Statewide Plastics Monitoring Strategy and Planning Framework

Diana Lin, Tony Hale, Kayli Paterson, Ezra Miller, Shelly Moore

San Francisco Estuary Institute

Moore Institute for Plastic Pollution Research

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Members of the Technical Advisory Committee are the following:

Monica Arienzo, Desert Research Institute

Julian Fulton, CSUS

Austin Gray, Virginia Tech

Leah Thornton Hampton, SCCWRP

Paul Helm, Ontario Ministry of the Environment, Conservation and Parks

Bushra Khan, UC, Davis; Marine Pollution Studies Laboratory at Granite Canyon

Thomas Novotny, SDSU Center for Tobacco and the Environment

Violet Renick, City of San Diego

Chelsea Rochman, University of Toronto

Meredith Evans Seeley, VIMS

Chris Sommers, EOA, Inc.

Theodore VonBitner, WSP USA Inc.

Members of the State Advisory Group include the following:

California Ocean Protection Council

Kaitlyn Kalua

Kyla Kelly

OEHHA

Scott Coffin

Wesley Smith

California Coastal Commission

Eben Schwartz

SWRCB and Regional Water Quality Boards

Ali Dunn, Office of Information Management & Analysis (OIMA)

Andrew Hamilton, OIMA

Erica Kalve, Div. of Water Quality (DWQ)

Helene Baribeau, Div. of Drinking Water

Manoela Romanó de Orte, (DWQ)

Lori Webber, OIMA

Jonathan Williams, DWQ

Tessa Fojut, OIMA

Thomas Mumley (retired), *Region 2*

Ivar Ridgeway, *Region 4*

Adam Fischer, *Region 8*

Chad Loflen, *Region 9*

California Air Resources Board

Mo Chen

Michelia Dam

Seungju Yoon

Sara Forestieri

Vahid Farahani

California Department of Public Health

Liz Hendrix

Marilyn Homan

CalRecycle

Laura Moreno

CalTrans

Nabiul Afrooz

Gerardo Dominguez

Jagjiwan Grewal

Joshua Gualco

Bhaskar Joshi

Hardeep Takhar

Walter Yu

Department of Toxic Substances Control

Dicle Yardimci

Valerie Hanley

State Lands Commission

Christopher Huit

List of Definitions

Vocabulary	Definition
Conceptual model	A visual representation used to express relationships and highlight key or dominant processes.
Cigarette filter	Single use attachment on nearly all commercial cigarettes, predominantly made of cellulose acetate fibers. Widely observed macroplastic debris which can degrade into microplastics in the environment.
Degradation	Combination of abiotic and biotic processes leading to breakdown of plastics into smaller microplastics.
Ecosystem services	The array of benefits that come from properly functioning natural systems, which are often used as a measurable basis for regulation, law, policy, and management.
Escaped trash	Waste material identifiable in the ambient environment, beyond the handling of conventional waste management procedures.
Impervious areas	Areas through which water cannot infiltrate, such as pavement or rooftops.
Fate	The degradation processes plastics are subject to and where they end up after environmental release.
Macroplastics	Plastic debris greater than 5 mm in size.
Matrix	Mediums through which plastics are dispersed in the environment. Examples include soil, sediment, water, or animal tissue.
Microfibers or Microplastic fibers	Microplastics that have a long, narrow thread-like shape, significantly longer in one dimension than in the other two dimensions, and less than 5 mm in all dimensions. Some members of the textile community use this term slightly differently, to refer to textiles made of very fine synthetic material threads.

Vocabulary	
Microplastics	Small plastic particles smaller than 5 mm. This report adopts California State Water Resources Control Board Resolution 2020-0021 defining 'microplastics in drinking water' for microplastics in the environment: "solid polymeric materials to which chemical additives or other substances may have been added, which are particles which have at least three dimensions that are greater than 1 nm and less than 5 mm. Polymers that are derived in nature that have not been chemically modified (other than by hydrolysis) are excluded; includes synthetic polymer composites, co-polymers, modified natural polymers (i.e., synthetic polymer-encapsulated natural polymers or natural polymers with synthetic polymer content greater than or equal to 1% by mass)."
Mitigation measures	Planned designs or approaches to reduce plastic waste and minimize their impacts on the environment. Includes broad range of opportunities ranging from preventative measures to reduce plastic use or generation of plastic waste and reduce release of plastic waste into the environment (e.g., source control measures such as single-use plastic bag bans) to remediative measures including collecting and removing plastic from waste streams and the environment (e.g., stormwater infrastructure, such as trash capture devices and bioretention rain gardens, or cleanup efforts). Mitigation measures can be implemented by industry, government, and consumers.
Nanoplastics	Plastic particles smaller than 1 µm. Included within this report's definition of microplastics.
Oxidation	The abiotic process that deteriorates organic material through contact with a chemical oxidizer (usually oxygen).
Pathway	The environmental compartment through which microplastics are transported from sources. Examples include stormwater and wastewater.
Plastic waste or debris	Plastic objects and particles (macroplastics and microplastics) unmanaged in the environment. Made from synthetic materials that contain carbon, often made with petroleum. Can come in many shapes, sizes, and colors and include plastic coatings and adhesives.
Primary microplastics	Microplastics that are designed and manufactured to be smaller than 5 mm for a variety of uses, including pellets for plastic production (e.g., "nurdles"), abrasive blasting, paints and adhesives, certain types of fertilizer applications, and for use in personal care

Vocabulary	
	products. Primary microplastics are released to the environment as a consequence of the use of products that intentionally contain or release them during maintenance and use.
Risks	Possibility of adverse effects due to exceedance of protective thresholds for aquatic life and/or human health.
Secondary microplastics	Microplastics that originate from the partial degradation of larger plastic items, regardless of when this breakdown occurs.
Standardized methods	From a regulatory perspective, standardized methods are those that have undergone extensive testing and inter-laboratory comparisons before receiving broad approval for authorized use by a wide range of stakeholders, including end-users and regulatory agencies themselves. Non-regulators may have different definitions.
Single-use plastics	Disposable plastic items designed to be used once (to serve, package, transport, and consume prepared food and beverages, including bags, bottles, bowls, caps, cups, cutlery, plates, straws, stirrers, takeout containers, trays, and wrappers) and easily disposed of.
Source	The product(s) from which microplastics originated and the producers or behaviors resulting in escaped macroplastics.
Stormwater	Runoff generated when precipitation from rain and snowmelt events flows over land or impervious surfaces without percolating into the ground.
Textiles	Material and finished products made from fibers. Can be woven or nonwoven.
Tire particles	All types of microplastics containing tire material, including both tire wear particles and microplastics created from end of life tires.
Tire and road wear particles	A subset of tire particles. Refers only to microplastics generated by tire wear on pavement.
Total Daily Maximum Load	Defined quantity of a pollutant that a water body can tolerate and still meet water quality standards, developed as part of plans to restore clean water.

Vocabulary	
Transport	The movement processes that microplastics are subject to after environmental release.
Trash	All improperly discarded materials generated by human activities (both plastic and non-plastic).
Urban runoff	Surface water runoff (includes storm-driven rain and dry weather flows) from urban landscapes (mostly impervious surface) that can pick up contaminants (trash, microplastics, chemicals, etc.) as the water flows towards receiving waters.
Washoff fraction	The portion of particles washed away in runoff instead of remaining on land.

Table of Acronyms

Acronym	Definition
BAMSC	Bay Area Municipal Stormwater Collaborative
BASMAA	Bay Area Stormwater Management Agencies Association
CalRecycle	California Department of Recycling
CDPH CTPP	California Department of Public Health California Tobacco Prevention Program
DDW	Division of Drinking Water
DQO	Data Quality Objectives
DTSC	Department of Toxic Substances Control
ELAP	Environmental Laboratory Accreditation Program
MQ	Management question defined in this report
NGO	Non-governmental organization
OPC	California Ocean Protection Council

Acronym	
OEHHA	Office of Environmental Health Hazard Assessment
PMC	Plastic Material Coefficient
QA/QC	Quality Assurance / Quality Control
RMP	Regional Monitoring Program for Water Quality in San Francisco Bay
RWQCB	Regional Water Quality Control Board
SWRCB	State Water Resources Control Board
SCCWRP	Southern California Coastal Water Research Project
SFEI	San Francisco Estuary Institute
SMC	Southern California Stormwater Monitoring Coalition
SOP	Standard Operating Procedure
SWAMP SPoT	Surface Water Ambient Monitoring Program: Stream Pollution Trends Monitoring Program
TAC	Technical Advisory Committee (see definition above)
TMDL	Total Maximum Daily Load
ToMEx	Toxicity of Microplastics Explorer

Executive Summary

Plastic pollution is a pervasive threat to California's aquatic environments, with impacts spanning ecological health, human well-being, and the integrity of natural resources. From visible macroplastics (trash) littering shorelines, cities, and waterways to microscopic particles infiltrating water, sediment, and wildlife, plastics are now present in virtually all areas across California. The state of California has a longstanding history and commitment to environmental stewardship and policy innovation, including concerted efforts to manage and reduce plastic pollution. This report was commissioned by the California Ocean Protection Council (OPC) to articulate a statewide strategy and planning framework for a future statewide plastics monitoring program that will inform management actions to mitigate plastic pollution in state waters.

The purpose of a statewide plastics monitoring program is to:

- establish a baseline of plastic contamination in state waters and identify trends over time;
- evaluate the impacts of this contamination;
- evaluate community benefits of successful trash and plastic management efforts;
- track California's progress in reducing plastic contamination;
- inform future management actions to reduce impacts.

This report describes a Statewide Microplastics Monitoring Strategy (Section 2) and a Statewide Macroplastics Monitoring Strategy (Section 4). Strategies to address microplastics (plastics smaller than 5 mm) and macroplastics (trash composed of plastic, defined in water quality policies and regulations as larger than 5 mm in size) are separate due to different monitoring information needs, sampling methods, and groups engaged in monitoring. The Microplastics and Macroplastics Monitoring Strategies together make up the Statewide Plastics Monitoring Strategy.

Goals

The Statewide Plastics Monitoring Strategy has the following goals:

- define key management questions that guide monitoring design and ensure policy relevance;

- establish a coordinated framework for a statewide monitoring program that connects and leverages diverse monitoring efforts and builds on existing programs;
- generate data to inform plastic mitigation measures that will protect aquatic ecosystems and human health.
- promote consistent, high-quality methods to improve data comparability, transparency, and data accessibility;
- address critical knowledge gaps related to plastic sources, pathways, transport, fate, and toxicity; and
- support equitable, regional decision making through targeted monitoring and public engagement.

Management Questions

A set of high-level management questions guide the Statewide Plastics Monitoring Strategy (referring to the combined Microplastics and Macroplastics Monitoring Strategies). These management questions define the primary information needs for a broad range of different roles: policymakers, regulators, and other stakeholders, including environmental non-government organizations and advocacy groups, community-based organizations, regulated municipalities and industries, researchers, and the public.

Management questions ask about levels of plastics (macroplastics and microplastics) in different aquatic ecosystems, and whether those levels impact aquatic ecosystems, ecosystem services, or human health. Additional management questions ask about upstream sources (products from which plastic waste originates) and pathways that transport macroplastic and microplastic debris (such as urban stormwater runoff and wastewater), as well as trends in plastic levels in the environment over time. These management questions are designed to ensure that monitoring activities and findings are relevant, actionable, and aligned with California’s environmental goals. They also support related regulatory program objectives. For example, monitoring that helps identify the major sources and pathways of macro- and microplastics debris can inform and help prioritize mitigation strategies and policy decisions.

Planning Frameworks

The Microplastics Monitoring Planning Framework (Section 3) and a Macroplastics Monitoring Framework (Section 5) include the following:

- recommended pilot monitoring studies that build on existing monitoring programs and related plastics monitoring efforts;

- priorities for near-term and long-term monitoring program implementation.

Section 6 describes crucial data management principles for a future statewide program to observe.

This Monitoring Strategy does not specify future program implementation by a specific agency, program, or regulatory means. It can be implemented in different ways to meet the needs of different entities and support discussions regarding state resources that may be needed to implement future monitoring program(s). It lays the foundation for a scientific, scalable, statewide program that can empower California to reduce plastic pollution through improved data and information, informed policies, and enhanced community engagement.

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1. Introduction

1.1 Purpose of the Statewide Plastics Monitoring Strategy

The Statewide Plastics Monitoring Strategy and Planning Framework was commissioned by the California Ocean Protection Council (OPC) to articulate a vision to guide implementation of a future statewide plastics monitoring program. The monitoring program will inform the management of macro- and microplastic debris to protect aquatic[1] health, as is consistent with OPC's Strategic Plan,[2] Statewide Microplastics Strategy[3], and the California Ocean Litter Strategy[4]. The Statewide Plastics Monitoring Strategy (Monitoring Strategy) is a roadmap to implement a future statewide plastics monitoring program that will provide data and information to inform questions about plastic contamination in aquatic ecosystems among water quality managers, the science community, non-governmental organizations, community-based organizations, and the general public.

The purpose of a statewide plastics monitoring program is to:

- Establish a baseline of plastic contamination in state waters and identify temporal trends;
- Evaluate the impacts of this contamination;
- Evaluate community benefits of successful trash and plastic management efforts;
- Track the State's progress in reducing plastic contamination;
- Inform future management actions to reduce impacts.

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[1] These plastics monitoring strategies are limited to environmental aquatic matrices, including surface waters (rivers, streams, estuaries, nearshore marine waters), associated sediments, and aquatic biota. The marine scope extends to California state waters. Monitoring of engineered systems—including wastewater and potable water treatment facilities, distribution infrastructure, end-use taps, and bottled water—is excluded, except where these systems influence plastic contamination in natural water bodies. Air and solid waste are also excluded unless directly contributing to aquatic plastic loading. Strategies are developed for California but may be applicable in other jurisdictions.

[2] OPC, California Ocean Protection Council Strategic Plan 2026-2030.

[3] OPC, Statewide Microplastics Strategy, 2022.

[4] OPC and NOAA, California Ocean Litter Strategy, 2022.

The following are examples of practical decisions that the envisioned monitoring program is designed to inform:

- **Prioritization of management actions:** What are the most impactful sources or pathways to target for mitigation?
- **Source identification and load estimation:** What are the dominant sources of macroplastics/microplastics to specific water bodies or regions?
- **Regulatory response:** Are levels of macroplastics/microplastics in certain areas high enough to warrant regulatory program intervention?
- **Prevention mechanisms:** Where and when is it impactful and practical to deploy signage and training programs designed to reduce levels of ambient macroplastics?
- **Effectiveness tracking:** Are existing policies or source-reduction efforts (e.g., single-use plastic bans, green stormwater infrastructure features, trash capture devices) reducing plastic levels in receiving waters?
- **Resource allocation:** Where should funding and monitoring efforts be focused to maximize environmental and public health benefit?

Macroplastics are persistent plastic trash defined in water quality policies and regulations as larger than 5 mm in size (about the length of a grain of rice).

Microplastics are plastics smaller than 5 mm. While some of these small particles are intentionally manufactured, the vast majority released into the environment come from the wear and breakdown of larger plastic materials.

Mitigation measures include a broad range of actions to address plastic in the environment and its impacts. They include preventive measures to reduce new plastic waste and reduce release of plastic waste into the environment (e.g., source control measures such as single-use plastic bag bans). They also include remediative "clean-up" measures to collect and remove plastic from the environment (e.g., stormwater infrastructure, such as trash capture devices and bioretention rain gardens, or cleanup efforts).

Urban Runoff and Urban Stormwater Runoff: Surface water runoff (including stormwater and dry weather flows) from urban landscapes can pick up contaminants (trash, microplastics, chemicals, etc.) as the water flows towards receiving waters. In most of California, urban runoff is discharged directly to receiving waters without treatment, and is transported through storm drain systems separately from municipal wastewater.

1.2 Existing Efforts to Address Plastic Contamination in California

California has a longstanding history and commitment to environmental stewardship and policy innovation, including concerted efforts to manage and reduce plastic pollution. These include local source reduction efforts targeting the use of plastic products, especially mismanaged single-use plastic products such as single-use plastic bags, foam packaging materials, and plastic straws. In 2022, the California legislature passed the California Plastic Pollution Prevention & Packaging Producer Responsibility Act,5 which aims to tackle plastic pollution by requiring covered materials to be recyclable through regulations implemented by California Department of Resources Recycling and Recovery (CalRecycle). California's State Water Resources Control Board (SWRCB) has also implemented stringent regulations to address trash flowing from urban environments to aquatic ecosystems, initially through the implementation of Total Maximum Daily Loads (TMDLs) for trash in specific water bodies, and now through the Statewide Trash Amendment (2015). Recognizing growing concern about microplastics as a new class of contaminants, the California legislature required state agencies to develop the Statewide Microplastics Strategy6,7 to protect aquatic ecosystems. The California legislature also responded to growing human health concern about microplastics in drinking water and required the SWRCB Division of Drinking Water (DDW) to advance microplastic science by monitoring for microplastics in drinking water8, and required the Office of Environmental Health Hazard Assessment (OEHHA) to develop guidelines for safe levels in drinking water.9

Monitoring is crucial to provide information about the levels of plastic debris in the environment, to evaluate impacts, and to inform mitigation strategies. Early trash monitoring initiatives, which began in the late 1970s, were largely limited to periodic cleanups by volunteers and local community groups. Over time, these activities evolved beyond simple litter tallies into comprehensive data collection programs (e.g., California Coastal Cleanup Day and International Coastal Cleanup) encompassing both marine and inland environments. As scientists and environmental regulatory agencies became more involved in monitoring plastics in the environment, assessment

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[5] SB-54, Allen, Chapter 75, Statutes of 2022

[6] SB-1263, Portantino, Chapter 609, Statutes of 2018.

[7] OPC, Statewide Microplastics Strategy.

[8] SB-1422, Portantino, Chapter 902, Statutes of 2018.

[9] SB-1147, Portantino, Chapter 881, Statues of 2024.

methods matured to incorporate rigorous scientific protocols, more frequent surveys, and finer-grained analyses of debris composition and sources.

With widespread plastic use and mismanaged waste, global plastic pollution has escalated dramatically since the 1970s, and projections suggest even steeper increases without significant policy and market interventions (Lebreton & Andrady, 2019). As monitoring methods and efforts have advanced over the years, so has our understanding of the scale and complexity of plastic pollution. The growing body of evidence not only highlights the ubiquitous presence of plastics in the environment, but also underscores the importance of ongoing data collection to inform effective response and protection strategies.

1.3 Vision and Mission Statement for Future Monitoring Program

VISION STATEMENT

A California environment with reduced plastic pollutants affecting our waters, wildlife, recreational resources, and citizens, as guided by a credible monitoring and evaluation system.

MISSION STATEMENT

An envisioned statewide plastics monitoring program coordinates existing plastics monitoring across the state, facilitates new monitoring opportunities, and addresses key management decisions by leveraging salient, interoperable, and accessible data produced through standardized monitoring methods.

1.4 Management Questions Define Scope of Monitoring Strategy

This Monitoring Strategy is guided by a set of high-level management questions (MQs) that were defined with representatives from state agencies, a group of leading microplastic scientists, and the public. The State Advisory Group included representatives from OEHHA, SWRCB, Regional Water Quality Control Boards, CalRecycle, California Department of Public Health California Tobacco Prevention Program (CDPH CTPP), and Department of Toxic Substances Control (DTSC) Safer Consumer Products Program. These resulting high-level management questions are framed as questions that policymakers and other water quality managers, scientists, and the public at large would ask about plastic pollution to inform management actions. The Microplastics and Macroplastics Monitoring Strategies are grounded in these management questions to ensure collection of data useful to state agencies. The scope of these questions is described in more detail in the context of the Statewide Microplastics Monitoring Strategy (Section 2) and Statewide Macroplastics Monitoring Strategy (Section 4).

Defining management questions is a best practice for developing a successful monitoring program. These questions ensure that monitoring activities respond to information needs relevant to management. Examples of successful monitoring programs that have well-defined management questions include the Regional Monitoring Program for Water Quality in San Francisco Bay, Southern California Bight Regional Monitoring Program, and SWRCB Surface Water Ambient Monitoring Program (SWAMP).

> **MQ 1:** What are the levels of **macroplastics** and **microplastics** in different aquatic ecosystems? Are **macroplastics** and **microplastics** at levels that may impact aquatic ecosystems and beneficial uses? Are **macroplastics** and **microplastics** at levels that may impact human health?
>
> **MQ 2:** What are the major sources, pathways, and relative loadings leading to **macroplastics/microplastics**-related contributions and impacts to California aquatic ecosystems?

MQ 3: Are **macroplastic** and **microplastic** levels changing over time? How effective are mitigation measures and regulatory controls? What are management actions that could drive changes in **macroplastic** and **microplastic** levels in California surface waters?

While several programs are eager for these environmental monitoring data to inform their effectiveness (e.g., CDPH CTPP programs to address tobacco waste, CalRecycle efforts to reduce plastic waste), they often lack resources to conduct environmental monitoring. This Monitoring Strategy recommends cross-agency coordination and leveraging resources to address these important and often collective information needs.

More specific management questions that State Advisory Group members shared are categorized under these three broad themes in Appendix B.

1.5 Strategic Objectives Linking Plastics Monitoring to Existing State Programs

In seeking input from state agencies, agency staff also identified the following strategic objectives for a future statewide plastics monitoring program (<u>underlined</u> below) that directly support existing and future state regulatory programs to reduce plastic pollution, protect aquatic ecosystems, and safeguard public health. Strategic objectives are described with examples of how they may support state actions and programs.

1. <u>Identify the major sources and pathways of macro- and microplastics debris</u>. Identifying important sources can inform and help prioritize mitigation strategies and policy decisions.

   Previous examples include state and federal laws that banned the use of microbeads in soap, toothpaste, and other personal care products to reduce microplastic pollution at the source. Future monitoring data could point to specific product types that can inform various agency efforts, such as DTSC's Safer Consumer Products Program evaluation of priority products that may release microplastics, and CalRecycle's various extended producer responsibility programs.

2. <u>Evaluate levels of macro- and microplastics debris in aquatic environments</u>. Monitoring can help identify vulnerable ecosystems and high-exposure zones, such as urban stormwater networks, river mouths, and nearshore marine areas.

Monitoring plastic levels can also inform a broad range of regulatory programs. Regulatory agencies can use baseline monitoring data to evaluate potential impacts and identify areas where impacts are observed to help optimize and deploy resources for mitigation. Monitoring data can support state agency efforts to develop threshold determinations for impairment.

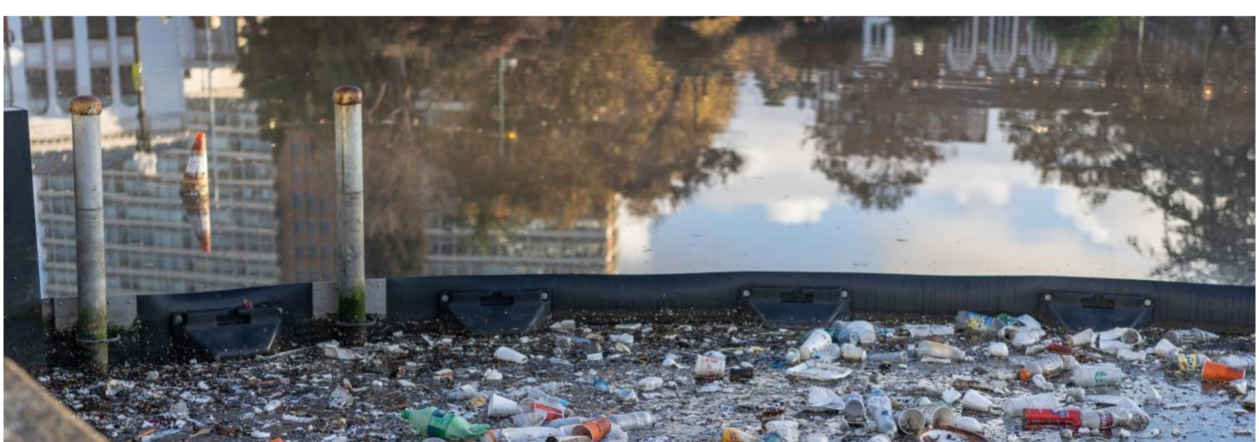
3. Gather and synthesize robust monitoring datasets consistently and continually over time to evaluate trends and assess recovery. Monitoring environmental trends can provide the feedback loop necessary to evaluate the performance of mitigation efforts and policies, such as stormwater infrastructure improvements, producer responsibility programs, or bans on specific plastic products.
4. Provide a framework for statewide collaboration in monitoring macroplastics and microplastics in the environment. Collaboration will also result in strengthened interagency coordination and integration with existing monitoring programs, such as those led by State and Regional Water Boards, environmental organizations, and volunteer community science groups.
5. Synthesize, interpret, and communicate monitoring data and results to a wide audience (policymakers, regulators, scientists, community-based organizations, and the interested public). Sharing information will increase public and stakeholder awareness, trust, and engagement in efforts to monitor and manage plastic pollution.
6. Support fair and just systems and practices in microplastic monitoring. Robust monitoring also supports the programmatic vision of equitable environmental protection by identifying disproportionately impacted communities and ensuring that data and information are accessible to the public, researchers, and decision makers.
7. Foster continued scientific innovation and progress in plastics sampling, analytical methods, and data interoperability. Adaptability is essential for keeping pace with emerging contaminants and novel plastic products and formulations. This will ensure that California stays at the forefront of micro- and macroplastic science.

1.6 Additional Governance is Needed to Support a Statewide Plastics Monitoring Program

This Monitoring Strategy does not specify future program implementation by a specific agency, program, or regulatory framework. This strategy is meant to inform discussions regarding state resources that may be needed to implement future monitoring program(s) and provide a framework for monitoring that can be implemented in different ways. This document does not define a program charter and steering committee, which are critical to developing and implementing a robust future monitoring program.

A robust monitoring program typically includes the following key components:

1. **Program Charter:** formally describes the purpose, function, and governance structure of the monitoring program.
   a. A steering committee, representing different stakeholder groups, is established to make program decisions, including defining and updating the program's guiding management questions, approving budgets and budget allocations, leading internal and external communications, and tracking and ensuring the program's success.
   b. A technical advisory committee is typically an independent body that ensures scientific and technical excellence of the program.
2. **Strategy and Planning Framework (this document):** articulates the guiding management questions that the program seeks to inform through monitoring and scientific studies, effectively synthesizes the state of the science for the monitoring program's primary audience, and describes the scientific approach and tools that will be applied to inform monitoring program management questions.
3. **Monitoring Workplan and Budget:** formally describes the amount and source of funding available for implementation of the monitoring program and how the budget is allocated to various program tasks and sub-programs for a projected period of time (typically 3-5 years).
4. **Data Collection, Data Management Plan, and Reporting:** a program or specific project plan for data collection, data management, and reporting is often formally documented in a program or project Quality Assurance Plan.



2. Statewide Microplastics Monitoring Strategy

2.1 Introduction

Every day, new scientific studies report on microplastics (plastics smaller than 5mm) detected everywhere around us. However, despite significant research on microplastics, there are still important data gaps in monitoring that are critical to informing management actions. This Statewide Microplastics Monitoring Strategy outlines a framework for coordinated statewide monitoring that will generate actionable data to inform statewide management and policy.

The purpose of this Statewide Microplastics Monitoring Strategy is to:

- Define management and monitoring questions that will contribute to strategic objectives (Section 2.3);
- Identify critical knowledge gaps relating to management questions, including exposure levels of microplastics, sources, and pathways (Sections 2.3, 2.4, Appendix F, Appendix G);
- Support implementation of a statewide plastics monitoring program by connecting diverse monitoring efforts and interests (Section 2.5);
- Promote consistent, harmonized, and high-quality methods to improve comparability, transparency, and data accessibility (Sections 2.4, 6, Appendix E).

2.2 Background

California has taken a nationally recognized leadership role in developing policies and initiatives to address microplastic pollution. Legislative mandates, pioneering scientific research on microplastics, interagency science collaborations, and a wide network of potential monitoring partners (Appendix C) together form a strong foundation for supporting a statewide Monitoring Strategy.

State Legislative Mandates

California's action has been catalyzed by key legislative mandates:

- **Assembly Bill 258 (2007)** required the State Water Resources Control Board (SWRCB) and Regional Boards to implement a program to control discharge of preproduction plastics (nurdles).

- **Senate Bill 1422 (2018)** required the SWRCB to define microplastics in drinking water and adopt a standardized methodology for monitoring microplastics in drinking water.
- **Senate Bill 1263 (2018)** directed the California Ocean Protection Council (OPC) to develop the **California Statewide Microplastics Strategy (2022)**. This document outlines a two-track approach to addressing microplastics: Track 1 outlines immediate, 'no regrets' actions and multi-benefit solutions to reduce and manage microplastics, while Track 2 outlines a research strategy to enhance the scientific foundation for microplastic monitoring, source identification, risk assessment, and development of management solutions.
- **Senate Bill 54 (2022)**, the Plastic Pollution Prevention and Packaging Producer Responsibility Act, mandated reductions in single-use plastics, advancing source control at the product level and embedding extended producer responsibility mechanisms.

Microplastics Monitoring in California

Monitored Locations

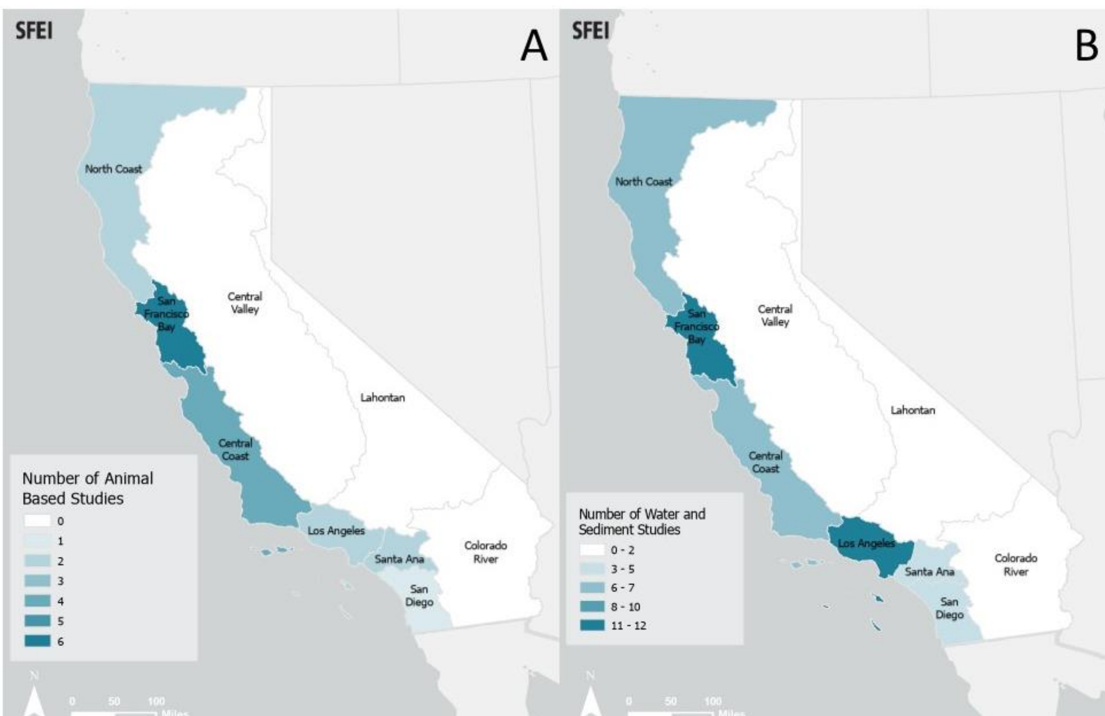
Previous studies have extensively reported microplastics in California waters (see Figure 2.1 and Appendix F for a more in-depth summary). Most studies have been conducted along California's coasts, with very few studies in the Central Valley, Lohontan, and Colorado River Basin regions covered by the Regional Water Quality Control Boards. Almost all microplastics monitoring studies have been led by or in collaboration with research institutions.

Multiple studies have also demonstrated that even 'pristine' or protected areas such as the Monterey Bay National Marine Sanctuary, Cordell Bank National Marine Sanctuary, Bodega Marine Reserve, and Greater Farallones National Marine Sanctuaries are contaminated with microplastics (Choy et al., 2019; Kashiwabara et al., 2021; Saley et al., 2019; Sutton et al., 2019). Studies of microplastics in marine wildlife in California and globally show that a wide variety of organisms ingest microplastics, including plankton, mollusks, fish, seabirds, marine mammals, and humans.

The most comprehensive microplastic study was conducted between 2016–2018 in San Francisco Bay, led by the San Francisco Estuary Institute (SFEI), the 5Gyres Institute, and the University of Toronto, which leveraged the resources of the Regional Monitoring Program for Water Quality in San Francisco Bay (RMP) with funding from the Gordon and Betty Moore Foundation. The San Francisco Bay study found microplastics to be abundant in San Francisco Bay waters, sediment, and aquatic wildlife, including prey fish and bivalves (Miller et al., 2019; Sutton et al., 2019; Zhu et al., 2021; Werbowski et al., 2021).

The San Francisco Bay study was the first to compare microplastic levels in wastewater effluent with urban stormwater runoff. Average concentrations of microplastics in urban stormwater runoff in the San Francisco Bay region were over a hundred times greater than wastewater effluent. Nearly half of the particles observed in urban stormwater were suspected to be tire wear particles due to their morphology, distinctive black color, and rubbery texture. Fibers were the second most common class of microplastics observed in stormwater. These findings pointed to tire wear particles and textiles as important sources of microplastics.

Current ongoing monitoring efforts include sediment and shellfish monitoring implemented by the Southern California Bight Regional Monitoring Program[10] and a comprehensive effort to quantify the movement of microplastics across the Monterey Bay watershed and ecosystem led by the California Marine Sanctuary Foundation.[11]



[10] SCCWRP, Bight Regional Monitoring Program.

[11] Sea Grant California.

Figure 2.1: Summary of microplastics monitoring studies conducted in California since 2023. Most studies have been conducted along California's coasts. (See Appendix F for list of references and specific locations.)

Understanding of Risks and Impacts

Evaluating risk is important to help water quality managers, policy makers, and the public at large understand whether there are possible adverse impacts to aquatic ecosystems or human health due to microplastic levels in the environment.

California has initiated two independent efforts to support and accelerate the development of scientific consensus on risk thresholds and risk evaluations. These initiatives recognize that understanding microplastic toxicity and hazards remains a rapidly evolving field with many uncertainties (see Appendix F for a detailed summary). At the same time, they acknowledge the urgent need from policymakers and regulators for scientifically grounded risk thresholds to guide risk evaluations.

The California Ocean Science Trust convened scientific experts between 2020–2021 to develop a risk assessment framework for microplastic pollution in California's marine environment and recommended a precautionary approach to assess and manage microplastic pollution risk (Brander et al., 2021). This recommendation was based on microplastic persistence, lack of feasible cleanup options, the projected rate of increased concentrations in the environment, and evidence that microplastics contaminate and may lead to adverse effects in organisms and humans. Other California groups, including the RMP, have adopted similar approaches to assessing risk from microplastics. This rationale has also been adopted in other countries. For example, the European Chemicals Agency has decided to classify microplastics as a non-threshold contaminant, meaning any discharge poses a risk, for risk assessment purposes (ECHA, 2019). Similarly, the Science Advice for Policy by European Academies states that while it is unlikely that current exceedances of risk thresholds are geographically widespread, broad ecological risk may arise within the next century with expected increases in exposure to microplastics (Lebreton & Andrady, 2019; Science Advice for Policy by European Academies, 2019).

During the second effort between 2021–2022, the Southern California Coastal Water Research Project (SCCWRP) convened a group of microplastics experts to develop a risk management framework for aquatic ecosystems that identifies four critical management thresholds, ranging from low regulatory concern to the highest level of concern where pollution control measures could be introduced to mitigate environmental emissions (Mehinto et al., 2022). This effort also resulted in the development of the Toxicity of Microplastics Explorer (ToMEx), an open access database and open source accompanying R Shiny web application that enables users to upload, search, visualize, and analyze microplastic toxicity data (Thornton Hampton et al., 2022). Proposed microplastics toxicity thresholds for two different effect mechanisms were developed using ToMEx (Mehinto et al., 2022). The expert group participants expressed high confidence in the proposed multi-tiered management framework and the use of species sensitivity distributions and data alignment calculations to derive these hazard threshold values. However, they expressed low to moderate confidence in the actual threshold estimates due to insufficiencies in the available toxicity data (Mehinto et al., 2022). A subsequent effort to update ToMEx roughly doubled the size of the database, but did not substantially alter the thresholds or their uncertainty intervals (Thornton Hampton et al., 2025).

2.3 Management and Monitoring Questions

The Statewide Microplastics Monitoring Strategy is guided by three high-level management questions that define the Strategy's scope, and stem from the overarching goals of the Statewide Plastics Monitoring Strategy to inform management decisions. More defined monitoring questions fit below management questions and describe what information would inform the corresponding management questions, and may be defined for specific monitoring plans or studies (Table 2.1).

Table 2.1: Management questions (MQs) and corresponding monitoring questions. Monitoring questions can be answered at statewide, regional, or local scales.

Management Questions	Monitoring Questions
MQ 1A: What are the levels of microplastics in different aquatic ecosystems? Are microplastics at levels that may impact aquatic ecosystems and beneficial uses? Are microplastics at levels that may impact human health?	• What are levels of microplastics in coastal subembayments? • Where are levels of microplastics in offshore marine waters? • What are levels of microplastics in freshwater watersheds? • What are levels of microplastics in freshwater lakes? • What types of microplastics are most prevalently observed in different ecosystems?
MQ 2A: What are the major sources, pathways, and relative loadings leading to microplastics-related contributions and impacts to	• What are the major sources of microplastics? • What are the levels of microplastics in urban runoff? • What are the levels of microplastics in wastewater?

California aquatic ecosystems?	• What are the levels of microplastics in agricultural runoff? • What are the levels of microplastics in air, and what does this indicate about the importance of local versus global sources and pathways of microplastics?
MQ 3A: Are plastic levels changing over time? How effective are the mitigation measures and regulatory controls? What are management actions that could drive changes in microplastic levels in California surface waters?	• What is the baseline concentration of microplastics for a given area (region, water body, etc.)? • Have microplastic concentrations increased, decreased, or stayed the same over a specified period of time? • How do changes in microplastic levels differ between areas with different mitigation measures and policies?

Management Question (MQ) 1A grounds this Monitoring Strategy to inform microplastics risk screening evaluations for potential adverse impacts to California's diverse aquatic ecosystems (marine, estuarine, freshwater) and other human uses of these water bodies. Monitoring study questions will determine selection of sampling matrices, such as water, sediment, and biota (e.g., prey fish, sport fish, and shellfish). For instance, sediment and water monitoring may be most appropriate for aquatic ecosystem risk screening purposes, while monitoring relevant fish and shellfish is needed to evaluate potential human health impacts from ingesting contaminated fish and bivalves. Study questions will also determine the type of ecosystems and geographic regions being monitored. Monitoring efforts may take place at the statewide, regional, or local level. At the statewide level, monitoring may focus on identifying the types of water bodies most vulnerable to microplastic pollution. Such studies often classify water bodies into categories, including marine environments (e.g., coastal subembayments, estuaries, nearshore, and offshore waters) and freshwater systems (e.g., lakes, creeks, and rivers).

This Monitoring Strategy focuses on monitoring microplastic particles to inform exposure assessment, which can contribute to risk evaluations conducted by other programs. Although various agencies and stakeholders may define and assess risk in different ways, we broadly define risk as the potential for adverse effects due to exceedance of protective thresholds for aquatic life and/or human health. Because risk is fundamentally a function of both hazard and exposure, and the hazards of microplastics are still poorly defined and an active area of research, this strategy focuses on the exposure portion of the equation. Risk evaluations involve comparing available exposure data to available hazard information. Different regulatory agencies, monitoring programs, and scientific groups may apply varying methodologies and data quality standards. Microplastics toxicity remains a major focus of ongoing research to better understand the hazards of microplastics and improve thresholds. Scientists have proposed a few risk screening frameworks (Appendix F).

MQ 2A reflects the goal of tracing microplastic pollution back to upstream sources and pathways and providing information to guide control measures, such as source control. The sources of microplastics can be particularly challenging to identify, though particle characteristics (e.g., morphology, color, size, polymer, chemical markers) can provide clues to potential upstream sources.

Monitoring pathways (e.g., wastewater, urban and agricultural runoff, and atmospheric transport and deposition) helps identify where microplastics originate, since each source tends to follow characteristic transport routes to receiving waters. For example, outdoor sources of macroplastics can degrade and fragment into microplastics on the terrestrial landscape and get transported to receiving waters via stormwater runoff to storm drains, urban creeks, and rivers. In contrast, fibers from laundering apparel and other household textiles can be washed down the drain and transported via wastewater.

Understanding the relative importance and contribution of different types of microplastics to receiving waters supports prioritization of monitoring and investigation efforts on the most significant sources, pathways, and processes. Urban runoff, which is surface water flowing over urban landscapes and can transport microplastics from terrestrial areas to receiving waters, is an especially important pathway.

MQ 3A focuses on collecting long-term datasets to understand how microplastic levels change over time, linking those trends to management actions to evaluate their effectiveness, and predicting how concentrations may shift under different mitigation strategies.

Monitoring studies related to this management question may evaluate mitigation measures focused on specific microplastic sources (e.g., microplastics from washing and drying laundry that can be discharged through wastewater and stormwater, respectively; tobacco waste; single-use plastics) or evaluate microplastic pollution trends more generally. Water quality managers must define the time scales required to answer these questions and their information needs.

Community members have pointed out that many mitigation measures are implemented at the local level (e.g., single-use plastic bans, including plastic straws, plastic bags, and styrofoam packaging). This may provide the opportunity to compare and contrast plastic pollution levels from municipalities with different prevention strategies to inform the effectiveness of these actions. While macroplastics are an important upstream source of microplastic pollution, it’s important to recognize that major sources of microplastics include much more diverse products such as tires, apparel and other textiles, and paints. Management actions and monitoring questions may therefore be different between macroplastics and microplastics. Study designs to address MQ 3A may be formulated very differently compared to study designs to address MQ 1A and MQ 2A.

2.4 Sampling and Analysis Methods

Microplastics research methods have evolved rapidly, driven by increased awareness, science and technological advancements, and policy needs. Sampling approaches range from simple grab sampling and bulk collection to more refined techniques such as pump filtration and sediment coring. Method selection depends on the matrix (e.g., water, sediment, stormwater, or biota) and study goals.

Each monitoring study should consider the study objectives and identify specific information and data quality needs to determine the appropriate methods. These methods may differ depending on study needs and constraints. This Monitoring Strategy embraces the need to balance a scientifically rigorous approach for addressing monitoring study objectives with practical and logistical constraints of availability of monitoring partners. Studies must define data quality objectives, including what level of individual particle information and characterization is needed, microplastic size limits (e.g., minimum size of 20 µm or 100 µm), and the level of accuracy and precision needed. Some scientists advocate for a "fit-for-purpose" principle for categorizing and reporting microplastics (Yu et al., 2022). At the least specific level, total particle count may be reported when detailed particle information is not needed. At the other end, detailed individual particle characteristics and quantification may be important for linking microplastic particles to upstream sources. Therefore, evaluation and selection of specific methods should consider the required accuracy, repeatability, and efficiency needed to address study questions and inform decision making.

At the same time, there is growing recognition among scientists, water quality managers, and policymakers that developing harmonized and/or standardized methods is critical to allow comparisons across studies and support a statewide microplastics monitoring program. California has made significant investments to support progress towards harmonization and standardization of microplastic sampling and analysis methods, as part of its Statewide Microplastics Strategy.[12] This Statewide Microplastics Monitoring Strategy is intended to build and leverage on these efforts, while recognizing that developing standardized methods for monitoring microplastics in

[12] OPC, Statewide Microplastics Strategy.

environmental matrices is still developing as science and technology improve (Section 2.5).

Sampling and analysis considerations relating to **MQ 1A**:

I. We **recommend sediment as a key matrix for monitoring microplastics levels in aquatic ecosystems** for statewide comparisons across sampling locations and sites (see Section 3). Sediment may be a more suitable matrix for evaluating long-term trends in aquatic ecosystems than water or biota; sediment acts as a long-term sink for microplastics, with most particles eventually settling out of the water column and accumulating in sediments over time. In contrast, surface water sampling tends to capture only a subset of microplastics—primarily buoyant particles—and biota sampling can be biased by species-specific feeding behaviors and site fidelity, which influence the types of microplastics ingested. Additionally, sediment samples are more easily archived compared to water and biota samples, allowing for collection over multiple time periods and analysis at a later date using consistent analytical methods for comparability. Sediment is an important matrix for monitoring microplastics in aquatic ecosystems because sediment is a sink for microplastics that are denser than water. In addition, microplastics that were originally buoyant and present in surface water will become less buoyant and sink to the sediment floor due to the growth of biofilm, aggregation, or ingestion by organisms that eventually die and sink to the sediment floor.

II. Monitoring other matrices is appropriate for specific applications. For example, **monitoring fish and shellfish** in specific water bodies may be **important to evaluate human health risk from ingestion of seafood**. On the other hand, water monitoring may be important for risk screening purposes for comparison to water-based ecotoxicity thresholds (e.g., Mehinto et al., 2022).

    OPC has collaborated with SCCWRP and microplastic scientists to summarize best practices for collecting sediment and biota and develop Standardized Operating Procedures (SOPs).[13] SCCWRP is working with University of Toronto and other microplastic researchers to publish guidance for sampling microplastics from surface waters, with anticipated publication in 2026.

III. **Field blanks and replicates are important for ensuring data quality and data interpretation**, and should be included in any environmental monitoring study. Field blanks are used to detect background and procedural contamination,

[13] Thornton Hampton, Mehinto, and Weisber, *Standard Operating Procedures for the Collection of Samples for Microplastics Analysis Part 1: Surface Sediment and Aquatic Biota*, 2025

which is especially important due to the high risk of contamination from clothing, dust, and ambient air during sampling. A field blank should be included with every sampling event. Trip blanks may be used to identify potential sources of contamination occurring from transport and storage of the sampling containers and samples. Microplastics in water, sediment, and biota can be very heterogeneous, and therefore field replicates are particularly important for microplastics. Field replicates, a standard practice in monitoring for chemical contaminants, are equally important for microplastics. Field replicates provide a measure of variability in sample collection and analysis and are critical for interpreting data across different regions and time periods, helping to determine whether observed differences are meaningful or simply reflect natural or methodological variability.

IV. **While to date there are not yet standardized, widely accepted methods for analysis of microplastics in complex matrices, such as sediment, wastewater, and urban stormwater runoff, laboratories can leverage and modify the drinking water methods for analysis of other matrices, while recognizing that these more complex matrices present additional challenges.** For example, analysis of microplastics in sediment is particularly challenging due to the need to extract and distinguish microplastics from other organic and inorganic materials in sediment. An interlaboratory validation study led by SCCWRP that included 15 laboratories identified several aspects that needed improvements for extraction and analysis of microplastics from complex matrices (e.g., sediment, biota tissue, and surface water), which included particle recovery rates, particularly for size fractions <20 µm and sample processing times (Thornton Hampton et al., 2023).

In 2021, the SWRCB published SOPs for analyzing microplastics in drinking water using Raman and IR spectroscopy (California State Water Resources Control Board & Coffin, 2022; California State Water Resources Control Board & Scott Coffin, 2022). California's Environmental Laboratory Accreditation Program (ELAP) now offers lab accreditation for analysis of microplastics in drinking water, which requires accredited laboratories to carefully demonstrate and document accuracy, reproducibility and credibility of microplastic data analysis by following rigorous requirements, including following SOPs, implementing contamination control measures, and demonstrating method performance.

V. **Analytical costs may limit the level of detailed analysis that can be included**, as well as the number of field samples and quality assurance/quality control samples that can be analyzed. Multiple samples (sediment, water, and biota) from a single site can be combined (composited) to reduce within-site variability, minimize the number of samples requiring analysis, and provide a more representative snapshot of microplastic contamination at that location.

VI. **Monitoring data to address MQ1 can provide important information about exposure to microplastics for aquatic ecosystems and humans from ingestion of seafood, which can be used by scientists and regulatory programs to evaluate risks and impacts.** While there is still a lot of uncertainty in evaluating potential risks, scientists have published risk screening approaches (see Appendix F) using available monitoring data and toxicity thresholds. These current approaches allow comparison of occurrence data for microplastics down to 1 µm with available toxicity thresholds. Therefore, monitoring data collected for the purpose of risk screening evaluations will be most useful if they quantify and/or estimate microplastics down to 1 µm with the best available methods. This could be achieved using a combination of complementary sampling, analysis, and modeling methods. For example, sampling methods could use a combination of in-situ pumped samples to capture sufficiently small particles for analysis with manta trawls that typically capture particles down to 355 µm that would provide more spatial sampling coverage. A subset of in-situ pumped samples could be analyzed down to the smallest size range possible, and particle-size distribution models could be used as a first approximation to extrapolate results (e.g., Coffin et al., 2022; Koelmans et al., 2020) until better methods are developed for sampling and quantifying smaller particles.

Sampling and analysis considerations relating to **MQ 2A**:

I. Monitoring wastewater and stormwater runoff are particularly important for informing MQ 2A (Table 2.1), and related Monitoring Questions. Monitoring **urban stormwater runoff is a priority for informing MQ 2A**.

Studies have demonstrated that urban stormwater runoff discharges can significantly increase microplastic concentrations in receiving waters (Moore et al., 2002; Lattin et al., 2004; Doyle et al., 2011; Sutton et al., 2019; Werbowski et al., 2021). Despite the importance of urban stormwater runoff as a pathway for microplastics, there are limited peer-reviewed published scientific studies from California because of the challenges with sampling this transient matrix and important data gaps on how to collect a representative sample. SCCWRP and UC Riverside are working on developing guidance for monitoring microplastics in urban stormwater runoff, with anticipated publication in late 2026. The Regional Monitoring Program for the San Francisco Bay has a microplastics monitoring strategy that also prioritizes monitoring urban stormwater runoff (Paterson et al., 2024), and is implementing studies in Bay area watersheds to inform future stormwater monitoring approaches.

There have been several studies of microplastics in wastewater in California (Carr et al., 2016; Dyachenko et al., 2017; Sutton et al., 2016, 2019; Wang et al., 2024;

Zhu et al., 2021) that provide wastewater sampling methods as well as reports on the abundance and composition of microplastics in wastewater effluent. ASTM has published standardized methods for sampling wastewater (ASTM D8332[14]) and analysis (ASTM D8401-24[15]). SCCWRP developed alternative analytical methods for extracting microplastics from wastewater samples (Lao, et al, 2024). Analytical methods continue to be improved as scientists make progress towards harmonization and standardization of methods.

II. **We recommend coordinating monitoring of wastewater in parallel with urban stormwater when needed to compare these two pathways.** The San Francisco Bay microplastics study (Sutton et al., 2019; Werbowski et al., 2021; Zhu et al., 2021) was the first study to compare loadings of microplastics from urban stormwater runoff and wastewater effluent. Loadings were compared by modeling and extrapolating measured concentrations of microplastics in wastewater effluent and stormwater runoff with estimated water flow volumes from these two pathways. This study was powerful in informing regional priorities for monitoring and management of microplastics (Paterson et al., 2024), as it revealed much higher loadings from stormwater than from wastewater in this part of the state.

III. **Analytical approaches for MQ 2 should prioritize analytical methods that identify particle properties that can be linked to upstream sources, such as microscopy and spectroscopy techniques that can identify particle morphologies and polymers.** More detailed characterization of individual particles and refinement of microplastic categories further strengthen source attribution and better inform management actions (Helm, 2017; Yu et al., 2022, 2024). Additionally, identification of fibers (Athey & Erdle, 2021), tire wear particles (Knight et al., 2020), paints (Diana et al., 2025), and small particles <50 µm may not be adequately quantified in typical microplastic analysis workstreams and require additional steps or analyses (e.g., pyrolysis GC-MS). However, there are still analytical challenges with linking many different types of microplastics in the environment back to their upstream sources. This is an area where further science and method development are needed.

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[14] ASTM D8332-20: "Standard Practice for Collection of Water Samples with High, Medium, or Low Suspended Solids for Identification and Quantification of Microplastic Particles and Fibers." https://store.astm.org/d8332-20.html

[15] ASTM D8401-24: "Standard Test Method for Identification of Polymer Type and Quantity of Microplastic Particles and Fibers in Waters with High to Low Suspended Solids Using Pyrolysis-Gas Chromatography/Mass Spectrometry." https://store.astm.org/d8401-24.html

In some studies, it may be appropriate to consider allocating a subset of samples for more detailed analysis to balance resources. Detailed analysis could employ multiple complementary methodologies to capture the broad diversity of microplastics and may require expertise and equipment across multiple laboratories.

IV. **Monitoring upstream of receiving water discharges may also be important to further inform source identification and potential source control and mitigation strategies.** For example, OPC and California Sea Grant have funded a special study to support SFEI in investigating the importance of dryer emissions as a source of microplastics to urban runoff. Upstream investigative studies like this may be appropriate to include as part of the monitoring plan to fill important data gaps about potential major sources of microplastics. Other industrial activities may be of interest for investigation, such as construction activity and different types of manufacturing activities.

V. **Monitoring agricultural runoff and air transport pathways are also a priority data gap.** Sampling and analysis methods for air and agricultural runoff are much less developed. Recognition of the need for more scientific investigations and method development to address these questions are included in the long-term monitoring planning framework (Section 3).

Sampling and analysis considerations relating to **MQ 3A**.

I. We **recommend sediment as a key matrix for monitoring temporal trends of microplastics levels in aquatic ecosystems.**

II. We **recommend archiving sediment samples that can be used to evaluate temporal trends in the future.** This is particularly important in anticipation of analytical methods improvements. This approach ensures analysis of samples from different periods are comparable.

III. Monitoring temporal trends in pathways (e.g., urban stormwater runoff and wastewater) may be important for monitoring efficacy of upstream management actions.

In Toronto, Canada, wastewater monitoring was used to evaluate the efficacy of Canadian and US restrictions on microbeads observed significant reductions in irregular polyethylene microplastics ("microbeads") after the bans, indicating that the bans were effective in reducing plastic microbeads entering receiving waters through the wastewater pathway (Akhbarizadeh et al., 2024). Interestingly, however, the Toronto study did not observe changes in other types of spherical microbeads, composed of synthetic/polyethylene wax, which were not regulated as plastics under the bans, pointing to the challenges of specific product type bans to mitigate microplastic pollution.

IV. **Beyond simply monitoring microplastic trends, policymakers and water quality managers have expressed particular interest in understanding whether macroplastic management actions have an impact on microplastic levels in aquatic ecosystems. More work is needed to understand this relationship (or lack thereof),** and improvements in analytical methods may be necessary. A statistically robust monitoring study designed to detect changes in microplastics over time requires a power analysis to decide on the number of sites, sampling intensity, and frequency of monitoring (Ryan et al., 2020).

Methodological Challenges

As of 2025, there are major challenges in monitoring microplastics in the environment; progress is currently being made to improve all of these fronts (See Appendix D and E for more discussion).

- There are <u>not yet standardized microplastic sampling and analysis methods</u> that have gone through extensive testing and inter-laboratory comparisons and received broad approval by both regulatory agencies and the regulated entities that could be required to do monitoring. Standardized methods, such as ASTM D8332[16] and ASTM D8401-24,[17] have been proposed, and ongoing discussions and collaborations among scientists, regulatory agency staff, and industry continue to make improvements and progress towards standardization and broad approval and use in the future.
- The lack of standardization is mainly driven by <u>important science and technology data gaps</u>. For example, the diversity of microplastics and our limited understanding of their transport and distribution in the environment adds complexity to field sampling design. Current analytical methods only quantify a subset of total microplastics as broadly defined by SWRCB. Some methods may not adequately or cost-effectively quantify tire-wear particles, fibers, and/or

[16] ASTM D8332-20: “Standard Practice for Collection of Water Samples with High, Medium, or Low Suspended Solids for Identification and Quantification of Microplastic Particles and Fibers.” https://store.astm.org/d8332-20.html

[17] ASTM D8401-24: “Standard Test Method for Identification of Polymer Type and Quantity of Microplastic Particles and Fibers in Waters with High to Low Suspended Solids Using Pyrolysis-Gas Chromatography/Mass Spectrometry.” https://store.astm.org/d8401-24.html

particles smaller than 20 μm in size. Important scientific progress is being made to automate and improve the size, material, and shape limitations of microplastic analysis.

- Current methods also require significant resources for analysis. As of 2025, microplastic analysis by laboratories that are ELAP accredited for SWRCB microplastics in drinking water methods routinely charge five to ten times more per sample compared to other water quality chemical analyses. Cost efficiencies are expected to improve as methods become more automated and with growing demand and support for microplastic analysis.
- Additionally, laboratory services for microplastic analysis are very limited. More detailed discussion of the ELAP accreditation and important data gaps to support standardization in microplastic analysis is in Appendix D and Appendix E.
- Another challenge is managing different data quality needs from diverse users. While microplastic researchers expressed confidence in applying currently available microplastics monitoring methods (as of 2025), regulatory agency staff emphasized the need for additional evaluation and testing to standardize methods required for regulatory monitoring. Depending on the goals of the monitoring, different groups will have different data requirements and different abilities to manage the analytical uncertainties in the data. Early phases of the monitoring program may require collaboration with microplastic scientists to implement monitoring studies and manage some of the uncertainties and challenges with monitoring microplastics.

Establishing a statewide monitoring program provides a framework and plan to address these challenges by:

- Supporting use of best available scientific methods for monitoring and promoting use of consistent and harmonized methods to ensure data quality and allow greater comparability among monitoring efforts.
- Learning from pilot efforts to understand advantages and disadvantages of different methods and approaches.
- Testing selected methods in collaboration with study partners, including field sampling teams and laboratory analysts, to ensure data consistency and comparability.
- Adopting fit-for-purpose methods to address study objectives. For example, choosing more intensive evaluation approaches when needed to meet study objectives and when resources are available.

- Serving as a central hub to openly communicate and share updates on methodology, lessons learned, and recommendations on study designs by serving as an educational or information resource.
- Providing more opportunities over time to address microplastic sampling and analytical challenges. As monitoring is scaled up, broader adoption of harmonized and consistent methods will provide more demand for analytical services and enable more standardized data collection. This may, in turn, provide economies of scale for expanded microplastic analyses that lead to innovations that reduce analytical costs.

2.5 Monitoring Program Partners

Establishing a statewide microplastics monitoring program would position California at the forefront of efforts to address microplastic contamination. While there have been numerous microplastic studies across California, there is no existing long-term microplastics monitoring program in California, nor in the country. Appendix C includes examples of state agencies, monitoring programs, research and science organizations and groups, and NGOs that could be connected to help implement a future microplastics monitoring program. While this list is incomplete, it is included as an illustration of the rich resources and networks that this Statewide Microplastics Monitoring Strategy can draw upon for monitoring implementation. This list should be further expanded through outreach, engagement, future program implementation, and funding opportunities. In addition to the California groups listed, there are other groups nationally and internationally that may be considered.

We recommend the statewide plastics monitoring program establish a governance and communication structure to support statewide coordination and collaborations among potential program partners. Leveraging ongoing monitoring efforts for microplastics monitoring will be more resource efficient than implementing separate monitoring efforts. Existing monitoring programs provide important long-term resources for monitoring, field experience, and conceptual understanding of contaminant transport, sources, and fate that are relevant to designing and interpreting microplastics monitoring studies with location-specific context. Additionally, existing monitoring programs have established stakeholder communication networks, strategies, and relationships that can be leveraged for a statewide microplastics monitoring program.

Developing a statewide monitoring program governance and communication network can also help coordinate diverse microplastics monitoring interests and efforts across the state. For example, microplastics monitoring in San Francisco Bay can serve as a case study for other urban regions in California. This could reduce the need for doing the same type of study at multiple locations. Other regions can use the lessons learned to focus on additional follow-up monitoring study questions.

Each region may have different and/or more specific management questions. The Statewide Microplastic Monitoring Strategy therefore allows for incorporation of local priorities and leadership in study design and implementation. It also provides resources and coordination of methods and analysis to support consistent and comparable results from monitoring efforts led by different groups. Additionally, given the evolving science of microplastic sampling and analysis, early monitoring efforts led by microplastics monitoring leaders offer valuable opportunities to test and refine the best available methods. These methods can later be improved and adopted by other partners as monitoring becomes more established.

Data synthesis and interpretation is a critical part of the Monitoring Strategy. Monitoring results need to be synthesized to evaluate study question hypotheses, provide a framework for future monitoring, and update this Monitoring Strategy. The monitoring program governance structure should provide resources to support sharing findings statewide.

2.6 Locations and Geographic Considerations

Each monitoring study should carefully consider the study questions and objectives, and develop a study design and identify sampling locations that inform those study questions. Below are some site selection considerations for each management question.

Site selection recommendations and considerations relating to **MQ 1A**.

I. **Identify representative sites** to provide understanding of microplastics pollution that can be extrapolated to other regions for statewide understanding.

II. Consider water bodies that are **likely** to represent **microplastic "hotspots"** with relatively higher levels of microplastics, such as locations that are the most impacted by urban discharges (e.g., coastal habitats receiving high urban land use inputs with low dilution hydrodynamics). Several studies have demonstrated that microplastics are more abundant in water bodies closer to urban influence, such as the San Francisco Bay (Sutton et al., 2019; Zhu et al., 2021), nearshore waters in Southern California between Los Angeles and San Diego (Doyle et al., 2011; Lattin et al., 2004; C. J. Moore et al., 2002, 2011), and Humboldt Bay (Marcus et al., 2023). Studies have also demonstrated that urban stormwater runoff discharges can significantly increase microplastic concentrations in receiving waters (Doyle et al., 2011; Lattin et al., 2004; Moore et al., 2002; Sutton et al., 2019). These studies highlight that the presence of significant urban runoff, and how that varies seasonally, should be considered an important site selection criterion for choosing sites more likely to be impacted by microplastics.

III. Consider including more **remote reference sites, as well as sites spanning a gradient of urban impacts** (from minimally to progressively greater urban impacts) to support data interpretation and improve understanding of what characteristics are important factors contributing to more impacted urban sites. Additionally, include sampling locations across different regions within the state for greater geographic representation.

IV. Consider types of water bodies that are **priority data gaps**. For instance, while a wide range of microplastics monitoring has been conducted in marine ecosystems, there has been very limited monitoring in freshwater ecosystems.

V. Leverage **ongoing monitoring programs and sampling efforts** that can support microplastics monitoring studies. For example, there are several regional and offshore monitoring programs that have established long-term monitoring efforts. As described above (Section 2.5) this can improve efficiency and benefit from shared institutional knowledge.

VI. Consider locations that represent **vulnerable ecosystems and communities**, such as those that are source waters for drinking water and/or there is commercial or subsistence fishing.

VII. Prioritize locations that address multiple considerations listed above. For example, locations that are likely microplastics "hotspots," have vulnerable ecosystems and communities, and have ongoing monitoring efforts that can be leveraged.

Site selection considerations relating to **MQ 2A**.

I. Consider urban **watersheds with a high proportion of urban land use** (e.g., commercial, industrial, transportation, high-density residential), particularly where there is a high proportion of impervious surfaces directly connected to storm drains.

II. Consider sites with urban **watersheds that have elevated trash levels** and/or high trash generation rates.

III. Consider **larger urban watersheds** that drain a greater urbanized area to better characterize microplastic contributions from broader land areas (Murphy-Hagan et al., 2025; Wong et al., 2024)

IV. See MQ 1A consideration III. Additionally, include gradients of sites to test hypotheses about factors contributing to high levels of microplastics in watersheds.

V. Consider watersheds with land uses that are **priority data gaps, such as freshwater watersheds and agricultural land uses** to understand sources and pathways.

VI. See MQ 1A consideration V.

VII. If applicable, coordinate monitoring design with the **development of conceptual and quantitative models** of sources pathways of microplastics, as well as transport from watersheds to receiving waters. Consider **coordinating wastewater and urban stormwater runoff monitoring** within a regional watershed to compare relative microplastics composition and levels from these two pathways.

Site selection considerations relating to **MQ 3A**.

I. Consider collecting and **archiving a time series of sedimen**t samples from the same location or region to be analyzed at a later date using consistent analytical methods; this approach ensures analysis of samples from different periods are comparable to evaluate temporal trends.

II. Consider collecting **sediment cores from carefully selected sites within a receiving water body (e.g., ocean, estuary, lake)** which provide an opportunity to evaluate temporal trends. Sites should be located in depositional zones with known deposition rates.

III. Consider **sediment cores and sediment traps near stormwater discharge locations or in stormwater detention ponds** to monitor microplastic trends in urban runoff. These samples provide a more integrated signal of changes in microplastic concentrations in urban stormwater runoff, which would reduce the variability in sampling and the number of samples needed to detect trends compared to sampling runoff more directly during or after storm events.

IV. **Leverage ongoing monitoring efforts that regularly monitor sediment, water, stormwater runoff, or wastewater to evaluate temporal microplastics trends.**

V. Consider **monitoring cities where mitigation measures have been implemented at the local level** (e.g., single-use plastic bans) to evaluate effectiveness of these actions.

3. Microplastics Monitoring Planning Framework

This Microplastics Monitoring Planning Framework describes recommendations to implement a statewide microplastics monitoring program guided by the Statewide Microplastics Monitoring Strategy (Section 2). This framework recommends a phased approach that can be adapted to available resources, partnerships, information, and priorities identified by a future steering committee.

The Monitoring Strategy's guiding principle is to work closely with the most relevant scientific development and apply lessons learned to achieve its vision and strategic objectives. This plan does not aim to implement microplastics monitoring in all, or even most, water bodies across California, but identifies priority and representative locations that are adequate and cost effective to support a statewide understanding of plastic pollution and informing management actions.

3.1 Cost Considerations

Implementing microplastics monitoring studies involves several cost considerations, summarized below.

Study design and development of a Sampling and Analysis Plan: Includes staff time for planning, coordination across sampling partners, and literature review. Costs may also include pilot studies to test sampling and analytical methods, assessments of data quality (e.g., evaluating field blank contamination), and support for harmonization or standardization of methods (e.g., interlaboratory comparisons to evaluate accuracy and precision).

Field sampling: Includes personnel and equipment costs for sample collection. Field sampling costs may include equipment, boat rental and crew time, supplies, and travel. Leveraging existing sampling efforts and selecting representative sampling locations can be more cost-effective, and site prioritization may also be necessary.

Laboratory analysis: Microplastics analysis is significantly more expensive than traditional water quality parameters. At the time of writing, analyzing a single sample using an ELAP-accredited FTIR spectroscopy method may cost well over $1,000. Analytical costs depend on the level of sample processing required and the minimum particle size threshold included in the analysis, as both factors increase processing time and labor. Complementary analytical methods, such as pyrolysis-GC/MS, may also be required depending on study goals and further increase costs.

Data management: Includes labor for ensuring completeness and accuracy of data collection, standardizing formats, applying quality assurance and quality control procedures, ensuring data accessibility and sharing, and archiving datasets.

Data interpretation and communication: Includes staff time to synthesize and interpret results and effectively communicate findings through reports, visualizations, presentations, and other products.

The pilot monitoring plan described below outlines studies that can be implemented with relatively limited resources by leveraging existing monitoring efforts. As additional resources become available, the monitoring program can expand by adding sampling locations and incorporating additional study questions, as described in the near-term (Section 3.3) and long-term (Section 3.4) plans.

3.2 Pilot Microplastics Monitoring Plan (0–3 years)

This section describes a pilot monitoring plan grounded in the Statewide Microplastics Monitoring Strategy (Section 2), with recommendations for monitoring studies to be implemented during the first few years of a statewide microplastics monitoring program. The authors recommend starting with informing MQ 1A as this was a priority identified by the projects' State Advisory Group.

This pilot monitoring plan leverages existing monitoring efforts, and study objectives are described as efforts that can be further expanded after interpretation and synthesis of results. As of 2025, microplastics monitoring and analysis methods, scientific understanding, and capacity are not yet available for a single standard approach that can be deployed statewide. Therefore, this plan takes an incremental approach to build and implement a statewide microplastics monitoring program by identifying opportunities to leverage current monitoring efforts, learn from successes and failures, and incentivize more robust collaboration and coordination, which will inform a more expansive monitoring plan in future iterations.

Pilot Monitoring Plan Recommendations:

- Implement screening-level monitoring studies that leverage ongoing statewide and regional monitoring activities (Section 3.5 and 3.6).
- Use best available methods to quantify microplastics, and complementary sampling and analytical methods as needed, to meet study objectives and data needs. Applying best available methods, even if methods are not yet standardized, will help inform monitoring and methodology data gaps.
    - SCCWRP has recently published sampling guidance for sediment and biota.[18] Sampling guidance for water and stormwater will be published later.
    - ASTM D8332-20[19] has published sample collection methods for wastewater.
- Archive samples that can be analyzed in future years to account for method changes to evaluate temporal changes.

[18] Thornton Hampton, Mehinto, and Weisber, *Standard Operating Procedures for the Collection of Samples for Microplastics Analysis Part 1: Surface Sediment and Aquatic Biota*, 2025

[19] ASTM D8332-20: Standard Practice for Collection of Water Samples with High, Medium, or Low Suspended Solids for Identification and Quantification of Microplastic Particles and Fibers.

- Prioritize monitoring water bodies most likely to be worst-case scenarios (e.g., impacted by urban transport pathways and/or including sensitive habitats).
    - Freshwater and sediment are important data gaps (See Appendix F).
- Monitor sites with a gradient of urban impacts including background reference sites to test site selection criteria.

Based on findings from pilot monitoring efforts:

- Evaluate the monitoring design needed to provide baseline concentrations of microplastics in coastal ecosystems (e.g., sediment) and determine an appropriate frequency of monitoring to evaluate trends (e.g., every five years). Use findings to determine whether sufficient resources are available to support statistically robust study design. Sampling frequency should consider how quickly evaluation of trends is needed to inform management actions, time needed to complete microplastic studies to inform the next sampling and analysis cycle, and available resources. An initial recommendation is to plan for a 3–5 year sampling frequency.
- Use findings to refine site selection criteria for water bodies most likely to be impacted by microplastic pollution and inform further monitoring activities.
- Consider expanding to other regions in the next iteration of the monitoring plan. This will establish a foundation for ongoing baseline monitoring. Future phases will build on this foundation, expanding monitoring to additional locations while continuing monitoring at original locations to evaluate changes over time.
- Support model development efforts to identify areas where microplastic exposure may be highest to inform future site selection.

Recommended pilot monitoring studies:

- A specific monitoring study that leverages SWAMP Stream Pollution Trends (SpoT) is described in Section 3.5. While SWAMP will be used in the pilot, further planning will be required to determine an appropriate lead for a long-term statewide monitoring program.
- A specific monitoring study that leverages regional monitoring programs is described in Section 3.6.

3.3 Near-future Monitoring Plan (3–8 years)

Lessons learned from implementing the pilot monitoring plan and developing methods should be applied to gradually expand the scope of the monitoring program. Below are important monitoring priorities identified in the Monitoring Strategy.

These monitoring recommendations build upon the baseline conditions established in the pilot phase to address MQ 1A, expanding geographic coverage, developing more robust baseline conditions, and supporting trend evaluation (MQ 3A). Additional special study recommendations are described to inform MQ 2A.

- Continue and expand monitoring of trends in aquatic ecosystems (addresses MQs 1A and 3A)
- Continue building on previous monitoring objectives and adapt study design as appropriate. For example, monitoring at similar locations to evaluate changes over time.
- Expand monitoring to different locations to improve understanding of what types of locations are most at risk of microplastic impacts.
- Pilot monitoring studies for nanoplastics if quantitative methods are available.
- Add fish and shellfish monitoring. In particular, we recommend monitoring studies to evaluate human health exposure to microplastics from ingesting fish and shellfish.
- Evaluate updated microplastic sampling and analysis methods for monitoring various matrices (e.g., sediment, water, biota) to support greater statewide monitoring and ensure comparability among sampling efforts. This should include an interlaboratory evaluation study of microplastic analytical method(s), and can use the framework of the interlaboratory study of microplastic methods led by SCCWRP (De Frond et al., 2022; Thornton Hampton et al., 2023).
- Establish a standardized reporting framework and data management system.

Below, special studies supporting MQ 2A are described to address specific information needs to support policy, management, and monitoring decisions. These studies are not meant to be repeated as regular monitoring efforts, but may lead to follow-up questions that require further study. As collection and analysis methods and technology advance, the best available methods will be applied to address study objectives.

- **Examples of urban runoff special studies:**

    - Monitor urban runoff to understand sources. Establish baseline levels to allow for future monitoring and evaluation of temporal trends.
    - Evaluate tire wear particle levels in urban runoff. Establish baseline levels that can be used to evaluate future changes and trends.
    - Compile a list of potential discharge sources to watersheds to inform a better understanding of sources and pathways.
    - Evaluate industrial or commercial emission rates to urban landscapes, such as industrial dryers, manufacturing, etc. to evaluate relative contributions from different sources.
    - Develop appropriate models to estimate potential loads from sources and pathways.
- **Examples of wastewater special studies:**
    - Investigate microplastics in the sewershed to evaluate relative contributions from specific industrial discharges and/or contribution from residential discharges.
    - Evaluate microplastic removal rates from different types of post-secondary wastewater treatment technologies to inform pollution control strategies.
- **Examples of agricultural runoff special studies:**
    - Identify data gaps that can inform management actions.
- **Examples of air transport special studies:**
    - Evaluate airborne microplastics, including tire-wear particles, particularly in high transit areas.
    - Identify additional data gaps that can inform management actions

3.4 Long-term Monitoring Plan (8+ years)

Evaluating trends in microplastic levels will take time and is an important long-term objective of the Monitoring Strategy. These monitoring recommendations continue to evaluate trends to inform MQ 1A, MQ 2A, and MQ 3A.

As monitoring efforts expand, sampling and analysis methods are expected to become more coordinated and harmonized, more efficient, and less costly. New pathways monitoring are therefore included here to inform MQ 2A.

- **Monitoring trends in aquatic ecosystems:**
  - Continue building on previous monitoring objectives and adapt study design as appropriate.
- **Monitoring trends in urban runoff:**
  - Adopt consistent and harmonized sampling methods and analysis and reporting formats to ensure comparability among sampling efforts.
  - Evaluate changes in tire wear particle levels in urban runoff, and compare to changes in vehicle fleet composition (e.g., transition to electric vehicles from traditional combustion engine vehicles).
  - Evaluate the efficacy of management actions. Consider the use of sediment cores or sediment traps that serve as integrated signals of stormwater discharge to reduce variability in sampling and reduce the number of samples needed to detect trends. Look to other scientific studies to develop study design.
  - Investigate effectiveness of BMPs, including street sweeping programs, green stormwater infrastructure, and other infrastructure improvements.
- **Wastewater special studies and monitoring:**
  - Adopt consistent and harmonized sampling methods and analysis and reporting formats to ensure comparability among sampling efforts.
- **Air transport and agricultural runoff monitoring**:
  - As methods for monitoring these pathways become more available and established, these may be incorporated into the monitoring plan and special studies may be conducted.

3.5 Microplastic Study Design Leveraging SWAMP SPoT Monitoring Program in Statewide Watersheds

This proposed pilot study may serve as a first step within the Pilot Monitoring Plan (described in Section 3.2) and seeks to provide important information about microplastic levels in freshwater sediments throughout the state, especially those impacted by urban activities. Table 3.1 below describes how this study related to the Statewide Monitoring Strategy management questions and monitoring questions.

Table 3.1. Study objectives and questions relevant to the Statewide Monitoring Strategy guiding management questions.

Monitoring Questions Related to Each Management Question	Study Objective	Example Information Application
MQ 1A: What are the levels of microplastics in freshwater lakes, creeks, and rivers? What are the levels and types of microplastics most prevalently observed?	Evaluate microplastic concentrations in stream sediments collected from various large watersheds statewide. Compare measured concentrations to available sediment ecotoxicity data.	Evaluating concentrations of microplastics in sediment against available ecotoxicity data will help determine if and where microplastic concentrations are at levels of concern. Evaluating the most prevalent types of microplastics observed will help identify sources to potentially target for source control and pollution management.
MQ 2A: What are the levels of microplastics in urban runoff?	Evaluate the relationship between microplastic sediment concentrations and watershed land use.	Evaluating how land use relates to microplastic loading will inform understanding of what land use activities generate more microplastics.
MQ 3A: What is the baseline concentration of microplastics for a given area (region, water body, etc.)?	Establish baseline microplastic concentrations in stream sediment collected from various large watersheds statewide. Archive sediment for future study to compare future concentrations with baseline archived sediment concentrations.	Informing future monitoring study design to evaluate microplastic concentration trends. Establishing a baseline will enable comparisons with future data that could be used to evaluate the efficacy of management

		actions to reduce plastic pollution.

Overview of Approach

Freshwater and sediment monitoring are important data gaps in microplastics monitoring in California to date. The study will leverage SWAMP SPoT's annual monitoring design over a two-year sampling period to examine levels of microplastics in a range of urban-impacted freshwater ecosystems. Results will provide critical information about microplastic levels in freshwater sediments throughout the state to inform the Statewide Monitoring Strategy management questions and monitoring questions as described in Table 3.1.

Several samples will be collected at all sites, including field replicates, samples for microplastics and separate samples for tire wear analysis, and samples to archive. At this time, we recommend planning a second round of sampling within a five year period to start analyzing trends, though analyzing data from the first two years of sampling may inform this decision.

The amount of resources needed is directly related to the number of sampled sites and can be scaled up or down. At a minimum, we recommend selecting 20 of the most urban impacted sites, an additional 20 that represent a gradient of low to moderate urban land use for comparison, and at least three reference sites that have minimal urban influence. Additionally, field replicates should be collected at a minimum of 9 sites (or 20% of sites) to evaluate variation.

Sampling Methods

The Southern California Coastal Water Research Project (SCCWRP) has published guidance on best practices for sampling sediment samples for microplastics analysis [20] (among other matrices). The Standard Operating Procedures (SOPs) should be evaluated and incorporated as appropriate for SPoT sediment sample collection. For the wadable streams, the SOP recommends using a hand coring device with a metal or acrylic barrel to collect the top 5 cm of sediment. The published SOP also provides procedures to minimize contamination and requires the collection of field blanks with each set of samples collected during the same sampling event.

[20] Thornton Hampton, Mehinto, and Weisber, *Standard Operating Procedures for the Collection of Samples for Microplastics Analysis Part 1: Surface Sediment and Aquatic Biota*, 2025.

Analysis Methods

Sediment will be analyzed for microplastics using spectroscopic methods for microplastic particle identification and abundance quantification. Separate samples will be analyzed using pyrolysis GC-MS for tire particle mass quantification.

Analysis of microplastics in sediment using spectroscopy requires isolating, extracting, and identifying microplastics from the rest of the sediment matrix, which is a complex process involving density separation to isolate lighter microplastic materials from denser sediment particles, oxidation to remove organic materials, and sieving to separate particles of desired size fractions. Additionally, spectroscopic identification is often needed to validate visual quantification of microplastics from other non-plastic particles. However, there are wide variations in how studies and laboratories have conducted these steps, and developing methods to improve the precision and accuracy of quantifying microplastics in sediment is still an important research data gap.

Spectroscopic methods are typically insufficient for quantifying tire particles; therefore, we recommend a separate work stream to quantify tire particles in sediment using pyrolysis GC-MS. A critical challenge is that analysis of tire particles in sediment using pyrolysis GC-MS is also an active area of research. Important questions remain about what chemical markers are best suited for quantifying tire particles and how to extrapolate quantification of tire chemical markers to estimate tire particles.

Another critical consideration is that microplastic analysis of sediment is very time consuming and labor intensive (Langknecht et al., 2023). It is important to acknowledge that it may be unrealistic to require complete analysis of all sediment samples given current methods and available budget and time constraints. Decisions need to be made regarding necessary and ideal data needs balanced with available resources.

Additional analytical considerations can be found in Section 3.7.

3.6 Microplastic Surface Water Monitoring Pilot

The Statewide Microplastics Monitoring Strategy outlines a framework to coordinate and leverage regional water quality monitoring programs statewide to monitor microplastics in ambient water and sediment to understand microplastic levels in a range of marine, estuarine, and freshwater ecosystems. In this pilot study design, we describe early monitoring that coordinates a few key regional monitoring programs that have started microplastics monitoring and special studies needed to support wider collaboration. Table 3.2 below describes how this study fits within the Statewide Monitoring Strategy management questions and monitoring questions.

The San Francisco Bay, Monterey Bay, and Southern California Bight regions have sampled microplastics through regional monitoring programs. This study proposes leveraging the experience and resources of these regional monitoring programs, to coordinate ambient water and sediment monitoring among them. Frameworks and lessons learned will be developed following pilot monitoring to provide recommendations for future expanded monitoring that informs statewide and regional information needs around microplastics. Future monitoring will be coordinated with other regions.

Table 3.2. Study objectives and questions relevant to the Statewide Monitoring Strategy guiding management questions.

Monitoring Questions Related to Each Management Question	Study Objective	Example Information Application
MQ 1A: What are the levels of microplastics in coastal subembayments, estuaries, nearshore and offshore marine waters? What are the levels and types of microplastics most prevalently observed in different ecosystems?	Evaluate microplastic (and tire particle) concentrations in coastal marine waters and sediment from three regions (San Francisco Bay, Monterey Bay, Southern California Bight). Compare measured concentrations among regions. Compare results with available water and sediment ecotoxicity thresholds. Establish framework and provide recommendations for future monitoring implementation with wider monitoring partners statewide.	Evaluating concentrations of microplastics in surface water against available ecotoxicity data will help determine if and where microplastic concentrations are at levels of concern.
MQ 2A: How do the levels and composition of microplastics	Compare microplastic levels and composition in water and sediment from different regions.	Evaluating whether sites with higher concentrations of microplastics are correlated with

Monitoring Questions Related to Each Management Question	Study Objective	Example Information Application
compare among different regions, and can this be explained by local sources and pathways?	Evaluate seasonal differences in microplastic levels and composition to assess the influence of different pathways (e.g., wastewater, urban stormwater runoff).	watersheds most impacted by urban land use to determine what urban land uses are biggest generators of microplastic pollution. Evaluating the most prevalent types of microplastics observed will help identify sources to potentially target for upstream management.
MQ 3A: What is the baseline concentration of microplastics for a given area (region, water body, etc.)? What are recommendations for future monitoring?	Evaluate baseline microplastic concentrations in ambient water and sediment from monitored regions. Archive sediment for future study to compare future concentrations with baseline archived sediment concentrations.	Comparing future studies to baseline levels evaluated in this study. Coordinating microplastic monitoring across regions will help inform methods and coordination frameworks for future statewide monitoring.

Overview of Monitoring Approach

Three regional monitoring programs will coordinate collection of ambient marine and estuarine water and sediment samples.

The amount of resources needed is directly related to the number of sampling sites and can be scaled up or down. At this time, we recommend collecting a minimum of 30 water and 30 sediment field samples from each monitoring program as a starting point. Selected sites should include those anticipated to be most impacted by urban influence and include a gradient of urban influence to evaluate a range of concentrations. Additionally, field replicates should be collected to evaluate variation within sites for each matrix. The number of water and sediment samples from each region should be developed in coordination with the regional monitoring programs to determine the minimum number of samples for a screening study. We recommend planning for a second round of sampling to start analyzing trends within a five year period, although this decision should be informed by this study's findings.

Sampling Methods

SCCWRP is currently funded by OPC to evaluate and facilitate the standardization of microplastic sample collection methods for water and sediment[21] (among other matrices) and is developing SOPs that provide guidance on best practices of microplastic sampling. The SOPs should be evaluated and incorporated as appropriate for this study sample collection. The draft water SOP (anticipated publication in early 2026) describes using in-situ filtration of microplastics from ambient water via pumps. The draft water SOP recommends 50 µm as the smallest mesh size and also recommends including depth-integrated sampling if feasible. Pilot sampling and analysis of microplastics should be coordinated and conducted to ensure sampling methods meet quality assurance/quality control standards (e.g., field and lab blanks, sample volume, matrix recovery, minimum reporting level). The draft water SOP does not specify the type of pump to be used, as the choice depends on monitoring objectives and sampling and logistical conditions. The draft water SOP also provides procedures to minimize contamination and requires the collection of field blanks with each set of samples collected during the same sampling event.

The Regional Monitoring Program (RMP) for Water Quality in San Francisco Bay has funded a special study to pilot surface water sampling methods and analysis of microplastic particles down to 20 µm using Laser Direct Infrared Imaging (LDIR) and via Raman spectroscopy. This study is expected to occur 2026–2027. This would be the first pilot study of this approach in California and would provide critical information and experience to help refine the study design and methods.

Analytical Methods

Both water and sediment samples will be analyzed for microplastics using spectroscopic methods for microplastic particle identification and abundance quantification. Duplicate sediment samples will be analyzed using pyrolysis GC-MS for tire particles and

[21] Thornton Hampton, Mehinto, and Weisber, *Standard Operating Procedures for the Collection of Samples for Microplastics Analysis Part 1: Surface Sediment and Aquatic Biota*, 2025

microplastics mass quantification. This is also an opportunity to include an add-on targeted study to analyze key plastic associated chemicals of interest in a small subset of samples.

Additional analytical considerations can be found in Section 3.7.

3.7 Considerations for both Pilot Studies

Analysis Considerations

Since samples are meant to be compared statewide (Table 3.1) and across regions (Table 3.2), ideally a single analytical partner will analyze all samples using a single standard method. If analysis must be split among multiple laboratories, then an inter-lab comparison study on a reference set of samples is necessary prior to analysis of field samples to ensure results are comparable.

Additionally, it is important to understand laboratory method performance, including quantifying method recoveries (measured with reference samples or matrix spikes, applied to different size fractions of microplastics) and background contamination (field and laboratory blanks).

As monitoring expands to more partners, developing standardized methods for sample analysis within the same study design and conducting inter-laboratory comparison studies will become critically important. Currently there are limited commercial options for microplastic analysis, and therefore collaboration with academic research partners may be a necessary part of this Monitoring Plan.

Data Interpretation and Reporting Considerations

Data interpretation is critical to inform management questions. Microplastic results (total abundance, as well as composition) will be statistically evaluated to address study questions (Tables 3.1 and 3.2). Additionally, data analysis will support recommendations for future monitoring, including whether a subset of sites should be prioritized to evaluate statewide trends.

Results will be shared in the form of a draft manuscript appropriate for peer-review publication.

Data will be shared through the Open Data Portal or another publicly available database.

4. Statewide Macroplastics Monitoring Strategy

4.1 Introduction

The Macroplastics Monitoring Strategy addresses mishandled macroplastics in the environment. It offers a policy-relevant framework for quantifying macroplastics levels, sources, and impacts across the state's aquatic environments. Macroplastics are plastics larger than 5mm.

The purpose of the Macroplastics Monitoring Strategy is to:

- Define management and monitoring questions that will contribute to strategic objectives (Section 4.3);
- Support implementation of a statewide macroplastics monitoring program by connecting diverse monitoring efforts and interests (Section 4.4);
- Promote consistent, harmonized, and high-quality methods to improve data comparability, transparency, and accessibility (Section 4.4);
- Support informed science-based decisions through effective program implementation (Section 4.7).

4.2 Background

The Macroplastics Monitoring Strategy takes into account existing regulatory mandates regarding macroplastics, such as the Statewide Trash Amendments, and the priority management questions shared by key state agency stakeholders. The strategy also bears in mind those agencies, such as the State Water Resources Control Board (SWRCB) and the California Ocean Protection Council (OPC), whose missions and primary activities safeguard California's water quality from contaminants such as plastic pollution. The Macroplastics Monitoring Strategy's management questions ensure that monitoring activities address spatial and temporal data gaps while maintaining consistent methods for improved analysis.

This Macroplastics Monitoring Strategy describes pathways for integrating consistent methods, implementing statewide coordination, and expanding analytical capacity. Due to ongoing rapid advancements in this field, this strategy does not prescribe many technical details that will quickly become outdated. The Macroplastic Monitoring Strategy's proposed structure and key elements are meant to validate the efficacy of management actions and adaptively respond to plastic hotspots and evolving standards in macroplastic detection methods.

State Legislative Mandates

California is a national leader in macroplastics management, with ambitious policy goals, regulatory action, key management decisions, and new technology deployment. Many state agencies already dedicate resources to macroplastics remediation, waste management improvements, and source control. The 2015 Trash Amendments and the resulting latest State Trash Policy are among the most consequential policy advancements related to trash and macroplastics. The State Trash Policy, enforced by Regional Water Quality Control Boards (RWQCB), has structured a two-track system to promote a goal of no trash (defined as improperly discarded solid materials greater than 5mm) discharged into California's receiving waters by Municipal Separate Storm Sewer System (MS4) permittees. Track 1 entails the deployment of trash capture devices in the MS4 system that comply with SWRCB-certified specifications for full trash capture systems. Under Track 2, permittees can elect to conform to full trash capture equivalency by other means, which requires monitoring to ensure compliance.

Other key macroplastic policy developments and the agencies responsible for them are described below.

Oversight & Agencies

- **California Environmental Protection Agency:** Oversees environmental policies broadly.
    - **CalRecycle:** Main state agency responsible for solid waste and recycling regulation.
    - **State Water Resources Control Board:** Regulates discharge of waste for statewide permittees, such as the Department of Transportation, in coordination with RWQCBs.
    - **Regional Water Quality Control Board:** Regulates MS4 systems regarding the discharge of waste that could affect the waters of the state.

Waste Diversion & Recycling Goals

- **California Integrated Waste Management Act (Assembly Bill 939, 1989):** Required local jurisdictions to divert 50% of waste from landfills through recycling and reuse.
- **Short-Lived Climate Pollutants (Senate Bill 1383, 2016):** Set goals to:
    - Reduce organic waste disposal by 75% by 2025 (compared to 2014 levels).

- Recover 20% of edible food that would otherwise be sent to landfills.

Single-Use Plastics & Packaging

- **Plastic Pollution Prevention and Packaging Producer Responsibility Act, (Senate Bill 54, 2022):**
  - Required that 65% of plastic packaging be recyclable or compostable by 2032.
  - Producers must reduce plastic waste at the source and fund recycling programs.
- **Statewide Plastic Bag Ban (Senate Bill 270, 2014):** Banned single-use plastic carryout bags; allows reusable or paper bags for a fee.
- **Strengthened Plastic Bag Ban (Senate Bill 1053, 2024):** Extended single-use plastic bag ban to additional retailers and prohibits the use of thicker "reusable" plastic bags.

Other Extended Producer Responsibility (EPR)

- **Carpet, paint, mattresses, and pharmaceuticals:** Manufacturers are required to manage the end-of-life disposal of their products.

Landfill Regulations

- **CalRecycle** oversees landfill operations, ensures compliance with waste limits, and promotes landfill alternatives.
- **Diversion of green waste** and other recoverable materials is mandated before landfilling.

Litter and Marine Debris Prevention

- **California Coastal Commission's Coastal Cleanup Day:** One of the largest annual trash-removal volunteer events.
- **Municipal Stormwater Permits:** Requires cities and other governmental organizations to prevent waste from entering waterways via their storm drain systems.
- **Water Code section 13367 via the statewide Industrial General Permit**: Imposes minimum best management practices to control the release of preproduction plastic.

- **Trash Amendments (SWRCB):** Described in detail earlier in this section. Mandates full trash capture systems or an equivalent system of pollution controls in urban areas to reduce stormwater trash pollution.

Selected Local & Municipal Actions

Many cities have additional local ordinances, including:

- **Zero Waste goals** (e.g., City of San Francisco).
- **Commercial recycling requirements** for businesses and multifamily housing.
- **Incentives and fines** for reducing waste or improper disposal.
- **Ban of tobacco sales** (Cities of Santa Cruz, Beverly Hills, Manhattan Beach).
- **Styrofoam bans:** Many cities have banned expanded polystyrene (EPS) containers.

4.3 Management and Monitoring Questions

The Statewide Macroplastics Monitoring Strategy is guided by three high-level management questions that define the Strategy's scope, and stem from the overarching goals of the Statewide Plastics Monitoring Strategy to inform management decisions. Monitoring questions fit below management questions and describe what information would inform the corresponding management questions, and may be defined for specific monitoring plans or studies (Table 4.1).

Table 4.1: Management questions and corresponding monitoring questions. Monitoring questions can be implemented at statewide, regional, or local scales.

Management Questions	Monitoring Questions
MQ 1B: What are the levels of macroplastics in different aquatic ecosystems? Are macroplastics at levels that may impact beneficial uses, including human health and welfare?	• What are the levels of macroplastics in coastal subembayments? • Where are macroplastics concentrated in offshore marine waters? • What are the levels of macroplastics in freshwater watersheds? • What are the levels of macroplastics in creeks, streams, and rivers?

	• What are the levels of macroplastics in urban watersheds? • What are the levels of macroplastics in areas of different land uses? • What are the levels by types of macroplastics most prevalently observed in different ecosystems?
MQ 2B: What are the major sources, pathways, and relative loadings for macroplastics-related contributions and impacts to California aquatic ecosystems?	• What are the major sources of macroplastics? • What are the levels of macroplastics in urban stormwater runoff, as distinguished from direct dumping and encampments? • What are the levels and types of macroplastics observed from different sources (e.g., recreational areas, bars, tobacco retailers, transportation corridors, commercial districts)?
MQ 3B: Are plastic levels changing over time? How effective are the mitigation measures and regulatory controls? What are management actions that could drive changes in macro-plastic levels in California surface waters?	• What is the baseline concentration of microplastics for a given area (region, water body, etc.)? • Have macroplastics and associated microplastic concentrations increased, decreased, or stayed the same over a specified period of time? • How do changes in macroplastic levels differ among areas with different mitigation measures and policies?

Management Question (MQ) 1B underscores how this Monitoring Strategy can identify whether present levels of macroplastics are impacting the beneficial uses of California's aquatic ecosystems (marine, estuarine, freshwater) and associated human uses, including recreation, aesthetic appreciation, economic activity, wildlife habitat quality, and other water quality metrics.

It is important for decision makers to know how much macroplastic exists in a particular place. Some litter reporting does not specify how much of the total material collected is plastic or differentiate the types of macroplastics (e.g., bags, food wrappers). These complexities underscore the need for systems sophisticated and versatile enough to address the most pressing, relevant concerns.

Despite the importance of establishing macroplastic levels over time, consistent ways to measure macroplastic loads and their impacts statewide are not available. Designs of existing macroplastic monitoring efforts—with specific monitoring questions—are often determined by the respective missions, goals, and near-term objectives of the local and regional programs. The monitoring questions also vary with geographic features, ecosystems, land use, and perceived contamination levels. However, when scaling statewide, related monitoring questions can generate opportunities for aggregation and cross-regional comparison. For instance, practitioners might compare beach surveys that categorize types of identified plastic materials to other coastal beach surveys found elsewhere. Likewise, surveys of creekside parks, embayments, and urban hubs might be compared across the state to identify patterns in the macroplastic loads.

MQ 2B reflects the goal of tracing microplastic pollution back to upstream sources and pathways and providing information to guide pollution reduction measures, such as source control. In a management context, "sources" for macroplastics can practically include land-use designations, such as commercial districts, transportation corridors, and areas of high-density population. Pathways include modes of conveyance such as direct dumping, encampments, and stormwater outfalls.

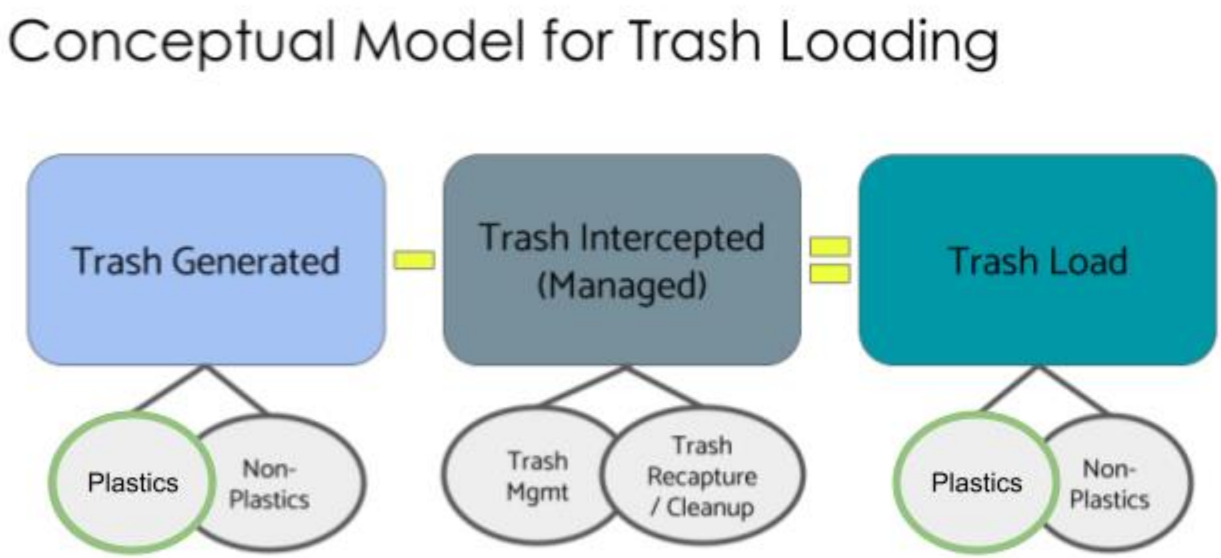

Figure 4.1. Management Question 1B focuses on quantifying plastic levels or loading, which in the case of macroplastics, refers to the amount of plastics discharged into the ambient environment in a given place and time.[22] This conceptual model for trash loading was adapted from the Bay Area Stormwater Management Agencies Association (BASMAA) (EOA, Inc., 2011).

[22] https://www.epa.gov/trash-free-waters/epas-escaped-trash-assessment-protocol-etap

A number of agencies are interested in MQ 2B. It is most relevant to those seeking to establish extended producer responsibility, including CalRecycle. SWRCB also asks this question to determine the sources for contaminants of concern, such as macroplastics.

Programs deploy a range of methods and strategies, as described below (and in more detail in Section 4.4), often with adaptations to accommodate a focus on identifying pathways and sources associated with plastic contamination.

- **Brand Identification:** Using a variant of the tally method (Figure 4.2), monitoring practitioners can identify discrete brands of beverages, tobacco products, foodware, and other escaped items. These manufacturing sources can then be flagged for concern if loading of that product reaches a recognized threshold.
- **Geographic Concentration:** Another common approach is to correlate human behavioral trends on the landscape with the amount of plastic to identify so-called "hotspots." Areas with higher than average amounts of macroplastic might require further study to determine the drivers for such concentrations (e.g., a social pattern, an economic activity, or a broken segment in the waste handling system). This correlation might direct attention to the appropriate source or pathway for the hotspot.

MQ 3B focuses on policy and management actions and their effects on plastic pollution in the environment. Management actions range from implementing trash capture devices and other engineered solutions, to deploying signage and trash receptacles, to launching public relations or education campaigns. Management actions can also include bans, regulatory enforcement, or special handling practices for specific materials or products. California often leads the way with such actions. However, determining the efficacy of these actions, as well as identifying new potential prevention and mitigation measures, depends on reliable monitoring data coordinated statewide.

- **Temporal Trends Analysis:** Another technique often used is analyzing trends over time. The seasonal changes detected in the amount in the landscape might indicate patterns in human behavior, commercial interests, or other changes to infrastructure that could be addressed.

4.4 Sampling and Analysis Methods for the Statewide Program

Over the past few decades, programs across California have developed nearly as many methods for measuring the amount, type, and locations of macroplastics in the environment as there are monitoring programs. Some types of monitoring that have emerged over time are better suited for a statewide program.

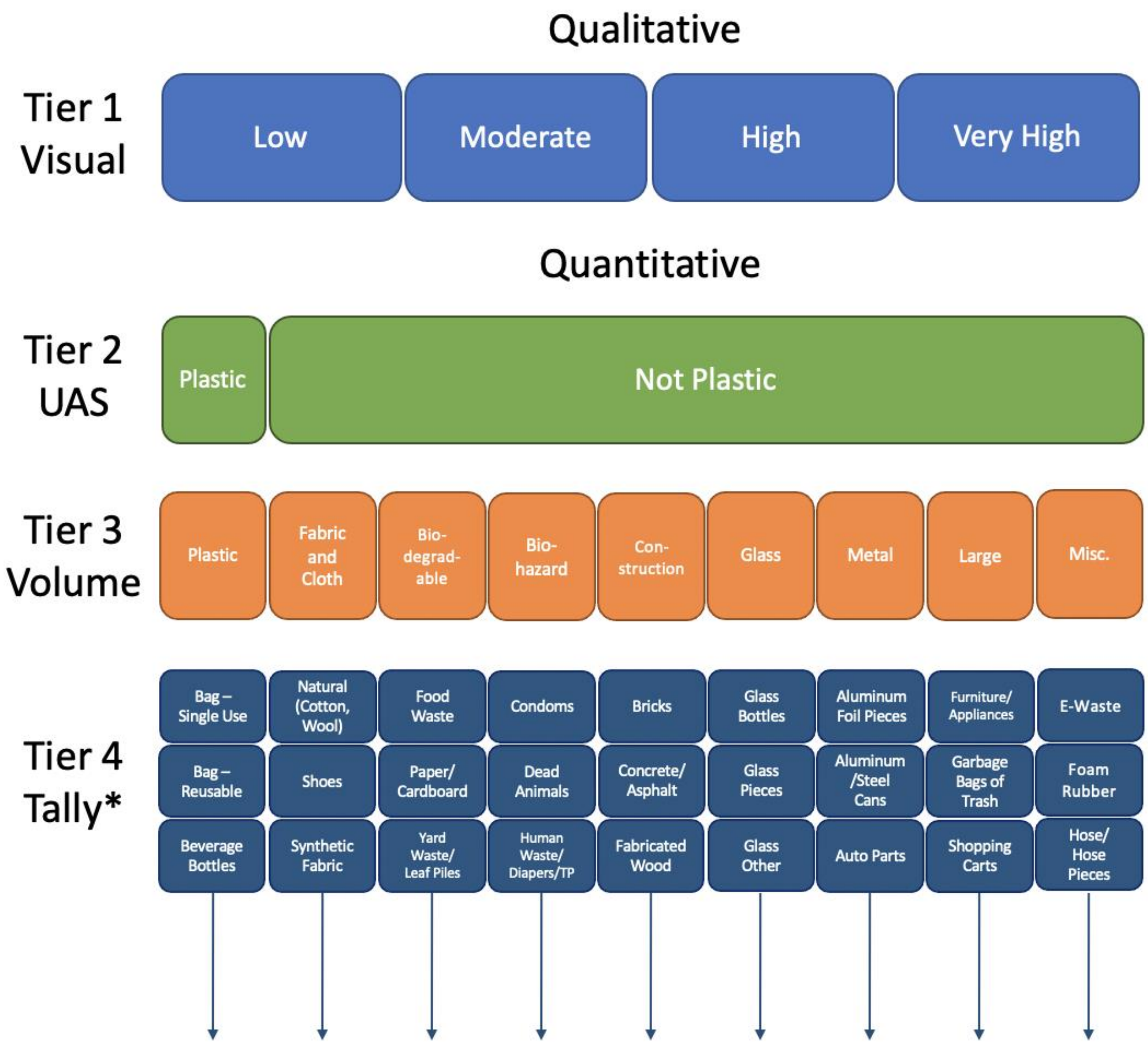

Figure 4.2. Four typical trash monitoring methods listed by type of information collected. Arrows at the bottom of the diagram indicate many more items that are not listed to conserve space. For the tally method (tier 4), larger categories are used similar to the volume method (tier 3) but can be further divided into more discrete types within each category. (Figure adapted from the *California Trash Monitoring Methods and Assessments Playbook*[23] with permission from the authors.)

[23] Moore, Hale, Weisberg, Flores, Kauhanen.

California Trash Monitoring Methods and Assessments Playbook. 2020.

Methodological Diversity

To date, macroplastics monitoring in California has largely been performed under the broader effort of trash monitoring. By implementing the Statewide Trash Amendments, the RWQCBs have established conventions for monitoring by their regulated entities to promote the goal of no releases of trash to California's receiving waters by 2030. To monitor progress towards this goal, trash monitoring methods have evolved, balancing highly resolved data with cost-effectiveness and practicality.

Compliance monitoring can leverage different methods, which can fall into two very broad trash monitoring categories: qualitative and quantitative assessments. Qualitative assessments are generally faster and therefore can cover greater areas with the same amount of resources. Quantitative assessments are more precise and provide more detailed information about the types of items observed, yet require more intensive training to perform consistently.

Beyond compliance monitoring, there is even greater diversity of methods and objectives; many trash reduction, advocacy, and environmental improvement programs perform monitoring to support their efforts, organizations, and research. The methodological differences among these and state programs often align with the influence of nearby RWQCB mandates: qualitative assessments ("how much trash is observable in this area") predominate in Northern California, while quantitative assessments ("what are the collected types and counts of trash in this area") are more influential in Southern California.

The *California Trash Monitoring Methods and Assessments Playbook* (S. Moore et al., 2020) describes the different categories of methods commonly used across California (Figure 4.2). While not every method finds a home in what is now commonly known as the *Trash Monitoring Playbook*, they can usually find close analogues. The document's primary goal is "[t]o create a foundation for developing a consistent, standardized approach to trash monitoring statewide." The *Playbook* assessed the accuracy, repeatability, and efficiency of some already developed trash monitoring methodologies and supported the evaluation of a new method. A byproduct of this analysis was characterizing methods into tiers corresponding to information needs that different classes of methods are capable of addressing. Lower tiers cost less but produce simpler data; higher tiers require more time and effort, but produce detailed data. California's statewide macroplastics monitoring program may emphasize methods that distinguish macroplastics from the broader escaped trash volume (tier 2 and above).

For a statewide macroplastics monitoring program, methods that distinguish macroplastics from general trash loads are particularly important. The tally method (tier

4), which quantifies and categorizes individual items, offers more opportunities for macroplastic quantification. This method identifies both the amount and type of plastic material recorded in an assessment. It is well suited to analyses that would inform the management questions within the Macroplastics Monitoring Strategy.

Monitoring practices across all tiers encompass a broad suite of technologies, from mobile applications and unoccupied aircraft system (UAS) flights to vehicle-based surveys and methods incorporating machine learning and other automated tools. Methods that estimate the current status of macroplastics (MQ 1) provide baselines for understanding conditions. Management Questions 2 and 3 (focused on identifying sources and pathways and detecting trends) introduce additional layers of complexity, and require methods that can support more advanced analyses.

Following consistent methods will result in more comparable data statewide. Keys to methodological consistency include:

- Development/adoption of a well-described written method
- Inclusion of qualitative and quantitative components to inform monitoring and management questions
- Intercalibration among trash monitoring practitioners to promote consistency in observations
- Taxonomic determinations to ensure that all practitioners are categorizing plastics according to preset terms

Figure 4.3. Trash monitoring practitioners gather to calibrate their assessments. Photo by Tony Hale, SFEI. 2019.

Advances in Data Collection and Analysis

Several new technological advances could be considered for use in a statewide monitoring program.

Stormwater programs can measure macroplastics in the landscape more broadly and frequently to observe changes over both space and time. Already, programs are using vehicles driven on city streets and freeways to identify trash and plastic "hotspots."

New research shows promise in distinguishing plastics from other materials when amassed in sufficient quantities under the right conditions. Hydrocarbons or plastics in dry and wet marine-harvested, washed-ashore, and virgin plastics can be detected via hyperspectral (UV, ~350 nm) to shortwave infrared (SWIR, ~2500 nm) reflectance techniques (Garaba & Dierssen, 2020; Knaeps et al., 2021). Santini et al. (2010) tested the efficacy of detecting macroplastics in highly turbid waters (Venice Lagoon) to prepare for deploying advanced satellites that use these wavelengths. However, many of these studies are based on laboratory observations and tests under highly controlled conditions. "Clearly, the detection of floating plastic litter in actual water bodies," write Mohammadali Olyaei and Ardeshir Ebtehaj, "is much more challenging than in a controlled environment due to background contamination of the spectral signatures in the presence of atmosphere and other optically active floating materials such as algal biomass, whitecaps, and waves" (Olyaei & Ebtehaj, 2024).

Similarly, detecting plastics partially obscured by sediment, tree canopies, and other non-plastic material can confound idealized detection optics (S. Moore et al., 2020). In field tests, using multispectral instead of more costly hyperspectral radiometers makes results even less reliable. Multispectral radiometers can detect some macroplastics when the plastics are not obscured by sediment, and when featured on distinctive materials such as pavement, asphalt, and other high-contrast backgrounds.

Nevertheless, this research and anticipated technical strides lend themselves to automated detection of macroplastics. Automated detection could work not only for macroplastics submerged in turbid waters, such as those in marine and estuarine environments around California, but also around the urban landscape. Such advances would further data collection in scale and scope in ways that can address questions regarding the status, loading, trends, and project impacts of macroplastics across the state.

Practitioners can already leverage different forms of remote sensing technologies to detect macroplastics with increasingly refined imagery. Some programs contract with unoccupied aerial vehicle (UAV) pilots to fly landscapes for vivid and highly detailed imagery. Others with more resources might contract an airplane pilot to fly across many watersheds at a time, with slightly less detailed visuals but greater geographic coverage. Closer observations generally correlate with more highly resolved images and smaller minimum detection limits of the plastic objects. A UAV flying at 30 meters in altitude will likely yield a much more highly resolved image than a satellite flying 200 kilometers above the earth. Optical differences aside, the atmosphere itself makes seeing a cigarette butt from the greater distance very challenging. But identifying larger pieces of extruded polystyrene (foam boards used for insulation) or larger collections of macroplastics is currently possible from a distance of low-orbit space.

A statewide monitoring program will continue to identify technological or methodological innovations that might scale to a statewide focus. It could also fund ambitious California-wide data collection campaigns. Following state guidance, the program should prioritize open-source and open-data solutions that foster collective participation.[24]

Managers can also benefit from the unprecedented analytical capabilities made possible by artificial intelligence, including both generative large language models and more established computer vision models. One application is using high-resolution landscape imagery to detect macroplastic.

- In the "Field Testing Report: California Trash Monitoring Methods," Moore et al. describe the development of a new **computer vision model** to detect trash, and macroplastic in particular, in the context of highly varied landscape scenes. Such "machine learning may be used to accelerate the assessments, thereby potentially expanding the geography and time period surveyed" (S. Moore et al., 2021). Since publishing these results in 2020, computer vision models and AI-based advances have only accelerated.
- Trash AI offers an **open source solution** to trash identification, counting, and categorization via image-based detection.[25] Applying Trash AI to a broad, community-based science project might provide a snapshot of trash in California. A broader collaborative effort to "snap your plastic" might be coordinated statewide.
- 2NFORM from 2ndNature offers another example of citywide analysis furnished by **automated detection of trash**. The trash detection and prediction tool is part of a suite of tools associated with stormwater management and monitoring.

Proposed Approach for Statewide Harmonization

Since many trash monitoring programs focus their attention on the broadest category of trash in general, while other programs focus on some limited portion of trash such as tobacco product waste or plastic bags or beverage rings, it is difficult to quantify plastic in California with existing data. A new program must offer a credible and authoritative solution to interpret statewide data. The central missing gap in some of the qualitative methods used by programs across the state is **determining the proportion of escaped trash that is plastic.**

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[24] Data Tool Kit - Open Source Code Handbook. https://www.waterboards.ca.gov/resources/oima/cowi/open_source_code_handbook.html

[25] Hollingsworth, S. 2022. Trash AI.

Our recommended approach is a conceptual instrument called the Plastic Material Coefficient or PMC. The PMC measures the volume of plastic in all escaped trash as a function of the total volume of escaped trash.

$$\mathbf{p}_{\mathbf{pmc}} = \text{Plastic Material Volume / Total Trash Volume}$$

If the plastic material volume is 25 m^3 and the total trash volume is 50 m^3, then the PMC is 0.5 or 50%. A PMC could be applied to translate qualitative trash loading assessments into plastics loading. For example, a qualitative assessment that measures the total trash volume to be 10 m^3 would estimate a plastic material volume of 5 m^3.

The PMC is a simple but potentially powerful tool to develop a common denominator for otherwise incompatible monitoring methods used broadly across California. While it focuses on characterizing plastic material as a whole, the PMC can also further speciate the escaped trash stream within reason to predict and test the amount of different categories of plastic bound for receiving waters. This could complement tobacco product waste assessments or specialized surveys for plastic bags.

Proposed Survey Innovation for Program Pilot

To prevent misuse or misinterpretation of the PMC, a pilot study must determine the boundary conditions for calculating the PMC. A PMC could be calibrated over particular areas and time periods to estimate plastics and total trash by volume in qualitative rapid assessments. Testing Northern California correlations to existing data from Southern California would be a natural place to start.

If successful, a quantitative trash assessment for a given place and time could measure the precise amount of plastic there. If the PMC is not successful and the variability for plastics in the escaped waste stream is too great to be statistically powerful, then we might test if it can apply within a smaller geography, matching land use, or similar demographic character.

To ensure scientific credibility and integrity, volume measurements for developing and testing the PMC should be based on direct observation, not estimated qualitative assessments. It will be important to distinguish between data derived from the PMC and directly observed measurements.

For analysis associated with the PMC, the PMC pilot team will need to review existing field surveys that feature both qualitative and quantitative assessments to assess its applicability. The pilot team should investigate the drivers for the PMC and note remarkable exceptions to the average proportion, with the goal of explaining such exceptions.

Secondarily, the team should explore subcategorization of plastics to determine how consistent the proportions are for given materials and habitat types. This will contribute to reports of efficacy for management decisions—how a bag ban influences the profile of escaped trash, for instance—and also potential extended producer responsibility concerns.

4.5 Monitoring Program Partners

Macroplastic monitoring programs with an array of methods exist across the state, and in some cases have for decades. Understanding the landscape of these programs will equip the new statewide program to best leverage their existing resources.

- Trash monitoring in the United States has increasingly gained importance as a means to manage and protect water quality and ecosystems. The **US Environmental Protection Agency (EPA)** has been instrumental in addressing trash-related pollution through initiatives like the Trash-Free Waters program,[26] which aims to reduce the volume of litter entering water bodies. The EPA also collaborates with local and state agencies to monitor stormwater systems and develop best practices for preventing trash pollution. Meanwhile, the **National Oceanic and Atmospheric Administration (NOAA) Marine Debris Program** focuses on tracking and mitigating marine debris, providing critical data on the sources and impacts of trash in marine environments, especially along the coastlines.[27]

- California's water quality management is organized by **nine regional water quality control boards** (Figure 4.4), and there are various water quality monitoring programs throughout the state implemented at regional levels in coordination with the **State Water Resources Control Board**. Over time, **regional monitoring programs** have evolved diverse program objectives, governance structures, data management procedures, and partners for implementation.

- California's SWRCB **Surface Water Ambient Monitoring Program (SWAMP)** has been seminal in trash monitoring efforts. This program developed its Rapid Trash Assessment Protocol (RTAP) to evaluate the presence and impacts of trash in freshwater ecosystems (S. M. Moore et al., 2007). These assessments inform regulatory actions and community initiatives aimed at trash reduction.

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[26] https://www.epa.gov/trash-free-waters

[27] NOAA, 2024. Marine Debris Program.

- A number of programs can trace their qualitative assessment methodologies to the advent of SWAMP's RTAP. In particular, the **Bay Area Municipal Stormwater Collaborative (BAMSC)** coordinates data collection and reporting techniques among municipal stormwater programs to support regulatory compliance. Regional collaborators such as the **Southern California Bight Program** and **Southern California Stormwater Monitoring Coalition (SMC)** enhance California's efforts to address trash pollution. The Bight Program conducts extensive surveys to evaluate the impact of trash on coastal ecosystems, while the Bay Area Municipal Stormwater Collaborative focuses on reducing urban runoff and stormwater pollution.

These initiatives emphasize the importance of coordinated monitoring, standardized methodologies, and public engagement to address trash pollution poses. See Appendix H for a list of select programs to illustrate the range of methods and objectives.

Figure 4.4: California is organized by nine regional water quality boards: Region 1 in avocado green - North Coast, Region 2 in pink - San Francisco Bay, Region 3 in purple - Central Coast, Region 4 in bright green - Los Angeles, Region 5 in mustard yellow - Central Valley, Region 6 in maroon - Lahontan, Region 7 in blue - Colorado River, Region 8 in hot pink - Santa Ana, Region 9 in lime green - San Diego

4.6 Locations and Geographic Considerations

Each monitoring study should carefully consider the study questions and objectives, as well as develop a study design and identify sampling locations that inform those study questions. Site selection considerations for MQ 1B and 2B are the same as those listed for microplastics (Section 2.6) except where nuances specific to microplastics are noted. Some site selection considerations for MQ 3B differ from those for MQ 3A, and are listed separately here.

Site selection considerations relating to **Management Question 3B**.

I. Consider **site revisitation** to collect data over multiple time periods. Analyze the resulting dataset using consistent methods to ensure that results are comparable for evaluating temporal trends.

II. Consider collecting **trash data from trash recapture investments (e.g., trash capture devices, booms, and nets)** to evaluate trends in macroplastic concentrations. Sites should be in areas with known flow rates.

III. Consider assessments **near stormwater outfall locations** to help characterize connected subwatersheds and monitor microplastic trends in urban runoff. Compared to sampling runoff directly during or after storm events, nearby samples provide a more integrated signal of changes in macroplastic concentrations in urban stormwater runoff. These types of samples would reduce the variability in sampling and the number of samples needed to detect trends.

IV. **Leverage ongoing efforts to monitor stormwater runoff and demographic factors to evaluate temporal trends**.

V. Consider **monitoring cities where mitigation measures have been implemented at the local level** (e.g., single-use plastic bans) to evaluate effectiveness of these actions.

4.7 Additional Considerations for Statewide Monitoring

Temporal Coordination

Trash is highly mobile and moves around the environment with wind, rain, and direct human intervention. Seasonality, weather, and land uses are therefore huge influences on the presence and absence of plastics in the environment. Given these factors, plastics monitoring might otherwise overlook a high volume of materials simply because it migrated beyond the assessment area at the time of sampling. Coordinating sampling events across teams can produce results strategically collected before and after anticipated movement, like storms and cleanups, and in so doing, increase the chances of accurately quantifying the volume of plastic materials across a broad geography. Generally, more tightly coordinated sampling events with consistent methods will produce more comparable results.

Effective Data Management Strategies

Collecting data alone is insufficient to produce optimal results. A proper data management plan (Section 6.1), with metadata, a clear chain of custody, and provisions for quality assurance/quality control confers greater credibility to such efforts. A well-constructed data management plan also helps analysts determine the comparability of datasets collected under varied conditions. These basic documentation practices will greatly enhance the statewide program's ability to aggregate and compare data if performed consistently.

Greater Community Engagement: Monitoring, Insight, and Stewardship

Unlike microplastics, the distinctive visibility of macroplastics presents an opportunity for a broad range of Californians to engage with monitoring. Many are already invested in doing so. Even without any specialized equipment or advanced technical training, community-based monitoring practitioners can effectively monitor their communities for trash. Community-based events might be layered over the same geography as formal practitioners but differ in methodology, training, monitoring objectives, and other factors.

Involving community-based scientists in plastics monitoring represents an opportunity too large to miss. Greater coordination would allow community-based monitoring to be more impactful and allow governmental programs to more efficiently use their resources, including data collection tools, data management innovations, and the resulting datasets.

A statewide plastics monitoring program must plan, issue guidance, and prepare to help community-based science generate data that's usable for key decision making. The success of contributing community-based efforts to formal trash assessments depends largely on a number of key factors.

- **Frequent and comprehensive training** is key to all effective monitoring, but especially for community-based efforts, which can often include volunteers and other more transient workforce members. Training new volunteers and re-training existing practitioners promotes consistent results.
- Although community science has an important role for data collection and can impact policy development, the **training, coordination, and data management practices described in this report are frequently not followed** by community-led monitoring efforts, either due to lack of awareness, lack of capacity, lack of infrastructural resources (material or educational), or lack of incentives to do so.

Opening the door to local participation, including outfitting local groups with the appropriate tools and resources, might be key to the statewide program's success as it grows in influence. A statewide plastics monitoring program should aim to integrate local programs into a larger, statewide framework without overburdening all participants.

5. Macroplastics Monitoring Planning Framework

This section describes the Macroplastics Monitoring Planning Framework, which outlines recommendations to implement a statewide macroplastics monitoring program. It will inform the management questions (Section 4.3) and strategic objectives (Section 1.5). This monitoring planning framework does not add new methodologies to an already crowded field of varied methods. Rather, it proposes a pilot effort to demonstrate how a statewide program can efficiently leverage existing monitoring efforts across California's varied geographies and regulatory terrain.

This pilot effort aims to incentivize further investment in the necessary data management, coordination, and synthesis projects that can make optimal use of current and future statewide data collection and analysis. Given the array of existing trash monitoring, there is ample opportunity to leverage current data to determine:

1. How to bridge across dissimilar methods to yield information relevant to management questions.
2. How to extract from current survey methods the types and volumes of plastic material in the waste stream.

The proposed pilot monitoring effort will help to address these concerns.

5.1 Cost Considerations

The Microplastics Monitoring Plan provides cost considerations related to the implementation and deployment of field and laboratory methods. The Macroplastics Monitoring Plan would heavily leverage established programs, which provides cost efficiencies. Page 17 of the *California Trash Monitoring Methods and Assessments Playbook* has relative estimates of resources, accuracy, and precision for each commonly practiced method.

5.2 Pilot Macroplastics Monitoring Plan (0–3 years)

Pilot Monitoring Plan Recommendations:

- Coordinate and leverage **regional ambient water quality monitoring programs statewide** to monitor macroplastics in creeks, rivers, other receiving waters, and their associated nearby watersheds statewide to understand macroplastic levels in a range of marine, estuarine, and freshwater ecosystems. Coordinating this Monitoring Strategy with regional monitoring programs is important to leverage existing management information needs for macroplastics/trash, while also leveraging common resources, regional knowledge, frameworks, and partners for monitoring to optimize study design.
- Calculate and test the **Plastics Materials Coefficient** (PMC, section 4.4) from the proportion of escaped trash load composed of plastic materials. While this information is derivable from current tally methods conducted in the Southern California Bight, the overall effort remains very time-intensive and limited to Southern California. Testing the PMC across regions could derive escaped plastic material estimates from qualitative rapid assessment methodologies.

Depending on the viability of the study's results, the use of the PMC might be broadly or narrowly applied under prescribed circumstances, geographies, and timeframes. This information will inform future expanded monitoring and coordination with other regions throughout the state.

Table 5.1 Study objectives and questions relevant to the Statewide Monitoring Strategy and guiding management questions.

Monitoring Questions Related to Each Management Question	Study Objective	Example Information Application
MQ 1B: What are the levels of macroplastics in receiving waters (creeks, rivers, streams, and oceans? Where are the levels and types of macroplastics most heavily concentrated?	Evaluate macroplastic levels in coastal marine waters and associated watersheds from three or more regions. Compare measured concentrations among regions to determine comparability and confounding factors. Establish framework and provide recommendations for future monitoring implementation with wider monitoring partners statewide.	Evaluating whether macroplastics are at levels of concern. Comparing how the levels and composition of macroplastics differ among regions. Establishing a framework for method comparability will promote more consistent sampling across regions. Documenting metadata will help with data interoperability and interpretation.
MQ 2B: How are sensitive habitats impacted by macroplastic pollution?	Consider locations that are particularly sensitive and/or important habitats. Evaluate results in terms of exposure to aquatic ecosystems, impacts on beneficial uses (e.g., recreational opportunities, economic activity).	Evaluating the levels of macroplastics in urban stormwater runoff. Evaluating the measured impacts on beneficial uses can justify greater investments in trash capture, recovery, and monitoring measures.
MQ 3B: How have the levels of macroplastic in a given location changed over time in its absolute amount? How have the levels of macroplastic in a given location changed over	Leverage historic data in the Southern California Bight to establish key hypotheses regarding the proportion of macroplastic in the broader escaped trash loading. Pilot test applicability at a small scale in areas with suitable monitoring.	Evaluating the proportion of macroplastics in trash will determine how variable this ratio is over time. Comparing quantity-based monitoring assessments to quality-based monitoring assessments to extend

Monitoring Questions Related to Each Management Question	Study Objective	Example Information Application
time as a function of the greater trash loadings?		comparability across regions.

Evaluating the PMC

Desktop Study Approach

Since the parameters of the proposed PMC can be evaluated based on quantitative and qualitative data gathered by the Southern California Bight Regional Monitoring Program, an initial phase of the work would begin with a desktop-based analysis of past monitoring data. This initial effort will yield useful information about the variability of plastic loadings, categorization, and geographic variation.

Comparing these observations and analyses to other quantitative data across California for similar geographic and temporal parameters might further inform the integrity of PMC calculations.

If the PMC concept proves viable, then a broader coordinated effort that includes other regions across California would follow. Otherwise, the PMC concept might be revised or replaced by a superior concept in response to practitioner feedback.

Ambient Receiving Waters Monitoring Approach

The proposed statewide program will coordinate collecting original ambient monitoring assessments to validate the PMC estimates, leveraging resources from the three regional monitoring programs named above. If resources allow, then community-based monitoring via prominent programs such as the Trash Rapid Assessment Data Exchange might also join the effort.

A minimum of 40 water and 40 watershed assessments from each region will ideally serve as a baseline to evaluate the predictive power of the PMC. The number of sampling sites can be scaled down based on resource constraints. The sampling site portfolio should include sites anticipated to be most impacted by macroplastic pollution. The sites should also include a diversity of land uses and demographic characteristics to evaluate a range of concentrations and parameters.

The specific number of assessments from each region should be developed in coordination with the regional monitoring programs to determine the minimum number of assessments for an initial study.

Building Upon Existing Sampling Methods

As part of the Southern California Bight Regional Monitoring Program, the Southern California Coastal Water Research Project (SCCWRP) and the Stormwater Monitoring Coalition (SMC) currently use tally-based methods for quantifying visible trash in creeks, rivers, and streams in Southern California. These assessments can be compared to the qualitative assessments performed by municipal practitioners in the San Francisco Bay Area that share common volumetric measurements. Such measurements are recorded when the surveys extract trash from the landscape for more precise measurements (BASMAA, 2018). Bay Area practitioners will need to perform some additional quantitative measurements to fully compare the assessments, but these extra steps hold promise to add substantial value.

Training

Northern California lacks routine quantitative methods in assessment scoring and riverine site delineations relative to Southern California. Robust training and cooperation will be necessary to make up this difference.

The pilot effort will be guided by experience from monitoring practitioners and programs. Accordingly, the training for quantitative methods would be provided by the Southern California Bight Program, the SMC, and their partners. This direct route to training and intercalibration will reduce the amount of variability produced by different monitoring techniques or monitoring practitioners.

After training is complete, ambient monitoring will be married to existing monitoring plans to leverage current resources.

5.3 Near-future Monitoring Plan (3–8 years)

If the PMC is successfully calibrated to observed plastic levels, it might be applied to emerging technologies across broader geographies. Ultimately, a refined PMC would allow practitioners to estimate the level of plastic material in an area by remotely sensing the amount of overall trash there.

The program itself will adapt to emerging needs and continue to develop its available resources.

Special Studies

Special studies are used to explore a topic, method, new geography, or emerging concern. They are not typically designed to be repeated as part of regular monitoring practices. As authorized by the program's governance structure, special studies are designed to share results that might help inform current or planned monitoring efforts.

Potential special studies beyond the pilot phase of a macroplastics monitoring program might include opportunities to test the applicability of current or new technologies and methods. For instance, CalTrans and monitoring practitioners in the Central Coast Water Regional Water Board deploy vehicle-based surveyors at regular intervals to assess the trash levels on given highways, streets, and thoroughfares. This form of rapid assessment can characterize broader regions, at the expense of precise item-based quantification and classification. If such surveys can confidently estimate the portion of the trash stream composed of plastic, then these data might influence management efforts and policy.

As optical advances in remote sensing devices increase precision in spectral analysis and resolution, low-earth orbit satellites, unoccupied aerial vehicles (UAVs), and other forms of data collection might help recalibrate the PMC for various geographies and time periods. These autonomous or semi-autonomous recalibrations should be highly cost-efficient.

Furthermore, the many forms of artificial intelligence could augment current data interpretation capabilities. Computer vision technologies are already used to identify plastic objects in imagery. In the future, these pilots might be expanded statewide, especially if the data collection efforts are consistent in their optical range, orientation, and spectra.

These and other innovations would be tested for efficacy through special studies in the near term.

Program Development

Over the course of a five-year period, the program will continue to grow and yield value. Based on current trends and past experience, the program should pursue some of the following opportunities for growth.

- **Source Identification in Aquatic and Marine Ecosystems**
  - Refine existing debris transport models to determine applicability to source identification.

    - Pair marine debris remote sensing data with terrestrial monitoring datasets to link anthropogenic activities to marine debris.
    - Leverage existing smaller-scale, community-based marine and estuarine monitoring programs to complement larger remote sensing of debris and derelict vehicles.
- **Statewide Macroplastics Monitoring Assessment**
    - **Monitoring Trends in Urban Centers**
        - Pursue the implementation of focused trash surveillance efforts in Municipal Separate Storm Sewer Systems to confirm the effectiveness of management actions, including trash capture devices. Such surveillance might include nets, moored optical sensors, or UAV-based monitoring.
        - Analyze best management practices (BMPs) across the state to corroborate current guidance on maintenance cycles for trash capture devices, intervals for street sweeping, and other practices related to escaped trash recapture.
    - **Monitoring Trends in Rural Districts**
        - Monitor the discharge of plastic sheet materials into receiving waters.
        - Examine downstream waste to identify sources of plastics in upstream agricultural areas.
    - **Develop a Statewide Status and Trends Report for Macroplastics**
        - Coordinate consistent qualitative and quantitative large-scale trash monitoring through existing stormwater monitoring in the San Francisco Bay, Central Coast, Southern California Bight and other participating regions.
- **Advance Data Management and Analysis**
    - Develop the online "home" for the program's new analysis and reporting, including key data visualizations to generate insights on statewide trends.
    - Ease the submission of datasets to promote statewide expansion of consistent data reporting.

- Promote and adopt emergent technologies that can help scale local and regional data collection efforts to inform a statewide macroplastics monitoring assessment.

About the Proposed Statewide Status and Trends Report

While the State Trash Policy sets a statewide goal of no trash discharged into California's receiving waters by Municipal Separate Storm Sewer System permittees, assessments are regional with no consistent mechanism to determine whether the policy produces consistent outcomes on a statewide scale. Without consistent methods, we cannot reliably measure progress in meeting plastic reduction goals over time.

For these reasons, a statewide macroplastics monitoring assessment at regularly established intervals can be a useful complement to existing monitoring programs. This assessment might begin with analysis of existing data to highlight areas of greatest opportunity for future sampling. By convening motivated stakeholders through statewide program governance, the new monitoring program might advance assessment of statewide status and trends for macroplastics.

5.4 Long-term Monitoring Plan (8+ years)

The longer-term Macroplastics Monitoring Planning Framework is highly contingent on the success of a still-nascent program implementation process. It will continue to develop aspects of the program in several areas.

- **Statewide Macroplastics Monitoring Assessment**
    - **Monitoring Trends in Aquatic Ecosystems**
        - Continue building on previous monitoring objectives and adapt study designs as appropriate.
    - **Monitoring Trends in Urban Centers**
        - Adopt consistent and harmonized sampling methods and analysis and reporting formats to ensure comparability among sampling efforts.
        - Evaluate the efficacy of management actions. Look to other scientific studies to develop any new study design.
        - Investigate effectiveness of BMPs (best management practices), including trash capture devices, green stormwater infrastructure, and other infrastructure improvements.

- **Monitoring Trends in Rural Districts**
  - With changes to agricultural practices, new macroplastic-based contamination may be introduced. Monitoring methods should adapt to detect such new material.
- **Adapt the Statewide Status and Trends Report for Macroplastics**
  - Include additional regions and community-based monitoring.
  - Augment suite of allowable methods.

- **Advance Data Management and Analysis**
  - Optimize artificial intelligence-based data management practices to yield greater cost-benefits for data collection, analysis, and reporting.
  - Embrace the adaptive management lifecycle to ensure the adoption of technology innovations in service of programmatic objectives.

6. Data Management Principles

Thoughtful data management planning is both a technical necessity and a foundational element for equitable, science-based plastic pollution policy and action. Data must be stewarded to ensure that the information is accessible, standardized, and scientifically robust.

To support decision making, this section emphasizes the integration of standardized monitoring methods, more uniform reporting frameworks, and coordinated data management systems. These components are critical for synthesizing information across different regions and timeframes.

6.1 Recommendations for Sharing Plastics Data

Accurate attribution, consistent classifications, and open formats enable data cross-comparison and integration across monitoring programs and places. For macroplastics, standard open formats (e.g., using Rapid Trash Assessment protocols and tools like the Trash Taxonomy Tool) offer greater opportunities for cross-dataset comparisons and aggregation.

For microplastics, the diversity of methods, research, and analytical objectives often produce a broad range of data formats. Emerging platforms such as the Microplastics Open Data Portal, developed by the Moore Institute and partners, and a range of data collection and distribution tools are paving the way for harmonized, open-access systems that can evolve alongside analytical methods.[28] These platforms must balance accessibility with technical rigor and support varied user needs—from scientists analyzing raw data to decision makers and the public seeking synthesized insights—while managing the complexity of non-standardized and evolving datasets.

This section outlines the data management strategy for plastics, emphasizing the need for standardized, open, and accessible data systems to address current challenges in data comparability, timely access, and clarity. While macroplastics data are routinely collected by municipalities, stormwater agencies, and other entities, they are often locked in static formats such as PDFs and spreadsheets, which limits their utility for analysis and decision making. On the other hand, microplastics data exchange is largely handled disparately by researchers, whose data formats are mainly shaped by the needs of individual studies. To overcome these impediments to broader data sharing, the Statewide Plastics Strategy recommends all data generated as part of the statewide plastics monitoring program be considered open and machine-readable data. Ensuring clear attribution of data contributors and submitting data to an open repository with replication to the California Open Data Portal will promote consistent data sharing, synthesis across datasets, and more effective communication to diverse audiences, including regulators, researchers, and the public. This will ultimately enhance the role of plastics data in environmental management and policy.[29]

[28] The Moore Institute, in collaboration with the SWRCB and SFEI and with funding and support from Possibility Lab, have developed a pilot open-source data collection and reporting tool (Microplastics Open Data Portal) to support storage, management, and communication of drinking water microplastics monitoring data by the SWRCB. The long-term vision of the Microplastics Open Data Portal is that the platform will be further expanded to inform the goals of this Monitoring Strategy by centralizing data collection, data validation, quality control, reporting, and synthesis of statewide microplastics monitoring data. An important challenge and opportunity for the Microplastics Open Data Portal is a set of problems left unaddressed by prior efforts: how to store, synthesize, and communicate the complexity and variability of microplastics monitoring datasets while ensuring that data are reported in a harmonized manner consistent with the broad and evolving definition of microplastics.

[29] The SWRCB and many other public agencies have fully embraced F.A.I.R. principles. The text described above aligns with the ideas represented by its acronym: Findable, Accessible, Interoperable, and Reusable data. Findable data are well-documented through effective metadata. Accessible data follow standard protocols for retrieving the data. Interoperable data enhance comparability with shared vocabularies and standardized language protocols. Reusable data offer guidance about proper usage, provenance, and meet community standards. https://www.go-fair.org/fair-principles/

Investments in Data Management

The vision promoted by this Plastics Monitoring Strategy will only be achieved through regular investments in key personnel, practices, and technologies. Past investments have already yielded significant successes, but at a broader scale, more investment of funds, time, and innovation is needed.

Such investments fall into the following categories.

Communication & Coordination

Existing forums such as the California Water Quality Monitoring Council and its Trash Monitoring Workgroup offer distinct opportunities to reach across California's regions according to a recurring schedule. Workgroups such as these should be leveraged to aid in cross-geographic coordination over issues related to data collection and processing, quality assurance, data visualization and interpretation, and data distribution. Such bodies should tackle taxonomic challenges, data harmonization issues, and opportunities to foster key innovations.

This form of organizational investment can foster a shared sense of purpose across an otherwise diverse set of stakeholders.

Technical Infrastructure

The current state infrastructure is not fully optimized for plastics-related data. The California Environmental Data Exchange Network (CEDEN), for instance, can accommodate some forms of habitat assessment-related macroplastics data, but is ill-equipped to collect and distribute microplastics data. We recommend investments in data infrastructure that serves the range of data formats for micro- and macroplastics program needs.

Leveraging Existing Resources

Regional and state repositories have been collecting trash-related data for years to support regulatory purposes, while universities and other research organizations within and beyond California have spent the last decade or more actively collecting and sharing specialized microplastics data for research purposes. The California Open Data Portal, as a generalized repository, also houses environmental data related to plastics. These and other data management technologies can be enhanced with needed upgrades, specific to macro- and microplastic domain specialization, to serve the proposed program.

Repurposing existing technologies ensures alignment with the ongoing stakeholder needs associated with each repository. It is also more fiscally responsible than creating a new repository.

Mandates and Incentives for Sharing

In some cases, sharing data will be mandated according to prescribed programmatic requirements. Even so, the investments in the data ingestion and distribution tools will help to ensure that data sharing is not a burden, but rather an advantage that lends credibility, rigor, and authority to all data that conforms to key data submission standards.

Currently, there are exceedingly very few organizations who wish to expend extra time, effort, and precious resources to contribute to the success of a statewide program, particularly if those contributions come at a cost to their own local efforts. It is therefore imperative that the incentive structures for statewide program participation be evaluated carefully to ensure that plastics monitoring is not perceived to be merely an extra burden without any locally realized benefits.

The primary solutions used to overcome this disincentive for sustained collaboration involve the following:

- Greater informational and comparative value
- Increased remuneration resources
- Enhanced data management resources

Key Functions for Data Systems

To facilitate data sharing, the following functions must be kept in mind.

Source Identification Through Consistent Classification

For macroplastics, open, structured data with consistent taxonomic classification make it possible to track sources over time and across geographic regions, supporting targeted source-reduction strategies. While microplastic source identification methods are currently limited, these same principles may apply to microplastics in the future. However, consistency must also be balanced against adaptability. Taxonomic structures must be adapted to suit today’s realities, with new plastic products and materials created across the world as well as evolving microplastic analytical capabilities..

Target Audiences for Sharing Plastics Monitoring Data

Many entities and individuals have interest in plastics monitoring data, including government decision makers, municipal stakeholders, Tribes, public advocates, researchers and academics, watershed groups, and the general public. Current plastics-related data is not accessible to all audiences. This is in part due to how data are stored and where they find them (if at all): in a mix of data repositories, spreadsheets, and documents. Moreover, there are many data formats, locations, and access rules from a diverse mix of stewards, interests, and drivers. Data are stored in state repositories, corporate repositories, research institution computers, and non-profit data stores. Plastics data overall is heterogeneous and ungoverned by standard data formats and access agreements.

The inadvertent result is opaque data access, even for data collected in the public interest. For instance, municipalities and counties often conduct hundreds of trash monitoring surveys, many of which produce results that are captured in annual stormwater program reports. These PDF reports are storehouses of data without capacity for analysis, aggregation, and filtering. These reports are semi-transparent in facilitating data access.

For the Statewide Plastics Strategy, it is critical to ensure full transparency for all of the data once it reaches an appropriate stage of review and readiness. To achieve consistent transparency, all plastics data should be:

- Formatted consistently according to open standards;
- Organized according to a shared taxonomic system for consistent categorization;
- Attributed to their respective data collectors, analysts, and all other contributors to the data lifecycle; and
- Submitted to an open data repository.

Documented quality control procedures

Ongoing monitoring requires standardized data formats, metadata protocols, and quality assurance/quality control (QA/QC) procedures to ensure that results can be compared across sites, time periods, and monitoring entities. Centralized repositories and open-access platforms reduce data silos and support collaborative monitoring networks across state and local agencies, academic researchers, and community partners. Data quality objectives, chains of custody, performance and system audits, and well-documented data collection methods together ensure that data reuse is maximized while enhancing the data's authority and credibility for decision making purposes.

QA/QC represents both specific procedures and the objectives to be fulfilled through adherence to those procedures. Both must be carefully documented and updated with changing requirements.

For the respective domains of macro- and microplastics, it is critical to develop data quality objectives as an important facet of minimum data requirements. These objectives in turn influence the data upload and processing procedures, which must also be documented. The business rules for data processing, including a clear description of the planned chain of custody for datasets, must also be developed and clearly documented in collaboration with program staff once the specific data sampling plans are developed.

All QA/QC-related documentation must be collected in a Data Upload Guidance document, with optional inclusion in the Data Action Plan (see below).

While the primary audience for the Data Upload Guidance document would be technical specialists seeking to adhere to the described business rules, agency staffers and the general public alike share an interest in quality control procedures. Without such procedures, data quality would vary. To protect data integrity of the program, regular audits may be necessary to show that procedures are followed.

Data Upload and Management Tools

There are a range of options for data formatting. For macroplastic taxonomy management, we propose leveraging the Trash Taxonomy Tool described above. This tool promises to "improve, create, and compare trash surveys, and provides practitioners with tools to integrate datasets and maximize comparability."[30] Attribution is important for open data since it promotes accountability and adherence to standards. It also motivates excellence by acknowledging meaningful contributions. For microplastics data, we recommend use of the Microplastics Open Data Portal formatting guidelines.

While original repositories might vary over time as regional needs vary, it is critical for all programmatic datasets to be submitted or replicated to the California Open Data Portal. This centralized repository will increase discoverability of all plastics-related datasets.

A Data Action Plan

[30]https://catalog.data.gov/dataset/trash-taxonomy-california-data-management-subcommittee-for-trash-monitoring-workgroup

To operationalize the above priorities, a robust Data Action Plan is essential. This plan should outline procedures for formatting, storing, sharing, and interpreting plastics monitoring data. It promotes transparency, interoperability, and utility across agencies and users. Core elements include adopting open data standards, applying shared taxonomies (e.g., Trash Taxonomy Tool), attributing data to contributors, and leveraging state repositories (e.g., CEDEN and data.ca.gov). The Data Action Plan should also describe the requisite data management plans, which are associated with datasets and describe key attributes related to the creation, stewardship, and longer term maintenance of the respective datasets. The Data Action Plan ensures that data collection efforts align with management goals, enable multi-user functionality, and remain adaptive to scientific and technological advancements.

6.2 Considerations for Overcoming Potential Challenges

The Microplastics Open Data Portal

The Microplastics Open Data Portal currently relies on standardized methods for pilot drinking water monitoring. However, as discussed above (Sections 2.4 and 3.7), methods for microplastics monitoring in more complex environmental matrices are not yet standardized and are likely to continue to evolve. The Microplastics Open Data Portal, or its equivalent in features and purpose, must be enhanced in the future to:

1. adapt to new and/or updated methodologies
2. sufficiently calibrate reported results among diverse methods for temporal and geographic comparisons
3. stay relevant with the latest microplastic science.

The Moore Institute is currently developing microplastic data harmonization routines to streamline this process as an open-source web tool.

The Microplastics Open Data Portal is unusual in that it uses the California Open Data Portal[31] as its actual authoritative destination for uploaded data. It is a conveyance system that performs quality-control measures prior to submission to the California Open Data Portal. Quality control is often a key obstacle to uploading data.

The Microplastics Open Data Portal can also provide access to submitted data collected via different methods. It is important for the Microplastics Open Data Portal to have functionality appropriate for different needs. At a minimum, subject matter

[31] https://data.ca.gov

experts must be able to download the raw data and metadata to conduct evaluations beyond the features available in the Microplastics Open Data Portal.

In contrast, some users of the Microplastics Open Data Portal may not have the expertise to differentiate how the data were collected or carefully evaluate the metadata and QA/QC considerations. Therefore, decisions on data handling and synthesis must be made on the back end to synthesize results and communicate findings to these users. The Microplastics Open Data Portal must also foreground scientifically interpreted results and summaries. This will discourage inaccurate interpretation by users who may not sufficiently understand the data.

Considerations for Data Synthesis and Interpretation

Data science is rapidly evolving to provide new tools for visualizing and synthesizing environmental data, including microplastics data. However, these tools are only as good as the data available. Many technical and analytical science challenges, as discussed above in section 4.4, must be overcome to provide robust, versatile, and large plastic monitoring datasets. Automatic data visualization requires harmonization and calibration across datasets. Regions undertaking the earliest stages of monitoring may not be ready for automated data visualization and synthesis for a regulatory and public audience.

In synthesizing the data for such audiences, the following questions should be considered for comparisons across datasets.

- How to compare and harmonize microplastic data that have different minimum and maximum particle size cutoffs
- How to harmonize data that might have specific non-standard exclusions, such as the exclusion of particles that present certain analytical challenges (e.g., fibers or tire wear)
- How to compare data from laboratories with different method detection limits
- How to compare tally results from trash cleanups performed by different teams under slightly different protocols
- What database structure (e.g., such as an extendable structural database proposed by Čerkasova et al. (2023)) is necessary to address these differences and synthesize data in a way that is scientific?

Approaches to these questions may change as plastic monitoring and science evolve.

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Appendices

Appendix A: Community and Public Engagement

A community and public engagement process was engaged in the early stages of this project (March 2024–August 2024) in order to: 1) cast an inclusive and wide net to bring together varied perspectives by providing opportunities for interested public stakeholders to provide early input on specific issues and geographic areas of concern relating to plastic pollution in State waters; 2) increase public awareness about plastic pollution and state efforts to mitigate plastic pollution; and 3) share the current statewide Monitoring Strategy development for further engagement as the Monitoring Strategy evolves, particularly to identify existing local programs or efforts that are potential collaborators on the Monitoring Strategy.

The public and community engagement included a public request for information from a broad audience through a questionnaire posted on a public website (Appendix A.1) and six virtual public meetings to allow for verbal feedback and discussion. The online questionnaire and virtual public meeting times were shared with a broad audience of potentially interested community-based organizations and non-government agencies compiled by OPC and Marie Rainwater & Associates in consultation with Environmental Justice Coalition for Water, who were subcontracted leads for the community engagement. OPC distributed information utilizing email distribution lists, notices on the OPC website, and by encouraging partner agencies and organizations to share with their distribution lists. San Francisco Estuary Institute (SFEI) also shared this project description with the California Water Quality Monitoring Council Microplastics Subcommittee meeting on January 24, 2024 and requested feedback from meeting attendees on draft Strategy management questions and priorities.

The questionnaire respondents (Appendix A.1: Questionnaire website responses) and virtual meeting attendees (Appendix A.2 Virtual meetings summary) expressed broad concerns about plastic pollution, including macroplastics and microplastics, from diverse sources (from tobacco-related debris to tire wear particles to large household items). There was also feedback on the need for monitoring both aquatic areas (beaches, oceans, urban rivers, creeks, streams), as well as recreational areas (public parks, transportation corridors, recycling centers, neighborhoods). Additionally, attendees and respondents shared examples of local efforts, such as beach cleanups and local water quality monitoring that can be leveraged for microplastic monitoring.

Appendix A.1: Public Request for Information Questionnaire

posted on public website as part of project Community Engagement Process

California Statewide Plastics Monitoring Plan - Request for Information

Link

California is actively addressing plastic pollution by taking wide ranging actions including single-use plastics restrictions and extended producer responsibility, requirements to prevent trash in state waters, monitoring microplastics in drinking water, and implementing the Statewide Microplastics Strategy.

San Francisco Estuary Institute, in partnership with the California Ocean Protection Council, is leading the development of a Statewide Plastics Strategy and Plan to track the state's progress and to support future efforts to reduce plastic pollution. The Statewide Plastics Monitoring Strategy and Plan aims to meet information needs to protect California's communities, coast, and aquatic environments by developing a phased, multi-year plastics monitoring plan.

This request for information provides the public with an opportunity to share information and input at the early stages of the development of a first-of-its kind comprehensive Statewide Plastics Monitoring Strategy and Plan. We are seeking public comment by Wednesday, April 3, 2024 11:59 PM Pacific Time to inform our efforts to develop a statewide plastics monitoring strategy.

Thank you for your engagement and feedback. We will review all comments received.

* Indicates required question

1. What types and sources of plastic debris are you most concerned about?*

- Food-related plastic packaging and containers (e.g., beverage bottles, food take-out containers, food packaging)
- Large household items (e.g., mattresses, used tires, large electronic waste)
- Construction materials (e.g., insulation, plastic packaging)
- Tobacco-related debris (e.g., cigarette butts, vapes, plastic packaging)

- Other plastic film (e.g., plastic bags)
- Microplastics from tires (e.g., tire wear or breakage)
- Microplastics from clothing and textiles (e.g., laundry water, shedding from clothes, dryer emissions)
- Microplastics that breakdown from larger plastic debris (e.g., plastic fragments from bottles, containers)
- Airborne microplastic emissions
- All plastic sources
- Other:

2. Why?

3. What are your concerns regarding the impacts of plastic pollution?*

- Impacts to wildlife from ingesting plastic debris (e.g., birds eating plastic bottle caps)
- Impacts to wildlife from entanglement with large plastic debris (e.g., turtles entangled in plastic 6-pack rings)
- Impacts to aquatic organisms and wildlife from microplastics (e.g., plastics smaller than a grain of rice that can be ingested or breathed through gills)
- Human health concerns from ingesting and drinking microplastics (e.g., microplastics in drinking water and food)
- Recreational use of beaches and public spaces (e.g., trash on the beach, lakes, rivers)
- Economic and negative impacts on land use (e.g., trash on local streets, neighborhoods, highways)
- All impacts described above
- Other:

4. Are there specific sites or water bodies that you think should be prioritized for monitoring?

- Beaches

- Oceans
- Urban rivers, creeks, and streams (e.g., in urban parks, concrete channels)
- Creeks, streams, and rivers in more natural environments
- Public or community parks
- Estuaries and marshes
- Community neighborhoods
- Highways, streets, transportation corridors
- Proximity to waste management, recycling centers, and/or plastic manufacturing facilities
- Proximity to vulnerable or disadvantaged communities
- Cities (e.g., proximity to food vendors, bars, fast food restaurants, tobacco vendors)
- Other:

5. Please list any specific priority locations.

6. Why are these locations important to you?

7. Are there specific existing ordinances or policies that you are aware of and think are important to monitor to understand their effectiveness and impact? (e.g., local bans on single-use plastic bags, foam packaging materials, plastic straws; implementation of the Trash Provisions)

8. Are there other ordinances or policies, which are not currently in place, that you think should be developed to address plastic pollution?

9. Are you involved with or participate in existing community cleanups of other trash/plastic monitoring initiatives? Where do these take place?

10. Please describe what types of information are collected, if any (e.g., weight of trash collected, trash or plastics tallied). Are there barriers to effectively collecting this trash-related information?

11. Are there additional issues, not listed here, to consider in the development of a statewide plastics monitoring plan?

12. Would you or your organization like to be part of the Statewide Plastics Monitoring Plan and Strategy? (Either in the development of the Monitoring Plan or efforts to implement the Plan) Would you or your organization like to be on our email list to receive updates on progress and future public engagement opportunities? *

- Yes
- No
- Maybe

13. Would you or your organization be interested in potential plan implementation opportunities?

Your email address (optional)

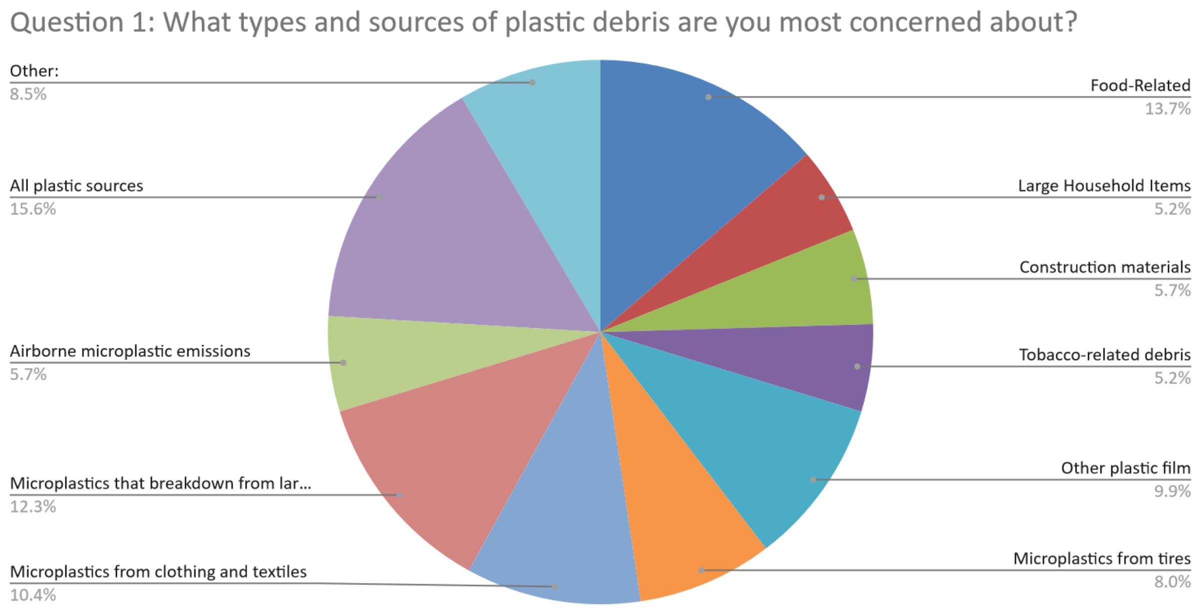
If you would like to remain involved, please add your information here.

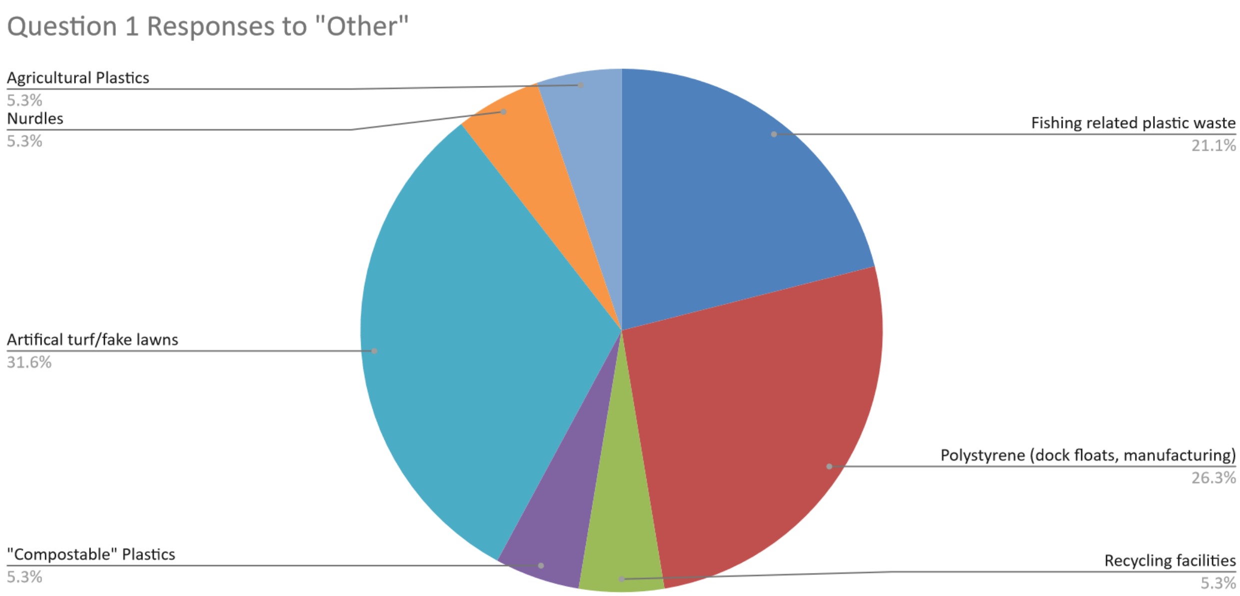
Appendix A.2: Public Request for Information Questionnaire Website Responses Aggregated

Public Request For Information to Inform Plastics Monitoring Plan

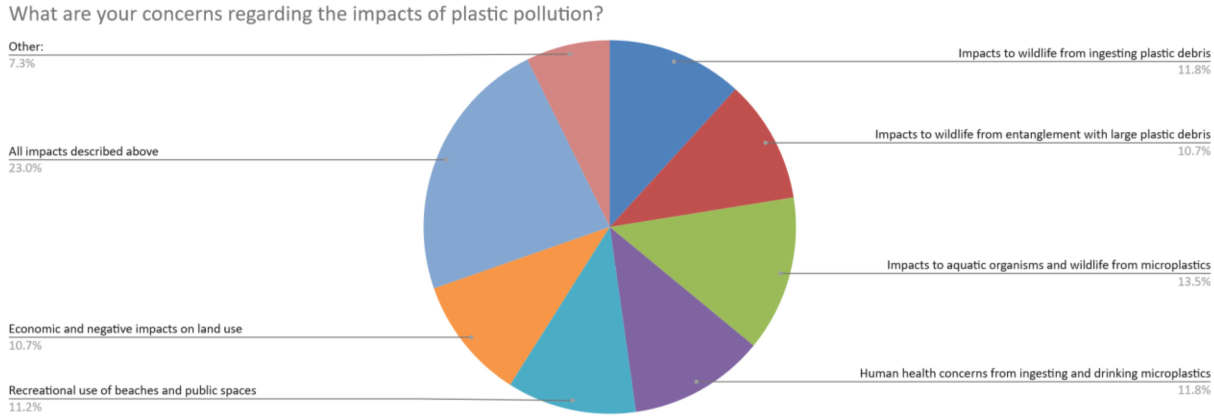
Summary of Responses (3/4-4/3/2024)

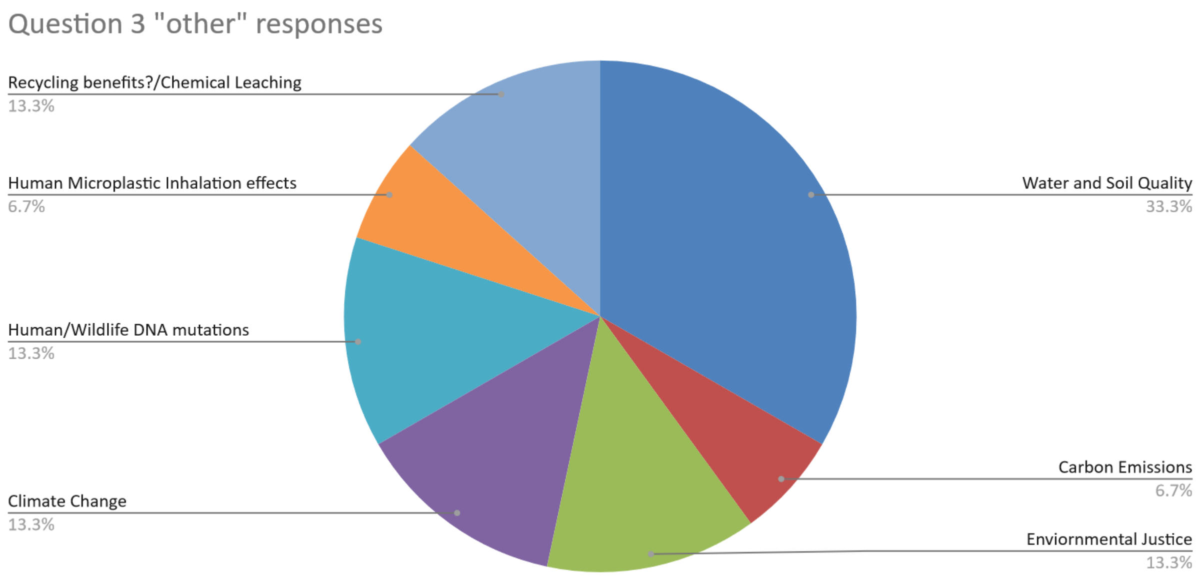
Question 1: What types and sources of plastic debris are you most concerned about? 49 participants, 212 responses to the question. Each participant selected on average around 4 categories.





Question 3: What are your concerns regarding the impacts of plastic pollution? 179 responses, average of 4 categories selected per participant.


What are your concerns regarding the impacts of plastic pollution?
Other:
7.3%
All impacts described above
23.0%
Economic and negative impacts on land use
10.7%
Recreational use of beaches and public spaces
11.2%
Impacts to wildlife from ingesting plastic debris
11.8%
Impacts to wildlife from entanglement with large plastic debris
10.7%
Impacts to aquatic organisms and wildlife from microplastics
13.5%
Human health concerns from ingesting and drinking microplastics
11.8%


Question 3 "other" responses
Recycling benefits?/Chemical Leaching
13.3%
Human Microplastic Inhalation effects
6.7%
Human/Wildlife DNA mutations
13.3%
Climate Change
13.3%
Water and Soil Quality
33.3%
Carbon Emissions
6.7%
Enviornmental Justice
13.3%

Appendix B: Comprehensive list of Management Questions from State Advisory Group

Representatives from state agencies submitted a list of plastics monitoring related questions that would be most useful for program efforts.

Additional Questions relating to MQ 2B

What are levels of [different types] macroplastics in different aquatic ecosystems? Are macroplastics debris at levels that may impact human health and welfare? Are levels of macroplastics debris at levels that may impact aquatic ecosystems?

- How do the levels of macroplastics in the environment impact human health?
- How do the levels of macroplastics in the environment impact ecosystem health?
- What are the harmful chemical plastic additives that are released from plastics? What are the concentrations of harmful chemical plastic additives?
- What are the current costs to local jurisdictions, government, and others to manage macroplastic releases? Are the impacts and costs concentrated in specific geographic areas or within specific communities?

Additional Questions relating to MQ 1A

What are the levels of [different types] microplastics in different aquatic ecosystems? Are microplastics at levels that may impact human health and welfare? Are levels of microplastics at levels that may impact aquatic ecosystems?

- What are the levels of nano-plastics surface waters?
- What are the levels of nano-plastics in urban creeks?
- How do the levels of microplastics in the environment impact human health?
- How do the levels of microplastics in the environment impact ecosystem health?

Additional questions relating to MQ 2B

What are the major sources, pathways, and relative loadings leading to macroplastics-related contributions and impacts to CA aquatic ecosystems.

- What is the distribution of tobacco product waste near housing and outdoor areas?
- Relating to artificial turf
  - What chemicals used to treat the turf (e.g., QACs) enter coastal environments through runoff?
  - What chemicals used in synthetic turf manufacturing enter coastal environments through runoff?
  - Can the loss of artificial turf fiber mass be quantified over time as the product is subject to weathering and high-abrasion activities?

Additional questions relating to MQ 2A

What are the major sources, pathways, and relative loadings leading to microplastics-related contributions and impacts to CA aquatic ecosystems?

- What are other major pathways of microplastics besides urban stormwater runoff, wastewater?
  - What are the major sources of microplastics besides tire wear particles?
  - What are the levels of microplastics in agricultural runoff? Is this a significant pathway for microplastics to receiving waters?
  - What are the major sources of microplastics to ambient air?
  - What are the levels of nanoplastics in nanoplastics in final effluent wastewater and stormwater?
- Relating to Tire Particles
  - Monitoring tire-derived chemicals and tire wear particle size distribution outside tire waste facilities, rubberized playgrounds and tracks, or places that use crumb rubber, like playing fields with artificial turf, will help illuminate both environmental and human exposure pathways.
  - Are there any crumb rubber-based artificial turf sports fields (including the ones located at school districts) or playgrounds close to the sampling sites?

  - What are the tire-wear emission factors, including airborne fraction?
  - What is the exposure level of airborne tire-wear PM and its health impact on underprivileged near-road neighborhoods?
  - Are there any VOCs or SVOCs emitted from tire wear that may contribute to secondary PM?
  - Where are the highest risk locations for sensitive coho salmon habitat from tire wear particle and chemical exposure?

Additional Questions relating to MQ 3B

Are macroplastics levels changing over time? How effective are the mitigation measures and regulatory controls? What are management actions that could drive changes in macroplastic levels in California surface waters? What is the efficacy of intervention programs in preventing litter, particularly tobacco product waste?

- What is the efficacy of filtration devices for washing machines?
- Are additional wastewater treatment needed or effective in mitigating impacts from microplastics in receiving waters?
- What are potential education and outreach strategies to decrease macroplastic releases for consumers, businesses, and other potential generators? What is the current level of awareness and knowledge about plastics and how does that awareness impact levels of plastics entering the environment?
- What feasible end-of-life solutions could be implemented to prevent further plastic pollution from the continued use of artificial turf? Are there new methods and technologies implemented to limit migration of particles from artificial turf fields? If so, how impactful have they been?

MQ 3A.

Are microplastics levels changing over time? How effective are the mitigation measures and regulatory controls? What are management actions that could drive changes in microplastic levels in California surface waters?

- What are potential education and outreach strategies to decrease micro-plastic releases for consumers, businesses, and other potential generators? What is the current level of awareness and knowledge about plastics and how does that awareness impact levels of plastics entering the environment?

- How do the current EV transition in tire formula and technologies change tire-wear PM emissions and compositions? What are the technologies to reduce tire wear emissions and toxicological components such as tire additives?

Appendix C: List of Potential Monitoring Program Partners

Here we briefly describe existing monitoring efforts in California that are the most promising partners and collaborators to implement this strategy. Role of strategy to bring together statewide coordination. This summary is certainly not comprehensive, but meant to support statewide coordination and leveraging efforts. We invite interested collaborators to add their efforts to this summary.

The State Advisory Group recommended monitoring at locations where existing monitoring programs and efforts can be leveraged, such as those associated with the Regional Monitoring Program for the San Francisco Bay, Southern California Bight Regional Monitoring Program, and Southern California Stormwater Monitoring Coalition.

Currently, there is no established microplastics monitoring program, although several groups that have led microplastics studies in California. These are briefly described below.

State and federal agencies

California Air Resources Board (CARB), including Mobile Source Emissions Research Program

CARB regulates air quality and greenhouse gas emissions in California. Their Mobile Source Emissions Research Program investigates pollutants from vehicles, including tire wear particles, which are a significant source of microplastics in the environment. ARB is interested in microplastics and tire wear particle air monitoring data to evaluate potential human health impacts.

California Coastal Commission

The California Coastal Commission manages coastal resources and development along California's coastline. They support research and policies aimed at reducing marine pollution.

California Department of Public Health (CDPH), including Tobacco Prevention Program, Exposure and Assessment Section, Center for Laboratory Sciences

CDPH protects public health through monitoring environmental hazards. The Tobacco Prevention Program has studied microplastics from cigarette butts as an emerging contaminant, assessing their impact on human and environmental health. The Exposure and Assessment Section has been considering the future need for microplastics monitoring. The Center for Laboratory Sciences has led several microplastic research studies.

California Department of Recycling (CalRecycle)

CalRecycle oversees waste management and recycling programs in California. They support initiatives aimed at reducing plastic waste and microplastic pollution through improved waste diversion and recycling strategies.

California Department of Transportation (CalTrans)

CalTrans manages California's transportation infrastructure.

California Ocean Protection Council (OPC)

The OPC coordinates ocean and coastal protection efforts statewide. They fund research and projects related to microplastics, focusing on reducing plastic pollution in marine environments through policy, science, and community engagement. OPC and NOAA co-develop the The California Ocean Litter Strategy. OPC is the coordinating agency for the Statewide Microplastics Strategy.

California State Lands Commission

The State Lands Commission manages state-owned lands, including tidelands and submerged lands.

California Water Quality Monitoring Council

This council coordinates water quality monitoring programs across California.

Delta Stewardship Council, Delta Science Program

The Delta Stewardship Council oversees the sustainable management of the Sacramento-San Joaquin Delta. Their science program supports research on microplastic contamination and its ecological effects within the Delta's freshwater system.

Department of Toxic Substances Control (DTSC), Safer Consumer Products Program

DTSC works to reduce hazardous substances in consumer products. They have proposed adding microplastics to its Candidate Chemical List, which enables the agency to evaluate products that contain or generate microplastics as potential

Priority Product in the future. Their 2024–2026 Priority Work Plan includes products that contain or generate microplastics.

Interstate Technology & Regulatory Council (ITRC)

ITRC develops guidance and best practices for environmental management. They have created resources related to microplastic monitoring and remediation to aid regulators and stakeholders in addressing microplastic pollution.

National Oceanic and Atmospheric Administration (NOAA), including Southwest Fisheries Science Center and Marine Debris Program

NOAA conducts extensive research on marine debris, including microplastics, through its Marine Debris Program. The Southwest Fisheries Science Center studies microplastic impacts on marine species and fisheries in California waters.

Office of Environmental Health Hazard Assessment (OEHHA)

OEHHA evaluates risks from environmental contaminants to protect public health. OEHHA is particularly interested in environmental monitoring data to evaluate human health exposure, such as sportfish, air, drinking water, biomonitoring, shellfish. Microplastics air monitoring is an important data gap.

Regional Water Quality Control Boards

The Regional Boards implement water quality protection at the regional level. Many have incorporated microplastic monitoring and management into their programs to reduce plastic pollution in California's waterways. Additionally, Regional Water Quality Boards can direct funds towards Supplemental Environmental Projects (SEP) that dischargers can participate in as part of fine settlements.

State Water Resources Control Board (SWRCB), Division of Water Quality and Division of Drinking Water, including SWAMP Program, STORM Water Program, and Contaminants of Emerging Concern Program

The SWRCB oversees statewide water quality standards and monitoring. Their SWAMP program and related initiatives actively monitor microplastics in surface waters and drinking water, developing data to inform regulatory actions.

The Stream Pollution Trends (SPoT) Monitoring Program is a core component of the SWB's Surface Water Ambient Monitoring Program (SWAMP). The SPoT program was initiated in 2008 with the primary goals to:

"1. Determine long-term, statewide trends in stream contaminant concentrations and effects.

2. Relate key water quality indicators to land-use characteristics and management efforts.

3. Establish a network of sites throughout the state to serve as a backbone for collaboration with local, regional, and federal monitoring programs and management agencies." (SWAMP SpoT program website)

The SPoT Monitoring Program is specifically designed to fill critical information needs for state, regional and local resource management programs… The program continues to evolve to address contaminants of emerging concern through collaborations with the California Department of Pesticide Regulation (CDPR), various federal and state agencies, university research groups, and others."

"SpoT program monitors analyzes sediment toxicity and chemical contaminants (i.e. metals polycyclic aromatic hydrocarbons, polychlorinated biphenyls, legacy pesticides, current use pesticides, and emerging contaminants such as fipronil and polybrominated diphenyl ethers (PBDEs) "stream sediment because this environmental compartment integrates chemical contamination over time. Many trace metal and organic pollutants that enter streams adhere to suspended sediment particles and organic matter, and this sediment-associated phase is the major pathway for contaminant loading in streams and downstream waterways. In addition, river benthic environments are ecologically important because they provide habitat to key elements of aquatic macroinvertebrate and algal communities. Sediment measurements are appropriate for long-term trend monitoring because pollutants that accumulate in depositional sediment on the stream bed are much more stable over time (~months to years) than dissolved or suspended pollutants that move downstream in pulses that are highly variable over short time scales (~hours). SPoT surveys are timed to collect sediment in summer after the high water season when most sediment and pollutant transport and deposition takes place."

"The sediment monitoring design was based on the US Geological Survey's National Water Quality Assessment (USGS; NAWQA: http://water.usgs.gov/nawqa/). The NAWQA program is designed to increase understanding of water-quality conditions, of whether conditions are getting better or worse over time, and how natural features and human activities affect those conditions. The NAWQA integrator site concept provided the basis for the SPoT monitoring design. NAWQA integrator sites are established near the base (discharge point) of larger, relatively heterogeneous drainage basins with complex combinations of environmental settings. Sediments collected from depositional areas at integrator sites provide a composite record of pollutants mobilized from throughout the watershed. While many hydrologic, engineering, and environmental variables affect the ability of this record to adequately characterize all pollutant-related activities, sediment samples collected from such areas are considered to be a relatively good and logistically feasible means of assessing large watersheds for long-term trends."

"SPoT employs a targeted monitoring design to enable trend detection on a site-specific basis. To serve their purpose as integrator sites, SPoT sites are located at the base of large watersheds containing a variety of land uses. Because samples of depositional sediment are needed, sites are targeted in locations with slow water flow and appropriate micro-morphology to allow deposition and accumulation. SPoT and NAWQA use integrator sites because both programs focus on understanding causes and sources of water quality impairment. The connection with land use is a major part of the assessment, and targeted sites allow greater discretion to adjust to significant land cover variation in lower watershed areas. A targeted approach allows SPoT flexibility to link to established sites and to support collaboration with other watershed and regional-based monitoring programs."

"The SPoT program covers a diversity of locations statewide, and comprises approximately 40% urban, 25% agriculture, and 35% open sites. The program currently targets 40 tier 2 sites annually, these sites are primarily urban land use based on a 5 km land use radius using the National Land Cover Database (NLCD) categories. An additional 50 sites are sampled every other year (i.e. half of these sites are sampled every other year). Together sampling locations represent 64 independent watersheds statewide, and 26 are in sub-watershed. These watersheds represent approximately one half of California's major watersheds. "Some northern and southern watersheds cross state and national borders… The SPoT network of sites was established through coordination with Regional Water Board monitoring programs and stormwater agencies, under the guidance of the SPoT Scientific Review Committee (SRC)... By coordinating with local and regional programs, SPoT provides statewide context for local results, and provides information useful for local management and land use planning activities."

"Additionally, SPoT seeks to continue to adapt and identify new collaborations to characterize new classes of contaminants and potential causes of biological impacts."[32]

[32] Phillips, B.M., Siegler, K., Voorhees, J.P., McCalla, L., Zamudio, S. Spatial and Temporal Trends in Toxicity and Chemical Contamination Relative to Land Use in California Watersheds: Stream Pollution Trends (SPoT) Monitoring Program Fifth Report

SWRCB Division of Drinking Water (DDW) is leading state regulatory efforts to adopt standard methods for microplastics sampling and analysis, and reporting requirements, in order to implement monitoring and testing of drinking water for microplastics. Pilot monitoring is expected to be conducted with approximately 30 California water systems that provide drinking water. While this Monitoring Strategy focuses on environmental monitoring for protection of aquatic ecosystems, there are important areas of overlap where drinking source water may also be important habitats. This Monitoring Strategy seeks to leverage efforts led by the DDW and harmonize microplastics monitoring methods and approaches. It aims to provide information on the prevalence of microplastics in drinking water.

The monitoring program, adopted in the form of a Policy Handbook, mandates that approximately 30 of California's water systems submit quarterly tests for two years of the occurrence of microplastics in source waters used for drinking water. To ensure submitted data are reliable and interoperable, the Division of Drinking Water will be requiring the use of a standardized sampling method that uses in-line filtration, and reporting through a harmonized data portal. The pilot program aims to provide valuable data on the prevalence of microplastic contamination in water used as sources of drinking water and in drinking water.

SWRCB STORMS is interested to engage with and supports monitoring and characterizing efforts for microplastics pollution. STORM unit is leading the evolution of stormwater management in California by promoting the perspective that stormwater is a valuable resource to augment water supply in California. The presence of emerging contaminants, including microplastics in urban runoff, could present significant challenges for stormwater capture and use or aquifer recharge through infiltration.

SWRCB Contaminants of Emerging Concern Program address CECs holistically—targeting root causes and considering chemical, biological, and physical factors. When fully implemented, this systematic change in California's approach to CECs will reduce contaminants in the environment while prioritizing transparency, collaboration, and stakeholder engagement.

U.S. Environmental Protection Agency (EPA), including Trash Free Waters Program, Microplastics Research Program

The EPA has led several expert workshops to identify and prioritize scientific needs around microplastics. Additionally, they co-led **Interagency Marine Debris Coordinating Committee Report on Microfiber Pollution**, submitted to Congress in 2024 as required by the Save Our Seas 2.0 Act.

U.S. Fish and Wildlife Service (USFWS)

USFWS manages and protects wildlife habitats.

U.S. Geological Survey (USGS)

USGS conducts environmental research, including monitoring microplastics in freshwater systems. Their studies provide critical data on microplastic distribution, transport, and ecological effects across various U.S. landscapes. Their report, Integrated Science for the Study of Microplastics in the Environment—A Strategic Science Vision for the U.S. Geological Survey, identifies important research gaps and leadership roles that play to USGS institutional strengths.

Existing Long-term Monitoring Programs

These programs may be interested to serve as potential partners and platforms for future long-term microplastics monitoring:

California Cooperative Oceanic Fisheries Investigations (CalCOFI)
CalCOFI is a long-term ecosystem research program off the coast of California that holistically studies the physics, chemistry, and biology of the ocean to inform the sustainable management of marine ecosystems in the context of climate variability and change. CalCOFI conducts quarterly cruises from north of San Francisco Bay to San Diego and extends from the coast to 300 miles (500 km) offshore, spanning state, national, and international waters. CalCOFI is a unique partnership between government and academic organizations including NOAA's Fisheries Service (federal partner), California Department of Fish & Wildlife (state partner), and Scripps Institution of Oceanography (academic partner).

California Publicly-Owned Treatment Works (POTWs) water quality monitoring programs required by National Pollutant Discharge Elimination System (NPDES) discharge permits, represented by California Association of Sanitation Agencies (CASA), Bay Area Clean Water Association (BACWA), and Southern California Alliance of Publicly Owned Treatment Works (SCAP).

These programs monitor effluent and receiving water quality from municipal wastewater treatment facilities to comply with Clean Water Act permit requirements. They contribute data to assess pollutant loads, treatment performance, and environmental impacts.

Delta program
The Delta monitoring programs, including those overseen by the Delta Stewardship Council and other regional entities, support coordinated monitoring of water quality,

ecosystem health, and contaminants in the Sacramento-San Joaquin Delta. These programs inform adaptive management of California's most critical water supply and ecological resource.

Municipal Stormwater Monitoring Network, including:

- **Bay Area Municipal Stormwater Collaborative (BAMSC)**
  BAMSC is a regional collaborative of Bay Area municipal stormwater permittees working together to implement coordinated monitoring and assessment programs. It focuses on pollutant source identification, receiving water impacts, and effectiveness of stormwater control measures under the San Francisco Bay Region's MS4 permits. BAMSC was formerly known as the Bay Area Stormwater Management Agencies Association (BASMAA).

- **Clean Water SoCal**
  Clean Water SoCal is a partnership of southern California stormwater agencies, regional boards, and research institutions that conducts collaborative, science-based monitoring of stormwater and receiving waters. Its work includes large-scale regional assessments, special studies, and development of innovative tools to improve stormwater management and regulatory decision making.

Other regional monitoring programs, including:

- **Central Coast Ambient Monitoring Program (CCAMP)**
  CCAMP is the Central Coast Regional Water Quality Control Board's primary water quality monitoring program. It focuses on assessing ambient water quality in rivers and streams to support watershed management, identify pollution sources, and evaluate beneficial use protection.

- **Central Coast Long-term Environmental Assessment Network (CCLEAN)**
  CCLEAN is a collaborative monitoring program that evaluates the long-term impacts of wastewater and stormwater discharges on coastal ocean water quality in the Monterey Bay region. It monitors pollutants in water, sediment, and tissue to assess compliance with water quality objectives.

- **Sacramento-San Joaquin Delta Regional Monitoring Program (Delta RMP)**
  The Delta RMP is a coordinated effort to monitor water quality in the Sacramento-San Joaquin Delta. It integrates data from multiple agencies to track contaminants, nutrients, and other stressors, providing information to support adaptive management and policy decisions.

- **Sacramento Watershed Coordinated Monitoring Program (SWCMP)**
  SWCMP is a collaborative watershed-based program designed to monitor water quality in the Sacramento River watershed. It coordinates efforts among dischargers and regulatory agencies to fulfill permit requirements and better understand cumulative watershed impacts.

Regional Monitoring Program for the San Francisco Bay (RMP)
The RMP is a collaborative science program that monitors water, sediment, and biota in San Francisco Bay to assess contaminant levels and ecological health. Led by the San Francisco Estuary Institute (SFEI), it supports science-based management and regulatory decisions. The RMP has a microplastics focus area led by SFEI, and has outlined a regional microplastics monitoring strategy.[33]

Southern California Bight Monitoring Program
This large-scale regional survey assesses the condition of coastal and marine habitats from Point Conception to the U.S.-Mexico border. Coordinated by the Southern California Coastal Water Research Project (SCCWRP), it occurs every five years, involves dozens of agencies, and is primarily focused on monitoring contaminants and ecological conditions in marine sediments. Launched its first microplastics monitoring study in 2023.

Surface Water Ambient Monitoring Program (SWAMP) led by the State Water Resources Control Board (SWRCB)
SWAMP is a statewide monitoring program that evaluates the quality of California's surface waters, including rivers, lakes, and coastal waters. It provides standardized data to support water quality assessment, regulatory reporting, and watershed management.

Central mission to provide resource managers and other decision makers and public with timely, cost effective, and high-quality information to evaluate conditions of surface water throughout the state. It has a defined set of assessment questions, including informing questions about overall quality of state surface waters, evaluating trends, and identifying water bodies with water quality problems, and anticipating areas most at risk of having water quality problems. Potential home for statewide plastics monitoring, although the program currently does not include plastics monitoring. Main statewide efforts are the SPoT program and Bioaccumulation program described below. Also coordinates with a wide network of regional monitoring

[33] Paterson, K; Miller, E; Lin, D. 2024. Microplastics Monitoring and Science Strategy for San Francisco Bay 2024 Revision. SFEI Contribution No. 1144. San Francisco Estuary Institute: Richmond, CA.

programs, of which some are listed here that might be most relevant to this Monitoring Strategy. [see SWAMP Strategy here]

- Stream Pollution Trends (SPoT) Monitoring Program: statewide monitoring program with guiding management questions to evaluate contaminants in statewide streams and relate water quality indicators to land-use characteristics and management efforts. Program goal includes establishing a network of sites throughout the state to serve as backbone for collaboration with local, regional, and federal monitoring programs and management agencies. Program assesses the health of California streams by analyzing sediment contaminants, toxicity, and correlates with local land use in stream draining large watersheds (2011 SWAMP achievement report). Monitors 90 sites throughout the state that covers 63 independent watersheds that cover the majority of geography in California. Includes 40 tier 2 sites that are heavily urbanized, defined as 40% land use within a 5 km area of draining watershed. Sampling sites selected to be depositional areas that provide a composite record of pollutants mobilized in the watershed. Diversity of watershed land use coverage in sampled watersheds, including range in urban, agricultural, open space land uses. Monitoring is implemented by Marine Pollution Studies Laboratory at Granite Canyon, part of Department of Environmental Toxicology at UC Davis.

Research and Science Organizations

5 Gyres Institute
Leads scientific research into plastic pollution in marine and aquatic resources, while also advocating for solutions and cultivating community awareness of the most pressing issues related to plastic pollution.

Adventure Scientists

A citizen scientist platform for researchers to post citizen science projects and volunteers to sign up for those projects and help out.

Algalita
Founded in Long Beach, Algalita focuses on plastic pollution research, community outreach, and education. Its Moore Center for Plastic Pollution in Alamitos Bay supports microplastics analysis and public-facing scientific engagement Algalita+1.

California Polytechnic State University (Cal Poly)

The Biological Sciences Department at Cal Poly is actively engaged in microplastics research, focusing on their presence and impact in coastal and terrestrial ecosystems.

California State University Channel Islands
In March 2024, CSUCI received a $236,908 grant from the U.S. Environmental Protection Agency (EPA), via a subaward from the San Francisco Estuary Partnership, to support a community-based microplastics monitoring project in East Palo Alto. This project, led by Professor Sean Anderson and Lecturer Timnit Kefela, aims to assess the effectiveness of the newly constructed Palo Alto Horizontal Levee Pilot in reducing microplastic pollution. The study emphasizes environmental justice by engaging local communities in the monitoring process and addressing disproportionate exposure to microplastic pollutants.

alifornia State University Council on Ocean Affairs, Science & Technology (CSU COAST)
This CSU-wide network supports marine research and education across campuses, and has recently funded specific research projects relating to microplastics.

California State University Long Beach
Actively engaged in microplastics research through various departments and faculty members.

California State University Monterey Bay
CSUMB houses several researchers focusing on microplastics within its Coastal and Marine Ecosystems program.

Community Trash Monitoring Program with Pasadena City College offers training for other scientists for trash monitoring and GIS data visualization of monitoring results.

Desert Research Institute (DRI)
The Microplastics and Environmental Chemistry Research Team at the Desert Research Institute applies chemical techniques to study human – environment interactions. Recently led Microplastics Working group in the region

Heal the Bay
A nonprofit focused on coastal water quality and public awareness, Heal the Bay supports beach pollution monitoring and advocacy, including efforts that relate to plastic debris and microplastic reduction.

LA River Monitoring Program assesses trash in addition to algae, benthic organisms, bacteria, and water chemistry.

Monterey Bay Aquarium Research Institute (MBARI)
MBARI conducted groundbreaking research revealing pervasive microplastic contamination throughout Monterey Bay's water column—from surface to seafloor—

using ROVs to sample across depths and assess entry into the food web.

Moore Institute for Plastic Pollution Research (MIPPR)
Their mission is to expand plastic knowledge and how they impact our environment and health. It is also one of the first laboratories to be accredited by the California Environmental Laboratory Accreditation Program (ELAP) for the analysis of microplastics in drinking water.

Ocean Conservancy

Offers TIDES, a public data system containing the world's largest ocean trash dataset, all collected by volunteers. These citizen science data are collected during the annual International Coastal Cleanup and by users of Clean Swell, Ocean Conservancy's ocean trash data collection app.

Ocean Science Trust
A neutral intermediary supporting science-informed marine policy in California. While not directly engaged in microplastics monitoring, the Trust helps integrate science (including emerging threats like microplastics) into policy and management discussions.

San Diego State University (SDSU)
SDSU is actively engaged in microplastics research through various departments and faculty members. This includes studies relating to tobacco and cannabis litter, and associated chemicals in tire wear particles. SDSU established the Center for Tobacco and the Environment and has developed an app for identifying and tracking tobacco product waste.

San Francisco Estuary Institute (SFEI)
SFEI co-conducted the first comprehensive microplastics assessment of San Francisco Bay with 5 Gyres, documenting some of the highest levels globally and clarifying stormwater as a dominant source San Francisco Estuary Institute.

Save Our Shores is a volunteer based nonprofit that also does advocacy for environmental issues related to Monterey County.

Southern California Coastal Water Research Project (SCCWRP)
SCCWRP facilitates large-scale regional monitoring, including the Southern California Bight programs. They have collaborated with UCR and others to model microplastic transport and distribution in coastal waters marinedebris-cms.orr.noaa.gov.

Stanford University, Hopkins Marine Station
Researchers at Hopkins Marine Station engage in studies that assess the impact of pollutants, such as microplastics, on marine life and ecosystems.

Surfrider Foundation
A grassroots organization dedicated to protecting coasts and oceans. Surfrider conducts citizen-science beach cleanups and plastic monitoring, which often engage issues surrounding microplastics and marine debris.

The Trash Rapid Assessment Data Exchange (TRADE) offers the following justification for its efforts:

> California's Trash Amendments require storm water permittees to achieve zero-trash discharge by 2030 and may serve as a model for similar policies in other states. To comply, many MS4 permittees are pursuing Track 2 (full capture equivalency), a path which requires extensive and ongoing trash monitoring in their jurisdictions. Citizen science can support those business needs if equipped with appropriate technology, training, and quality assurance.

University of California at Davis (UC Davis)
With its Bodega Marine Laboratory and Earth & Planetary Sciences department, UC Davis supports diverse marine and watershed research, positioning it well for microplastics studies in coastal and freshwater systems.

University of California Riverside (UC Riverside)
UC Riverside, through the Watershed Science Group and Andy Gray's team, conducts modeling and field studies of microplastics in river and urban systems, notably within Southern California.

University of California San Diego (Scripps Institution of Oceanography)
Scripps researchers have partnered with MBARI to study microplastic distribution through the Monterey Bay water column and its effects on marine food webs.

University of California Santa Barbara (Bren School)

The Bren School has been addressing tobacco and cannabis product waste in marine environments through the development of a community-based science method (Temourian et al., 2025).

University of California Santa Cruz (UC Santa Cruz)

UC Santa Cruz researchers collaborate with MBARI and NOAA on marine pollution monitoring. While specific microplastic programs may exist, direct references are not cited prominently in available literature.

Appendix D: Current Microplastics Laboratory Accreditation Steps and Remaining Data Gaps to Achieve Standardization for Microplastics Analysis in Drinking Water

Achieving accreditation is a multi-step process that can be time-consuming for laboratories not familiar with the accreditation requirements. Key steps include: preparing the laboratory, contacting and hiring a third-party assessor (TPA), sending documentation to the TPA, setting up a TPA visit, addressing deficiencies identified by the TPA, approval by the TPA, and submission of application to ELAP.

Preparing the laboratory includes ensuring the method can be performed as required and the necessary documentation is created. Documentation consists of a quality manual, procedures and policies, record keeping.

The Quality Manual is a comprehensive document outlining a laboratory's quality management system, detailing their procedures and practices to ensure consistent and reliable data, specifically designed to comply with the standards set by the National Environmental Laboratory Accreditation Conference (NELAC). A template of this document can be purchased from The NELAC Institute (TNI) website. In May of 2020, California's State Water Resources Control Board passed new regulations requiring California environmental labs overseen by CA ELAP to implement the 2016 TNI Standard (minus two exceptions—CCR Article 2 section 64802.05(a)(1) and 62802.15(b)(1)—regarding the Technical Manager and Proficiency Testing). As of 2023, all laboratories must meet the “TNI minus two” standards.

Achieving (CA ELAP) accreditation requires implementing robust policies and procedures that align with the program's strict quality standards. Specific procedures should address sample handling and custody, method validation, equipment calibration and maintenance, analyst training and competency, and adherence to approved analytical methods. Laboratories must also implement rigorous documentation practices for all activities, maintain traceability of results, and conduct regular internal audits to ensure compliance. These policies and procedures must be periodically reviewed and updated to reflect regulatory changes and laboratory advancements, ensuring sustained accreditation and operational excellence.

Record keeping requires the development of a Laboratory Information Management System (LIMS). This is essential for achieving and maintaining CA ELAP accreditation, as it streamlines data management, enhances compliance, and improves overall laboratory efficiency. A well-designed LIMS facilitates accurate and traceable data recording, ensuring that sample tracking, analytical results, and quality control measures meet the stringent documentation requirements of ELAP. By automating processes such as data entry, report generation, and regulatory compliance tracking, the LIMS reduces the risk of human error and enhances the reliability of results. Additionally, a LIMS provides centralized access to critical information, enabling laboratories to efficiently conduct audits, respond to inspections, and demonstrate adherence to California’s regulatory standards. Implementing a robust LIMS not only supports accreditation efforts but also promotes operational consistency, scalability, and long-term laboratory success.

The process of obtaining CA ELAP accreditation typically takes several months to over a year, depending on the laboratory's preparedness and experience with accreditation. For laboratories that already have established quality management systems and experience with accreditation, the timeline may be shorter, as they are likely to meet many of the requirements upfront. However, laboratories without prior accreditation experience may face a longer timeline due to the need to develop and implement comprehensive policies, procedures, and documentation that comply with ELAP standards. Additional time may also be required for staff training, method validation, and addressing any deficiencies identified during the application review or on-site assessment. Laboratories should plan for this variability and allocate sufficient resources to ensure all requirements are met, recognizing that thorough preparation is key to achieving and maintaining accreditation.

The methods approved by the State Water Resources Control Board for microplastics analysis are broadly descriptive, leaving room for laboratories to interpret and adapt some of their own procedures. For instance, if a sample contains significant organic material, digestion may be necessary. Laboratories are allowed to perform digestion using methods they have independently developed, which can lead to variability in approaches and potentially impact compatibility between laboratories. Methodological gaps, such as this one, highlight the remaining data gaps critical for method standardization. Key areas for improvement needed for method standardization include:

- Incorporating digestion methods into published protocols.

  The currently approved state method does not include a standardized procedure for digestion. Establishing standard digestion methods would ensure that laboratories treat samples in a consistent manner and provide clear guidance for performing this often challenging step in the analysis. This would improve the reliability and comparability of results while addressing the complexities involved in isolating microplastics from diverse matrices.

- Developing a standardized density separation method.

  The currently approved state method does not include a standardized procedure for density separation. Implementing standard density separation methods would ensure laboratories process samples consistently and provide clear guidance for performing this critical step in the analysis, reducing variability and improving comparability of results across studies. Additionally, it is difficult to separate out heavier particles, such as tire wear particles, from sediment, which could result in missed or underreported numbers of particles and polymer types.

- Establishing standards for Laboratory Fortified Blanks (LFBs).

  Currently, laboratories are creating their own Laboratory Fortified Blanks (LFBs), leading to potential variability in measurement and counting practices. LFBs are required as part of the accreditation process and consist of adding known quantities and types of plastic particles to 1um filtered water test samples. The LFB is analyzed in the same manner as a sample and is used as a Demonstration of Capability to verify method performance for precision and accuracy. To promote consistency and accuracy across laboratories, it is essential to develop standardized LFBs supplied by an external, reliable source. This would ensure uniform quality control and enhance the comparability of results.

- Providing guidance on spectral reference libraries, including which libraries to use.

  Numerous spectral libraries are currently in use, with many laboratories developing their own customized versions. Adopting a standardized set of recognized spectral libraries would enhance the consistency and comparability of results across different studies and laboratories, reducing variability and improving the reliability of microplastics identification.

- Offering clear guidance on subsampling procedures.

  Currently accepted methods permit subsampling when a sample contains a large number of microplastics. However, there is no standardized guidance on how to perform subsampling, which can introduce variability into the measurements and impact the reliability of the results. Establishing clear and consistent protocols for subsampling could significantly reduce this variability, ensuring more accurate and comparable measurements across studies.

- Size limitations

  As the understanding of microplastics evolved, scientists realized that microplastics were more abundant in smaller size fractions. The most widely used Raman and FTIR spectroscopy methods for microplastic particle identification have a size limitation due to the size of the wavelengths of probing light, making the lower size limits theoretically 10μm FTIR and 1μm for Raman (Käppler et al., 2016; Matsui et al., 2020). While those are the lower limits identified for those machines, the current methodologies approved by the state are at 50 μm for the FTIR and 20 μm for the Raman. New methods and instruments will be required to measure microplastics smaller than 20 μm.

Addressing these gaps is essential to improving consistency and reliability across microplastics analysis processes, and efforts to tackle these challenges are already underway. Ongoing projects are focused on refining methods for sample digestion and density separation, developing standardized laboratory-fortified blanks (LFBs), method refinements for analyzing different matrices (soil, tissue, stormwater, etc.), and sample collection. These advancements will significantly improve the robustness and reproducibility of microplastics analyses.

Appendix E: Background on Microplastic Methods

Sampling and Analytical Methods for Monitoring are Evolving

Microplastics research has undergone rapid methodological evolution, driven by increased awareness, policy needs, and technological advancements. Sampling approaches range from simple grab sampling and bulk collection to more refined techniques such as pump filtration and sediment coring. These methods vary depending on the matrix (e.g., water, sediment, stormwater, or biota) and study goals.

Analytical techniques have expanded significantly. Traditional visual sorting is often supported by microscopy and spectroscopic tools, such as Fourier-transform infrared spectroscopy (FTIR) and Raman spectroscopy, which allow for polymer identification. Other advanced techniques, including pyrolysis-GC/MS, are gaining traction for complex matrices and mixed polymer compositions.

Ongoing standardization efforts, such as interlaboratory studies, have helped identify best practices and performance metrics. However, variability still exists in how samples are collected, processed, and analyzed, highlighting the need for adaptable but rigorous protocols.

Technological innovations continue to improve detection limits and throughput. Miniaturized filters, automated particle recognition, new digestion methods, and combustion analytical methods are under development. The field is also pushing toward detecting smaller particles (<50 µm) and nanoplastics, which remain methodologically challenging.

Current Microplastic Methods Have Improved Quality Assurance and Quality Control

Quality assurance and control (QA/QC) procedures are critical for ensuring the accuracy, reproducibility, and credibility of microplastics monitoring data. Laboratories now commonly implement field and lab blanks, matrix spikes, and contamination control measures. Recovery studies and interlaboratory comparisons are used to verify method performance.

The development of Standard Operating Procedures (SOPs) and method validation protocols—especially in regulatory contexts such as California's Environmental Laboratory Accreditation Program (ELAP)—has strengthened the reliability of data. Accreditation efforts require comprehensive documentation of QA/QC protocols, instrument calibration, and staff training.

However, more work is needed. There remains a lack of certified reference materials for microplastics, particularly in complex matrices like sediment and biota. In addition, method comparability across labs can be limited by differences in detection thresholds, analyst training, and instrumentation. These issues highlight the importance of continued investment in QA/QC standardization and infrastructure. See Appendix D for more detailed discussion on data gaps in standardized methods.

Analyzing microplastics <20 µm presents analytical and resource challenges

Microplastic toxicity is dependent on particle size, with greater toxicity generally associated with smaller particles (Brander et al., 2021; Thornton Hampton et al., 2022), yet most microplastic surface water monitoring data are based on particle sizes greater than 355 µm (the pore size of widely used manta trawl nets). Smaller microplastic particles of sizes down to 1 µm are hypothesized to be exponentially more abundant than larger microplastics (Coverton et al., 2019; Kooi et al., 2021), so current monitoring data may not accurately reflect the true exposures of aquatic organisms without being corrected for size.

Microplastic monitoring designed to inform risk screening may require microplastic monitoring methods to push the boundaries of analytical limitations to quantify a greater diversity of microplastics, including microplastics between 1-20 um, tire wear particles, and fibers. Prior to 2025, many microplastic laboratories described challenges with quantifying microplastics smaller than 20 µm (De Frond et al., 2022). Scientists have proposed to get around these analytical limitations by applying models to extrapolate and estimate smaller microplastics (Coffin et al., 2022; Koelmans et al., 2020; Kooi & Koelmans, 2019). The monitoring strategy can help improve these models by improving available monitoring data and addressing the small particle challenges. Additionally, development of different methods, including automated imaging coupled with Raman and FTIR, mass-based quantification with pyrolysis GC-MS, and LDIR are pushing and expanding the boundaries of the types of microplastics laboratories are able to quantify.

Limited Microplastic Analysis Capacity is a Challenge for Microplastics Monitoring

One of the most pressing bottlenecks in scaling up microplastics monitoring is the limited analysis capacity available in California and beyond. Microplastic analysis is time-intensive, laborious, and requires specialized instruments and training. A limited number of labs possess the technical capability and accreditation required for regulatory-quality data production.

Instrument availability is another constraint. FTIR imaging systems, Raman microscopes, and pyrolysis-GC/MS setups are costly and require regular maintenance. Analytical workflows can take weeks per batch of samples, and the backlog of samples during large-scale studies can significantly delay data delivery.

Workforce limitations also contribute to this bottleneck. There is a shortage of analysts trained in microplastics methods, and existing staff must often divide time among competing priorities. These constraints limit the number of samples that can be processed, increase per-sample costs, and reduce the scalability of regional or statewide programs.

Quantifying Tire Wear Particles in Sediment and Stormwater Matrices is Important

Tire wear particles (TWPs) have emerged as a critical component of the microplastics problem, particularly in urban environments. These particles are a major contributor to total microplastic loads in stormwater runoff and road-adjacent sediments, and are associated with the toxic chemical 6PPD-quinone, which has been linked to coho salmon mortality.

Monitoring tire particles poses unique analytical challenges. Their physical and chemical properties—black, rubbery, carbon-filled—make them difficult to distinguish from other environmental particles using standard spectroscopic methods. Advanced approaches such as scanning electron microscopy, thermogravimetric analysis, and chemical markers are being explored to improve specificity and quantification.

Because tire particles are a known source of concern for aquatic ecosystems and are increasingly the focus of regulatory interest, it is essential that monitoring programs include protocols that can reliably detect and quantify them in relevant matrices.

Data gaps in stormwater monitoring methods

Stormwater runoff is a major but understudied pathway, with significant uncertainties around sampling methods, particle transport dynamics that can influence sampling approach. Due to the logistical challenges and science data gaps for urban stormwater microplastic sampling, study implementation will necessitate collaboration between science researchers and local stormwater monitoring efforts. Further special studies are needed to improve and evaluate urban stormwater runoff sampling. OPC is currently funding SCCWRP and Dr. Andy Gray's research group at UC Riverside to address some of these science data gaps. Dr. Andy Gray's group is evaluating different stormwater sampling methods (i.e., net, pump, isokinetic sampler) both in the field and in controlled flume studies. Results will provide some guidance on stormwater sampling methods.

The San Francisco Bay region has a very different size stormwater conveyance system compared to the Los Angeles region, and watersheds generally drain through numerous much smaller watersheds and flow through a combination of sewer systems, developed and undeveloped urban creeks, and rivers. The RMP is currently conducting special studies to evaluate microplastic transport in channelized creeks to evaluate whether microplastics are generally well-mixed in the water column during fast-flowing storm events. This will inform and provide guidance on stormwater sampling methods.

Remaining important data gaps for inform methods for sampling urban stormwater runoff include, but are not limited to:

- microplastic concentration profiles in the water column under different hydrodynamic conditions in different stormwater conveyance systems,
- microplastic concentration changes through a storm event (pollutograph),
- microplastic concentration variations from different storm events,
- microplastic wash off from different land uses.

Monitoring Strategy Will Need to Adapt to New Methods in the Future

As the science of microplastics continues to evolve, so too must the monitoring strategies used to track them. The emergence of new detection technologies, such as portable field instruments and AI-based particle classification tools, is transforming the landscape of environmental monitoring.

Soon, the capability to detect nanoplastics, characterize complex particle mixtures, and integrate microplastics data with chemical and biological endpoints will become increasingly feasible. These developments will require flexible monitoring strategies that can accommodate new SOPs, instruments, and data types without undermining regulatory comparability.

A successful statewide monitoring strategy should include mechanisms for periodic method review, scientific consultation, and modular program design that can scale with both capacity and innovation. Investments in method development, lab accreditation, and analyst training will be essential to keep pace with scientific advancements and emerging regulatory priorities.

Appendix F: Summary of Microplastics Monitoring in California

What do we know about levels of microplastics in California waters and potential impacts to aquatic ecosystems?

MQ 1A. What are the levels of microplastics in different aquatic ecosystems? Are microplastics at levels that may impact aquatic ecosystems? Are microplastics at levels that may impact human health and welfare?

Many studies have documented microplastics in California aquatic ecosystems.

Previous studies have extensively reported microplastics in California waters. Most studies have focused on surface water concentrations in coastal and offshore marine waters.

Measured concentrations in surface waters vary by several orders of magnitude. Studies have also shown that microplastic concentrations measured in the same water body can vary by several orders of magnitude (Law et al., 2014). Even field replicates collected in the San Francisco Bay, collected by manta trawl at the same location right after each other, showed relative percent differences of up to 100%, reflecting the heterogeneous and ephemeral nature of microplastics in surface waters (Sutton et al., 2019). This heterogeneity has important implications for this Monitoring Strategy. Study design will need to consider sufficient sampling to adequately represent microplastic concentrations in surface water bodies to serve study needs. Additionally, evaluating microplastic concentration trends in open oceans will be challenging and require robust datasets.

While most studies have focused on sampling surface water for microplastics, a limited number of studies evaluated concentrations across the pelagic water column (0–1000 m) and confirmed that microplastics are present at every depth and sometimes more abundant at lower depths (200–500 m) than on the surface (Choy et al., 2019; Kashiwabara et al., 2021; Marcus et al., 2023). Therefore this Monitoring Strategy should also consider the need to evaluate water column concentrations to accurately estimate microplastic exposure, considering the hydrodynamics of the water body being evaluated.

Several studies have demonstrated that microplastics are more abundant in water bodies closer to urban influence, such as the San Francisco Bay (Sutton et al., 2019; Zhu et al., 2021), nearshore waters in Southern California between Los Angeles and San Diego (Doyle et al., 2011; Lattin et al., 2004; Moore et al., 2002, 2011), and Humboldt Bay (Marcus et al., 2023). Studies have also demonstrated that urban stormwater runoff discharges can significantly increase microplastic concentrations in receiving waters (Moore et al., 2002; Lattin et al., 2004; Doyle et al., 2011; Sutton et al., 2019). These studies highlight that water bodies receiving significant urban runoff are likely to have higher concentrations of microplastics, which may be an important site selection criteria for choosing sites more likely to be impacted by microplastics, as well as the importance of considering seasonal impacts from stormwater runoff.

Multiple studies have also demonstrated that even ‘pristine’ or protected areas such as the Monterey Bay National Marine Sanctuary, Cordell Bank National Marine Sanctuary, Bodega Marine Reserve, and Greater Farallones National Marine Sanctuaries, seemingly far away from direct human influence, are contaminated with microplastics (Choy et al., 2019; Kashiwabara et al., 2021; Saley et al., 2019; Sutton et al., 2019). Therefore, study designs should carefully consider the selection of remote reference sites and consider how results from reference sites will be used to compare to more impacted sites.

Aquatic Organisms in California, from Plankton to Fish to Marine Mammals, Are Exposed to Microplastics

Most of the microplastic monitoring studies conducted to date in California have focused on marine and estuarine ecosystems. Studies of microplastics in marine wildlife in California and globally show that microplastics are ingested by a wide variety of organisms ranging from plankton, mollusks, fish, sea birds, and marine mammals. The vast majority of the microplastics quantified in the digestive tracts were fibers (i.e., Hamilton et al., 2021; Horn et al., 2019; Klasios et al., 2021; Leviner & Perrine, 2023; Michishita et al., 2023; Sutton et al., 2016, 2019). In Monterey Bay, microplastics were reported in the digestive tracts of northern anchovies and common murres (Michishita et al., 2023), as well as deep-sea organisms from 17 taxonomic groups of fishes, crustaceans, mollusks, and gelatinous animals (Hamilton et al., 2021). In San Francisco Bay, nearly all northern anchovies, topsmelt, and bivalves sampled contained microplastic fibers (Klasios et al., 2021; Sutton et al., 2019). Along California’s coasts, microplastics have been reported in Pacific mole crabs from 38 beaches (Horn et al., 2019), snails in tidepools in a nonurban California coastal area (Saley et al., 2019), and in salps (planktonic species) in the Northern Pacific Subtropical Gyre and California coasts (Brandon et al., 2019). Microplastics have also been reported in the fecal matter of Northern Seals living in the Channel Islands (Donohue et al., 2019).

Important Data Gaps in Monitoring Microplastics in Sediment

Microplastic monitoring in over 80 beaches along California's coast from Humboldt Bay to San Diego to the Channel Islands (Heard, 2024; Horn et al., 2019; Marcus et al., 2023; Steele & Miller, 2022) show microplastics are abundant in California beach sediment, with urban beaches tending to have higher levels of microplastics compared to non-urban beaches. At the same time, even sparsely inhabited beaches are contaminated with microplastics (Heard, 2024). Fibers, when counted, were found to be the most common type of microplastics identified (Horn et al., 2019). All of these beach studies relied on visual techniques to identify microplastics.

There are limited studies of microplastics in marine sediment, and to our knowledge, this is currently limited to sediment monitoring in the San Francisco Bay (Dronjak et al., 2023; Sutton et al., 2019; Zhu et al., 2021). Analyzing microplastics in sediment samples is challenging due to the need to extract and distinguish microplastics from other organic and inorganic materials in sediment. Microplastic concentrations in Bay sediment ranged by two orders of magnitude, reflecting significant microplastic heterogeneity in sediment. Regions of the Bay most impacted by urban influence tended to have the highest measured concentrations of microplastics.

Additionally, the quantification of tire wear particles is an important data gap in sediment monitoring. Tire wear particles have been identified in San Francisco Bay sediment, but levels have not been quantified due to methodology data gaps (Sutton et al., 2019; Zhu et al., 2021; Dronjak et al., 2023).

Limited Microplastics Monitoring in Freshwater Ecosystems and Sediment

In contrast to the wide range of microplastic monitoring that has been conducted in marine ecosystems, there has been very limited monitoring in freshwater ecosystems. Microplastic monitoring has been reported in urban creeks in the San Francisco Bay region (Sutton et al., 2016, 2019); the San Joaquin River in the Delta region (Rochman et al., 2022); and the Los Angeles River (Moore et al., 2011; Wiggin & Holland, 2019), Coyote Creek (Moore et al., 2011), and the San Gabriel River in Southern California (Moore et al., 2011; Wiggin & Holland, 2019). Lessons learned from these studies are summarized in the context of informing MQ 2 in Section 3.3.

Priority data gaps in previous monitoring studies

Initial microplastic studies (early 2000s) were focused on establishing the presence of microplastics in coastal and nearshore ocean waters. These early studies lacked a consistent definition of microplastics and it was common not to include QA/QC standards such as field blanks and processing controls, making findings from these studies more qualitative given the uncertainty in the reported microplastic levels. This uncertainty in quantification makes it challenging to compare across studies to evaluate temporal and geographic trends. Nevertheless, these studies demonstrate the ubiquitous presence of microplastics in California coastal waters and subembayments (Lattin et al., 2004; Moore et al., 2002; Sutton et al., 2016) as well as offshore ocean waters away from direct human influence (Doyle et al., 2011; Law et al., 2014; Moore et al., 2001).

Methods to sample, quantify, and identify microplastics are continuing to evolve; improving the precision and accuracy of earlier quantification methods and improving microplastic particle characteristic descriptions. Additional QA/QC measures, such as field blanks, laboratory blanks, and matrix recovery are now standard procedures in microplastic sampling and analysis. Complementary analytical methods, such as fluorescence staining techniques or spectroscopy methods, are widely used to improve identification and differentiation between microplastics and natural particles (Brandon et al., 2019, Sutton et al., 2019). These additional QA/QC measures are critical to improving the quality of microplastic studies necessary for informing this Monitoring Strategy. However, microplastic analysis is still a costly analytical endeavor. Study design must include careful consideration of the data needed to meet study objectives, and a careful cost-benefit analysis to determine the best approach (Lusher and Primpke, 2023). Often spectroscopic analysis needs to be done manually, which drives up the cost, making microplastic analysis both an expensive and time consuming process. Due to resource constraints, studies often applied spectroscopy to a subset of microparticles (Sutton et al., 2019) to estimate microplastic abundance. This Monitoring Strategy recognizes that subsampling strategies will need to be incorporated in specific study design to meet specific study data quality needs that are balanced with resource constraints.

As more tools and resources are applied to microplastic studies, we are increasingly finding that certain types of microplastics have been severely undercounted or not counted at all, such as fibers, tire wear particles, and smaller size microplastics. Measured concentrations are often significantly higher when smaller particles (< 333 µm) and fibers are included (i.e., Brandon et al., 2019; Sutton et al., 2019). The majority of aquatic studies have only quantified microplastics larger than 300 µm, which can skew load estimates, as the majority of particles are hypothesized or shown to be < 300 µm (Conkle et al., 2018). Therefore, careful consideration of what size particles should be included in study design is necessary, balancing data needs with available resources and methods. Additionally, this Monitoring Strategy needs to consider how datasets collected from different monitoring efforts will be used and compared, and establish sampling, analysis, and reporting framework to support this.

The methodologies used for microplastic evaluations between studies have little to no consistency, making comparability between studies difficult to evaluate across species or spatial and temporal scales.

Currently, there is still an important science research gap on how best to use biota monitoring as a bioindicator of plastic pollution because there is limited understanding of the relationship between plastics in the environment and plastic ingestion for most species (Savoca et al., 2024). This Monitoring Strategy emphasizes monitoring biota to evaluate human exposure from ingesting contaminated fish and bivalves. This approach could evolve as science develops.

What do we know about potential impacts of microplastics to aquatic ecosystems?

From prior monitoring described above, we know that microplastics are ubiquitous in California’s surface water, sediment, and biota. Evaluating impacts also requires understanding of hazards to evaluate potential impacts. California convened two important efforts to further our understanding of microplastics. The first one was organized by the California Ocean Science Trust, and a second one was organized by the SCCWRP.

A working group of scientific experts convened by the California Ocean Science Trust to develop a risk assessment framework for microplastic pollution in California’s marine environment recommended a precautionary approach to assess and manage microplastic pollution risk (Brander et al., 2021). This recommendation was based on microplastic persistence, lack of feasible cleanup options, the projected rate of increased concentrations in the environment, and evidence that microplastics contaminate and may lead to adverse effects in organisms and humans. Other California groups, including the Regional Monitoring Program for Water Quality in San Francisco Bay (RMP), have adopted similar approaches to assessing risk from microplastics. This rationale has also been adopted in other countries. For example, the European Chemicals Agency has decided to classify microplastics as a non-threshold contaminant, meaning any discharge poses a risk, for risk assessment purposes (ECHA, 2019). Similarly, the Science Advice for Policy by European Academies states that while it is unlikely that current exceedances of risk thresholds are geographically widespread, with expected increases in exposure to microplastics (Lebreton & Andrady, 2019), widespread ecological risk may arise within the next century (Science Advice for Policy by European Academies, 2019).

In response to the State of California legislative mandates for enhanced microplastic management, SCCWRP led the convening of a group of microplastics experts proposed a risk management framework for aquatic ecosystems that identifies four critical management thresholds, ranging from low regulatory concern to the highest level of concern where pollution control measures could be introduced to mitigate environmental emissions (Mehinto et al., 2022). This expert effort also resulted in the development of the Toxicity of Microplastics Explorer (ToMEx), an open access database and open source accompanying R Shiny web application that enables users to upload, search, visualize, and analyze microplastic toxicity data (Thornton Hampton et al., 2022). All studies in ToMEx have been scored by at least two independent reviewers according to microplastics-specific technical and risk assessment quality criteria (de Ruijter et al., 2020). Proposed microplastics toxicity thresholds for two different effect mechanisms were developed using ToMEx (Mehinto et al., 2022). While the expert group participants expressed high confidence in the proposed multi-tiered management framework and the use of species sensitivity distributions and data alignment calculations to derive these hazard threshold values, they expressed low to moderate confidence in the actual threshold estimates due to insufficiencies in the available toxicity data (Mehinto et al., 2022).

There is definitive evidence that microplastics can cause harm to aquatic organisms through both physical mechanisms, such as physically blocking feeding structures, impairing respiration by clogging gills, or causing lacerations, and chemical mechanisms, such as eliciting an adverse immune or stress response by causing the production of reactive oxygen species, inflammation, or cell damage. However, due to the diversity of physical and chemical characteristics (e.g., sizes, morphologies, polymer types, chemical additives, sorbed chemicals, and impurities) within the category of microplastics, the many microplastic toxicity studies published to date do not yet paint a clear picture of microplastic concentrations likely to cause risk to aquatic ecosystems. Evidence demonstrated by numerous laboratory studies using different combinations of organisms and microplastics with varying characteristics, such as polymer type, size, shape, and associated chemical mixtures, indicates that microplastic toxicity likely depends on multiple factors (Rochman et al., 2019). There is currently sufficient evidence indicating particle size and shape are critical determinants of toxicological outcomes, particularly for the mechanisms of food dilution and tissue translocation, but the effects of other particle characteristics remain unclear (Brander et al., 2021; Thornton Hampton et al., 2022). Understanding microplastic toxicity and risk is further confounded by the use of differing measures of microplastic concentrations (e.g., particle number or mass per volume, rarely both) and the lack of standardized reporting of microplastic characteristics in both toxicity studies and environmental monitoring.

Despite the difficulty in understanding and harmonizing microplastic toxicity data and environmental monitoring data for risk assessment, several ecotoxicity thresholds have been proposed in the literature. However, these thresholds have high uncertainty and are based on toxicity testing data with particles that are not necessarily representative of microplastics found in California's aquatic environments: primarily spheres of only a few polymer types.

Microplastic toxicity is dependent on particle size, with greater toxicity generally associated with smaller particles (Brander et al., 2021; Thornton Hampton et al., 2022), yet most microplastic surface water monitoring data are based on particle sizes greater than 355 µm (the pore size of widely used manta trawl nets). Smaller microplastic particles of sizes down to 1 µm are hypothesized to be exponentially more abundant than larger microplastics (Covernton et al., 2019; Kooi et al., 2021), so current monitoring data may not accurately reflect the true exposures of aquatic organisms without being corrected for size. Particle size distribution models to extrapolate environmental monitoring data to smaller sizes not captured in environmental sampling have been proposed (Koelmans et al., 2020; Kooi & Koelmans, 2019). However, these proposed size re-alignment methods have large amounts of uncertainty. Therefore, the current size distribution models used to rescale manta trawl data to assess microplastic risk may not accurately represent environmental microplastics, and the validity and uncertainty of using these models to conduct risk characterization is currently unknown.

These size re-alignment models were used by Coffin et al. (2022) to extrapolate microplastic concentrations down to 1 µm particle size from existing monitoring data for microplastics in San Francisco Bay (Sutton et al., 2019; Zhu et al., 2021) to assess microplastic exposure risk using the proposed microplastics risk management framework for aquatic ecosystems (Mehinto et al., 2022). Using this approach, as well as additional rescaling to estimate fibers that were not quantified in the manta trawl samples, more than three-quarters of samples exceeded the most conservative food dilution management threshold, while no samples exceeded any tissue translocation threshold with statistical significance (Coffin et al., 2022). Both the particle size rescaling and fiber count adjustment introduces significant uncertainty in the estimated microplastic concentrations in San Francisco Bay and associated risk characterization. This comparison was cited in the 2024 California Integrated Report, which recommends placing three water bodies (San Francisco Bay [Lower and Central] and San Leandro Bay) in Category 3 (insufficient data and/or information to make a beneficial use support determination but data and/or information indicates beneficial uses may be potentially threatened) and four water bodies (San Francisco Bay [South], San Pablo Bay, Suisun Bay, and a segment of the Pacific Ocean off the coast of Marin County) in Category 2 (insufficient data and/or information to determine core beneficial use support) (California State Water Resources Control Board, 2024). No other California water bodies were included due to a lack of monitoring data. The report states that current microplastic thresholds are not suitable for assessing beneficial use support for listing a water body as impaired on the 303(d) list due to the uncertainty regarding input data, but there is a scientific basis to use them to inform Clean Water Act 305(b) water quality condition reporting (California State Water Resources Control Board, 2024).

New microplastic toxicity studies that could potentially help improve the quality of ecotoxicity thresholds are constantly being published. An update to ToMEx is currently underway, and the authors expect to publicly release ToMEx 2.0 and publish associated manuscripts in peer-reviewed journals by spring 2025. The ToMEx database update represents a useful resource to inform this Monitoring Strategy, while also demonstrating a continued need for high quality, fit-for-purpose toxicity data. There is still very little toxicity data on many types of particle polymers/morphologies and on more environmentally realistic exposures of weathered particles or particle mixtures. Additionally, even with updates and improvements, some key data gaps will still remain for microplastic risk characterization because the size distribution and types of microplastic particles for which toxicity data exist are different from the size distribution and types of microplastics that have been monitored in the environment.

Microplastic toxicity is complex and driven not just by exposure to particles but also by the chemicals the particles contain and release. Understanding potential impacts from microplastic contamination therefore necessitates understanding the impacts of chemicals in microplastics. For example, modeling studies estimate that tire wear may be one of the top sources of microplastic releases to the environment globally (Boucher & Friot, 2017; Hann et al., 2018; Kole et al., 2017; Sieber et al., 2020). These tire particles contain hundreds of chemicals, some of which are known or suspected to be toxic to aquatic organisms or to have toxic transformation products (Mayer et al., 2024). Appropriate risk assessment of tire particles must therefore include their known toxic chemical constituents and may need to coordinate with chemical monitoring efforts and/or be separated from risk assessment of other microplastics. For all other microplastics, the working group convened by the California Ocean Science Trust recommended managing and assessing microplastic pollution risk using a particulate approach over a toxicant approach, until California-specific data are available and the chemical effects of microplastics are fully understood (Brander et al., 2021).

Although a robust risk assessment of microplastics in California ecosystems is still hindered by data gaps and uncertainties, a screening-level risk evaluation approach to guide future monitoring studies and management actions is possible. The working group convened by the California Ocean Science Trust recommended characterizing and ranking risk by relating source tonnage and microplastics internalization potential using a weight-of-evidence approach (Brander et al., 2021). Current thresholds and frameworks such as those of the RMP and microplastic experts (Mehinto et al., 2022) can allow risk screening and prioritization of monitoring and management even without a full understanding of potential microplastic impacts.

Table J.1: Brief summary of California microplastic studies published in peer-reviewed literature.

Reference	Location	Matrices	Microplastic Size Range	Most Common Microplastic Type
Barrows et al. (2018)	Coastal California Waters (nearshore)	Marine Surface Waters	100 µm - 5 mm	Fibers
Brandon et al. (2019)	Northern California Current (Off-Shore)	Zooplankton, Marine Surface Waters	5 - 333 µm	Fibers
Carr et al. (2016)	Los Angeles	Wastewater	45 - 400 µm	Fragments
Choy et al. (2019)	Monterey Bay	Pelagic water column (Marine Waters)	20 µm - 5 mm	Not Reported
Cowger et al. (2022)	Los Angeles	Fresh Surface Waters (River)	20 µm - 5 mm	Not Reported
Donohue et al. (2019)	San Miguel Island	Northern Fur Seal Feces	1 - 10 mm	Fibers and Fragments
Doyle et al. (2011)	Southern California Coast	Zooplankton, Marine Surface Waters	1 - 10 mm	Fragments

Dronjak et al. (2024)	San Francisco Bay Area	Sediment (surface and cores)	25 µm - 5 mm	Fibers
Dyachenko et al. (2017)	San Francisco Bay Area (EBMUD)	Wastewater	125 - 355 µm	Fragments
Gaston et al. (2020)	Channel Islands	Air (indoor/outdoor)	20 - 8961 µm	Fibers and Fragments
Gilbreath et al. (2019)	El Cerrito	Stormwater	125 - 355 µm	Fibers
Gilfillan et al. (2009)	San Diego Coastal area	Zooplankton, Marine Surace Waters	0.505 - 3.5 mm	Not Reported
Hamilton et al. (2021)	Monterey Bay	Crustacean, Fish, Mollusk, Jellyfish, Zooplankton	0.1 - 5mm	Fibers
Heard et al. (2024)	Central California Coast	Coastal Beaches	2 - <25mm	Cigarette butts and Hard plastic fragments
Horn et al. (2019)	California Coast	Sediment (Beaches), Crabs	>300 µm	Fibers
Hung et al. (2020)	San Francisco Bay Area	Marine Surface Waters	20 - 500 µm	Fibers
Kashiwabara et al. (2021)	Monterey Bay	Marine Surface Water (near shore/off shore)	25 µm - 5 mm	Fibers
Klasios et al. (2021)	San Francisco Bay Area	Mussels and clams	25 - 125 µm	Fibers
Lattin et al. (2004)	Santa Monica Bay	Marine Surface Waters	>333 µm	Not Reported

Law et al. (2019)	Coastal California Waters	Marine Surface Waters	>355 µm	Fragments
Leviner and Perrine (2023)	Morro Bay	Terrestrial Birds (GI-track)	>2.5 µm	Fibers
Marcus et al. (2023)	Humboldt Bay	Marine Surface Waters and Tidal Sediment	0.5 - 5.0 mm	Fibers and Fragments
Michishita et al. (2023)	Monterey Bay	Anchovy, Sea Birds, Marine Surface Waters	119 - 500 µm	Fibers
Miller et al. (2018)	Channel Islands, Los Angeles, Santa Barbara, Ventura	Beach Sediments (sand)	<5 mm	Fibers and Fragments
Moore et al. (2002)	Long Beach (Coastal)	Zooplankton, Marine Surface Waters	0.355 - >4.75 mm	Fragments
Moore et al. (2011)	Los Angeles	Freshwater (Urban river)	1 - 5 mm	Fragments
Rochman et al. (2022)	Sacramento Delta, compared to Lake Ontario and Chesapeake Bay	Agricultural runoff, wastewater, urban runoff	>125 µm	Fibers and Fragments
Saley et al. (2019)	Bodega Marine Reserve, Sonoma County	Benthic Organisms, Marine Surface Waters, Sediment (sand), Snails	36 - >180 µm	Not Reported

Steele and Miller (2022)	Channel Islands	Beach Sediments (sand)	<5 mm	Not Reported
Sutton et al. (2019)	San Francisco Bay Area	Stormwater, Wastewater, Marine Surface Water, Sediment, Prey Fish	125 - 355 µm	Fibers and Black Rubbery Fragments
Sutton et al. (2016)	San Francisco Bay Area	Marine Surface Water, Treated Wastewater, Prey Fish	0.333 - 4.75 mm	Fibers
Werbowski et al. (2021)	San Francisco Bay Area	Urban Stormwater	125 µm - 1 mm	Fibers and Black Rubbery Fragments
Wiggin and Holland (2019)	Los Angeles	Freshwater (Urban river)	3 - 1000 µm	Fibers
Zhu et al. (2021)	San Francisco Bay Area	Stormwater, Wastewater, Marine Surface Water, Sediment, Prey Fish	0.333 - 4.75 mm	Fibers and Black Rubbery Fragments

Appendix G: Summary of Microplastic Sources

Understanding the dominant sources and environmental pathways of microplastics (Figure 3.2) is essential for designing effective monitoring efforts and informing targeted pollution prevention strategies. This section outlines the current scientific understanding of key microplastic sources (e.g., tire wear, textiles, paints, and macroplastic litter) and the environmental pathways through which microplastics are transported to California's aquatic ecosystems, including urban runoff, wastewater, atmospheric deposition, and agricultural runoff. It also highlights priority data gaps and monitoring needs to support source reduction efforts.

Top Sources of Microplastics Include Tire Wear Particles, Textiles, Paints, and Macroplastics Litter

Almost any plastic material littered in the environment or subject to wear and degradation in the environment can be a source of microplastics. The use of plastics has increased on a worldwide scale over the past century, which has resulted in an increase of plastic debris in our oceans and virtually every environment on Earth.

One of the major challenges to addressing microplastic pollution is identifying the product source of microplastics, as well as the pathways by which they are transported into the environment (e.g., urban runoff or wastewater). Understanding the sources of microplastics, as well as their dominant transport pathways to receiving waters, is crucial to informing microplastic management strategies and policies to direct actions to reduce pollution.

Data on microplastic characteristics such as polymer composition, color, size, and morphology are commonly collected to provide clues as to their potential sources. Further refinement of these characteristics, as well as characterizing surface topology (Cowger et al., 2020), tensile strength (e.g., hard or soft), and texture (e.g., elastic/compressible or brittle) have been suggested to further help link microplastics to their potential sources. However, in most cases, it is challenging to confirm the sources of microplastics because so many products are now made of plastic, meaning there are many potential sources for widely detected microplastic polymers such as polyethylene, polypropylene, and polystyrene.

Monitoring studies designed to link microplastics to sources should focus analysis to identify characteristics that can best link to sources. Both fibers and tire wear particles are abundant in urban runoff staples (Sutton et al., 2019) and therefore should be included in analysis. Current standard microplastic analysis typically categorizes microplastic particles by broadly defined categories including morphology (e.g., fibers, fragments, spheres, film), color, and polymer. More detailed characterization of individual particles and refinement of microplastic categories may be needed to link microplastics to upstream sources and better inform management actions (Helm, 2017; J. T. Yu, 2024; X. Yu et al., 2022). Proposed "source-apportionment" categories include distinguishing between primary and secondary microplastics, and further categorizing microplastic spheres into irregular and regular microbeads in the 100 µm–2 mm range from industrial pellets in the –2 2mm–5mm size range, as well as including separate categories for tire wear particles and paints (Yu et al., 2022). Analytical methods and reporting categories applying this approach are not standard practice and are a developing science

This level of detailed categorization is currently recommended for larger particles (e.g., >100 µm; Yu et al., 2022). Note that this type of source categorization could be subjective, and it is important to archive data and photo documentation so that results can be re-evaluated as methods evolve and are standardized. Many microplastic sources may not yet be identifiable, and archived data can be revisited as methods improve (Yu, 2024; Yu et al., 2022). This detailed analysis of and categorization of microplastics can be applied to a subset of microplastic particles depending on resource constraints.

Emissions inventories have also been used to estimate the top sources of microplastics from urban areas. These include tire rubber (mostly from vehicle miles traveled) (Boucher & Friot, 2017; Zhu et al., 2024), paint (from houses and roads, recognizing that paints are composed of plastic polymers, which can be released during application, wear and tear, and maintenance activities; Zhu et al., 2024), macroplastic litter (Zhu et al., 2024), textiles (Clayer et al., 2021), plastic litter and mismanaged waste (this is a lumped term for many sources; Zhu et at., 2024). Emission inventories are often limited by scientific data gaps in emissions from various sources, and therefore may not be comprehensive. For example, there are no microplastic studies to date available to estimate emission rates from clothing dryers. Most US residential and commercial clothing dryers vent directly to the outdoors without treatment, dispersing fibers not collected in lint traps to the outdoors, which can be a source to urban runoff.

Urban Runoff Is a Major Pathway for Microplastics Transport to Receiving Waters

Monitoring environmental pathways, such as urban runoff and wastewater is an important approach to investigating microplastic sources.

In most urban environments in California, rainfall and runoff wash particles into stormwater collection systems that discharge directly to receiving waters (including streams, creeks, rivers, wetlands, and oceans) without treatment. The existence of separate storm drain systems for urban runoff and wastewater helps distinguish between sources more likely to contribute to one pathway or the other. Compared to wastewater monitoring, urban runoff is an under-studied pathway for microplastics. The limited studies of microplastics in urban stormwater runoff indicate this as a major pathway for microplastic impacts to receiving waters and likely even more important compared to the wastewater pathway (Gilbreath et al., 2019; Moore et al., 2011; Sutton et al., 2019; Werbowski et al., 2021; Wiggin & Holland, 2019; Zhu et al., 2021). High microplastic loadings from urban stormwater runoff compared to those from wastewater have been reported in urban creeks in the San Francisco Bay region (Sutton et al., 2019; Zhu et al., 2021) and major rivers in Southern California (Moore et al., 2011; Wiggin & Holland, 2019).

Tire-wear Particles and Fibers may Represent the Majority of Microplastics in Urban Stormwater Runoff

Nearly half of the particles observed in urban stormwater runoff in the San Francisco Bay Microplastics Study were suspected to be tire wear particles due to their morphology, distinctive black color, and rubbery texture (Sutton et al., 2019; Werbowski et al., 2021). Fibers were the second most common class of microplastics observed in stormwater. The majority of fibers were identified as 'anthropogenic unknown' (indicating they had been dyed with a dye or coloring agent, but the underlying fiber composition could not be identified), polyester, or cellulose acetate (which could come from cigarette filters). Other microplastics observed in stormwater less extensively include fragments of polypropylene (PP) and polyethylene (PE), common plastics used in a variety of products.

Wastewater Treatment Plants Remove Most Microplastics from Effluent but Not All

Wastewater is the most studied microplastic pathway and a number of studies have reported microplastics in wastewater effluent (Carr et al., 2016; Sutton et al., 2016, 2019; Wong et al., 2024) and levels reported in California studies are consistent with other microplastic wastewater studies in North America. Reported concentrations in wastewater effluent range by several orders of magnitude, but Sutton et al. (2019) showed average concentrations to be significantly lower compared to urban stormwater runoff. A wastewater screening study led by SCCWRP and funded by OPC found over 95% removal of microplastics from influent to final effluent at all plants (Wong et al., 2024). This can explain the lower levels of microplastics in wastewater effluent compared to urban stormwater runoff, which generally is untreated.

Microbeads Represent Only a Small Fraction of Microplastics in Wastewater

The United States Microbead-Free Waters Act of 2015[34] (which followed California's statewide microbead ban), banned the use of plastic microbeads in wash-off personal care products such as facial scrubs, toothpaste, and body wash for the purpose of exfoliation by 2018. Following these bans, microplastic spheres that may have come from microbeads in personal care products were observed in wastewater effluent, but were generally composed of a very small fraction of total microplastics observed (Sutton et al., 2019).

Agricultural Runoff and Atmospheric Transport are Additional Pathways for Microplastics that Require More Scientific Study

Agricultural runoff may also be an important pathway for microplastics, but there are insufficient studies to evaluate the importance of this pathway compared to wastewater and urban runoff. A single study of microplastics in agricultural runoff in the Sacramento Delta region, an area with significant agricultural activity, showed higher concentrations of microplastics in agricultural runoff compared to wastewater effluent (Rochman et al., 2022). Biosolids from wastewater treatment are often added as soil amendments to agricultural lands and are hypothesized to be an important pathway for microplastics in wastewater to re-enter the environment through land application on agricultural soils (Crossman et al., 2020; Golwala et al., 2021), but this hypothesis has not yet been tested.

Short-range and long-range atmospheric transport is likely another important pathway for microplastics to enter and leave different watersheds (Allen et al., 2019; Dris et al., 2015). Microplastic atmospheric fallout in urban areas has been documented as being higher than non-urban areas with fibers being the most frequently identified microplastic type (Dris et al., 2016). Tire wear particles from roadways have been

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[34] H.R. 1321 - 114th Congress (2015-2016): Microbead-Free Waters Act of 2015, Pub. L. NO. 114-114, H.R. 1321 (2015). https://www.congress.gov/bill/114th-congress/house-bill/1321

profiled traveling through the atmosphere near motorways; however, the distance they can disperse from roadways and their possible effects on affected communities are understudied (Sommer et al., 2018). Mechanical air clothing dryers with outdoor ventilation may be a significant source of fibers emitted to the urban landscape, but realistic emission rates have not been investigated (Moran et al., 2021).

Landfills (Loppi et al., 2021) and recycling centers (Brown et al., 2023) have been noted as potential additional sources for microplastic environmental discharge, but the magnitude of their contribution has yet to be explored.

Monitoring Studies to Evaluate Agricultural Runoff and Air Transport Require More Research and Pilot Sampling and Analysis Methods are Needed

Investigating and monitoring agricultural runoff is important to understand agricultural sources of microplastics to receiving waters. However, this is a very wide science research data gap, and there is little information to inform the relative importance of this pathway. Therefore, we recognize this as an important research data gap that is not quite ready to incorporate into this Monitoring Strategy, but may be in the future.

The monitoring question about air seeks to understand the role of atmospheric transport for microplastics. This question encompasses both air transport as a pathway to urban runoff and the role microplastic sources outside California may have on microplastics in urban stormwater runoff and receiving waters in California. There are still important research science questions about how to monitor and design microplastic air monitoring studies. This Monitoring Strategy recognizes this topic as an important research science data gap directly relevant to informing Management Questions. However, it is not quite ready to incorporate into this Monitoring Strategy.

Table G.1 Summary of Critical Science Gaps Important for Informing Management Questions and Monitoring Strategy

Category	Critical Science Data Gaps
Analytical Methods	There is not yet scientific consensus on analytical methods for quantifying tire wear particles in environmental samples. There are important science data gaps in tire tread chemical composition, particularly as this can vary from region to region and change over time as new vehicle fleets replace older fleets.

Category	Critical Science Data Gaps
Analytical Methods	Laboratories have challenges quantifying microplastics smaller than 20 µm accurately and precisely.
Analytical Methods	Improved methods to clearly identify sources of microplastics based on microplastic chemical and physical characteristics are needed.
Monitoring	Monitoring of microplastics in statewide marine and freshwater ecosystems (e.g., water and sediment) is needed. This includes quantifying microplastics smaller than 100 µm, including fibers and tire wear particles. These microplastics are abundant in the environment and important for informing risk screening efforts but have been under-counted in previous studies due to scientific method gaps and limitations.
Monitoring	There are important data gaps in understanding the generation of emissions of microplastics from various sources, such as apparel shedding and macroplastic degradation rates.
Monitoring	Monitoring studies of agricultural sources and pathways of microplastics to receiving waters are needed, including the development of methods.
Monitoring	Monitoring and modeling of microplastic air transport from local and long-range sources is needed to inform the efficacy of local management actions to mitigate local microplastic concentrations.
Transport	Due to the diversity of microplastic shapes and densities, there are major science gaps in understanding of microplastic transport under different hydrodynamic conditions in various receiving water and stormwater conveyance systems. This is important for informing sampling approaches and methods to ensure methods are adequately representative for informing management and monitoring questions.
Toxicity	Due to the diversity of microplastic physical and chemical characteristics, understanding the toxicity of microplastics and their impacts to aquatic ecosystems remains a significant and multi-faceted research topic.

Appendix H: Prominent Macroplastics / Trash Monitoring Programs Serving California

While plastics monitoring forms a central feature of many stormwater monitoring programs, academic-related endeavors, and community-based actions, very few programs are dedicated exclusively to the nuances of macroplastic monitoring. As a result, there are different ways to identify and classify programs devoted to plastics monitoring. For our purposes, we will identify prominent trash monitoring programs across California by their methodologies.

NOAA Marine Debris Program

Since its inception in 2006, the NOAA Marine Debris Program has funded and supported efforts to reduce the proliferation of marine debris along US coastlines. Promoting a combination of preventative measures, active removal events and practices, funded research efforts, coordination of related efforts, emergency response planning, and monitoring, the program exerts a strong influence over monitoring efforts and cleanups along California's coastal waters.

In particular, NOAA uses a mobile app as part of its cleanup efforts to measure the presence of plastics in the marine debris that they locate and remove from California's coastlines. The Marine Debris Tracker was first developed in 2010, in collaboration with the University of Georgia College of Engineering, where it facilitates the capture of data vital to accurate plastic debris accounting. It focuses largely on the broad audience of community-based scientists who individually and collectively contribute their trash assessment through visual monitoring and cleanup programs.

The Marine Debris Tracker is now in alignment with the EPA's Escaped Trash Assessment Protocol, which facilitates tally-based accounting of plastic by specific categories. As a broadly used tool, it is associated with a range of community-based initiatives and organizations, from Heal the Bay to the Surfrider Foundation.

National Pollutant Discharge Elimination System (NPDES) Permittees

Every five years, the San Francisco Bay Regional Water Quality Control Board reissues the Municipal Regional Stormwater Permit (MRP) to its permittees around the San Francisco Bay. This permit is issued under the National Pollutant Discharge Elimination System (NPDES).

The State Trash Policy clarifies and defines the objectives for California's trash reduction goals, and the MRP is one example of the application of this policy. The MRP represents a regional streamlining of the permit-issuing process for the Bay Area's counties including Alameda, Contra Costa, San Mateo, and Santa Clara counties, and within Solano County, the cities of Fairfield, Suisun City, and Vallejo, and the Vallejo Flood and Wastewater District. By consolidating individual stormwater pollution prevention requirements into a single permit, the MRP offers clear regulations governing activities such as construction, industrial site management, and municipal operations across a regional scale.

In the San Francisco Bay Area, many MRP permittees follow a rapid assessment methodology that is largely qualitative in nature. For both on-land and in-stream visual assessments, monitoring practitioners serving on behalf of their respective stormwater programs walk the landscape and assess its condition according to a four- or twelve-point scale. For the in-stream visual assessment, developed largely by EOA, a multi-disciplinary environmental consulting firm, for BASMAA, the method leverages aspects of the SWAMP Rapid Trash Assessment Method (Moore et al., 2007), in addition to the standard national Stream Visual Assessment Protocol, Version 2 (United States Department of Agriculture, 2009). This rapid assessment method facilitates a greater number of assessments than more time-intensive methods might afford.

Additionally, with respect to regulations for plastic resin pellets and powdered coloring for plastics in manufacturing, handling, or transportation facilities, Water Code section 13367 (Chapter 5.2. Preproduction Plastic Debris Program) prescribes minimum control measures for NPDES permits. This section also requires the regional boards to implement a control program for preproduction plastic from point and nonpoint sources, implemented through the General Industrial Permit.

Southern California Bight Regional Monitoring Program

The qualitative method used in the Bay Area differs from the quantitative method used by those participating in the Southern California Bight Regional Monitoring Program, where the stormwater agencies in the jurisdictions of the Los Angeles and San Diego Regional Water Quality Control Boards have leaned more heavily on tally-based methods since 2001.

Office of Water Programs, California State University Sacramento

The Office of Water Programs facilitates the State Parks Stormwater Program, which notes that "litter is the most common pollutant in the California State Park system."[35] Their method largely conforms to the on-land visual assessments first developed by EOA for BASMAA.

With limited resources, the Office of Water Programs, like many other stakeholders, does not count, identify, and categorize every individual item, but rather characterizes the landscape condition as a whole.

California Department of Public Health, California Tobacco Prevention Program (CTPP) and San Diego State University, Center for Tobacco and the Environment (CTE)

Both the CTPP and the CTE share a common mission to reduce tobacco use and its associated impacts on the environment. As a plastic product, cigarette butts are macroplastic that become microplastic at a fairly predictable rate under known conditions. As such, they are among the clearest "bridge products" that integrate macro- and microplastics monitoring interests.

The two programs have separately sought to develop mobile applications to aid with monitoring tobacco product waste. The CTE has a mobile application that leverages computer vision to identify and count cigarette butts in the environment. The CTPP has a similar tool, but without the benefit of computer vision. However, the CTPP application sets the assessment area in clearly delineated spatial and temporal terms, from which concentration values are able to be generated.

Other Community-Based Applications

Across California, community-based groups leverage mobile apps to organize campaigns, enforce consistent data collection rules, and promote interoperable, intercomparable results. The ability to help manage data is a key value of these

[35] Office of Water Programs, California State University Sacramento. 2024. https://www.owp.csus.edu/

applications with respect to community-based programs, who might otherwise lack even basic data management resources.

Some applications used in terrestrial, aquatic, and marine environments include the following:

- Litteratti (commercial venture): https://www.litterati.org/
- Clean Swell® (non-profit): https://oceanconservancy.org/trash-free-seas/international-coastal-cleanup/cleanswell/
- Coastal Commission's California Coastal Cleanup Day: https://www.coastal.ca.gov/publiced/ccd/ccd.html
- Pirika (commercial venture): https://corp.pirika.org/en/service/pirika/
- Litter CleanUp (non-profit): https://www.litter-cleanup.org/
- Rubbish (commercial venture): https://www.rubbish.love/
- 2ndNature 2NFORM (commercial venture): https://www.2ndnaturewater.com/
- Trash Rapid Assessment Data Exchange (TRADE): https://trade-csusr.hub.arcgis.com/

This list is far from exhaustive. There are many mobile apps that facilitate trash and plastic data collection that are often highly specialized. Programs often leverage "off-the-shelf" software, such as Esri's Survey 1-2-3, to generate highly effective, program-specific data collection methods. Others might create highly customized survey tools individually at great expense.

Producing a veritable treasure trove of data, the California Coast Cleanup Day offers a more than 37-year history of coordinated annual cleanup efforts across California's coast. It is the largest annual volunteer event in the nation's history. Removing tons of debris is its own reward, of course, but California also benefits from data that can highlight the top ten items found each year and other longitudinal findings.

Among the oldest mobile applications is the Marine Debris Tracker, which was originally developed in 2010, soon after smartphones began to dominate the popular phone market. The longevity and diversity of these apps reveal the heterogeneity of goals, objectives, and missions for those interested in tracking trash. This represents both a challenge and opportunity. For instance, the availability of digitized data, even among low-resource organizations, provides an opportunity to leverage such data at much broader scales, transforming local and regional efforts into statewide analyses.

However, comparing assessments across programs to assemble a statewide dataset for commonly collected data remains elusive, due in part to the incompatibility of the toolsets.

More recently, scientists at the Moore Institute for Plastic Pollution Research (Moore Institute) have made strides in optimizing some sources of friction regarding these diverse data sources. They developed the Trash Taxonomy Tool to offer crosswalking for divergent trash classifications and achieve harmonization of related data sources (Hapich et al., 2022). The Trash Taxonomy Tool promises to "facilitate improvements in assessing trends across space and time, identifying targets for mitigation, evaluating the effectiveness of prevention measures, informing policymaking, and holding producers responsible."

Each method has its own training and re-training frequency. Some – such as the Marine Debris Tracker, Rubbish, and Litterati – offer self-paced, self-guided training without any formal certification. Others – such as the Southern California Bight Program, SMC, and BAMSC – offer routine in-person training designed to intercalibrate practitioner data to offer reduced variability, and program-certified results. Depending on the data quality objectives, one form of training and data collection might be more desirable than another.