SCOPE OF WORK

08/30/2022

Effect of Street Sweeping on Wet Weather Pollutant Loading and Concentrations from Southern California Roadways, Phase 1

The primary goal of this Scope of Work (SOW) is to quantify the positive impact of street sweeping on pollutant loading and concentrations from roadways through a field monitoring campaign. In its most basic form, this compares wet weather runoff from swept and unswept road surfaces. The study design adopts an approach of isolating runoff from heavily trafficked asphalt surface segments using simulated storm events, to maximize the opportunity to measure differences in pollutant loads between swept and unswept conditions. The recommended method was derived through consultation with a technical working group (TWG) of SMC Steering Committee members, informed by an extensive literature review that ultimately concluded that the multiple confounding effects reflected within catchment-scale studies (e.g., sampling at outfalls) preclude measuring effects of a street-scale non-structural best management practice (BMP) such as street sweeping.

Many SMC agencies currently assume that street sweeping reduces pollutant loads from 5-10%. Several studies in the literature have documented pollutant masses collected by street sweeping (City of San Diego, 2010-2015; Lloyd et al. 2019; Muhammad et al. 2006; Schueler et al. 2016; Seattle Public Utilities and Herrera Environmental Consultants 2009), which often show measurable masses of pollutants in road debris. There is no generally accepted method to translate loads captured by street sweepers during dry weather into reductions in urban runoff event mean concentrations (EMCs). No study to date has shown an effect of street sweeping on downstream water quality, e.g., at outfalls, nor has any study definitively quantified differences in stormwater runoff concentrations between swept and unswept streets (Kang et al. 2009; Kang and Stenstrom 2008; Muhammad et al. 2006; Pearson et al. 2018). High event-to-event variability in pollutant build-up and wash-off has been identified as a challenge in measuring downstream benefits (or lack thereof). Study designs may have also prevented conclusive findings at outfalls, since the roadway is usually only a fraction of the total contributing catchment. The most common factors used to characterize studies include land use in the surrounding catchment, average daily traffic (or other indicator of road usage), and street sweeping frequency.

A TWG of SMC agency members was convened to prioritize study design elements, in light of the potential challenges and costs associated with a large-scale field monitoring campaign. The TWG recognized that factors such as climate, road usage, road surface type, and street sweeping frequency (Table 1) are potentially influencing factors on EMCs. Heavily trafficked, asphalt-surface road or parking lot segments subjected to synthetic rainfall events were prioritized for monitoring in a Phase 1 project because:

- Heavy traffic is presumed to create the greatest particulate pollutant loads, which are also more likely to be removed by street sweeping.
- The majority of road surfaces subject to street sweeping in southern California are asphalt. Concrete road surfaces are typically found on highways.

- Controlled testing using simulated rainfall limits confounding effects of storm-to-storm variability in rainfall that drives the wash-off process.

Simulated storm events over isolated segments of roadways or parking lots are proposed as the main means for data collection, to reduce the influence of confounding effects (natural rainfall variability, runoff from other parts of the catchment, etc.) noted in previously published field studies, supplemented by sampling a limited number of natural storm events for validation. Outfall monitoring is excluded because of the confounding effects of runoff from other land-uses across the catchments.

Table 1. List of potential influencing factors to be tested in this study

Factor	Variables
Climate	Rain fall volume Rainfall intensity Rainfall duration
Road Use	Average Daily Traffic Number of lanes Light duty vs heavy duty vehicles Road classification*: interstate, arterials, collectors, local roads
Road surface	Material of construction Level of service
Sweeper frequency	Static frequency Time since rainfall

*https://safety.fhwa.dot.gov/speedmgt/data_facts/docs/rd_func_class_1_42.pdf

This SOW details seven tasks for Phase 1. Initial tasks are designed to help define and refine the study design and workplan. Later tasks will implement the sampling and analysis.

The anticipated outcome of the testing is to quantify the extent to which street sweeping influences wet weather runoff EMCs for pollutants selected by TWG. Should the testing prove successful in detecting differences in wet-weather EMCs between swept and unswept road segments, the method can be applied in other scenarios in a future Phase 2 effort, broadening the scope to capture more of the potential influencing factors from Table 1, with additional information to support management decisions. For example, measuring EMCs after variable durations of pollutant build-up may support cost-benefit decisions on sweeper frequency. Whether differences arise on roads with different levels of service may help prioritize resource allocation for sweepers or road re-surfacing. Each additional factor explicitly tested increases the number of sampling events exponentially, then multiplied by the number of replicates. The TWG focused on narrowing the scope in Phase 1 to support effective resource allocation.

Task 1. Expand the Technical Working Group

The TWG of SMC member agencies convened to establish this Phase 1 scope of work will be expanded for project implementation, at the beginning of the project. The charge to the TWG is to: a) finalize the study design created at the initiation of the study (Task 2), b) assist the Project Study Team in identifying and accessing study sites, c) review interim results during simulated and natural rainfall events to refine and improve the study design, and d) review and approve final oral and written reports. The TWG will be facilitated by the Project Study Team, but ultimately reports to the Steering Committee.

Product: List of TWG members

Task 2. Finalize the Phase 1 Workplan

As described previously, the Phase 1 study design reflects an underlying motivation to maximize the opportunity for detecting differences in EMCs from swept versus unswept road segments, that has previously eluded conclusive evidence quantifying effects.

The Phase 1 Workplan will ideally sample runoff from swept and unswept segments of the same street or parking lot (see Task 3 for site selection). Sweeper type is not considered a factor to be tested since the literature is clear that regenerative or vacuum-assisted sweepers provide far superior performance compared to mechanical sweepers, in terms of the mass of street debris captured.

Sweeping will occur at the project outset on all segments to establish similar initial conditions[1]. An iterative process follows, whereby simulated rainfall events are applied to a confined, known extent of road surface, runoff samples are collected, and a dry weather period specified by the TWG follows for pollutant build-up. After the specified antecedent dry weather period (ADWP), sweeping occurs on the designated “swept” road segment(s), and the subsequent simulated rainfall and sampling activities occur on both swept and unswept segments (Figure 1 and 2). The process is repeated for as many iterations as deemed necessary by the TWG for statistical confidence. Multiple “swept” and “unswept” segments may be tested concurrently, depending on resource effort and suitable site identification (Task 3).

TWG will establish the desired initial conditions, determine the ADWP, and the number of concurrently tested segments. Street sweeping is often conducted bi-weekly or twice per month for many member agencies; however, a longer ADWP should promote pollutant build-up. Consideration should be given to initiating the study with a monthly ADWP to establish whether differences between swept and unswept EMCs are detected. If successful, the study plan can expand to investigate the influence of sweeping frequency by testing with shorter ADWP.

[1] An alternative approach would initiate the project with sweeping on only the “swept” segments. In this manner, the initial sampling would reflect wash-off after potentially a very long ADWP, depending on when the study is initiated, conditions which may not be able to be repeated.

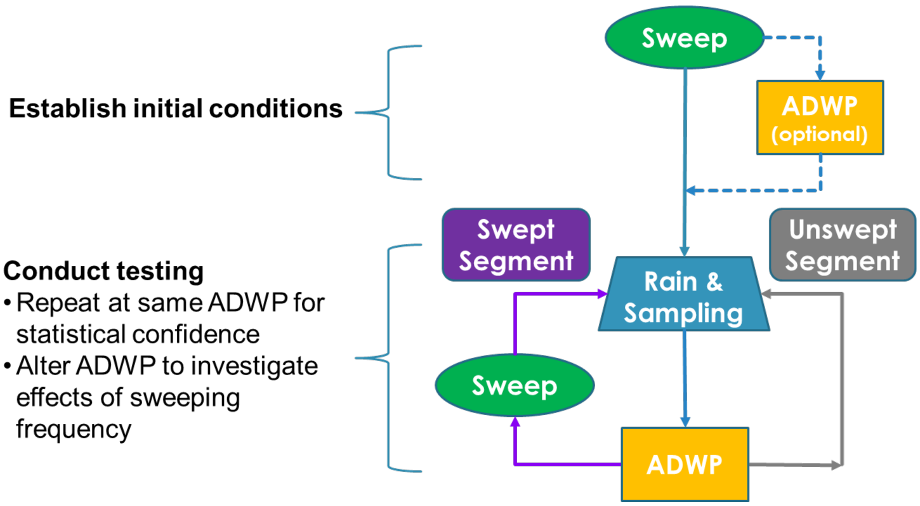

Figure 1. Testing overview.

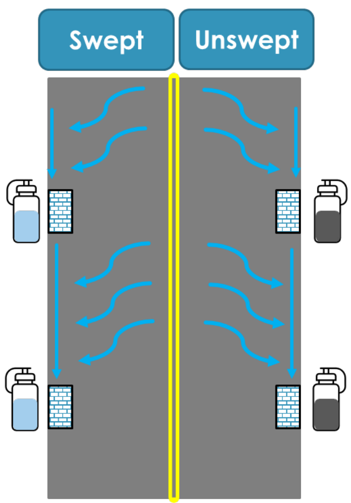

Figure 2. Conceptual field monitoring site whereby multiple swept and unswept road segments are subject to simulated rainfall concurrently. The presence of a catch basin is not required. They are used here as indicators of sampling points where a contributing drainage area can be clearly defined.

In addition to study design, the TWG will approve the Study Team's recommendations for pollutant analytes to be measured. Street sweeping reduces pollutants in runoff by physically removing debris and particulate road deposits, typically with greater success for particles greater than ~75 mm. Removal of other pollutants therefore depends on sediment-attachment, which may also depend on specific combinations of pollutant type and particle size (e.g., heavy metals have been shown to preferentially adhere to smaller particle fractions).

The Study Team will measure total suspended solids and total trace metals, at a minimum, in runoff from swept and unswept catchments. Other analytes to be considered include dissolved trace metals, polynuclear aromatic hydrocarbons (PAHs), total nitrogen, total phosphorus, toxicity, microbiology (e.g., total or fecal coliform, enterococcus and/or E. coli), grain size of suspended particulates, at a minimum. The Workplan shall also defined quality assurance and quality control limits for field sampling and laboratory analysis.

Road debris captured by the street sweepers should be appropriately stored for possible future analysis, such as particulate-attached pollutant concentrations, particle size distribution, and mass, should resources become available. These analyses are not included within the current scope of work.

TWG will determine the number of simulated and natural rainfall events to be sampled, depending on member agency priorities and level of effort. The TWG should also determine the target intensity (or range of intensities) of simulated rainfall, and the characteristics of natural rainfall events eligible for sampling. Logistics of the rainfall simulator may influence the range of intensities for testing, but again simulated rainfall characteristics should reflect the best possible conditions for detecting measurable differences between swept and unswept segment EMCs. Hydrologic parameters to be measured include rainfall applied and flow.

Product: Workplan approved by the TWG and Steering Committee

Task 3. Select and Set Up Sampling Sites

The first step for implementing the Workplan is to identify sites for sampling. SMC members will be needed to find sites where street sweeping controls exist or are able to be introduced and where the drainage area for each monitoring location is measurable and isolated to asphalt surfaces. Members will be expected to provide or enable traffic control, access to catch basins and right of way access to sample public easements. Study sites include any asphalt surface "segment" subject to vehicle traffic, and may include active roadways as well as travel lanes within or accessing parking lots. The size of the asphalt segment tested may be constrained by the rainfall simulator.

Considerations for site selection include:

- Priority should be given to "average" condition segments with homogeneous surfaces. Newly surface or soon-to-be resurfaced asphalt are less desirable for testing.
- Heavily trafficked/traveled segments, or segments within industrial areas are likely to promote heavier pollutant loadings, and thus improve the potential for detecting pollutants and measuring differences in EMCs.
- Consistent characteristics are identified in condition and traffic amongst segments, especially if/where swept and unswept segments are not on the same street or parking lot.

Product: list of sampling sites with documentation

Task 4. Simulated Rainfall Events

At least three sampling events are suggested to be conducted using simulated rainfall directed over isolated roadway segments. Simulated rainfall is used to: a) remove variability due to differences in rainfall complicating comparisons between site-events, b) confirm storm characteristics such as rainfall volume or intensity, 3) control for antecedent rainfall, 4) control for catchment area, and 5) ensure timely completion of the study.

Constant rainfall intensity will be applied during each simulated rainfall to simplify flow measurement and sample compositing, according to the rate(s) determined by the TWG in Task 2. Each simulated rainfall event shall be documented with multiple measuring devices for rainfall across the test area, whether swept or unswept. The test area is limited to the road surface to ensure the best opportunity for measuring effects. The runoff volume for each simulated event will be documented using either flow sensors or total volume capture. All measurement devices shall be calibrated prior to sampling.

Simulated rainfall samples will include water collected from the rainfall simulator prior to impacting the street surface, and street runoff samples after being rained upon. All samples will be composited across the entire storm. Subsamples will be collected from the composite according to methods used by the SMC (SMC Chemistry Guidance Manual 2xxx).

Samples will be analyzed for the analytes listed in the Workplan from Task 2.

Product: Sampling summary memo

Task 5. Natural Rainfall Events

A limited number of natural rainfall events will be collected from both swept and unswept road surfaces at the street-scale as a means to validate the results collected from the simulated rainfall events. Natural rainfall samples should be collected in as similar a fashion as possible to the simulated rainfall events, with the exception that samples shall be flow-weighted for compositing.

Product: Sampling summary memo

Task 6. Data Analysis

Upon completion of the simulated and natural rainfall events, data management should be conducted to ensure the project data are complete, qualified where necessary, and fully documented with metadata.

Data analysis shall focus on statistical evidence supporting differences, or lack thereof, between EMCs from swept and unswept road segments. Uncertainty and/or confidence in the data will be quantified. Data characterization using plots or tables of average concentration per factor(s) will be prepared.

Recommendations for Phase 2 testing scope will be prepared, as appropriate.

Product: Oral presentation of study results to the TWG and Steering Committee.

Task 7. Reporting

A final report will be prepared by the Study Team describing the goals of the study and study question(s), methods used to answer the question(s), answers to the study questions (from Task 6), and a discussion describing the final conclusions and limitations from the study. All raw data and meta data from Task 6 will also be submitted.

Product: Draft and Final Report reviewed and approved by the TWG and Steering Committee

Schedule

TASK	PRODUCT	DEADLINE (months from project start)
1) Technical Working Group	List of TWG members	1
2) Finalize Workplan	Workplan	3
3) Set Up Sampling Sites	list of sampling sites	6
4) Simulated Rainfall Events	Sampling summary memo	12
5) Natural Rainfall Events	Sampling summary memo	18
6) Data Analysis	Oral presentation to TWG	24
7) Reporting	Draft and Final Report	30

Budget Estimate

Task	Cost per Event	Events	Subtotal
Equipment (rainfall simulator, flow meters, etc.)	$50,000	1	$50,000
Conducting each simulated rainfall event (2 sampling locations per simulated event)	$10,000	3	$30,000
Natural rainfall event sampling (2 sampling locations per natural event)	$10,000	2	$20,000
Water quality analysis per sampling event* (2 composite samples per event)	$3000	5	$15,000
Data management	$24,000	1	$24,000
Reporting	$15,000	1	$15,000
Total			$154,000

* Solids, nutrients, trace metals, general chemistry, PAHs, microbiology. Not included are microplastics or pesticides.