some times but not others?	The term "hot spot" varies based on the municipality definition of what is "hot" for their community. Therefore, for some communities, sites with moderate levels and possibly even low levels would be considered "hot".
44	Section 5 (Conclusions)	George Leonard	Is there some value in calculating the trash as amount/per person in the watershed, given the EPA calculations trash generation rates on the per capita basis?	This is an interesting concept, but is beyond the scope of this project. Given our experience in conducting on-land visual assessments and trash volume measurements, a number of factors are correlated with trash levels, including population density (not just population) and income.
45	Section 5 (Conclusions)	George Leonard	This suggest we don't need more booms in the watershed. We need to stop illegal dumping and clean up illegal encampments. Is that a correct interpretation?	Agreed. Study results do suggest that management actions that address illegal dumping and illegal encampments would have the greatest reduction in amount of trash observed in waterbodies.

Comments from Peer Reviewers Shelly Moore and George Leonard on the Draft Trash Receiving Waters Monitoring Report and Responses from Project Consultants
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Comment #	Report Section	Peer Reviewer	Comment	Project Consultant's Response to Comments
46	Section 6.3	Shelly Moore	It would be good to provide some actual estimated costs for visual assessment (to support statement made of cost-effective)	Cost estimates were not developed as part of this project, but we're happy to work with SFEI and SCCWRP to assist in developing cost estimates to include in the California statewide evaluation of trash monitoring methods, which includes the methods used in this study.
47	Section 6.3	George Leonard	I don't remember you calculating the relative efficiency (in time and dollars) of the two methods. That would be worth doing. How MUCH more efficient is it? I suspect a lot.	See response above.
48	Section 6.3	Shelly Moore	Measuring trash pathways using these categories creates too much error and variation and these measurements should be dropped	While we agree that estimating trash pathways was very subjective and has high degree of uncertainty, they are important from a trash management perspective. While we don't believe that the pathway identification methods developed as part of this project were precise, we do believe that refining the methods to create high levels of certainty in the results is an important next step, should monitoring continue in the future.
49	Section 6.3	George Leonard	This is a general concern of mine about these pathways. You have no direct evidence that these materials came from the assumed pathway and it is possible and likely probable that a given material can take multiple pathways. Who gets to decide?	Understand that when the pathways are identified, the field crews started with the obvious trash that originated from a specific pathway (e.g., illegal dumping or encampments). Then any trash that couldn't be reliably assigned to a speck pathway based on its characteristics, was assigned to the other/stormwater pathway. For that reason, one should look at the volumes and percentages of trash originating from the littering, illegal dumping, and encampments categories as likely low estimates, and the volumes and percentages from the other/stormwater pathways as likely high estimates.
50	Section 6.4	George Leonard	I am still confused here. Did the booms cover 100% of the potential pathways, allowing you to draw this conclusion? Or was it that they simply didn't cover ALL pathways and thus it is difficult to estimate their effectiveness?	For the sake of the comparison, we assumed that all trash captured at trash boom was associated with other/stormwater.

Responses to Guiding Questions – Peer Reviewer Shelly Moore

Guiding Questions for Peer Reviewers

1. Monitoring Question #1 - Are significantly strong correlations observed between qualitative and quantitative methods?

    - *Peer Review Question 1a - Does the correlation between qualitative and quantitative trash assessment methods described in the Final Report support the conclusion that qualitative (visual) trash assessment method is valid approach to assessing trash conditions of creeks in the MRP urban area?*

      Yes, I agree that the correlations are good between qualitative trash condition scores and trash density (volume per unit area) at both a regional and countywide scale. The visual assessment tool is a valid approach for volume – if your monitoring question is about volume. Saying that it is a valid approach for assessing trash conditions is a general statement that does not necessarily apply to what other methods might indicate. For the quantitative tally assessment, it is not a valid approach – the data I have seen does not show good correlation with the visual assessment and is often dependent on the size of the trash. I would recommend changing the wording in Key Finding 1 so as to indicate this is a valid approach to assess trash conditions as it relates to trash volume as a means for assessing trash conditions in creeks.

    - *Peer Review Question 1b - Could the visual assessment method also be an effective approach to address other potential monitoring objectives (e.g., trends, measure trash reduction efforts)? If not, what refinements in the method do you suggest?*

      Yes. It can be used I believe to address the trends in the overall trash amounts relative to volume. I would want to see some estimates of the types of trash present. Not in a detailed way but on a larger scale, e.g. plastic, metal, glass, etc. As people are looking to see if there are reductions based on management decisions, it would be important to know if one particular type of trash has increased vs decreased. Right now, plastic is something that is on everyone's radar and it would be good to have some way to estimate reduction.

2. Monitoring Question #2 - What is the current level of trash deposited in flowing waterbodies in the entire MRP area?

    - *Peer Review Question 2a - Did the study adequately estimate the current level of trash deposited in flowing waterbodies in the entire MRP urban area?*

      Given the sample size and the inclusion of targeted sites and probabilistic sites, I do think the study adequately estimated the current level of trash. Estimating the current level of trash deposited in flowing waterbodies is a difficult task by itself; however, estimating the contribution of trash from encampments adds another level of difficulty and I believe in some cases this leads to an underestimate of trash. Overall, I do think the team used the information from this study in the best way possible to estimate the current level of trash.

    - *Peer Review Question 2b - Is the protocol that was used to define an assessment area (i.e., where trash monitoring was conducted) clear, practical to implement, and repeatable? If not, what recommendations might you have to improve it.*

      Yes, the protocol that was used to define an assessment area was clear, practical to implement, and repeatable. Personally, I do not like using "bankfull width" as the method for defining the assessment area width. It can be inconsistently measured by different surveyors and is even measured differently in different parts of California. I have had many conversations with others looking for a better way to measure the assessment width and have yet to find one. My recommendation would be to continue to use "bankfull width" at this time and focus and providing adequate training and a well written description of the method.

- *Peer Review Question 2c - Would you suggest that other methods (e.g., design, sampling or analysis/interpretation) be employed to help answer Monitoring Question #2, should future trash monitoring occur in the MRP area?*

  At this time, I would not suggest other methods be used. I would recommend that future trash monitoring continue in the MRP area. The only way to assess whether things are getting better or worse is to monitor spatially and over time. It will particularly be interesting to see what these areas look like over the next year as much single-use items have been used over the last few months.

3. Monitoring Question #3 - What is the range of trash levels observed at sites targeted for cleanup? How do these ranges compare to levels in all flowing waterbodies?

   - *Peer Review Question 3a - Were the quantitative methods developed and employed by BASMAA to evaluate trash levels at targeted sites adequate to answer Monitoring Question #3?*

     Yes, the quantitative methods were adequate at targeted sites to answer Monitoring Question #3. Some of the larger, unusually shaped trash items may have been difficult to estimate but with clear guidance on doing this both in training and in the documentation, this can be minimized.

   - *Peer Review Question 3b - Should future trash monitoring occur to evaluate trash conditions in streams, would you recommend that a strictly probabilistic-based approach be used (with the goal that all stream types and trash conditions would be assessed over time) or should an approach that uses targeted sites at known trash problem areas be included?*

     Great question! I would recommend the probabilistic-based approach be used. However, I would suggest that as part of the probabilistic sample draw other strata be included. For instance, you could force probabilistic samples into known areas of encampments. You can also force samples into other areas of interest. For example, I have thought it would be interesting to look at trash in areas where there is a sharp turn in a creek/river or some other area of interest that is perhaps more susceptible to collating trash. Doing this would allow you to make statements about trash in the overall region, trash in encampment areas, etc.

4. Monitoring Question #4 - Do trash levels in flowing waterbodies differ significantly between wet and dry seasons?

   - *Peer Review Question 4a - Did the study adequately assess if trash conditions are significantly different between wet and dry seasons in receiving waters?*

     Yes, the study adequately assessed if trash conditions are different between wet and dry seasons. Much of this is due to the timing and severity of storms in the wet season and it can be different in different regions as well. I thought this part of the report was well explained and made sense. It would be interesting to look at these differences in Northern versus Southern California.

   - *Peer Review Question 4b - What additional data would you suggest should be collected or evaluated, should monitoring continue into the future, to identify optimal timing for trash assessments?*

     I think this study did identify the optimal time for trash assessments as far as seasons go. The dry season seems to be optimal. Easier access during the dry season and safer conditions are always the best way to go. The timing of when to do it during the dry season should be considered though – should it be done at the end of the dry season when perhaps the trash is at its highest? Or maybe in the middle of the summer? It might be good to look at in season differences.

Responses to Guiding Questions – Peer Reviewer Shelly Moore

5. Monitoring Question #5 - What percentages of trash observed in receiving waters are attributable to wind/litter, illegal dumping, illegal encampments and other (stormwater/upstream sources)?

   - *Peer Review Question 5a - Was the method developed and used adequate for estimating the relative contribution of trash from the four trash pathways (wind/litter, illegal dumping, illegal encampments, and other (stormwater/upstream sources))? If not, what refinements in the method are suggested?*

     This is the area where I have the most concern regarding the study results. The study team acknowledged that this is a difficult assessment to make albeit an important one. My experience in the field makes me think this is an impossible task to do with any accuracy. I am not sure what refinements to make in the method at this time to better the estimates of trash relative to their contribution from the four trash pathways.

   - *Peer Review Question 5b - Are there suggested refinements to methods that could specifically improve the accuracy of estimating the contribution from the stormwater pathway?*

     Again, this is difficult and technically all of the trash could be defined as coming from the stormwater pathway as once it reaches the storm drain it is in that path. I have no recommendations to refine the methods at this time.

6. Monitoring Question #6 - Do trash levels in flowing waterbodies strongly correlate to trash generation levels depicted on Permittee maps?

   - *Peer Review Question 6 - Were the analysis methods employed in the study to compare trash levels observed in streams to trash generation levels depicted on Permittee maps adequate? If not, what improvements to the methods used would you recommend?*

     Yes, the analysis methods were adequate. I can't think of any improvements to the methods at this time.

Additional Questions for Peer Reviewers

7. *Peer Review Question 7 - Were the data quality objectives and measurement quality objectives developed for the study achieved? Do you have suggestions on how to improve quality assurance/controls for future data collection efforts, should they occur?*

   Data quality objectives and measurement quality objectives can be difficult to set when the data collected is subjective or has a lot of variation. For this study these objectives varied in being met depending on the factor measured. I think it is appropriate to revisit these objectives by factor when they have varying results. I would also recommend setting MQO's specific to the different levels of factors being measured. The example given in this study was the Trash Condition Score and how it differed for numbers below and above 5. Perhaps different MQO's should be set for above and below 5. In any case, a difference of 1 in the trash condition score should not necessarily exceed an MQO. Since this was the first study with the MQO's set as they were some latitude should be given before the DQO/MQO's are set.

8. *Peer Review Question 8 - What are your suggestions on how best to standardize qualitative assessment methods across sites that range in the levels of physical access to observe the site at a close distance?*

   Good question! The best way to standardize this is through training. The first question I ask new people when I take them out in the field to do this assessment is how they would score the site. They often have much different answers than the people who have been going out for a while. I think most of it has to do

with them actually seeing the different levels of trash in different areas. I think pictures help, but there is nothing better than being in the field and explaining why you gave a site a particular score. This also applies to how to assess sites that have different levels of physical access. Often the amount of trash in or near the water is the most difficult to see.

9. *Peer Review Question 9 - What are your recommendations on refinements to site characterization data (e.g., percent bank/channel cover) collection methods? Are there other factors that may be influencing trash conditions that should be considered if future data collection efforts were to move forward?*

   Other physical information on the creek/river might be useful, i.e. is the site near a turn in the creek/river or are there any physical structures that trash might get caught up in – such as a groin. That kind of information often makes it into the comments but is not collected as part of the data.

   It might be worth it to offer up the data to some data hackers/college students to see if they can identify any other factors that may influence trash levels using GIS exercises, etc. I know previous work has been done by the study team to investigate other factors, but new and different eyes might have some other ideas.

10. *Peer Review Question 10 - What management or monitoring questions can be answered via data collected at trash booms in receiving waters?*

    I think booms can provide some useful information but data about their trash collection abilities needs to be collected to make any statements about the amounts collected by booms. The booms I have seen are all slightly different – have different diameters and different skirt lengths. I wonder too, how much trash (even floatable trash) gets pushed underneath the boom during a storm. Most collect boom data now only measure how much is removed and do not look at what specifically makes up the trash.

    At this point I have too many questions about the booms themselves and their ability to collect trash to be able to say anything about the data.