Sweeper Summit 2026 Stormwater/Sweeper Nexus Workshop

Hosted by the National Municipal Stormwater Alliance

Agenda

Section 1 - Stormwater and Sweeping Basics and the CS=CW Initiative Overview

- Steven Calvillo, TYMCO
- Seth Brown, PhD, PE, Executive Director, NMSA

Section 2 – The Latest on Stormwater and Sweeping Research

- Jamie Houle, PhD, PE, UNH Stormwater Center
- Elizabeth Fassman-Beck, PhD, Department Head, Engineering, Southern California Coastal Water Research Project

Section 3 - Enhanced Street Sweeping, Case Study, and Workshop Wrap Up

- Roger Sutherland, PE, Owner, Cascade Water Resources LLC
- Maribel Guerrero, MPA, Director of Engineering and Public Works, City of Brownsville, TX
- All speakers for Q&A and Discussion

Housekeeping

- This webcast is being recorded
- Recording of the event and a PDF of slides will be made available
  - https://www.youtube.com/@nationalstormwateralliance
- 3.5 PDHs are available for online participation via NMSA
- Attendee input via typed in questions
- Please send technical/technological questions via chat function

Section 1 – Stormwater and Sweeping Basics and CS=CW Initiative Overview

History & Basics of Street Sweeping and Stormwater

Sweeper Summit

November 3, 2026

Steven Calvillo

TYMCO, Inc.

About this Session

Session Description

- Street dirt presents a dual potential risk for stormwater and air quality affecting the environment as well as human health. We will examine the reasons for sweeping, sources of dirt and debris on paved surfaces, environmental contaminants, environmental regulations, which incentivize sweeping, and street cleaning studies.

Overview:

1. **History of Sweeping and Sweeper Technologies**
2. **Reasons for sweeping**
   a. Origins of street sweepings
   b. Contents of street sweepings
   c. Regulations pertaining to sweepers / sweeping
3. **Review of Select Sweeper Studies**

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Sweeping History and Sweeper Technology Review

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Early Accounts of Street Cleaning

Late 1700s - Philadelphia – Benjamin Franklin

- First street cleaning program in the USA (Fleming 1978, Michaels 1977)

Late 1890s - George A. Warring, Jr.

- Designer and advocate for Municipal Separate Storm Sewer Systems
- Ended cholera and yellow fever epidemics in Memphis, TN
- New York City – White Wings
  - Decline in sickness and death rate 2.68% (1882-1894) to 1.96% (1897)
  - Made NYC a model for other cities (Armstrong et al. 1976; Fleming 1978; Richmann 1962; Soper 1909).

1909 – Modern Methods of Street Cleaning (George A. Soper, Ph.D.)

- Published by the American Society of Civil Engineers
- First comprehensive accounting of street cleaning methods in New York and various European cities



Richmann 1962

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Street Sweeper Technologies

Society of Automotive Engineers (SAE International) J2130-1 Standard

Identification of Self-Propelled Sweepers and Cleaning Equipment Part 1 - Machines with a Gross Vehicle Mass >5000 kg
(2008, 2015, 2021, 2026)

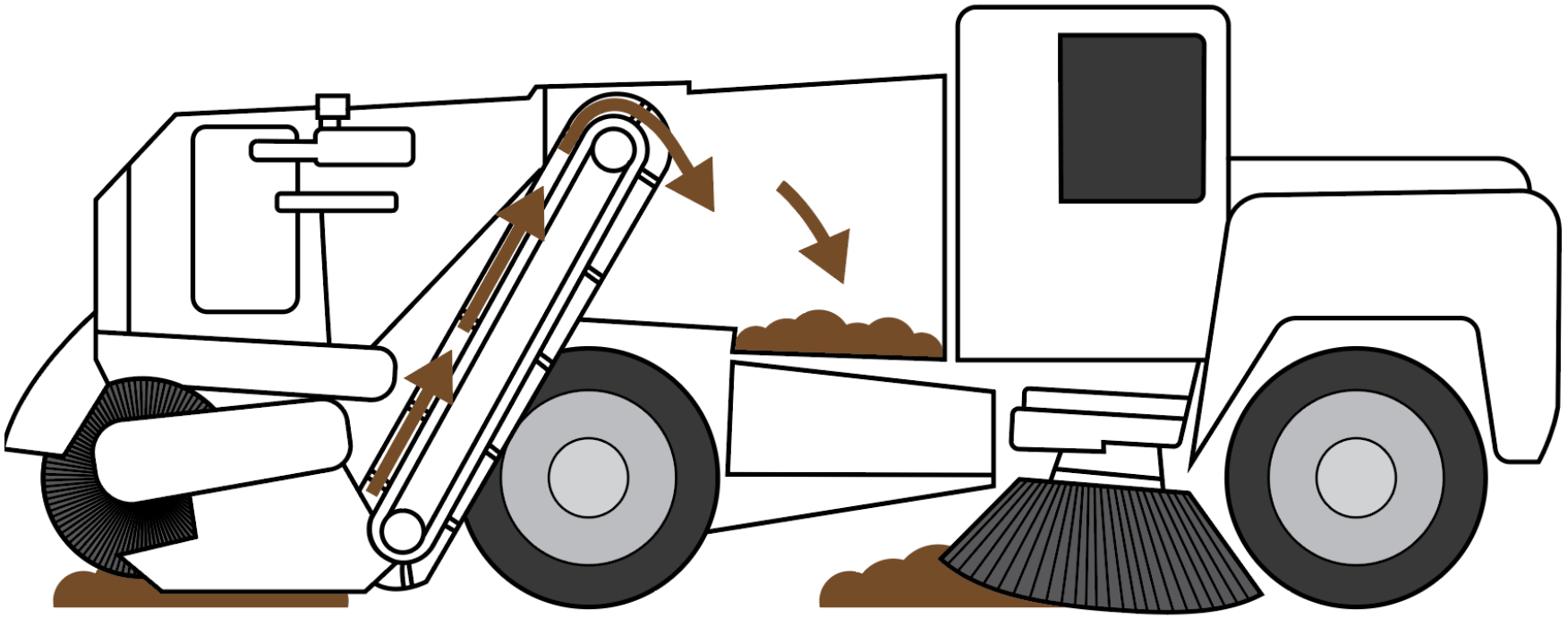
1. Mechanical

2. Vacuum

3. Regenerative Air

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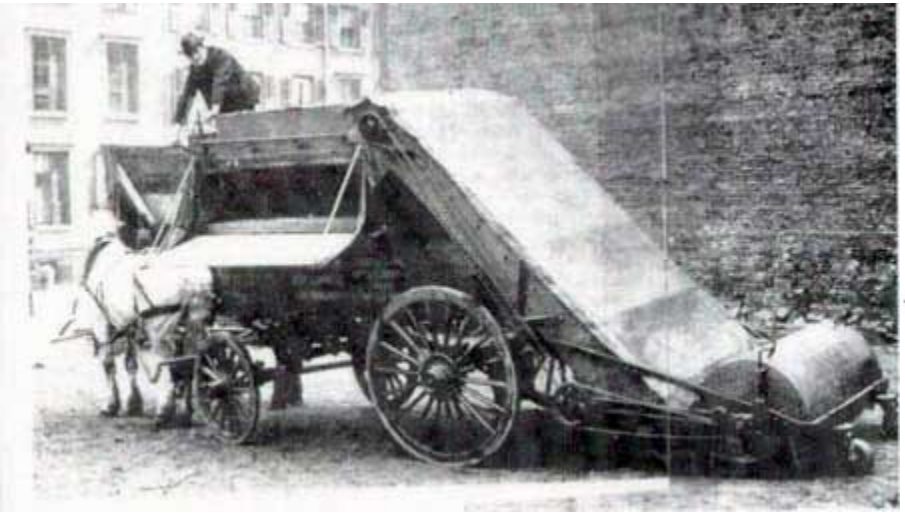
Mechanical Sweepers



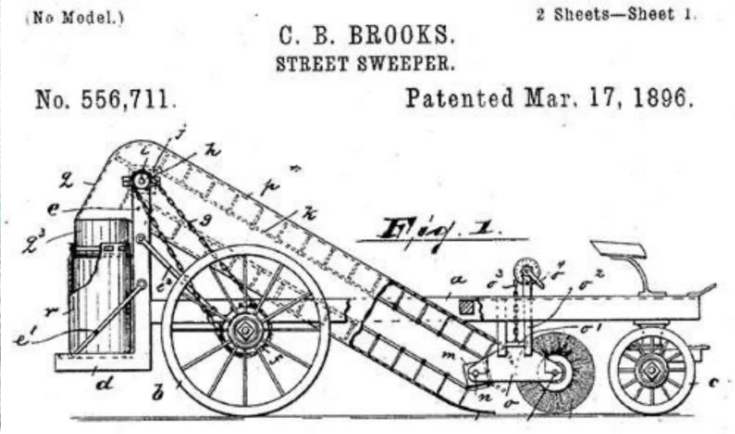
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Mechanical Sweepers

1843 – Horse drawn, Invented in Manchester, England – Joseph Whitworth (Richmann 1962)
1868 – Self-propelled sweeper used to clean railroad tracks (Kidwell-Ross 2012)
1891 – Steam-powered sweeper (Kidwell-Ross 2012)
1895 – Charles B. Brooks, Newark New Jersey, made improvements (Helton 2018)
1911 – First internal combustion powered mechanical broom sweeper (Richmann 1962)
1914 – The first practical and commercially successful self-propelled mechanical sweeper was sold in Boise, Idaho. Invented by John M. Murphy in a partnership with American Tower and Tank Company, which would later become Elgin Sweeper Company (Richmann 1962)



(Richmann 1962)

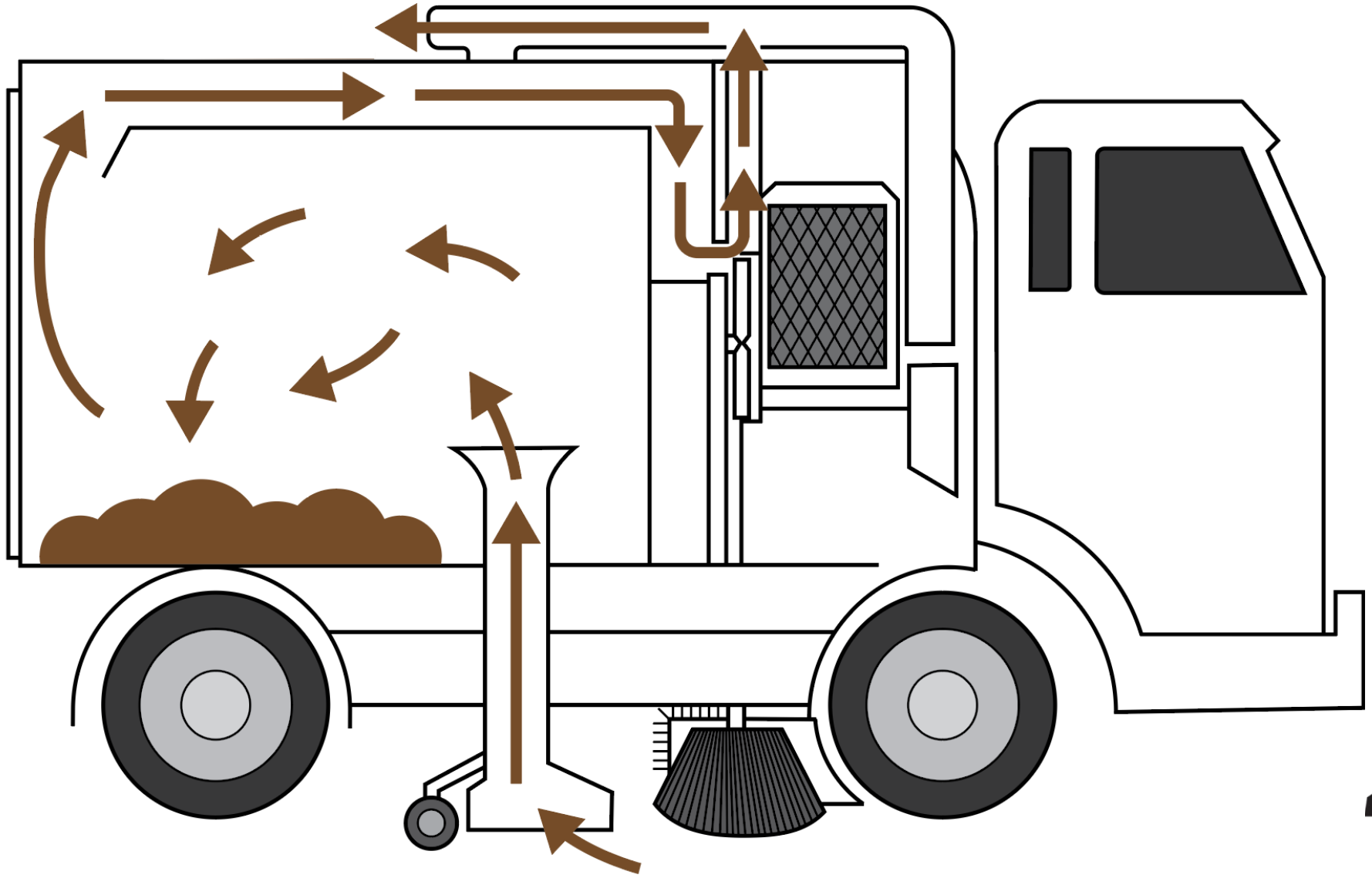




Boise, Idaho 1914
(Richman 1962)

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Vacuum Sweepers



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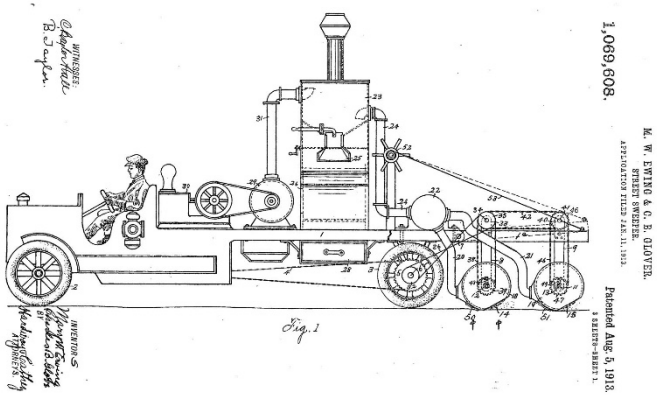
Vacuum Sweepers

1913 – Patent applications filed by Mary W. Ewing & Charles B. Glover of Houston, Texas.

1913, 1914, 1916 – Patent applications filed by Bernard Kern of Sandusky, Ohio for the Waycleanse vacuum street sweeper.

1960 – First truck mounted sweeper (Bucher Municipal 2025)

1970s – Gained popularity due to concern with environmental quality (Armstrong et al. 1976)





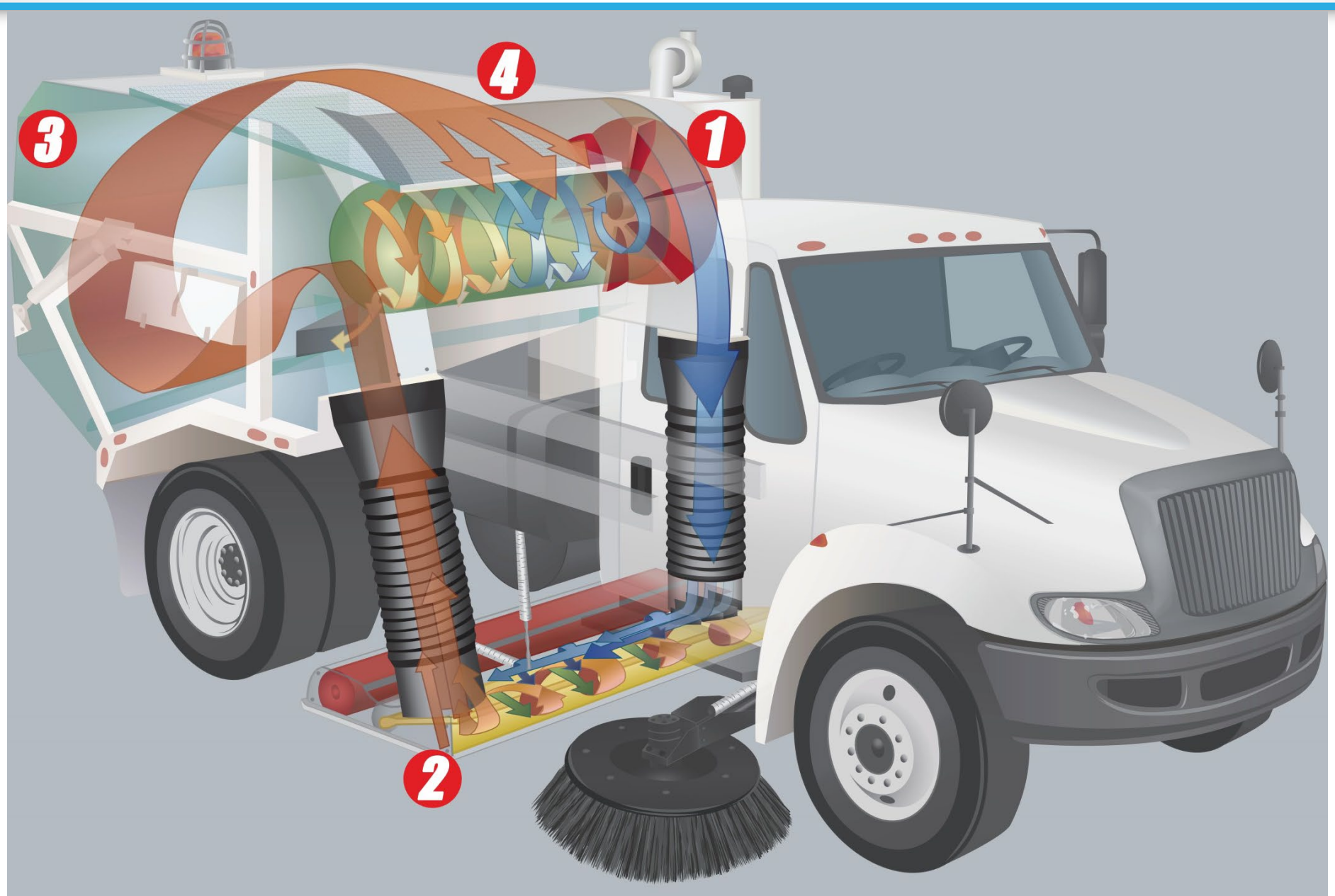
(Leggett 1921)



(Bucher Municipal 2025)

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Regenerative Air Sweepers



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Regenerative Air Sweepers

1946 – Founding of Young Brothers Construction

1961, 1963 – Patents filed for Slurry Seal machine

1966 – Patents filed for “Air Flow Surface Cleaning Apparatus” by B.W. Young, TYMCO founder

1980s – Gained popularity

1984 – Dustless sweeping

Today – At least 7 manufacturers of Regenerative Air Sweepers with multiple models each









Why Sweep?

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Why Sweep?

- Infrastructure Protection, Maintenance, & Aesthetics
- Stormwater Runoff & Air Quality
  - Human health
  - Wildlife protection
- Environmental Regulation

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Environmental Regulation

- **Federal Water Pollution Control Act (FWPCA) 1948**
  - First major US water quality legislation
- **Clean Water Act (CWA) 1972**
  - Set standards for industry discharges & **surface water**
  - Established the **National Pollutant Discharge Elimination System (NPDES)**
    - Requires permits for **point source** discharges
- **1981 Revisions**
  - Streamlined the municipal construction grants process, improving the capabilities of treatment plants built under the program
- **Water Quality Act (WQA) 1987**
  - Requires permits for **non-point source** discharges
    - Construction activities
    - Industrial activities
    - Municipal Separate Storm Sewer Systems (MS4s)
      - Phase I (issued by EPA in 1990) – urbanized areas ≥ 100,000 population
      - Phase II (issued by EPA in 1999) – urbanized areas ≥ 50,000 population
        - » Introduced Six Minimum Control Measures

(USEPA 2013, 2022)

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Environmental Regulation

- **Minimum Control Measures (MCMs) / Best Management Practices (BMPs)**

1. Public education and outreach (e.g., distribution of educational materials about the impacts of stormwater discharge on water quality);

2. Public participation and involvement (e.g., public hearings on stormwater regulations)

3. Detection and elimination of illicit discharges (e.g., enforcement, inspections, & fines)

4. Runoff control for construction sites (e.g. silt fences)

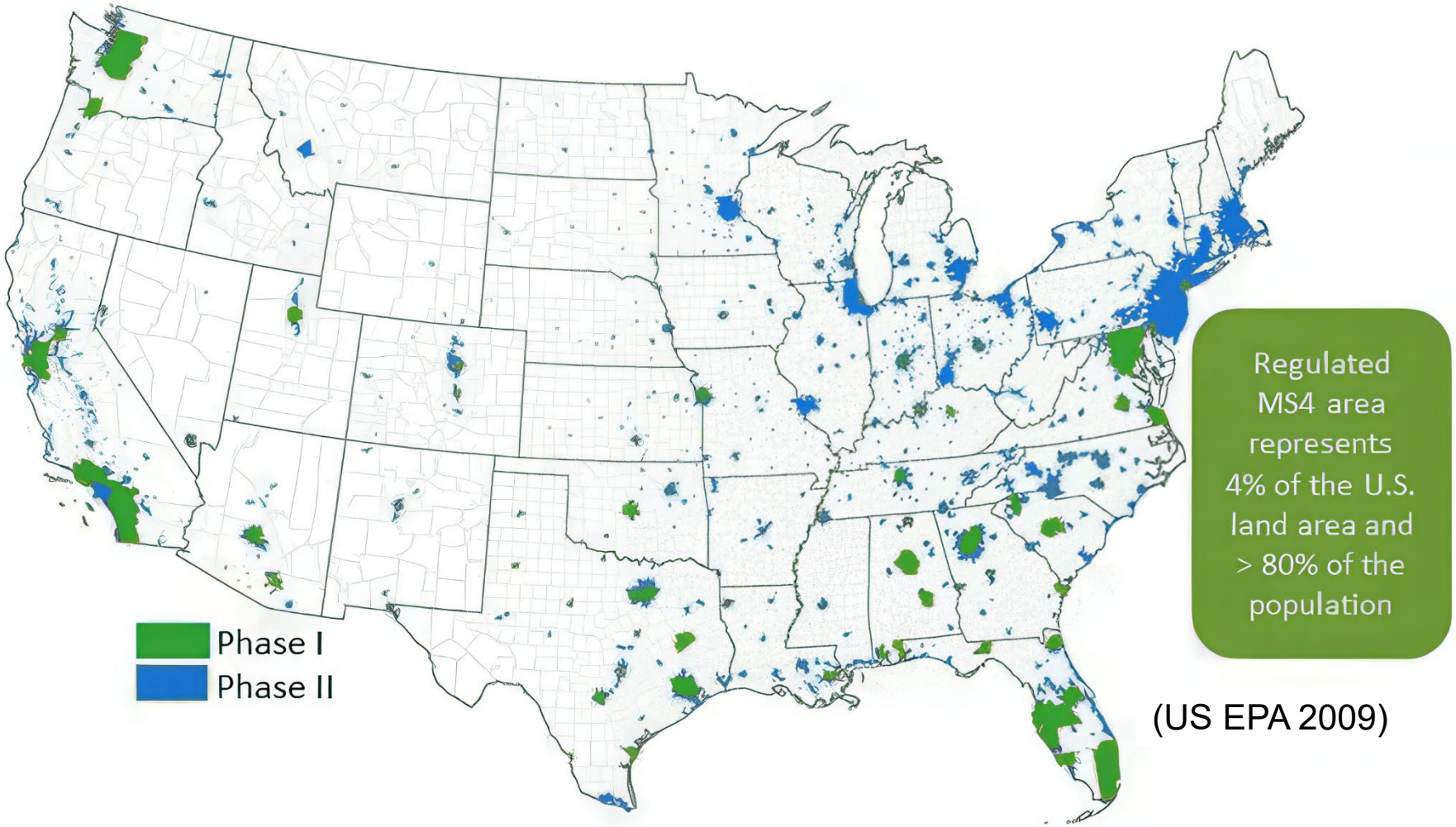
5. Development and maintenance of on-site wastewater treatment systems (e.g., detention ponds, wetlands, porous pavement)

6. Pollution prevention/good housekeeping with control measures (e.g., **regular street sweeping**, catch basin cleaning)

(USEPA 2013)

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National Map of Regulated MS4s



Regulated MS4 area represents 4% of the U.S. land area and > 80% of the population

(US EPA 2009)

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Where does Street Dust come from?
What is in Street Dust?

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Origins of Street Dust

Soil and sediment

Vegetation

Motor vehicles

Industrial emissions

Litter

Animal carcasses



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Environmental Contaminants in Street Dust

Metals

Organics

Nutrients

PM_{10} and $PM_{2.5}$



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Metals

- Commonly found on streets: Aluminum, Cadmium, Chromium, Copper, Lead, Nickel, Zinc

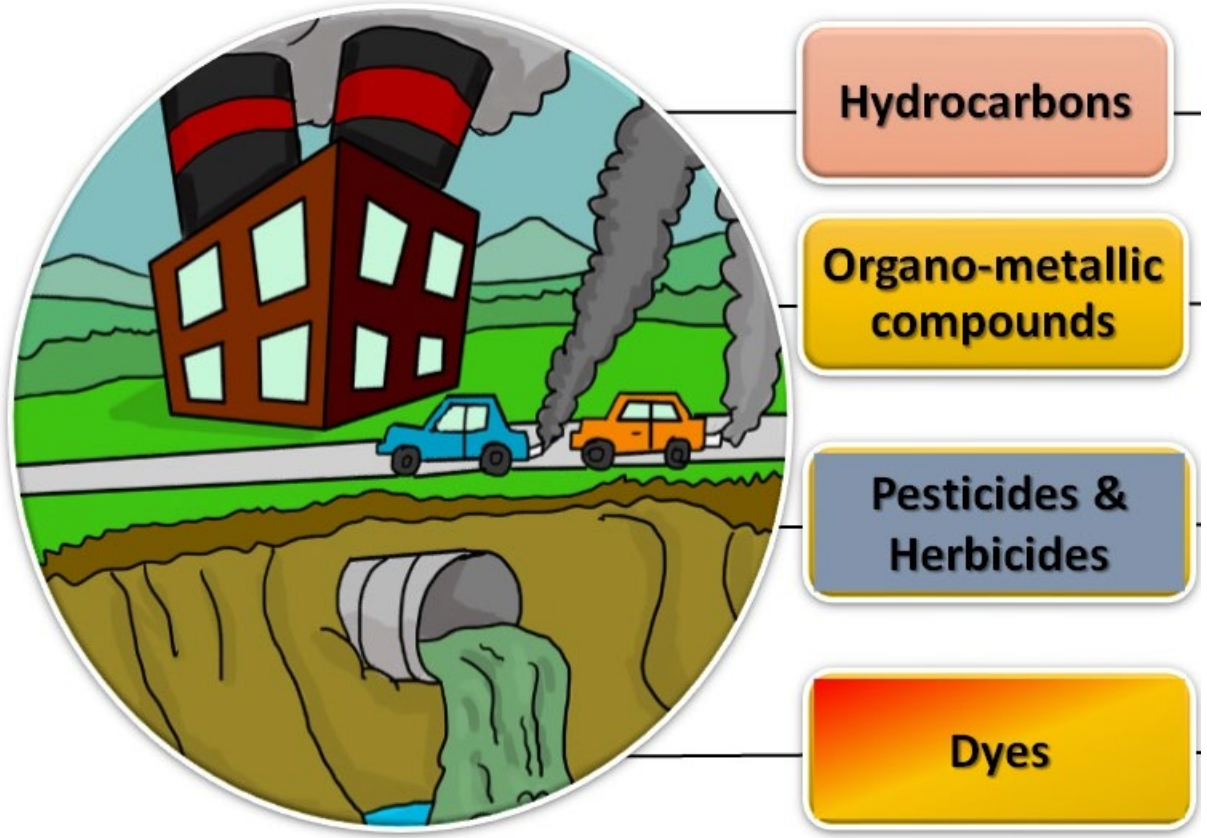
- From vehicle wear, vehicle fluids, brake dust, weathering of structures, crustal materials



(Iowa State University 2022)

Organics

- Polycyclic aromatic hydrocarbons (PAHs) – Combustion and leakage of fossil fuels
- Plastics
  - Phthalates – Chemicals used to make plastics stronger. Pose a threat as endocrine (hormonal) disruptors.
  - 6PPD-quinone – Rubber stabilizer found in tires. Causes acute mortality in vulnerable aquatic species like the coho salmon.
- Pesticides



(Touliabah et al. 2022)

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Nutrients

- Nitrogen and Phosphorus
- From fertilizer, yard waste, vegetation, animal waste
- Eutrophication – over-enrichment of nutrients in water
- Harmful Algal Blooms (HABS) – Decay of excess algae affects odor and taste of water, depletes oxygen, and contribute to hypoxia in aquatic wildlife
- Blue-green algae (cyanobacteria) produces neurotoxins, which can be dangerous to humans, pets, and aquatic wildlife

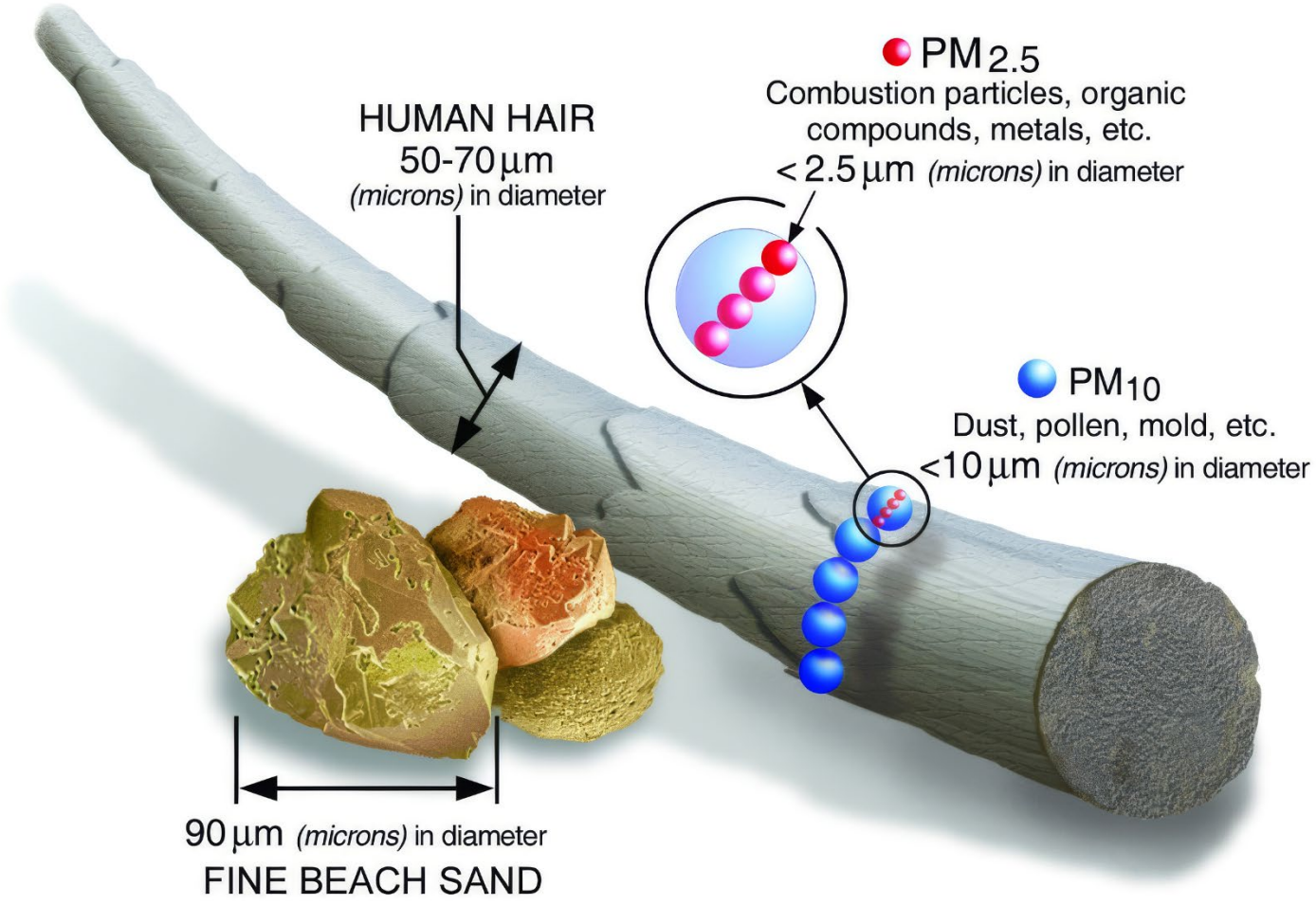


(Pugliese 2022)

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Particulate Matter (PM)

- PM implies no chemistry
- Human health consequences
  - Cardio-vascular and pulmonary impacts when exposed in high concentrations or for extended periods



Source: www.epa.gov/pm-pollution/particulate-matter-pm-basics

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Highlights of Sweeper Studies

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Highlights of Sweeper Studies

- **Lee et al., U.S. Naval Radiological Defense Laboratory (NRDL) (1948-1959)** – Evaluated sweepers for removal of nuclear fallout material - 12-33% pickup of simulant material
- **Sartor and Boyd (1972) US EPA Report** – Reviewed data from NRDL, manufacturers, & municipalities – 11-78% pickup
- **Pitt (1979) US EPA Report** – Established a method for testing, began development for Source Loading and Management Model (SLAMM)
- **Athayde et al. (1983) Nationwide Urban Runoff Plan (NURP) US EPA Report** – 1978-1983, $30 million (approximately $114 million today), <50% reduction of concentrations
- **Sutherland & Jelen (1997)** – "Street Sweeping Can be an Effective BMP" - Simplified Particulate Transport Model (SIMPTM) showed up to 80% reduction of annual TSS washoff by sweeping bimonthly to weekly with modern air sweepers.

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A Brief History of Sweeper Studies

- **South Coast Air Quality Management District Rule 1186 (1999)**
  - Livestock operations
  - Unpaved roads
  - Sweepers - PM_{10} Street Sweeper Test Protocol
- **City of Toronto Clean Roads to Clean Air (2005)**
  - PM_{10} and $PM_{2.5}$ Street Sweeper Test Protocol
  - Operational On-Street Sweeper Test Protocol
  - ISO 14034:2016 Environmental Technology Verification (ETV)
- **USGS Scientific Investigations Report 2012–5292 (Sorenson 2013)**
  - Source Loading & Management Model for Windows (WinSLAMM) showed improved phosphorus and solids reductions for regenerative air sweepers over mechanical and vacuum sweepers in Cambridge, Massachusetts.

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Calvillo et al. 2015

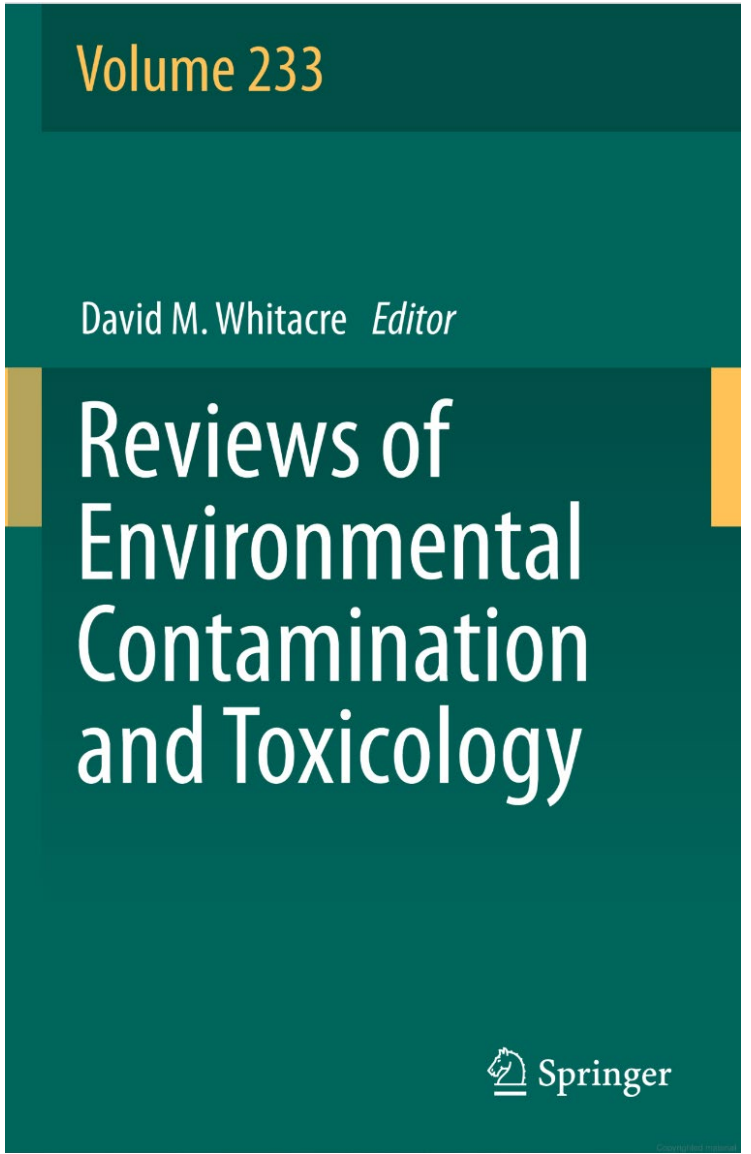
Most of the material contained in this presentation was reviewed in *Street Dust: Implications for Stormwater and Air Quality, and Environmental Management Through Street Sweeping* by

Steven J. Calvillo, M.E.S., M.B.A. – Marketing & Technical Communications, TYMCO, Inc.

Bryan W. Brooks, Ph.D. - Distinguished Professor, Environmental Science and Biomedical Studies, Baylor University

E. Spencer Williams, Ph.D., DABT – Former Research Assistant Professor, Environmental Health Science Program, Baylor University. Currently a Toxicologist at NASA.

Published in *Reviews of Environmental Contamination and Toxicology. Volume 233.*



Calvillo et al. 2015

Objectives

1. Critically review the available literature regarding street dust and potential impacts on stormwater and air quality

2. Develop an understanding of available street sweeping technologies and their relative efficacy

3. Extrapolate the relative efficacy of multiple street sweeping technologies to the context of ecological risk and human health risk

4. Provide recommendations for future research studies

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Calvillo et al. 2015 Literature Breakdown

- Searched Web of Science using key words
- (1,187) documents - “street dust,” “road dust,” “urban dust,” or “roadway sediments”
- (89) documents - “street sweeping,” “street cleaning,” “road sweeping,” “road cleaning”
- (49) documents addressed street cleaning
- (9) documents compared sweeper technologies
  - (6) empirical studies / (3) reviews based on computer models
  - (7) government reports / (2) peer reviewed journal articles
  - (0) made a comparative risk assessment to human health and the environment

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Calvillo et al. 2015

Conclusions

1. **Street dust contains significant concentrations of contaminants that have the potential to negatively impact human and ecological health.**

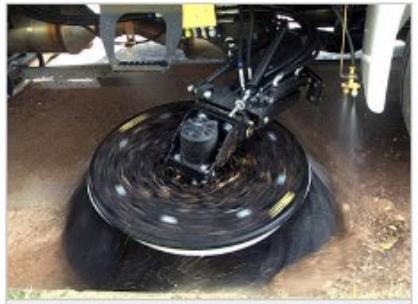
2. **Regenerative air sweepers appear to be most effective at collecting the smallest particles and preventing re-entrainment of particulate matter.**

3. **Several variables make it difficult to compare various sweeper studies, including:**
   a) Test protocols, pickup material
   b) Customization of sweeper settings, options, and conditions
   c) Street conditions, pavement type, crown, slope, existence of curb and gutter
   d) Operator error, sweeping speeds, time of year/weather, local climate

4. **No widely accepted protocol for assessing the effectiveness of street cleaning presently exists.**
   a) The City of Toronto Sweeper test protocols represent a reasonable model for future research.
   b) Recommend a tiered risk assessment approach for evaluating sweeper technologies by starting with a controlled model and gradually introducing variables, approaching “real world” conditions.

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More Resources on tymco.com/environment



Why You Should Sweep

Environmental Benefits of Street Sweeping

LEARN MORE



Street Cleaning Technologies

Three Main Types of Sweepers

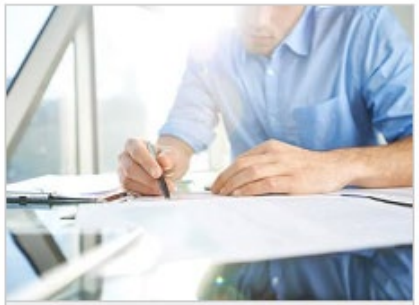
LEARN MORE



Alternative Fuels

Compressed Natural Gas (CNG) Sweepers

LEARN MORE



Environmental Studies & Articles

Includes Peer Reviewed Scientific Journal Articles

LEARN MORE



Dustless Sweeping Technology

Dustless Sweeping Began in 1984 at TYMCO

LEARN MORE



Stormwater Runoff Quality

Preventing Water Pollution

LEARN MORE



Air Quality

Cleaner Air by Reducing Emissions

LEARN MORE

Environmental Technology Verification (ETV)

ETV Validates Performance Claims

LEARN MORE

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800-258-9626



Clean Streets = Cleaner Waters Initiative Overview and Stormwater 101

Sweeper Summit Stormwater/Sweeper Workshop

— November 3, 2026 —

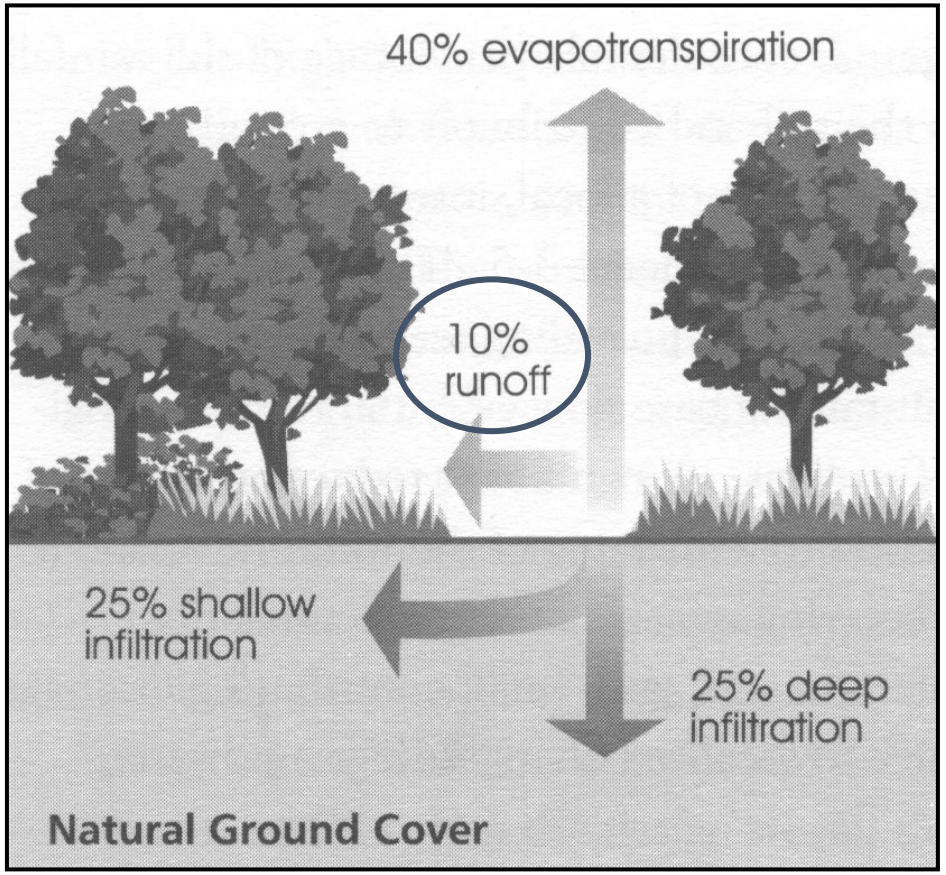
Seth Brown, PhD, PE | *Executive Director, NMSA*

Agenda

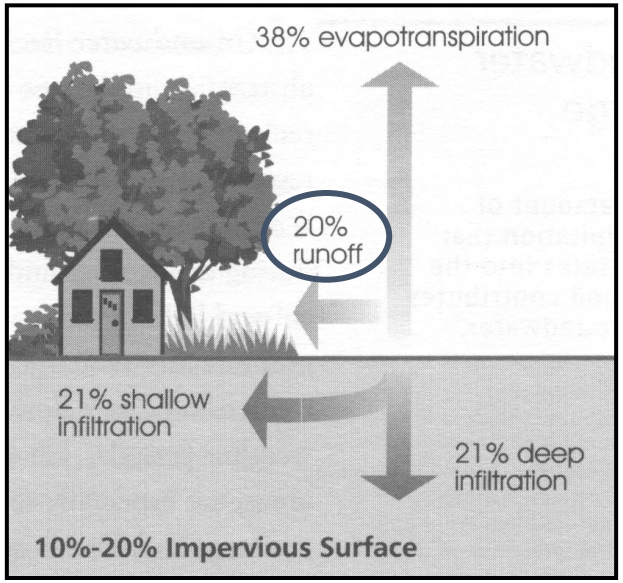
- Stormwater 101 – and Ties to Sweeping
- NMSA Background/Overview
- CS=CW Initiative Background Updates
- Wrap up

The Impact of Development on Stormwater Runoff

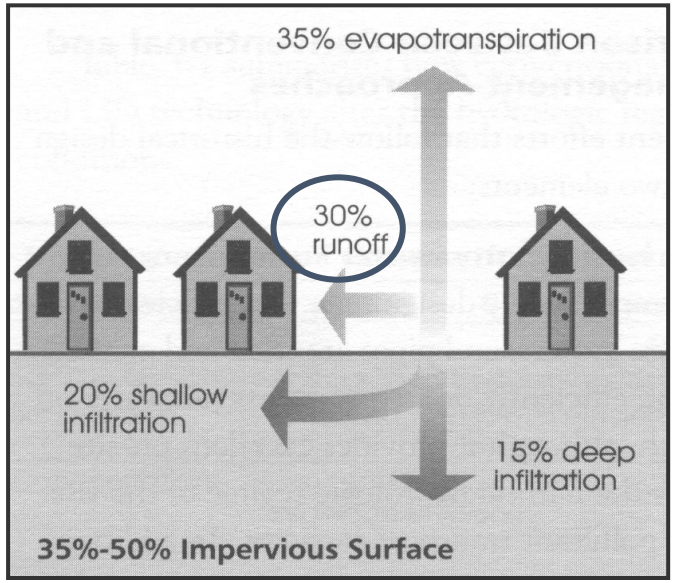
“Natural” Conditions



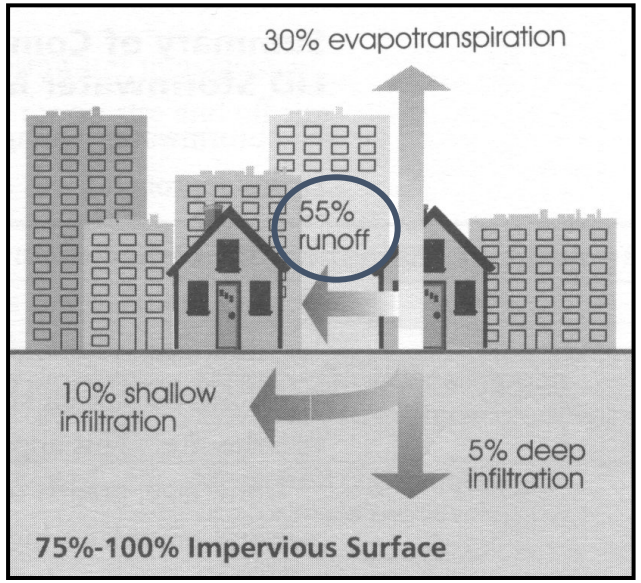
The Impact of Development on Stormwater Runoff



Low Density Development

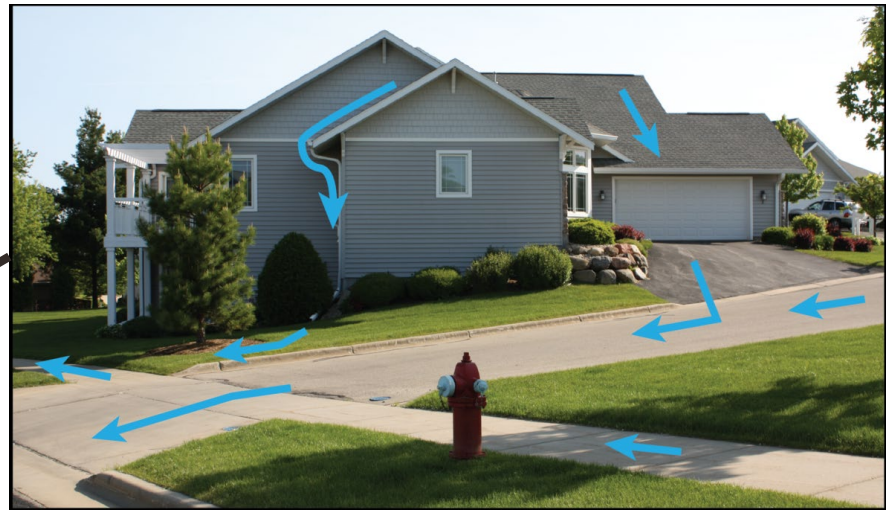


Medium Density Development



Urban Development

What is Stormwater Runoff?



USGS

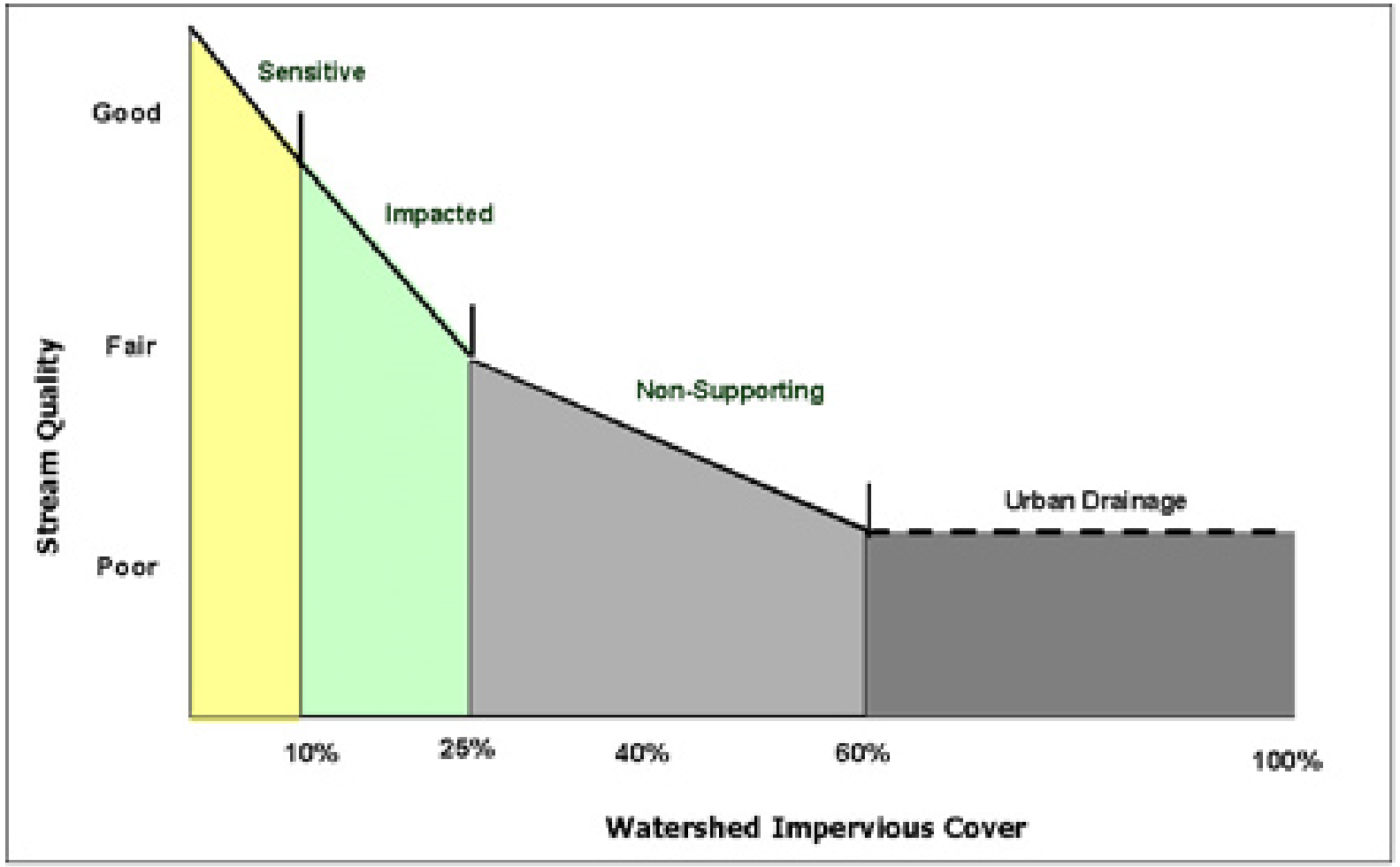


Capitol Region Water District



UC-Santa Barbara

Impervious Cover & Stream Quality



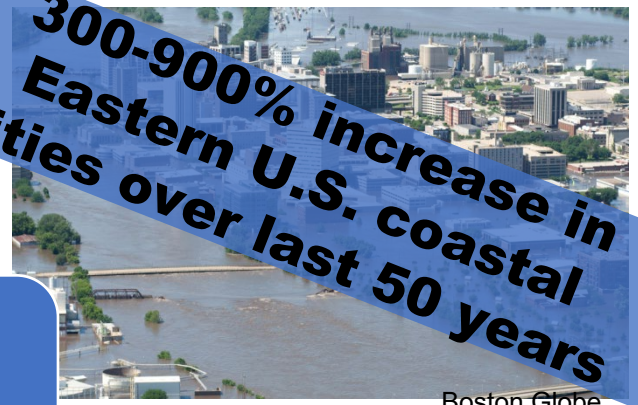
Center for Watershed Protection, 1999

"Only Major Growing Source of Water Pollution" – U.S. EPA



40-80%of sediment in Chesapeake Bay is from eroded urban streams

Forestsforwatersheds.org, 2014



300-900% increase in Eastern U.S. coastal cities over last 50 years

Boston Globe, 2013

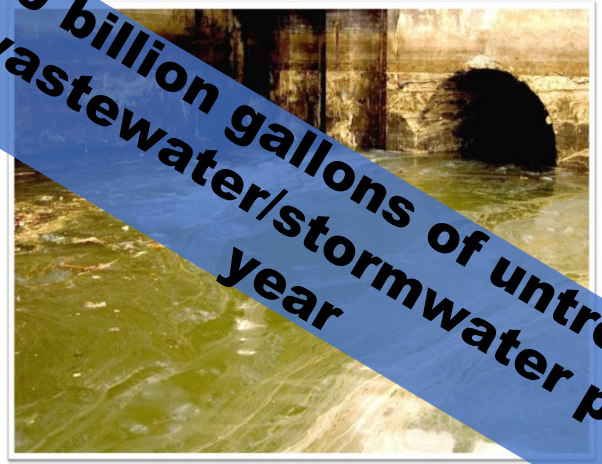
Water Quality Impairments

Flooding

Urban Stormwater Runoff

Combined Sewer Overflows

Ecological Impacts



850 billion gallons of untreated wastewater/stormwater per year

NRDC, 2013



Chesapeake Bay Report Card Has Massive Drop in 2018

WTOP, 2014

Drivers for Change – Clean Water Act



photo credit James Thomas, from Cleveland Press Collection, Cleveland State University Library

Compelling Driver for Change?



From http://crlazlo2.blogspot.com/

Clean Water Act – MS4 Program

History

- CWA expanded definition of “point source” to include stormwater in 1987
  - **Municipal Separate Storm Sewer Systems (MS4s)**
- First phase implemented in 1990
  - For large communities and construction sites
- Second phase implemented in 2003
  - For “small/mid-sized” urban areas and construction sites
- Rulemaking occurred in 2009-2014
  - Attempted to establish first national performance, retention-based standard



Structural Controls



Collect

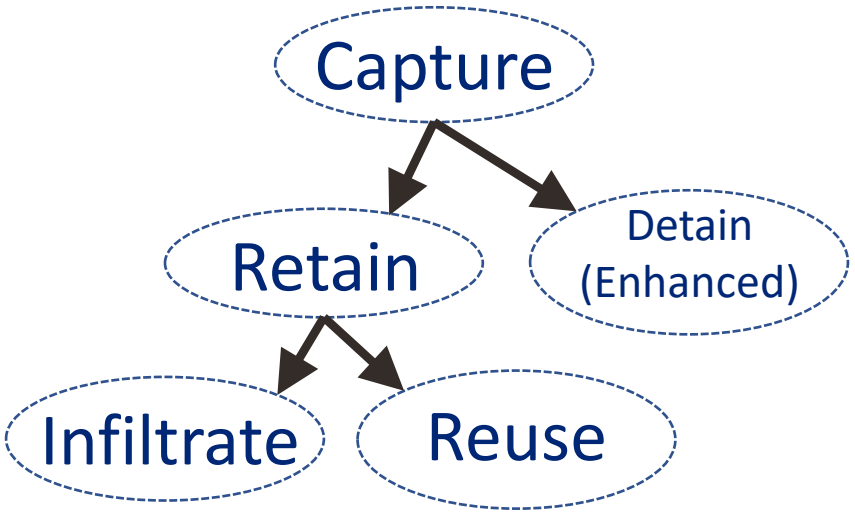


Convey

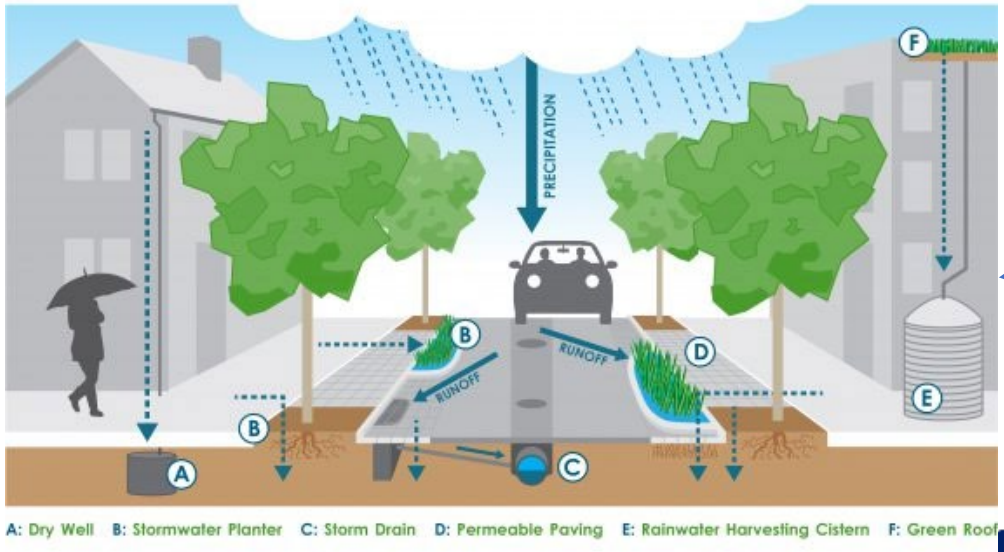


Detain

Traditional Stormwater Management



Nature-based Solutions



City of Atlanta

Non-Structural Controls

- Good Housekeeping Practices
  - Spill prevention, routine cleaning, proper waste handling, etc.
- Pollution Prevention Plan
- Protect Sensitive and Special Value Resources
- Minimize Disturbance
- Reduce Impervious Cover
- Disconnect / Distribute / Decentralize
- Source Control (**including street sweeping**)

Street Sweeping & Stormwater Nexus

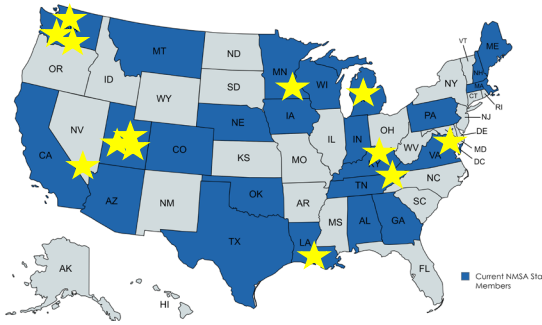
Source Control for Water Quality…and More

- Pollution prevention is typically the most cost-effective options
- Pollutants Addressed
  - Organic debris (nutrients)
  - Gross solids (trash)
  - Microplastics incl. tire & roadway wear particles
  - Pollutants absorbed on to particles (nutrients, bacteria/pathogens)
- Water quantity issued reduces through less clogging
- Reduced maintenance issues & expenses for downstream features

NMSA Background & Overview

NMSA State of Membership

- **26 state groups currently members of NMSA**
  - Represents approximately 4,400 of the total 7,500 MS4s in the U.S.
  - Represents over half of the urban population in the U.S. subject to MS4 regulations
- **MS4, Affiliate, and Emeritus Members can join**
- **Mission, Vision and Action Areas**



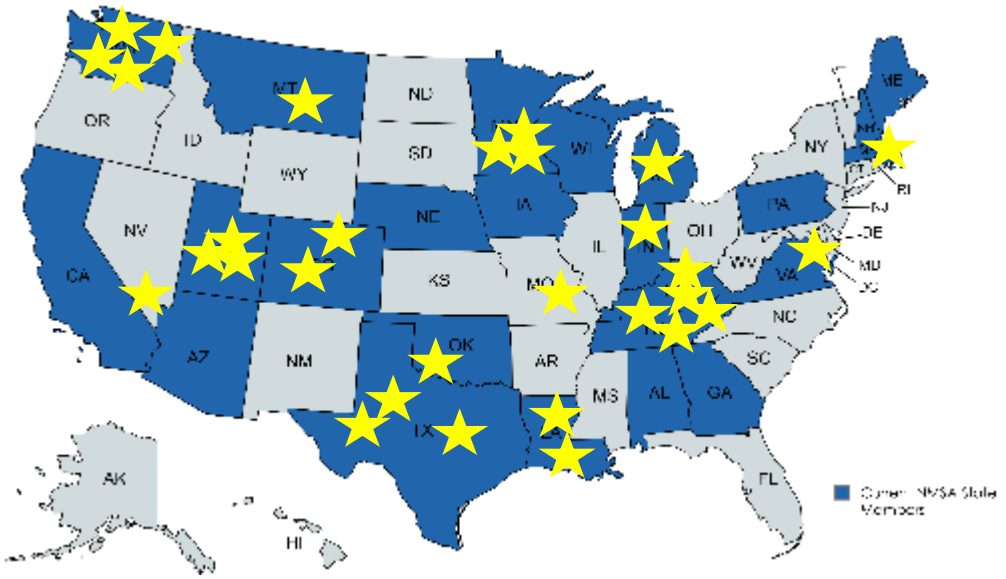
To join NMSA online use this QR code or go to:

- https://ms4nmsa.org/our-memberships/

MS4 Membership

Current MS4 NMSA Members

1. Utah County, UT
2. Clinton, UT
3. Scottsbluff, NE
4. Cedar Hills, UT
5. Salem, UT
6. Battle Ground, WA
7. Centralia, WA
8. Payson City, UT
9. Lindon City, UT
10. Mapleton City, UT
11. Provo City, UT
12. Farr West, UT
13. Springville City, UT
14. Logan City, UT
15. Katysville City, UT
16. Odessa, TX
17. Washington, D.C.
18. Baton Rouge, LA
19. King County, WA
20. Capitol Region Watershed District (St. Paul, MN)
21. Kitsap County, WA
22. Austin, TX
23. Garland, TX
24. St. Tammany, LA
25. Moberly, MO
26. Asotin County, WA
27. Pierce County, WA
28. Eden Prairie, MN
29. Lafayette Regional Airport, LA
30. Altus, OK
31. Parks Tacoma, WA
32. Great Falls, MT
33. Littleton, CO
34. Greely, CO
35. Thurston County, WA
36. Regional Flood Control District (Clark County, NV)
37. Tri-County Regional Planning Commission (Clinton, Eaton, and Ingham Counties, MI)
38. Lebanon, IN
39. Sanitation District No. 1
40. Louisville (KY) MSD
41. Gallatin, TN
42. Springfield, TN
43. Kingsport, TN
44. Missoula, MT
45. St. Cloud, MN
46. Gwinnett County, GA
47. Dedham, MA
48. Mukilteo, WA
49. Hennepin County, MN



★ = Current NMSA MS4 Members

NMSA Activities/Services

- National Stormwater Policy Forum
- National Stormwater Day
- NMSA Stormwater Community Training Hub
- Stormwater Center of Excellence
- Stormwater Testing and Evaluation for Products and Practices (STEPP) Program

STEPP Stormwater Testing and Evaluation for Products and Practices = CR Consumer Reports™ for



NMSA / STEPP Membership

Overview of the CS=CW Initiative Phase I

Clean Streets = Cleaner Water Initiative
Leadership/Partnerships

Leadership

National Municipal Stormwater Alliance (NMSA)

Seth P. Brown, PE, PhD (NMSA) — Executive Director, National Municipal Stormwater Alliance

- Developer of **STEPP** — *Stormwater Testing and Evaluation for Products and Practices*.

Gregory L. McPartlin, Progressive Sweeping / Urban Quarries

- Industry veteran leading coordination between manufacturers, contractors, and regulators to turn stormwater compliance into business growth.

Industry Partners

1-800-SWEEPER – Industry Network Leader

North American Power Sweeping Association (NAPSA)

Manufacturing Partners

TYMCO

Elgin

Schwarze

Stewart-Amos

Clean Streets = Cleaner Water Initiative
Overview and Purpose

The CS=CW Initiative has been established to bridge the gap between research and policy and drive a broader adoption of power sweeper technologies to address stormwater pollution.

Phase I - Exploration

- Collecting and compile information on regulations and policy to capture the current status of street sweeping and stormwater treatment.
- Develop a pathway forward for the stormwater sector and power sweeper industry to use as a blueprint for the future.

CS=CW Steering Committee

CW=CW Steering Committee Function

Phase I of the CS=CW Initiative relied on the Steering Committee to guide direction and provide input in the analysis and findings outlined in the Phase I report.

CS=CW Steering Committee Members

- **Andrew Sheerin, PhD** – University of Rhode Island (**CHAIR**)
- **Cole Watts, MS** – NAPSA, More Clean of Texas
- **Dustin Moist** – NAPSA, Cantel Sweeping
- **Mike Trojan, PhD** – MN Pollution Control Agency (ret.), NMSA/STEPP
- **Margaret Schneemann, PhD** – CMAP / IL–IN Sea Grant
- **Jamie Houle, PhD** – Univ of New Hampshire Stormwater Center
- **Todd Snyder** – City of San Diego
- **Paula Kalinosky, PhD** – Minnesota Pollution Control Agency
- **Bill Selbig, PhD** – USGS
- **Jane Clary** – Wright Water Engineers, Inc., International Stormwater BMP Database
- **Dylan Ahearn, PhD** – Herrera, Principal Scientist
- **Seth P. Brown, PhD PE** – NMSA (**Project Team**)
- **Gregory L. McPartlin** – Progressive Sweeping / Urban Quarries (**Project Team**)

Clean Streets = Cleaner Water Initiative
Phase I Report Out - Research

Findings and Considerations

- Early research suggested that sweeping effectiveness reduce street/roadway particulates was limited (subsequent research has corrected the record on this).
- Research shows effectiveness to address both organic debris and non-organic particulates, and the level of effectiveness varies by a number of factors.
- Research showing downstream water quality improvements is limited, which is a significant gap in the literature.
- **No standardized protocol exists for assessing sweeping across technologies and operating conditions.**

Clean Streets = Cleaner Water Initiative
Phase I Report Out – Programmatic

Findings and Considerations

- Sweeping identified as second most developed aspect of municipal stormwater programs (WEF 2022 MS4 Survey).
- Municipal stormwater programs structure their sweeping programs **based upon state regulatory policies**.
- Limited funds identified as consistent top need for stormwater programs.
- Stormwater/water quality markets can catalyze sweeping/stormwater activities in stormwater programs – including for private properties.

Clean Streets = Cleaner Water Initiative
Phase I Report Out – Regulatory/Policy

Findings and Considerations

- ***A plurality of states MS4 general permits (42%) contain no language of sweeping/stormwater nexus.***
- Performance varies by equipment, operator, conditions, pollutant type, and frequency.
- Evidence of downstream water-quality improvement remains limited.
- **Load-reduction crediting and standardized performance testing are still needed.**

Clean Streets = Cleaner Water Initiative
Funding and Financing

Examples of SRF Investments in Street Sweeping

- **Clayton County, Georgia**: In 2024, the Clayton County Water Authority secured a $960,000 CWSRF loan through the Georgia Environmental Finance Authority (GEFA) to purchase a street sweeper and a vacuum truck. The project was aimed at preventing sewer spills and protecting local impaired streams, qualifying for a reduced interest rate of 1.24%.

- **Town of Exeter, New Hampshire**: The town utilized a $219,823 CWSRF loan specifically for its Street Sweeper Purchase Project. The equipment was acquired to improve roadway runoff quality and maintain compliance with the town's NPDES Phase II MS4 stormwater permit. Notably, this agreement included 20% principal forgiveness under federal capitalization grant guidelines.

Clean Streets = Cleaner Water Initiative
Funding and Financing

Examples of SRF Investments in Street Sweeping

- **Barnegat Bay, New Jersey**: The New Jersey Department of Environmental Protection and the New Jersey Infrastructure Bank (NJIB) allocated $350,000 in CWSRF funding for a mechanical street sweeper. This was part of a targeted effort to reduce stormwater pollution and nutrient loading impacting the Barnegat Bay watershed.
- **Arlington and Lacey, Washington**: The Washington State Department of Ecology frequently blends state grants with the federal State Revolving Fund to finance high-efficiency street sweepers. These high-efficiency vacuum units are specifically funded because they capture microscopic particulates that traditional brooms leave behind, preventing toxic runoff from hitting salmon-bearing streams.

Clean Streets = Cleaner Water Initiative

Phase I Report Out – Implications

Take Aways

- Link verified sweeping performance to **regulatory crediting**.
- **Standardize** performance metrics and verification through STEPP and ASTM E64.
- Open up **funding and financing** options for sweeping.
- Develop a performance-based, cost-effective **Enhanced Street Sweeping Program Framework**.
- Expand stormwater-focused **technical and operator training**.

Clean Streets = Cleaner Water Initiative *Phase I Report Out – Recommendations for the Future*

- Establish a Street Sweeping/Stormwater Nexus Community of Practice (CoP).
- Develop the Enhanced Street Sweeping Program framework.
- Collect, organize, curate, and share research/operational data on street sweeping for stormwater management.
- Create template language and a framework for regulatory crediting.
- Develop clearer and more practical metrics for quantifying pollutants removed from paved surfaces.

Clean Streets = Cleaner Water Initiative *Phase I Report Out – Recommendations for the Future*

- Explore and promote technologies that can optimize sweeping operations for stormwater outcomes.
- Initiate engagement with state regulators and EPA on the CS=CW framework and related concepts.
- Survey the MS4 sector on sweeping prevalence, activities, and technologies in use.
- Engage in high-profile stormwater and sweeping conferences to promote the initiative and its products.
- Initiate engagement with the STEPP program and begin planning for the identification and development of ASTM performance testing standards.

What it All Means to the Stormwater Sector?

Bottom Line

- Sweeping is under-valued as a technology for stormwater.
- …but sweeping is not the silver bullet.
- Holistic stormwater management is balanced and considers quantity as well as quality.
- MS4s need solid performance information.
- Sweeping is multi-beneficial – high value!
  - Safey, resilience, aesthetics – AND water quality
- Sweeping has immediate impacts/benefits.
- Sweeping is cost effective – and has funding/financing sources!

Training Hub

Questions?

NMSA / STEPP Membership

Visit the CS=CW webpage at **https://ms4nmsa.org/cs-cw/**

Seth Brown, PhD, PE | NMSA

Need more information?

Seth Brown, PhD, PE | NMSA Executive Director
seth.brown@nationalstormwateralliance.org

NMSA Newsletter

MS4 Permit Improvement

Break

15 minute break

Section 2 – The Latest on Stormwater and Sweeping Research



Clean Sweep

Ground Truthing Organic Matter Collection for New Hampshire Communities

November 2026
Sweeping Summit
James Houle, UNHSC

NH Stormwater Center

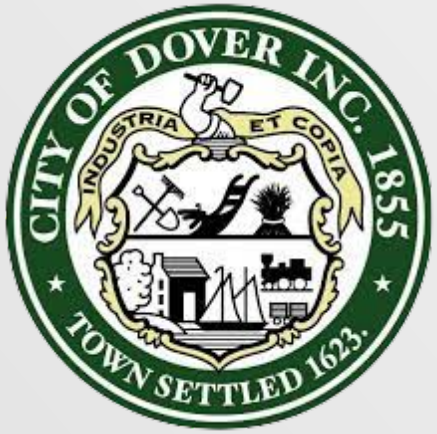
PREP
Piscataqua Region Estuaries Partnership

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NH Stormwater Center
PREP Piscataqua Region Estuaries Partnership

Street Sweeping Credits

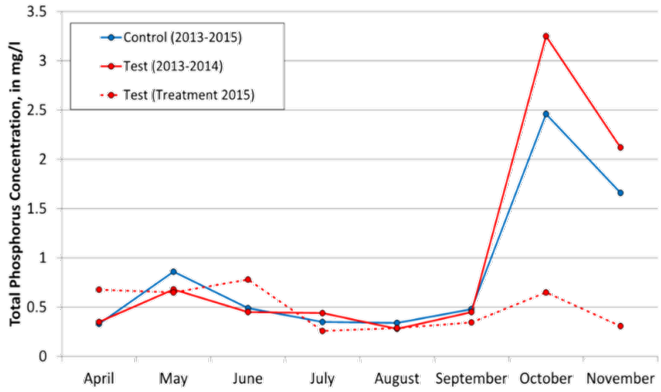
- James Houle
- UNH Stormwater Center
- NHDES
- PREP
- Roca
- Town of Durham, NH
- City of Dover
- EPA Region 1

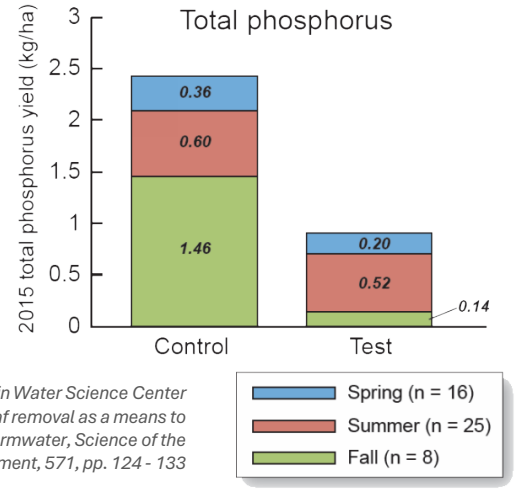


Recent USGS Research on Leaf Litter Cleanup

- Recent Leaf Litter Research in the Mid-West. Leaves in suburban landscapes are a major source of phosphorus

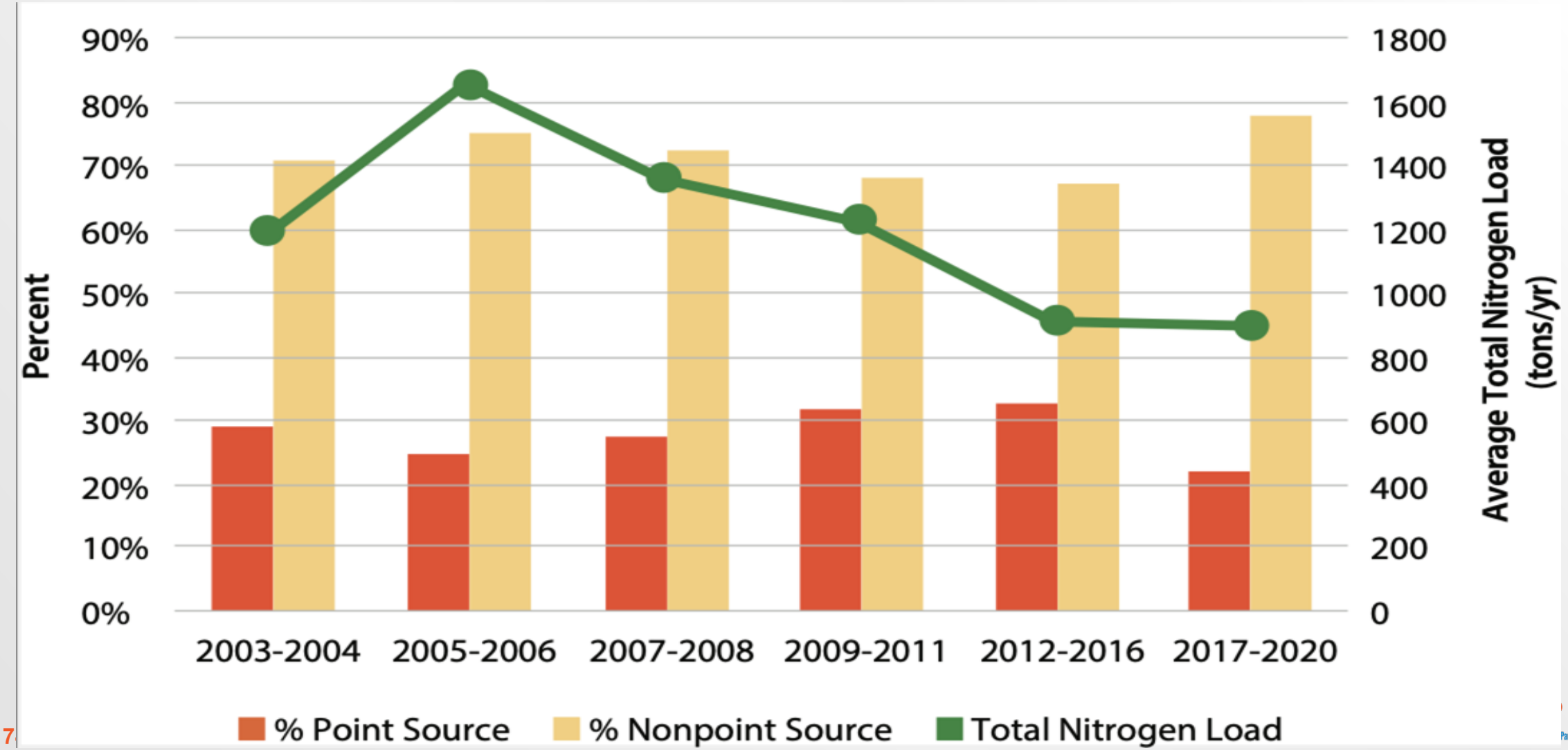
- Up to 60% of the annual phosphorus load from residential land uses can occur from leaf litter in the fall





Courtesy of William Selbig, USGS – Wisconsin Water Science Center
wrselbig@usgs.gov Selbig, W.R., 2016, Evaluation of leaf removal as a means to reduce nutrient concentrations and loads in urban stormwater, Science of the Total Environment, 571, pp. 124 - 133

Total Nitrogen Load To Great Bay



Three Problems, One Solution



1. Nutrient pollution is mostly nonpoint.

2. Street cleaning is an underutilized BMP.

3. Science suggests *more credit* is warranted

Empower communities to protect water quality & earn more credit through flexible, science-based, street cleaning regulations.

Three Problems, One Solution



1. **Nutrient pollution is mostly nonpoint.**
2. **Street cleaning is an underutilized BMP.**
3. **Science suggests *more credit* is warranted**

Expert panel process gave us New Hampshire communities new flexible, science-based options to earn credit for street cleaning.

Recommend a new measured credit for NE

Clean Sweep Outreach Toolkit

Panelists & Advisory Committee Members: *Thank you* for participating in this project. We deeply appreciate your willingness to share your time, expertise, and thoughtfulness. We developed this simple toolkit to support you in sharing project results within your organization and throughout your professional networks. Our goal is to honor your investment in this collaboration by making every effort to ensure the final results are as accessible as possible.

Each file is set to view only, but you are free to download and edit all of them to suit your purposes. If you have questions, please contact a member of the Clean Sweep Team: James Houle, Abigail Lyon, Elizabeth Buschert, or Dolores Leonard.

Clean Sweep Outreach Toolkit		
Tool	**Purpose**	**Download it**
Final Technical Memorandum	Summarizes the recommendations of an expert panel to update New Hampshire's current Enhanced Street/Pavement Cleaning credit (USEPA 2017) and create a new measured credit for organic matter collection.	Here
Project Summary	Two-page overview of the Clean Sweep project and its results— for anyone, including regulators, municipal officials and staff.	Here
Case Study	An example of how a New Hampshire town could apply organic matter collection to help meet their nitrogen load reduction goals. Based on New Hampshire field data and practices.	Here
Summary / Case Study	Document two-page overview and case study.	Here
Addendum	Results of a pilot study to ground truth Minnesota data for New Hampshire—an Addendum to the Clean Sweep Technical Memo.	Here
FAST Overview	Two-page overview of the expert panel process for anyone interested in how the panel reached its decisions	Here
FAST Guide	Twelve-page guide to the expert process for those interested in applying the expert panel approach used in Clean Sweep to another management question	Here
Slide Deck	Slides with messages, graphics, and notes to support sharing Clean Sweep's expert panel process	Here
Slide Deck	Slides with messages, graphics, and notes to support sharing Clean Sweep's pilot study to ground truth Minnesota data for New Hampshire	Here

How Do the Approaches Compare?

Approach	Imperv area (ac)	Lane Miles Swept	Effort Level	Annual Frequency	Season	Wet Mass Collected (lbs)	P credit lb/yr	N credit lb/yr
Collection	13.27	NA	NA	NA	Fall	83520	**37.2**	**120**
Modeled (NEW)	13.27	13.68	Medium	NA	NA	NA	**3.9**	**28.06**
Modeled (OLD)	13.27	13.68	NA	0.17	NA	NA	**0.04**	**0.31**

Best Management Practice (BMP)	TP reduced (lb/ac/year)	TN reduced (lb/ac/year)	Estimated Cost	$/lb TP	$/lb TN
Fall: Organic Matter Collection	**2.8**	**9.0**	**$2300**	**$820**	**$260**
Fall: Updated Street Cleaning	**0.3**	**2.8**	**$2300**	$7,700	$820
Biofiltration	1.0	4.5	$58,000	$58,000	$12,889
Bioretention	1.9	14.1	$58,000	$30,526	$4,113
Enhanced Biofiltration	1.5	10.6	$59,000	$39,333	$5,566
Dry Detention Basin	0.4	1.8	$26,000	$65,000	$14,444
Gravel Wetland	1.2	9.6	$33,000	$27,500	$3,438
Sand Filter	1.9	14.0	$47,000	$24,737	$3,357
Surface Infiltration	1.9	14.1	$24,000	$12,632	$1,702
Water Quality Grass Swale	0.4	1.8	$21,000	$52,500	$11,667
Wet Pond	1.0	4.5	$26,000	$26,000	$5,778

*Structural BMPs sized to treat the 1" storm and assume a 1"/hr infiltration rate where applicable.

NH Stormwater Center
PREP™
Piscataqua Region Estuaries Partnership

Non-Structural Phosphorus and Nitrogen Reduction Analysis - Clean Sweep Policy Measured Organic Matter Collection Credit	
Total Collected Wet Mass of Street Sweepings (lbs.) =	27,320 lbs.
Total Collected Wet Mass of Street Sweepings per Roadway Mile Swept (lb./mi) =	7,687 lbs./mi
Dry Mass (lbs.) =	14,206 lbs.
Dry Mass (kg) =	6,444 kg
TP Removed	5.52 kg
TP Removed	12.17 lbs.
TP Removed	3.42 lbs. TP/mi
TN Removed (kg) =	17.79 kg
TN Removed (lbs.) =	39.24 lbs.
TN Removed per Roadway Mile Swept (lb./mi) =	11.04 lbs. TN/mi
Total Cost ($) =	$2,049
Total Cost per Lane Mile Swept ($/mi) =	$288/mi
Cost per pound of TP Removed =	$168.40/lbs. of TP

Cost per pound of TN Removed = $52

MN Sweeping Credit

- A mass-based measured approach has regulatory precedent in Minnesota and offers a powerful incentive for municipalities to enhance existing sweeping programs, often at a lower cost than structural SCMs.
- The process is incentivizing inspection and maintenance programs and helping build the case for equipment purchase and increased staff related to these types of operations.
- MN credit is based on weight; however, many communities do not have equipment to assess weight of material collection.

Measured Bulk Density

	Number of Samples Analyzed	Average Wet Bulk Density *lb/ft^3*
Fall	27	232.5
Not Fall	38	1559

UNH Clean Sweep Approach

- We addressed the weight factor by creating a volume to mass conversion for both fall and non-fall seasons.
- Moisture content was quantified and confirmed consistent with MN values by additional monitoring in NH.
- Calculated moisture content is not required in the measured approach and is modeled or estimated from empirical measurements
- Use of the measured approach is no different than using pollutant load export rates for land uses or SCM performance curves derived from common DSV values.
- The Municipal Alliance for Adaptive Management (MAAM) received EPA approval to use the updated methods toward compliance with the GBTNGP.

EPA R1 Concerns in the 2024 Draft MA MS4 Permit

- Concerns about implementation logistics, such as weighing methods and moisture content.
- Concerns about “monitoring” or measuring non-structural SCMs vs equivalent measuring of structural SCMs.
- Really no different from modeled performance curves as the values are still abstracted from empirical results.
- Also, volume or mass of material removed from street sweeping AND CB cleaning are listed as acceptable methods in the Draft MA MS4 Permit





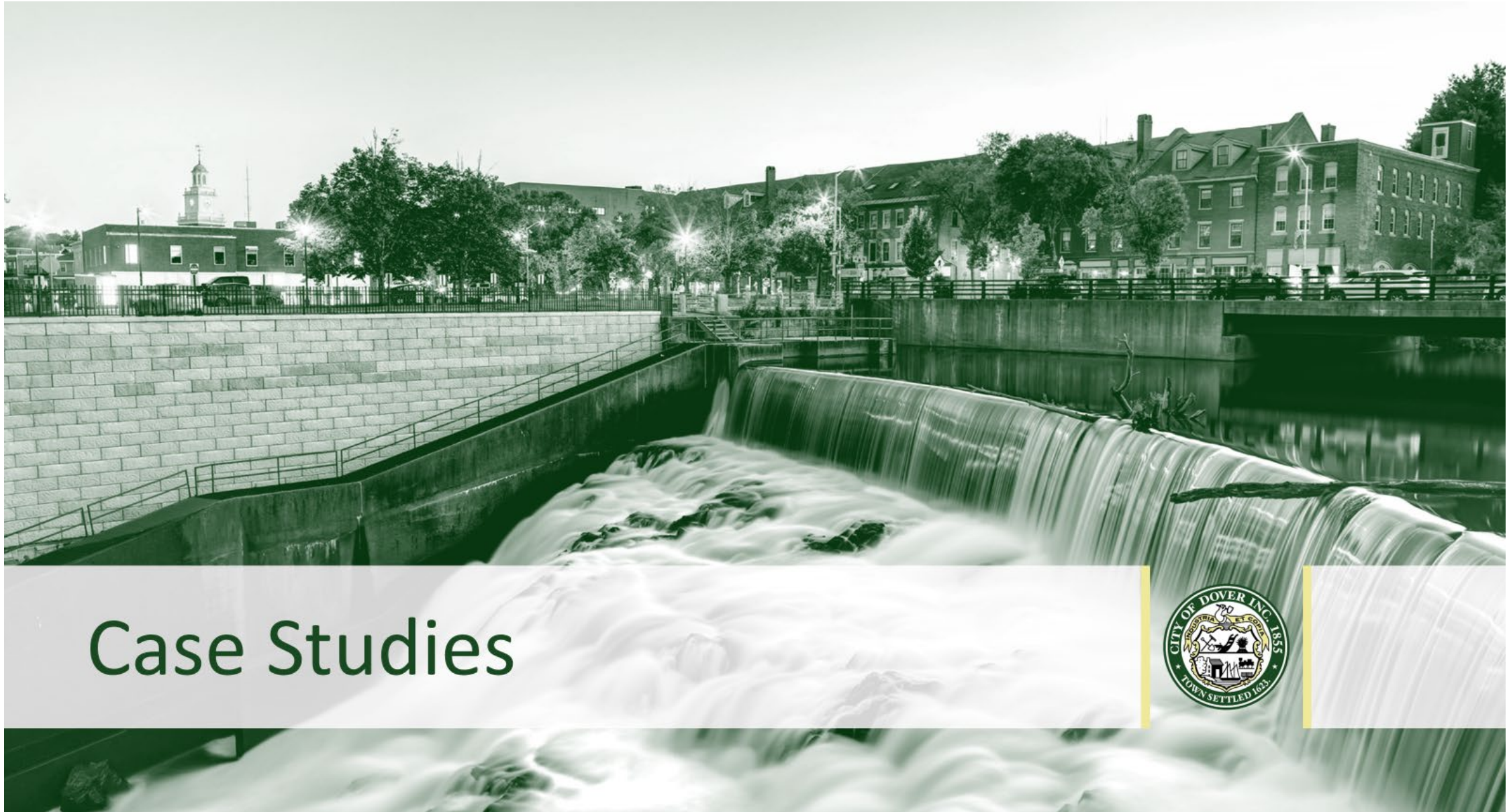

Why is Measured Credits for Street Sweeping So Important?

Street sweeping or street cleaning in the fall (non-sweeper leaf collection) is one of the most effective actions to reduce nutrient wash off in developed watersheds.[1]



[1] https://www.usgs.gov/centers/upper-midwest-water-science-center/science/using-leaf-collection-and-street-cleaning-reduce

Sweeping is an Operation, Not a Single Technology









Various Sweeping Approaches

- Vary by region/municipality
- More of an operations approach than a single technology



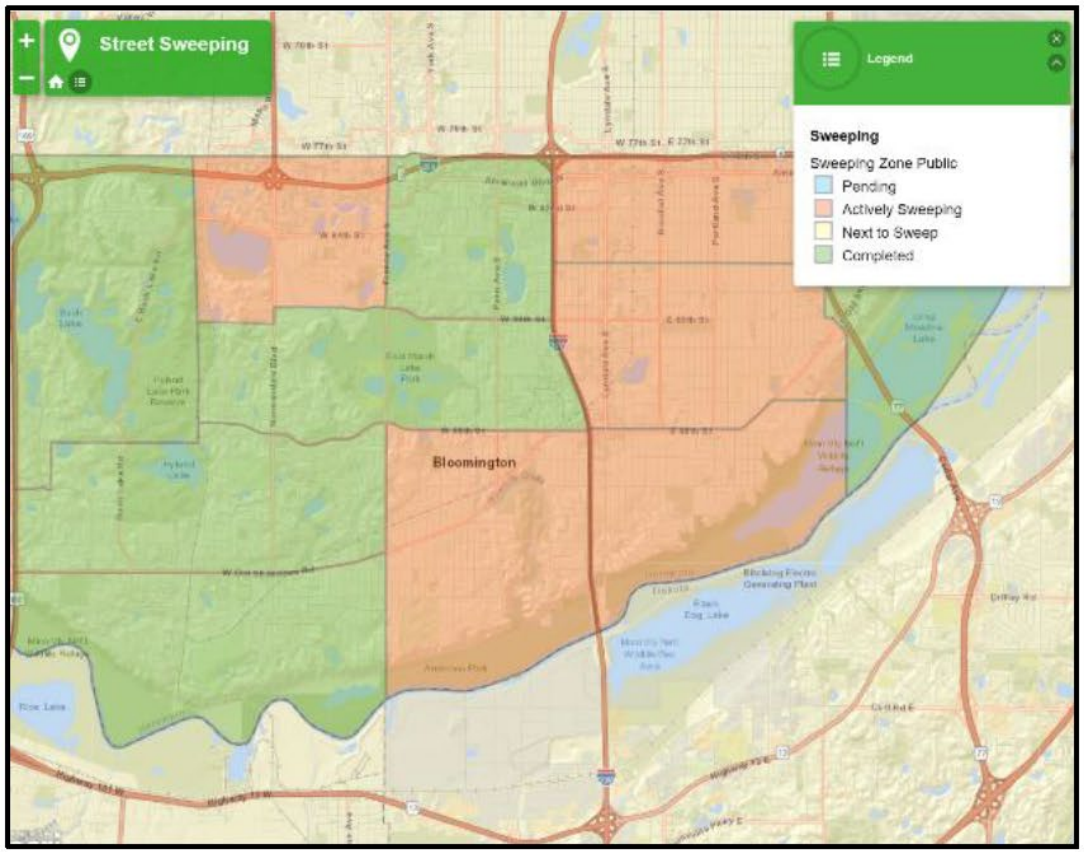
Leaves on a Minneapolis Street



Pink “No Parking” signs posted for street sweeping



Leaf composting facility



GIS Mapping of Bloomington Street Cleaning Activities



City of Auburn staff using blowers and rakes to collect debris ahead of the truck mounted and broom sweepers.



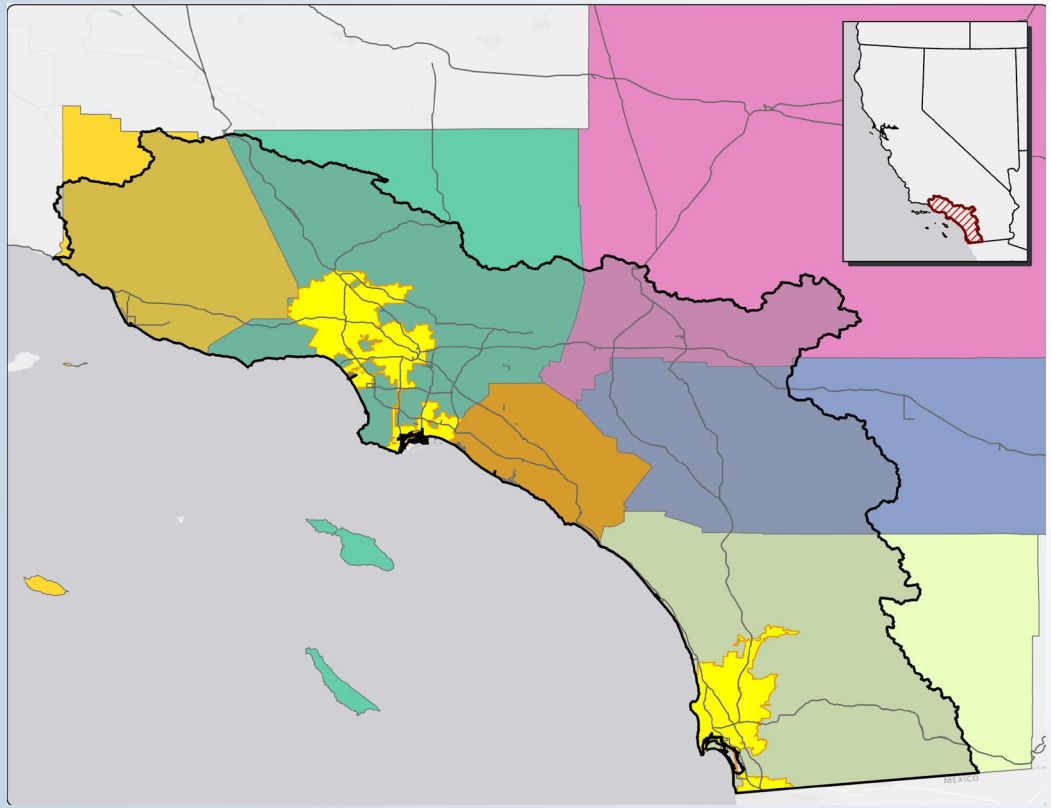
Questions?



Overview of Research on Street Sweeping and Stormwater in Southern California

Elizabeth Fassman-Beck, Ph.D.
Engineering Department Head
Southern California Coastal Water Research Project
elizabethfb@sccwrp.org

Southern California Stormwater Monitoring Coalition www.socalsmc.org



- Voluntary collaboration/ cooperation amongst 18 public agencies addressing stormwater across Southern California
- 5-yr MOU renewal cycle, beginning 2001
- Mission: to solve stormwater management challenges across southern California by building regional consensus around best-in-class tools, methods and monitoring strategies

SMC Member Agencies

Permittees

- City of Santa Barbara
- Ventura County
- Los Angeles County
- City of Los Angeles
- City of Long Beach
- Riverside County
- San Bernardino County
- Orange County
- San Diego County
- City of San Diego
- Caltrans

Regulators

- Central Coast RWQCB
- Los Angeles RWQCB
- Santa Ana RWQCB
- San Diego RWQCB
- State Water Resources Control Board
- US EPA Office of Applied Science and Environmental Solutions

Research

- SCCWRP

Background – Street Sweeping & Stormwater in SoCal

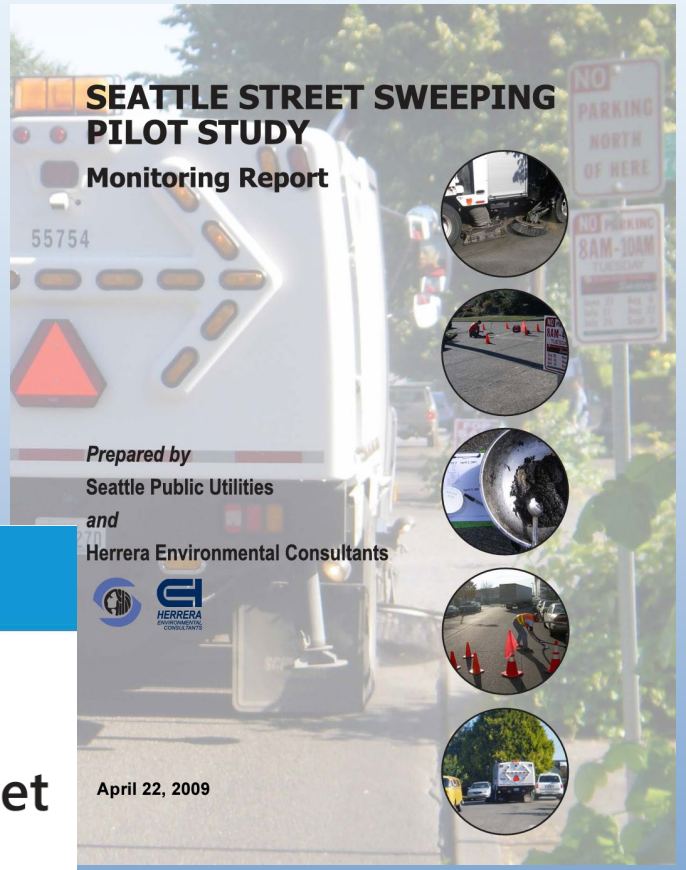
- Non-structural BMPs are the preferred first option for pollution prevention in NPDES permits & watershed management plans
  - "Enhanced" street sweeping: beyond minimum requirements (e.g., swept miles, sweeping frequency, sweeper type, etc.)
- Permitting agencies: quantitative evidence required for load reduction credit
  - Historically 5-10% reduction based on best professional judgement
  - Credit for enhanced street sweeping already eliminated in at least 1 SoCal permit

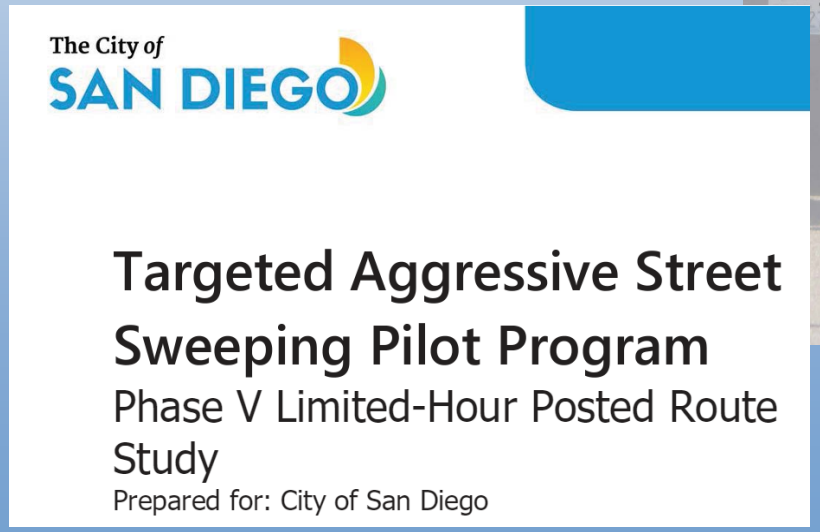


- Permittees: we need the credit
  - "Easy" programs to expand compared to building structural BMPs
  - If not effective, need to develop alternative solutions

Street Sweeping & Stormwater – What do we know?

- Sweepers get the debris.
- Newer/advanced sweeping technologies are better than mechanical brooms.
- Not sure if they remove “runoff pollutants.”





Priority Research Question

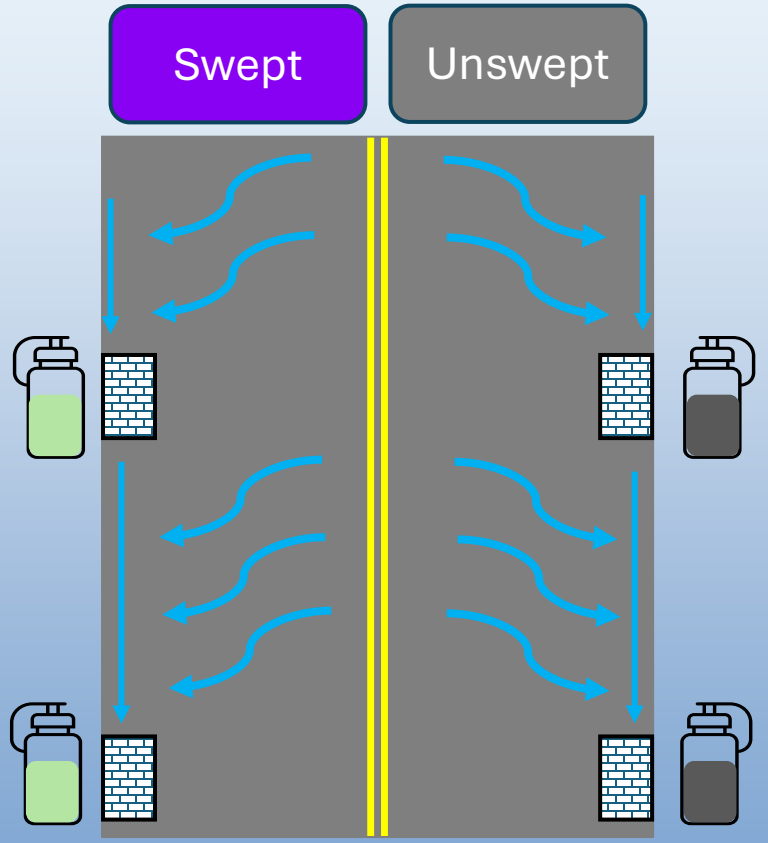
What is the pollutant concentration reduction in runoff, if any, due to street sweeping ?

Approach

1. Develop a reliable method to measure a difference in runoff quality between swept and unswept pavements at field scale.

2. Deploy method across SoCal to generate the data.

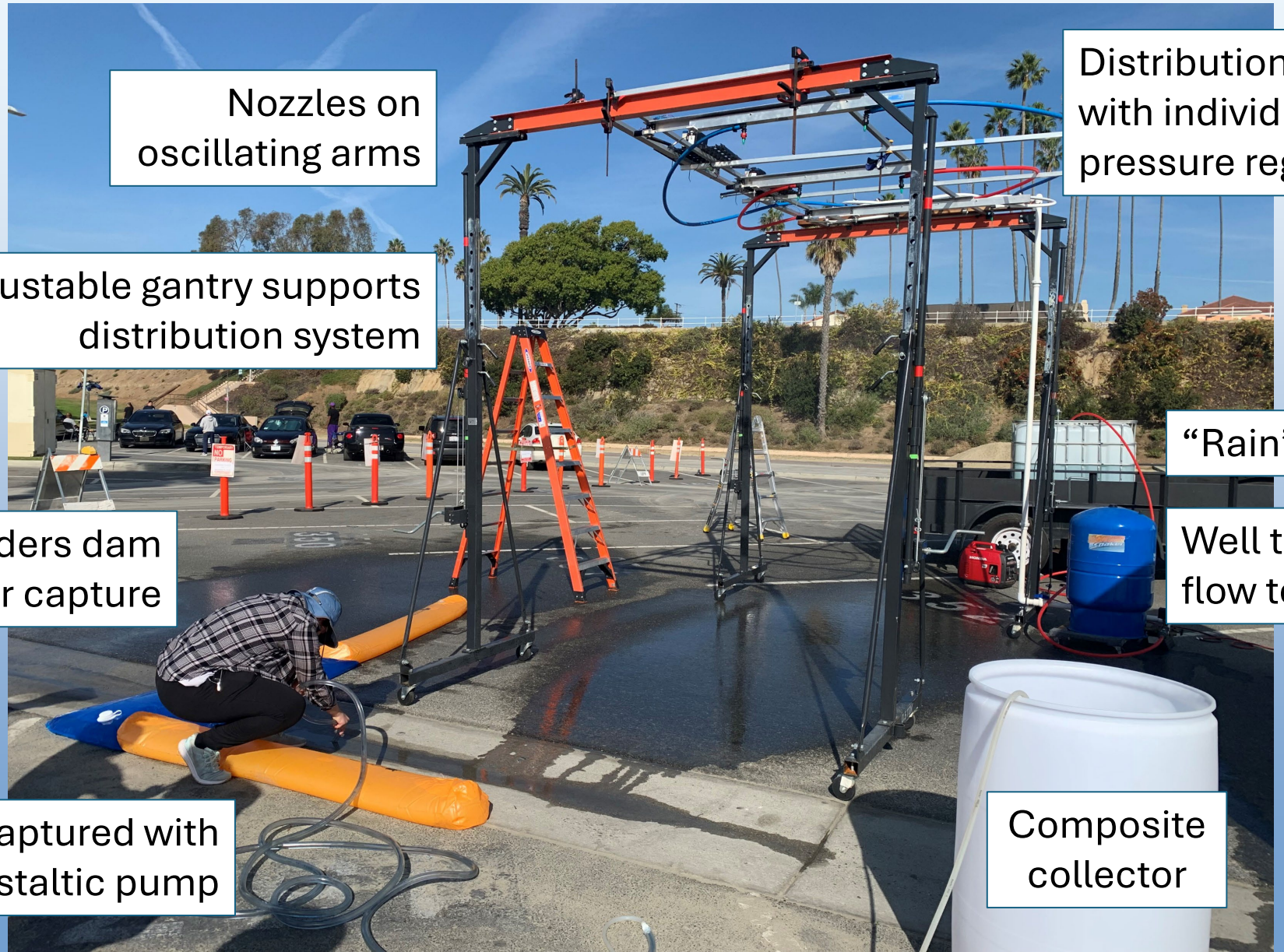
Test Method Criteria



- Isolate street surface area
  - No surrounding land use
- Standardize testing conditions for repeatable measurements
  - Same rainfall characteristics, same area, same traffic patterns, same sweeping techniques
- Apparatus must be mobile and built from readily-available parts



Rainfall Generator & Runoff Collection System

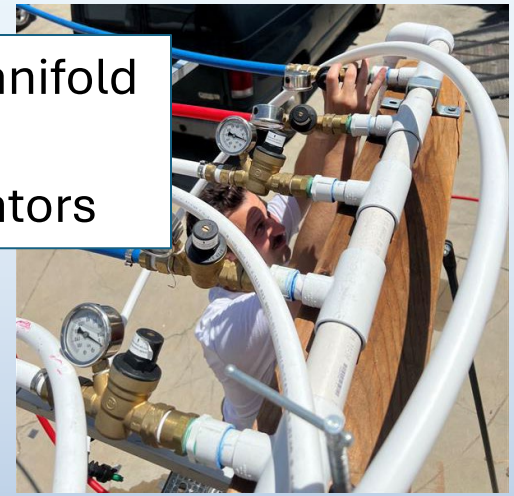


Nozzles on oscillating arms

Adjustable gantry supports distribution system

Water bladders dam runoff for capture

Runoff captured with peristaltic pump



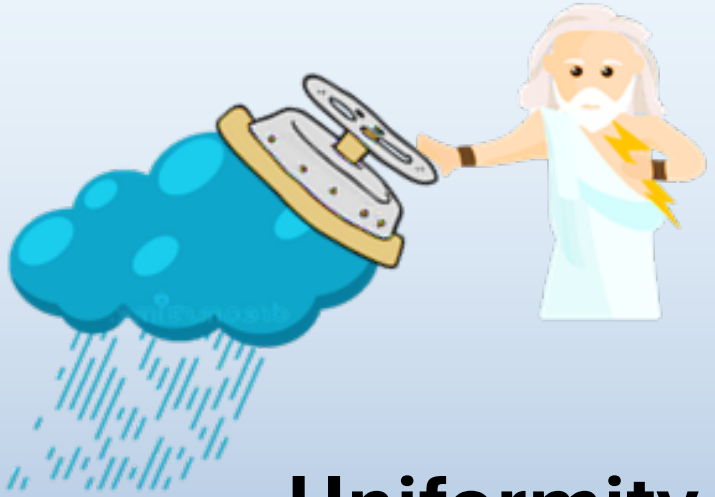
Distribution manifold with individual pressure regulators

“Rain” source tank

Well tank pressurizes flow to manifold

Composite collector

What makes a great rainfall simulator?



Kinetic Energy

Do the raindrops hit the ground hard enough to mobilize pollutants?

Uniformity

Is the rainfall applied evenly?

Nozzle

Intensity

Is the rainfall rate realistic for the study area/question?

- ✓ Drop size
- ✓ Spacing
- ✓ Height

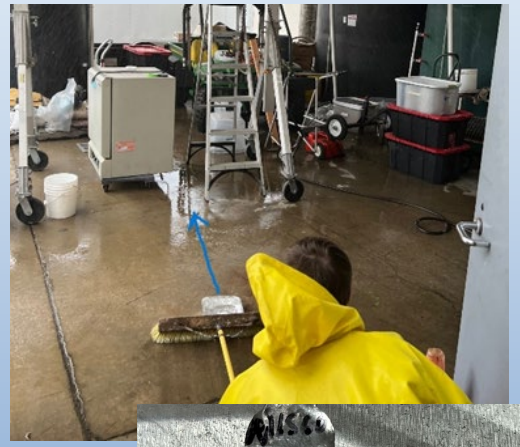
SCCWRPer Soaker Development

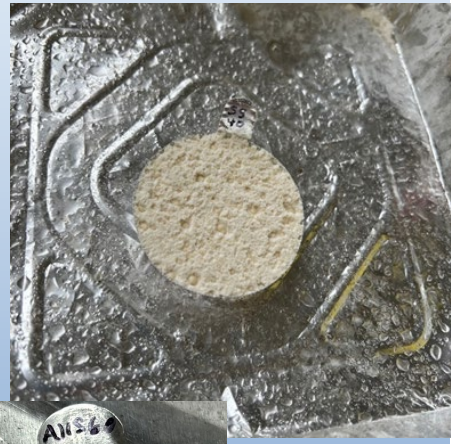
Area = 70 ft²

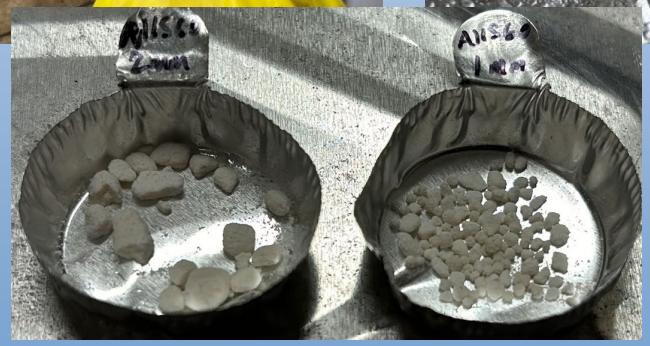
Kinetic energy of Mediterranean rainfall

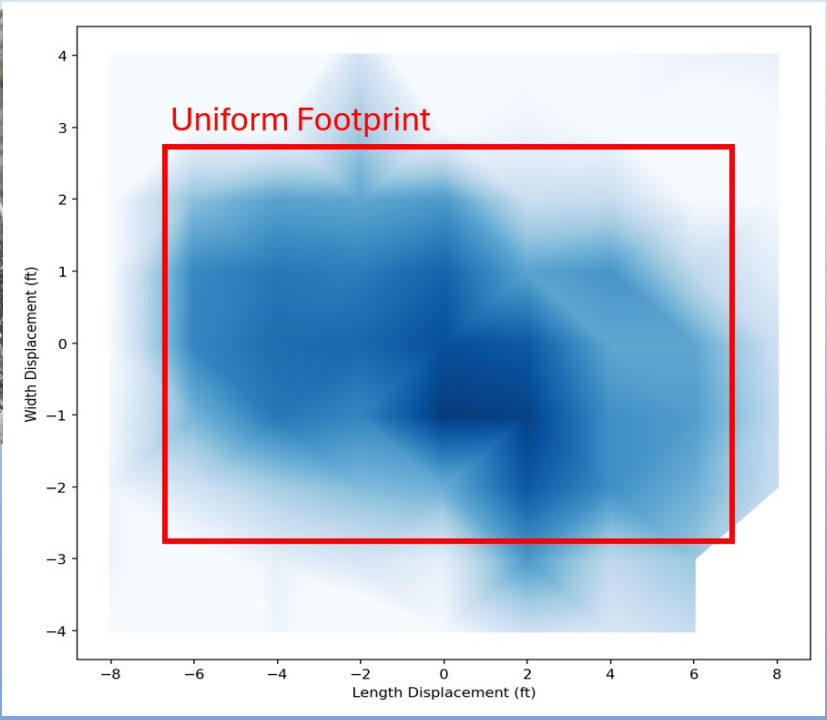
Intensity = 1.25 in/hr
Coeff. of Uniformity = 0.73











Pilot Test: Junipero Beach, Long Beach



- Side-by-side testing swept and unswept pavements
- 3 iterations
- ✓ Unswept runoff concentrations were consistent with literature
- ✓ Variable, but generally consistent results across all three tests
- ✓ Positive indication of measurable pollutant removal across a range of contaminants

Approach

1. Develop a reliable method to measure a difference in runoff quality between swept and unswept pavements at field scale.

2. Deploy method across SoCal to generate the data.

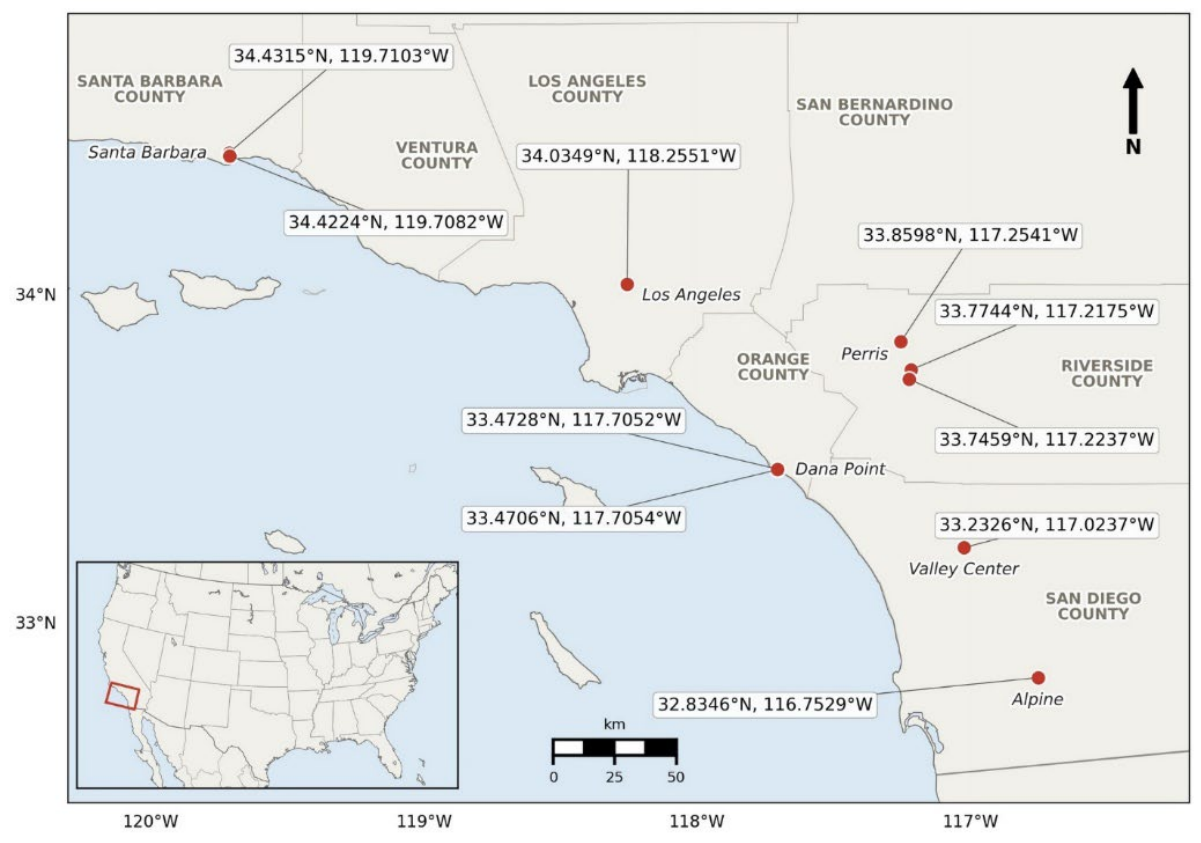
   What is the pollutant concentration reduction in runoff due to street sweeping ?

Deployment Across SoCal – Study Design

- Identify testing locations (sites) with “like” characteristics to minimize confounding factors
  - Anticipate high site-to-site variability
  - Confidence comes from testing many sites
- Weekly sweeping frequency
- No measurable rain in the week prior to testing
  - Antecedent dry period 8-117 days
- Final sites grouped by land use in surrounding catchment & sweeper type
- Road condition
  - Average ADT 1,161-9,964
  - Road resurfaced 2017-2024 (+ 1 in 2011)



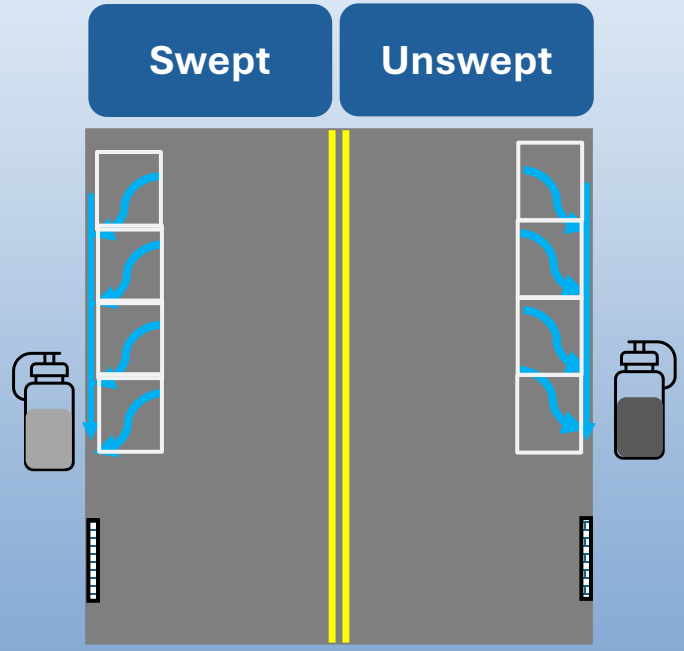
10 Testing Locations



5 x **RR** sites: **Residential** land use, swept by **Regenerative** air sweeper

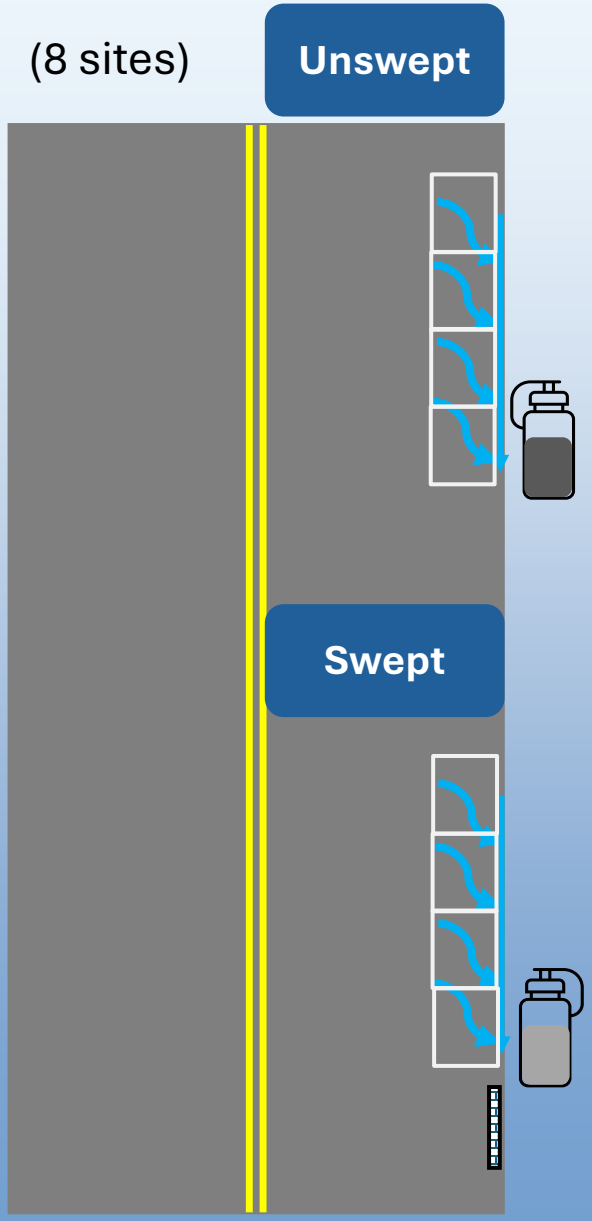
5 x **CIM** sites: **Commercial/ Industrial** land use, swept by **Mechanical** sweeper

(2 sites)



Field experiment (video)

(8 sites)



Pollutants

- Sediment
  - Total suspended solids (TSS) & particle size distribution
- Fecal indicator bacteria
  - Total coliform, E. coli, Enterococcus
- Heavy Metals
  - total and dissolved
  - Zinc, Copper, Lead, Arsenic, Cadmium, Chromium, Selenium, Nickel
- Nutrients
  - Total nitrogen (TN) & phosphorus (TP)



- Polycyclic aromatic hydrocarbons (PAHs)
  - 25 analytes
- Microplastics (prelim data analysis today)
- Pesticides (>110 analytes)
- 6-PPD & 6 PPD-Q
- PFAS

Data under review

Quantifying Performance - Results

Research Question: What is the pollutant concentration reduction in runoff due to street sweeping ?

- EMC: Event mean concentration = a weighted average concentration accounting for flow and pollutant dynamics
- $EMC_{unswept}$ did not differ amongst land use
  - Differences in EMC_{swept} are attributed to sweeper type
- High variability amongst/between sites & pollutants
  - Statistically, $EMC_{swept} < EMC_{unswept}$ at RR sites only for clay size particles, total nitrogen, total nickel, total zinc, and dissolved cadmium
  - Trends noted otherwise

Effect on runoff EMCs

Summary Trends	 RR Residential-Regenerative-air	 CIM Commercial/industrial Mechanical-broom
Fine sediment	↓	↑
Nutrients (TP, TN)	↓	≈
Metals	↓	↑
Bacteria (FIB)	↓	↓
PAHs	↑	≈

↓ lower ↑ higher ≈ no consistent change

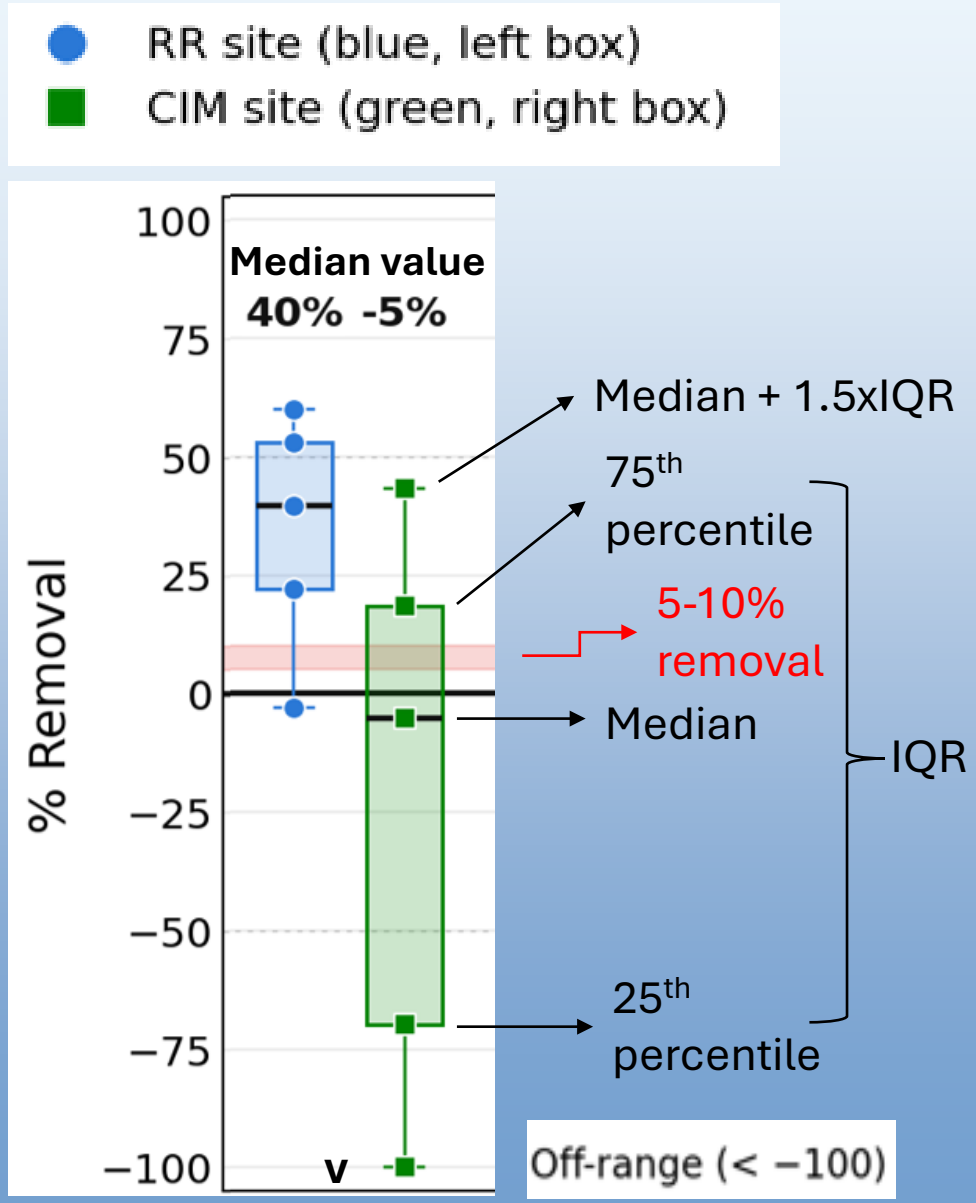
Quantifying Performance - Orientation

Research Question: What is the pollutant concentration reduction in runoff due to street sweeping ?

- EMC: Event mean concentration = a weighted average concentration accounting for flow and pollutant dynamics
- Metrics
  - **EMC_{swept}**: How clean is swept pavement runoff?
  - **% "removal"** a.k.a. %-reduction, %-difference

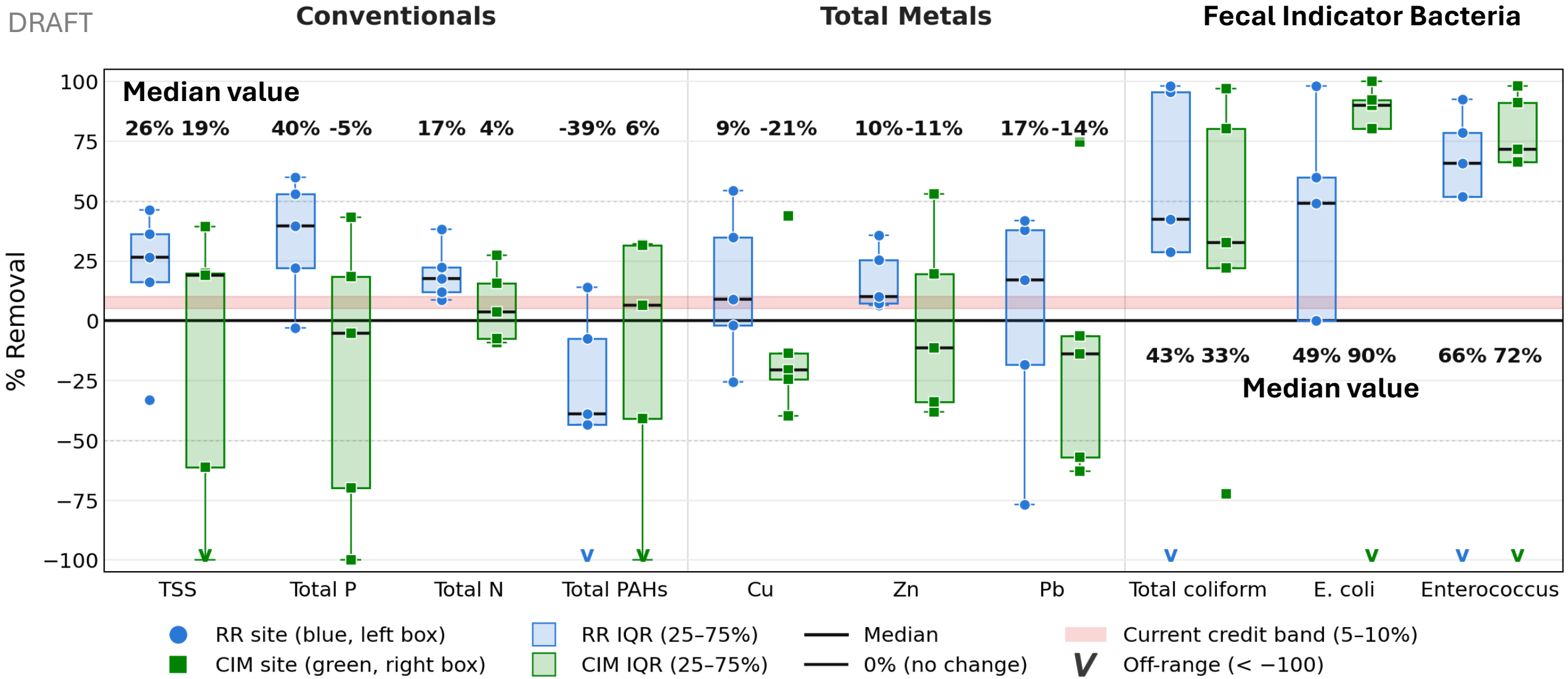
$$\% \text{ Removal} = \frac{EMC_{unswept} - EMC_{swept}}{EMC_{unswept}} \times 100\%$$

- *All results considered DRAFT until publication*



Results : EMC % Removal

DRAFT



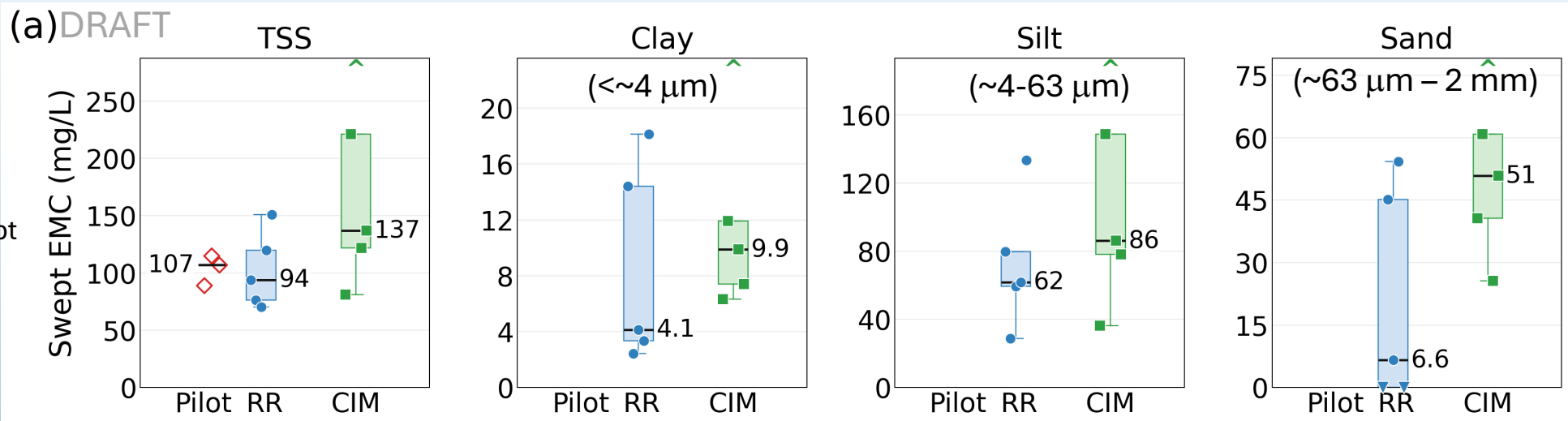
Sediment Performance

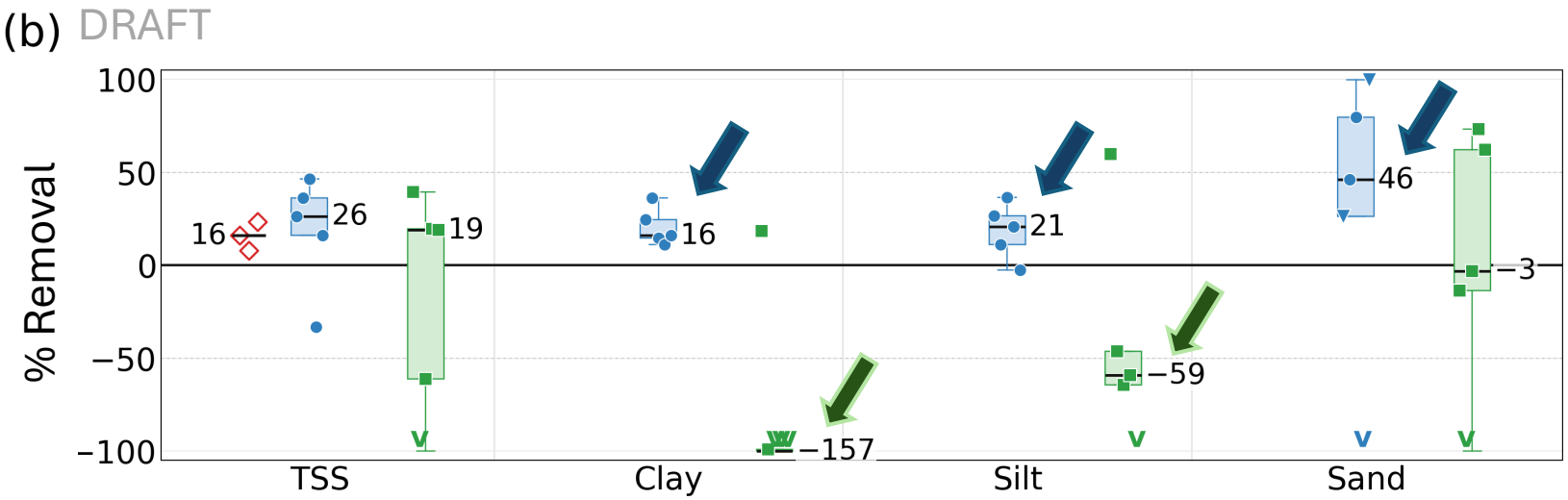
Key Take-Aways

- Median

RR EMC_{swept} < CIM EMC_{swept}

- Regenerative-air sweepers reduced TSS & all particle-size fractions
- Median reduction increased with particle size at RR sites
- CIM increased clay & silt at 4/5 sites





◇ Pilot events (regenerative air)
● RR sites (regenerative air)
■ CIM sites (mechanical broom)

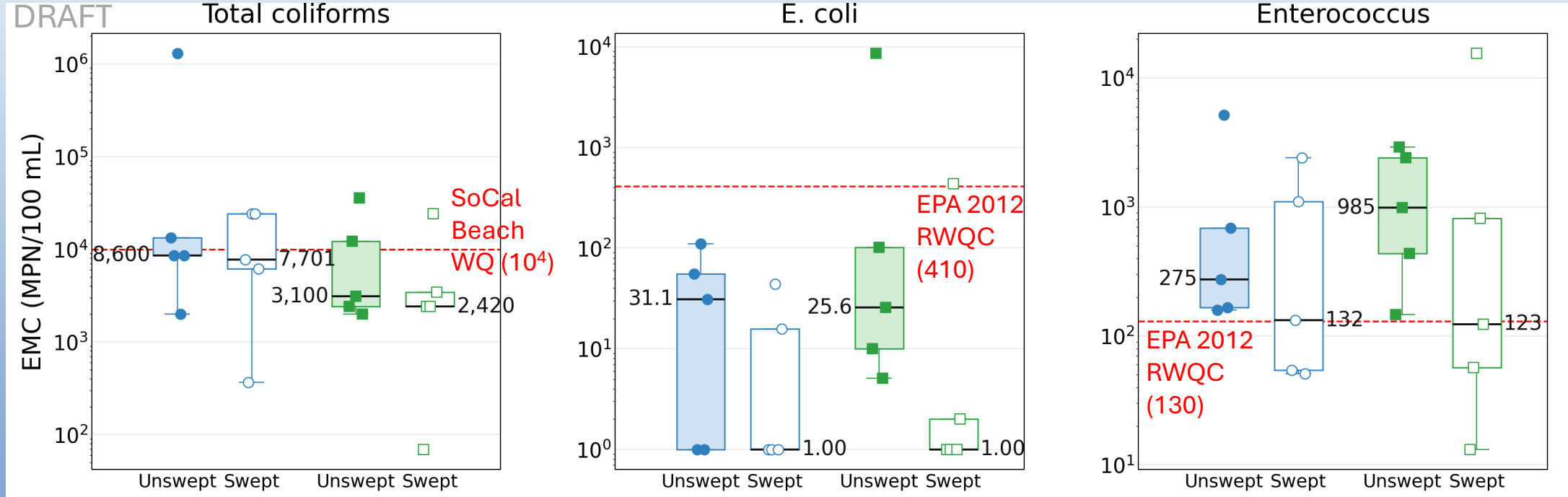
TSS = total suspended solids

All results considered DRAFT until publication

Fecal Indicator Bacteria (FIB) Performance

Key Take-Aways

- $EMC_{unswept}$ were relatively low compared to catchment-scale measurements
- Both sweeper types consistently reduced FIB EMCs, despite small size of FIB
- FIB removal may be due to other mechanisms, rather than physical collection alone



RWQC = recreational water quality criteria (grab samples)

Performance – PAHs & Heavy Metals

- PAHs (25 analytes)
  - No consistent removal of total PAHs, with either sweeper type
  - Median swept EMCs reflected differences in corresponding unswept EMCs rather than sweeping effects
  - Many compounds below detection limits
- Heavy Metals (8 metals)
  - Positive median %-reduction at RR sites for all metals, except Selenium
    - Statistically significant for total Zinc, total Nickel, dissolved Cadmium
  - Sweeping *increased* median EMCs for all total metals at CIM sites
  - Median RR EMC_{swept} was lower than CIM EMC_{swept} for 7/8 metals (except Se)

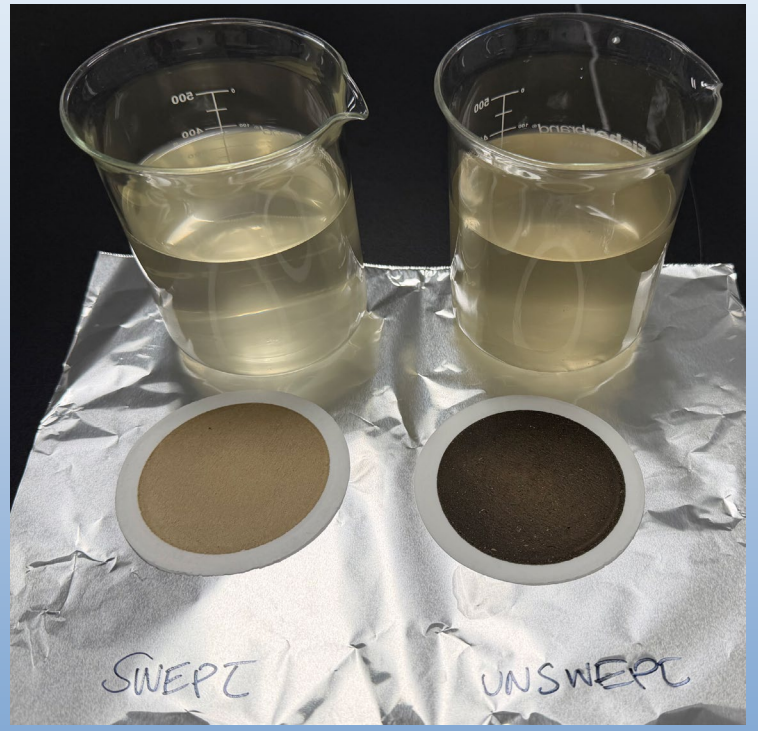
Potential Explanation?

Does sweeping-induced surface scraping outweigh the benefits of street sweeping pick up for PAHs?

Is abrasion of bristles from the rear broom on mechanical sweepers during operation the reason for differences between RR and CIM?

Microplastics – preliminary indications

- By size
  - 20-63 um → 10,000s particles/L
  - 63-125 um → 1,000s particles/L
  - 125-355 um → 100s particles/L
  - 355-500 um → 10s particles/L
  - > 500 um → 10s particles/L
- Both sweepers reduced median concentrations of total microplastics
  - Overall removal: ~20%
  - RR outperformed CIM: ~40% vs. ~17%
- RR performance by size fraction generally consistent with traditional sediment



Thank you to City of Santa Barbara, NOAA-funded Clean Streets, Clean Seas Research Program

City of Santa Barbara SUSTAINABILITY & RESILIENCE

Summary Findings

- Repeatable, mobile method for testing runoff water quality.
- What is the pollutant concentration reduction in runoff due to street sweeping?
  - → Removal varied by site and by contaminant
  - → Positive (and >5%) median removal for TSS, TP, TN, total Zn, FIBs, and microplastics, but not for total PAHs, total Cu, or total Pb
- Do contaminant concentrations under unswept conditions differ by land use? If not, could sweeper type be a potential influencing factor?
  - → No significant differences in contaminant concentrations between residential and commercial/industrial sites
  - → Regenerative-air sweeper outperformed mechanical-broom sweepers for TSS, TN, TP, total Cu, Zn, Pb, and microplastics.

Effect on runoff EMCs

Summary Trends	 RR Residential-Regenerative-air	 CIM Commercial/industrial Mechanical-broom
Fine sediment	↓	↑
Nutrients (TP, TN)	↓	≈
Metals	↓	↑
Bacteria (FIB)	↓	↓
PAHs	↑	≈

↓ lower ↑ higher ≈ no consistent change

More to Come...

- Data will be here: https://smcbmp.sccwrp.org/performance-index-app/
- Results of this study from pesticides, PFAS, 6-PPD & 6-PPDQ

SAFE CLEAN WATER PROGRAM

- More testing! 10 additional locations in Los Angeles County via the Safe, Clean Water Program Scientific Studies
- Testing anticipated Jan.-April 2027
- Results Dec. (ish) 2027









Thank you! Questions?

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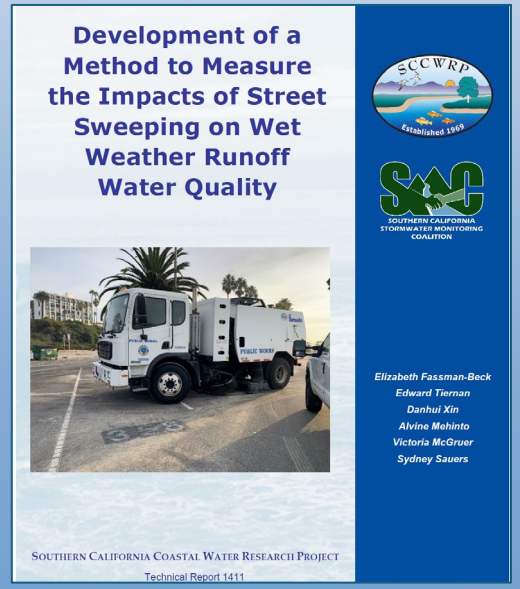
https://socalsmc.org/

https://www.dri.edu/swstormwatercenter/

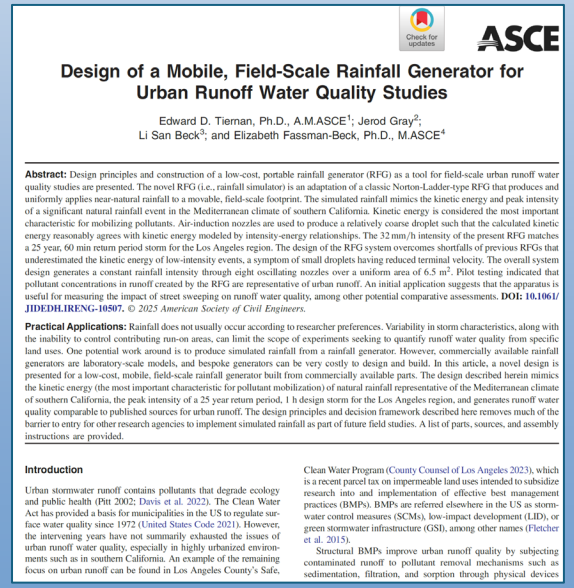
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Dario Diehl
Andrea Benitez
Shelby Marhoefer-Jess

Data will soon be here:
https://smcbmp.sccwrp.org/performance-index-app/

Method development



www.sccwrp.org → publications → search on my name



https://doi.org/10.1061/JIDEDH.IRENG-10507

Build your own rainfall generator



Plans, parts & instructions
https://osf.io/2b4vh/

Break

15 minute break

Section 3 – Enhanced Street Sweeping and Case Study

SWEEPER SUMMIT

The Pathway Toward Enhanced Street Sweeping

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WHY ENHANCED SWEEPING

The Cheapest Pound of Pollutant You'll Ever Remove

A 2007–2019 study across 14 Florida MS4 locations compared the cost of removing nitrogen (TN), phosphorus (TP), and particulate matter (PM) using different stormwater BMPs. Street cleaning was, by far, the least expensive method for every pollutant measured.

Cost per pound removed (TN / TP / PM), 2020 CPI-adjusted

BMP Treatment Train	TN $1,068	TP $37,243	PM $29.70
FL Statewide BMP Database	TN $2,171	TP $11,995	PM $46.84
Screened Hydrodynamic Separator	TN $4,261	TP $10,521	PM $4.60
Baffled Hydrodynamic Separator	TN $3,450	TP $8,511	PM $3.43
Catch Basin Cleaning	TN $1,016	TP $1,656	PM $0.70
Street Cleaning (lowest cost)	**TN $189**	**TP $294**	**PM $0.11**

2X

A 2024 controlled pickup performance test for the City of LA found a regenerative-air sweeper removed pollutants more than twice as efficiently as a mechanical broom sweeper.

Air sweepers are now widely seen as the most cost-effective remedy for pavement-based pollutant removal.

EQUIPMENT

Sweeper Type is Extremely Important

Regenerative air sweepers have been documented picking up 90–95% of material on pavement — including the small-micron particles that carry the most pollution.

LIMITED USE

M

Mechanical Broom

- No vacuum component — debris is tossed onto a conveyor belt
- Reserve for freeways/no-curb areas and heavy post-storm accumulation or as a tandem sweeper followed by air

SITUATIONAL

V

Vacuum

- One type of air machine; strong on porous surfaces
- Continually exhausts used air — can affect local air quality
- Competitive to regenerative air

RECOMMENDED

R

Regenerative Air

- Recirculates its air supply internally
- Best overall pickup of fine, heavily-polluted particles

Vehicle Removal is of Paramount Importance

The only way to maximize pickup of pavement-based pollutants is to move vehicles out of the sweeper's path.

30–60%

increase in particulate pickup when vehicles are mandatorily removed vs. swept around

1 parked car blocks 3 curb lengths. 2 spaced cars can block 6.

Parking-fine revenue can offset the cost of a removal program while significantly improving pickup.

- ✓ **Sample the street dirt**
  Test dirt in the current watershed to calculate the pollutant load being left on the road because vehicles weren't moved.
- ✓ **Test before you invest**
  Have the operator use a counter to log how many car-lengths are missed when removal is voluntary — quantify what's really being left behind.
- ✓ **Notify, don't just enforce**
  Phone/computer apps alert residents that a sweeper is coming — and again once it has passed — so cars can be moved and re-parked quickly.
- ✓ **Streamline enforcement**
  Camera-based ticketing on the sweeper itself transmits directly to the ticketing agency, cutting the cost of enforcement while still funding the program.

Getting the Basics Right

1 Speed

3–6 mph for heavy accumulation. But 8–10 mph only cuts pickup 10–15% — often worth it to cover more curb-miles per day.

2 Frequency

Match to land use: weekly, twice monthly, or monthly. Daily/twice-weekly downtown sweeping is often wasteful for a goal of pollutant removal.

3 Pavement Condition

Poor/fair pavement traps dirt in cracks and depressions. Seal cracks, support repaving, and prioritize curbed streets — that's where dirt accumulates.

4 Maintenance

Well-maintained air machines outperform neglected ones. Replace worn gutter brooms, keep engines and moving parts in good order.

5 Tandem Sweeping

In very heavy debris, run an air sweeper behind a mechanical broom to recover the fine, toxic particulates the broom leaves behind. Best overall results.

6 Data & Modeling

Use tools like SIMPTM or SWPT to model removal and allocate resources by data — not by habit.

A PRACTICAL FRAMEWORK

Maximizing Your Sweeping Program

Four steps to move from a routine schedule to a data-driven pollutant-removal program: sample; quantify; model; and, match your equipment to the model.

STEP 1 OF 4

Find Out What's Really on the Street

Before changing anything, establish this baseline: How much of your target pollutant is actually in the street dirt along a given route?

1	**Sample the route**	Collect street-dirt samples from several representative spots along a sweeping route — vary land use, traffic, and canopy cover.
2	**Test for target pollutants**	Lab-analyze the samples for the pollutants you care about most (e.g., phosphorus, nitrogen, zinc, copper, microplastics and emerging contaminants). Lab analyze for particle size distribution and the pollutants you care about most.
3	**Weigh what the sweeper picks up**	Record how much material (by weight) the sweeper actually collects on that same route.
4	**Calculate pounds removed**	Multiply the pollutant concentration in the dirt by the total weight picked up to get pounds of that pollutant removed per sweep.

Result: a defensible, site-specific number for pounds of pollutant removed per sweep — the foundation for every calculation that follows, including future credit applications.

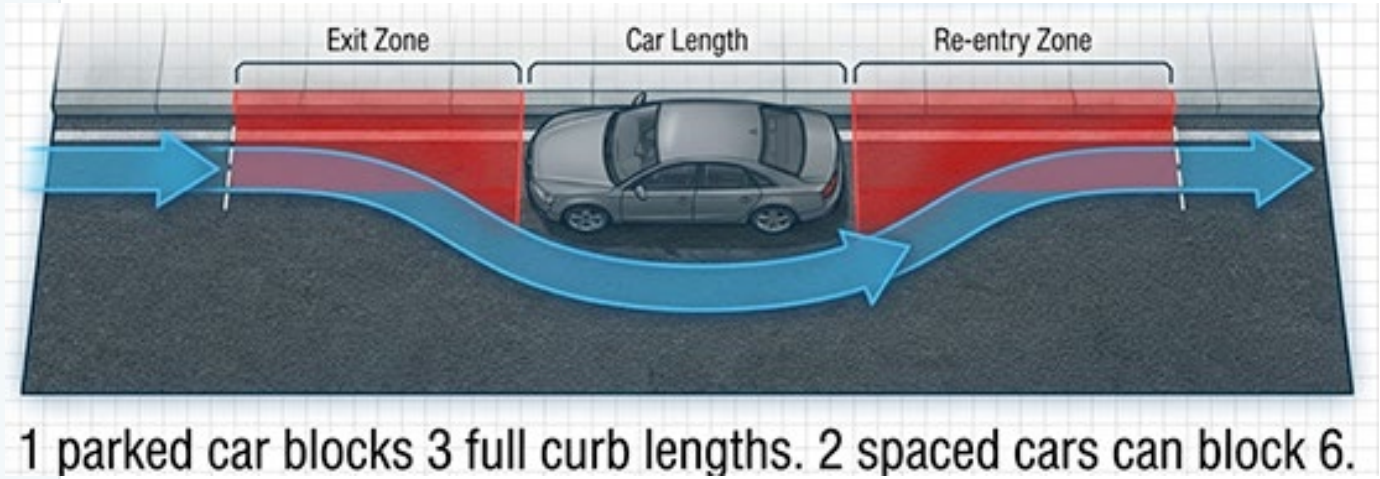
STEP 2 OF 4

Quantify the Cost of Parked Cars

A simple clicker turns a familiar operational headache into hard data on pollutant removal you're leaving behind.

3 sweeping spots missed

(the exit zone, the car's own length, and the re-entry zone)



The Method

- Give the operator a hand counter for one representative route.
- Click once for every solitary parked car encountered — each one costs ~3 curb-length “spots” not swept.
- Multiply car count × 3 to get total curb-spots missed on an average day.

The Math

Pounds picked up on an average day ÷ curb-spots actually swept = pounds per spot.
Multiply by spots missed to parked cars = pollutant left on the street because of parking.

STEP 3 OF 4

Model When and Where to Sweep

Pollutant-transport models like SIMPTM and SWPT simulate accumulation, rain wash-off, and sweeper removal — so scheduling can follow the weather, not the calendar.

Fixed Biweekly Schedule (every two weeks)

Sweeps every two weeks regardless of rain. Often sweeps after the biggest pollutant load has already washed off — or misses a storm entirely.

~50% reduction in stormwater pollution vs. no sweeping

Rain-Forecast-Based Schedule

Sweeps as close as possible ahead of a forecast rain event, removing material before it can wash off into receiving waters.

~15–20% increase over the fixed schedule sweeping — often using half the sweeping (or less)

The models also answer "where to sweep"

Layer in GIS data — land use, tree canopy, traffic volume — to prioritize routes. Nutrient concerns (phosphorus, nitrogen) point to canopy-covered and residential streets; heavy-metal concerns point to high-traffic commercial and industrial corridors. High-priority routes get swept ahead of storms; lower-priority routes stay on a routine schedule. Sweeping every two weeks in Lavonia, MI, resulted in a 30% reduction in nutrient runoff and up to 70% less heavy metal.

STEP 4 OF 4

Match Sweeper Technology to the Model

This will allow factoring in which sweeper technology is assigned to a route — because mechanical broom, regenerative air, and vacuum machines differ sharply in their ability to capture the smallest, most-polluted particles.

only 25%

of material on a street may be 250 microns or smaller —

but can be 60%

of the pollutant load. That fine fraction is also the most likely to wash off or go airborne.

Track by particle size & pollutant

Model outputs by particle-size range and, within those, specific pollutants — phosphorus, zinc, copper — rather than one blended number.

Quantify annual reductions

Convert that into pounds reduced per year, in a form that can plug directly into a crediting framework where one exists (or is being developed).

Assign the right machine to the right route

A high-nutrient residential route may call for a regenerative-air sweeper; a heavy-debris corridor may still need a mechanical broom pass first.

THE PAYOFF

Turning Data Into Regulatory Credit

Where credits are moving

- Over 70% of state MS4 permitting agencies do not require or provide a nutrient or sediment reduction credit for street sweeping, regardless of whether there is an applicable TMDL.
- The Clean Streets = Cleaner Water initiative (led by NMSA's Seth Brown and Greg McPartlin) is working toward guidance for a nationwide crediting framework.
- Current credit amounts by most MS4s are not realistic

up to 700%

more effective at removing phosphorus and nitrogen from the runoff stream than the next best BMP (catch-basin cleaning), per recent street-sweeping data — a strong basis for enacting permit-credit regulations.

Over 1,000 U.S. cities are currently out of compliance with runoff programs — better data, easier access, and stronger decision tools can help close that gap.

EMERGING POLLUTANTS

Microplastics: The Clean Streets, Clean Seas Project

City of Santa Barbara, USC Sea Grant, and UC Santa Barbara — funded by a $1.26M NOAA grant — are testing how well sweeping removes microplastics before they reach creeks and oceans.

Regardless of sweeper type, water use, or speed, microplastics and tire-wear particles are picked up at equal or greater rates than ordinary street dirt.

Tire wear is the hard part

Tire-wear particles — a major share of microplastic pollution — are removed at a lower rate than other microplastics, and overall efficiency drops as particle size shrinks.

The operator matters most

Operator skill has a greater impact on removal performance than which machine is used.

6PPD-quinone

A tire-preservative byproduct now linked to acute toxicity in coho salmon, even at very low concentrations — raising the stakes for tire-wear capture.

Sweeping may outperform assumptions

SCCWRP's new rainfall-simulator test method suggests street sweeping may reduce runoff contamination **significantly** more than the traditionally assumed 5–10%.

How to feasibly implement Enhanced Street Sweeping

1. **Regulation and technology have to advance together**
   and how much credit those states actually give
2. **Three ways to measure what a sweeping program removes**
   and why the strongest one should earn the most credit
3. **What the data says about the drivers of urban street pollution**
   and how it answers where to sweep
4. **Using models to simulate pollutant transport**
   and how they answer when to sweep

FRAMING

Regulation and technology have to move together

REGULATION

What a permit will accept

- Permit language that names sweeping
- An adopted crediting method
- Reporting and verification rules

TECHNOLOGY

What we can actually measure

- Data on what is on each street
- Models simulate and optimize sweeping activities
- Equipment and sampling that measure recovery

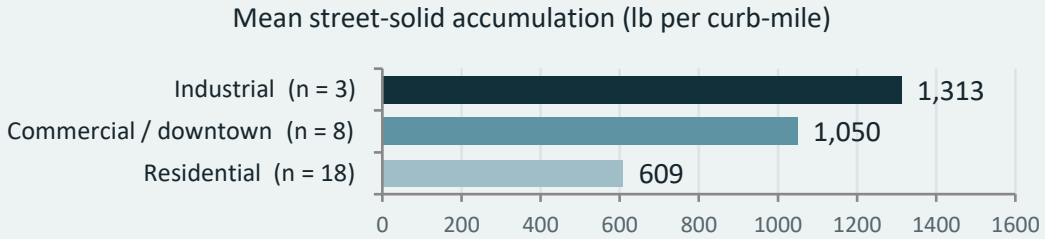
Neither track gets there alone. A crediting method with no way to produce a local number goes unused. Better local numbers with no method willing to accept them never reach a permit. The gap closes only when both sides move at the same time.

DATA IS THE SOLUTION

The Drivers of Urban Street Pollution

Land use

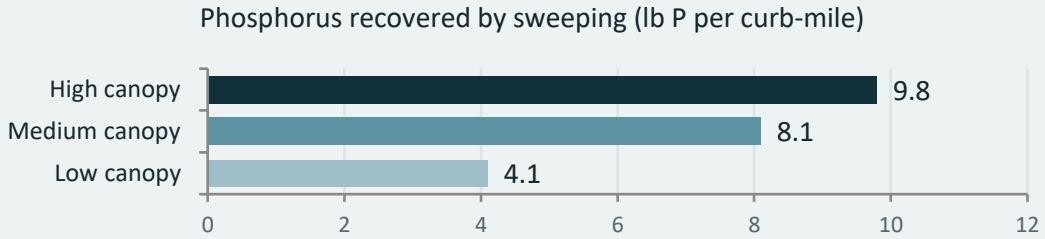
Indicates the total load and pollutant matrix on the street.



29 curb-mile records, full range 130–4,788. Sartor & Boyd (1972); Pitt (1979); Selbig & Bannerman (2007); Sorenson (2012).

Tree canopy

Indicates the organic and nutrient load, seasonally.



Route-level sweeping records, Minneapolis–St. Paul, 2011–2013. Kalinosky et al. (2014).

Traffic

Sets the vehicle-derived load, and it scales with vehicle-miles.

10× more tire-wear particles and microplastics on high-traffic streets (>30,000 ADT)

5.6–14.5 mg of tire-wear PM_{10} per vehicle-mile, light-duty vehicles. Brake wear adds 3.2–14.2 mg more

Mierzynska et al. (2024), paired high- and low-traffic streets; Ntziachristos et al. (2014), PM_{10} emission factors.

Season

Recovered mass peaks in spring; nutrient load peaks in autumn.

0.19 → 3.5 lb of nitrogen recovered per curb-mile per month, from a low-canopy August route to a high-canopy October route

125–500 lb of sand and grit applied per lane-mile per winter treatment

Kalinosky et al. (2014), monthly route sampling; NHDES & UNH T2 (2022); Hobbie et al. (2023), 3 years of route-level nutrient sampling.

DATA SOURCES

GIS Data Serves as a Proxy for the Drivers



Traffic

HPMS annual average daily traffic

Tree canopy

1 m canopy height model

Land use and cover

NLCD, 30 m raster

Road network

OpenStreetMap centerline, split into 200 ft segments

What these layers are

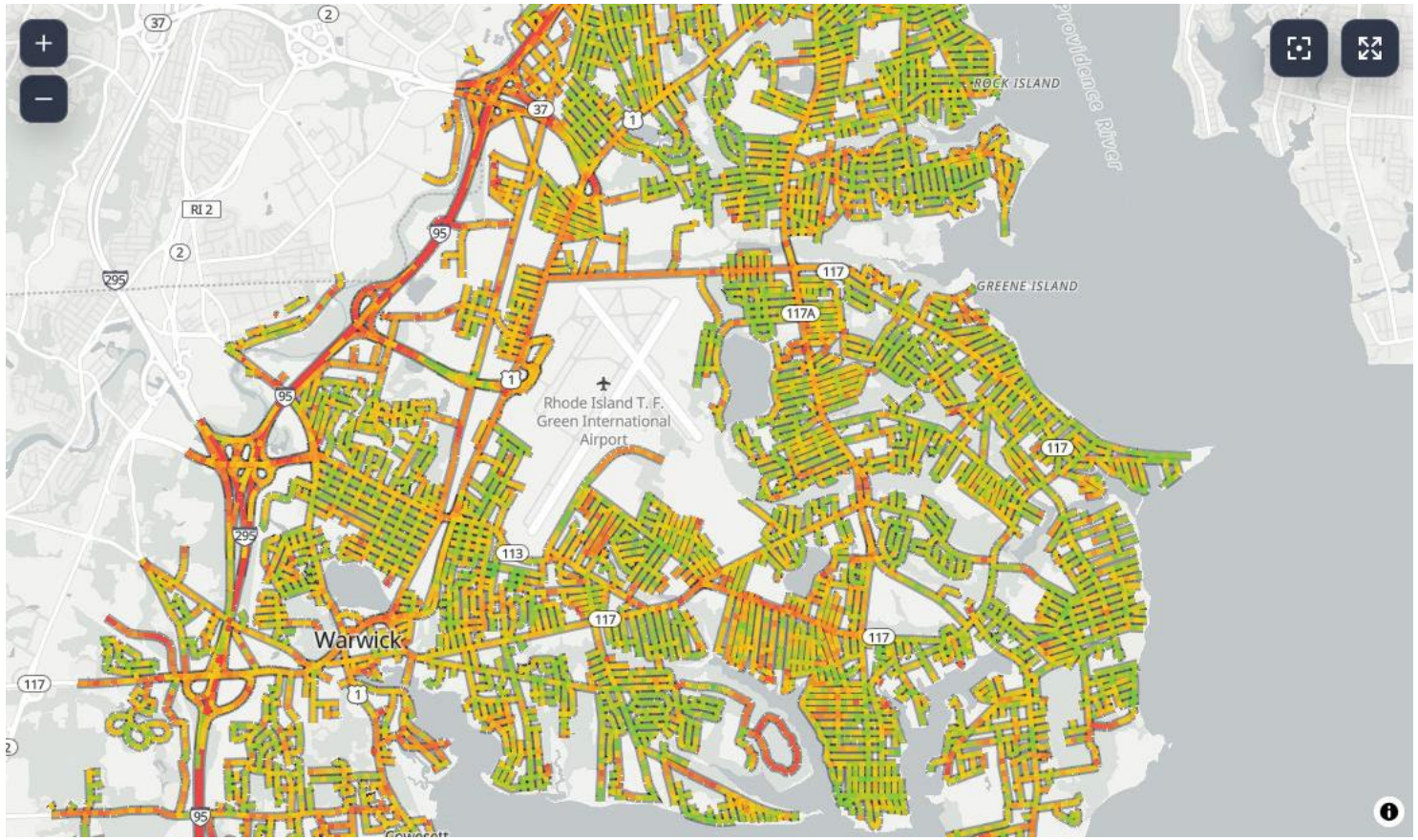
Indicators of what is likely on the pavement — **proxies for the drivers**. They help identify which streets probably carry the heaviest load. They are available nationwide, at no cost.

Limitations

HPMS traffic on local streets is scarce, so we need to extrapolate. NLCD at 30 m cannot see inside a block. **Local data enrichment** is needed to turn this baseline into something defensible.

THE OUTPUT

Which streets to sweep with the budget you have



Warwick, RI road network scored for a **heavy-metal focus**: industrial/commercial land use and traffic both weighted **higher** than canopy coverage. Priority is a within-network relative rank, not a pollutant mass.

Turning a ranking into a route

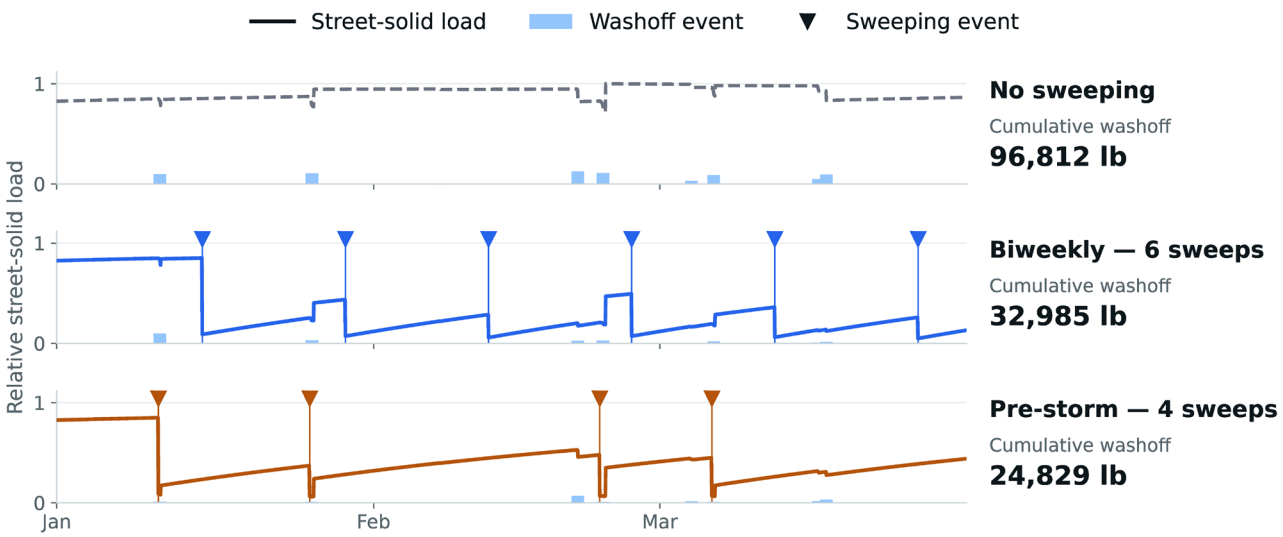
- **Score every 200 ft segment** on land use, canopy and traffic
- **Prioritize the whole network** on one consistent scale
- **Sweep the highest-priority segments first**, ahead of large storms, as resources allow
- **Re-prioritize for the season** and the pollutant you're targeting

- Prioritization helps decide **where to sweep**
- Next, we will discuss **when to sweep**

Timing is the crucial factor: sweep before the storm

What a model does: simulate material accumulating between storms, then compare a sweeping schedule against a no-sweeping baseline. It is a scheduling tool — it answers when and where to sweep, not how much a permit should credit.

SWPT/SIMPTM buildup–washoff simulation, Warwick, RI road network (434 road-miles), Jan 1 – Mar 31, 2026, observed rainfall (8.7 in, 9 storms)



Fixed Interval Sweeping

50-60%
washoff reduction

washoff reduction from a twice-monthly schedule, against a no-sweeping baseline

Pre-Storm Sweeping

~15%
relative increase

washoff reduction when the sweep is timed ahead of an intense rain event

Cost Efficiency

~40% cheaper
per pound removed

when implementing pre-storm sweeping with 33% fewer sweeps (only 4 sweeps instead of 6)

Why timing is essential: if the goal is reducing stormwater pollution, street material has to be removed with respect to storm events, not on a fixed calendar. A sweep that misses the storm buys nothing downstream.

LIMITATIONS

Models do not replace measurement

WHAT THE MODEL ASSUMES

- How fast material rebuilds after a sweep
- How much of it a storm can actually mobilize
- How much the sweeper picks up, by particle size
- How much pollutant each size fraction carries

WHAT SAMPLING MEASURES

- Street dirt loading on your own routes
- Particle size distribution of that material
- Pollutant concentration on that distribution
- Mass collected per sweep

Calibrated parameters are not stable

Urban loading is heterogeneous. Buildup and washoff coefficients shift with land use, geography and season, and the same catchment has produced coefficients differing by factors of several between calibration windows.

The real world is hard to replicate

Parked cars close off the curb line. Pavement condition changes what a sweeper can lift. Rain forecasts are wrong often enough to matter. Every one of them erodes the performance a model assumes.

Models and measurement go together

A model drifts unless measurement pulls it back. A continuous stream of field data — mass recovered, particle size, curb access — is what keeps it grounded, and that is where the technology is headed.

CLOSING

Roger's Enhanced Street Sweeping bucket list

A lot needs to happen before enhanced street sweeping is implemented across the nation.

Integrate SIMPTM with the Storm Water Pollution Tracker

Put a calibrated, physically based simulation engine underneath the prioritization and crediting tools.

Create a free, citizen-friendly mobile notification application

Get vehicles off the curb line by making compliance easier than a ticket.

Standardize pollution credits for MS4 and TMDL compliance

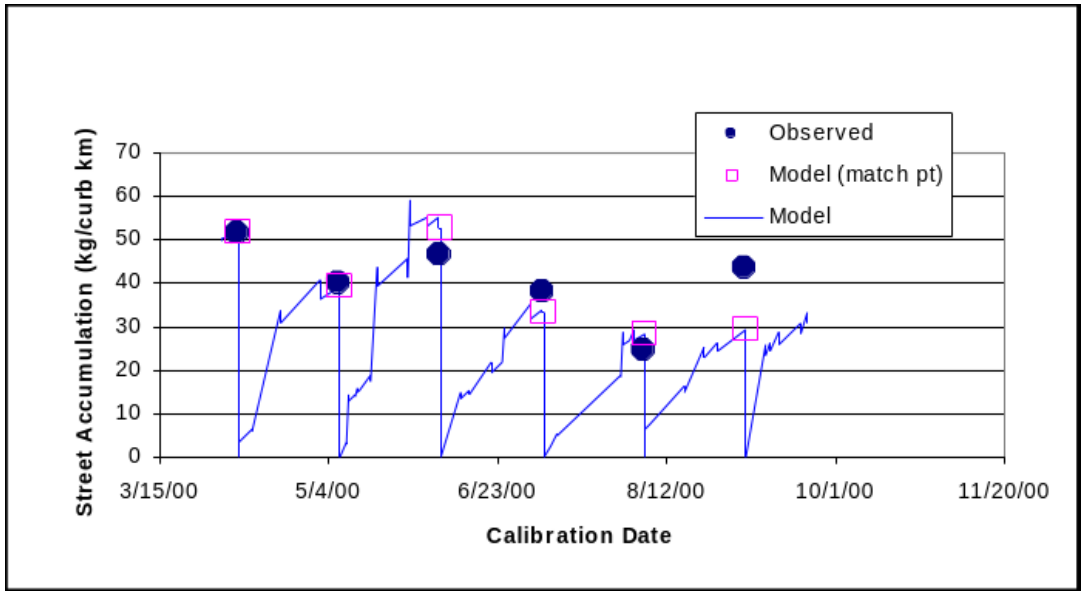
Replace unrealistically low credits with numbers that match what sweeping actually removes.

BUCKET LIST ITEM #1

Integrate SIMPTM with the Storm Water Pollution Tracker

SIMPTM becomes the simulation engine for SWPT

- Simulates the continuous accumulation and washoff of particulate matter and its associated pollutants
- Simulates pollutant reductions from specific enhanced sweeping operations, by mass and by concentration



SIMPTM street-accumulation calibration, observed versus modeled. Figure supplied by Roger Sutherland, Cascade Water Resources.

WHY SIMPTM

Physically-based washoff

Sediment transport equations for overland and gutter flow, with shallow-flow hydraulics. SWMM, WinSLAMM and P8 do not work this way.

Wet weather washon

Intense storms carry sediment off impervious areas and onto the street. Only SIMPTM and SWPT account for it.

So the others run low

Without washon, a model misses street dirt that is genuinely available to wash off — and understates what sweeping removes.

WHAT THE INTEGRATION UNLOCKS

- Repaving credited as a water-quality practice
- Regional differences in sweeping effectiveness
- Realistic crediting tools for MS4 and TMDL compliance

BUCKET LIST ITEM #2

A free, citizen-friendly notification app

Everything existing apps do, plus two alerts that change behavior at the curb.

- **Scheduled, and cancelled**

  Reminds residents when sweeping is coming, and tells them when it has been called off, so nobody moves a vehicle for nothing.

- **A mile out**

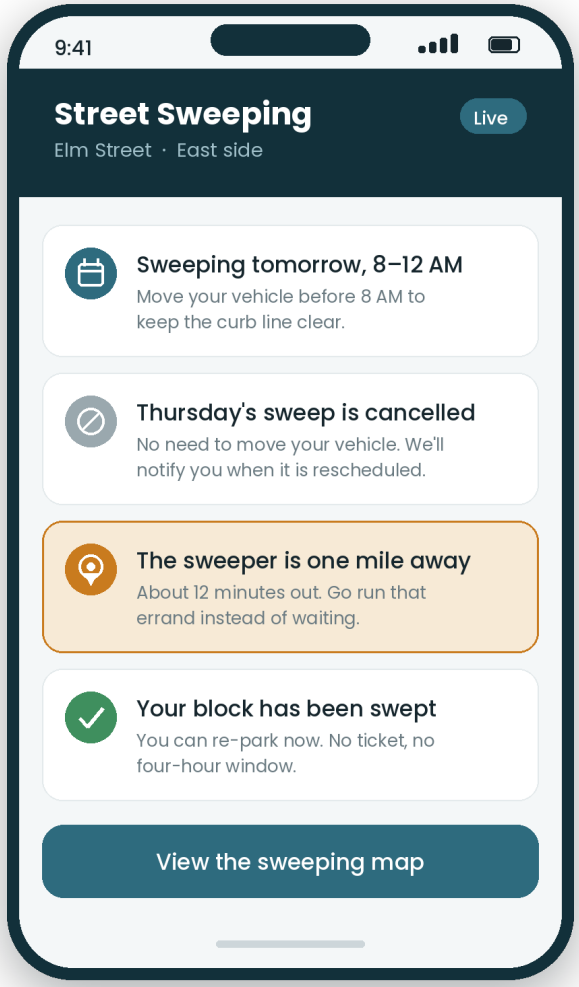
  Alerts you when the sweeper is a mile away, so you can run an errand instead of holding a four-hour parking window.

- **And once it has passed**

  Tells you the moment your block has been swept, so you can re-park straight away.

It only works paired with enforcement. Cameras on the sweeper identify the vehicles that actually blocked its path, so residents are not ticketed simply for being parked inside the window — and the program funds itself.

The ask: Southern California municipalities that already require mandatory vehicle removal and want to join a grant-funded project to build and test this app.



BUCKET LISTITEM #3

Standardize pollution credits for MS4 and TMDL compliance

Andrew's review identified every state that offers any pollutant-reduction credit for sweeping. **Outside the handful that credit measured mass, those credits are unrealistically low.**

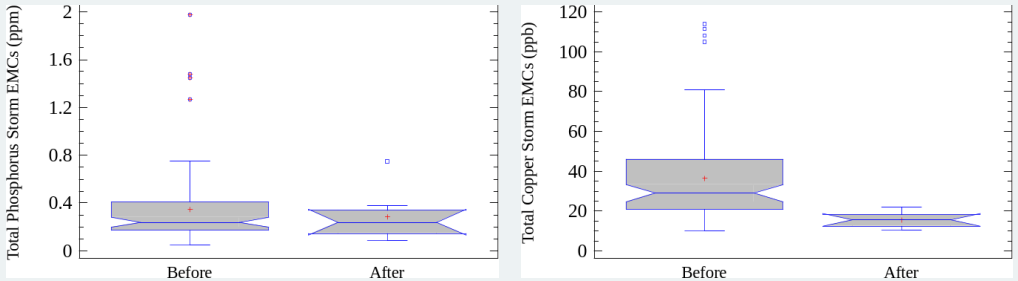
What enhanced sweeping actually removes

Mass load reductions, defensible from field studies

Twice-a-month enhanced sweeping	**50–60%** TSS
Storm-driven enhanced sweeping	**60–70%** TSS
Nutrients	**30–40%**
Heavy metals	**50–70%+**

Event mean concentration reductions for TSS are smaller than these mass reductions, but still well above what is credited today.

Measured, not modeled



Storm event mean concentrations before and after an enhanced sweeping program. Total phosphorus, left; total copper, right.

Field monitoring keeps landing well above the credits on the books.

Standardizing the credit is how that gap finally closes.

Questions? Get in Touch!

Be guided by the knowledge that “street sweeping is the first line of defense for pavement-based pollutant removal.”

Want help applying enhanced street sweeping to your program? Reach out to any of us for assistance.

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How Street Sweeping Supports Each Minimum Control Measure (MCM)



Maribel Guerrero, MPA
Managing Director of Engineering and Public Works

City of BROWNSVILLE Texas
On the Border By the Sea and Beyond

CITY OF BROWNSVILLE TIER MS4

The City of Brownsville maintains a comprehensive Stormwater Management Program (SWMP) designed to meet all requirements established by the Texas Commission on Environmental Quality (TCEQ).

As a **Tier 4 Municipal Separate Storm Sewer System (MS4) Operator** under the Small MS4 General Permit, the City implements the six **Minimum Control Measures (MCMs)** throughout the community to ensure ongoing compliance and the effective protection of local water resources.

These MCMs include:

1. Public Education, Outreach, and Involvement
2. Illicit Discharge Detection and Elimination (IDDE)
3. Construction Site Stormwater Runoff Control
4. Post-Construction Stormwater Management in New Development and Redevelopment
5. Pollution Prevention and Good Housekeeping for Municipal Operations
6. Industrial Stormwater Sources

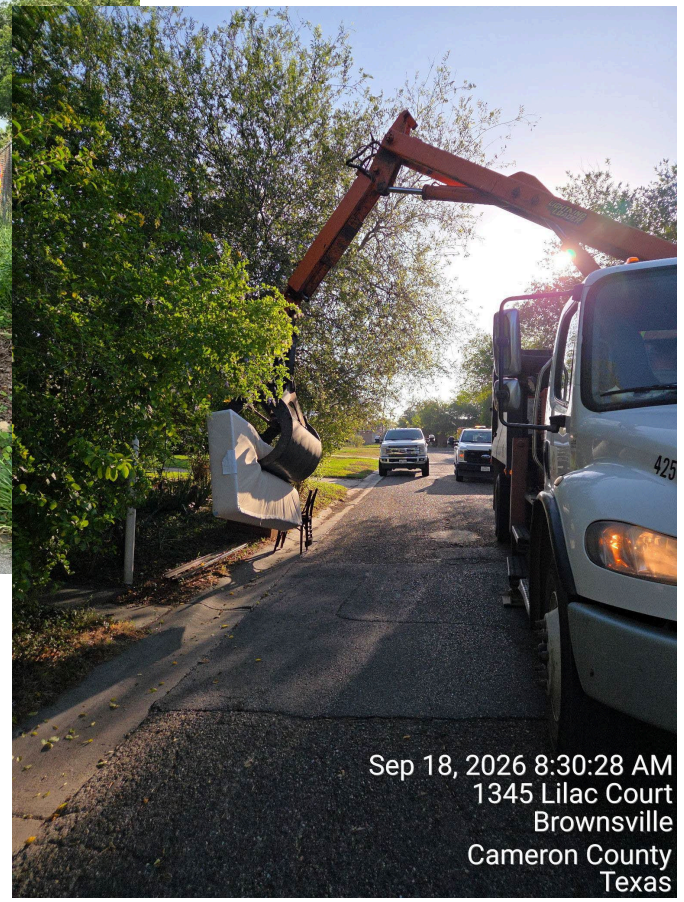
MS4 Minimum Control Measures (MCMs)

MCM 1:

Public Education, Outreach, and Involvement

The sweeping program demonstrates the City's visible commitment to clean waterways, helping reinforce public education messages about pollution prevention.





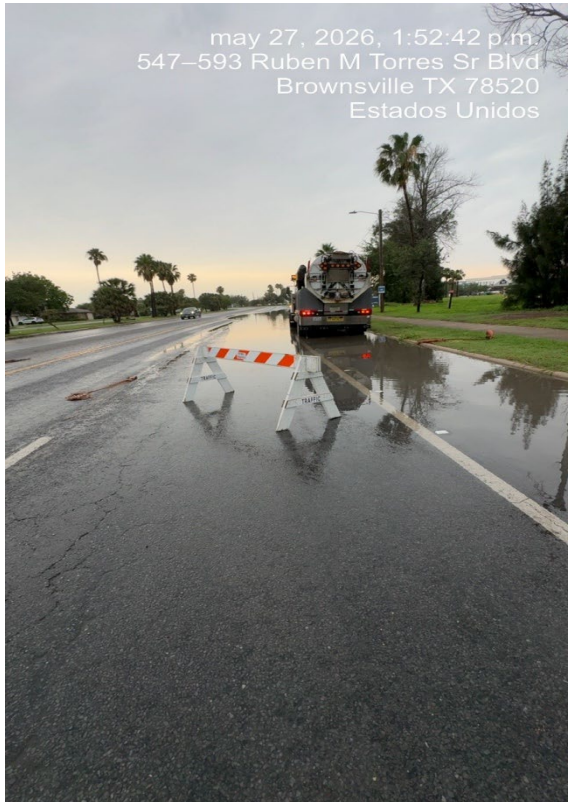
MS4 Minimum Control Measures (MCMs)

MCM 2: Illicit Discharge Detection and Elimination (IDDE)

Regular sweeping helps limit the accumulation of materials that can mask or obscure signs of illicit discharges.







MS4 Minimum Control Measures (MCMs)

MCM 3: Construction Site Stormwater Runoff Control

Sweeping reduces sediment and debris that may migrate from construction sites onto public road minimize sediment loading into the storm sewer system.

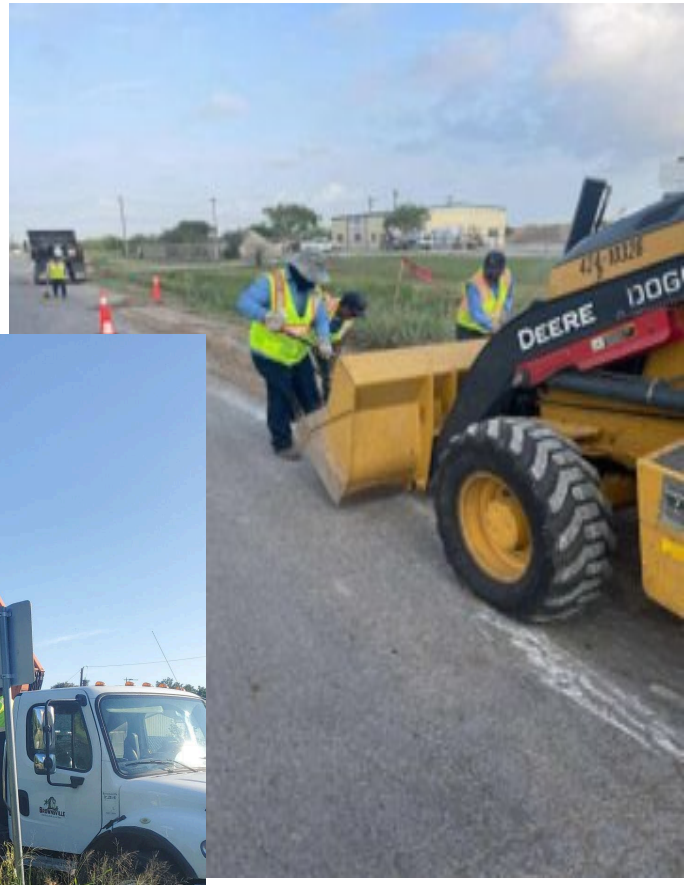




MS4 Minimum Control Measures (MCMs)

MCM 4: Post-Construction Stormwater Management in Development and Redevelopment

The program helps maintain long-term stormwater quality by removing pollutants generated from developed areas, including oils, metals, trash, and sediments that accumulate on impervious surfaces.

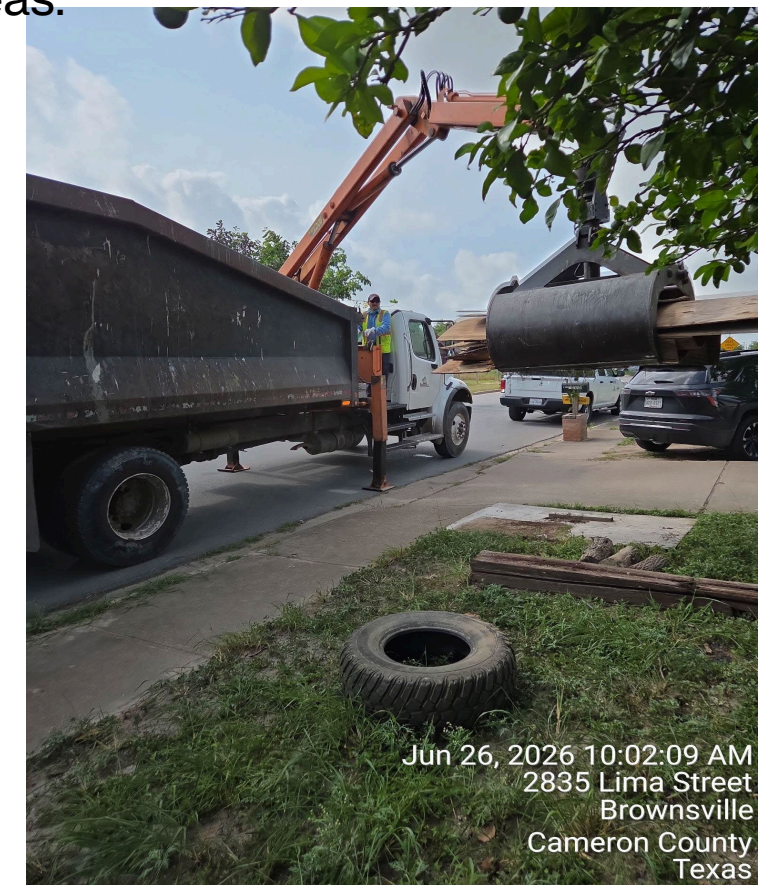




MS4 Minimum Control Measures (MCMs)

MCM 5: Pollution Prevention and Good Housekeeping for Municipal Operations

Street sweeping is a core pollution-prevention practice that reduces pollutant sources from municipal streets, rights-of-way, and maintenance areas.





MS4 Minimum Control Measures (MCMs)

MCM 6: Industrial Stormwater Sources

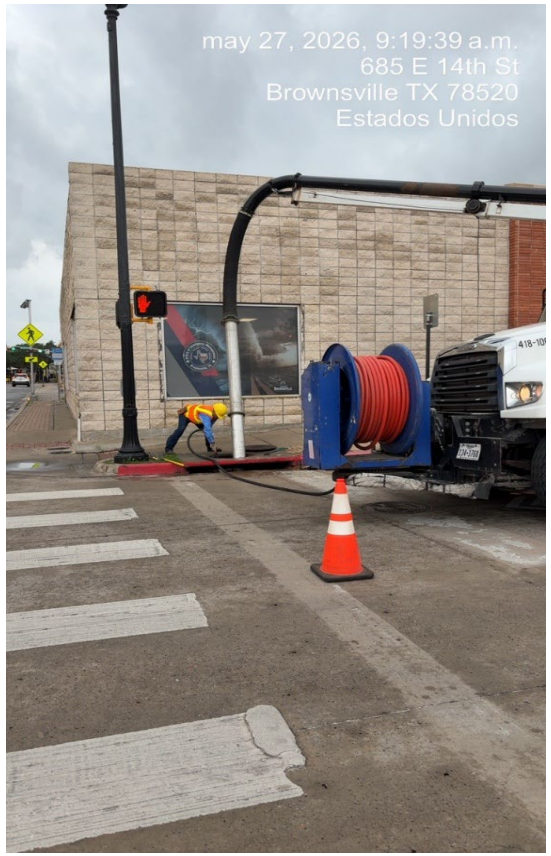
Sweeping around industrial corridors and transportation routes minimizes the buildup of materials that can contribute to industrial stormwater pollution.





Support for Vacuum Truck Operations and Inlet Maintenance

Sweeping reduces the number of debris that reaches storm drain inlets, allowing vacuum truck crews to clean inlets more efficiently and helping prevent blockages, sediment buildup, and potential localized flooding.







Street Sweeping Program Overview

- Equipment and Staffing
  - 5 sweepers currently operational
  - 4 operator positions budgeted

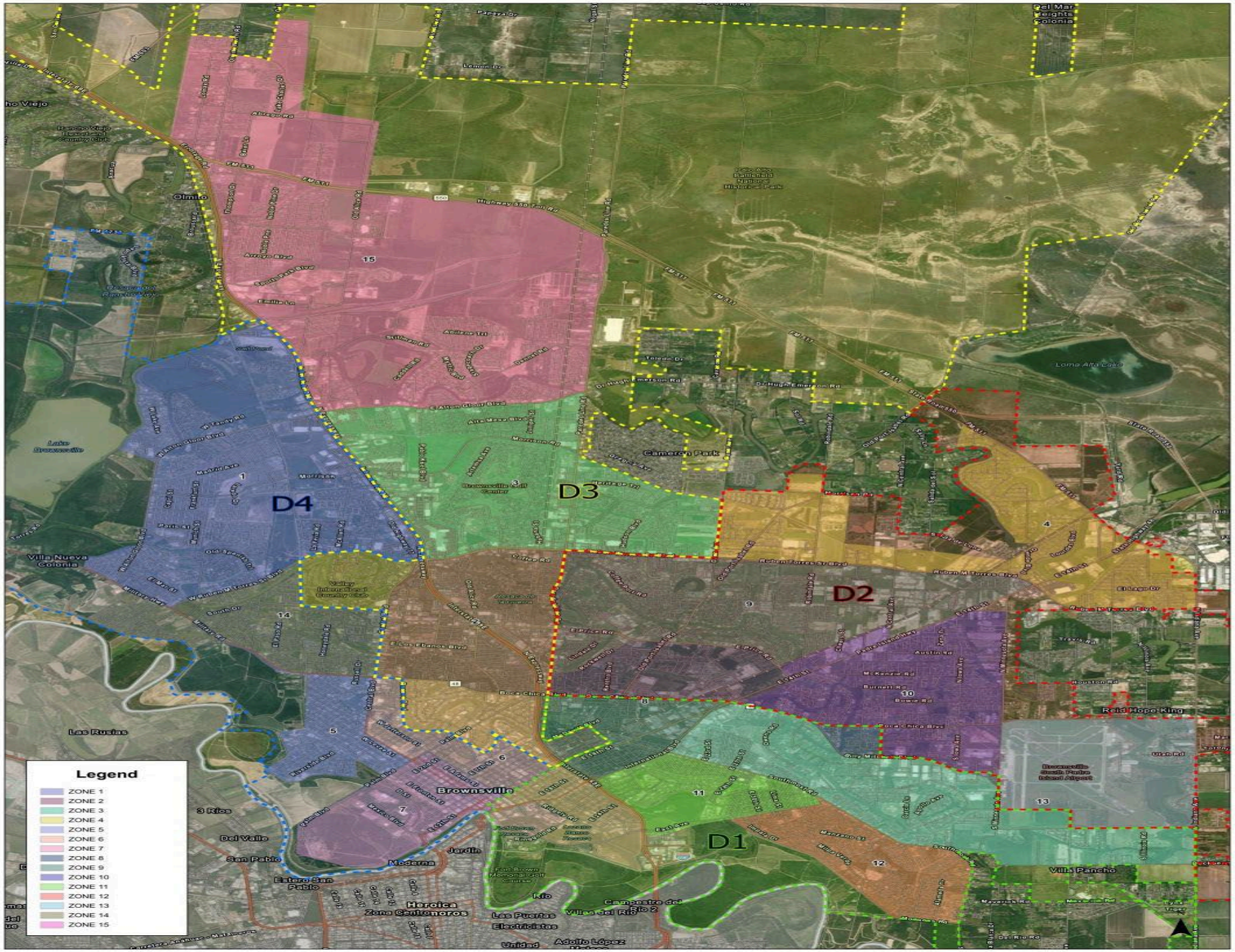
- Sweeping Schedule
  - Six sweeping cycles completed annually
  - 15 sweeping zones covered every two-month cycle

- Zone Assignments by District:

District 1	Zones 8, 11, 12, 13
District 2	Zones 4, 9, 10
District 3	Zones 2, 3, 5, 6
District 4	Zones 1, 5, 7 ,14



15 Sweeper Zones

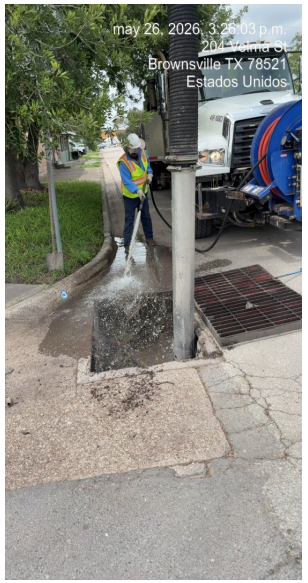


Engineering and Public Works Sweeping Program

The City of Brownsville's **sweeping program plays a central role** in coordinating Public Works field operations, with various divisions scheduling their work to coincide with designated sweeper zones.

Since routine maintenance activities can generate debris, sediment, and organic waste, aligning these activities with street sweeping schedules helps maximize pollutant removal and prevents materials from entering the storm drain system. This makes the sweeping program a key frontline pollution-prevention tool throughout the city.



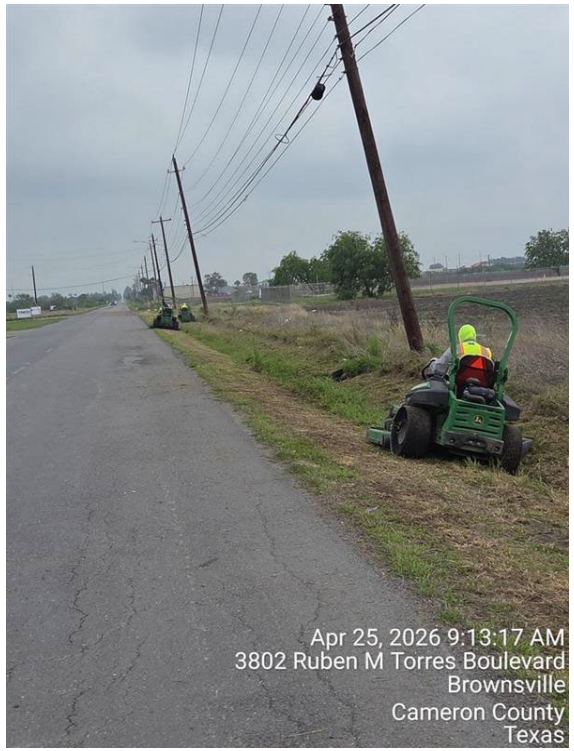


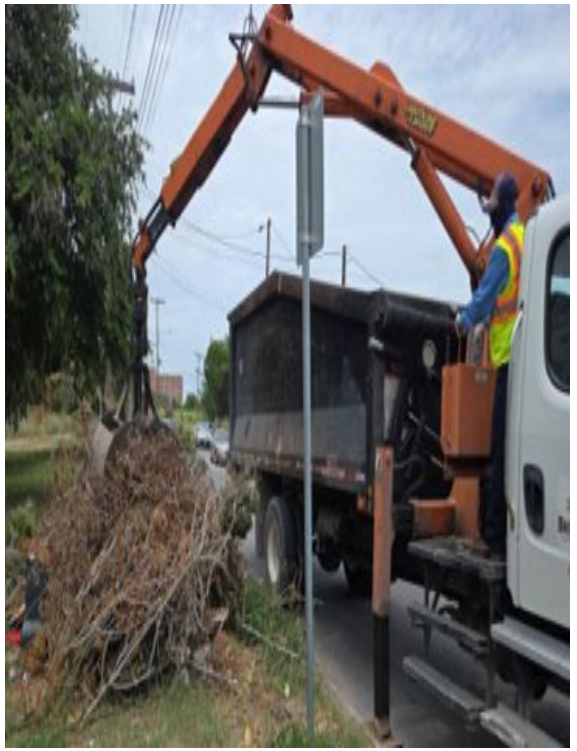


Support for Greens Division
(Mowing, Trimming, and Right of Way Maintenance

Right of way mowing and vegetation maintenance can leave behind grass clippings, leaves, and organic debris that become pollutants when washed into storm drains. Mowing is scheduled before sweeping operations to remove residual materials, preventing nutrient-rich organic waste from entering the stormwater system and contributing to water quality degradation.







- **220 mowing areas on a monthly rotation**
- **7800 acres mowed for year ending 2025-2026**
- **2635 tons of trash and debris picked up off streets for 2025-2026 year**

Support for Streets, Patching and Repair Crews

Street repair activities, including pothole patching, grading, and asphalt maintenance, can generate loose sediment, asphalt millings, and other construction-related debris. To support effective pollutant control, street repair operations are scheduled in coordination with designated sweeper zones, allowing sweepers to remove residual materials. This coordinated approach minimizes the potential for sediment and debris to enter curb inlets, drainage channels, and the municipal stormwater system.



- Mill/Overlaid: Sixteen streets totaling approx 4.5 miles.
- Alleys from FY2025: Thirteen alleys were milled and overlaid, totaling approx 3.2 miles.
- Alleys from FY2026: Sixteen alleys were milled and overlaid, totaling approx 2 miles
- Special Projects Mill and Overlaid: W St. Francis, Villa De Mar, Pablo Kisel, and Robindale Rd., totaling approx 7 miles

- BPUB Patching work orders: 335 received from 10/1/2025 to 09/30/2026; 290 have been completed.
- GovQAs 860 work orders complete
- Crack sealing 6000 linear feet
- Seal coat 2000 Gallons

Program Tracking and Performance Measures

- Total Lane Miles Swept
- Quantity of Debris Removed
- Scheduled Sweeping Frequency by Zone
- Municipal Separate Storm Sewer System (MS4) Reporting Metrics and Compliance Data



Street sweeping protects:

- ✓ public infrastructure
- ✓ improves community appearance
- ✓ reduces pollution
- ✓ helps with MS4 stormwater requirements



Metrics

FY October 25 Sept 26

STREET SWEEPING – 7,873 LM

COMPLETED SWEPT ZONES – 79

CURB SCRAPING - 43.95 LM

DITCH MOWING - 69.85 LM

PICKED UP DEBRIS - 1,616.28 TN

Support Across All Municipal Operations

Because nearly all municipal field operations generate some level of debris or pollutant sources, the **sweeping program provides a consistent and effective method of capturing pollutants** before rainfall can transport them into the MS4.

Syncing interdepartmental operations with sweeping schedules helps support:

- Litter, sediment, metals, oils and organic waste are removed from road surfaces.
- Municipal activities do not unintentionally violate discharge prohibitions.
- Waterways remain as clean as possible through proactive maintenance rather than reactive cleanup.

Through these collaborative efforts, the sweeping program plays a central role in reducing pollutant loading supporting the City's compliance efforts and upholding the goals of the Stormwater Management Program.



Thank You

Questions?

Q&A and Open Discussion