

Monitoring Considerations for the Trash Amendments

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ABOUT AND SCOPE

The State Water Resources Control Board (SWRCB) and the California Ocean Protection Council (OPC) have requested Ocean Science Trust develop a guidance document that provides monitoring considerations for the State and Regional Water Boards and municipal separate storm sewer system (MS4) permittees¹ who are developing plans for trash monitoring in various water bodies.

The audiences for this report include those interested in trash monitoring, with a particular focus on State and Regional Water Board Staff responsible for writing, reading, and reviewing MS4 permits, as well as monitoring personnel. Thus the report provides a high-level overview of the challenges and opportunities of monitoring the discharge of trash and trash loads in receiving waters. This report synthesizes lessons-learned from past and current trash monitoring efforts, and translates these results into guidance that may be considered in the context of monitoring considerations outlined within the Trash Amendments.

In this document, we define “monitoring” as an initial assessment and ongoing observation to check the progress or quality of the subject being monitored over a period of time. While the content of report is applicable to debris monitoring for non-management purposes, it is framed by two broad questions in the Trash Amendments:

- Q4: Has the amount of trash discharged from the MS4 decreased from the previous year? If so, by how much? If not, explain why?
- Q5: Has the amount of trash in the MS4s receiving water(s) decreased from the previous year? If so, by how much? If not, explain why?

These questions are included in the Trash Amendments for MS4 permittees to consider in the development of their monitoring reports to be submitted to the relevant regulatory authority for review each year. For the purposes of this report, we view these questions as a valuable framework to organize monitoring guidance and considerations as they relate to the Trash Amendments. This document does not address what constitutes compliance with the Trash Amendments and therefore is not intended to outline a specific process to evaluate or determine compliance with permit requirements of any type. The State and Regional Water Boards are responsible for guiding permittees towards the assessment and/or monitoring approaches that are considered compliant.

This document was developed by California Ocean Science Trust in consultation with the OPC and the SWRCB. In addition, Ocean Science Trust convened debris monitoring and management experts in a Workshop on April 17th 2017 to develop and receive input on the content included within the report (Appendix B). Many of the workshop participants provided comments on an early draft of this document. Two anonymous external peer-reviewers then provided a technical review. Finally, staff at the OPC and the SWRCB reviewed the document to ensure the content is relevant to scope and useful for decision-making. The report was finalized and submitted to the OPC in July 2017.

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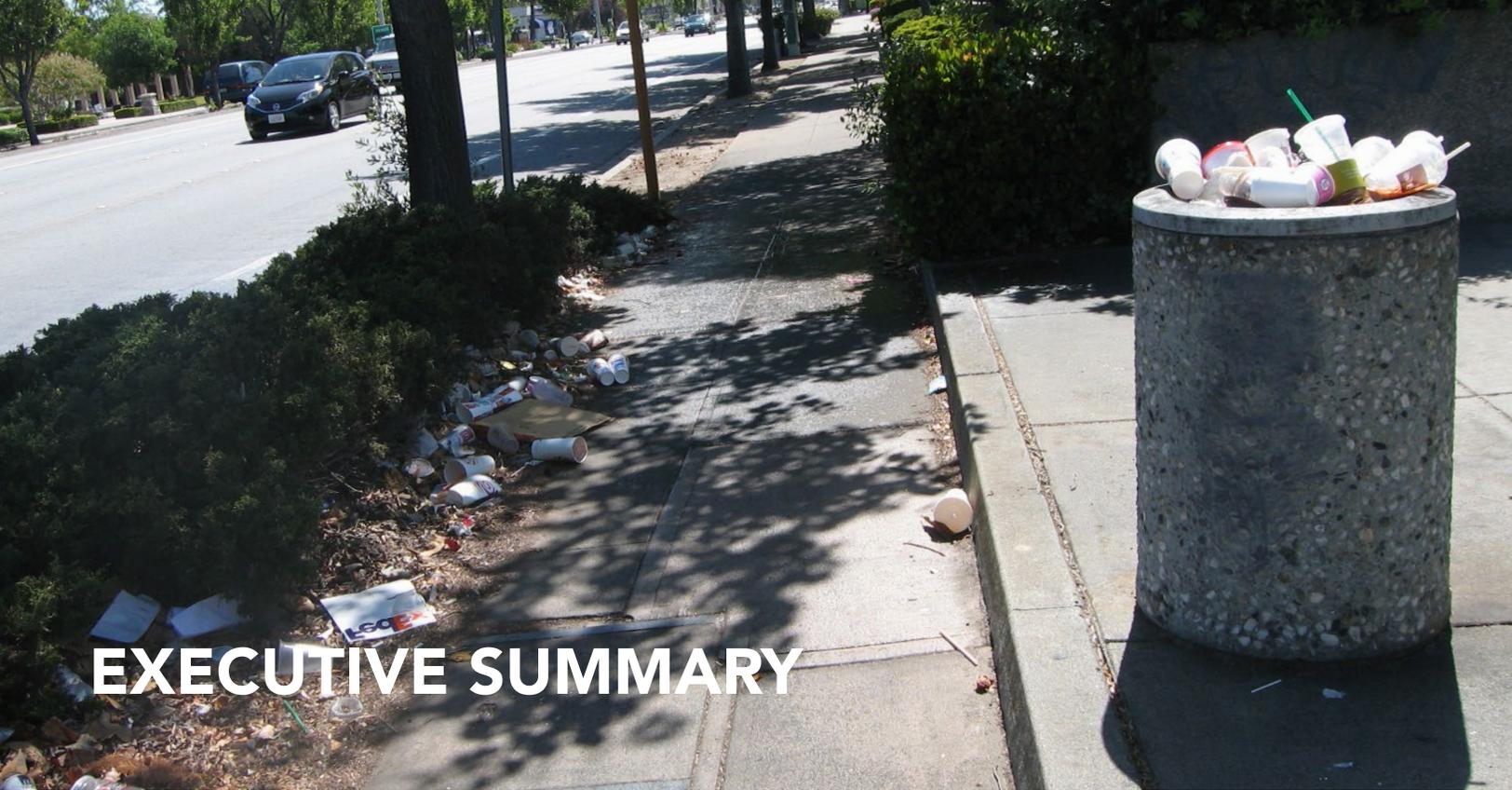
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Funding support was provided by the California Ocean Protection Council. Participants in the April 17th Workshop, Monitoring Considerations for the Trash Amendments, provided content and feedback during the development of this report. Three external experts in trash monitoring provided a technical review of the report.

Cover image: Edward Conde

¹ The Municipal Storm Water Permitting Program regulates storm water discharges from municipal separate storm sewer systems (MS4s). http://www.waterboards.ca.gov/water_issues/programs/stormwater/municipal.shtml



EXECUTIVE SUMMARY

With the passage of the Trash Amendments in 2015, there is need to synthesize monitoring considerations for the State and Regional Water Boards and municipal separate storm sewer system (MS4) permittees who are developing plans for trash monitoring in various water bodies. This report synthesizes lessons learned from past and current trash monitoring efforts and translates these results into monitoring considerations in the context of the Trash Amendments, which include provisions to demonstrate progress toward meeting trash reduction goals.

The Trash Amendments and the Need for Monitoring Guidance

The phrase “Trash Amendments” refer to an Amendment to the Water Quality Control Plan for Ocean Waters of California (Ocean Plan), and the Water Quality Control Plan for Inland Surface Waters, Enclosed Bays, and Estuaries (ISWEBE Plan) passed by the SWRCB on April 7, 2015. The purpose of the Trash Amendments are to reduce trash entering waterways statewide, provide consistency in the SWRCB’s regulatory approach to protect aquatic life and public health beneficial uses, and reduce environmental issues associated with trash in state waters. As written, the Amendments leave some flexibility in how permittees may develop monitoring programs, though there are questions for permittees to consider in developing their monitoring reports, including:

- Has the amount of Trash discharged from the MS4 decreased from the previous year? If so, by how much? If not, explain why.
- Has the amount of Trash in the MS4’s receiving water(s) decreased from the previous year? If so, by how much? If not, explain why.

The SWRCB and the OPC recognized the need for trash monitoring guidance as it relates to the Trash Amendments. This report is intended to provide a high level overview of the challenges and opportunities of monitoring the discharge of trash and trash loads in receiving waters. The audiences for this report include those interested in trash monitoring, with a particular focus on State and Regional Water Board staff

responsible for writing, reading, and reviewing MS4 permits, as well as monitoring personnel. We use the questions above as a framework to organize monitoring guidance and considerations as they relate to the Trash Amendments.

Monitoring Considerations for the Trash Amendments

The report explores the primary factors to consider in the development of a trash monitoring program, including trash measurement methods, establishing a baseline, site selection, sampling frequency, prioritizing efforts and collaboration, quality control, training, safety, and data comparability. In general, there are multiple ways to assess the amount of trash discharged from an MS4 and in receiving waters, including qualitative, semi-qualitative, and quantitative methods. With each assessment type, there are tradeoffs in cost, efficiency, accuracy, feasibility, safety, comparability, and the type of information that each conveys. Making decisions about which measurement type to employ in a monitoring program will depend on the priority management questions of interest, the information available to address those questions, and the degree to which the factors listed above constrain or limit the assessment type that may be employed. Identifying specific management questions of interest will focus monitoring investments and ensure that efforts are designed to meet specific outcomes.

One of the primary challenges associated with trash monitoring is the inherent spatial and temporal variability of trash in the environment, making it difficult to detect any reduction in the amount of trash over short periods of time, identify differences among regions, or other categories of interest. A key strategy to overcoming this challenge is to conduct a robust, initial baseline data collection effort, which can be used to characterize variability, evaluate trade-offs in sampling effort, and streamline future monitoring efforts. A key need for existing and future monitoring efforts is leadership and/or coordination among groups to facilitate comparability in monitoring methods and data reporting. Comparable data are needed to quantify and compare trash pollution across the State and to other areas, identify hotspots of trash pollution, and identify solutions or strategies to reduce trash pollution.

Monitoring Discharge of Trash in Receiving Waters

An important monitoring goal is to determine the amount of trash discharged, and how it is changing through time. There are multiple different habitat types that may be present in MS4 receiving waters and each, including lakes, marine waters, creeks and rivers, and benthic sediment, may require a unique monitoring method. Monitoring may be required on or within storm drains (e.g., curb inlet screens, auto-retractable screens, etc.), and utilize various proxy measures and pilot studies of on-land-visual assessments to provide information about trash entering storm drains. There exists a range of related monitoring information and protocols. Monitoring programs can and should consider lessons-learned from efforts to date. Moreover, preparation of this guidance has illuminated science and research needs on this topic to continue to advance monitoring practices.



1. OVERVIEW

Photo Credit: California Department of Fish and Wildlife

1.1 The Trash Amendments

The phrase “Trash Amendments” refer to an Amendment to the Water Quality Control Plan for Ocean Waters of California (Ocean Plan), and the Water Quality Control Plan for Inland Surface Waters, Enclosed Bays, and Estuaries (ISWEBE Plan) passed by the SWRCB on April 7, 2015. The purpose of the Trash Amendments are to reduce trash entering waterways statewide, provide consistency in the SWRCB’s regulatory approach to protect aquatic life and public health beneficial uses, and reduce environmental issues associated with trash in state waters. A goal of these Amendments is that trash shall not be present in ocean waters, along shorelines or adjacent areas in amounts that adversely affect beneficial uses or cause nuisance.

A central element of the Trash Amendments is a land-use based compliance approach that targets high trash generating areas. Within this are two alternative compliance tracks:

- Track 1: Permittees install, operate, and maintain a network of certified Full Capture Systems (FCS) to capture trash in the storm drains, located in priority land use areas for municipal systems, and the entire facility for industrial and commercial permit holders.
- Track 2: Permittees install, operate, and maintain any combination of controls (structural and/or institutional) anywhere in their jurisdiction as long as they can demonstrate that their system performs as well as Track 1 (e.g., Full Capture System Equivalency).

The Trash Amendments provide a framework for permittees to implement its provisions. Whether permittees elect to comply with Track 1 or Track 2, permits shall state that full compliance shall occur within 10 years of the effective date of the permit. The permit shall also require permittees to demonstrate interim milestones such as average load reductions of 10% per year or other progress to full implementation. However, specific guidance on what specifically constitutes compliance and associated requirements such as load reductions is still being developed.

1.2 The Need for Monitoring Guidance

The SWRCB and the OPC recognized the need for debris monitoring guidance as it relates to the Trash Amendments and debris management, generally. There are two priority monitoring needs: First, the State seeks to understand if the implementation of the Trash Amendments is having a measurable effect on reducing trash in waterways statewide. Consistent or comparable monitoring methods or data are invaluable

in achieving this goal. Second, the SWRCB identified Track 1 as potentially the most effective approach, but is allowing Track 2 to provide flexibility in instances where Track 1 is not feasible. It is important to SWRCB to understand if Track 2 is performing as well as Track 1 and meeting the debris reduction goals within the Trash Amendments.

Permittees that implement strategies under Track 1 are not required to monitor the discharge of trash, or the amount of trash in receiving waters in order to comply with the Trash Amendments. Conversely, permittees under Track 2 shall develop and implement monitoring plans that demonstrate the effectiveness of the FCSs, multi-benefit projects, other treatment controls, and/or institutional controls and compliance with FCS equivalency (Appendix D and Appendix E, Trash Amendments 2015). Currently, permittees have some flexibility in the design and implementation of their monitoring program, however, they shall be required to submit annual monitoring reports to the permitting authority, which will subsequently review and determine whether the permittee is in compliance. Specifically, permittees should consider implementing monitoring programs to evaluate the discharge of trash and amount of trash in receiving waters. The Trash Amendments provide the following questions for permittees to consider in the context of monitoring and reporting:

- Q4: Has the amount of trash discharged from the MS4 decreased from the previous year? If so, by how much? If not, explain why?
- Q5: Has the amount of trash in the MS4s receiving water(s) decreased from the previous year? If so, by how much? If not, explain why?

These questions for consideration highlight the value of monitoring guidance that supports permittees in the design of effective and feasible monitoring programs that demonstrate FCS equivalency. Monitoring guidance is also needed because outcome-based trash assessment methods to assess progress toward reduction goals are not well established by the scientific and management communities.

1.3 Overview of Trash Pollution in CA Waterways

There is a growing recognition that trash pollution in California waterways is an issue of management concern. In California, the levels of trash entering a stormwater system are dependent on levels of trash that accumulate on streets and sidewalks (and other impervious surfaces), which is furthermore dependent on the extent and magnitude of trash sources, types of land use, and income levels within the land area draining to a stormwater system. In general, the average volumes of trash entering stormwater conveyance systems on an annual basis can range from 0.5 to over 150 gallons per acre per year, depending on the factors stated above (County of Los Angeles 2004a, 2004b; EOA, Inc. and 5 Gyres 2014; Talley et al. 2016, San Diego Bay Debris Study Workgroup 2016). Trash ends up in receiving waters through a variety of mechanisms including discharge from streets and storm drains, illegal dumping and litter, illegal encampments, wind, and upstream sources that deliver trash downstream (San Diego Bay Debris Study Workgroup 2016). One of the primary pathways of trash to marine receiving waters is urban runoff in nearshore areas that is transported via creeks and bays. Another important source of trash to oceans and shorelines is fishing boats in offshore areas (Moore and Allen, 2000).

Surveys have found trash distribution is not typically uniform and debris may be disproportionately higher at a few key areas or “hotspots” in a watershed (San Diego Bay Debris Study Work Group 2016, Moore et al. 2016). Generally, urban, relative to non-urban, areas have been shown to have higher abundance of trash (Moore et al. 2007). For example, Moore et al. (2016) found imperviousness and proximity to roads (especially large roads) to be strongly linked to trash abundance in waterways. The abundance of trash in waterways may also be linked to environmental or other processes that influence the generation, transport and accumulation of trash in certain areas. For example, surveys employing the Rapid Trash Assessment (REF) revealed that high trash levels were most common at the lower end of a watershed (e.g., estuaries, marshes, etc.), where both upstream accumulation and local littering was prevalent (Moore et al. 2007, Moore et al. 2016, San Diego Bay Debris Study Work Group 2016). In particular, mudflats and salt marshes have been found to be notable sinks for debris, especially plastic litter (Moore et al. 2007, San Diego Debris Study Work Group 2016). Urban runoff

is likely an important source of floatable plastic found in the ocean and on beaches as marine debris (Moore et al. 2007).

Trash levels may also be influenced by weather patterns, including season and, in particular, rainfall. During dry seasons, discharge of trash into receiving waters was primarily associated with localized littering and dumping, wind-blown trash from nearby sources, and at certain sites, accumulation from upstream sources due to dry season runoff (Moore et al. 2007). During wet seasons, trash levels may be primarily influenced by upstream sources, whereby debris is mobilized and transported into and/or through waterways during precipitation events (Talley et al. 2016, San Diego Bay Debris Study Work Group 2016). Due to the multiple sources of trash and the complex nature by which it ends up in receiving waters, there is no one solution to preventing trash discharge and loads in receiving waters. For this reason, permittees may use multiple strategies to reduce trash discharge and pollution.

1.4 Overview of Trash Reduction Strategies

The Trash Amendments group trash reduction strategies into two compliance options: Track 1, which refers to Certified Full Capture Systems (FCS), and Track 2, referring to any combination of structural, institutional, or non-institutional controls of trash, and may include FCSs (Appendix D and Appendix E, Trash Amendments 2015).

1.4.1 Track 1: Full Capture Systems as Trash Reduction Strategies

A trash FCS is defined as a single device (or a series of devices) that traps all particles that are 5 mm or greater, and has a design treatment capacity that is either not less than the peak flow rate resulting from a one-year, one-hour, storm in the subdrainage area, or appropriately sized to, and designed to carry at least the same flows as, the corresponding storm drain (SWRCB 2015). Prior to installation, FCSs must be certified by the Executive Director, or designee, of the SWRCB. Uncertified FCSs will not satisfy the requirements of the trash provisions. In addition, low impact development (LID) (see Box 1.) that meet the treatment capacity outlined above are also considered a FCS (SWRCB 2015). The Trash Amendments do not require permittees to monitor the effectiveness of FCSs implemented under Track 1, though monitoring provisions do require permittees to demonstrate the installation, operation, maintenance, and the location and drainage area served by the FCS on an annual basis. Locations of FCSs and the drainage area must be provided as Geographic Information System (GIS) maps.



1.4.2 Track 2: Trash Reduction Strategies

Institutional controls that may be implemented under Track 2 include non-structural best management practices such as street sweeping, sidewalk trash bind and collection, anti-litter educational programs, producer take-back for packaging, and ordinances. Other strategies include, but are not limited to, litter booms and curtains, auto-retractable curb inlet screens, and pump station racks. A review by EOA, Inc. (2014) on behalf of the Tracking California's Trash (TCT) project evaluates the existing knowledge of monitoring methods for: 1) assessing the performance of street sweeping with and without partial capture devices in removing trash from public right-of-ways; 2) conducting on-land visual assessments to evaluate the effectiveness of trash control measures; and 3) conducting receiving water monitoring to quantify the concentrations and loads of trash transported via creeks, rivers and channels to bays, estuaries and oceans. This review was used to inform the development of TCT's Sampling and Analysis Plan, and ongoing conceptual monitoring program design.

The Trash Amendments recognize that FCSs may not be feasible to implement in every context. For this reason, the Trash Amendments include the option for permittees to implement other trash reduction strategies. While permittees have flexibility in the types of strategies they pursue, the Trash Amendments are designed to encourage the implementation of FCSs to the full extent possible. The incentive to implement a FCS lies within the additional monitoring requirements of Track 2. Another incentive is that Track 2 permittees that implement a combination of FCS and other Track 2 trash reduction strategies are only required to monitor locations or areas where FCSs were not implemented (e.g., locations where other Track 2 strategies were employed).

Unlike Track 1, MS4 permittees that elect to comply with Track 2 are required to develop and implement monitoring plans that demonstrate the effectiveness of trash reduction strategies, which may include FCSs, multi-benefit projects, other treatment controls, and/or institutional controls, and whether these strategies are equivalent to FCSs. There is therefore an implicit assumption that FCSs trap all particles that are 5 mm or greater, thus Track 2 strategies must be equally effective. Each year, monitoring reports must be submitted to the relevant permitting authority for review. Monitoring reports shall also include the GIS-mapped locations and drainage area served for each of the FCSs and other trash reduction strategies installed or implemented by the permittee

designed to encourage the implementation of FCS to the full extent possible. The incentive to implement FCS lies within the additional monitoring requirements of Track 2. Unlike Track 1, MS4 permittees that elect to comply with Track 2 are required to develop and implement monitoring plans that demonstrate the effectiveness of trash-reduction strategies (e.g., multi-benefit projects, other treatment controls, and/or institutional controls) and whether these strategies are as effective as FCS (i.e. full capture equivalency). Each year, monitoring reports must be submitted to the relevant permitting authority for review. Monitoring reports shall also include the GIS-mapped locations and drainage area served for each of the full capture systems and other trash-reduction strategies installed or implemented by the permittee. One incentive to encourage the implementation of FCS is that Track 2 permittees that implement a combination of FCS and other track 2 trash-reduction strategies are only required to monitor locations or areas where FCS were not implemented (e.g., locations where other Track 2 strategies were employed).



2. MONITORING CONSIDERATIONS FOR THE TRASH AMENDMENTS

Photo Credit: Kevin Krejci

2.1 General Monitoring Guidance

This section outlines general principles and practices for trash monitoring, including data collection considerations with respect to measurements of types of trash, establishing a baseline, site selection, sampling frequency, sample size, prioritizing efforts and collaboration, quality control, training and safety, and data management and comparability. These are general principles that pertain to the development of a trash monitoring program, and thus, the considerations outlined in this section are applicable to both discharge and receiving water monitoring, unless otherwise indicated.

2.1.1 Data Collection Considerations

TRASH MEASUREMENTS

There are multiple ways to assess the amount of trash discharged from an MS4 and in receiving waters. With each assessment type, there are tradeoffs in cost, efficiency, accuracy, feasibility, safety, comparability, and the type of information that each conveys. Making decisions about which measurement type to employ in a monitoring program will depend on the priority management questions of interest, the information available to address those questions, and the degree to which the factors listed above constrain or limit the assessment type that may be employed.

Broadly, the amount of trash discharged may be assessed using qualitative, quantitative, and/or semi-quantitative assessment:

- *Qualitative:* Assessment using pre-defined 'bins' or categories that correspond to different levels of trash. For example, a scale of 0-4 was employed by the Tracking California's Trash program (reviewed in EOA Inc. and 5 Gyres 2014, employed in EOA, Inc. 2016). In this context, a score of "0" corresponds to no trash being present. Higher scores corresponded to increasing levels of trash observed in a visual assessment.
- *Semi-quantitative:* Assessment using 'bins' or categories associated with specific quantities of trash (typically counts of trash items (e.g., as in the Rapid Trash Assessment, Moore et al. 2007).
- *Quantitative:* A numerical assessment of the amount or dynamics in trash such as the number of items, concentration, and accumulation.

True of all assessment types are options to characterize trash, which entails identifying specific trash items collected. Broad categories include: plastic (hard, foamed, film), metal, rubber, glass, processed lumber, cloth/

Table 1. The pros and cons of qualitative, semi-quantitative, and quantitative trash assessment approaches.

| Measurement Type | Pros | Cons |
|-------------------------------|---|---|
| 1. Qualitative | <ul style="list-style-type: none"> Helps to identify sources of trash | <ul style="list-style-type: none"> May be less accurate than other measurement types (or “the least accurate method”) |
| 1.1 Trash Characterization | <ul style="list-style-type: none"> Helps to identify sources of trash May be required for assessment of product bans | <ul style="list-style-type: none"> Time consuming to implement Weathering of debris can make it difficult to identify trash type and may result in under- or mis-classification |
| 1.2 On-Land Visual Assessment | <ul style="list-style-type: none"> Requires less time to implement Reduced sampling time enables more sites to be monitored for a given effort Logistically easy to implement, particularly for sampling locations that are challenging to access Measurement error is relatively low, with sufficient training | <ul style="list-style-type: none"> Limited application and validation in receiving waters Requires an initial paired quantitative assessment in order to develop a conversion factor from qualitative scores to quantitative values Categorical score definitions need to be consistent in order for data to be comparable to other OLVA monitoring programs With out established conversion factors, OLVA data alone prevent the calculation of a percent change in the amount of trash over a given time period |
| 2. Semi-quantitative | <ul style="list-style-type: none"> Cost-effective compromise if quantitative methods are infeasible | <ul style="list-style-type: none"> Less accurate and lower data comparability than quantitative assessments |
| 2.1 Rapid Trash Assessment | <ul style="list-style-type: none"> Provides a systematic approach for non-catchment systems (e.g., streams and shorelines) Examines types of trash and identification of sources Can generate consistent and comparable results Most useful for identifying site-specific management actions to reduce trash loading in streams | <ul style="list-style-type: none"> Risk of observer bias Does not measure loading of trash downstream |
| 3. Quantitative | <ul style="list-style-type: none"> Precise Higher data comparability Amenable to statistical analyses | <ul style="list-style-type: none"> Can be time consuming, difficult to implement, or may require technical training |
| 3.1 Counts | <ul style="list-style-type: none"> Easy to train staff and other volunteers Established protocols developed A common assessment type, particularly for marine habitats Method more informative relative to weight for light items (e.g., styrofoam and plastic bags) | <ul style="list-style-type: none"> Time consuming Many trash items break apart during the collection process (e.g., Styrofoam), introducing measurement error and/or bias into measurements Small items are weighted equally to large items, unless the method categorizes counts by litter size |
| 3.2 Weight (dry) | <ul style="list-style-type: none"> Reduces bias due to trash water absorption | <ul style="list-style-type: none"> Limited application Trash items vary significantly in weight (heavy items are less mobile, lights materials are more mobile and, generally, pose a higher risk to species) |
| 3.3 Weight (wet) | <ul style="list-style-type: none"> Commonly used by media to communicate a story (e.g., X tons removed) Track 1 will be recording data as weight | <ul style="list-style-type: none"> Higher potential to under value plastic or other light items because of the limited ability to detect changes in the amount or ratio of light trash types (e.g, plastic bags), which generally have a greater environmental impact Higher measurement error in the conversion of weight to counts (vs. counts to weight) |
| Volume | <ul style="list-style-type: none"> Easy to interpret (e.g., tells you how much litter was measured) Less susceptible to bias by light materials relative to weight | <ul style="list-style-type: none"> Difficult to measure for many trash items with irregular shapes Compacting trash in collection process changes volume measurements and creates unnecessary variability in results |

fabric, other/unclassifiable. For a review of litter characterization methods, see Moore et al. 2007, Cheshire et al. 2009, and Lippiatt et al. 2013. Within each of these broad categories, individual trash types may be characterized to the specificity that best suits the management question of interest. Monitoring programs designed to understand the impact of true source control (e.g., bans of specific materials like the plastic bag ban implemented in California in 2016) or the impact of specific trash types (e.g., plastic bags or styrofoam), will require the characterization of litter in assessments in order to understand how quantities of specific trash change before and after the implementation of the ban. One of the challenges of litter characterization is that many trash items foul, break apart, and/or change shape, making it difficult to determine the original source or characteristics of the trash item. In general, debris that has been in the natural environment for longer periods of time may be more difficult to characterize.

Within these three broad assessment types, there are multiple options to measure the amount of trash, each with their own unit of measurement (Cheshire et al. 2009, Lippiatt et al. 2013). The most common assessment approaches are described below, and their pros and cons are outlined in Table 1.

Qualitative

Qualitative on-land visual assessment (OLVA, defined in Geosyntec Consultants et al. 2014)

(Unit: a categorical score, A, B, C, or D of the assessment surface area):

A visual methodology that categorizes trash levels into 'bins' or scores is used to assess the trash condition or amount in an area. The assessment area should be pre-defined and documented. This method employs qualitative estimates of the amount of trash generated on specific street segments, sidewalks and adjacent areas that may be transported to a municipal stormwater conveyance system. One of the motivations for validating the accuracy of OLVA relative to quantitative methods is that a visual assessment requires considerably less time to implement when compared to quantitative methods that require manual collection or identification of trash items. Qualitative scores have been shown to correlate with quantitative assessments measured in the same area, suggesting that the trash scores are relatively accurate at representing the quantity of trash in the assessment area and the amount discharged (EOA, Inc. 2016). In California, this qualitative OLVA method was developed, tested and validated through the implementation of the Tracking California's Trash Project (Geosyntec Consultants et al. 2014, EOA, Inc. 2016). The Tracking California Trash Project found that the time it takes to implement the OLVA method is relatively short, which means that implementing this strategy may enable field crews to sample multiple sites in the same amount of time that a single site can be sampled using a more rigorous quantitative method. In this protocol (Geosyntec Consultants et al. 2014), four trash conditions are defined (A-D):

- *Condition A – Low Trash Level:* Effectively no trash can be observed on a city block or the equivalent. There may be some small pieces in the area, but they are not obvious at first glance and one individual could quickly pick them up.
- *Condition B – Moderate Trash Level:* Predominantly free of trash except for a few pieces that are easily observed along a city block, or the equivalent. The trash could be collected by one or two individuals in a short period of time.
- *Condition C – High Trash Level:* Trash is widely/evenly distributed and/or small accumulations are visible on the street, sidewalks, or inlets. It would take a more organized effort to remove the litter.
- *Condition D – Very High Trash Level:* Trash is continuously seen throughout the area, with large piles and a strong impression of lack of concern for litter in the area. There is often significant litter even along gutters that are swept.

Semi-quantitative

Semi-quantitative Scores within the Rapid Trash Assessment (defined in Moore et al. 2007) where a unit is a categorical score from 0 to 20, which corresponds to the visually assessed condition of the site:

A pilot effort conducted by the Surface Water Ambient Monitoring Program (SWAMP) to systematically assess trash levels in streams, the Rapid Trash Assessment (RTA) protocol examines the amount and types of trash present in stream channels, the impacts of trash, and potential sources of trash. The protocol combines qualitative and semi-quantitative components:

- *Qualitative component:* At each site an initial visual assessment is conducted for the “Level of Trash,” which is intended to reflect a qualitative “first impression” of the aesthetic condition of the site after an initial observation period. Scores include: poor, marginal, sub-optimal, optimal. Within each of these condition categories, there are numerical scores that span a total range of 0 to 20.
- *Semi-quantitative component:* Based on the tally of trash along a 100-foot reach, a score is selected within the appropriate condition category based on the number of tallied items. Where more than 100 items have been tallied, the following scores are assigned: 5: 101-200 items; 4: 201-300 items; 3: 301-400 items; 2: 401-500 items; 1: 501-600 items; 0: over 600 items. Similar guidelines are used to score other condition categories: Treat to Aquatic Life, Threat to Human Health, Illegal Dumping and Littering, and Accumulation of Trash. For details on this assessment method, see CRWQCBSFR 2004 and Moore et al. 2007

Quantitative

There are a variety of protocols that describe methodologies to enumerate the amount and dynamics of trash in the environment. This report examines methodologies and approaches developed in California that shed light on different quantitative assessment options based on the relevant management question (Moore et al. 2007, EOA, Inc. 2014, Lippiatt et al. 2013, Geosyntec Consultants et al. 2014, 5 Gyres et al. 2017, EOA, Inc. 2017)

- *Counts* (Unit = number of items per surface area or volume sampled, #/ m²): In a visual assessment or trash collection effort, trash items or pieces are enumerated in a specified assessment area or volume. The total number of trash items may be counted or items may be counted within predefined trash types (e.g., plastic, metal, styrofoam, etc.). Typically, numerical assessments of trash are conducted using a linear transect, where trash is collected within certain distance from the transect tape (e.g., 1 meter to the right and/or left of the transect tape). In this case, the assessment area can be calculated as:

Surface area = length of transect x width of transect

A similar method is to sample square-meter plots (or another specified area) at specified (or random) distances along a transect. In this method, trash items are enumerated within each plot and averaged for each transect. In-water sampling may collect trash using collection devices (e.g., trawls, booms, etc.), and count measurements are normalized to the volume of water sampled.

- *Dry or wet weight* (Unit = kilograms of trash collected per surface area sampled, kg/m²): A dry or wet weight methodology is an assessment whereby trash items or pieces are collected in a specified assessment area and weighed. Wet weight measurements enable field crews to complete the assessment in the field. Unless trash types are separated, weight measurements are highly influenced by heavy trash types and the contribution of lighter items are generally underestimated (e.g., plastic bags, styrofoam). Wet weight may also be influenced by wet weather and/or the frequency with which land-based sources (e.g., sprinklers) and the collection area come into contact, thereby enabling debris to soak up additional water and weight. Dry weight assessments require debris to go through a desiccation process to remove any water picked up from the environment and water within the original debris material. This type of measurement improves data comparability by removing the influence of external factors over the weight of debris items. However, debris must be collected and processed in a laboratory, requiring additional the staff time and training.
- *Volume* (Unit = volume of trash collected per area sampled, m³ or liters per m²): An assessment whereby trash items or pieces are collected in a specified assessment area and their volume is measured as

either m³ or gallons per assessment area. Volume measurements enable field crews to complete the assessment in the field

Concentration vs. Accumulation

Another consideration for quantifying litter is whether to measure debris concentration (e.g., the standing stock) or accumulation (e.g., flux). Standing stock measurements may be defined generally as a snapshot of trash at a point in time. This generally entails trash observation, but not necessarily trash removal. Standing stock measurements typically are measured as density or concentration (e.g., amount per surface area). Standing stock may be calculated for different habitat types:

- Street or Shoreline: concentration = amount per surface area
- Sediment: concentration = amount / (area x depth of sample)
- In-water (creek, river, lake, marine): concentration = amount / volume water sampled

Accumulation or flux can be defined as the rate of trash accrual over a specific period of time. Monitoring accumulation requires trash clearance and should not be used to evaluate debris loads or cumulative impacts (Lippiatt et al. 2013).

Management goals and questions will determine whether knowledge of the concentration or flux of trash is more informative in addressing the management goal. For example, knowing the concentration of trash at specific locations or sites would be needed in order to evaluate cumulative impacts or conduct risk analyses associated with trash pollution (Lippiatt et al. 2013). Conversely, measurements of the flux may be more informative in evaluating the different drivers of trash pollution (e.g., weather, the effectiveness of trash reduction strategies efforts, or other factors). In either context, monitoring reports should clearly indicate whether or not trash was removed during the surveys.

ESTABLISHING A BASELINE

In any monitoring program, it is important to conduct an initial assessment or “baseline” to serve as a benchmark to track future change and/or progress towards meeting the targets within the Trash Amendments. A key consideration for baseline assessment is to ensure that the data being collected is usable for detecting future change. One of the challenges associated with establishing a baseline is the inherent spatial and temporal variability of trash in the environment, making it difficult to detect a significant spatial or temporal change over time or among locations, particularly if data is collected in a quantitative manner. A sample size that achieves a ‘within group variance’ low enough for statistical analyses (e.g., Analysis of Variance) to distinguish differences among groups (e.g, sites, years, or some other factor of interest) may be infeasible with limited time and resources (Ryan et al. 2009, Vesar, Inc. 2012). For this reason, baseline assessments may require multiple years of sampling in order to sufficiently characterize the variability in the system. Implementing a robust baseline assessment may also enable monitoring programs to streamline future assessments.

The Trash Amendments are intentionally not explicit on what constitutes a robust baseline in order to allow more careful consideration of the amount of time and frequency of site visits that may be required. As the number of observations increases, ones confidence increases, while the level of error decreases because the temporal variability is better accounted for. Thus an acceptable tolerance level for error must be selected, which should be user-defined and based on the level of confidence that user would like to have in the value/estimate (EOC, Inc. 2017). For example, as part of the TCT’s Evaluation of On-Land-Visual Assessment (OVTA) protocol, a tolerance level of 0.25 was selected, or an acceptable error of one-quarter of an OVTA scoring category when establishing a baseline level of trash generation (EOA, Inc. 2017). They then found that conducting 4 assessments at a site had a 93% probability of falling within the acceptable tolerance level (EOA, Inc. 2017).

Given the inherent variability of trash in the environment, monitoring programs may consider implementing a

more robust initial baseline monitoring effort that can be used to evaluate the contribution of multiple factors that can affect trash levels (e.g., factors other than those implemented under Track 2, such as rainfall, wind, site characteristics, etc.)(MSFD 2013). This initial effort will help characterize spatial or temporal variability of data, thus providing the necessary information to prioritize future monitoring investments or effort. For example, baseline assessments that quantify spatial and/or temporal variability in trash abundance may be used to determine the sampling frequency and/or number of sites needed to be able to detect a desired change in abundance (i.e., percent reduction over a particular time frame). A power analysis calculation is a robust method to conduct this type of analysis (for background on how to conduct a power analysis, see Quinn and Keough 2001). In addition, if the initial baseline assessment discovers that within-site temporal variability exceeds that of spatial variability, future monitoring efforts may increase the frequency of sampling at a particular site (reducing temporal variability), and as a trade-off, the total number of sites may be reduced. Data quality (as opposed to quantity) is very important for usability and, depending on what is driving variability of trash in the system, it may be more valuable to sample more sites less frequently vs. less sites more frequently (or vice versa).

It may also be beneficial for baseline assessments to conduct both qualitative and quantitative assessments simultaneously. This will enable a robust assessment of “proxy” measures (e.g., qualitative scores) and the development of conversion factors to calculate the quantity of trash discharged by using a qualitative score assessment method. With this approach, future monitoring efforts could save time, effort, and cost by implementing a qualitative approach, while still enabling a numerical calculation of debris in the environment. In addition, qualitative approaches allow for a greater number of sites to be assessed with the same resources. Repeated sampling of the same site could reduce questions regarding temporal variability of sites and help to determine the effort needed to establish a baseline (EOA, Inc. and 5 gyres 2014).

SITE SELECTION

In any monitoring program, there needs to be some sort of process to determine both the location and number of sampling sites. The location and number of sampling is dependent on the number of factors (e.g., land use types, population density, drainage area) of interest, and the spatial and temporal variance, respectively. Conceptually, the monitoring program should be designed so that you have a sufficient number of sites to represent each factor. These decisions will depend on the goal of the monitoring program as driven by management questions, and available resources. For instance, is the primary goal to extrapolate across an area? Or to monitor trends at hotspots or key areas of interest? In many cases, a hybrid approach is desired or most appropriate.

If the goal is to extrapolate across a broad area, it may be beneficial to select sites that represent the range of conditions found in the jurisdiction of the MS4. Random sampling within each land-use area will ensure data is collected in a way that meets the assumptions of statistical analyses (e.g, regression and/or Analysis of Variance) that require random sampling of data within each group. Consider spacing sampling locations so that they are separated a sufficient distance apart to prevent spatial autocorrelation of data. This approach is similar to that implemented in The Rapid Trash Assessment, which selected sites representing the range of conditions found in the tributaries to San Francisco Bay, from rural residential areas in the foothills to dense, urbanized areas in the plains. All sites were near or within city limits, representing areas of public access (e.g., parks) or at the bottom of watersheds (Moore et al. 2007). There are a range of factors that may affect trash generation rates that should be considered in the development of monitoring programs, such as population density, income, and drainage area (EOA, Inc. 2014). However, sites should be representative of the land use areas, and a general rule of thumb is to have at least one site per land use type (Monitoring Considerations for the Trash Amendments Workshop participant, personal communication).

Conversely, a monitoring program may have specific goals that would require non-random site selection. For example, if the intention is to monitor the effectiveness of a particular control measure (e.g., a regular clean-up program), it may be valuable to monitor directly downstream of that control measure. Similarly, if the goal is to track change at a particular ‘hotspot,’ monitoring programs would need assessments at that particular

site. Other considerations include:

- The size of the city or MS4 may be important to consider when determining the number of sites needed to represent that area. Larger cities may benefit from additional monitoring sites.
- Consider sites that have sufficient area to enable minimum sampling effort (e.g., site is larger than the size of transect, trawl, plot etc.).
- Consider spacing sampling locations so that they are separated a sufficient distance apart to prevent spatial autocorrelation of data.

SAMPLING FREQUENCY

When making decisions about sampling frequency in a monitoring program it is important to consider the tradeoffs in cost (e.g, monitoring personnel time and effort) and data quality (e.g, variance or error that may inhibit ability to detect effects of a chosen reduction method). Due to the inherent variability in trash concentration and accumulation in an MS4 and its receiving waters, there is a need for sufficient number of surveys to reduce variance in the data to adequately characterize trash levels and enable the comparison of trends over time or among locations. Frequent sampling, however, requires sufficient staff and time to carry out the surveys, which comes at a cost. Selecting a sampling method that requires less time and effort to implement may reduce these costs. It will be important to consider and evaluate these tradeoffs when developing a monitoring program.

Monitoring programs focused on discharge rates may consider sampling relative to known influences. For example, sampling right before street sweeping when there is likely to be the highest amount of trash on the street (EOA, Inc. 2016). This strategy would allow standardizing the timing of sampling to reduce the potential for bias that could occur from variable timing of sampling in relation to chosen methods.

Monitoring programs may need to consider and account for external factors, such as weather and season, and independent human activities (e.g., community clean up efforts, post-holiday inputs), which may influence the amount of trash in an MS4 or its receiving waters (Talley et al. 2016). Sampling in both wet and dry season conditions may be needed to understand and interpret debris concentration data collection in a monitoring program. For example, the Rapid Trash Assessment found littering and dumping were more commonly documented in dry weather conditions between sampling events (e.g., during the summer months when tourist activity is higher) (Moore et al. 2007). In addition, there was a seasonal component to the downstream transport and accumulation of trash that occurred at the bottom of watersheds, with greater amounts of trash in wet weather conditions between sampling events. Because rainfall has the potential to significantly affect the dynamics of trash in watersheds (Moore et al. 2007), weather should be taken into account when interpreting measurements of the concentration or flux of trash. Existing data sources are available to support monitoring. For example, weather and other relevant environmental data are publically available on the National Oceanic and Atmospheric Administration (www.noaa.gov), the United States Geological Survey (www.usgs.gov), and CEDEN (www.ceden.org) websites.

Monitoring programs that focus on the trash accumulation rates (as opposed to standing stock or snapshot concentrations) may need to consider standardizing sampling interval in order to successfully interpret or compare accumulation rates over time and among sites. Frequent sampling reduces biases owing to rapid debris turnover, but estimates are more variable relative to longer sampling intervals, and therefore may require greater sampling effort to reduce variance to an acceptable level (Ryan et al. 2009). In addition, on beaches and shorelines, there is evidence to suggest that longer revisit time periods underestimate true accumulation rates (Moore et al. 2016, Lippiatt et al. 2013, Eriksson et al. 2013). Conducting frequent monitoring to characterize the reaccumulation rates at known high-accumulation sites can provide valuable information on the success of mitigation efforts over a long-term period (Ryan et al. 2009). In general, accumulation survey frequencies should be identical for comparison between studies (Ribic et al. 1992). However, we acknowledge that it may be very challenging to consistently sample at the same interval in a monitoring program. In developing a monitoring plan, it will be beneficial to collect data in such a way that it

can be normalized to per unit area and timeframe, such as gallons/acre day¹ or gallons/acre year¹ (EOA Inc. 2016). Annual rates are also the same unit used in previous trash generation studies (EOA Inc., 2014).

SAMPLE SIZE

In any monitoring program, the sample size, length of transect, number of replicates, etc. should to be specified and selected in a way that enables the analysis of data to address priority management questions. The inherent spatial and temporal heterogeneity of trash complicates monitoring designs. In order to overcome this challenge, pilot studies and/or baseline monitoring efforts can be used to determine appropriate sample sizes needed to identify trends or differences among groups (e.g., how many samples are needed to detect a certain percent change or difference?). Pilot studies that estimate variability in sample data and then conduct power analysis to determine sample sizes can help future monitoring efforts to be effective at identifying differences or changes in trash levels over time or among sites (see “Establishing a Baseline” and Ryan et al. 2009). Similarly, the minimum length or area sampled could be determined by a power analysis based on estimates of variability in accumulation data from pilot studies and on considerations of the minimum rate of change to be detected (Ribic & Ganio 1996). Sample size may also be determined by the “law of diminishing returns.” In this approach, sample size is determined by the number that corresponds to the level at which increasing the sample size has no change (appreciably) on the average measurement.

Sample size is largely driven by the management questions. In general, it will be important to consider the number of “groups” or categories (e.g., methods tried or locations sampled) you would like to compare to address management questions. Within each group, you will want a minimum of three different samples, as that is the minimum number required to calculate standard error and conduct statistical analyses such as an Analysis of Variance. In practice, sample size may be limited by staff capacity, funding, or other related factors. In general, larger areas or areas with a diversity of habitat types may require more sites to be sampled.

PRIORITIZING EFFORTS AND COLLABORATION

In the development of a monitoring plan, permittees may consider conducting an initial assessment to identify the trade-offs associated with different monitoring approaches. As part of this effort, permittees should consider identifying specific management questions of interest, because these will focus monitoring investments and ensure that efforts are designed to inform pertinent management needs. In the course of conducting initial assessment and monitoring planning processes, permittees can assess the pros and cons related to various approaches based upon:

- ranked priority management questions;
- tradeoffs in feasibility, cost, sampling effort (sample size, frequency, method, etc.), and safety;
- safety hazards or other potential restrictions (e.g., locations or areas where access may be restricted or where sampling may cause significant harm to habitats or species); and
- additional monitoring questions and science needs.

An additional component should be to inventory opportunities and assets, including funding and potential partnerships. Monitoring programs may benefit by exploring ways to coordinate with and/or leverage other efforts (Moore et al. 2016). When evaluating trade-offs in sample size, sampling frequency and methods, it may be beneficial to conduct an assessment of existing monitoring or research efforts and identify potential partnerships and leverage assets or monitoring efforts. Collaboration with citizen science groups, universities, institutions, non-governmental organizations, schools or other science groups may help reduce costs while increasing monitoring effort. A challenge related to collaborating with external groups is maintaining consistency in data collection. This challenge may be overcome with sufficient training and audits. In addition, consistency may be achieved through standard data reporting methods and/or tools. For example, digitizing data in one place or portal will help build consistency and comparability of data.

One key challenge with trash monitoring is resolving the tradeoffs associated with counting and characterizing

trash (see Table 1. The pros and cons of qualitative, semi-quantitative and quantitative trash assessment approaches). It is generally accepted that knowledge of the different trash types discharged from an MS4 or within receiving waters is crucial information to help understand sources of trash, identify solutions, and measure the effectiveness of targeted reduction strategies. We acknowledge that it may be very difficult for many cities and municipalities with limited staff time and funding to include trash characterization or counting in their monitoring programs. However, there are technologies in development that may be applied to characterize and count trash using computer programs that analyze photographs. Given that many monitoring programs may remove trash during surveys, this serves as a potential opportunity to document the abundance of trash using photographs, which may be analyzed when photographic software become available and affordable. For example, collected trash that is displayed and photographed on a uniform background, such as a tarp, may be analyzed at a later date to generate a quantitative assessment of the number of items present. For conspicuous items, such as cigarette butts, it may be possible for software to identify and count the items of a particular trash type. This will not only support data comparability, but also enable monitoring programs to “back calculate” previous surveys and, possibly, develop conversion factors among counts and other measurements collected simultaneously.

QUALITY CONTROL, TRAINING, AND SAFETY

In any monitoring program, it is recommended that there are protocols in place for quality control, staff training, and safety. In order to ensure data are collected in a way that preserves data quality, it is important to hold the appropriate level of training for staff and volunteers including development and use of Standards of Practice (SOP), gear lists and datasheets. Implementing regular audits in both field and lab settings are an important tool to identify errors or issues with monitoring implementation. Audits typically consist of a re-analysis of a subset of sites or samples and comparing the mean and variance in data to those collected by monitoring personnel. For example, in the San Diego Bay Debris Project (2016), debris items collected at 10% of sites were retained for reanalysis. Variations of more than 30% in identified debris types were considered to be sufficient basis for flagging the portion of the data quality in question. NOAA recommends that an auditor conduct 20% of surveys or transects for quality control (Lippiatt et al. 2013). Follow up inspections are another strategy to improve quality data collection and ensure staff trainings are successful. Quality control for trash characterization is challenging as replication of results is difficult. For this reason, highly trained or experienced personnel may be needed for surveys that include a trash characterization component (EOA, Inc. 2017).

Safety should be a top priority during any monitoring program as there are inherent hazards associated with field sampling both within an MS4 and in its receiving waters. It is imperative that experienced personnel conduct a thorough investigation of sites in order to identify other possible hazards before the monitoring phase of a project begins (CalTrans 2015). A key strategy to avoiding safety hazards is to select sites that have safe entry and exit points and to avoid sites that have risk of injury, are located on private or restricted-access land, or have other safety hazards. Consider using the buddy system when conducting surveys and require personnel to carry first aid kits or other relevant medical supplies (Lippiatt et al. 2013). Training of staff in the deployment and use of sampling equipment may prevent injury due to equipment failures or improper use. In addition to training, safety gear may be recommended (e.g., gloves, life jackets, etc.). Monitoring personnel should be provided a cellular telephone to facilitate communication, particularly if sampling during storm events or at night (CalTrans 2015). Having prior knowledge of medical facilities nearby sampling locations may reduce the extent of injury, if incurred. Sampling methods that have higher risk of injury should be avoided. For example, in-water sampling of large rivers (natural or channelized) during storm or high-flow events can be very unsafe and/or infeasible (5 Gyres 2017). Specialized equipment will be necessary for effective and safe survey implementation.

DATA MANAGEMENT AND COMPARABILITY

Monitoring reports submitted to the permitting authority must include GIS-mapped locations and drainage area served for each of the FCSs, multi-benefit projects, other treatment controls, and/or institutional

controls installed or utilized by the MS4 permittee. GIS coordinates, in combination with comparable trash monitoring data of (a) the discharge of trash and (b) the amount of trash within receiving waters, may enable the development of Statewide maps of trash capture strategies and associated trash levels. Together, these data will help Statewide efforts to evaluate the effectiveness of trash reduction strategies. However, the Trash Amendments do not specify how permittees should measure amount, posing a challenge to data comparability among monitoring programs.

The collection of data such that it is comparable to other research and monitoring efforts is needed to support efforts to (a) quantify and compare trash pollution across the State and to other areas, (b) identify hotspots of trash pollution, and (c) identify solutions or strategies to reduce trash pollution. The Trash Amendments, however, do not specify a monitoring method or unit of measurement to be included in annual monitoring reports. This lack of clarity poses a challenge to those interested in synthesizing monitoring data among MS4s and comparing trends across the State. A simple strategy to encourage data comparability is to identify an ideal data format and where possible, provide templates for data recording and online submission. For example, an ideal data management system is a field application that links to a geospatial database. This format encourages consistency across all programs. Currently, this type of system does not exist for trash monitoring, but it represents a goal for programs to build towards and ultimately use. An example of a similar type of database that currently exists is California Environmental Data Exchange Network (CEDEN).

Other opportunities to increase data comparability are to encourage the collection of data in a way such that it can be normalized to per unit area and timeframe, such as gallons per acre per year or number of items per meter-squared per day (EOA Inc., 2016). Additionally, in situations where resources are limited it may be necessary to develop conversion factors that enable qualitative scores to be converted into quantitative values (e.g., a conversion of a visual assessment score to weight). While not ideal from a scientific point of view, there are pilot studies in the Bay Area that have demonstrated the feasibility of such conversions (EOA Inc., 2016). While qualitative scores are useful and cost-effective, the ability to “see the numbers” may be needed to tell a compelling story about trash pollution and the management or policy actions that do or have the potential to improve conditions. Acknowledging that it is difficult to know the sizes of trash items found, the situation may demand the development of methods to convert the weight of a particular trash type (e.g., plastic bags or cigarette butts) into counts or items. Counting trash items is very time consuming, but is a common assessment method, particularly in marine environments. This type of conversion factor would improve data comparability between on-land trash monitoring (where weight measurements are more common) and marine monitoring programs (where counts are more common).

2.2 Considerations for Monitoring the Discharge of Trash

This section builds upon the monitoring guidance above by summarizing current efforts and remaining science needs for monitoring the discharge of trash, which may inform permittees as they consider the question posed in the Trash Amendments:

- Has the amount of Trash discharged from the MS4 decreased from the previous year?
- If so, by how much? If not, explain why.

These questions, as posed, suggest that an important monitoring goal is to determine the amount of trash discharged and how it is changing through time, and an explanation if no change was observed. The Trash Amendments intentionally do not specify monitoring requirements in order to account for the need for flexibility in implementation moving forward. However, in reviewing the information, there are key monitoring considerations and challenges that may be gleaned to guide next steps. In approaching these questions, the amount of trash discharged may be defined as the amount of trash that was captured or reduced by the trash reduction strategy that would have been discharged to a receiving water body if that strategy were not in place.

First, in terms of measuring discharge, Track 2 strategies implemented on or within storm drains (e.g., curb

Box: Low Impact Development, Opportunities and Challenges

Low-impact development controls (LIDs) are treatment controls that employ natural and constructed features that reduce the rate of stormwater runoff, filter out pollutants, facilitate stormwater storage onsite, infiltrate stormwater into the ground to replenish groundwater supplies, or improve the quality of receiving groundwater and surface water (See Water Code 10564.). An example is green street strategies, which refer to sustainable strategies that use natural systems (e.g., vegetated facilities) to manage stormwater, reduce flows, improve water quality, and enhance watershed health and neighborhood livability. Low-impact development controls that meet certain criteria* are considered as FCS by the Trash Amendments. LIDs, however, vary widely in their design and typically trash collection is not the primary motivation for their design and/or installation. For this reason, there still are many open questions about which design features and maintenance strategies maximize trash collection. In general, LIDs are likely to be more effective at capturing trash if stormwater has a direct or lower angle of entry into the device (see Fig 1A, B, C.). In addition, design features that prevent trash from escaping LIDs, such as grates or screens, may also improve their effectiveness at trash capture devices (see Fig 1D.).

A unique feature of LIDs is their potential to capture small litter items or micro-debris. Because most LIDs have a primary purpose of improving stormwater quality, they are designed using a series of filters and screens - both natural and artificial - to remove contaminants such as metals, oils, pesticides and other pollutants (A. Gilbreath, personal communication April 17th 2017). They may be particularly suited to remove micro-debris (<5 mm in size). While the Trash Amendments focus on debris larger than 5 mm, there is growing recognition that small debris particles, plastic in particular, may be particularly harmful to living organisms (A. Gilbreath, personal communication April 17th 2017).

The Trash Amendments require permittees to provide information about the maintenance of FCSs as part of their annual reporting. It may be valuable for permittees to consider including information in their report that demonstrates LID maintenance practices preserve the function of the LID as a trash capture device. Trash removal from LIDs will likely need to occur on a regular basis to ensure that LIDs do not overflow with debris, particularly in wet seasons when debris inputs may be higher.

*LID that trap all particles that are 5 mm or greater, and has a design treatment capacity that is either: a) of not less than the peak flow rate resulting from a one-year, one-hour, storm in the subdrainage area, or b) appropriately sized to, and designed to carry at least the same flows as, the corresponding storm drain.



Figure 1. LID designs with high (A), low (B) and intermediate (C) angles of storm water entry; and LID with a screen design feature (D). Image credit A. Gilbreath (A-C) and Iron Age Designs (D).

inlet screens, auto-retractable screens, etc.) may require monitoring of debris in the drains themselves or at inaccessible outfalls in order to effectively measure discharge. For Track 2 strategies implemented in locations prior to trash entering the stormwater system (e.g., increased street sweeping, product bans, clean-up efforts, education, etc.), streets and/or sidewalks surveys near storm drains may serve as valuable proxy measures of discharge. In addition, pilot studies of on-land-visual assessments may provide valuable information about the amount of trash that enters storm drains. If the data collected establish a relationship between the accumulation of trash on-land and trash in storm drain inlets, the amount of trash on-land could be used as a metric for discharge (EOA, Inc. 2017).

Second, if no change in the amount of trash was observed from the last year, accounting for external factors such as weather, illegal dumping, insufficient maintenance of trash reduction strategies, etc. in monitoring programs could help tease apart the multiple factors that potentially drive variation in the discharge of trash. Such factors can impact the amount discharge. Thus this approach will help understand whether the amount of trash may be changing (or not) as a result of trash reduction strategies implemented under Track 2, or some other factor.

Finally, the management goals, as they are translated into specific monitoring questions, may determine the monitoring method permittees will implement. Translating management goals into explicit monitoring questions will be an important part of the process of developing a monitoring program. For example, the Trash Amendments do not specify the “amount” of trash that should be measured, leaving it up to the permittee to make decisions about what measurement unit(s) (e.g., qualitative scores, counts, weight, etc.) to include. Monitoring questions typically identify the method, unit of measurement, habitat/location, factors of interest, and confidence interval (e.g., Has the count per area of trash changed by 10% on streets and sidewalks over the last year with an 80% confidence?). The development of monitoring questions will help ensure data collection proceeds in a matter that is relevant and useful to addressing the questions of interest. Permittees should be specific about what they are trying to accomplish by translating management questions into explicit scientific monitoring questions.

2.2.1 Lessons Learned:

Drawing upon the efforts described in the wealth of resources in Appendix A, we have summarized some lessons learned and science needs to address knowledge gaps. There are several completed or existing monitoring efforts that reviewed, validated, or implemented monitoring protocols for the discharge of trash that are valuable resources for permittees with limited capacity to develop and validate novel methodologies.

LESSONS LEARNED

The substantial spatial and temporal variability of trash in the environment will make it very difficult to detect changes in the amount of trash within and between years, even with a substantial investment in monitoring surveys (Ryan et al. 2009, Vesar, Inc. 2012):

1. *Establish a robust baseline:* Allowing enough time to establish a robust baseline collection effort spanning multiple years, followed by a streamlined and targeted monitoring program over subsequent years, will improve the ability to detect changes in the amount of trash discharged from an MS4 relative to baseline conditions.

In addition, temporal and spatial variability of the discharge of trash highlights the need to encompass a range of priority land use areas sites and conduct surveys in both dry and wet seasons:

2. *Account for other factors of interest:* Accounting for multiple factors, such as the type of trash reduction strategy implemented, proximity to significant trash sourced (e.g., illegal encampments) will support efforts to identify the desired level of change one wishes to observe with statistical confidence, and interpret trends in monitoring data



Photo Credit: Carolyn Box

SCIENCE NEEDS

Many institutional Track 2 trash reduction strategies (e.g., autoretractable screens, partial capture devices) have design features to prevent flooding during large flows, which typically consists of a release or opening of the trash capture device, allowing trash to flow through the device. Given that stormwater is a notable vector of trash, this highlights the potential for significant amounts of trash to enter MS4s during large storms:

1. Measure the amount of trash that enters MS4 when trash capture devices release during large storms.

In addition, many visual assessment methods occur on streets and sidewalks, which means that they do not directly measure the potential contribution of this type of trash vector in their total assessment of trash discharge:

2. Evaluate whether on-land visual assessments of trash can serve as proxies for this trash vector.

2.3 Considerations for Monitoring Trash in Receiving Waters

Another component of the central questions in the Trash Amendments is monitoring trash in receiving waters. There are multiple different habitat types that may be present in MS4s receiving waters, and each habitat type may require a unique monitoring method (e.g., specialized equipment, measurement type, etc.). Most natural or channelized shoreline use a transects or plots method of sampling. Trash observed within the sample area may be counted, weighed, measured for volume, or characterized into litter types. Given that debris typically concentrates along the high water line, it may be advisable to set transects long the high water line (Moore et al. 2007). In natural streams, the high water line curves and transects may be placed along the natural curve of the shoreline. Trash may be measured within a defined distance from the transect line (width) and over a particular length of interest. These two distances will enable the sample area to be quantified (e.g., length x width) and used in calculations for concentration or accumulation. There are also some recent efforts to implement qualitative assessments in natural shorelines, using a modified method of the on-land visual

assessment survey (AMEC Foster Wheeler, unpublished data).

Larger water bodies (e.g., lakes, marine) may be sampled using trawls, such as a manta trawl (Leecaster et al. 2002, Lippiatt et al. 2013, Mason et al. 2016, 5 Gyres 2017) or neuston net (Baldwin et al. 2016), which are deployed for a sufficient period of time to successfully collect debris without overloading the net. Additionally, visual surveys have been developed and applied to survey surface waters in the marine environment (Lippiatt et al. 2013).

Flowing water bodies (e.g., natural or channelized creeks and rivers) may be sampled using trawls (e.g., manta trawl). For trawl surveys, catch per unit area (or volume) would be the most robust approach to quantification (Ribic et al. 1992). Marina skimmers or booms may also be deployed and used as trash collection devices in a monitoring program (San Diego Debris Study Work Group 2016). Litter booms have been shown to trap large quantities of floatable materials. However, a significant portion of trash in urban runoff likely escapes or evades a boom because they are designed to capture floating trash (Gordon and Zamist 2006).

Finally, litter that collects in benthic sediment may be sampled using sediment cores. Calculations of concentration or accumulation should account for the volume of sediment core sampled. As with discharge, permittees will have to translate broad management questions into scientific monitoring questions of interest to the MS4, which will drive the appropriate methodology.

LESSONS LEARNED

Similar to discharge monitoring, the significant variability of trash in the environment will make it very difficult to detect changes in the amount of trash within and between years.

Dynamics of trash in receiving waters is likely to differ among locations and regions in California, particularly for highly channelized or urbanized areas relative to rural areas:

1. Account for spatial/temporal heterogeneity:
 - a. Monitoring programs should focus in areas where channelized streams are common, and may benefit from monitoring during dry and wet weather, or by monitoring both shorelines and in-water habitats, in order to effectively characterize the dynamics of trash. Due to the lack of rugosity, debris typically flows rapidly through channels during storm events in channelized streams, and thus trash



Photo Credit: Carolyn Box

may or may not always be present along the shorelines of channelized streams (Talley et al. 2016, 5 Gyres 2017).

- b. In the course of storm events, calculating the flux of trash in flowing water bodies requires measuring the water velocity through trawl nets during the sampling period. This may be achieved by directly measuring water flow using a flow meter (5 Gyres 2017). If unavailable, flow rates may be approximated by nearby USGS flow gauges, though permittees should be aware that this method will introduce measurement error.

One of the biggest challenges of receiving water monitoring is that there are multiple sources of trash and effectively no robust methods to identify or distinguish the relative contribution of different sources:

2. Gain insight into potential sources:

- c. One of the most informative methods is to characterize trash types, particularly as it relates to potential MS4 sources, such as food packaging, industrial debris, or other items that might indicate a specific source.
- d. The location of trash along a shoreline may also provide insight into whether the debris was transported by wind, water or illegal dumping. Debris transported by wind is likely to reside above the high water line, while debris transported by water is likely to reside along the high water line or within the receiving water itself (in-water or in the sediment/substrate). Debris transported by illegal dumping typically are highly concentrated or located near an entry point (e.g., near a fence or bridge).
- e. Site characterizations may support efforts to identify sources of trash. For instance, noting whether the sampling location is near a road, illegal encampment, or other source, may help interpret monitoring data. Consider whether such site features might accumulate or limit debris composition (Lippiatt et al. 2013).
- f. Consider selecting sites that are closest to the sources of trash (e.g., outfalls) as this may increase the likelihood of observing a change in the receiving waters due to the strategy implemented in the MS4. Selecting a specific monitoring site near an upstream source of interest may be warranted if a targeted design is desired to address a specific management question. However, selecting sites that have trash accumulation or dampening characteristics may increase bias in the data and, therefore, may not be recommended if the intent is to extrapolate data across an entire area.
- g. Monitoring reference sites (e.g, sampling in the upper watershed) may be helpful to understand dynamics of trash in receiving waters and potential debris sources. However, if cost or staff time and capacity are limited, it may be beneficial to focus on monitoring receiving waters within the MS4.

Monitoring receiving waters can also pose logistical and other challenges to the people conducting site visits:

3. Ensure safety and feasibility of site visits:

- d. Avoid sites where sampling activity is likely to significantly degrade habitat or impact endangered species. Additionally, sites that include endangered species habitat may require additional permits to enable monitoring personnel to access the site.
- e. Consider selecting sites that are easy to access, have safe entry and exit points, and enable monitoring personnel to access the sites regularly. Avoid site that have risk of injury or other safety hazards.
- f. In-water sampling of large rivers (natural or channelized) during storm events can be very unsafe and/or infeasible (5 Gyres 2017). Specialized equipment will be necessary for effective and safe survey implementation

Science and technology also continue to advance to strengthen monitoring in receiving waters. This is a critical need given the heterogeneity, sources of error, logistical and other challenges. Also, we may be able to make science and technology more cost-effective and efficient:

7. Advance development of methods and equipment:
 - a. A weighted rectangular trawl is a promising and new tool to sample water along the benthos of a natural or channelized river (5 Gyres 2017). Further testing of this equipment is needed.
 - b. Recently, a qualitative on-land visual assessment method, adapted from that implemented by EOA, Inc. 2016, was applied to Southern California Streams (AMEC Foster Wheeler, unpublished data). This effort found that implementing a qualitative assessment in natural streams is possible. Preliminary results suggest that this method was effective at providing a general characterization of the amount of trash in the environment. In addition, because this method required less time to implement, it enabled staff to survey more sites, including upstream locations that supported efforts to identify potential sources of trash. Additionally, this method was found to be less susceptible to fine-scale spatial variability in the amount of trash.

SCIENCE NEEDS

There is much to learn about the dynamics of trash in receiving waters and efficacy of removal methods given spatial and temporal variability. In general, there are five broad management questions that will require additional science and research to address. These broad questions were identified at a workshop hosted by the Ocean Protection Council (*Trash Monitoring Methods Development: Conceptual Modeling Workshop*, April 18-19, 2017).

1. What is the composition and spatial distribution of trash?
 - b. Where are hotspots and what accumulates there?
 - c. How does trash amount and composition compare between reference and focal areas?
 - d. How does trash amount and composition vary within and among receiving waters?
2. How does the composition and amount of trash vary with time?
3. What are the sources, drivers and relative contributions of MS4 and non-MS4 sources of trash?
 - a. Within MS4, what are the land uses and land-use practices that contribute most?
 - b. Within non-MS4, what source types contribute the most?
4. What are the contributions of management activities to reducing trash in particular locations or scenarios?
 - e. Regulatory actions?
 - f. Treatment controls?
 - g. Education?
 - h. Other?
9. What is the effect or cost of the impact of trash on the environment?
 - a. On biota?
 - b. On aesthetics?
 - c. On human safety?

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APPENDIX A. Resource List

The list below includes some valuable resources and sources of information on trash pollution, removal strategies, and monitoring. This list primarily draws from the literature in the United States, with a focus on efforts in California. This list is intended to serve as a resource for those interested in learning more about California trash pollution reduction strategies and methods to monitor trash in urbanized and natural environments.

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APPENDIX B. Workshop agenda and participant list

WORKSHOP

Monitoring Considerations for Trash Amendment Compliance

APRIL 17TH, 2017

Room 9

1515 Clay Street, Oakland, CA

BACKGROUND:

The State Water Resources Control Board (the Water Board) and the Ocean Protection Council (OPC) have requested the California Ocean Science Trust to develop a “playbook” of monitoring considerations for the Water Boards and permittees developing plans for trash monitoring in various California water bodies. Given the challenges associated with monitoring the discharge of trash and the amount of trash in receiving waters, a guidance document is needed that synthesizes:

- general monitoring guidelines for municipal separate storm sewer systems (MS4) permittees to demonstrate compliance with the Trash Amendments;
- considerations related to quantifying litter, safety, data comparability, as well as other issues related to monitoring for compliance with the Trash Amendments;
- an overview of the benefits and challenges of different monitoring strategies that may be employed to monitor discharge and trash in receiving waters; and
- a summary of key resources and existing monitoring protocols.

The guidance document will draw from the scientific literature, expert interviews, and case studies in other locations.

WORKSHOP GOALS:

Our aim is produce a document the provides guidance for the Water Boards and permittees to consider as they develop monitoring plans to comply with the Trash Amendments. The goals of the workshop are to discuss:

- emerging challenges and opportunities in trash monitoring; and
- to receive direct input on the draft guidance document.

An annotated outline of the guidance document will be provided as supplemental materials for this workshop. In order to maximize productivity during the workshop, participants will be asked to familiarize themselves with the outline during specified times. During the workshop, participants will also be asked to provide direct input on the guidance document.

DRAFT AGENDA:**9:00 am - 12:00 pm****Morning Session: Building a Shared Understanding of the Opportunities and Challenges to Comply with the Trash Amendments***9:00 am, Welcome and Introductions*

- Opening remarks and introductions of workshop participants: Sarah Wheeler, California Ocean Science Trust; Holly Wyer, California Ocean Protection Council

9:20 am, Overview of Workshop Goals

- Presentation: Sarah Wheeler, California Ocean Science Trust
- Discuss goals, discussion topics, and desired outcomes

9:30 am, Overview of the Trash Amendments and Current Monitoring Needs

- Presentation: Greg Gearhart, State Water Resources Control Board

9:50 am, Current challenges in trash monitoring

- Presentation: Shelly Moore, Southern California Coastal Water Research Project

10:10 am, Lessons Learned on Qualitative vs. Quantitative Monitoring

- Presentation: Chris Sommers, EOA, Inc.

10:30, Discussion: Quantitative vs. Qualitative Assessments

- Facilitated discussion: Emily Knight and Sarah Wheeler, California Ocean Science Trust
- Discussion topics:
 - o What are the pros and cons of using qualitative assessments to measure the discharge of trash?
 - o What are the pros and cons of using quantitative assessments?
 - o Solicit advice, considerations, and guidance

- 11:10 am BREAK -

11:25 am, Overview of Draft Guidance Document

- Presentation: Sarah Wheeler, California Ocean Science Trust

- 12 pm LUNCH -

1 - 5pm

Afternoon Session: Structured Review of Draft Guidance Document

1:00 pm, Review Part 1: Considerations for Trash Amendment Compliance

Part 1a. Monitoring Opportunities and Challenges to Comply with Q4

- Facilitators: Emily Knight and Sarah Wheeler, California Ocean Science Trust
- Q4: Has the amount of Trash discharged from the MS4 decreased from the previous year? If so, by how much? If not, explain why.
- Discussion topics:
 - Identify challenges and opportunities in monitoring
 - Solicit advice, considerations, and guidance

Part 1b. Monitoring Opportunities and Challenges to Comply with Q5

- Facilitators: Emily Knight and Sarah Wheeler, California Ocean Science Trust
- Q5: Has the amount of Trash in the MS4's receiving water(s) decreased from the previous year? If so, by how much? If not, explain why.
- Discussion Topics:
 - Identify challenges and opportunities in monitoring
 - Solicit advice, considerations, and guidance

Part 1c. Synthesis: Considerations for Trash Amendment Compliance

- Facilitator: Sarah Wheeler, California Ocean Science Trust
- Synthesize key points discussed

- 2:30 pm BREAK -

WORKSHOP PARTICIPANTS

Donna Bodine, Geosyntec

Sean Bothwell, California Coastkeeper Alliance

Dale Boyer, California State Water Resources Control Regional Board 2

Carolynn Box, 5 Gyres

Betty Fetscher, San Diego Regional Water Quality Control Board

Amy Franz, San Francisco Estuary Institute

Greg Gearheart, California State Water Resources Control Board

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Sarah Wheeler, Ocean Science Trust

Liz Whiteman, Ocean Science Trust

Steve Weisberg, Southern California Coastal Water Research Project

Holly Wyer, Ocean Protection Council