

Street Sweeping:

Clearly America's *First Line of Defense*
for Stormwater Pollution Runoff Abatement

presentation by:

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The beginning of street sweeping...



- Invented to clean up mostly... horse poop and similar waste products.
- Emphasis on cosmetic results, not water quality.

Nationwide Urban Runoff Program (NURP) Test of Old-Style Mechanical Broom Sweepers



- Early 1980s NURP studied the effectiveness of street sweepers in reducing Event Mean Concentrations (EMCs) for five pollutants of interest (i.e., TSS, COD, TP, TKN, and Pb) at ten sites located in four states — North Carolina, Illinois, Washington and Wisconsin.
- Unexplainable negative results from two sites in N. Carolina and one in Wisconsin resulted in the conclusion that “street sweeping is generally ineffective as a technique for improving the quality of urban runoff” — despite the fact that data showed EMC decreases in 34 of the 50 site/pollutant investigations.
- “Statistically indeterminant” results have hampered sweeping’s perceived BMP value for stormwater runoff pollution ever since.

The good news:

Today's mechanical broom sweepers have doubled or even tripled the pollutant pickup efficiency of old-style machines.

- Today's technologically advanced mechanical broom sweepers offer much better particulate material (PM) pick-up including small-micron pickup.
- Pick-up Performance Testing of Elgin Eagle broom sweeper by the presenter (Sutherland, 2008) showed a mass pickup efficiency for particles 250 microns or less to be 86.4%.
- Testing results showed that the use of water spray for dust suppression *reduced* fine particle pickup efficiency by 20% — compared to not using water — bringing it *down* to 69.6%.



Even Better News:

Modern air sweepers vastly increase the ability of sweepers to pick up pollutants and remove them from runoff stream

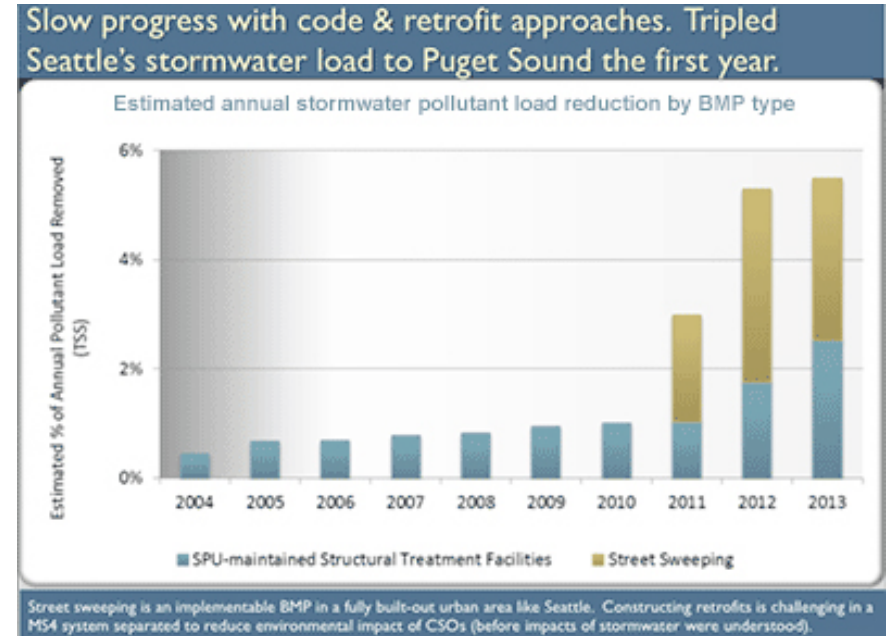


- Use of regenerative air and vacuum sweepers (i.e., air sweepers) has vastly improved pickup efficiency of particles of all sizes — but especially those under 250 microns — by far the most bioavailable and mobile fraction of all debris sizes. Removals of 90% to 95% have been achieved.

Want to design the best possible pollutant removal program? Tandem operation of a mechanical broom sweeper followed by an air sweeper will likely provide the most effective pick-up performance

- A 1994 City of Portland Study that monitored the pick-up performance of a monthly tandem sweeping operation, using before and after street dirt sampling, against that of the standard mechanical-only operation over a six-month period. Concluded that the average pick-up of PM from the tandem operation was 74.2% vs. 39.8% for the stand-alone broom operation.
- These results help to explain the 16 site/pollutant NURP investigations that found higher pollutant concentrations after aggressive broom sweeping. Broom machines of that era only removed the much larger-sized PM (particulate material) which exposed the fines to washoff from storms that follow. A tandem operation has a greater capacity to remove large bulky material (tire casings, mufflers, etc.) as well as fine particles of less than 250 microns. As a result, the concentration of pollutants washed off in the storms that follow will be lower.
- The 1994 cost analysis showed that the higher cost of tandem sweeping is more than offset by its greater recovery benefit. However, the question that remains to be answered is: Given the increased effectiveness of modern-day sweepers is the tandem operation still the most cost-effective?
- See info at: <https://www.worldsweeper.com/Street/BestPractices/v4n1emphasis.html>

Seattle's 2009 Street Sweeping Pilot suggested that adding sweeping as a 'stormwater pollutant runoff approach' could significantly increase the mass amount of pollutant removal from stormwater



- When Seattle enacted sweeping as adjunct to existing end-of-pipe solutions in 2011 they determined that over a 2-year period they increased the amount of pollutants being removed from stormwater by over 300%.
- Further study by Seattle resulted in doubling of budget for sweeping.
- Source: www.worldsweeper.com/Street/BestPractices/SeattleSweepingProgram6.15.html

Sweeping Reduces Pollutant Concentrations

City of San Diego: Targeted Aggressive Street Sweeping Pilot Study Effectiveness Assessment, June 2010 Measured EMCs

Storm Event	Type of Sweeping	Copper (µg/L)	Lead (µg/L)	Zinc (µg/L)	TSS (mg/L)
12/07/2009	Unswept	143.0	71.8	1,689.4	703.8
	Mechanical	50.9	30.7	443.6	112.8
	Vacuum	51.2	22.3	362.7	130.2
01/18/2010	Unswept	218.4	234.0	1,210.9	1,719.6
	Mechanical	83.1	77.8	610.1	431.6
	Vacuum	34.1	23.5	307.6	145.2
02/05/2010	Unswept	73.7	59.2	452.1	357.6
	Mechanical	55.4	38.5	353.8	187.1
	Vacuum	39.4	15.2	366.1	132.0
Mean of Three Storms	Unswept	145.0	121.7	1,117.5	927.0
	Mechanical	63.1	49.0	469.2	243.8
	Vacuum	41.6	20.3	345.5	135.8

TSS was reduced 74% by mechanical sweeping and 85% by vacuum sweeping. Reductions of metals ranged from 56% to 60% for mechanical and 69% to 83% for vacuum.



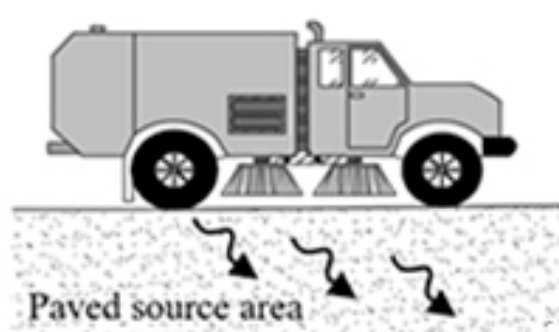
2007, 2011 and 2019:

Studies conducted by the U of Florida involving 12 to 14 Florida MS4s in association with the Florida Stormwater Association found street sweeping was the best BMP — up to almost *seven times more cost-effective* than any other of the BMPs for TN and TP recovery

- Studies measured the amount of material captured by the complete range of all available BMPs — from sweeping to catchbasin cleaning to a variety of structural, end-of-the-pipe measures.
- Cost of capturing a pound of nitrogen and/or a pound of phosphorus was calculated for each type of BMP recovery method.
- Sweeping was the lowest cost per pound; catchbasin cleaning was 2nd in all instances.

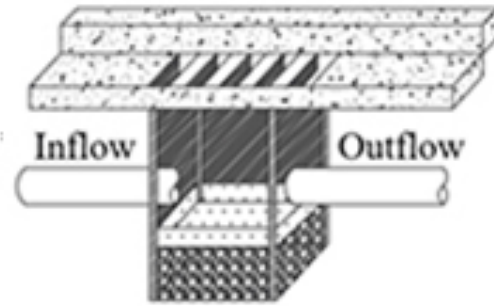


Relative costs of removing Total Nitrogen (TN)



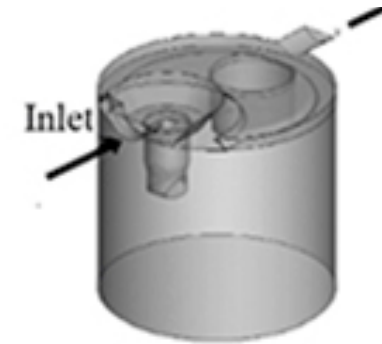
Street Sweeping
(SS)

\$189 / lb.



Catch Basin
(CB)

\$1,162 / lb.



Best Management
Practice (BMP)

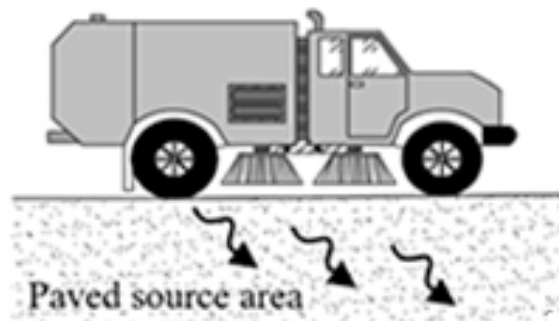
\$2,173 / lb.

Study data combined broom and air sweeper performance: air sweeper data expected to be better.

Source: www.worldsweeper.com/Street/Studies/UFloridaSansaloneInterview12.19.html

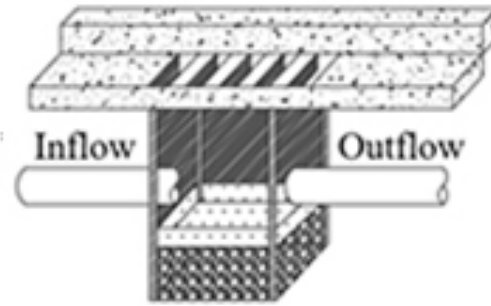


Relative costs of removing Total Phosphorus (TP)



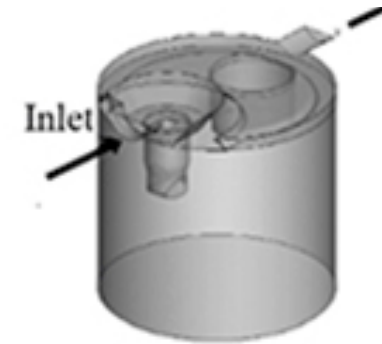
Street Sweeping
(SS)

\$294 / lb.



Catch Basin
(CB)

\$1,894 / lb.



Best Management
Practice (BMP)

\$12,006 / lb.

Study data combined broom and air sweeper performance: air sweeper data expected to be better.

Source: www.worldsweeper.com/Street/Studies/UFloridaSansaloneInterview12.19.html

Recovery of Particulate Material (PM) Matters

(Proving That Street Dirt Pick-Up Recovery Also Matters!)

The Florida studies found street sweeping to be the most economical and dominant practice that MS4s could implement in order to maximize nutrient (TN and TP) and particulate matter (PM) recovery benefits to urban drainage systems and the receiving waters discharged into.

Recovery of PM matters:
More recovered = more pollutant reduction. **The study results are statistically defensible at a 95% confidence level (CL) when combining all 14 MS4s for PM, TN and TP.**

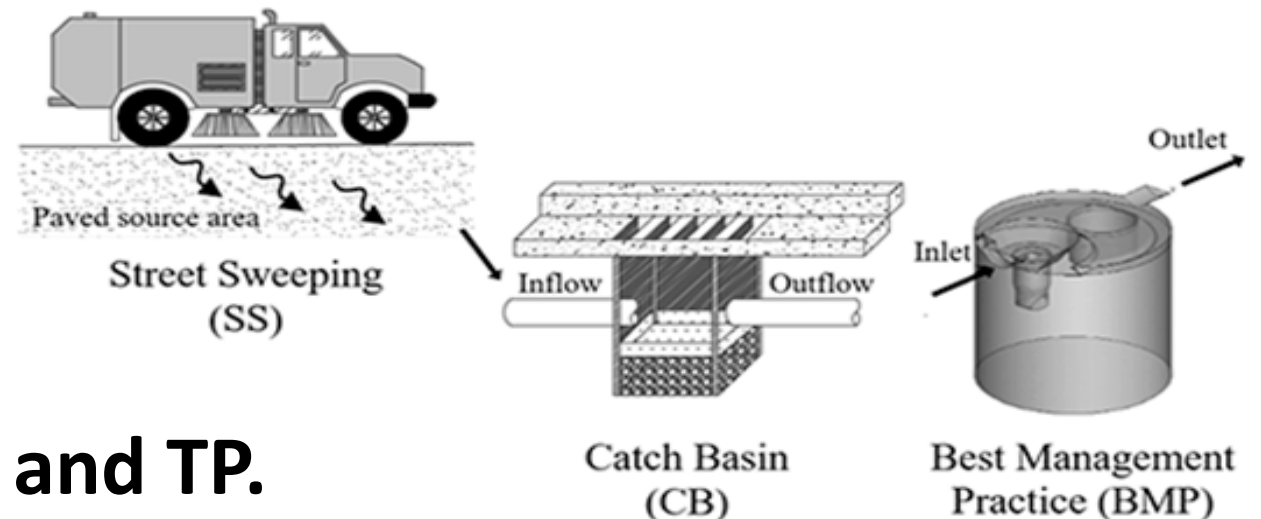


Figure 2 Conceptual illustration of hydrologic functional units (HFUs) sampled in this study.

Crediting Programs for Street Sweeping Waste are in Communities Located in 14 States Nationwide, including:

- Chesapeake Bay Watershed TMDL Permittees (6 states)
- California – Limited Cities and Counties
- Florida – All MS4 Communities with street sweeping waste data
- Massachusetts – All Communities
- New Hampshire – MS4 Permittees
- North Carolina – Under Development
- Washington – MS4 Permittees with TMDL's
- Wisconsin – All Communities
- Vermont – Under Development

Street Sweeping Waste Crediting Programs

- **These programs have a wide range of methods used to calculate the credit**
 - Reduction efficiency; Mass load reduction; Lane miles swept
 - Modeled load reduction
 - Percentage of Mass load reduction
 - Performance-based compliance
- **Programs have a range of pollutants included but most have TP and TN or TKN**
- It's now time to standardize these crediting calculations based on a form of Performance Based Compliance like implementation of the procedures documented in the game-changing Florida studies which are based on a statistically defensible chemical analysis of street sweeping waste collected by the community. That is the most scientific approach.

Street Sweeping Waste Crediting Programs in California

- Orange County and MS4 Co-permittees
 - Based on a Reduction efficiency %
 - Includes Bacteria and Sediment
- City of Santa Cruz, California
 - Modeled load reduction
 - Includes Sediment
- County and City of San Diego and MS4 Co-permittees
 - Performance-based compliance
 - Includes Cu, Zn, Pb, TKN, TP

[Survey of street sweeping crediting approaches - Minnesota Stormwater Manual \(state.mn.us\)](#)

Street Sweeping-Related Research Projects Underway or Planned in Southern California

- City of Los Angeles is currently testing street sweeper pickup performance using the procedures Sutherland documented dating back to 2008 [Real World Street Cleaner Pickup Performance Testing \(worldsweeper.com\)](http://www.worldsweeper.com)
- City of Los Angeles has applied for Measure W funding to identify and support potential enhancements to the City's street sweeping program that could significantly increase pollutant removal and improve downstream water quality
- The Southern California Coastal Water Research Project Authority (SCCWRP) will be initiating a study entitled "Effect of Street Sweeping on Wet Weather Pollutant Loading and Concentrations from Southern California Roadways, Phase 1"
 - The study design adopts an approach of isolating runoff from heavily trafficked asphalt surface segments using simulated storm events, in order to maximize the opportunity to measure differences in pollutant loads between swept and unswept conditions.

How to Increase a Street Sweeping Program's Ability to Collect Contaminated Material More Effectively

Change Type of Sweeper and Operation Parameters

Particulate pickup performance is important. Well-maintained air machines are more effective than well-maintained mechanical broom machines. However, tandem operations — a broom sweeper immediately followed by an air sweeper — may prove to be the most cost-effective method per pound of a pollutant, especially toxic pollutants that have an affinity for attaching themselves to very fine particulate material.

Modify Forward Speed of the Sweeper

3-to-6 mph is usually recommended especially for heavy accumulations; however, studies have shown that sweeping in the 8-to-10 mph range only reduces particulate pick-up by 10-to-15% and the program ends up sweeping more street miles in a sweeping shift, thus removing more particulates and associated pollutants.

Increase Frequency of Street Cleaning

Usually varies by land use and/or street types with weekly, bimonthly and monthly the most popular choices. Frequency should vary by street dirt accumulation with the quickest and highest accumulating streets receiving the most frequent cleaning. Daily or bi-weekly sweeping of downtown CBD is a waste of financial resources if maximizing particulate material collection is the primary sweeping objective as it now should be.

Eliminate Parked Car Interference

Mandatory vehicle removal during sweeping can increase PM pickup by 30-to-60% depending on parking density. Parking fines can greatly offset the cost of implementing a vehicle removal program. Vehicle removal likely the most cost-effective way to significantly increase PM pick-up at the lowest cost expenditure.

Plus and Minus Aspects of Street Sweeping...

Commonly cited disadvantages:

- Cost of sweepers plus operation and maintenance expense.
- Citizen resistance to vehicle removal requirements.
- Generally can't operate during heavy rain & freezing weather.

When it comes to other pavement-based pollutant removal, advantages of sweeping far outweigh:

- No real estate or property owner dislocation costs.
- No infrastructure to develop or maintain.
- No periodic structures or filters to check and maintain.
- And, we now know...

Sweeping is the most effective *and* costs the least!

Enhance sweeping's value to your community

Use available software to predict sweeper program needs:

- Software like Sutherland's SIMPTM can accurately model sweeper pollutant removal, eliminating need for expensive paired basin studies.
- Then, optimize value via allocation of sweeping program resources.
- Tip: Add sweeping dept. to stormwater dept. in order to maximize \$\$.

Analyze your needs to determine correct mix of air and broom sweepers:

- Use your specific goals to maximize sweeper fleet capabilities.
- Broom sweepers not as efficient at small-micron pickup.
- Vacuum sweepers excel on porous pavement.
- Regenerative air typically best for general city street sweeping.
- Should you explore tandem sweeping?

Street sweepers can include value-added items

- Sweepers may be outfitted with data collection/notification systems for downed signs, potholes, low limbs, etc
- Can provide direct notification to repair departments!



#3: Downed sign notice goes to Dept. A

#6: Low-hanging branches notice goes to Dept. B

#9: Pothole notice goes to Dept. C

- Sweeper hopper graphics can advertise a variety of civic goals.
- Sweeper naming can provide community buy-in, education opportunity.
- Sweepers offer both health and safety benefits; proof city is proud to keep residents healthy, safe and with clean water.

Education Enhances Citizen Understanding

Educate citizens about sweeping's pollution removal value:

- Touch-a-truck events: Have handouts and tout web info locations.
- Develop grade-specific education modules in schools.

Educate about the “one vehicle equals three car lengths” problem:

- One parked car = three blocked ‘sweeper spaces.’
- Multiple parked cars per block = up to zero sweeping gets done.
- Areas left unswept are both unsightly and unhealthy.

The only way to maximize removal of pavement-based pollution — and general debris — is to move vehicles out of the way of sweepers.

Debris Removal by Sweepers: By far Least Expensive Way to Keep Community Pavement Looking Good:

“With conventional BMPs, particulate matter removal costs dollars per pound, anywhere from \$4 to \$41. For street sweeping the cost for removing a pound of particulate matter was 10 cents! That’s really the only thing people need to know.”

— Dr. John Sansalone, principal investigator, U of Florida

Source: www.worldsweeper.com/Street/Studies/UFloridaSansaloneInterview12.19.html

Develop Citizen-friendly Vehicle Removal Program: Technological Advances = Very Improved Outcomes

Internet apps are 'game changers' for sweeping programs:

- Phone/computer apps can provide alerts to vehicle owners.
- Uber-like apps can show where sweepers are in real time.
- Citizens can move cars back immediately after sweeper passes.
- Makes environmental value of street sweeping an easier 'sell.'

Streamlined (less expensive) sweeping program ticketing:

- Ticket via cameras on sweepers; this eliminates parking enforcement involvement and reduces ticketing expense.
- Allow residents to re-park after sweeper goes by without penalty.
- Tickets will still pay for significant portion of sweeping program.

To Ensure a 'BMP Outcome,' Implement a Vehicle Removal Program That Answers These Questions:

1. How can I be reminded about when I need to move my car?
2. How can the city notify me if changes occur at the last minute in the schedule and my street will not be swept as scheduled?
3. How do I determine whether my street has been swept so I can move my car back to the curb?
4. How will you ensure that I won't get a ticket if I move my car back after the sweeper goes by but before the posted no parking timeframe expires?

When Implementing Sweeping, Remember...

- Citizen “vehicle removal pushback” is minimized through education.
- A real-time notification system is needed for schedule changes.
- Implement a vehicle removal system that allows immediate re-parking.
- Coordinate ticket writers with sweeper cameras
- Use app so as to eliminate 4-hour window

***Extra Credit:** Work to enact regulations in your state to gain credits for pollutant removal via street sweeping. (Florida now offers pollution removal credits aligned with both MS4 and TMDL compliance!).*

Be guided by your knowledge that...

Street sweeping is the first line of defense for pavement-based pollutant removal!

Upcoming \$1.3 Million Microplastics Study

Clean Streets, Clean Seas:

Innovating Public Works to Intercept Microplastics in Urban Runoff



Study will develop BMPs for upstream control of the fast-escalating threat to marine ecosystems: microplastic (defined as material under 5mm in width).

Project includes an optimization study to learn if microplastic pickup rates can be improved with varying street sweeper speeds, technologies, and frequencies.

Multi-Agency Involvement Includes:

- City of Santa Barbara
- University of California at Santa Barbara
- University of Southern California Sea Grant Program
- San Francisco Estuary Institute
- Moore Institute for Plastic Pollution Research
- USA Environment & Infrastructure, Inc.
- Southern California Coastal Water Research Project
- Roger Sutherland, Cascade Water Resources, LLC
- Ranger Kidwell-Ross, WorldSweeper/World Sweeping Association

Study will include developing BMPs for removal of microplastics (including tire particles) as well as for larger 'trash' removal

Sweeping Portion Protocols

Roger and Ranger are Tasked With:

- Consulting on vehicle removal app design and BMPs
- Implementing outreach to Public Works community on the use of various sweeper types/technologies and street sweeper pickup BMPs as they are developed and documented
- Engaging with the street sweeping industry to announce and educate on the findings re: BMPs for microplastics removal
- Consulting on sweeper testing methodology, including testing parameters and protocol, developing best simulant for 'street dirt,' and more
- Developing presentations of study findings for users of street sweepers throughout the US



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Sign up to receive it at:

www.worldsweeper.com/guestbook.html

To see the largest collection of information about street sweeping on the internet go to:

www.worldsweeper.com/Street

EARTH'S LARGEST POWER SWEEPING RESOURCE SM



For More Information...

As of 2023, the two presenters had a combined 93 years of experience with street sweeping. For assistance with any aspect of your sweeping program, contact:

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