Real World Street Cleaner Pick-up Performance Testing

Presented by:

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StormCon®
The North American Surface Water Quality Conference & Exposition

Controversy surrounds the question of how much of the pollution found in urban stormwater can street cleaning remove

A year long pilot study in Seattle found that regenerative air sweeping once every two weeks removed 2,200 to 3,100 lbs of dry material per acre per year

Estimated life cycle costs for a full-scale street cleaning program in Seattle were $1.37 per lb of material removed

TSS removal costs are only 15% to 50% of those estimated for regional stormwater treatment

For any assessment of street cleaning program costs accurate pick-up performance data is needed

Sweeping Controversy Continues

Environmental and public health reasons

- Improves aesthetics
- Reduces pollutant loadings
- Reduces gross solids and street litter
- Could improve air quality

Legal Compliance

- Phase I or II NPDES MS4 Permits
- TMDL Plan implementation

Effectiveness and Cost-effectiveness

- Streets are the largest single source of stormwater pollution under the control of most jurisdictions
- Sweeping is likely the cheapest BMP based on $ per pound of pollutant removed
- Unlike most other BMPs, sweeping can have an immediate impact

Street Cleaning is a Cost Effective BMP

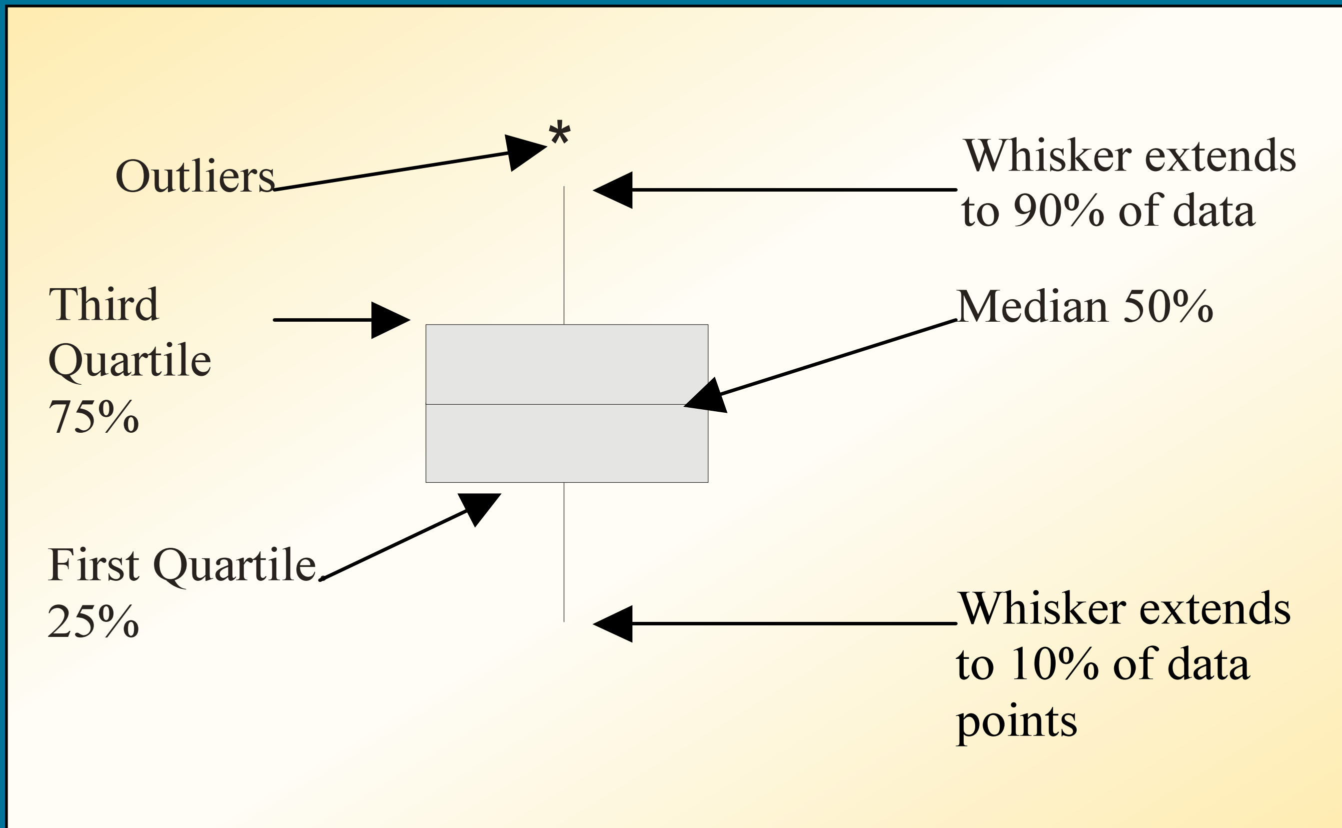
- Streets and parking lots cover ~20% of the urban landscape
- These surfaces likely contribute half, if not more, of the toxic stormwater pollutants entering urban waterways
- Structural treatment cost ~$10 to ~$50 per pound of TSS removed
- Sweeping costs $1 to $5 per pound of TSS removed

Contrary to Conventional Wisdom

The Number One Reason to Clean is:

Street Cleaning Cost Effectively Reduces Stormwater Pollutant Loadings Entering Urban Waterways which Satisfies the MEP Requirement and Improves Water Quality

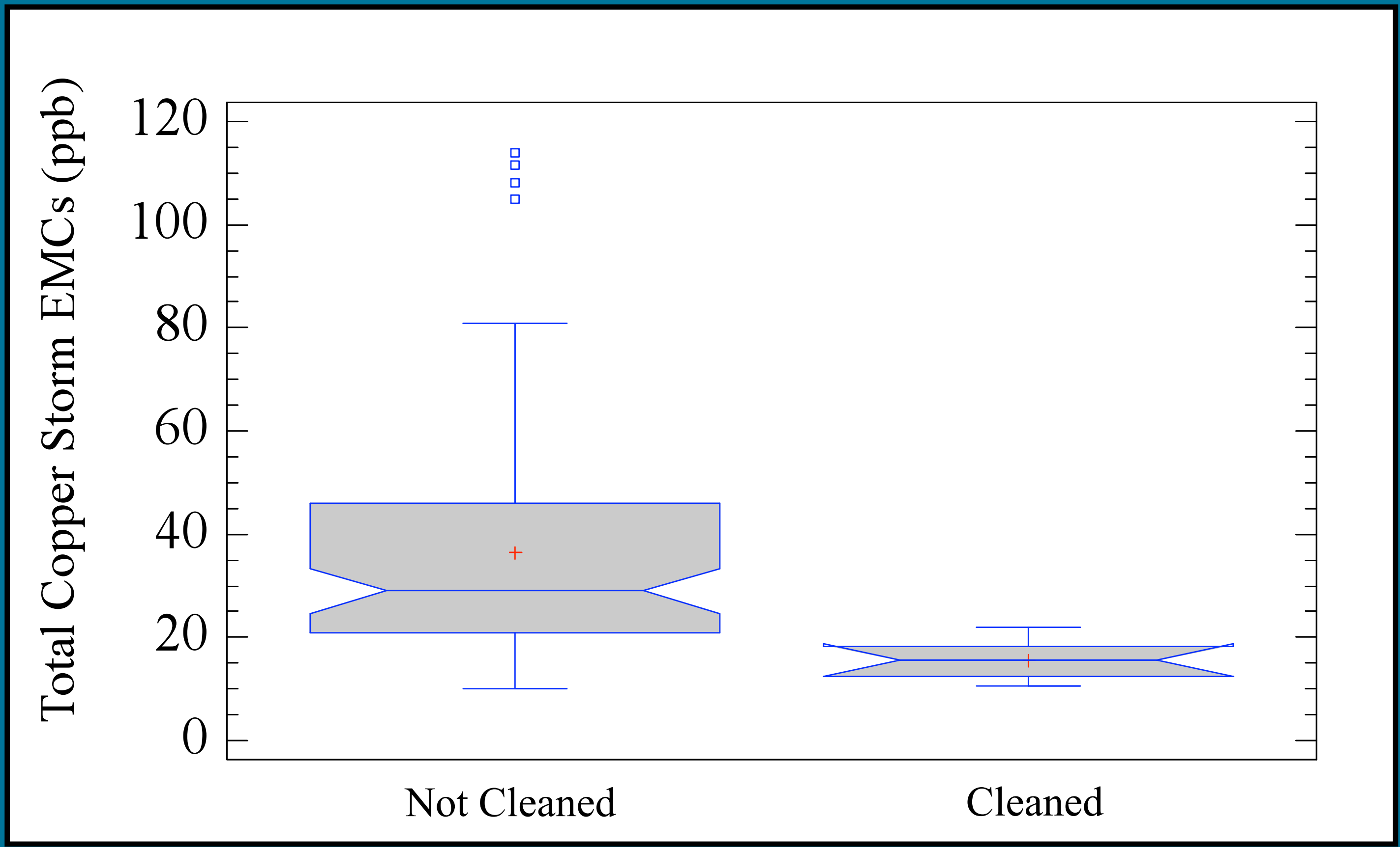
Box & Whisker Plots



What Are Box & Whisker Plots

Baltimore Street Cleaning Pilot Study

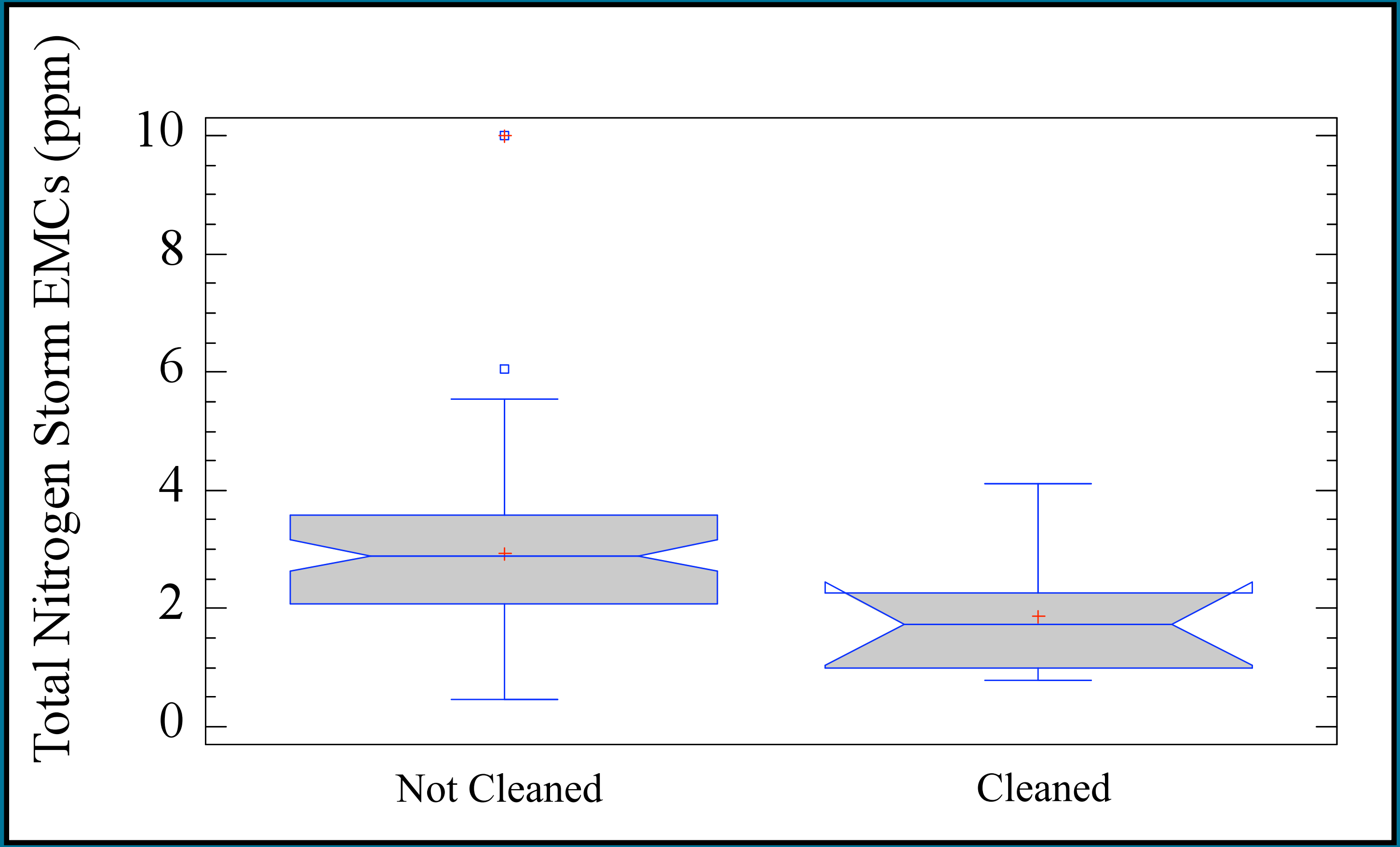
Copper concentration declined (early results)



Cleaning Reduces Pollutant Loadings

Baltimore Street Cleaning Pilot Study

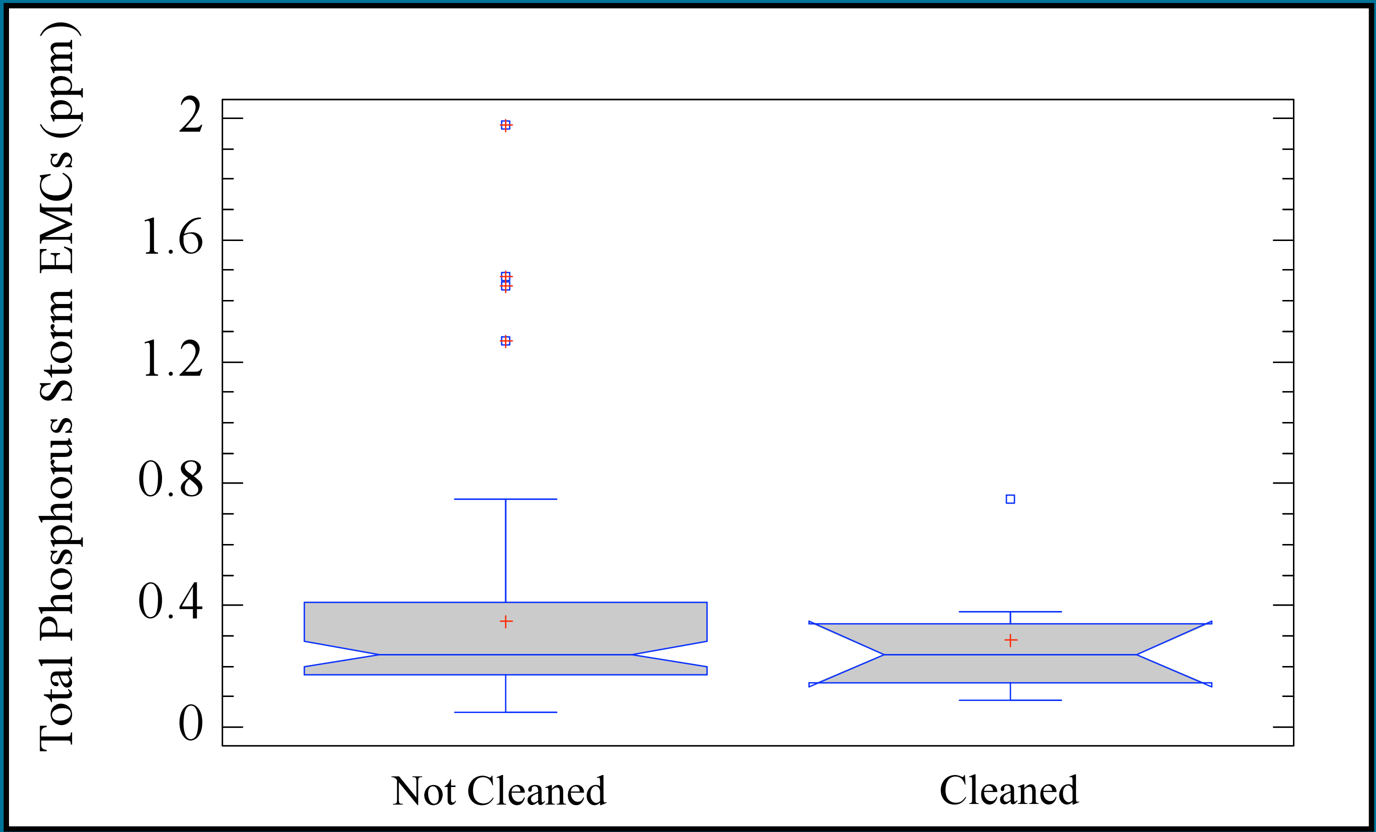
Total nitrogen concentration declined (early results)



Cleaning Reduces Pollutant Loadings

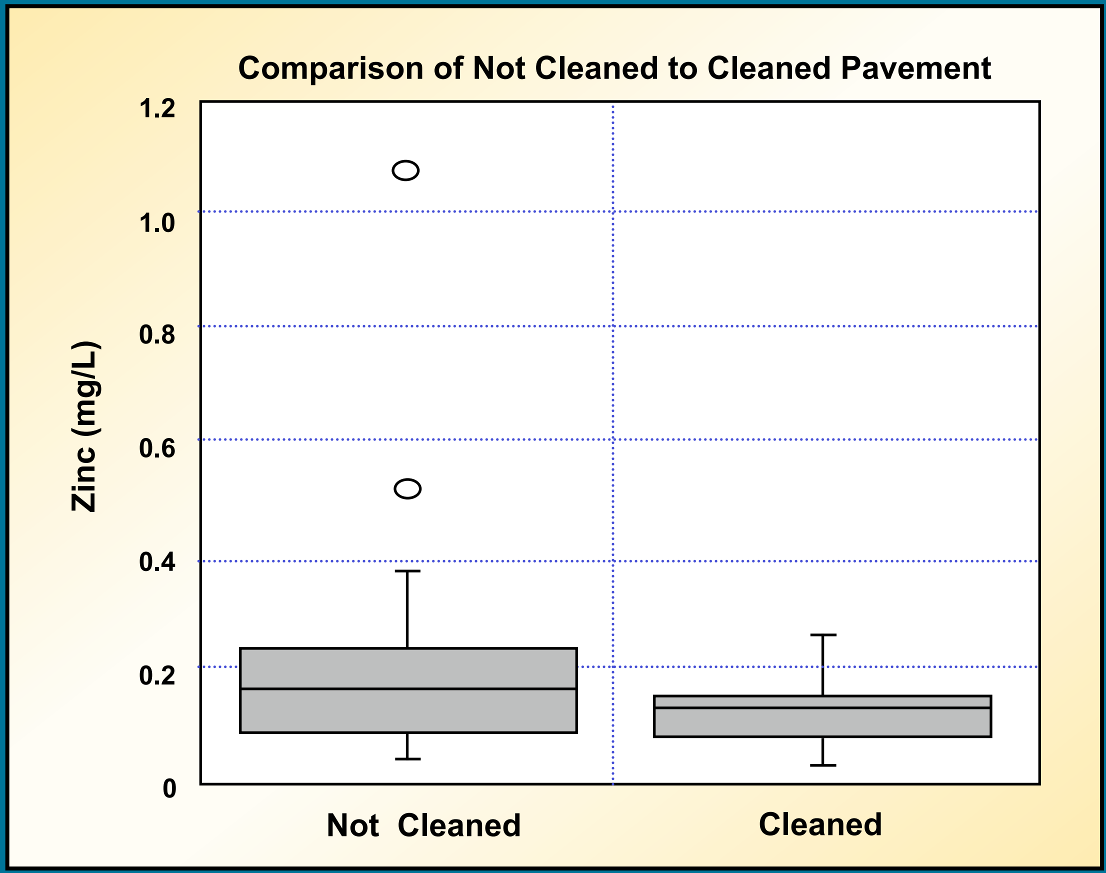
Baltimore Street Cleaning Pilot Study

Reduction of higher concentrations for total phosphorus (early results)



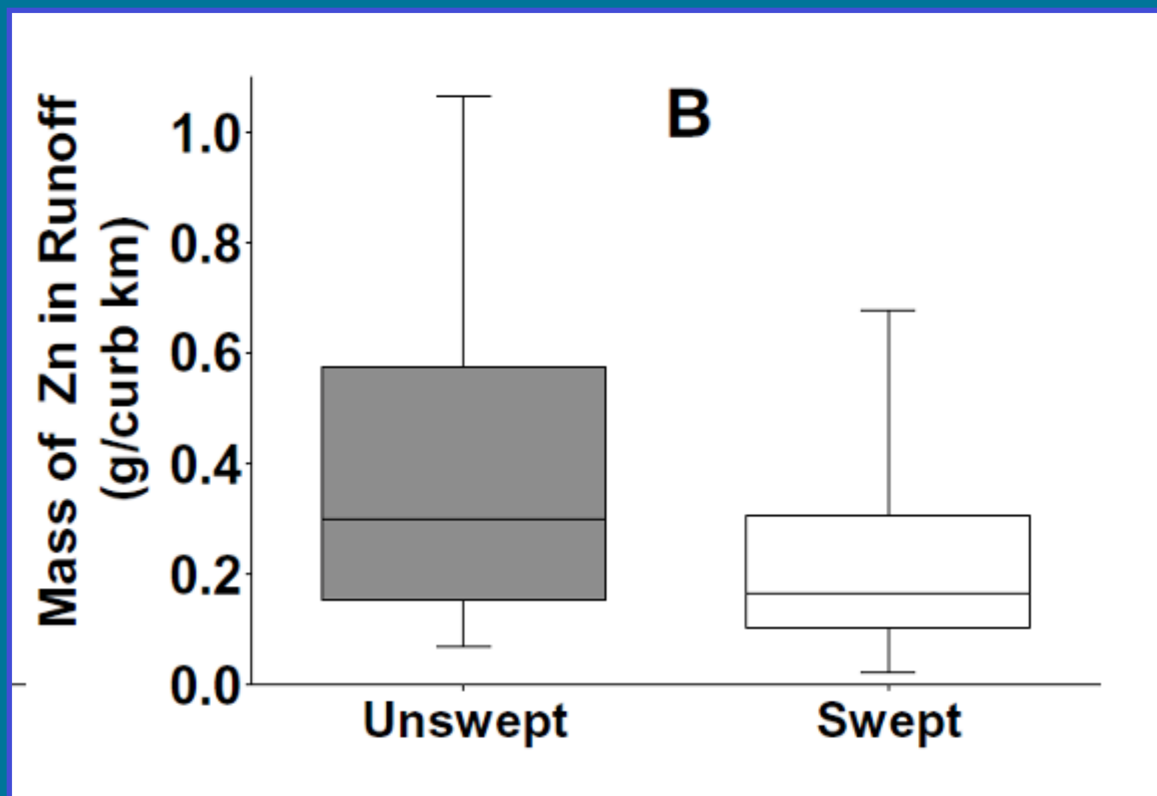
Cleaning Reduces Pollutant Loadings

Cross Israel Highway (CIH) Stormwater Quality Study



Cleaning Reduces Pollutant Loadings

Toronto Canada Roadway Street Sweeping Study



Cleaning Reduces Pollutant Loadings

When cleaning to reduce pollutant loadings:

Sediment and associated pollutant pick-up efficiency should be an important aspect of street cleaner selection

Sweeper pick-up efficiency is a function of:

- Initial accumulation
  - Magnitude
  - Particle size distribution (PSD)
- Street texture and condition
- Type of sweeper (mechanical, vacuum or regenerative air)
- Forward speed of sweeper
- Interference with parked cars
- Street surface moisture

Street Cleaner Pick-up Performance

PWR Principal Roger Sutherland has designed and implemented sweeper pick-up tests for well over 25 years

- Washoe Co Council of Governments - Reno/Sparks, Nevada (1982)
- Portland Bureau of Environmental Services (BES) – Portland, Oregon (1992)
- Port of Seattle - SeaTac International Airport (1995)
- Enviro Whirl Technologies – Centralia, Illinois (1995)
- Cross Israel Highway - Tel Aviv, Israel (2002)
- Seattle Public Utilities (SPU) – Seattle, Washington (2004)
- D.C. Dept. of Public Works - Washington D.C. (2007)

Previous Pick-up Performance Testing

- Pacific Water Resources was asked by Elgin Sweeper Company to independently design and conduct pick-up performance tests of four different sweeper models and document the results
- PWR had complete control over the test procedures, supervised the tests, directly contracted with the laboratory doing the seiving, maintained the chain of custody regarding the transport of the remaining material collected from the sweeper tests and documented the test results
- The sweeper models and types tested were:
  - Crosswind (NX) (Regenerative Air with air controls)
  - Crosswind (Regenerative Air)
  - Whirlwind (MV) (Vacuum)
  - Eagle (Mechanical tested with & without water spray)

Elgin Sweepers Tested

Pick-up Performance Testing Mandate from Elgin:

Design a test such that the important test variables are truly representative of average real world sweeping conditions

Important Test Variables:

- Pavement moisture
- Pavement condition
- Initial accumulation and particle size distribution
- Curbed street with realistic distribution of accumulated material across the street
- Forward sweeping speed
- Safe testing conditions

Important Test Variables

Most Street Cleaning Programs Request Pick-up Performance Demonstrations of Candidates' Cleaners

However, the test conditions imposed rarely involve realistic day-to-day sweeping conditions.

Typical Unrealistic Test Conditions

Unrealistic Performance Demonstrations

Test Location & Dry Pavement Conditions are Important

- Testing scheduled to occur over a three day period during the month of July 2008 in St. Charles, Illinois
- Testing procedure requires initially dry pavement conditions
- Initial conditions including pavement moisture must be identical for each individual test

Problem:

It rains in Illinois during the summer

Solution:

Test under a huge tent erected in a large parking lot owned by Elgin's parent company so dry and safe conditions will be maintained throughout the test period

Test Location & Dry Pavement Ensured

Test Location & Dry Pavement Ensured

Realistic Test Track Conditions

- 50 ft long and 2 ft wide
- Asphalt pavement
- Fair pavement condition
- Uneven surface
- Numerous cracks
- Cracks are sealed
- Safe testing environment

Realistic Test Track With Curb

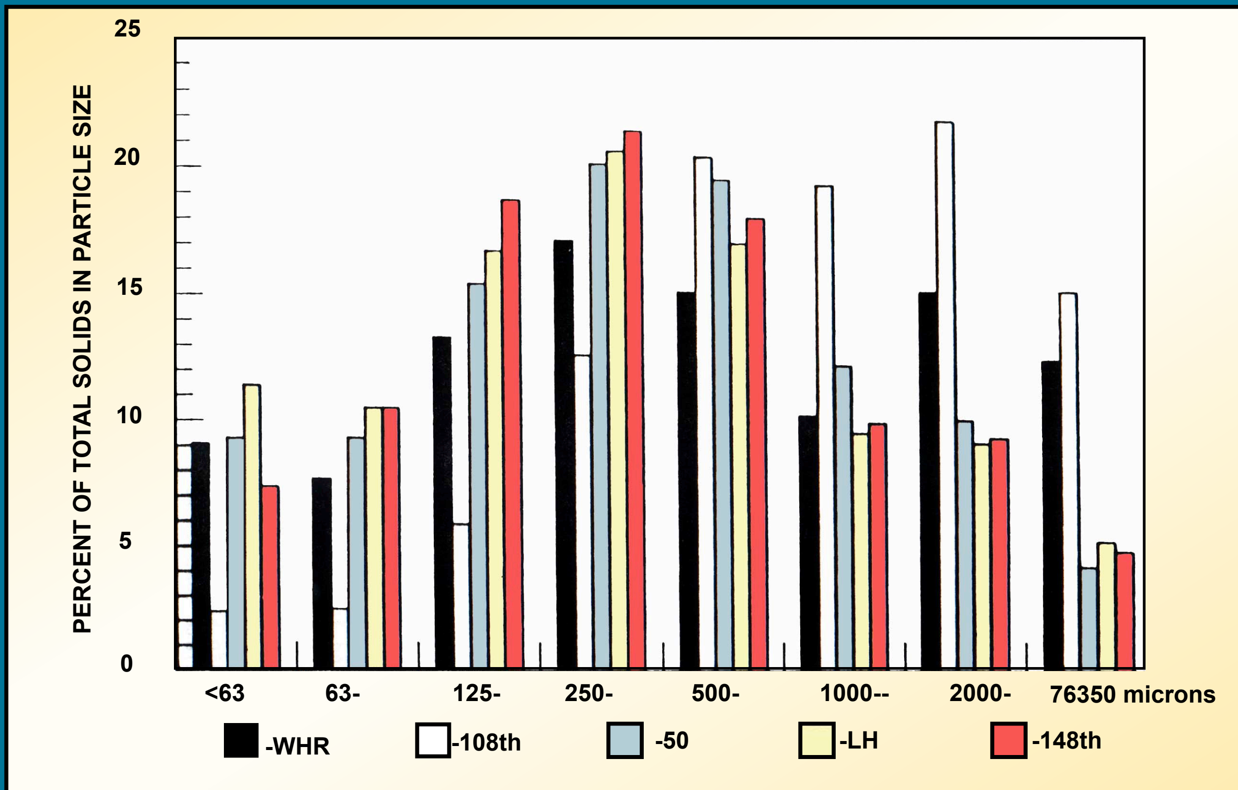
- Create a batch of representative “street dirt” simulant.
- Sieve a representative sample of the simulant into eight preselected particle size (PS) groups so its particle size distribution (PSD) is known.
- Spread a known and realistic quantity of street dirt simulant evenly on the test track using a calibrated fertilizer spreader.
- Execute a single pass of a sweeper maintaining a specified forward speed while two observers record the actual time spent cleaning the tesk track with stopwatches.
- Using an industrial vacuum with a smooth stainless steel canister, hand vacuum the remaining simulant.
- Carefully transfer the material to a plastic zip-lock bag, weigh it, label it and establish the chain of custody.

Pick-up Performance Test Procedure

Street Dirt Material is a Important Test Variable

- Ingredients should have the same specific gravity of street dirt which is about 2.60
- Must be combined in a recipe that results in a particle size distribution (PSD) of actual street dirt.
- Simulant used was a mixture of six different manufactured silica products designed to mimic the average PS distributions found in the City of Bellevue (suburb of Seattle) in the early 1980's as part of the Nationwide Urban Runoff Program (NURP).

Dry Season Particle Size Distributions (PSD) in Bellevue, Washington



Observed PSDs for Street Dirt

Particle Size Distribution (PSD) of Street Dirt Simulant

Table 1 – Particle Size Distribution (PSD) of Street Dirt Simulant

PS No.	Sieve No.	Size Range (microns)	Bellevue NURP Average Incremental Mass (%)	Incremental Mass (%)	Percent Retained	Percent Passing
8	1/4	>6370	8.2	0.0	0.0	100.0
7	10	2000-6370	13.0	16.9	16.9	83.1
6	18	1000-2000	11.8	10.8	27.7	72.3
5	30	600-1000	17.8	7.1	34.8	65.2
4	60	250-600	19.1	19.4	54.2	45.8
3	120	125-250	14.2	30.1	84.3	15.7
2	230	63-125	8.0	7.1	91.4	8.6
1	Pan	<63	7.9	8.6	100	0.0

Initial Accumulation & Distribution is Important

- Bellevue NURP data showed average dry season accumulations ranged from 160 to 920 lbs per curb mile (45 to 259 grams per curb meter) which is typical for most street dirt studies
- 7.5 lbs (3405 grams) of simultant applied evenly alone the 50 ft track which resulted in 792 lbs per curb mile (222 grams per curb meter)
- Material was evenly spread within 2 ft of the curb face which is typically where 90+% of street dirt is actually found

Initial Accumulation & Distribution

Forward Sweeping Speed is Important

- Recommended forward sweeping speed is typically 4 to 6 mph
- Test called for maintaining a forward speed of 5 mph
- Sweeper will travel the test track length of 50 feet in 6.8 seconds
- Stopwatches were used during multiple practice runs to time the sweeper on the test track by two observers to ensure that the desired speed can be maintained

Practice Sweeper Runs

Testing the Elgin Crosswind NX

Pick-up Performance Testing for Elgin Sweeper

Vacuuming the Remaining Material

Pick-up Performance Testing for Elgin Sweeper

Transferring Material to Zip Lock Bag

Overall Pick-up Performance Results

Sweeper Model	Type	Remaining Mass (gms)	Initial Mass (gms)	Pick -up Mass (gms)	Pick - Up %	Forward Sweeping Speed (mph)
Crosswind (NX)	Regenerative	85.6	3405	3319.4	97.5	4.7
Crosswind	Regenerative	121.1	3405	3283.9	96.4	4.9
Eagle (FW)	Mechanical	288.3	3405	3116.7	91.5	4.9
Eagle (FW) with water	Mechanical	646.0	3405	**2759.0**	81.0	4.7
Whirlwind (MV)	Vacuum	221.1	3405	3183.9	93.5	5.1

Pick-up Efficiencies by Particle Size Range

(Percent of Initial Mass)

PS No.	Size Range (microns)	Crosswind NX	Crosswind Std.	Eagle FW wa terless	Eagle FW wit h water	Whirlwind MV
7	2000 -6370	99.4	99.4	95.9	95.8	99.3
6	1000 -2000	98.5	98.7	93.3	91.2	98.2
5	600 - 1000	97.8	98.1	93.1	88.3	96.3
4	250 -600	97.9	97.6	93.4	84.2	93.5
3	125 -250	97.7	95.7	91.1	72.0	89.6
2	63 - 125	97.0	93.0	89.9	68.7	86.5
1	<63	90.8	89. 4	78.1	68.2	93.5

Pick-up Performance Test Results

- Test results were excellent and real world test conditions were simulated
- Machine performance conformed to expectations:
  - Regenerative air machines performed best with the Crosswind (NX) with dust control at 97.5% and the standard Crosswind at 96.4%
  - Vacuum-based Whirlwind (MV) was third at 93.5%
  - Mechanical Eagle (FW) without water was at 91.5% and the Eagle (FW) with water was 81.0%
- Pick-up performance is reduced when water is used for dust suppression but fugitive dust losses were not measured

Discussion of Results

- Fine particle (less than 63 microns) pick-up performance is a major concern
- Air machines outperformed mechanical ones with 89.4% to 93.5% pick-up of finest range although the mechanical Eagle (FW) without water was impressive at 78.1%
- Vacuum-based Whirlwind (MV) was the highest in fine particle pick-up at 93.5%
- Fugitive dust losses were not measured Crosswind (NX) and Eagle (FW) without water had essentially no visible dust losses

Discussion of Results

- Approximately 50 different sweeper models are available for purchase nationwide from four major sweeper manufacturers
- Only 4 models from one major manufacturer have been tested using controlled real world sweeping conditions.
- Real world testing of the models available from the other three major manufacturers should be conducted
- With the increased regulation of stormwater runoff through the NPDES and TMDL programs, the need for real world pick-up performance testing is greater today than ever before

Other Manufacturer Testing is Needed

Important Things the Street Cleaning Program Can Control

- **Type and model of sweeper used**
  (pick-up performance is most important)
- **Forward speed of the sweeper**
  (4-to-6 miles per hour is recommended)
- **Parked car interference**
  (requires a political will, ordinances and enforcement; on the up side, fines can be used to support the cleaning program)
- **Frequency of street cleaning**
  (should vary by street dirt accumulation characteristics drived largely by traffic volume)

What Can Cleaning Programs Control

How does a street cleaning program determine the most cost-effective program for reducing stormwater pollutant washoff?

For accurate estimates, computer modeling must be used

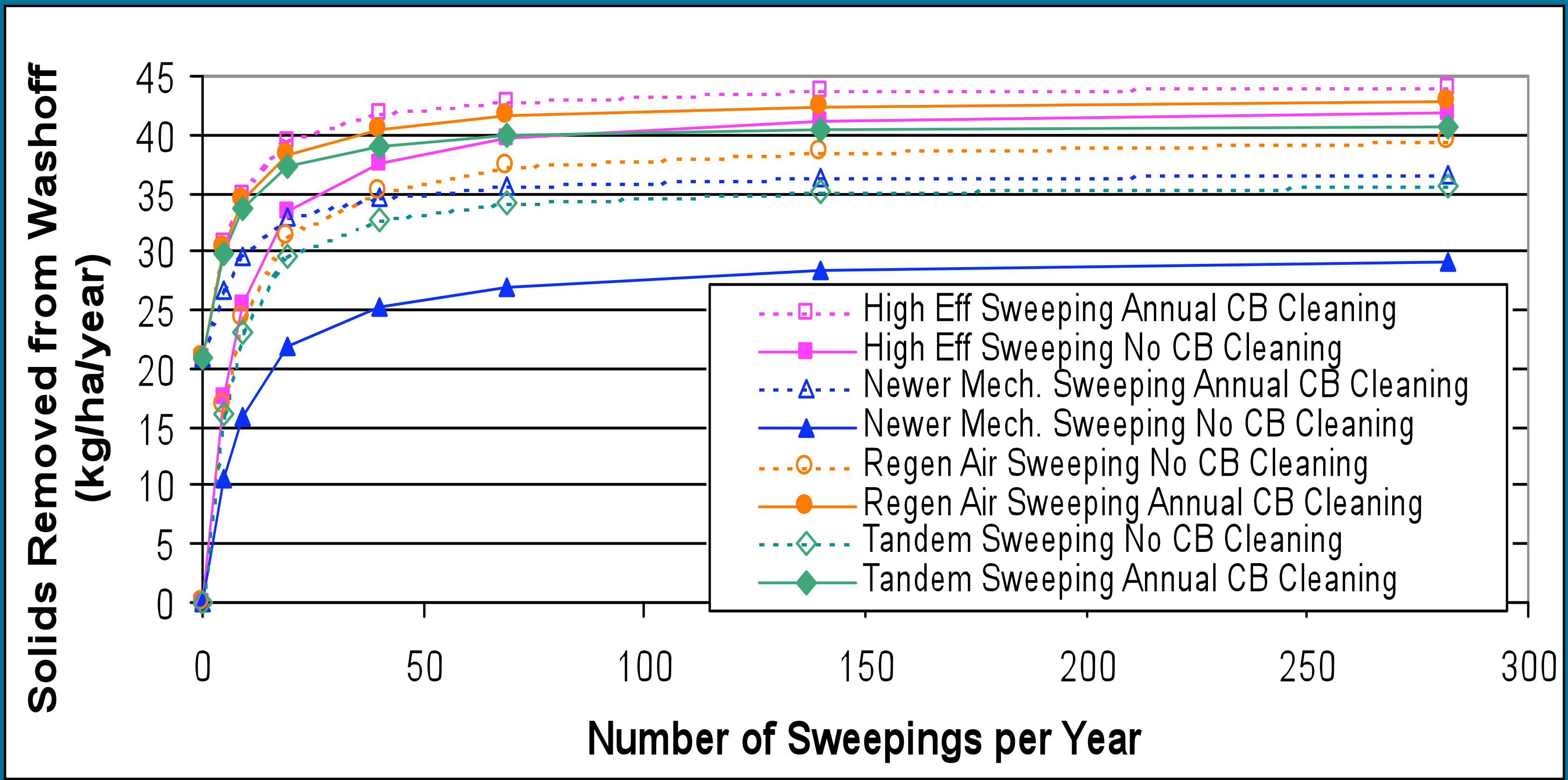
Pacific Water Resources has available a model they developed called SIMPTM

What Are the Benefits of Using SIMPTM

- SIMPTM estimates stormwater pollutant loadings for both NPDES and/or TMDL planning and reporting
- SIMPTM can establish the relationship between frequency of cleaning by land use or street category and the amount of TSS and other pollutants removed from urban stormwater using a historic rainfall record of unlimited length

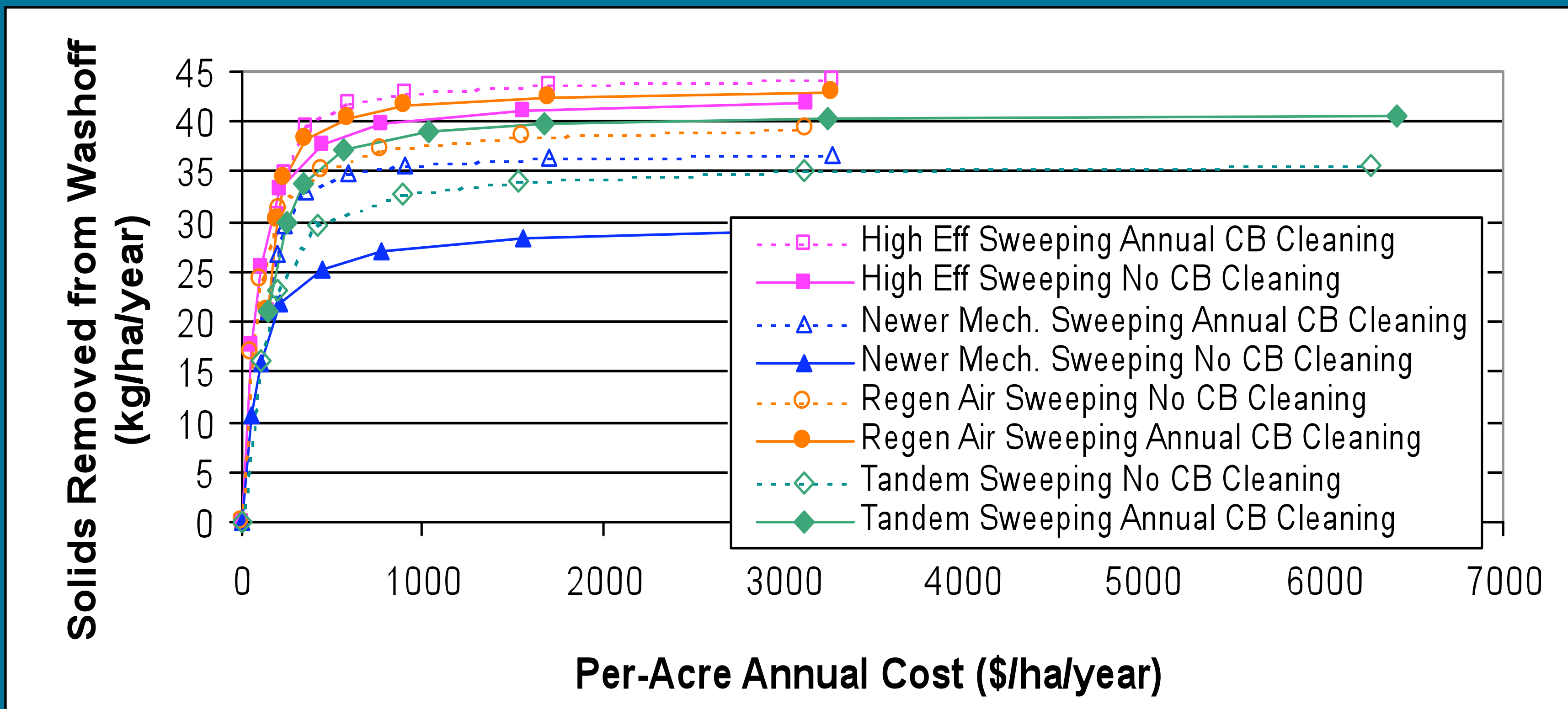
BMP Production Functions

Single-Family Residential



BMP Total Cost Curves

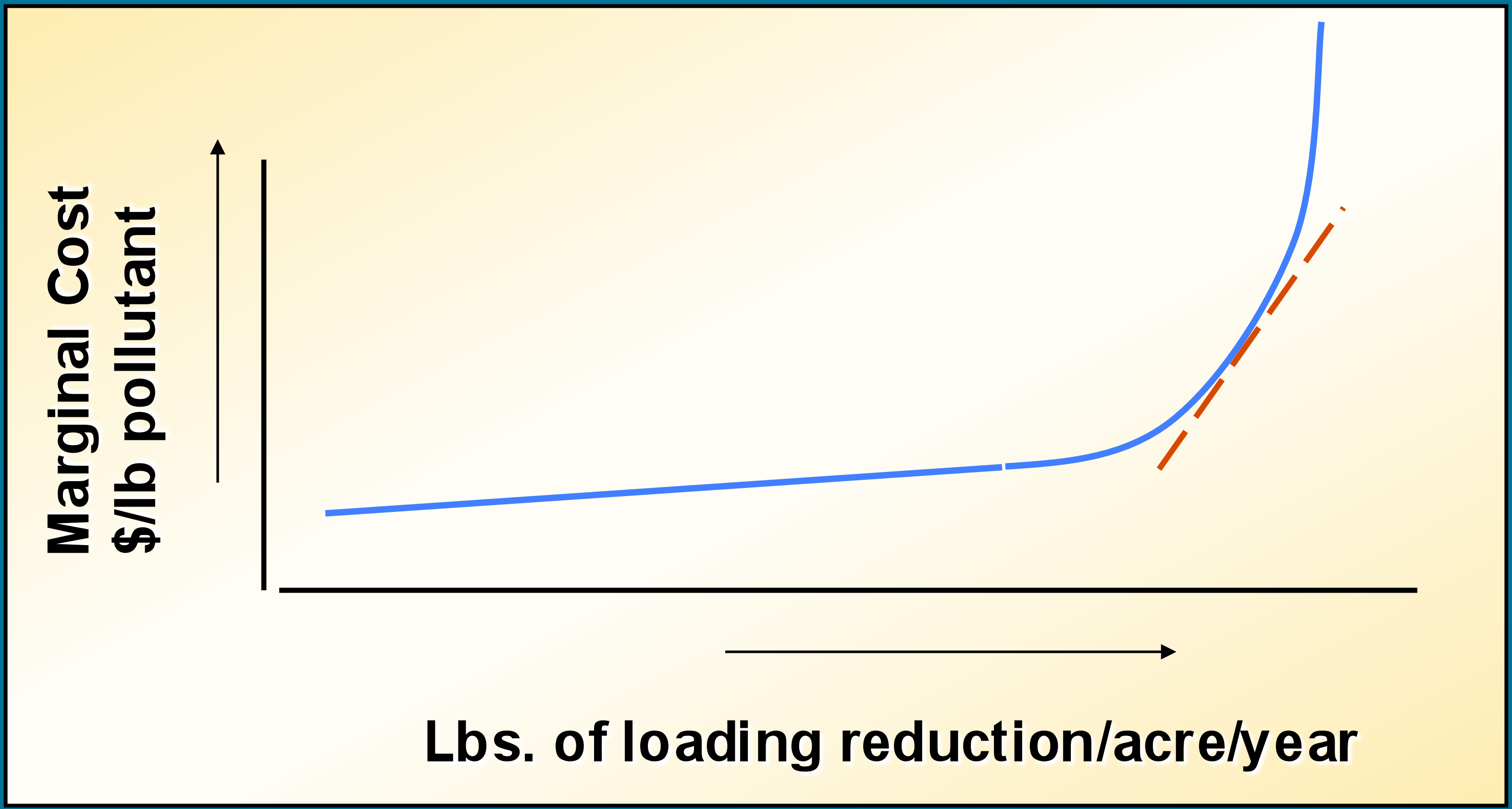
Single-Family Residential



Livonia, MI Case Study

SIMPTM Modeling Results

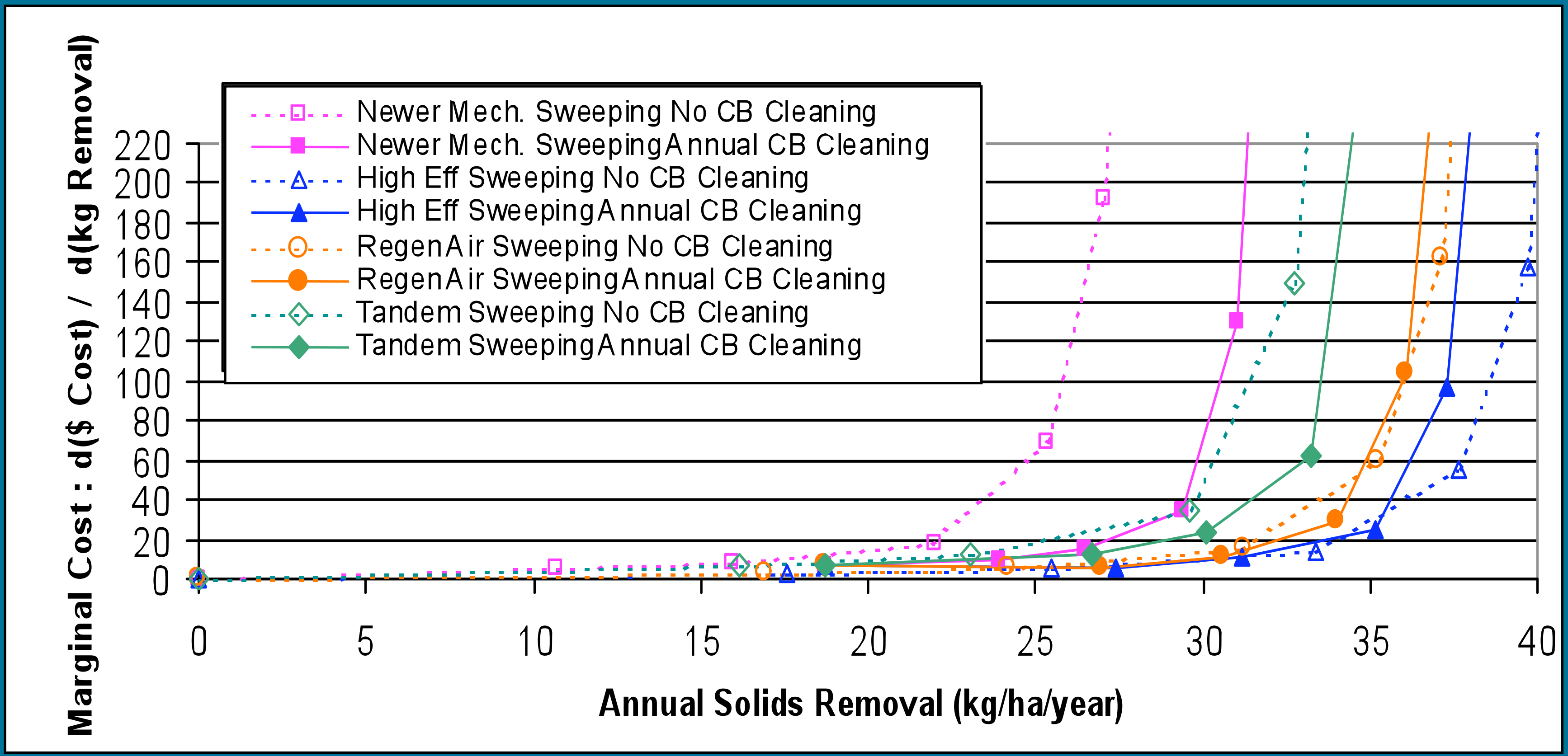
As related to …Program Dollars Spent and the *Maximum Extent Practicable*



SIMPTM Modeling Results

BMP Marginal Cost Curves

Single-Family Residential



Livonia, MI Case Study

SIMPTM Modeling Results

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