AN ANALYSIS OF POLLUTION RESULTING FROM POWER SWEEPER ENGINE EMISSIONS AS COMPARED TO SMALL-MICRON PARTICLE REDUCTION DURING OPERATION

prepared for review by

CALIFORNIA AIR RESOURCES BOARD

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Executive Summary and Author Overview:
The following information is being submitted to the California Air Resources Board in order to further the Agency's understanding of the link between street sweeping and removal of pavement-based, small-micron particulates from fugitive air entrainment and the storm water runoff stream. Further, it discusses typical scenarios that occur in terms of reductions in sweeper usage with an increase in cost of sweeping per mile and/or per hour.

Author is Ranger Kidwell-Ross, editor of WorldSweeper.com. Since 1988, Kidwell-Ross has been the world's most published author of articles and information about power sweeping. He has interviewed and consulted with a variety of government organizations, and others, on the topic of Best Management Practices in regard to power sweeping, throughout Asia, Europe and Australia, as well as in his native United States.

Overview and Analysis:
The role that modern day street sweepers play in removal of small-micron (PM-10 and smaller) particles, in addition to gross amounts of 'street dirt,' is little recognized. In speaking to groups of public works directors and others at national tradeshows and conventions, I routinely ask if they saw dirt in the curb line of the host city while they've been there. The answer is, invariably, "Yes."

However, when I then inquire if they've seen any dirt roads during their visit, or other 'dirt areas' where the dirt on the roads might have originated, they indicate they have not. And, many go on to admit they haven't previously made a connection in that regard.

The point is that even public works professionals typically fail to recognize that street debris is no longer 'dirt' in the traditional, farming-type sense in which the word has long been used. Rather, it is increasingly composed of a wide variety of

pollutants, from hydrocarbons to heavy metals and more. And, because relatively few national studies have targeted this area, the linkage between street dirt removal and fugitive dust and storm water runoff pollution is also little recognized.

In 2006, WorldSweeper.com sponsored two seminars for storm water runoff professionals in California. With almost complete unanimity, the 100+ participants were very familiar with the monies being collected via storm water runoff fees based on impervious surface area, as well as knew in a general sense how the monies were being spent for pollution reduction in their jurisdiction.

Yet, when asked essentially the same question about sweeping frequency, the typical agency manager attendee responded that sweeping frequency was whatever their current, often-shrinking, budget would allow. Astonishingly, little-to-zero linkage existed for them between air and water pollution, street sweeping frequency and relative efficiencies of sweeper types.
After attending the seminar and learning the facts, the average attendee expressed an opinion that their jurisdiction would benefit environmentally by sweeping from twice to four times more often.

In today's environmental climate, not recognizing the positive value street sweeping provides to the reduction in fugitive dust and storm water runoff pollution is an enormous oversight. The practice is also a bargain, as compared to other pollution reduction methods available.

The California Department of Transportation (Caltrans) recently completed an assessment of the cost of pollutant removal from urban highway runoff using structural BMPs. Using the CalTrans data, noted Seattle area stormwater consultant, Gary Minton, of Seattle-based Resource Planning Associates, concluded that the average cost of removing one pound of total suspended solids (TSS) from the runoff stream ranged from $10 to $60, depending on the device (and not including any land costs associated with the treatment method).

In contrast, several detailed studies by arguably the leading power sweeping researcher in the United States, Roger Sutherland, of Oregon-based Pacific Water Resources, Inc. (www.pacificwr.com) indicate that mechanical broom sweepers remove TSS from stormwater at a cost of $5 and $10 per pound.

Regenerative air and vacuum-assisted sweepers offer an even higher level of efficiency, removing TSS at a cost of $2 to $5 per pound of pollutant that would otherwise be transported in runoff. These figures show clearly that when considering storm water runoff pollutants, power sweeping is an absolute bargain.

However, I am aware that my reading audience, in this instance, is the California *Air* Resources Board. Therefore, since a similar lack of knowledge may currently

prevail, let's explore the linkage between power sweeping and the reduction of fugitive dust emissions, especially as compared to emissions from Tier Zero engines.

Most would agree that removal of particles sized 10-microns in diameter and under, commonly termed PM-10s, are central to the fugitive dust issue. The Clean Air Act addresses removal of particles of size PM-2.5. A central question is, what is the ability of street sweepers to pick up such small particles, when they are actually constructed so as to maximize the removal of larger, gross debris?

Unfortunately, since the marketplace has, to date, been unwilling to pay a premium for sweepers designed to do both, there is no question that street sweepers, both mechanical broom and air-based, are not as good at small-micron pickup as available technology might allow. However, because of the sheer volume of material that sweepers remove during operation, the results they achieve are still far from insignificant.

When it comes to comparing the small-micron efficiency of air sweepers (which employ a vacuum component) and mechanical broom sweepers (which have little or no air component), the relative efficiencies are generally illustrated by the CalTrans comparative example, above. The small-micron removal of air sweepers is estimated to be as much as a factor of 10 times better than that of mechanical broom sweepers.

However, the question is: what does that mean in the context of the current ARB regulations that would, in essence, retire much of California's current sweeper fleet because of the engines they use to operate?

To show why it seems clear that continued use of current street sweepers should be grandfathered in by CARB, let me provide an illustration of the expected PM-10 removal efficiencies of the street sweepers with the worst pickup efficiencies, mechanical broom sweepers, as compared to their estimated output of pollutants while operating.

In collaboration with Roger Sutherland, we estimate that the pickup and containment of PM-10 material even by relatively inefficient broom sweepers, depending upon native soil type and other factors, might approach 2% and 4% of total material removed. However, use of even a more conservative 1% will underscore the value of continued operation of current sweepers. For purposes of this analysis, the assumption will be that only 1% of the material picked up by a typical mechanical broom sweeper is sized at 10-microns or less.

To aid in developing this analysis, I requested that a California street sweeping contractor provide me with the company's total sweeper hourmeter hours, fuel usage (in gallons), and total pounds of debris collected/disposed of for the year

2007. It is assumed that the following will be roughly replicable using data from other contractors or municipalities in the region.

In rounded figures, the contractor used a total of 36,000 gallons of diesel (or 255,600 lbs. at 7.1 lbs./gallon) to collect 1.6 million pounds (amount delivered to landfill) of street debris. Combined hourmeter results of all sweepers used showed that approximately 12,000 hours of sweeper operation were needed in order to pick up this volume.

The average total brake horsepower of the sweeper engine(s) is considered to be about 200, a value that appears to err on the high side. The multiplication of 12,000 (hours) times 200 horsepower results in a total of 2,400,000 brake horsepower hours used to pick up all debris cited above.

Note: There is little difference in total brake horsepower whether the sweeper is a single-engine or a dual-engine machine. In the former case, the relatively larger chassis engine's output will approach 200-brake hp, since it is operating both the sweeper and the chassis portion of the machine. In the case of a dual-engine sweeper, the chassis engine is operating at a low rpm to propel the sweeper at or near 5 mph, while the engine used to operate the sweeper, approximately 80 to 100 hp in size, will be operating at an average of about half capacity.

Although I could not locate emissions' figures for the Tier Zero engine model used by the sweepers the contractor operates, an Internet search showed output for a (much larger) diesel locomotive engine to be .6 grams of pollution emissions output per brake horsepower per hour of operation. Multiplying .6 times 2,400,000 results in a total of 1,440,000 grams of pollutants, or approximately 3,214 lbs of total pollutants being emitted as a result of operating all the street sweepers in the company's fleet. Because low sulfur fuel is being used, emissions are reduced by approximately 10%, resulting in a total emissions output from the engine(s) for the year of just under 3,000 lbs.

So, even utilizing worst-case assumptions:
• Only 1% of total picked up by the sweepers to be PM-10 material or smaller,
• A higher horsepower output during operation than is probably occurring, and
• Average emissions' figures for what is probably a 'dirtier' engine,
an objective analysis shows that the sweepers in use by this particular contractor will have picked up approximately 16,000 lbs of small-micron material while emitting less than 3,000 lbs. of small-material as engine exhaust.

Although this analysis is of just a single contractor, there is no apparent reason why similar results would not be obtained when using figures supplied by other contractors and/or municipal sweeping agencies.

These particular results show that operation of current sweepers with Tier Zero engines will result in a net reduction of pavement-based material available to

become fugitive dust in excess of 500%. For that reason it seems apparent that power sweepers should be provided with a 'grandfather status' that allows them to continue operating at current levels.

In addition to the information quantified above, any removal of sweepers will be subject to a basic economic concept called 'elasticity of demand.' In short, this is a calculation of how the number of units of anything purchased changes due to increases/decreases with changes in the price of the item. If something has an inelastic demand curve, it means the same number of units would be purchased at any price.

By far more 'real world' is that demand changes significantly with price, increasing with a lower cost and decreasing with a higher cost. Although we might quibble about the amount of change that would occur in this instance, most or all would agree that the demand for sweeping services, given budgetary and other constraints, is far from inelastic. (For more information on the concept of elasticity, go to: http://www.netmba.com/econ/micro/demand/elasticity/price/).

Common sense dictates that, for any increase in the price per hour of operating a sweeper, the number of hours of sweeping that will be purchased will drop by some commensurate amount. The cost of new, street-class sweepers today approaches $200,000 per machine. If California cities and contractors are forced to upgrade their fleets, especially with short notice, the amortized cost per hour to operate sweepers will rise significantly, affecting all users.

Additional costs would also be borne through re-training of mechanics, an inability to service some newer technology components in-house, higher cost of parts where an aftermarket infrastructure has not been established, etc.

Since demand for sweeping is not inelastic by any means, the net result will be fewer sweepers re-purchased. Then, each of those will be used, on average, for fewer hours each (given their new, higher equilibrium price per hour). It is clear that this scenario *will not* provide the overall improvement in air quality being sought by CARB and the State of California.

The above is only an outline of the dilemma facing CARB in regard to its proposed inclusion of sweepers when outlawing use of previous technology engines. Because most individuals outside of the sweeping industry do not understand the net environmental value of sweeping, I am submitting this analysis in an attempt to further CARB management's understanding of the most likely outcome of legislating the removal of current sweepers from use.

Each sweeper retired from the state's fleet because they cannot meet one or more of the various CARB regulations—even those with the dirtiest, Tier Zero engines—actually increases the very particulate matter CARB is striving to reduce.

It seems clear that exempting power sweepers as a class, and thus allowing normal fleet turnover that will result in newer, cleaner vehicles over the next few years, will better serve to optimize the number of sweepers available. At the same time, the net ability of power sweepers to assist the State of California in meeting its clean water and clean air mandates will be maximized.

Given the intent to improve the air quality of California, it seems clear that power sweepers should be classified as exempt from any regulations mandating removal of current machines now in widespread usage. Analysis clearly appears to show that doing otherwise can only increase the pressure on CARB to make up the difference in other ways.

Please feel free to contact my office with your comments, or for further information, explanation, or analysis regarding this white paper.

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For overview on author credentials, see attached Vita

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Power Sweeping Industry Qualifications

Sweeping Industry Experience Timeline

- 2005 – present Founder/editor WorldSweeper.com, "Earth's Largest Power Sweeping Resource." SM As of March 2008, the WorldSweeper.com website contained over 5,000 files and photos about power sweeping.
- 1995 – present Developed and keep updated *Fundamentals of the Power Sweeping Business*. the most complete written 'how-to' information resource available for power sweeping contractors.
- 1994 – 2004 Founder/editor *American Sweeper* magazine and the AmericanSweeper.com website, which contained the largest sweeping industry database in the U.S. until WorldSweeper.com.
- 1990 – 2004 Wrote and updated the widely distributed *Introduction to the Power Sweeping Industry.*
- 1988 – 1992 Developed for Schwarze Industries, Inc. the first U.S. publication designed for sweeping contractors, *The Supervac Quarterly*.
- 1988 – 2004 Consultant to U.S. sweeper manufacturer, Schwarze Industries, Inc.
  Reported to company president; final oversight of all company websites, brochures, dealer training materials, company branding and public relations.

Overview of Information Development

- Winner of 19 national APEX Awards of Excellence on sweeping-related work since 1994.
- Have had sweeper stories published in a number of U.S. trade publications, including in two issues of *Better Roads* magazine in 2007.
- In addition to writing and publishing sweeper-related information from around the U.S., have written articles on power sweeping from personal interviews conducted with officials located in Amsterdam, Australia, Canada, China, Denmark, England, France, Holland, Japan, Portugal, Scotland, Singapore, Switzerland and Thailand.
- Attendee and participant at the annual *National Pavement Exposition* and *American Public Works Congress & Exhibition* for more than a decade.
- Promote/produce/participate in seminars that promote effective sweeping practices re: USEPA Clean Air Act and Clean Water Act.
- World's most prolific writer of published articles on the topic of power sweeping.

Education

Masters in Economics, 1976 (Western Washington University)
Bachelors in Economics, 1973