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Paved Roads

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MRI REPORT

Emission Factor Documentation for AP-42, Sections 11.2.5 and 11.2.6

Paved Roads

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NOTICE

This document is a preliminary draft. It has not been formally released by the U.S. Environmental Protection Agency and should not at this stage be construed to represent Agency policy. It is being circulated for comments on its technical merit and policy implications.

PREFACE

This report was prepared for Mr. Dennis Shipman of the Emission Inventory Branch, Technical Support Division, Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, under EPA Contract No. 68-DO-0123, Work Assignment No. I-44. This report describes the development of a new AP-42 section to replace current sections 11.2.5, "Urban Paved Roads," and 11.2.6, "Industrial Paved Roads." Midwest Research Institute's Project Leader for the assignment is Dr. Gregory E. Muleski. Dr. Muleski and Dr. Chatten Cowherd prepared this report.

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SECTION 1

INTRODUCTION

The document "Compilation of Air Pollutant Emissions Factors" (AP-42) has been published by the U.S. Environmental Protection Agency (EPA) since 1972. Supplements to AP-42 have been routinely published to add new emission source categories and to update existing emission factors. AP-42 is periodically updated by EPA to respond to new emission factor needs of EPA, State, and local air pollution control programs and industry.

An emission factor relates the quantity (weight) of pollutants emitted to a unit of activity of the source. The uses for the emission factors reported in AP-42 include:

1. Estimates of area-wide emissions.

2. Estimates of emissions for a specific facility.

3. Evaluation of emissions relative to ambient air quality.

The purpose of this report is to provide background information from test reports and other information to support preparation of a consolidated AP-42 section to replace existing Sections 11.2.5, "Urban Paved Roads," and 11.2.6, "Industrial Paved Roads."

The principal pollutant of interest in this report is "particulate matter" (PM), with special emphasis placed on "PM-10"—particulate matter no greater than 10 µmA (microns in aerodynamic diameter). PM-10 forms the basis for the current National Ambient Air Quality Standards (NAAQSs) for particulate matter.

PM-10 thus represents the size range of particulate matter that is of the greatest regulatory interest. Nevertheless, formal establishment of PM-10 as the standard basis is relatively recent, and many emission tests have referenced other particle size ranges. Other size ranges employed in this report are:

TSP Total Suspended Particulate, as measured by the standard high-volume (hi-vol) air sampler. TSP was the basis for the previous NAAQSs for particulate matter. TSP consists of a relatively coarse particle size fraction. While the particle capture characteristics of the hi-vol sampler are dependent upon approach wind velocity, the effective D50 (i.e., 50% of the particles are captured and 50% are not) varies roughly from 25 to 50 µmA.

SP Suspended Particulate, which is used as a surrogate for TSP. Defined as PM no greater than 30 µmA. SP also may be denoted as "PM-30."

IP Inhalable Particulate, defined as PM no greater than 15 µmA. Throughout the late 1970s and the early 1980s, it was clear that EPA intended to revise the NAAQSs to reflect a particle size range finer than TSP. What was not clear was the size fraction that would be eventually used, with values between 7 and 15 µmA frequently mentioned. Thus, many field studies were conducted using IP emission measurements because it was believed that IP would be the basis for the new NAAQS. IP may also be represented by "PM-15."

FP Fine Particulate, defined as PM no greater than 2.5 µmA. FP also may be denoted as "PM-2.5."

This background report consists of five sections. Section 1 provides an introduction to the report. Section 2 presents descriptions of the paved road source types and emissions from those sources as well as a brief history of the current AP-42 emission factors. Section 3 is a review of emissions data collection and analysis procedures; it describes the literature search, the screening of emission test reports, and the quality rating system for both emission data and emission factors. Section 4 details the development of paved road emission factors for the draft AP-42 section; it includes the review of specific data sets and the results of data analysis. Section 5 presents the AP-42 section for paved roads.

SECTION 2

SOURCE DESCRIPTION

Particulate emissions occur whenever vehicles travel over a paved surface, such as public and industrial roads and parking lots. These emissions may originate from material previously deposited on the travel surface, or resuspension of material from tires and undercarriages. In general, emissions arise primarily from the surface material loading (measured as mass of material per unit area). Surface loading is in turn replenished by other sources (e.g., pavement wear, deposition of material from vehicles, deposition from other nearby sources, carryout from surrounding unpaved areas, and litter). Because of the importance of the surface loading, available control techniques either attempt to prevent material from being deposited on the surface or to remove (from the travel lanes) any material that has been deposited.

2.1 PUBLIC AND INDUSTRIAL ROADS

While the mechanisms of particle deposition and resuspension are largely the same for public and industrial roads, there can be major differences in surface loading characteristics, emission levels, traffic characteristics, and viable control options. For the purpose of estimating particulate emissions and determining control programs, the distinction between public and industrial roads is not a question of ownership but rather a question of surface loading and traffic characteristics.

Although public roads generally tend to have lower surface loadings than industrial roads, the fact that these roads have far greater traffic volumes may result in a substantial contribution to the measured air quality in certain areas. In addition, public roads in industrial areas can be often heavily loaded and traveled by heavy vehicles. In that instance, better emission estimates might be obtained by treating these roads as industrial roads. In an extreme case, an industrial road or parking lot may have such a high surface loading that the paved surface is essentially covered and is easily mistaken for an unpaved surface. In that event, use of a paved road emission factor may actually result in a higher estimate than that obtained from the unpaved road emission factor, and the road is better characterized as unpaved in nature rather than paved.

2.2 REVIEW OF CURRENT PAVED ROAD EMISSION FACTORS

AP-42 currently contains two sections concerning paved road fugitive emissions. The first, Section 11.2.5, is entitled "Urban Paved Roads" and was first drafted in 1984 using test results from public paved roads.[2] Emission factors are given in the form of the following equation:

$$E = k\,(sL/0.5)^{p} \qquad (2\text{-}1)$$

where:

	E	=	particulate emission factor (g/VKT)
	s	=	surface material content silt, defined as particles < 75 µm in diameter (%)
	L	=	surface material loading, defined as mass of particles per unit area of the travel surface (g/m^2)
	k	=	base emission factor (g/VKT)
	p	=	exponent (dimensionless)

The factors k and p are given by

Particle size fraction	k (g/VKT)	p
TSP	5.87	0.9
PM-15	2.54	0.8
PM-10	2.28	0.8
PM-2.5	1.02	0.6

The form of the emission factor model is reasonably consistent throughout all particle size fractions of interest.

The urban paved road emission factors represented by Equation 2-1 have not changed since their inclusion in the 4th Edition (September 1985). It should be noted that these emission factors have not been quality rated "A" through "E." (See Section 3 for an overview of the AP-42 quality rating scheme.)

Section 11.2.6, "Industrial Paved Roads," was first published in 1983[3] and was slightly modified in Supplement B (1988) to the 4th Edition. Section 11.2.6 contains three distinct sets of emission factor models as described below.

For TSP, the following equation is recommended:

$$E = 0.022\ I\ \left(\frac{4}{n}\right)\left(\frac{s}{10}\right)\left(\frac{L}{280}\right)\left(\frac{W}{2.7}\right)^{0.7} \qquad (2\text{-}2)$$

where:

E	=	emission factor (kg/VKT)
I	=	industrial augmentation factor (dimensionless)
n	=	number of traffic lanes (dimensionless)
s	=	surface material silt content (%)
L	=	surface material loading across all traffic lanes (kg/km)
W	=	average vehicle weight (Mg)

The basic form of Equation 2-2 dates from a 1979 report[4] and was originally included in Supplement 14 to AP-42 (May 1983). The version currently in AP-42 was slightly revised in that the leading term (i.e., 0.022 in Eq. [2-2]) was reduced by 14%. The industrial road augmentation factor (I) was included to take into account for higher emissions from industrial roads than from urban roads; it varies from 1 to 7. The emission factor equation is rated "B" for cases with I = 1 and "D" otherwise.

For smaller particle size ranges, models somewhat similar to those in Eq. (2-1) are recommended:

$$E = k\ (sL/12)^{0.3} \tag{2-3}$$

where	E	=	emission factor (kg/VKT)
	k	=	base emission factor (kg/VKT), see below
	sL	=	road surface silt loading (g/m^2)

The base emission factor (k) above varies with aerodynamic size range as follows:

Particle size fraction	k (g/VKT)
PM-15	0.28
PM-10	0.22
PM-2.5	0.081

These models represented by Equation 2-3 were first developed in 1984[3] from 15 emission tests of uncontrolled paved roads and they are rated "A."

During the development of Eq. (2-3), tests of light-duty traffic on heavily loaded road surfaces were identified as a separate subset, for which separate single-valued emission factors were developed. Section 11.2.6 recommends the following for light-duty (less than 4 tons) vehicles traveling over dry, heavily loaded (silt loading greater than 15 g/m^2):

$$E = k \tag{2-4}$$

where E = emission factor (kg/VKT)

k = single-valued factor depending on particle size range of interest (see below)

Particle size fraction	k (g/VKT)
PM-15	0.12
PM-10	0.093

The single-valued emission factors are quality rated "C."

Since the time that the current models first appeared in Sections 11.2.5 and 11.2.6, several users of AP-42 have noted difficulty selecting the appropriate emission factor model to use in their applications.[5,6,7] For example, inventories of industrial facilities (particularly of iron and steel plants) conducted throughout the 1980s have yielded measured silt loading values substantially lower than those in the Section 11.2.6 data base. In extreme cases when the models were used with silt loading values outside the range for which they were developed, estimated PM-10 emission factors were larger than the corresponding TSP emission factors.

Furthermore, the distinction between "urban" and "industrial" paved roads has become blurred. For the purpose of estimating emissions, it was gradually realized that source emission levels are not a question of ownership but rather a question of surface loading and traffic characteristics. Confirmatory evidence was obtained in a

1989 field program[5] which found that paved roads at an iron and steel facility far more closely resembled "urban" roads rather than "industrial" roads in terms of emission characteristics.

Finally, it is unknown how well current emission factors perform for cases of increased surface loading on public roads, such as after application of antiskid materials or within areas of trackout from unpaved areas.[6] These situations are of considerable interest to several state and local regulatory agencies, most notably in the western United States.

The current update attempts to correct as many of those shortcomings as possible. To that end, the update employs an approach slightly different than that used in the past. In addition to reviewing test data obtained since the previous update,[8] previous test data were also included for reexamination in the final data set. In assembling the data base, no distinction was made between public and industrial roads or between controlled and uncontrolled tests, with the anticipation that the reformulated emission factor will be applicable over a far greater range of source conditions.

Inclusion of controlled tests represents a break with EPA guidelines for preparing AP-42 sections.[9] Those guidelines present a clear preference that only uncontrolled tests be used to develop an emission factor. However, the principal control measures for paved roads seek to reduce the value of an independent variable in the emission factor equation, i.e., the silt loading.

SECTION 3

GENERAL DATA REVIEW AND ANALYSIS

To reduce the amount of literature collected to a final group of references from which emission factors could be developed, the following general criteria were used:

1. Emissions data must be from a primary reference:

    a. Source testing must be from a referenced study that does not reiterate information from previous studies.

    b. The document must constitute the original source of test data. For example, a technical paper was not included if the original study was contained in the previous document. If the exact source of the data could not be determined, the document was eliminated.

2. The referenced study must contain test results based on more than one test run.

3. The report must contain sufficient data to evaluate the testing procedures and source operating conditions.

A final set of reference materials was compiled after a thorough review of the pertinent reports, documents, and information according to these criteria.

3.1 LITERATURE SEARCH AND SCREENING

Review of available literature identified three paved road testing programs (presented later as Table 4-1) since the time of the last Section 11.2 update.[8] The individual programs are discussed in detail in the next section. In addition, as discussed at the end of Section 2, earlier controlled industrial road test data were reexamined. The previous update[8] noted that Eq. (2-4) yielded quite good estimates for emissions from vacuum swept and water flushed roads. Furthermore, it became apparent that previous distinctions between "industrial" and "urban" roads had become blurred as interest focused on heavily loaded urban roads (e.g., after snow/ice controls) and on cleaner industrial roads (as the result of plant-wide control programs).

3.2 EMISSION DATA QUALITY RATING SYSTEM

As part of the analysis of the emission data, the quantity and quality of the information contained in the final set of reference documents were evaluated. The following data are to be excluded from consideration:

1. Test series averages reported in units cannot be converted to the selected reporting units.

2. Test series representing incompatible test methods (i.e., comparison of EPA Method 5 front-half with EPA Method 5 front- and back-half).

3. Test series of controlled emissions for which the control device is not specified.

4. Test series in which the source process is not clearly identified and described.

5. Test series in which it is not clear whether the emissions were measured before or after the control device.

Test data sets that were not excluded were assigned a quality rating. The rating system used was that specified by EIB for preparing AP-42 sections.[9] The data were rated as follows:

A Multiple tests that were performed on the same source using sound methodology and reported in enough detail for adequate validation. These tests do not necessarily conform to the methodology specified in EPA reference test methods, although these methods were used as a guide for the methodology actually used.

B Tests that were performed by a generally sound methodology, but lack enough detail for adequate validation.

C Tests that were based on an untested or new methodology or that lacked a significant amount of background data.

D Tests that were based on a generally unacceptable method but may provide an order-of-magnitude value for the source.

The following criteria were used to evaluate source test reports for sound methodology and adequate detail:

1. <u>Source operation</u>. The manner in which the source was operated is well documented in the report. The source was operating within typical parameters during the test.

2. Sampling procedures. The sampling procedures conformed to a generally acceptable methodology. If actual procedures deviated from accepted methods, the deviations are well documented. When this occurred, an evaluation was made of the extent such alternative procedures could influence the test results.

3. Sampling and process data. Adequate sampling and process data are documented in the report, and any variations in the sampling and process operation are noted. If a large spread between test results cannot be explained by information contained in the test report, the data are suspect and were given a lower rating.

4. Analysis and calculations. The test reports contain original raw data sheets. The nomenclature and equations used were compared to those (if any) specified by EPA to establish equivalency. The depth of review of the calculations was dictated by the reviewer's confidence in the ability and conscientiousness of the tester, which in turn was based on factors such as consistency of results and completeness of other areas of the test report.

3.3 EMISSION FACTOR QUALITY RATING SYSTEM

The quality of the emission factors developed from analysis of the test data was rated utilizing the following general criteria:

A—Excellent: Developed only from A-rated test data taken from many randomly chosen facilities in the industry population. The source category is specific enough so that variability within the source category population may be minimized.

B—Above average: Developed only from A-rated test data from a reasonable number of facilities. Although no specific bias is evident, it is not clear if the facilities tested represent a random sample of the industries. The source category is specific enough so that variability within the source category population may be minimized.

C—Average: Developed only from A- and B-rated test data from a reasonable number of facilities. Although no specific bias is evident, it is not clear if the facilities tested represent a random sample of the industry. In addition, the source category is specific enough so that variability within the source category population may be minimized.

D—Below average: The emission factor was developed only from A- and B-rated test data from a small number of facilities, and there is reason to suspect that these facilities do not represent a random sample of the industry. There also may be evidence of variability within the source category population. Limitations on the use of the emission factor are noted in the emission factor table.

E—Poor: The emission factor was developed from C- and D-rated test data, and there is reason to suspect that the facilities tested do not represent a random sample of the industry. There also may be evidence of variability within the source category population. Limitations on the use of these factors are always noted.

The use of these criteria is somewhat subjective and depends to an extent on the individual reviewer.

3.4 METHODS OF EMISSION FACTOR DETERMINATION

Fugitive dust emission rates and particle size distributions are difficult to quantify because of the diffuse and variable nature of such sources and the wide range of particle size involved including particles which deposit immediately adjacent to the source. Standard source testing methods, which are designed for application to confined flows under steady state, forced-flow conditions, are not suitable for measurement of fugitive emissions unless the plume can be draw into a forced-flow system. The following presents a brief overview of applicable measurement techniques. More detail can be found in earlier AP-42 updates.[8,10]

3.4.1 Mass Emission Measurements

Because it is usually impractical to enclose open dust sources or to capture the entire emissions plume, only the upwind-downwind and exposure profiling methods are suitable for measurement of particulate emissions from most open dust sources.[10] These two methods are discussed separately below.

The basic procedure of the upwind-downwind method involves the measurement of particulate concentrations both upwind and downwind of the pollutant source. The number of upwind sampling instruments depends on the degree of isolation of the source operation of concern (i.e., the absence of interference from other sources upwind). Increasing the number of downwind instruments improves the reliability in determining the emission rate by providing better plume definition. In order to reasonably define the plume emanating from a point source, instruments need to be located at two downwind distances and three crosswind distances, at a minimum. The same sampling requirements pertain to line sources except that measurement need not be made at multiple crosswind distances.

Net downwind (i.e., downwind minus upwind) concentrations are used as input to dispersion equations (normally of the Gaussian type) to backcalculate the particulate emission rate (i.e., source strength) required to generate the pollutant concentration measured. Emission factors are obtained by dividing the calculated emission rate by a source activity rate (e.g., number of vehicles, or weight of material transferred per unit time). A number of meteorological parameters must be concurrently recorded for input to this dispersion equation. At a minimum the wind direction and speed must be recorded on-site.

While the upwind-downwind method is applicable to virtually all types of sources, it has significant limitations with regard to development of source-specific emission factors. The major limitations are as follows:

1. In attempting to quantify a large area source, overlapping of plumes from upwind (background) sources may preclude the determination of the specific contribution of the area source.

2. Because of the impracticality of adjusting the locations of the sampling array for shifts in wind direction during sampling, it cannot be assumed that plume position is fixed in the application of the dispersion model.

3. The usual assumption that an area source is uniformly emitting does not allow for realistic representation of spatial variation in source activity.

4. The typical use of uncalibrated atmospheric dispersion models introduces the possibility of substantial error (a factor of three according to Reference 11) in the calculated emission rate, even if the stringent requirement of unobstructed dispersion from a simplified (e.g., constant emission rate from a single point) source configuration is met.

The other measurement technique, exposure profiling, offers distinct advantages for source-specific quantification of fugitive emissions from open dust sources. The method uses the isokinetic profiling concept that is the basis for conventional (ducted) source testing. The passage of airborne pollutant immediately downwind of the source is measured directly by means of simultaneous multipoint sampling over the effective cross section of the fugitive emissions plume. This technique uses a mass-balance calculation scheme similar to EPA Method 5 stack testing rather than requiring indirect calculation through the application of a generalized atmospheric dispersion model.

For measurement of nonbuoyant fugitive emissions, profiling sampling heads are distributed over a vertical network positioned just downwind (usually about 5 m) from the source. If total particulate emissions are to be measured, sampling intakes are pointed into the wind and sampling velocity is adjusted to match the local mean wind speed, as monitored by anemometers distributed over height above ground level.

The size of the sampling grid needed for exposure profiling of a particular source may be estimated by observation of the visible size of the plume or by calculation of plume dispersion. Grid size adjustments may be required based on the results of preliminary testing. Particulate sampling heads should be symmetrically distributed over the concentrated portion of the plume containing about 90% of the total mass flux (exposure). For example, assuming that the exposure from a point source is normally distributed, the exposure values measured by the samplers at the edge of the grid should be about 25% of the centerline exposure.

To calculate emission rates using the exposure profiling technique, a conservation of mass approach is used. The passage of airborne particulate (i.e., the quantity of emissions per unit of source activity) is obtained by spatial integration of distributed measurements of exposure (mass/area) over the effective cross section of the plume. The exposure is the point value of the flux (mass/area/time) of airborne particulate integrated over the time of measurement.

3.4.2 Emission Factor Derivation

Usually the final emission factor for a given source operation, as presented in a test report, is derived simply as the arithmetic average of the individual emission factors calculated from each test of that source. Frequently the range of individual emission factor values is also presented.

As an alternative to the presentation of a final emission factor as a single-valued arithmetic mean, an emission factor may be presented in the form of a predictive equation derived by regression analysis of test data. Such an equation mathematically relates emissions to parameters when characterize source conditions. These parameters may be grouped into three categories:

1. Measures of source activity or energy expended (e.g., the speed and weight of a vehicle traveling on an unpaved road).

2. Properties of the material being disturbed (e.g., the content of suspendable fines in the surface material on an unpaved road).

3. Climatic parameters (e.g., number of precipitation-free days per year on which emissions tend to be at a maximum).

An emission factor equation is useful if it is successful in "explaining" much of the observed variance in emission factor values on the basis of corresponding variance sin specific source parameters. This enables more reliable estimates of source emissions on a site-specific basis.

A generic emission factor equation is one that is developed for a source operation defined on the basis of a single dust generation mechanism which crosses industry lines. An example would be vehicular traffic on unpaved roads. To establish its applicability, a generic equation should be developed from test data obtained in different industries.

3.5 EMISSION FACTOR QUALITY RATING SCHEME USED IN THIS STUDY

The uncontrolled emission factor quality rating scheme used in this study is identical to that used in two earlier updates[8,11] and represents a refinement of the rating system developed by EPA for AP-42 emission factors, as described in Section 3.3. The scheme entails the rating of test data quality followed by the rating of the emission factor(s) developed from the test data.

Test data that were developed from well documented, sound methodologies were assigned an A rating. Data generated by a methodology that was generally sound but either did not meet a minimum test system requirements or lacked enough detail for adequate validation received a B rating.

In evaluating whether an upwind-downwind sampling strategy qualified as a sound methodology, the following minimum test system requirements were used. At least five particulate measuring devices must be operated during a test, with one device located upwind and the other located at two downwind and three crosswind distances. The requirement of measurements at crosswind distances is waived for the case of line sources. Also wind direction and speed must be monitored concurrently on-site.

The minimum requirements for a sound exposure profiling program were the following. A one-dimensional, vertical grid of at least three samplers is sufficient for measurement of emissions from line or moving point sources while a two-dimensional array of at least five samplers is required for quantification of fixed virtual point source missions. At least one upwind sampler must be operated to measure background concentration, and wind speed must be measured on-site.

Neither the upwind-downwind nor the exposure profiling method can be expected to produce A-rated emissions data when applied to large, poorly defined area sources, or under very light and variable wind flow conditions. In these situations, data ratings based on degree of compliance with minimum test system requirements were reduced one letter.

After the test data supporting a particular single-valued emission factor were evaluated, the criteria presented in Table 3-1 were used to assign a quality rating to the resulting emission factor. These criteria were developed to provide objective definition for: (a) industry representativeness; and (b) levels of variability within the data set for the source category. The rating system obviously does not include estimates of statistical confidence, nor does it reflect the expected accuracy of fugitive dust emission factors relative to conventional stack emission factors. It does, however, serve as useful tool for evaluation of the quality of a given set of emission factors relative to the entire available fugitive dust emission factor data base.

Minimum industry representativeness is defined in terms of number of test sites and number of tests per site. These criteria were derived from two principles:

1. Traditionally, three tests of a source represent the minimum requirement for reliable quantification.

2. More than two plant sites are needed to provide minimum industry representativeness.

TABLE 3-1. QUALITY RATING SCHEME FOR SINGLE-VALUED EMISSION FACTORS

Code	No. of test sites	No. of tests per site	Total No. of tests	Test data variability[a]	Adjustment for EF rating[b]
1	≥ 3	≥ 3	–	< F2	0
2	≥ 3	≥ 3	–	> F2	−1
3	2	≥ 2	≥ 5	< F2	−1
4	2	≥ 2	≥ 5	> F2	−2
5	–	–	≥ 3	< F2	−2
6	–	–	≥ 3	> F2	−3
7	1	2	2	> F2	−3
8	1	2	2	> F2	−4
9	1	1	1	–	−4

[a] Data spread in relation to central value. F2 denotes factor of two

[b] Difference between emission factor rating and test data rating.

The level of variability within an emission factor data set was defined in terms of the spread of the original emission factor data values about the mean or median single-valued factor for the source category. The fairly rigorous criterion that all data points must lie within a factor of two of the central value was adopted. It is recognized that this criterion is not insensitive to sample size in that for a sufficiently large test series, at least one value may be expected to fall outside the factor-of-two limits. However, this is not considered to be a problem because most of the current single-valued factors for fugitive dust sources are based on relatively small sample sizes.

Development of quality ratings for emission factor equations also required consideration of data representativeness and variability, as in the case of single-valued emission factors. However, the criteria used to assign ratings (Table 3-2) were different, reflecting the more sophisticated model being used to represent the test

TABLE 3-2. QUALITY RATING SCHEME FOR EMISSION FACTORS EQUATIONS

Code	No. of test sites	No. of tests per site	Total No. of tests[a]	Adjustment for EF rating[b]
1	≥ 3	≥ 3	$\geq (9 + 3P)$	0
2	≥ 2	≥ 3	$\geq 3P$	−1
3	≥ 1	–	$< 3P$	−1

[a] P denotes number of correction parameters in emission factor equation.

[b] Difference between emission factor rating and test data rating.

data. As a general principle, the quality rating for a given equation should lie between the test data rating and the rating that would assigned to a single-valued factor based on the test data. The following criteria were established for an emission factor equation to have the same rating as the supporting test data:

1. At least three test sites and three tests per site, plus an additional three tests for each independent parameter in the equation.

2. Quantitative indication that a significant portion of the emission factor variation is attributable to the independent parameter(s) in the equation.

Loss of quality rating in the translation of these data to an emission factor equation occurs when these criteria are not met. In practice, the first criterion was far more influential than the second in rating an emission factor equation, because development of an equation implies that a substantial portion of the emission factor variation is attributable to the independent parameter(s). As indicated in Table 3-2, the rating was reduced by one level below the test data rating if the number of tests did not meet the first criterion, but was at least three times greater than the number of independent parameters in the equation. The rating was reduced two levels if this supplementary criterion was not met.

The rationale for the supplementary criterion follows from the fact that the likelihood of including "spurious" relationships between the dependent variable (emissions) and the independent parameters in the equation increases as the ratio of number of independent parameters to sample size increases. For example, a four parameter equation based on five tests would exhibit perfect explanation (R^2 = 1.0) of the emission factor data, but the relationships expressed by such an equation cannot be expected to hold true in independent applications.

SECTION 4

AP-42 SECTION DEVELOPMENT

4.1 REVISIONS TO SECTION NARRATIVE

The draft AP-42 presented later in this background document is intended to replace the current versions of both Section 11.2.5 "Urban Paved Roads" and Section 11.2.6 "Industrial Paved Roads" in AP-42. Both sections date from the mid-1980s and only slight revisions have been made over the past 8 years.

As discussed earlier in this report, some AP-42 users have noted difficulty in selecting the appropriate emission factor model to use in particular applications. For example, field-measurement-based inventories have demonstrated that silt loading has tended to decrease at industrial facilities throughout the 1980s, so that, at present, silt loadings found on industrial roads often can be substantially lower than those in the underlying data base. In extreme cases of silt loading outside the range supporting the models, resulting PM_{10} factors may be greater than corresponding TSP factors. Due to the trend of lower silt loadings, the distinction made between "urban" and "industrial" paved roads in AP-42 has not been found as clear-cut in real-world situations.

Several investigators have also commented that the current emission factors for public paved roads may not be applicable when the equilibrium between deposition and removal processes is upset. This situation can occur for various reasons, including (a) application of snow and ice controls, (b) trackout from construction activities in the area, and (c) wind and/or water erosion from surrounding unstabilized areas.

4.2 POLLUTANT EMISSION FACTOR DEVELOPMENT

This update to Sections 11.2.5 and 11.2.6 was planned to address the shortcomings described above. In order to achieve this goal, the following general approach was taken

1. Assemble the available test data for paved roads in a single data base, making no distinction between public and industrial roads or between controlled and uncontrolled roads.

2. Conduct a series of stepwise linear regression analyses of the revised data base to develop an emission factor model with:

   silt loading,
   mean vehicle weight,
   mean number of wheels, and,
   mean travel speeds

   as potential correction parameters.

3. Conduct an appropriate validation study of the reformulated model.

4.2.1 Review of Specific Data Sets

Table 4-1 presents the specific test reports reviewed in this update. As can be seen, test reports reviewed in the 1987 update were again reviewed to determine if

TABLE 4-1. APPLICABLE TEST REPORTS

New reports since 1987 update:

I. PEI Associates 1989. "Street Sanding Emissions and Control Study," EPA Contract No. 68-02-4394, Work Assignment No. 27, prepared for U.S. Environmental Protection Agency, Region 8. October 1989.

II. Midwest Research Institute 1990. "Roadway Emission Field Tests at U.S. Steel's Fairless Works." USX Purchase Order No. 146-0001191-0068, prepared for United States Steel Corporation. May 1990.

III. RTP Environmental Associates 1990. "Street Sanding Emissions and Control Study," prepared for the Colorado Department of Health. July 1990.

Reports[a] considered during 1987 update:

1. T. Cuscino, Jr., et al., *Iron and Steel Plant Open Source Fugitive Emission Control Evaluation*, EPA-600/2-83-110, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, October 1983.

5. G. E. Muleski, *Measurement of Fugitive Dust Emissions from Prilled Sulfur Handling*, Final Report, MRI Project No. 7995-L, Prepared for Gardinier, Inc., June 1984.

8. T. F. Eckle and D. L. Trozzo, "Verification of the Efficiency of a Road-Dust Emission-Reduction Program by Exposure Profile Measurement," Presented at EPA/AISI Symposium on Iron and Steel Pollution Abatement, Cleveland, Ohio, October 1984.

[a] Same numbers as in 1987 update.[8]

controlled emissions data should be included in the final data set. Test reports I, II, and III are new since the 1987 update. Test reports 1, 5, and 8 are those from the 1987 update that were re-reviewed.

Test Report I. This test program was undertaken to characterize PM-10 emissions from six streets that were periodically sanded for anti-skid control within the Denver area. The primary objective was given as development of a predictive algorithm for clean and sanded streets, with a secondary objective stated as defining the effectiveness of control measures. Summary information is given in Table 4-2.

Sampling employed six to eight 8 PM-10 samplers equipped with volumetric flow control. Samplers were arranged in two upwind/downwind configurations. The "basic" configuration consisted of six samplers arranged in identical patterns upwind and downwind of the test road, with one sampler and one pair of samplers at nominal distances of 20 and 5 m, respectively, from the road.

The second configuration was used for tests of control measure effectiveness. The road segment was divided into two halves, corresponding to the treated and experimental control (untreated) portions. Identical sampling arrays were again used upwind and downwind on both halves, at nominal distances of 20 and 5 m. Because this array employed all eight samplers available, no collocation was possible for the second configuration.

In addition to the PM-10 concentration measurements, several other types of samples were collected:

- Wind speed/direction and incoming solar radiation were collected on-site, and the results were combined to estimate atmospheric stability class needed to calculate emission factors.

TABLE 4-2. SUMMARY INFORMATION FOR TEST REPORT I

Operation	Location	State	Test dates	No. of tests	PM_{10} emission factor (g/VKT)	
					Geom. mean	Range
Vehicle traffic	Colfax	Colorado	3-4/89	17	1.33	0.53-9.01
Vehicle traffic	York St.	Colorado	4/89	1	1.07	1.07
Vehicle traffic	Belleview	Colorado	4/89	4	1.62	1.10-4.77
Vehicle traffic	I-225	Colorado	4/89	9	0.31	0.17-0.51
Vehicle traffic	Evans	Colorado	5-6/89	29	1.06	0.21-7.83
Vehicle traffic	Louisiana	Colorado	6/89	7	0.96	0.42-1.73

- Colorado Air Pollution Control Division (APCD) representatives collected traffic data, including traffic counts, travel speeds, and percentage of heavy-duty vehicles.

- Vacuums with disposable paper bags were used to collect the loose material from the road surface. In addition to samples taken from the travel lanes, the field crew took daily samples of material adjacent to curbs and periodic duplicate samples.

The study collected PM-10 concentration data on 24 different days and calculated a total of 69 different emission rates for baseline, sanded and controlled paved road surfaces. Emission factors were obtained by back-calculation from the CALINE3 dispersion model[12] together with a series of assumptions involving mixing widths and heights and an effective release height. Although data collected at the 20 m distance were used to evaluate results, the test report did not describe any sensitivity analysis to determine how dependent the emission rates were on the underlying assumptions.

The testing program found difficulty in defining "upwind" concentrations for several of the runs, including cases with wind reversals or winds nearly parallel to the roadway orientation. A total of eight of the 69 tests required that either an average concentration from other test days or a downwind concentration be used to define "upwind" conditions. In addition, the test report described another seven runs as invalid for reasons such as wet road surfaces, nearby dust sources or concentrations increasing with downwind distance.

A series of stepwise regression analyses were conducted, with different predictive equations presented for (a) baseline conditions, (b) sanded roads, and (c) roads swept to remove the sand applied, and (d) all conditions combined. In each case, only one independent variable was included in the predictive equation: silt loading, for cases (a) and (d); and time since treatment, for (b) and (c).

In general, Test Report I is reasonably well documented in terms of describing test conditions, sampling methodology, data reduction and analysis. A chief limitation lies in the fact that neither sampling configuration fully met minimum requirements for the upwind-downwind method presented in Section 3.4. Specifically, only two or three samplers were used downwind rather than the minimum of four.

Furthermore, a later report[6] drawing upon the results from Test Reports I and III effectively eliminated 24% of the combined baseline tests because of wind directions. In addition, the later report[6] noted that the baseline data should be considered as "conservatively high" because roughly 70% of the data were calculated assuming the most unstable atmospheric class (which results in the highest backcalculated emission factor). Because of these limitations, the emission data have been given an overall rating of between "B" and "C."

<u>Test Report II</u>. This 1989 field program used exposure profiling to characterize emissions from paved roads at an integrated iron and steel plant. In many respects, this program arose because of uncertainties with paved road emission factor models used outside their range of applicability. During the preparation of an alternative emission reduction ("bubble") plan for the plant, questions arose about the use of AP-42 equations and other EPA guidance[13] in estimating roadway emissions involved in the emissions trade. This program provided site-specific data to support the bubble plan. This testing program also represents the first exposure profiling data to supplement the AP-42 paved road data base since 1984. Table 4-3 provides summary information.

The program involved two paved road test sites. The first (site "C") was along the four-lane main access route to the plant. Average daily traffic (ADT) had been

TABLE 4-3. SUMMARY INFORMATION FOR TEST REPORT II

					Emission factor (g/VKT) TSP		Emission factors (g/VKT) PM_{10}	
Operation	Location	State	Test dates	No. of test	Geom. mean	Range	Geom. mean	Range
Vehicle traffic	Unpaved road	Pennsylvania	11/89	2	172	110-270	45.1	40-51
Vehicle traffic	Site C	Pennsylvania	11/89	6	9.19	3.4-34	2.69	0.25-10
Vehicle traffic	Site E	Pennsylvania	11/89	4	21.9	9.3-84	6.21	2-10

estimated as more than 4,000 vehicle passes per day, with most vehicles representative of "foreign" equipment (i.e., cars, pickups, and semi-trailers rather than plant haul trucks and other equipment). Site "E," on the other hand, was located near the iron- and steel-making facilities and had both lower ADT and heavier vehicles than site "C." The plant regularly vacuum swept paved roads, and two cleaning frequencies (two times and five times per week) were considered during the test program.

Depending on traffic characteristics of the road being tested, a 6 to 7.5 m high profiling array was used to measure downwind mass flux. This array consisted of four or five total particulate sampling heads spaced at 1.5 m heights and was positioned at a nominal 5 m distance downwind from the road. Additional concentration and particle size measurements were obtained from standard high volume ("hi-vol") sampler and cyclone/cascade impactor combination operated downwind as well as a standard hi-vol/impactor combination operated upwind. The height for downwind sizing devices (2.2 m) was selected after review of prior test results. It approximated the height in a roadway dust plume at which half the mass emissions pass above and half below.

Additional samples included:

- Average wind speeds at two heights and wind direction at one height were recorded during testing to maintain isokinetic sampling.

- Traffic data, including traffic counts, travel speeds, and vehicle class were recorded manually.

- Vacuums with disposable paper bags were used to collect the loose material from the road surface.

The sampling equipment met the requirements of a sound exposure profiling methodology specified in Section 3.4 so that the emission test data are rated "A." The test report presents emission factors for total particulate (TP), total suspended particulate (TSP) and PM-10, for the ten paved road emission tests conducted.

Test Report II found that the emission factors and silt loadings more closely resembled those in the "urban" rather than the "industrial" data base. That is to say, emissions agreed more closely with factors estimated by the methods of AP-42 Section 11.2.5 than by methods in Section 11.2.6. Given the traffic rate of 4000 vehicles per day at Site "C," this finding was not terribly surprising. What was far more surprising was that emissions at Site "E" were also more "urban" than "industrial." Although the TSP and PM-10 models in Section 11.2.5 showed a slight tendency to underpredict, the Section 11.2.6 PM-10 model overestimated measured emissions by at least an order of magnitude. The performance of the industrial TSP model, on the other hand, was only slightly poorer than that for the urban TSP model.

Test Report III. This test program was quite similar to that described in Test Report I and used an essentially identical methodology. In fact, the two test reports are very similar in outline, and many passages in the two reports are identical. The primary objective was given as expanding the data base in Test Report I to further develop predictive algorithms for clean and sanded streets. Summary information is given in Table 4-4.

The test program employed the same two basic PM-10 sampling arrays as did Test Report I. A third configuration was used for "profile" tests, in which additional samplers were placed at 10 and 20 ft heights. (Analysis of results from elevated samplers is not presented in Test Report III.)

As was the case in Test Report I, additional samples were collected including:

- Wind speed/direction were collected on-site, and the results used in estimating atmospheric stability class needed to calculate emission

TABLE 4-4. SUMMARY INFORMATION FOR TEST REPORT III

Operation	Location	State	Test dates	No. of test	PM-10 emission factor (g/VKT)	
					Geom. mean	Range
Vehicle traffic	Mexico	Colorado	2/90	3	2.75	1.08-6.45
Vehicle traffic	State Hwy 36	Colorado	1-3/90	13	1.31	0.14-4.18
Vehicle traffic	Colfax	Colorado	2-4/90	41	1.32	0.27-5.04
Vehicle traffic	Park Rd.	Colorado	4/90	11	1.26	0.69-3.33
Vehicle traffic	Evans	Colorado	2-3/90	11	2.10	0.87-7.27
Vehicle traffic	Louisiana	Colorado	1,3/90	9	3.24	1.40-5.66
Vehicle traffic	Jewell	Colorado	1/90	1	6.36	6.36
Vehicle traffic	Bryon	Colorado	4/90	3	8.38	5.53-14.72

factors. (Unlike Test Report I, solar radiation measurements were not collected.)

- Traffic data, including traffic counts, travel speeds, and percentage of heavy-duty vehicles were collected.

- Vacuums with disposable paper bags were used to collect the loose material from the road surface. The program developed an extensive set of collocated samples of material along the edges of the roadway.

The study collected PM-10 concentration data on 33 days and calculated a total of 131 different emission rates for baseline, sanded and controlled paved road surfaces. Emission factors were obtained by back-calculation from the CALINE3 dispersion model[12] together with essentially the same assumptions as those in Test Report I. This report also noted the same difficulty as Test Report I in defining "upwind" concentrations in cases with wind reversals or winds nearly parallel to the roadway orientation. Unlike Test Report I, however, this report does not provide readily available information on how many tests used either an average concentration from other test days or a downwind concentration to define "upwind" conditions. Test Report III does, however, describe seven tests as invalid because of filter problems or because upwind concentrations were higher than downwind values.

As with the Test Report I program, a series of stepwise regression analyses were conducted. This test program combined data from Test Reports I and III and considered predictive equations for (a) baseline conditions, (b) sanded roads, and (c) roads swept to remove the sand applied, and (d) all conditions combined.

Unlike Test Report I, however, Test Report III appears to present silt loading values that are based on <u>wet sieving</u> (see page 8 of the test report) rather than the dry sieving technique (as described in Appendix E to AP-42) routinely used in fugitive dust tests. (MRI could not obtain any clarifying information during telephone calls to the testing organization and the laboratory that analyzed the samples.) Wet sieving disaggregates composite particles and results from the two types of sieving are not comparable.

There is additional confusion over the silt loading values given in Test Report III for cleaning tests. Specifically, the same silt loading value is associated with both the treatment and the experimental control. This point could not be clarified during telephone conversation with the testing organization. Attempts to clarify using test report appendices were unsuccessful. Two appendices appear to interchange silt loading with silt percentage. More importantly, it could not be determined whether the surface sample results reported in Appendix D to Test Report III pertain to treated or the experimental control segment, and with which emission rate a silt loading should be associated.

Test Report III contains substantial amounts of information, but is not particularly well documented in terms of describing test conditions, sampling methodology, data reduction and analysis. In addition, the same limitations mentioned in connection with Test Report I are equally applicable to Test Report III, as follows:

- not meeting the minimum number of samplers.
- numerous tests conducted under variable wind conditions.
- frequent use (70% to 80% of the tests) of the most unstable atmospheric stability class in the CALINE 3 model which will result in the highest calculated emission rate.

Because of these limitations, emission rate data have been given an overall rating of "C." Furthermore, the silt loading data in this report are considered suspect for reasons noted above.

Reexamination of Earlier Data Sets. As remarked earlier, it was decided to assemble paved road test data distinguishing neither between public and industrial roads nor between controlled and uncontrolled tests. In addition to simply combining the data bases supporting Sections 11.2.5 and 11.2.6, this involved reexamining earlier reports for controlled test results. Specifically, the paved road Test Reports 1, 5, and 8 identified in the 1987 update (see Table 4-1) were reexamined.

Test Report 1 in 1987 update: This study evaluated paved road control techniques at two different iron and steel plants. (See Tables 9 and 10 in Reference 8.) Data were quality rated as "A," and uncontrolled test results were incorporated into the data base for Section 11.2.6. The only use of the controlled test results, however, has been the following addition to Section 11.2.6.4 in 1988:

> "Although there are relatively few quantitative data on emissions from controlled paved roads, those that are available indicate that adequate estimates generally may be obtained by substituting controlled loading values into .. [Equations (2-2) and (2-3)].... The major exception to this is water flushing combined with broom sweeping. In that case, the equations tend to overestimate emissions substantially (by an average factor of 4 or more)."

In the current update, the controlled emission factors have been used as part of the overall data base to develop predictive models. Although PM-10 emission data are not specifically presented in the report, appropriate values were previously developed by log-normal interpolation of the PM-15 and PM-2.5 factors.[8]

Test Report 5 in 1987 update: This was first report identified to suggest that heavily loaded paved roads may be better considered as unpaved in terms of emission estimates. The program produced three tests of emissions from end-loader travel over paved surfaces. Two of the three tests were conducted on very heavily loaded surface, while the third was on a cleaned paved surface. (See Tables 20 and 21 of the 1987 update.)[8]

No PM-10 emission factors were reported; results were presented for total particulate (TP) and suspended particulate (SP, or PM-30). Data were quality rated "A" in the 1987 report.

Because no PM-10 data were given, Test Report 5 data were most directly useful as independent data against which the TSP emission factor model (Eq. (2-2)) could be assessed. This comparison showed generally good agreement between predicted and observed with agreement becoming better as source conditions approached those in the underlying data base.

The 1987 update[8] developed PM-10 emission factors based on information contained in the test report. When compared to the single valued factors (Equation [2-4]), agreement for the first two tests was within a factor of approximately two. The third test—that of the cleaned surface—could not be used to assess the performance of either Eq. (2-1) or Eq. (2-3) because the surface loading value could not be converted to the necessary units with information presented in the report.

Test Report 8 in 1987 update: This paper discussed the development of an exposure profiling system as well as an evaluation of the effectiveness of a paved road vacuum sweeping program. Because no reference is made to an earlier test report, this paper is considered to be the original source of the test data. Although ten uncontrolled and five controlled tests are mentioned, test data are reported only in terms of averages. (See Tables 24 and 25 in Reference 8.) Only TSP emission factors are presented. Although data were obtained using a sound methodology, data were rated "B" because of inadequate detail in the paper.

Averaged data from Test Report 8 were used in an independent assessment of Eq. (2-2). Although only average emission levels could be compared, the data suggested that TSP emissions could be estimated within very acceptable limits.

4.2.2 Compilation of Final Data Base

In keeping with the results from the data set review, a final data base was compiled by combining the following sets:

1. Data base supporting Section 11.2.5
2. Data base supporting Section 11.2.6
3. The controlled tests of Test Report 1 in the 1987 update
4. All data contained in Test Report II

The final PM-10 data base is shown in Figure 4-1, with the origin of each of the 64 data points indicated by a key letter:

I - Data point used to develop the predictive equations in Section 11.2.6.

i - Data point used in developing the single-valued factors in Section 11.2.6.

U - Data point used to develop the predictive equation in Section 11.2.5.

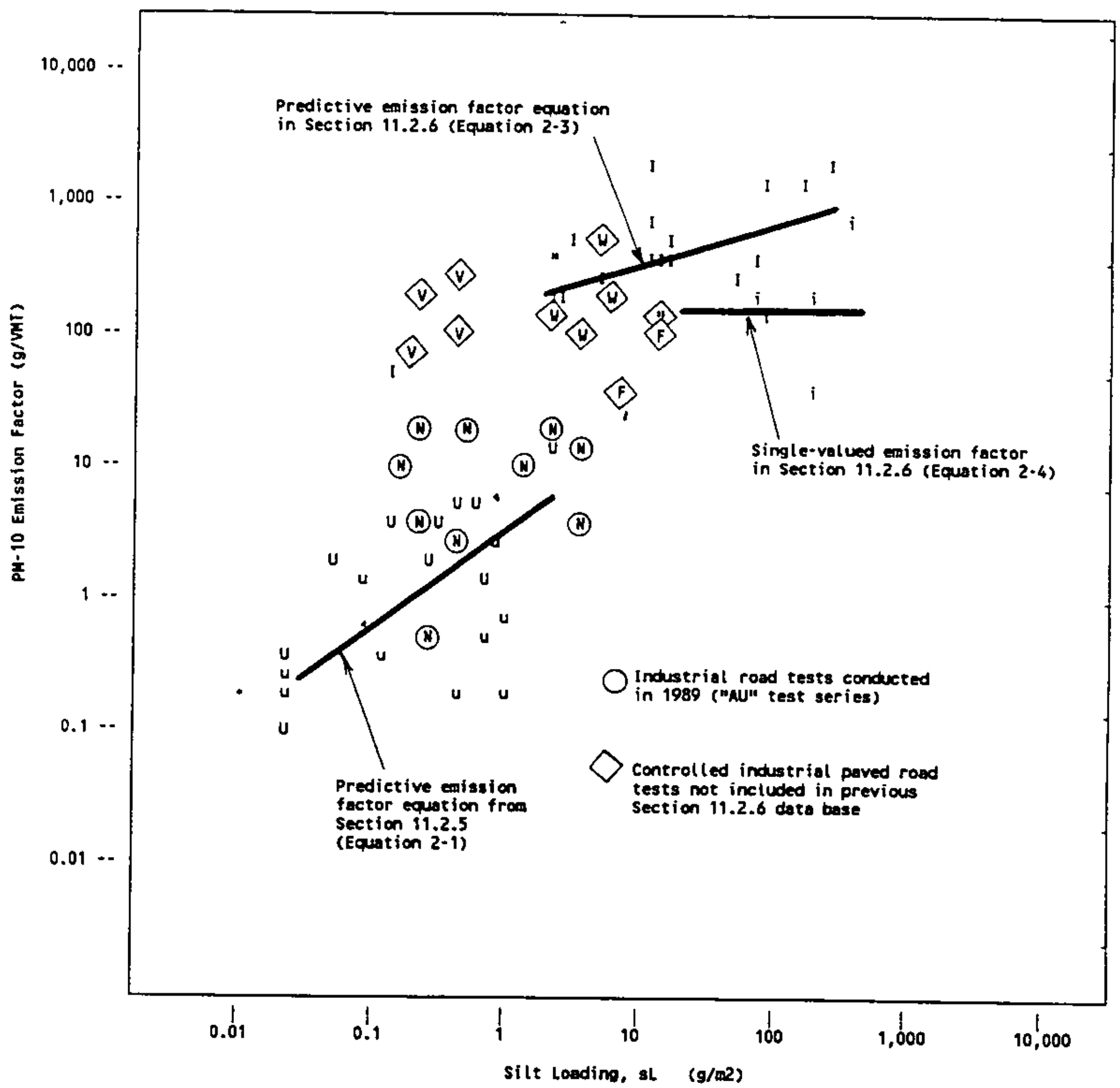

Figure 4-1. Final data set. See text for key letters.

u - Data point excluded during development of the urban paved road equation (Section 11.2.5).

V,W,F - Controlled industrial test in Test Report 1 corresponding to vacuum swept, water flushed or flushed/broom swept.

N - Data from Test Report II

The "new" data, namely those in data sets (3) and (4), are shown in diamonds or circles in the figure. Note that the new data sets function somewhat like "glue" in combining the old industrial and urban data sets in the sense that the new data effectively bridge the two older data sets.

Test data from Test Reports I and III were excluded from the final data base for the following reasons:

a. Only PM-10 emission factors were available, rather than a group of particle size ranges.

b. Unresolved questions about the silt loading values in Test Report III remain.

Note, however, that Test Report I data provide very useful information about the accuracy of the revised emission factor model. Figure 4-2 presents the 43 data points from Test Report I used in the validation study.

4.2.3 Emission Factor Development

Stepwise multiple linear regression[14] was used to develop a predictive model with the final data set. The potential correction factors included:

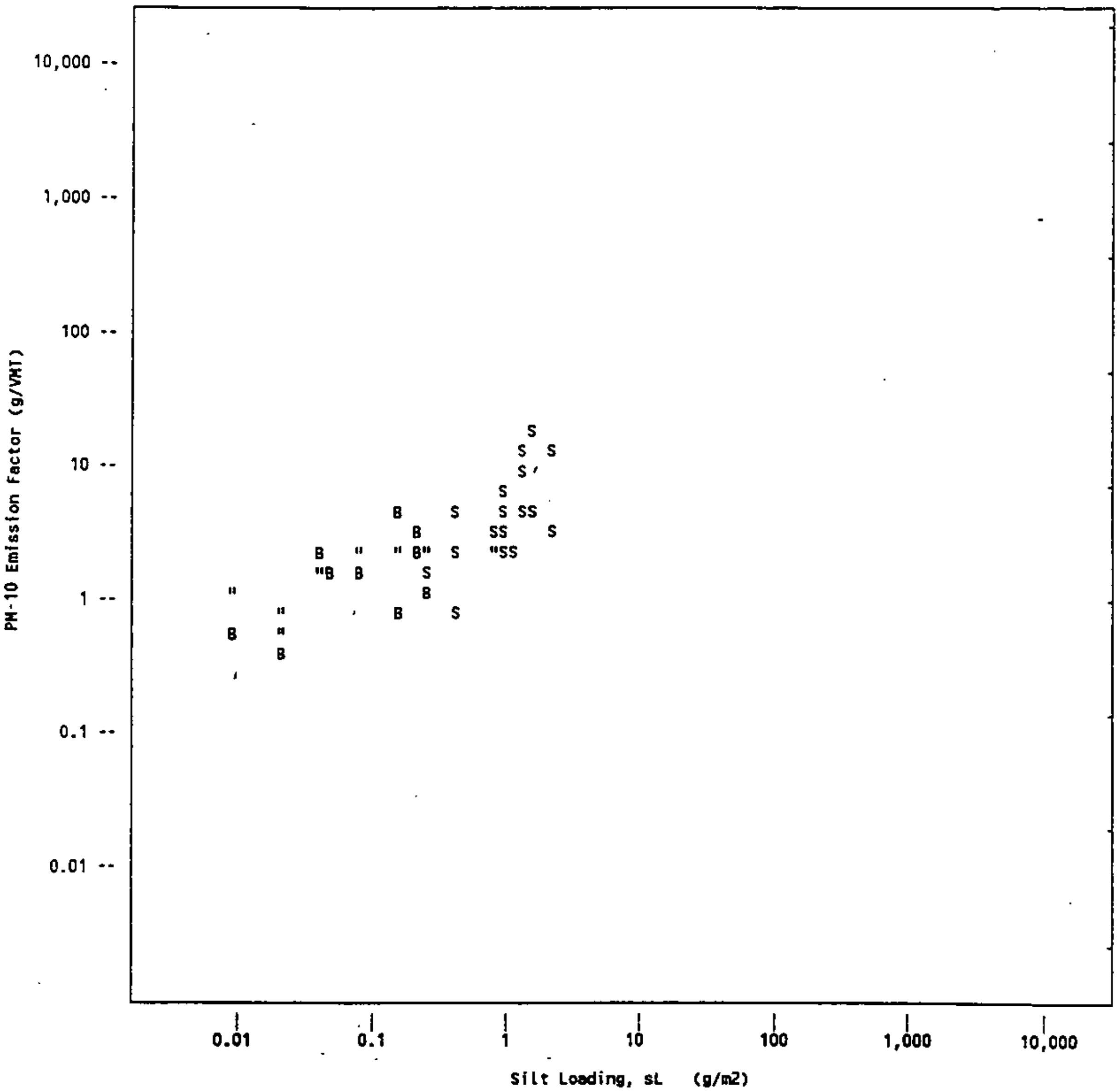

Figure 4-2. Validation data from Test Report I. "B" represents a baseline while "S" indicates a sand road test.

- silt loading, sL
- mean vehicle weight, W
- mean vehicle speed, S
- mean number of wheels, w

All variables were log-transformed in order to obtain a multiplicative model as in the past. Figure 4-3 presents the correlation matrix of the log-transformed independent and dependent variables, as well as the multiple regression results. The most notable features of the correlation matrix are the high degree of interdependence between silt loading, emission factors, and speed; and the low degree of interdependence between silt loading and weight. This suggests that silt loading and weight may be effectively used to derive an emission factor model.

Several points should be noted about the regression results. First, the expression for PM-10 was always considered first so that a series of models comparable over several size ranges would result. As Figure 4-3 shows, the models for PM-30 and PM-15 are quite similar to that for PM-10; the expression for PM-2.5, on the other hand, has substantially lower exponents for both sL and W.

Second, during an initial exploratory phase, it was found that models with essentially equivalent accuracy could be developed using only the independent variables of weight W and speed S. Nevertheless, those two variables cannot be expected to vary substantially during the year. In other words, a model based on W and S could not be expected to predict higher emission levels known to occur after road sanding, etc. Models incorporating surface loading values as an independent variable were pursued because surface loading represents a reasonable means of introducing seasonal variability.

PEARSON CORRELATION MATRIX FOR PM-2.5

	LGVMT	LSL	LTONS	LMPH	LWHEELS
LGVMT	1.000				
LSL	0.697	1.000			
LTONS	0.646	0.282	1.000		
LMPH	-0.812	-0.809	-0.208	1.000	
LWHEELS	-0.006	-0.596	0.885	0.513	1.000

FREQUENCY TABLE

	LGVMT	LSL	LTONS	LMPH	LWHEELS
LGVMT	52				
LSL	52	52			
LTONS	52	52	52		
LMPH	30	30	30	30	
LWHEELS	13	13	13	13	13

PEARSON CORRELATION MATRIX FOR PM-10

	LGVMT	LSL	LTONS	LMPH	LWHEELS
LGVMT	1.000				
LSL	0.751	1.000			
LTONS	0.676	0.347	1.000		
LMPH	-0.768	-0.837	-0.202	1.000	
LWHEELS	0.141	-0.596	0.885	0.513	1.000

FREQUENCY TABLE

	LGVMT	LSL	LTONS	LMPH	LWHEELS
LGVMT	65				
LSL	64	64			
LTONS	65	64	65		
LMPH	42	42	42	42	
LWHEELS	13	13	13	13	13

PEARSON CORRELATION MATRIX FOR PM-15

	LGVMT	LSL	LTONS	LMPH	LWHEELS
LGVMT	1.000				
LSL	0.765	1.000			
LTONS	0.672	0.348	1.000		
LMPH	-0.775	-0.837	-0.202	1.000	
LWHEELS	0.159	-0.596	0.885	0.513	1.000

FREQUENCY TABLE

	LGVMT	LSL	LTONS	LMPH	LWHEELS
LGVMT	64				
LSL	64	64			
LTONS	64	64	64		
LMPH	42	42	42	42	
LWHEELS	13	13	13	13	13

PEARSON CORRELATION MATRIX FOR PM-30

	LGVMT	LSL	LTONS	LMPH	LWHEELS
LGVMT	1.000				
LSL	0.748	1.000			
LTONS	0.787	0.568	1.000		
LMPH	-0.737	-0.875	-0.338	1.000	
LWHEELS	.	.	.	.	.

FREQUENCY TABLE

	LGVMT	LSL	LTONS	LMPH	LWHEELS
LGVMT	18				
LSL	18	18			
LTONS	18	18	18		
LMPH	12	12	12	12	
LWHEELS	0	0	0	0	0

Multiple Linear Regression for PM-10

DEP VAR: LGVMT N: 64 MULTIPLE R: .873 SQUARED MULTIPLE R: .761
ADJUSTED SQUARED MULTIPLE R: .754 STANDARD ERROR OF ESTIMATE: 1.393

VARIABLE	COEFFICIENT	STD ERROR	STD COEF	TOLERANCE	T	P(2 TAIL)
CONSTANT	-0.099	0.424	0.000	.	-0.232	0.817
LSL	0.648	0.074	0.586	0.880	8.790	0.000
LTONS	1.487	0.209	0.474	0.880	7.117	0.000

ANALYSIS OF VARIANCE

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
REGRESSION	377.698	2	188.849	97.371	0.000
RESIDUAL	118.309	61	1.939		

Multiple Linear Regression for PM-2.5

DEP VAR: LGVMT N: 52 MULTIPLE R: .839 SQUARED MULTIPLE R: .705
ADJUSTED SQUARED MULTIPLE R: .693 STANDARD ERROR OF ESTIMATE: 1.264

VARIABLE	COEFFICIENT	STD ERROR	STD COEF	TOLERANCE	T	P(2 TAIL)
CONSTANT	0.007	0.457	0.000	.	0.015	0.988
LSL	0.487	0.070	0.559	0.920	6.912	0.000
LTONS	1.258	0.209	0.488	0.920	6.030	0.000

ANALYSIS OF VARIANCE

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
REGRESSION	186.960	2	93.480	58.472	0.000
RESIDUAL	78.337	49	1.599		

Multiple Linear Regression for PM-15

DEP VAR: LGVMT N: 64 MULTIPLE R: .879 SQUARED MULTIPLE R: .772
ADJUSTED SQUARED MULTIPLE R: .765 STANDARD ERROR OF ESTIMATE: 1.383

VARIABLE	COEFFICIENT	STD ERROR	STD COEF	TOLERANCE	T	P(2 TAIL)
CONSTANT	0.182	0.422	0.000	.	0.432	0.667
LSL	0.678	0.073	0.604	0.879	9.264	0.000
LTONS	1.470	0.208	0.462	0.879	7.081	0.000

ANALYSIS OF VARIANCE

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
REGRESSION	395.337	2	197.669	103.275	0.000
RESIDUAL	116.754	61	1.914		

Multiple Linear Regression for PM-30

DEP VAR: LGVMT N: 18 MULTIPLE R: .868 SQUARED MULTIPLE R: .753
ADJUSTED SQUARED MULTIPLE R: .720 STANDARD ERROR OF ESTIMATE: 0.876

VARIABLE	COEFFICIENT	STD ERROR	STD COEF	TOLERANCE	T	P(2 TAIL)
CONSTANT	1.342	0.815	0.000	.	1.648	0.120
LSL	0.596	0.210	0.443	0.677	2.843	0.012
LTONS	1.638	0.477	0.535	0.677	3.434	0.004

ANALYSIS OF VARIANCE

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
REGRESSION	35.115	2	17.557	22.883	0.000
RESIDUAL	11.509	15	0.767		

Figure 4-3. Correlation and regression results for the data set.

The following equation presents the final recommended emission factor models.

$$e = k\ (sL)^{0.65}\ (W)^{1.5}$$

where e is emission factor in g/vehicle-mile traveled (g/VMT), sL is silt loading in g/m^2, W is mean vehicle weight in tons, and k is constant given in Table 4-5.

TABLE 4-5. RECOMMENDED EMISSION FACTOR MODELS

Size range	Sample size	k	Multiple R^2
PM-2.5	52	0.41	NA
PM-10	64	0.90	0.761
PM-15	65	1.1	0.765
PM-30	18	4.7	0.752

All models, except that for PM-2.5, are quality rated "A." The expression for PM-2.5 was based on a mean ratio of PM-2.5 to PM-10 because of slightly different powers on the sL and W terms; the PM-2.5 factor is rated "B." The high R2 values for the other size ranges indicate that approximately 75% of variability in emission factors are "explained" by the predictive equation.

4.2.4 Validation Studies

Two sets of validation studies were undertaken to assess the predictive capability of the revised paved road emission model for PM-10. The first employed a standard cross-validation (CV) technique.[15] Using this technique, each point in the underlying data base is excluded one at a time, and the equation generated from the reduced data base is used to estimate the missing value. The second evaluation applied the new PM-10 expression to the independent data of Test Report I.

By using a CV technique, "n" quasi-independent estimates are obtained from a data base of "n" tests, and the overall validity of using stepwise regression to obtain a model of the form

$$e = k\ (sL)^a\ (W)^b$$

is evaluated. Summary information is shown in Table 4-6.

TABLE 4-6. RESULTS OF CROSS-VALIDATION STUDY

	Variable	Minimum	Maximum	Mean	Std. deviation
a	Exponent of sL	0.63	0.67	0.649	0.009
b	Exponent of W	1.42	1.57	1.49	0.027
k	Leading term	0.79	1.07	0.90[a]	1.058[a]
	Ratio of quasi-independent estimate to measured emission factor	0.050	30	1.004[a]	4.23[a]

[a] Geometric mean/standard deviation.

Figure 4-4 presents the cumulative frequency distribution of the ratio of the quasi-independent estimate to the measured emission factor. A little over half of the estimates are within a factor of 3 and approximately 70% are within a factor of 5. The 90% confidence interval corresponds to a factor of approximately 8.

The second validation study applied the recommended PM-10 emission factor model to the data of Test Report I (see Figure 4-2). This represents an independent application of the equation in that none of the Test Report I data were used to develop the equation. Summary information is given in Table 4-7:

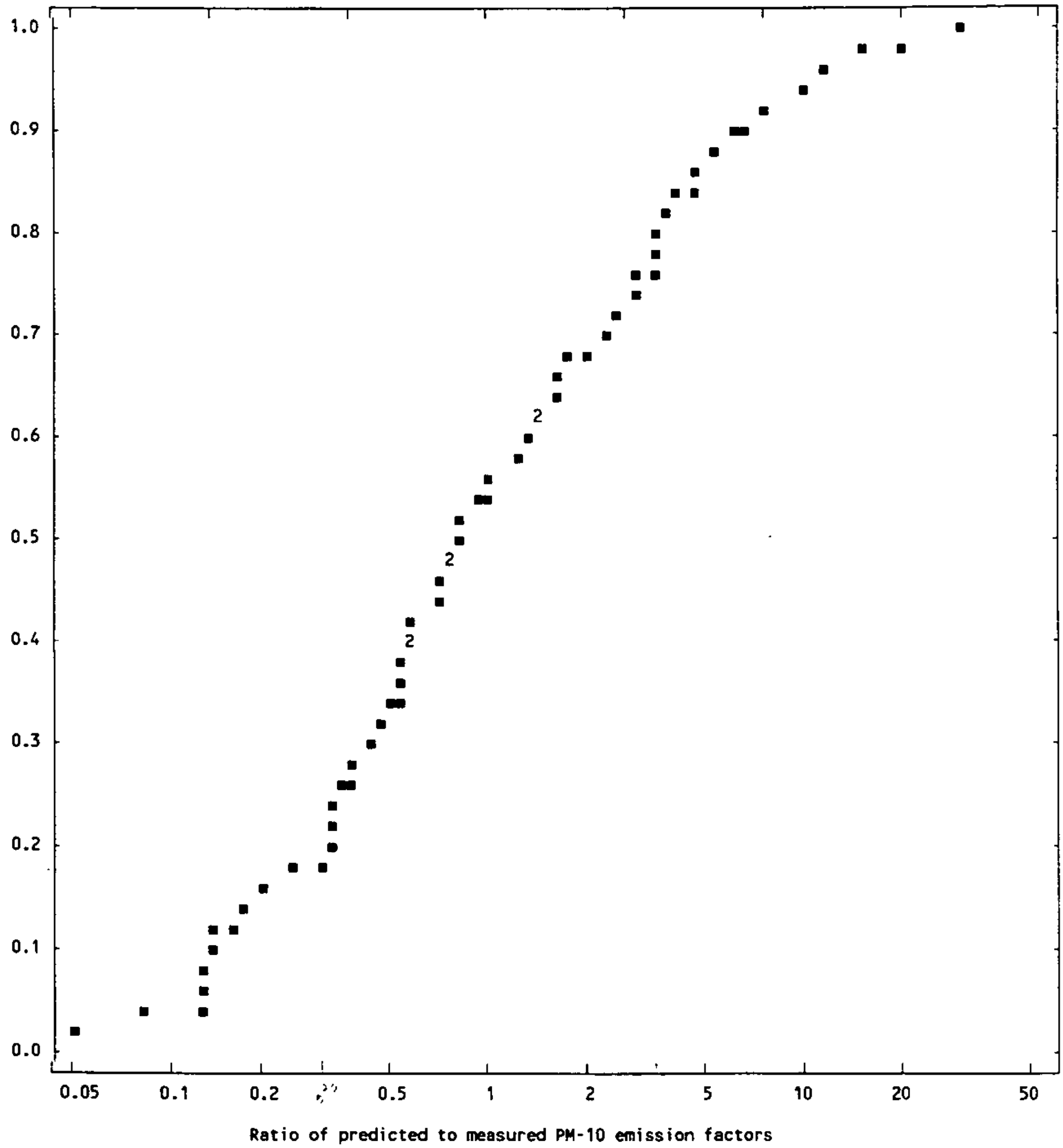

Figure 4-4. Cumulative frequency distribution obtained during cross-validation study.

TABLE 4-7. RESULTS FROM INDEPENDENT APPLICATION OF THE PM-10 MODEL

	Sample size	Ratio of predicted to observed PM-10 emission factor			
		Minimum	Maximum	Geo. mean	Geo. std. deviation
Baseline roads	23	0.23	1.59	0.528	1.69
Sanded roads	20	0.35	2.51	1.03	1.69
Overall	43	0.23	2.51	0.724	1.86

As can be seen, agreement is generally quite good, especially for sanded roads.

For baseline (unsanded) roads, the new PM-10 emission factor model tends to underpredict emissions. Recall that a later report[6] making use of Test Reports I and III stated that the combined baseline data "should be considered to be conservatively high." If that is true, then the tendency of the new model to underpredict could be expected.

One final examination compared performance of the new PM-10 versus the current AP-42 factors and EPA guidance.[13] The document "Control of Open Fugitive Dust Sources" (EPA-450/3-88-008) presented the following decision rule for paved road emission estimates (Table 4-8).

TABLE 4-8. DECISION RULE FOR PAVED ROAD EMISSION ESTIMATES

Silt loading (sL) (g/m^2)	Average vehicle weight (W) (tons)	Use model given by
$sL < 2$	$W > 4$	Equation (2-3)
$sL < 2$	$W < 4$	Equation (2-1)
$sL > 2$[a]	$W > 6$	Equation (2-3)
$2 < sL < 15$	$W < 6$	Equation (2-3)
$sL > 15$[a]	$W < 6$	Equation (2-4)

[a] For heavily loaded surfaces (i.e., $sL < \sim 300$ to $400\ g/m^2$) it is recommended that the resulting estimate be compared to that from the unpaved road models.

Table 4-9 presents the results from this comparison. As can be seen, in almost every data set comparison, results using the new model are comparable, if not better, than those using the three different equations currently contained in AP-42, together with the selection method of Table 4-8.

4.3 DEVELOPMENT OF OTHER MATERIAL IN AP-42 SECTION

Concurrent with the development of the revised AP-42 section for paved roads, a separate effort was conducted to assemble a silt loading data base for nonindustrial roads. Over the past 10 years, numerous organizations have collected silt loading samples from public paved roads. Unfortunately, uniformity—in sampling and analysis methodology as well as roadway classification schemes—has been sorely lacking in these studies.

Silt loading data were compiled in the following manner. Persons knowledgeable about PM-10 at each EPA regional office were asked to identify sL data for public roads. In many instances, the EPA representatives identified state/local air regulatory personnel who were then asked to supply the data. Given that the relative importance of PM-10 emissions from public sources is greater in the western United States, it is not surprising that most of the data are from that area of the country. What is surprising, perhaps, is that Montana has collected roughly two-thirds of all data. Furthermore, only Montana had data collected from the same road over extended periods of time, thus permitting examination of temporal variation.

The assembled data set did not yield any readily identifiable, coherent relationship between silt loading and road class, average daily traffic (ADT), etc. Much of the difficulty is probably due to the fact that not all variables were reported by each organization. Further complicating the analysis is the fact that, in many parts of the country, paved road silt loading varies greatly over the course of the year. Recall that repeated sampling at Montana municipalities indicated a very noticeable annual

TABLE 4-9. RATIO OF PREDICTED TO MEASURED PM-10 EMISSION FACTORS

Data set code[a]	Sample size	Minimum[b]	Maximum[b]	Geo. mean[b]	Std. geo. deviation[b]
I	19	0.086 / 0.056	2.9 / 12	0.80 / 0.70	2.3 / 4.5
i	5	0.24 / 0.39	4.1 / 5.5	0.96 / 1.0	2.8 / 2.8
U	10	0.39 / 0.38	170 / 6.6	8.8 / 1.2	6.8 / 2.4
u	9	0.61 / 0.56	300 /18	14 / 3.4	7.7 / 2.9
V, F, W	11	0.52 / 0.14	8.6 / 3.7	1.7 / 0.54	2.4 / 2.9
N	10	0.13 / 0.094	79 / 28	5.8 / 1.1	10 / 5.5
Overall	64	0.086 / 0.056	300 / 28	2.7 / 1.0	6.4 / 3.9

[a] Same data subset code as for Figure 4-1.

[b] First entry represents value using current AP-42 factors and decision rule in Table 4-8. Second entry represents value using new PM-10 equation.

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cycle. Nevertheless, it is questionable whether the seasonal variation noted in the Montana data base could successfully predict variations for many other sites. While one could possibly expect similar variations for, say, Idaho or Wyoming roads, there is far less reason to suspect a similar cycle in, say, Maine or Michigan, in the absence of additional information.

Because no meaningful relationship could be established between sL and an independent variable, the decision was made to directly employ the nonindustrial data base in the AP-42 section. The draft AP-42 section presents the cumulative frequency distribution for the sL data base, with subdivisions into (a) low-ADT (< 5000 vehicles/day) and high-ADT roads and (b) first and second halves of the year. Suggested default values are based on the 50th and 90th percentile values.

The second use of the assembled data set recognizes that the end users of AP-42 are the most capable in identifying which roads in the data base are similar to roads of interest to them. The draft AP-42 section presents the paved road surface loading values together with the city, state, road name, collection date (samples collected from the same road during the same month are averaged), road ADT if reported, classification of the roadway, etc. Readers of AP-42 are invited to review the data base and to select values that they deem appropriate for the roads and seasons of interest.

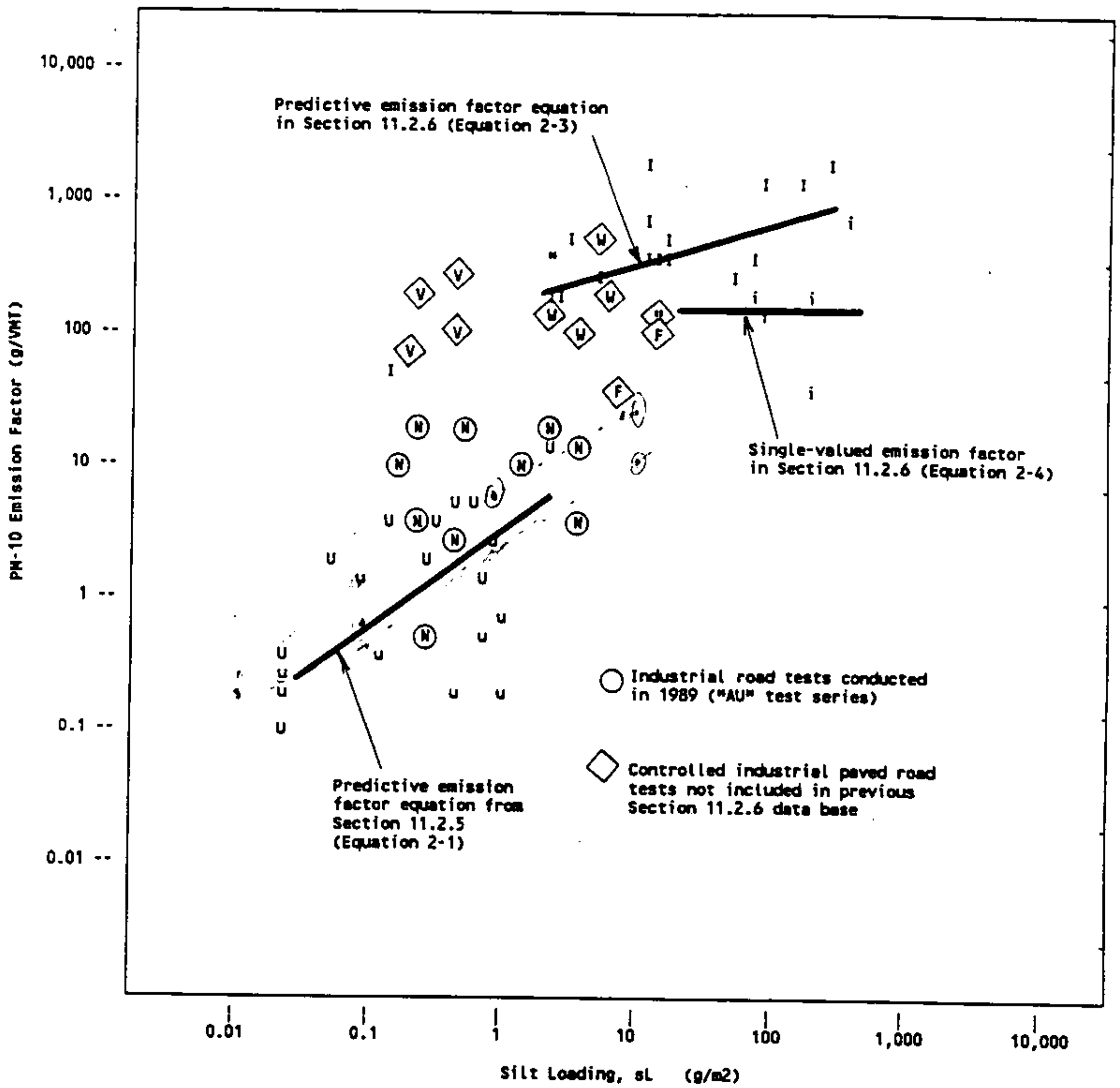

Figure 4-1. Final data set. See text for key letters.

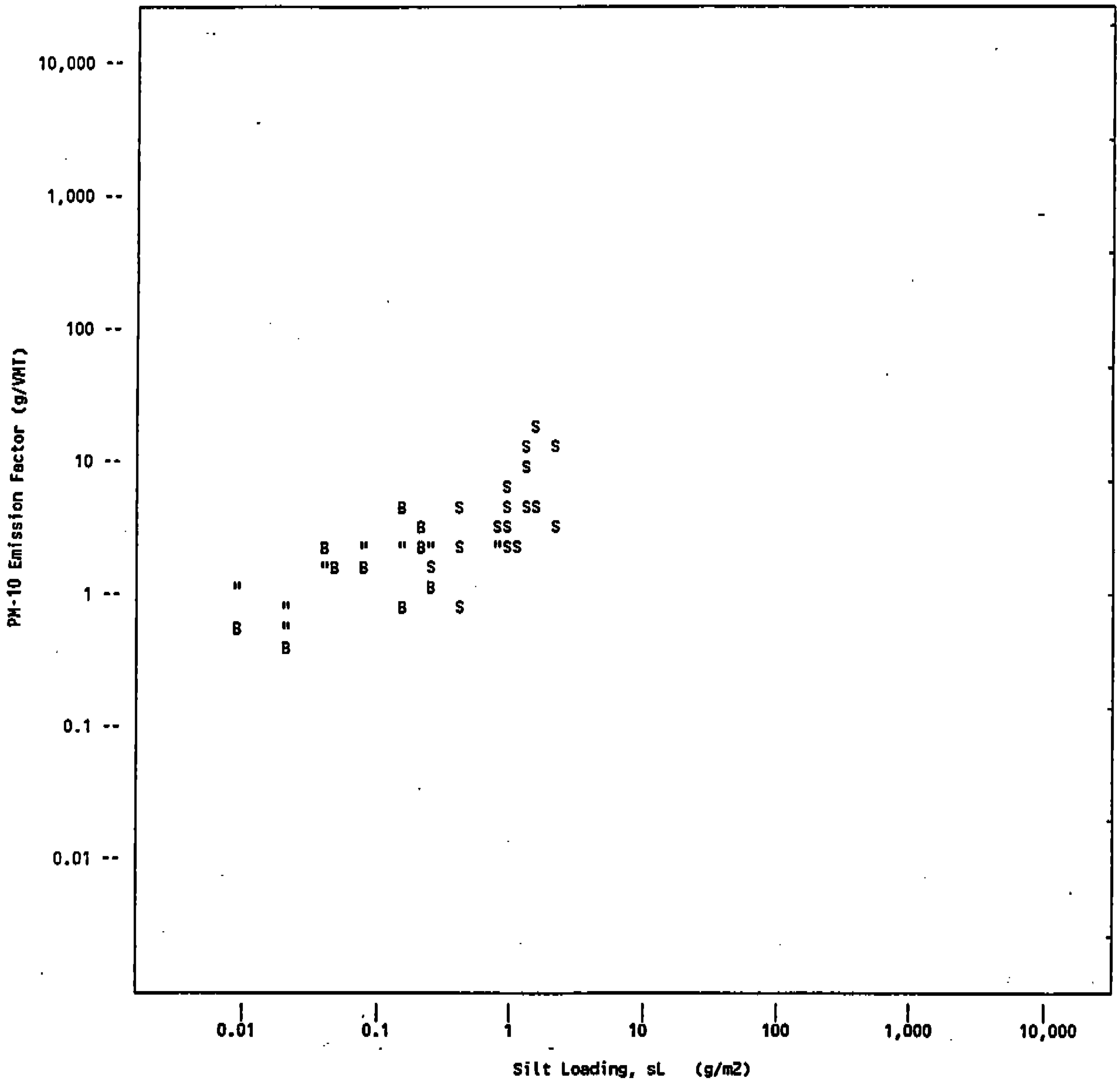

Figure 4-2. Validation data from Test Report I. "B" represents a baseline while "S" indicates a sand road test.

- silt loading, sL
- mean vehicle weight, W
- mean vehicle speed, S
- mean number of wheels, w

All variables were log-transformed in order to obtain a multiplicative model as in the past. Figure 4-3 presents the correlation matrix of the log-transformed independent and dependent variables, as well as the multiple regression results. The most notable features of the correlation matrix are the high degree of interdependence between silt loading, emission factors, and speed; and the low degree of interdependence between silt loading and weight. This suggests that silt loading and weight may be effectively used to derive an emission factor model.

Several points should be noted about the regression results. First, the expression for PM-10 was always considered first so that a series of models comparable over several size ranges would result. As Figure 4-3 shows, the models for PM-30 and PM-15 are quite similar to that for PM-10; the expression for PM-2.5, on the other hand, has substantially lower exponents for both sL and W.

Second, during an initial exploratory phase, it was found that models with essentially equivalent accuracy could be developed using only the independent variables of weight W and speed S. Nevertheless, those two variables cannot be expected to vary substantially during the year. In other words, a model based on W and S could not be expected to predict higher emission levels known to occur after road sanding, etc. Models incorporating surface loading values as an independent variable were pursued because surface loading represents a reasonable means of introducing seasonal variability.

PEARSON CORRELATION MATRIX FOR PM-2.5

	LGVMT	LSL	LTONS	LMPH	LWHEELS
LGVMT	1.000				
LSL	0.697	1.000			
LTONS	0.646	0.282	1.000		
LMPH	-0.812	-0.809	-0.208	1.000	
LWHEELS	-0.006	-0.596	0.885	0.513	1.000

FREQUENCY TABLE

	LGVMT	LSL	LTONS	LMPH	LWHEELS
LGVMT	52				
LSL	52	52			
LTONS	52	52	52		
LMPH	30	30	30	30	
LWHEELS	13	13	13	13	13

PEARSON CORRELATION MATRIX FOR PM-10

	LGVMT	LSL	LTONS	LMPH	LWHEELS
LGVMT	1.000				
LSL	0.751	1.000			
LTONS	0.676	0.347	1.000		
LMPH	-0.768	-0.837	-0.202	1.000	
LWHEELS	0.141	-0.596	0.885	0.513	1.000

FREQUENCY TABLE

	LGVMT	LSL	LTONS	LMPH	LWHEELS
LGVMT	65				
LSL	64	64			
LTONS	65	64	65		
LMPH	42	42	42	42	
LWHEELS	13	13	13	13	13

PEARSON CORRELATION MATRIX FOR PM-15

	LGVMT	LSL	LTONS	LMPH	LWHEELS
LGVMT	1.000				
LSL	0.765	1.000			
LTONS	0.672	0.348	1.000		
LMPH	-0.775	-0.837	-0.202	1.000	
LWHEELS	0.159	-0.596	0.885	0.513	1.000

FREQUENCY TABLE

	LGVMT	LSL	LTONS	LMPH	LWHEELS
LGVMT	64				
LSL	64	64			
LTONS	64	64	64		
LMPH	42	42	42	42	
LWHEELS	13	13	13	13	13

PEARSON CORRELATION MATRIX FOR PM-30

	LGVMT	LSL	LTONS	LMPH	LWHEELS
LGVMT	1.000				
LSL	0.748	1.000			
LTONS	0.787	0.568	1.000		
LMPH	-0.737	-0.875	-0.338	1.000	
LWHEELS	.	.	.	.	.

FREQUENCY TABLE

	LGVMT	LSL	LTONS	LMPH	LWHEELS
LGVMT	18				
LSL	18	18			
LTONS	18	18	18		
LMPH	12	12	12	12	
LWHEELS	0	0	0	0	0

Multiple Linear Regression for PM-10

DEP VAR: LGVMT N: 64 MULTIPLE R: .873 SQUARED MULTIPLE R: .761
ADJUSTED SQUARED MULTIPLE R: .754 STANDARD ERROR OF ESTIMATE: 1.393

VARIABLE	COEFFICIENT	STD ERROR	STD COEF	TOLERANCE	T	P(2 TAIL)
CONSTANT	-0.099	0.424	0.000	.	-0.232	0.817
LSL	0.648	0.074	0.586	0.880	8.790	0.000
LTONS	1.487	0.209	0.474	0.880	7.117	0.000

ANALYSIS OF VARIANCE

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
REGRESSION	377.698	2	188.849	97.371	0.000
RESIDUAL	118.309	61	1.939		

Multiple Linear Regression for PM-2.5

DEP VAR: LGVMT N: 52 MULTIPLE R: .839 SQUARED MULTIPLE R: .705
ADJUSTED SQUARED MULTIPLE R: .693 STANDARD ERROR OF ESTIMATE: 1.264

VARIABLE	COEFFICIENT	STD ERROR	STD COEF	TOLERANCE	T	P(2 TAIL)
CONSTANT	0.007	0.457	0.000	.	0.015	0.988
LSL	0.487	0.070	0.559	0.920	6.912	0.000
LTONS	1.258	0.209	0.488	0.920	6.030	0.000

ANALYSIS OF VARIANCE

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
REGRESSION	186.960	2	93.480	58.472	0.000
RESIDUAL	78.337	49	1.599		

Multiple Linear Regression for PM-15

DEP VAR: LGVMT N: 64 MULTIPLE R: .879 SQUARED MULTIPLE R: .772
ADJUSTED SQUARED MULTIPLE R: .765 STANDARD ERROR OF ESTIMATE: 1.383

VARIABLE	COEFFICIENT	STD ERROR	STD COEF	TOLERANCE	T	P(2 TAIL)
CONSTANT	0.182	0.422	0.000	.	0.432	0.667
LSL	0.678	0.073	0.604	0.879	9.264	0.000
LTONS	1.470	0.208	0.462	0.879	7.081	0.000

ANALYSIS OF VARIANCE

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
REGRESSION	395.337	2	197.669	103.275	0.000
RESIDUAL	116.754	61	1.914		

Multiple Linear Regression for PM-30

DEP VAR: LGVMT N: 18 MULTIPLE R: .868 SQUARED MULTIPLE R: .753
ADJUSTED SQUARED MULTIPLE R: .720 STANDARD ERROR OF ESTIMATE: 0.876

VARIABLE	COEFFICIENT	STD ERROR	STD COEF	TOLERANCE	T	P(2 TAIL)
CONSTANT	1.342	0.815	0.000	.	1.648	0.120
LSL	0.596	0.210	0.443	0.677	2.843	0.012
LTONS	1.638	0.477	0.535	0.677	3.434	0.004

ANALYSIS OF VARIANCE

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
REGRESSION	35.115	2	17.557	22.883	0.000
RESIDUAL	11.509	15	0.767		

Figure 4-3. Correlation and regression results for the data set.

The following equation presents the final recommended emission factor models.

$$e = k\ (sL)^{0.65}\ (W)^{1.5}$$

where e is emission factor in g/vehicle-mile traveled (g/VMT), sL is silt loading in g/m^2, W is mean vehicle weight in tons, and k is constant given in Table 4-5.

TABLE 4-5. RECOMMENDED EMISSION FACTOR MODELS

Size range	Sample size	k	Multiple R^2
PM-2.5	52	0.41	NA
PM-10	64	0.90	0.761
PM-15	65	1.1	0.765
PM-30	18	4.7	0.752

All models, except that for PM-2.5, are quality rated "A." The expression for PM-2.5 was based on a mean ratio of PM-2.5 to PM-10 because of slightly different powers on the sL and W terms; the PM-2.5 factor is rated "B." The high R2 values for the other size ranges indicate that approximately 75% of variability in emission factors are "explained" by the predictive equation.

4.2.4 Validation Studies

Two sets of validation studies were undertaken to assess the predictive capability of the revised paved road emission model for PM-10. The first employed a standard cross-validation (CV) technique.[15] Using this technique, each point in the underlying data base is excluded one at a time, and the equation generated from the reduced data base is used to estimate the missing value. The second evaluation applied the new PM-10 expression to the independent data of Test Report I.

By using a CV technique, "n" quasi-independent estimates are obtained from a data base of "n" tests, and the overall validity of using stepwise regression to obtain a model of the form

$$e = k\,(sL)^a\,(W)^b$$

is evaluated. Summary information is shown in Table 4-6.

TABLE 4-6. RESULTS OF CROSS-VALIDATION STUDY

	Variable	Minimum	Maximum	Mean	Std. deviation
a	Exponent of sL	0.63	0.67	0.649	0.009
b	Exponent of W	1.42	1.57	1.49	0.027
k	Leading term	0.79	1.07	0.90[a]	1.058[a]
	Ratio of quasi-independent estimate to measured emission factor	0.050	30	1.004[a]	4.23[a]

[a] Geometric mean/standard deviation.

Figure 4-4 presents the cumulative frequency distribution of the ratio of the quasi-independent estimate to the measured emission factor. A little over half of the estimates are within a factor of 3 and approximately 70% are within a factor of 5. The 90% confidence interval corresponds to a factor of approximately 8.

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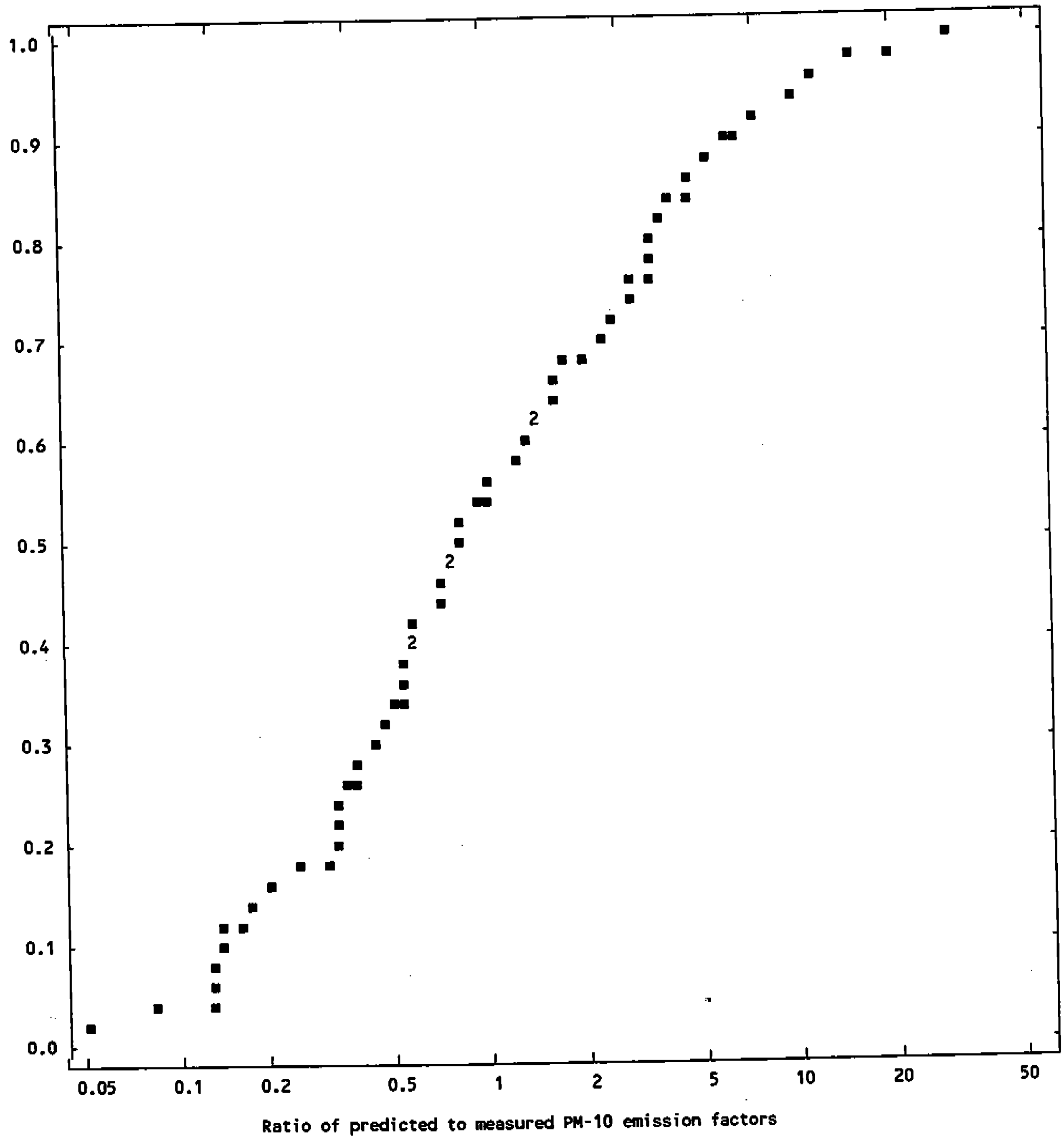

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AP42 Section:	13.2.1 Paved Roads
Title: 11.2.5 and 11.2.6	Addendum to Emission Factor Documentation for AP-42, Sections
	Paved Roads
	EPA Contract 68-D2-0159
	September 1997

Addendum to Emission Factor Documentation for AP-42 Section 11.2.5 and 11.2.6 (Now 13.2.1)

Paved Roads

Final Report

For U. S. Environmental Protection Agency
Office of Air Quality Planning and Standards
Emission Factor and Inventory Group
Research Triangle Park, NC 27711

Attn: Mr. Ron Myers (MD-14)

EPA Contract 68-D2-0159
Work Assignment No. 4-02

MRI Project No. 4604-02

September 1997

NOTICE

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PREFACE

This report was prepared by Midwest Research Institute (MRI) for the Office of Air Quality Planning and Standards (OAQPS), U. S. Environmental Protection Agency (EPA), under Contract No. 68-D2-0159, Work Assignment No. 4-02. Mr. Ron Myers was the requester of the work.

Approved for:

MIDWEST RESEARCH INSTITUTE

Roy Neulicht
Program Manager
Environmental Engineering Department

Jeff Shular
Director, Environmental Engineering
Department

September, 1997

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1.0 BACKGROUND DOCUMENTATION--PAVED ROADS SECTION 13.2.1

This document is an addendum to *Emission Factor Documentation for AP-42, Sections 11.2.5 and 11.2.6, Paved Roads*, EPA Contract No. 68-D0-0123, Assignment 44, dated March 8, 1993 and prepared for the Office of Air Quality Planning and Standards, U. S. Environmental Protection Agency (EPA). Since the preparation of the 1993 document, the Fifth edition of AP-42 incorporated Sections 11.2.5, Paved Urban Roads, and 11.2.6, Industrial Paved Roads, into Section 13.2.1, Paved Roads. An update to AP-42 Section 13.2.1 is warranted to address the U. S. EPA's recent focus on particulate matter (PM) emissions less than 2.5 μm in aerodynamic diameter (PM-2.5) and to permit the reexamination of test information on public road surface silt loadings.

Information in this Addendum includes descriptions of the test reports used to develop the current emission factor equation in AP-42, Section 13.2.1; a narrative of the reexamination of the road surface silt loading data base; and a summary of changes included in the AP-42 Paved Road Section including the new emission factor equation multiplier for PM-2.5. The format for this Addendum is as follows: (a) Section 1.1 - Test Report Descriptions, (b) Section 1.2 - Revision of the Public Paved Road Silt Loading Default Values, (c) Section 1.3 - Summary of Changes to AP-42 Section 13.2.1, (d) Section 2 - a copy of the revised AP-42 Section 13.2.1, (e) Attachment 1 - Comments/Response Logs for external review comments on the March 8, 1993 Paved Road Background Document , (f) Attachment 2 - Public Paved Road Surface Loading AP-42 data base from March 8, 1993, and (g) Attachment 3 - New Silt Loading Data Set..

1.1 Section 1--Test Report Descriptions

Test reports containing data used to develop the paved road emission factor equation in the March 8, 1993, Paved Road Background Document, are discussed in the following subsections. Summary emission data and detailed test data from each of the four test reports are provided along with a brief description of each test site and test methodology.

Profiling methodologies are used for these test reports and include the following test parameters: (a) downwind test equipment should be located approximately 5 meters from the source, (b) background equipment should be located approximately 15 meters upwind of the source, (c) and no disturbances should exist immediately upwind or downwind of the testing location. For wind conditions to remain acceptable during an exposure profiling test, 5- to 10-minute averages of speed and direction are examined. If the mean wind direction moves out of an arc within 45 degrees of the line perpendicular to the road centerline for two consecutive averaging periods, testing is suspended. Similarly, if the mean wind speed falls outside the acceptable range (typically 4 to 20 mph) for two consecutive periods, testing is suspended. While sampling is suspended, mean wind speed and direction are still monitored. To restart a test, analogous criteria are used. That is to say, if the mean wind direction lies within 45 degree of the perpendicular for two consecutive averaging periods, testing can be reinitiated. Likewise, if the average wind speed falls in the acceptable range for two consecutive periods, sampling may resume.

When following standard testing methodologies some vehicle heights may exceed the height of the sampling equipment; however, the fact that the emissions originate at the road curve and the emission plume can be characterized as decreasing with height indicates the total plume can be estimated. Vehicle heights are not generally reported in the source test reports. Analyses for silt content of the road surface follow methodologies described in Appendix C.1 and Appendix C.2 of AP-42. Moisture content was reported for several of these paved road studies. Variations from the generally accepted test methodology stated above or any other nontraditional methodology are discussed within the individual test report reviews. Test reports were not down graded on their qualities ratings due to unreported data if it was not significant to the paved road emission factor equation development.

1.1.1 Reference 1 - Midwest Research Institute, Roadway Emissions Field Tests at US Steel's Fairless Works, for U.S. Steel Corporation, May 1990.

This testing program focused on paved and unpaved road PM emissions at an integrated iron and steel plant near Philadelphia, Pennsylvania, in November 1989. Exposure profiling was used to characterize emissions from two paved roads. Site C-1 was located along the main access route and had a mix of light- and medium-duty vehicles. Site E-2 was located near the southwest corner of the plant and the traffic consisted mostly of plant equipment.

Tests were conducted using a profiling array, with four sampling heights from 1.5 m to 6.0 m, for measuring the downwind mass flux of airborne PM. A high-volume sampler with a parallel-slot cascade impactor and a cyclone preseparator (cutpoint of 15 µmA) was employed to measure the downwind particle size distribution, and a standard high-volume sampler was utilized to determine the downwind mass fraction of total suspended particulate matter (TSP). The upwind (background) particle size distribution was determined with a high-volume cyclone/ impactor combination. Warm wire anemometers at two heights measured wind speed.

Eight tests were conducted at Site C-1 and four tests were conducted at Site E-2. The paved road test sites were considered uncontrolled. The road width, moisture content, and mean number of wheels were not reported. The test data are assigned an A rating. Table A1-1 presents summary information and Table A1-2 presents detailed test information. Warm wire anemometers at two heights measured wind speed.

1.1.2 Reference 2 - Midwest Research Institute, *Paved Road Particulate Emissions - Source Category Report*, for U.S. EPA, July 1984

This document reports the results of testing of paved roads conducted in 1980 at sites in Kansas City, MO, St. Louis, MO, Tonganoxie, KS, and Granite City, IL. Paved road test sites included commercial/industrial roads, commercial/residential roads, expressways, and a street in a rural town. The expanded measurement program reported in this document was used to develop emission factors for paved roads and focused on the following particle sizes: PM-15 (inhalable particulate matter [IP]), PM-10, and PM-2.5.

Total airborne PM emissions were characterized using an exposure profiler containing four sampling heads. High-volume samplers with size selective inlets (SSI) having a cutpoint of 15 µmA were used to characterize upwind and downwind PM-15 concentrations. A high-volume sampler with a SSI and a cascade impactor was also located downwind to characterize particle size distribution within the PM-15 component. Upwind and downwind standard high-volume samplers measured TSP concentrations. Warm wire anemometers at two heights measured wind speed.

A total of 19 paved road emission tests were conducted in four cities. These included four tests of commercial/industrial paved roads, ten tests of commercial/residential paved roads, four expressway tests, and one test of a street in a rural town. Additionally, as part of this study, 81 dust samples were collected in 12 cities. The mean number of vehicle wheels was not reported. The test data are assigned an A rating. Table A1-3 presents summary test data and Table A1-4 presents detailed test information.

TABLE A1-1. SUMMARY INFORMATION FOR REFERENCE 1

Operation	Location	State	Test dates	No. of tests	TSP emission factor, lb/VMT		PM-10 emission factor, lb/VMT	
					Geom. mean	Range	Geom. mean	Range
Vehicle traffic	AU-X (Unpaved road)	PA	11/89	2	0.61	0.39-0.96	0.16	0.14-0.18
Vehicle traffic	Paved road	PA	11/89	6	0.033	0.012-0.12	0.0095	0.0009-0.036
Vehicle traffic	Paved road	PA	11/89	4	0.078	0.033-0.30	0.022	0.0071-0.036

1 lb/VMT = 281.9 g/VKT.

TABLE A1-2. DETAILED INFORMATION FROM PAVED ROAD TESTS FOR REFERENCE 1

Test runs	PM-10 emission factor, lb/VMT	Duration, min	Meterorology		Vehicle characteristics			Silt loading, g/m^2	Silt, %
			Temperature, °F	Mean wind speed, mph	No. of vehicle passes	Mean vehicle weight, ton	Mean vehicle speed[a]		
AU-C-3	0.00497	103	50	12	836	5.5	(27)	0.42	10
AU-C-4	0.0355	147	63	11	1057	6.0	25	0.52	12
AU-C-5	0.0337	120	62	14	963	3.9	29	0.23	9.7
AU-C-6	0.00816[c]	187	39	14	685	6.2	(27)	0.23	8.6
AU-C-7	0.000887	96	42	12	703	3.0	(27)	0.26	7.7
AU-C-8	0.0174	218	40	15	779	2.0	(27)	0.15	9.9
AU-E-1	0.00709	154	43	12	210	12	15	4.0	17
AU-E-2	0.0234	89	44	13	373	5.1	16	4.0	17
AU-E-3	0.0355	118	41	9.3	330	2.6	(15)	2.2	18
AU-E-4	0.0199	130	41	9.3	364	2.6	(15)	1.3	15

[a]Value in parentheses is the average speed measured for test road during the field exercise.
[b]*Test conducted on a paved road surface vacuum-swept five times per week.*
[c]Mean TSP/TP or PM10/TP ratio applied.
1 lb/VMT = 281.9 g/VKT.
1 g/m^2 = 1.434 gr/ft^2

TABLE A1-3. SUMMARY INFORMATION FOR REFERENCE 2

Operation	State	Test dates	No. of tests	PM-15 emission factor, lb/VMT		PM-10 emission factor, lb/VMT		PM-2.5 emission factor, lb/VMT	
				Geom. mean	Range	Geom. mean	Range	Geom. mean	Range
Commercial/ Industrial	MO	2/80	4	0.0078	0.0036 - 0.013	0.0068	0.0034 - 0.011	0.0045	0.0030 - 0.0063
Commercial/ Residential	MO, IL	2/80	10	0.0021	0.0006 - 0.012	0.0017	0.0004 - 0.0093	0.0011	0.0002 - 0.0037
Expressway	MO	5/80	4	0.0004	0.0002 - 0.0008	0.0004	0.0002 - 0.0007	0.0002	0.0001 - 0.0003
Rural Town	KS	3/80	1	0.031	0.031	0.025	0.025	0.005	0.005

1 lb/VMT = 281.9 g/VKT.

TABLE A1-4. DETAILED INFORMATION FOR PAVED ROAD TESTS FOR REFERENCE 2

Category	Run test No.	PM-10 emission factor, lb/VMT	Duration, min.	Temp., °F	Mean wind speed, mph	Road width, ft	No. of vehicle passes	Mean vehicle speed, mph	Mean vehicle weight, tons	Silt loading, g/m^2	Silt (%)
Commercial/Industrial	M-1	0.0110	120	28	7.4	44	2,627	30	5.6	0.46	10.7
Commercial/Industrial	M-2	0.00340	86	27	6.5	44	2,166	30	3.8	0.26	6.2
Commercial/Industrial	M-3	0.00781	120	28	7.8	44	2,144	30	4.5	0.15	3.5
Commercial/Industrial	M-9	0.00712	136	50	7.4	44	3,248	30	4.1	0.29	12.2
Commercial/Residential	M-4	0.000400	240	38	7.8	36	2,763	35	2.1	0.43	18.8
Commercial/Residential	M-5	0.00153	226	53	2.2	36	2,473	35	2.2	1.00	21.4
Commercial/Residential	M-6	0.00304	281	35	5.6	36	3,204	30	2.1	0.68	21.7
Commercial/Residential	M-13	0.00680	194	60	2.7	22	5,190	35	2.7	0.11	13.7
Commercial/Residential	M-14	0.00301	178	55	9.2	22	3,940	35	2.7	0.079	-
Commercial/Residential	M-15	0.00323	135	77	11.4	22	4,040	35	2.7	0.047	8.1
Commercial/Residential	M-17	0.00582	150	75	4.0	40	3,390	30	2.0	0.83	5.7
Commercial/Residential	M-18	0.000800	172	75	5.1	40	3,670	30	2.0	0.73	7.1
Commercial/Residential	M-19	0.000390	488	70	2.7	20	5,800	30	2.4	0.93	8.6
Expressway	M-10	0.000390	182	60	2.9	96	11,148	55	4.5	0.022	-
Expressway	M-11	0.000700	181	56	8.7	96	11,099	55	4.8	0.022	-
Expressway	M-12	0.000190	150	65	4.7	96	9,812	55	3.8	0.022	-
Expressway	M-16	0.000530	254	70	4.0	96	15,430	55	4.3	0.022	-
Rural Town	M-8	0.0247	345	50	4.7	30	1,975	20	2.2	2.50	14.5

1 lb/VMT = 281.9 g/VKT.
1 g/m^2 = 1.434 gr/ft^2

1.1.3 Reference 3 - Midwest Research Institute, *Size Specific Particulate Emission Factors for Uncontrolled Industrial and Rural Roads*, for U. S. EPA, January 1983

This document reports the results of testing conducted in 1981 and 1982 at industrial unpaved and paved roads and at rural unpaved roads. Unpaved industrial roads were tested at a sand and gravel processing facility in Kansas, a copper smelting facility in Arizona, and both a concrete batch and asphalt batch plant in Missouri. The study was conducted to increase the existing data base for size-specific PM emissions. The following particle sizes were of specific interest for the study: PM-15, PM-10, and PM-2.5.

Exposure profiling was utilized to characterize total PM emissions. Five sampling heads, located at heights of up to 5 m, were deployed on the profiler. A standard high-volume sampler and a high-volume sampler with an SSI (cutpoint of 15 µmA) were also deployed downwind. In addition, two high-volume cyclone/impactors were operated to measure particle size distribution. A standard high-volume sampler, a high-volume sampler with an SSI, and a high-volume cyclone/impactor were utilized to characterize the upwind TSP and PM-15 concentrations and the particle size distribution within the PM-15 fraction. Wind speed was monitored with warm wire anemometers.

A total of 18 paved road tests and 21 unpaved road tests are completed. The test data are assigned an A rating. Industrial paved road tests were conducted as follows: three unpaved road tests at the sand and gravel processing plant, three paved road tests at the copper smelting plant, four paved road tests at the asphalt batch facility, and three paved road tests at the concrete batch facility. The industrial road tests were considered uncontrolled and were conducted with heavy duty vehicles at the sand and gravel processing plant and with medium duty vehicles at the asphalt batch, concrete batch, and copper smelting plants. Table A1-5 presents summary test data and Table A1-6 presents detailed test information.

1.1.4 Reference 4 - Midwest Research Institute, *Iron and Steel Plant Open Source Fugitive Emission Control Evaluation*, for U. S. EPA, August 1983

This test report centered on the measurement of the effectiveness of different control techniques for PM emissions from fugitive dust sources in the iron and steel industry. The test program was performed at two integrated iron and steel plants, one located in Houston, Texas, and the other in Middletown, Ohio. Control techniques to reduce emissions from paved roads, unpaved roads, and coal storage piles were evaluated. For paved roads, control techniques included vacuum sweeping, water flushing, and flushing with broom sweeping. Particle emission sizes of interest in this study were total PM, PM-15, and PM-2.5.

The exposure profiling method was used to measure paved road particulate emissions at the Iron and Steel plants. For this study, a profiler with four or five sampling heads located at heights of 1 to 5 m was deployed. Two high-volume cascade impactors with cyclone preseparators (cutpoint of 15 µmA), one at 1 m and the other at 3 m, measured the downwind particle size distribution. A standard high-volume sampler and an additional high-volume sampler fitted with a SSI (cutpoint of 15 µmA) were located downwind at a height 2 m. One standard high-volume sampler and two high-volume samplers with SSIs were located upwind for measurement of background concentrations of TSP and PM-15.

Twenty-three paved road tests of controlled and uncontrolled emissions were performed. These included 11 uncontrolled tests, 4 vacuum sweeping tests, 4 water flushing tests, and 4 flushing and broom sweeping tests. For paved roads, this test report does not present vehicle speeds, mean number of wheels, or moisture contents. Because vehicle speeds and moisture content do not figure into the emission

TABLE A1-5. SUMMARY OF PAVED ROAD EMISSION FACTORS FOR REFERENCE 3

Industrial category	Type	TP, lb/VMT		PM-15, lb/VMT		PM-10, lb/VMT		PM-2.5, lb/VMT	
		Geo. mean	Range	Geo. mean	Range	Geo. mean	Range	Geo. mean	Range
Asphalt Batching	Medium duty	1.83	0.750-3.65	0.437	0.124-0.741	0.295	0.0801-0.441	0.130	0.0427-0.214
Concrete Batching	Medium duty	4.74	2.25-7.23	1.66	0.976-2.34	1.17	0.699-1.63	0.381	0.200-0.562
Copper Smelting	Medium duty	11.2	7.07-15.7	4.01	2.02-5.56	2.78	1.35-3.86	0.607	0.260-0.846
Sand and Gravel Processing	Medium Duty	5.50	4.35-6.64	1.02	0.783-1.26	0.633	0.513-0.753	0.203	0.194-0.211

1 lb/VMT = 281.9 g/VKT.

TABLE A1-6. DETAILED INFORMATION FOR PAVED ROAD TESTS FOR REFERENCE 3

Run No.	Industrial category	Traffic	PM-10 emission factor, lb/VMT	Duration, min.	Mean wind speed, mph	Road width, ft	No. of vehicle passes	Vehicle characteristics: Mean vehicle weight, tons	Vehicle characteristics: No. of wheels	Vehicle characteristics: Mean vehicle speed, mph	Moisture content, %	Silt loading, g/m²	Silt, %
Y-1	Asphalt Batching	Medium Duty	0.257	274	5.37	13.8	47	3.6	6	10	0.22	91	2.6
Y-2	Asphalt Batching	Medium Duty	0.401	344	4.70	14.1	76	3.7	7	10	0.51	76	2.7
Y-3	Asphalt Batching	Medium Duty	0.0801	95	6.04	14.1	100	3.8	6.5	10	0.32	193	4.6
Y-4	Asphalt Batching	Medium Duty	0.441	102	5.59	14.1	150	3.7	6	10	0.32	193	4.6
Z-1	Concrete Batching	Medium Duty	0.699	170	6.71	24.3	149	8.0	10	10	a	11.3	6.0
Z-2	Concrete Batching	Medium Duty	1.63	143	9.84	24.9	161	8.0	10	15	a	12.4	5.2
Z-3	Concrete Batching	Medium Duty	4.01	109	9.62	24.9	62	8.0	10	15	a	12.4	5.2
AC-4	Copper Smelting	Medium Duty	3.86	38	8.72	34.8	45	5.7	7.4	10	0.43	287	19.8
AC-5	Copper Smelting	Medium Duty	3.13	36	9.62	34.8	36	7.0	6.2	15	0.43	188	15.4
AC-6	Copper Smelting	Medium Duty	1.35	33	4.92	34.8	42	3.1	4.2	20	0.53	400	21.7
AD-1	Sand and Gravel	Heavy Duty	3.27	110	7.61	12.1	11	42	11	23	a	94.8	6.4
AD-2	Sand and Gravel	Heavy Duty	0.753	69	5.15	12.1	16	39	17	23	a	63.6	7.9
AD-3	Sand and Gravel	Heavy Duty	0.513	76	3.13	12.1	20	40	15	23	a	52.6	7.0

1 lb/VMT = 281.9 g/VKT.
1 $g/m^2 = 1.434\ gr/ft^2$
a Not measured.

equation, the test data are assigned an A rating. Table A1-7 presents summary test data and Table A1-8 presents detailed test information. The PM-10 emission factors presented in Table A1-8 were calculated from the PM-15 and PM-2.5 data using logarithmic interpolation.

After vacuum sweeping, emissions were reduced slightly more than 50 percent for two test runs and less than 16 percent for two test runs. Water flushing applied at 0.48 gal/yd^2 achieved emission reductions ranging from 30 percent to 70 percent. Flushing at 0.48 gal/yd^2 combined with broom sweeping resulted in emission reductions ranging from 35 percent to 90 percent.

TABLE A1-7. SUMMARY OF PAVED ROAD EMISSION FACTORS FROM REFERENCE 4

Control method	Location	State	Test date	No. of tests	TP, lb/VMT		PM-15, lb/VMT		PM-2.5, lb/VMT	
					Geo mean	Range	Geo mean	Range	Geo mean	Range
None	A,D,F,J	OH	7/80, 10/80, & 11/80	7	1.22	0.29-5.50	0.38	0.13-2.14	0.10	0.04-0.52
Vacuum Sweeping	A	OH	10/80 & 11/80	4	0.87	0.53-1.46	0.45	0.27-0.87	0.14	0.08-0.26
Water Flushing	D,L	TX	6/81	4	1.43	1.30-1.74	0.47	0.32-0.65	0.08	0.08-0.09
Flushing & Broom Sweep	K,L,M	TX	6/81	4	0.96	0.54-2.03	0.20	0.10-0.49	0.07	0.04-0.13
None	L,M	TX	6/81	4	3.12	0.83-5.46	0.92	0.31-1.83	0.26	0.06-0.62

1 lb/VMT = 281.9 g/VKT.

TABLE A1-8. DETAILED INFORMATION FOR PAVED ROAD TESTS FROM REFERENCE 4

Site	Test Run No.	Control method	PM-10 emission factor, lb/VMT	Duration, min.	Temp., °F	Mean wind speed, mph	No. of vehicle passes	Mean vehicle weight, tons	Silt loading, g/m^2	Silt, %
A	F-34	None	0.536	62	90	4.2	79	28	2.79	16
A	F-35	None	0.849	127	90	7.5	130	25	2.03	10.4
A	F-36	VS	0.147	335	50	5.9	263	8.3	0.202	18.3
A	F-37	VS	0.209	241	50	4.8	199	17	0.043	26.4
A	F-38	VS	0.430	127	50	4.5	141	18	0.217	27.9
A	F-39	VS	0.686	215	50	6.4	190	18	0.441	19.6
D	F-61	None	1.35	108	40	11.0	93	40	17.9	21.0
D	F-62	None	0.929	77	45	12.1	94	36	14.4	20.3
D	F-74	WF	1.32	205	50	9.0	67	29	5.59	9.45
F	F-27	None	0.357	91	100	9.5	158	14	17.7	35.7
F	F-45	None	0.608	135	50	4.0	172	16	5.11	28.4
J	F-32	none	0.144	259	90	5.8	301	14	0.117	13.4
K	B-52	FBS	0.0946	60	90	2.9	119	12	7.19	34.3
L	B-50	FBS	0.230	104	90	5.6	123	9.4	13.6	28.2
L	B-51	FBS	0.435	93	90	4.2	127	11	13.6	28.2
L	B-54	WF	0.268	101	90	5.4	118	10	3.77	22.6
L	B-55	WF	0.575	82	90	8.5	98	11	6.29	19.6
L	B-56	WF	0.398	61	90	6.3	118	9.2	2.40	11.2
L	B-58	None	1.08	96	90	6.7	67	18	10.4	17.9
M	B-53	FBS	0.161	81	90	5.3	72	20	--	9.94
M	B-57	0.554	None	101	90	3.6	68	12	2.32	6.45
M	B-59	0.993	None	114	90	6.1	67	11	2.06	14.0
M	B-60	1.18	None	112	90	5.0	50	12	3.19	13.5

[a]Average of 2+ values
[b]Sample used for more than 1 run.
[c]PM-10 emission factors were calculated from the PM-15 and PM-2.5 data using logarithmic interpolation.
VS = Vacuum sweeping; WF = Water flushing; FBS = Water flushing and broom sweeping; 1 lb/VMT = 281.9 g/VKT; 1 g/m^2 = 1.434 gr/ft^2

References for Section 1

1. *Roadway Emissions Field Tests at U.S. Steel's Fairless Works*, U.S. Steel Corporation, Fairless Hills, PA, USX Purchase Order No. 146-0001191-0068, May 1990.

2. *Paved Road Particulate Emissions—Source Category Report*, U. S. Environmental Protection Agency, Research Triangle Park, NC, EPA Contract No. 68-02-3158, Assignment 19, July 1984.

3. *Size Specific Particulate Emission Factors for Uncontrolled Industrial and Rural Roads*, U.S. Environmental Protection Agency, Research Triangle Park, NC, EPA Contract No. 68-02-3158, Assignment 12, January 1983.

4. *Iron and Steel Plant Open Source Fugitive Emission Control Evaluation*, U.S. Environmental Protection Agency, Research Triangle Park, NC, EPA Contract No. 68-02-3177, Assignment 4, August 1983.

5. *Emission Factor Documentation for AP-42, Sections 11.2.5 and 11.2.6—Paved Roads*, EPA Contract No. 68-D0-0123, Midwest Research Institute, Kansas City, MO, March 1993.

1.2 Revision of the Public Paved Road Silt Loading Default Values

During the preparation of the March 8, 1993 Paved Road Background Document[1], the available public road silt loading ("sL") values from test reports dated 1992 and earlier were assembled into a data base. Appendices C.1 and C.2 to AP-42 describe the sampling and analysis procedures, respectively, used to determine sL values. This "old" data set was originally presented as Appendix X in the March 8, 1993 background report. Subsequently, EPA requested that the sL data set be moved into the AP-42 Section. In response, MRI prepared the current Table 13.2.1-2. (An electronic version of the old sL data set has been supplied with this addendum.)

Although hundreds of public paved road sL measurements had been collected from 1980 until 1992 [2-10], the paved road sL data base was limited in its usefulness for various reasons:

1. Almost two-thirds of the available data had been collected in one state (Montana).

2. Only Montana had collected extensive data that addressed temporal variation of sL. While this provided very useful information on the annual cycle of silt loadings, the data were not generally transferable to most regions in the United States.

3. There had been no uniformity in either the sampling/analysis methods used to generate sL values or in schemes used to report roadway classifications. Similarly, the different sampling programs do not all report the necessary information to develop a coherent data set. For example, the following items are not always reported: whether the road is curbed; the posted speed limit; if surrounding land use would lead to trackout from unpaved shoulders or parking lots; or, if anti-skid materials were recently applied. These unknowns result from the lack of uniform reporting.

4. Examination of the data base did not reveal any meaningful relationship between silt loading and other variables (such as average daily traffic [ADT], road class, etc.). For example, a significant negative correlation was found between sL and ADT for roads with ADTs of 5,000 or more. However, on further investigation of that road class, it was found that there was a significant positive and a significant negative correlation over the first and second halves, respectively, of the calendar year.

5. There were strong reasons to suspect that the assembled data base was skewed towards high values:

- -- The majority of measurements were collected during the first calendar half (which was found to have substantially higher values than the second half).
- -- There was anecdotal information that at least some of the sampling programs focused on suspected trouble spots that were heavily loaded (such as after snow/ice storms, near construction sites, etc.).

Note that the assembled data base was composed of "point values" of silt loading. Here the term "point value" is used to denote samples collected at a specific point along a roadway and at a single point in time. In this sense, the term is contrasted with "composite" samples, for which increments from different roadways and/or from different times are aggregated in a single vacuum bag. The resulting composite sample thus represents a spatially or temporally averaged value of silt loading. At the time the data base was assembled, two sets of spatial averages were available –one set covering the South Coast Air Quality Management District (REF 11) and another from three study areas in Oregon (REF 12). Because of their composite nature, these measurements were not included in the data base assembled for the 1993 background document.

Although there were strong reasons to suspect that the assembled data base was biased towards high values, independent data were not available to confirm the suspicions. Since the time that the background document was prepared, a number of field sampling programs have been undertaken; the references that document these programs are shown in Table A1-9.

TABLE A1-9. PAVED ROAD SILT LOADING STUDIES SINCE THE 1993 BACKGROUND REPORT

Reference	Study description
13	A characterization of control measures to reduce mud/dirt carryout onto paved roads from a construction site in Kansas City
14	Collection of late winter/early spring silt loadings in the Pocatello, Idaho area, emphasizing post-storm conditions
15	A yearlong study to define temporal variations of silt loading on roads in the Reno, Nevada area.
16	Collection of sets of spatially averaged silt loadings in four study areas of the desert southwest: South Coast, Coachella Valley, Las Vegas, Bakersfield
17	An ongoing study to track silt loading trends over a yearlong period in the Pocatello, Idaho area

Note that the first two studies in Table A1-9 were directed to higher values of sL due to their focus on mud/dirt carryout and post-winter storm conditions. As such, results from these two studies were excluded from further consideration in revising the public road silt loading values. Data from the second Pocatello study (Reference 17) were not available at the time of this addendum.

Results from References 15 and 16, together with results from the composite samples in References 11 and 12 and the silt loading values from the recent PM-2.5/PM-10 study[18] for baseline road surface conditions (i.e., not immediately after road sanding), formed the basis for revising the default values for public paved road silt loading. An electronic version of the new sL data set has been supplied with this addendum. Table A1-10 presents summary statistics for the new data set.

TABLE A1-10. SUMMARY STATISTICS FOR RECENT PAVED ROAD SILT LOADING STUDIES

		Silt loading, g/m^2				
Data set	Sample size	Range	Geo. mean	Geo. std. dev.	Median	90th percentile
High ADT[a]	50	0.01 - 1.02	0.093	3.13	0.086	0.38
Low ADT	103	0.054 - 6.82	0.41	2.64	0.39	1.52
Overall	169[b]	0.01 - 6.82	0.26	3.34	0.27	1.05

[a]In this context, high ADT refers to roadways with at least 5,000 vehicles per day.
[b]The overall data set includes 16 spatially average samples that included increments from both high and low ADT roads.

When the results in Table A1-10 are compared to those presented in Table 13.2.1-2 of AP-42, it becomes immediately apparent that the current default guidance in Section 13.2 leads to overly conservative values for silt loading. Values in the newer data set are roughly 5 times lower than those in the data set compiled for the 1993 background document. Consequently, it is recommended that AP-42 Table 13.2.1-2 be modified to include the (rounded) median values from Table A2-2 for "normal" conditions. However, the newer data set also indicates that substantially higher or lower than "normal" silt loadings may occur on public paved roads. As a result, it is further recommended that the modified AP-42 table present the former median values for the January-to-June period as suitable for use when estimates of elevated silt loading (e.g., after snow/ice controls or near trackout areas) are desired.

Additional revisions are recommended for default values for limited access roads. Reference 18 presents the results from not only baseline sampling, but also samples collected immediately after sanding an interstate highway in Denver:

Baseline: 0.0127 g/m^2
After sanding: 0.184 g/m^2

After averaging the baseline with the older data for limited access roads, the recommended default for limited access roads under "normal" conditions is 0.015 g/m^2. Furthermore, the section text has been revised to suggest a default value of 0.2 g/m^2 for short periods of time following the application of snow/ice controls (antiskid abrasives) to limited access roads.

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17. Personal communication with J. Light, c/o Bannock Planning Organization, Pocatello, ID.

18. *Fugitive Particulate Matter Emissions*, EPA Contract No. 68-D2-0159, Work Assignment No. 4-06, Midwest Research Institute, Kansas City, MO, April 1997.

1.3 Summary of Changes to AP-42 Section 13.2.1

Although the equation for particulate emissions from paved roads remains unchanged, the PM-2.5 multiplier has been updated based on findings in Reference 22. The PM-2.5 multiplier update is reflected in the list of particle size multipliers for the paved road equation. Also, the default silt loading (sL) values for public paved roads have been updated. Table 13.2.1-2 has been revised along with associated text to reflect this new analysis. The silt loading data base, formerly presented as Table 13.2.1-3, will only be available as an electronic file. (The new sL data set is also available as an electronic file.)

Section 13.2.1 follows with text removed from the old AP-42 version striked out and new text in bold. Although not shown here, no changes were made to Figure 13.2.1-1, and Figures 13.2.1-2 through 13.2.1-7 (showing the silt loading frequency distribution) have been removed from the AP-42 section.

13.2.1 Paved Roads

13.2.1.1 General

Particulate emissions occur whenever vehicles travel over a paved surface, such as a road or parking lot. **Particulate emissions from paved roads are due to direct exhaust from vehicles and resuspension of loose material on the road surface.** In general terms, **the resuspended** particulate emissions from paved roads originate from the loose material present on the surface. In turn, that surface loading, as it is moved or removed, is continuously replenished by other sources. At industrial sites, surface loading is replenished by spillage of material and trackout from unpaved roads and staging areas. Figure 13.2.1-1 illustrates several transfer processes occurring on public streets.

Various field studies have found that public streets and highways, as well as roadways at industrial facilities, can be major sources of the atmospheric particulate matter within an area.[1-9] Of particular interest in many parts of the United States are the increased levels of emissions from public paved roads when the equilibrium between deposition and removal processes is upset. This situation can occur for various reasons, including application of snow and ice controls, carryout from construction activities in the area, and wind and/or water erosion from surrounding unstabilized areas. **In the absence of continuous addition of fresh material (through localized trackout or application of antiskid material), paved road surface loading should reach equilibrium values in which the amount of material resuspended matches the amount replenished. The equilibrium sL value depends upon numerous factors. It is believed that the most important factors are: mean speed of vehicles traveling the road; the average daily traffic (ADT); the number of lanes and ADT per lane; the fraction of heavy vehicles (buses and trucks); and the presence/absence of curbs, storm sewers and parking lanes.**

13.2.1.2 Emissions And Correction Parameters

Dust emissions from paved roads have been found to vary with what is termed the "silt loading" present on the road surface as well as the average weight of vehicles traveling the road. The term silt loading (sL) refers to the mass of silt-size material (equal to or less than 75 micrometers [μm] in physical diameter) per unit area of the travel surface.[4-5] The total road surface dust loading is that of loose material that can be collected by broom sweeping and vacuuming of the traveled portion of the paved road. The silt fraction is determined by measuring the proportion of the loose dry surface dust that passes through a 200-mesh screen, using the ASTM-C-136 method. Silt loading is the product of the silt fraction and the total loading, and is abbreviated "sL". Additional details on the sampling and analysis of such material are provided in AP-42 Appendices C.1 and C.2.

The surface sL provides a reasonable means of characterizing seasonal variability in a paved road emission inventory.[9] In many areas of the country, road surface loadings are heaviest during the late winter and early spring months when the residual loading from snow/ice controls is greatest. **As noted earlier, once replenishment of fresh material is eliminated, the road surface loading can be expected to reach an equilibrium value, which is substantially lower than the late winter/early spring value.**

13.2.1.3 Predictive Emission Factor Equations[10]

The quantity of dust emissions from vehicle traffic on a paved road may be estimated using the following empirical expression:

$$E=k\,(sL/2)^{0.65}\,(W/3)^{1.5} \tag{1}$$

where:

E = particulate emission factor (having units matching the units of k)
k = base emission factor for particle size range and units of interest (see below)
sL = road surface silt loading (grams per square meter) (g/m^2)
W = average weight (tons) of the vehicles traveling the road

It is important to note that Equation 1 calls for the average weight of all vehicles traveling the road. For example, if 99 percent of traffic on the road are 2 Mg cars/trucks while the remaining 1 percent consists of 20 Mg trucks, then the mean weight "W" is 2.2 Mg. More specifically, Equation 1 is *not* intended to be used to calculate a separate emission factor for each vehicle weight class. Instead, only one emission factor should be calculated to represent the "fleet" average weight of all vehicles traveling the road.

The particle size multiplier (k) above varies with aerodynamic size range as ~~follows:~~ **shown in Table 13.2.1-1.** To determine particulate emissions for a specific particle size range, use the appropriate value of k **shown in Table 13.2.1-1.**.

The above equation is based on a regression analysis of numerous emission tests, including 65 tests for PM-10.[10] Sources tested include public paved roads, as well as controlled and uncontrolled industrial paved roads. No tests of "stop-and-go" traffic were available for inclusion in the data base. The equations retain the quality rating of A (B for PM-2.5), if applied within the range of source conditions that were tested in developing the equation as follows:

Silt loading:	0.02 - 400 g/m^2
	0.03 - 570 grains/square foot (ft^2)
Mean vehicle weight:	1.8 - 38 megagrams (Mg)
	2.0 - 42 tons
Mean vehicle speed:	16 - 88 kilometers per hour (kph)
	10 - 55 miles per hour (mph)

To retain the quality rating for the emission factor equation when it is applied to a specific paved road, it is necessary that reliable correction parameter values for the specific road in question be determined. **With the exception of limited access roadways, which are difficult to sample, the collection and use of site-specific sL data for public paved road emission inventories are strongly recommended**. The field and laboratory procedures for determining surface material silt content and surface dust loading are summarized in Appendices C.1 and C.2. In the event that site-specific values

Table 13.2.1-1. PARTICLE SIZE MULTIPLIERS FOR PAVED ROAD EQUATION

Size range[a]	Multiplier k[b]		
	g/VKT	g/VMT	lb/VMT
PM-2.5[c]	~~2.1~~	~~3.3~~	~~0.0073~~
	1.1	**1.8**	**0.0040**
PM-10	4.6	7.3	0.016
PM-15	5.5	9.0	0.020
PM-30[cd]	24	38	0.082

[a] Refers to airborne particulate matter (PM-x) with an aerodynamic diameter equal to or less than x micrometers.

[b] Units shown are grams per vehicle kilometer traveled (g/VKT), grams per vehicle mile traveled (g/VMT), and pounds per vehicle mile traveled (lb/VMT). **The muliplier k includes unit conversions to produce emission factors in the units shown for the indicated size range from the mixed units required in Equation 1.**

[c] **Ratio of PM-2.5 to PM-10 taken from Reference 22.**

[c d] PM-30 is sometimes termed "suspendable particulate" (SP) and is often used as a surrogate for TSP.

cannot be obtained, an appropriate value for an industrial road may be selected from the mean values given in Table 13.2.1-2, but the quality rating of the equation should be reduced by 1 level.

~~With the exception of limited access roadways, which are difficult to sample, the collection and use of site-specific sL data fr public paved road emission inventories are strongly recommended. Although hundreds of public paved road sL measurements have been made since 1980,[8, 14-21] uniformity has been lacking in sampling equipment and analysis techniques, in roadway classification schemes, and in the types of data reported.[10] The assembled data set (described below) does not yield any readily identifiable, coherent relationship between sL and road class, average daily traffic (ADT), etc., even though an inverse relationship between sL and ADT had been found for a subclass of curbed paved roads in urban areas.[8] The absence of such a relationship in the composite data set is believed to be due to the blending of data (industrial and nonindustrial, uncontrolled, and controlled, and so on). Further complicating any analysis is the fact that, in many parts of the country, paved road sL varies greatly over the course of the year, probably because of cyclic variations in mud/dirt carryout and in use of anti-skid materials. For example, repeated sampling of the same roads over a period of 3 calendar years at 4 Montana municipalities indicated a noticeable annual cycle. In those areas, silt loading declines during the first 2 calendar quarters and increases during the fourth quarter.~~

~~Figure 13.2.1-2 and Figure 13.2.1-3 present the cumulative frequency distribution for the public paved road sL data base assembled during the preparation of this AP-42 section.[10] The data base includes samples taken from roads that were treated with sand and other snow/ice controls. Roadways are grouped into high- and low-ADT sets, with 5000 vehicles per day being the approximate cutpoint. Figure 13.2.1-2 and Figure 13.2.1-3, respectively, present the cumulative frequency distributions for high- and low-ADT roads.~~

~~In the absence of site-specific sL data to serve as input to a public paved road inventory, conservatively high emission estimates can be obtained by using the following values taken from the~~

~~figures. For annual conditions, the median sL values of 0.4 g/m² can be used for high-ADT roads (excluding limited access roads that are discussed below) and 2.5 g/m² for low-ADT roads. Worst-case loadings can be estimated for high-ADT (excluding limited access roads) and low-ADT roads, respectively, with the 90th percentile values of 7 and 25 g/m². Figure 13.2.1-4, Figure 13.2.1-5, Figure 13.2.1-6, and Figure 13.2.1-7 present similar cumulative frequency distribution information for high- and low-ADT roads, except that the sets were divided based on whether the sample was collected during the first or second half of the year. Information on the 50th and 90th percentile values is summarized in Table 13.2.1-2.~~

~~Table 13.2.1-2 (Metric Units). PERCENTILES FOR NONINDUSTRIAL SILT LOADING (g/m²) DATA BASE~~

~~Averaging Period~~	~~High-ADT Roads~~		~~Low-ADT Roads~~	
	~~50th~~	~~90th~~	~~50th~~	~~90th~~
~~Annual~~	~~0.4~~	~~7~~	~~2.5~~	~~25~~
~~January-June~~	~~0.5~~	~~14~~	~~3~~	~~30~~
~~July-December~~	~~0.3~~	~~3~~	~~1.5~~	~~5~~

During the preparation of the background document (Reference 10), public road silt loading values from 1992 and earlier were assembled into a data base. This data base is available as __________. Although hundreds of public paved road sL measurements had been collected, there was no uniformity in sampling equipment and analysis techniques, in roadway classification schemes, and in the types of data reported. Not surprisingly, the data set did not yield a coherent relationship between sL and road class, average daily traffic (ADT), etc., even though an inverse relationship between sL and ADT has been found for a subclass of curbed paved roads in urban areas. Further complicating the analysis is the fact that, in many parts of the country, paved road sL varies greatly over the course of the year, probably because of cyclic variations in mud/dirt carryout and in use of anti-skid materials. Although there were strong reasons to suspect that the assembled data base was skewed towards high values, independent data were not available to confirm the suspicions.

Since the time that the background document was prepared, new field sampling programs have shown that the assembled sL data set is biased high for "normal" situations. Just as importantly, however, the newer programs confirm that substantially higher than "normal" silt loadings can occur on public paved roads. As a result, two sets of default values are provided in Table 13.2.1-2, one for "normal" conditions and another for worst-case conditions (such as after winter storm seasons or in areas with substantial mud/dirt trackout). The newer sL data base is available as ____________.

The range of sL values in the data base for normal conditions is 0.01 to 1.0 for high-ADT roads and 0.054 to 6.8 for low-ADT roads. Consequently the use of a default value from Table 13.2.1-2 should be expected to yield only an order-of-magnitude estimate of the emission factor. Public paved road silt loadings are dependent upon: traffic characteristics (speed, ADT, and fraction of heavy vehicles); road characteristics (curbs, number of lanes, parking lanes); local land use (agriculture, new residential construction) and regional/seasonal factors (snow/ice controls, wind blown dust). As a result, the collection and use of site-specific silt loading data is highly recommended.

Table 13.2.1-2 (Metric Units). RECOMMENDED DEFAULT SILT LOADING (g/m^2) VALUES FOR PUBLIC PAVED ROADS[a]

	High ADT roads[b]	Low ADT roads
Normal conditions	0.1	0.4
Worst-case conditions[c]	0.5	3

[a] Excluding limited access roads. See discussion in text. 1 g/m^2 is equal to 1.43 $grains/ft^2$
[b] High ADT refers to roads with at least 5,000 vehicles per day.
[c] For conditions such as post-winter-storm or areas with substantial mud/dirt carryout.

~~In the event that sL values are taken from any of the cumulative frequency distribution figures, the quality ratings for the emission estimates should be downgraded 2 levels.~~

In the event that default sL values are used the quality ratings for the equation should be downgraded 2 levels.

~~As an alternative method of selecting sL values in the absence of site-specific data, users can review the public (I. e., nonindustrial) paved road sL data base presented in Table 13.2.1-3 and can select values that are appropriate for the roads and seasons of interest. Table 13.2.1-3 presents paved road surface loading values together with the city, state, road name, collection date (samples collected from the same road during the same month are averaged), road ADT if reported, classification of the roadway, etc. Recommendation of this approach recognizes that end users of AP-42 are capable of identifying roads in the data base that are similar to roads in the area being inventoried. In the event that sL values are developed in this way, and that the selection process is fully described, then the quality ratings for the emission estimates should be downgraded only 1 level~~.

Limited access roadways pose severe logistical difficulties in terms of surface sampling, and few sL data are available for such roads. Nevertheless, the available data do not suggest great variation in sL for limited access roadways from 1 part of the country to another. For annual conditions, a default value of ~~0.02~~ **0.015** g/m^2 is recommended for limited access roadways.[9,22] Even fewer of the available data correspond to worst-case situations, and elevated loadings are observed to be quickly depleted because of high ADT rates. A default value of ~~0.1~~ **0.2** g/m^2 is recommended for short periods of time following application of snow/ice controls to limited access roads.[22]

13.2.1.4 Controls[6,~~22~~ 23]

Because of the importance of the surface loading, control techniques for paved roads attempt either to prevent material from being deposited onto the surface (preventive controls) or to remove from the travel lanes any material that has been deposited (mitigative controls). Regulations requiring the covering of loads in trucks, or the paving of access areas to unpaved lots or construction sites, are preventive measures. Examples of mitigative controls include vacuum sweeping, water flushing, and broom sweeping and flushing. It is particularly important to note that street sweeping of gutters and curb areas may actually increase the silt loading on the traveled portion of the road. Redistribution of loose material onto the travel lanes will actually produce a short-term increase in the emissions.

In general, preventive controls are usually more cost effective than mitigative controls. The cost-effectiveness of mitigative controls falls off dramatically as the size of an area to be treated increases. The cost-effectiveness of mitigative measures is also unfavorable if only a short period of time is required for the road to return to equilibrium silt loading condition. That is to say, the number and length of public roads within most areas of interest preclude any widespread and routine use of mitigative controls. On the other hand, because of the more limited scope of roads at an industrial site, mitigative measures may be used quite successfully (especially in situations where truck spillage occurs). Note, however, that public agencies could make effective use of mitigative controls to remove sand/salt from roads after the winter ends.

Because available controls will affect the sL, controlled emission factors may be obtained by substituting controlled silt loading values into the equation. (Emission factors from controlled industrial roads were used in the development of the equation.) The collection of surface loading samples from treated, as well as baseline (untreated), roads provides a means to track effectiveness of the controls over time.

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2.0 PROPOSED AP-42 SECTION 13.2.1

The proposed AP-42 Section for paved roads is presented on the following pages as it would appear in the document.

13.2.1 Paved Roads

13.2.1.1 General

Particulate emissions occur whenever vehicles travel over a paved surface, such as a road or parking lot. Particulate emissions from paved roads are due to direct exhaust from vehicles and resuspension of loose material on the road surface. In general terms, particulate emissions from paved roads originate from the loose material present on the surface. In turn, that surface loading, as it is moved or removed, is continuously replenished by other sources. At industrial sites, surface loading is replenished by spillage of material and trackout from unpaved roads and staging areas. Figure 13.2.1-1 illustrates several transfer processes occurring on public streets.

Various field studies have found that public streets and highways, as well as roadways at industrial facilities, can be major sources of the atmospheric particulate matter within an area.[1-9] Of particular interest in many parts of the United States are the increased levels of emissions from public paved roads when the equilibrium between deposition and removal processes is upset. This situation can occur for various reasons, including application of snow and ice controls, carryout from construction activities in the area, and wind and/or water erosion from surrounding unstabilized areas. In the absence of continuous addition of fresh material (through localized trackout or application of antiskid material), paved road surface loading should reach equilibrium values in which the amount of material resuspended matches the amount replenished. The equilibrium sL value depends upon numerous factors. It is believed that the most important factors are: mean speed of vehicles traveling the road; the average daily traffic (ADT); the number of lanes and ADT per lane; the fraction of heavy vehicles (buses and trucks); and the presence/absence of curbs, storm sewers and parking lanes.

13.2.1.2 Emissions And Correction Parameters

Dust emissions from paved roads have been found to vary with what is termed the "silt loading" present on the road surface as well as the average weight of vehicles traveling the road. The term silt loading (sL) refers to the mass of silt-size material (equal to or less than 75 micrometers [μm] in physical diameter) per unit area of the travel surface.[4-5] The total road surface dust loading is that of loose material that can be collected by broom sweeping and vacuuming of the traveled portion of the paved road. The silt fraction is determined by measuring the proportion of the loose dry surface dust that passes through a 200-mesh screen, using the ASTM-C-136 method. Silt loading is the product of the silt fraction and the total loading, and is abbreviated "sL". Additional details on the sampling and analysis of such material are provided in AP-42 Appendices C.1 and C.2.

The surface sL provides a reasonable means of characterizing seasonal variability in a paved road emission inventory.[9] In many areas of the country, road surface loadings are heaviest during the late winter and early spring months when the residual loading from snow/ice controls is greatest. As noted earlier, once replenishment of fresh material is eliminated, the road surface loading can be expected to reach an equilibrium value, which is substantially lower than the late winter/early spring value.

13.2.1.3 Predictive Emission Factor Equations[10]

The quantity of dust emissions from vehicle traffic on a paved road may be estimated using the following empirical expression:

$$E = k\,(sL/2)^{0.65}\,(W/3)^{1.5} \qquad (1)$$

where:

E = particulate emission factor (having units matching the units of k)
k = base emission factor for particle size range and units of interest (see below)
sL = road surface silt loading (grams per square meter) (g/m^2)
W = average weight (tons) of the vehicles traveling the road

It is important to note that Equation 1 calls for the average weight of all vehicles traveling the road. For example, if 99 percent of traffic on the road are 2 Mg cars/trucks while the remaining 1 percent consists of 20 Mg trucks, then the mean weight "W" is 2.2 Mg. More specifically, Equation 1 is *not* intended to be used to calculate a separate emission factor for each vehicle weight class. Instead, only one emission factor should be calculated to represent the "fleet" average weight of all vehicles traveling the road.

The particle size multiplier (k) above varies with aerodynamic size range as shown in Table 13.2.1-1. To determine particulate emissions for a specific particle size range, use the appropriate value of k shown in Table 13.2.1-1.

Table 13.2-1.1. PARTICLE SIZE MULTIPLIERS FOR PAVED ROAD EQUATION

Size range[a]	Multiplier k[b]		
	g/VKT	g/VMT	lb/VMT
PM-2.5[c]	1.1	1.8	0.0040
PM-10	4.6	7.3	0.016
PM-15	5.5	9.0	0.020
PM-30[d]	24	38	0.082

[a] Refers to airborne particulate matter (PM-x) with an aerodynamic diameter equal to or less than x micrometers.

[b] Units shown are grams per vehicle kilometer traveled (g/VKT), grams per vehicle mile traveled (g/VMT), and pounds per vehicle mile traveled (lb/VMT). The muliplier k includes unit conversions to produce emission factors in the units shown for the indicated size range from the mixed units required in Equation 1.

[c] Ratio of PM-2.5 to PM-10 taken from Reference 22.

[d] PM-30 is sometimes termed "suspendable particulate" (SP) and is often used as a surrogate for TSP.

The above equation is based on a regression analysis of numerous emission tests, including 65 tests for PM-10.[10] Sources tested include public paved roads, as well as controlled and uncontrolled industrial paved roads. No tests of "stop-and-go" traffic were available for inclusion in the data base. The equations retain the quality rating of A (B for PM-2.5), if applied within the range of source conditions that were tested in developing the equation as follows:

Silt loading:	0.02 - 400 g/m^2
	0.03 - 570 grains/square foot (ft^2)
Mean vehicle weight:	1.8 - 38 megagrams (Mg)
	2.0 - 42 tons
Mean vehicle speed:	16 - 88 kilometers per hour (kph)
	10 - 55 miles per hour (mph)

To retain the quality rating for the emission factor equation when it is applied to a specific paved road, it is necessary that reliable correction parameter values for the specific road in question be determined. With the exception of limited access roadways, which are difficult to sample, the collection and use of site-specific sL data for public paved road emission inventories are strongly recommended. The field and laboratory procedures for determining surface material silt content and surface dust loading are summarized in Appendices C.1 and C.2. In the event that site-specific values cannot be obtained, an appropriate value for an industrial road may be selected from the mean values given in Table 13.2.1-2, but the quality rating of the equation should be reduced by 1 level. Also, recall that Equation 1 refers to emissions due to freely flowing (not stop-and-go) traffic.

During the preparation of the background document (Reference 10), public road silt loading values from 1992 and earlier were assembled into a data base. This data base is available as __________. Although hundreds of public paved road sL measurements had been collected, there was no uniformity in sampling equipment and analysis techniques, in roadway classification schemes, and in the types of data reported. Not surprisingly, the data set did not yield a coherent relationship between sL and road class, average daily traffic (ADT), etc., even though an inverse relationship between sL and ADT has been found for a subclass of curbed paved roads in urban areas. Further complicating the analysis is the fact that, in many parts of the country, paved road sL varies greatly over the course of the year, probably because of cyclic variations in mud/dirt carryout and in use of anti-skid materials. Although there were strong reasons to suspect that the assembled data base was skewed towards high values, independent data were not available to confirm the suspicions.

Since the time that the background document was prepared, new field sampling programs have shown that the assembled sL data set is biased high for "normal" situations. Just as importantly, however, the newer programs confirm that substantially higher than "normal" silt loadings can occur on public paved roads. As a result, two sets of default values are provided in Table 13.2.1-2, one for "normal" conditions and another for worst-case conditions (such as after winter storm seasons or in areas with substantial mud/dirt trackout). The newer sL data base is available as __________.

Table 13.2.1-2 (Metric Units). RECOMMENDED DEFAULT SILT LOADING (g/m^2) VALUES FOR PUBLIC PAVED ROADS[a]

	High ADT roads[b]	Low ADT roads
Normal conditions	0.1	0.4
Worst-case conditions[c]	0.5	3

[a] Excluding limited access roads. See discussion in text. 1 g/m^2 is equal to 1.43 grains/ft^2

[b] High ADT refers to roads with at least 5,000 vehicles per day.

[c] For conditions such as post-winter-storm or areas with substantial mud/dirt carryout.

The range of sL values in the data base for normal conditions is 0.01 to 1.0 for high-ADT roads and 0.054 to 6.8 for low-ADT roads. Consequently the use of a default value from Table 13.2.1-2 should be expected to yield only an order-of-magnitude estimate of the emission factor. Public paved road silt loadings are dependent upon: traffic characteristics (speed, ADT, and fraction of heavy vehicles); road characteristics (curbs, number of lanes, parking lanes); local land use (agriculture, new residential construction) and regional/seasonal factors (snow/ice controls, wind blown dust). As a result, the collection and use of site-specific silt loading data is highly recommended. In the event that default sL values are used, the quality ratings for the equation should be downgraded 2 levels.

Limited access roadways pose severe logistical difficulties in terms of surface sampling, and few sL data are available for such roads. Nevertheless, the available data do not suggest great variation in sL for limited access roadways from 1 part of the country to another. For annual conditions, a default value of 0.015 g/m^2 is recommended for limited access roadways.[9,22] Even fewer of the available data correspond to worst-case situations, and elevated loadings are observed to be quickly depleted because of high ADT rates. A default value of 0.2 g/m^2 is recommended for short periods of time following application of snow/ice controls to limited access roads.[22]

13.2.1.4 Controls[6,23]

Because of the importance of the surface loading, control techniques for paved roads attempt either to prevent material from being deposited onto the surface (preventive controls) or to remove from the travel lanes any material that has been deposited (mitigative controls). Regulations requiring the covering of loads in trucks, or the paving of access areas to unpaved lots or construction sites, are preventive measures. Examples of mitigative controls include vacuum sweeping, water flushing, and broom sweeping and flushing. It is particularly important to note that street sweeping of gutters and curb areas may actually increase the silt loading on the traveled portion of the road. Redistribution of loose material onto the travel lanes will actually produce a short-term increase in the emissions.

In general, preventive controls are usually more cost effective than mitigative controls. The cost-effectiveness of mitigative controls falls off dramatically as the size of an area to be treated increases. The cost-effectiveness of mitigative measures is also unfavorable if only a short period of time is required for the road to return to equilibrium silt loading condition. That is to say, the number and length of public roads within most areas of interest preclude any widespread and routine use of mitigative controls. On the other hand, because of the more limited scope of roads at an industrial site, mitigative measures may be used quite successfully (especially in situations where truck spillage occurs). Note, however, that public agencies could make effective use of mitigative controls to remove sand/salt from roads after the winter ends.

Because available controls will affect the sL, controlled emission factors may be obtained by substituting controlled silt loading values into the equation. (Emission factors from controlled industrial roads were used in the development of the equation.) The collection of surface loading samples from treated, as well as baseline (untreated), roads provides a means to track effectiveness of the controls over time.

References For Section 13.2.1

1. D. R. Dunbar, *Resuspension Of Particulate Matter*, EPA-450/2-76-031, U. S. Environmental Protection Agency, Research Triangle Park, NC, March 1976.

2. R. Bohn, *et al.*, *Fugitive Emissions From Integrated Iron And Steel Plants*, EPA-600/2-78-050, U. S. Environmental Protection Agency, Cincinnati, OH, March 1978.

3. C. Cowherd, Jr., *et al.*, *Iron And Steel Plant Open Dust Source Fugitive Emission Evaluation*, EPA-600/2-79-103, U. S. Environmental Protection Agency, Cincinnati, OH, May 1979.

4. C. Cowherd, Jr., *et al.*, *Quantification Of Dust Entrainment From Paved Roadways*, EPA-450/3-77-027, U. S. Environmental Protection Agency, Research Triangle Park, NC, July 1977.

5. *Size Specific Particulate Emission Factors For Uncontrolled Industrial And Rural Roads*, EPA Contract No. 68-02-3158, Midwest Research Institute, Kansas City, MO, September 1983.

6. T. Cuscino, Jr., *et al.*, *Iron And Steel Plant Open Source Fugitive Emission Control Evaluation*, EPA-600/2-83-110, U. S. Environmental Protection Agency, Cincinnati, OH, October 1983.

7. J. P. Reider, *Size-specific Particulate Emission Factors For Uncontrolled Industrial And Rural Roads*, EPA Contract 68-02-3158, Midwest Research Institute, Kansas City, MO, September 1983.

8. C. Cowherd, Jr., and P. J. Englehart, *Paved Road Particulate Emissions*, EPA-600/7-84-077, U. S. Environmental Protection Agency, Cincinnati, OH, July 1984.

9. C. Cowherd, Jr., and P. J. Englehart, *Size Specific Particulate Emission Factors For Industrial And Rural Roads*, EPA-600/7-85-038, U. S. Environmental Protection Agency, Cincinnati, OH, September 1985.

10. *Emission Factor Documentation For AP-42, Sections 11.2.5 and 11.2.6 — Paved Roads*, EPA Contract No. 68-D0-0123, Midwest Research Institute, Kansas City, MO, March 1993.

11. *Evaluation Of Open Dust Sources In The Vicinity Of Buffalo, New York*, EPA Contract No. 68-02-2545, Midwest Research Institute, Kansas City, MO, March 1979.

12. *PM-10 Emission Inventory Of Landfills In The Lake Calumet Area*, EPA Contract No. 68-02-3891, Midwest Research Institute, Kansas City, MO, September 1987.

13. *Chicago Area Particulate Matter Emission Inventory — Sampling And Analysis*, Contract No. 68-02-4395, Midwest Research Institute, Kansas City, MO, May 1988.

14. *Montana Street Sampling Data*, Montana Department Of Health And Environmental Sciences, Helena, MT, July 1992.

15. *Street Sanding Emissions And Control Study*, PEI Associates, Inc., Cincinnati, OH, October 1989.

16. *Evaluation Of PM-10 Emission Factors For Paved Streets*, Harding Lawson Associates, Denver, CO, October 1991.

17. *Street Sanding Emissions And Control Study*, RTP Environmental Associates, Inc., Denver, CO, July 1990.

18. *Post-storm Measurement Results — Salt Lake County Road Dust Silt Loading Winter 1991/92 Measurement Program*, Aerovironment, Inc., Monrovia, CA, June 1992.

19. Written communication from Harold Glasser, Department of Health, Clark County (NV).

20. *PM-10 Emissions Inventory Data For The Maricopa And Pima Planning Areas*, EPA Contract No. 68-02-3888, Engineering-Science, Pasadena, CA, January 1987.

21. *Characterization Of PM-10 Emissions From Antiskid Materials Applied To Ice- And Snow-Covered Roadways*, EPA Contract No. 68-D0-0137, Midwest Research Institute, Kansas City, MO, October 1992.

22. *Fugitive Particulate Matter Emissions*, EPA Contract No. 68-D2-0159, Work Assignment No. 4-06, Midwest Research Institute, Kansas City, MO, April 1997.

23. C. Cowherd, Jr., *et al., Control Of Open Fugitive Dust Sources*, EPA-450/3-88-008, U. S. Environmental Protection Agency, Research Triangle Park, NC, September 1988.

24. Written communication from G. Muleski, Midwest Research Institute, Kansas City, MO, to R. Myers, U. S. Environmental Protection Agency, Research Triangle Park, NC, September 30, 1997.

Attachment 1

Comment/Response Log for March 8, 1993, Paved Road Background Document

RESPONSE TO COMMENTS MADE IN ATTACHMENTS TO WILLIAM R. BARNARD LETTER OF MAY 12, 1993
PAVED ROADS

COMMENT	RESPONSE
1. Page 2-2, 1st paragraph, sentence that starts "In addition..." change from "can be often heavily loaded" to "can often be..." Page 2-2, In definitions of equation 2-1, change "s=surface material content silt" to read "surface material silt content" Page 2-4, 1st paragraph at the top, sentence that begins "The industrial road augmentation factor..." change "was included to take into account for..." to "was included to account for..."	1 These all address typographical errors or recommended wording changes to the background document. Changes will be made in any revision to the background document.
2. Although I know that you are simply "quoting" AP-42, it is very confusing to the reader that in equation 2-1, s = surface material silt content and L = surface material loading, but in equation 2-3, sL = road surface silt loading and has the same units as L alone in equation 2-1.	2. MRI agrees that the use of "sL" and the combination of "s" and "L" can prove confusing. Because the revised AP-42 section will replace all three paved road equations currently contained in Sections 11.2.5 and 11.2.6, "sL" will be used in only one sense thus eliminating any confusion.
3. I would suggest moving most of section 3 forward (to become section 2) and would place section 2 as the new section 3. It would seem more logical to have a general description of the ratings system prior to summarizing the existing information, including the current ratings for current AP-42 emission factors. I also think that sections 3.0 and 3.1 would be better "tagged" onto the end of section 2 and the remaining current section 3 moved to section 2 as indicated above.	3. MRI will consider the merit of reorganizing the background document prior to any revision to the report.
4. In the discussion on page 2-6, the indication is that the reformulated emission factor will include data using controls. Although a rationale is given for this, I strongly question the wisdom of this approach. If controlled and uncontrolled information is used to generate the emission factor, then it becomes extremely difficult to perform any control strategy analyses for SIP purposes using an emission factor that may already incorporate some level of control. There is virtually no data on how much the various control options for paved roads reduce silt content (which is the information needed with the new approach), while there is limited data on overall control efficiency. Although I know that most of the control approaches are aimed at reducing the silt loading, what happens if you are wrong and the silt loading is not really the controlling factor for paved road emissions?	4. MRI firmly believes that the approach employed in the background document is "best" in the sense that the approach • addresses confusion that may result from having two or more different paved road models might be used to estimate emissions in various size ranges from roads at a single facility, municipality, etc. • recognizes the very dynamic nature of silt loading in that emissions are reduced substantially (i.e., "controlled") through rainfall. To a very real extent, a truly "uncontrolled" paved road would have to be completely sheltered from the direct rain and water runoff. • provides the regulatory and regulated communities a cost-effective means (through relatively inexpensive surface sampling) to evaluate seasonal variations in emissions and the efficiency of control programs • recognizes that there is a far larger data base in which efficiency is tied to reduction in silt loading rather than reduction in the emission factor With reference to the potential for mistaking the importance of silt loading, please see discussion on page 4-20. As stated there, the most notable features about the correlation matrix are the high degree of interdependence between (i) emisison factor; (ii) speed: and (iii) silt loading; and, the low degree of interdependence between (a) silt loading and weight and (b) weight and speed. The selection of combination (a) over combination (b) is explained at the bottom of page 4-20.

COMMENT	RESPONSE
5. I think another criteria should be added to all reviews and AP-42 chapter development efforts. All primary source reports should contain sufficient information and data so that all data reduction procedures and/or calculations can be verified. Frequently, even when information has been given in fugitive emission factor development reports, the data cannot be used to give reproducible results using the data reduction/calculation methods presented. Section 2, page 2-6 next to last paragraph indicates that previous test data were included in the reexamination and that no distinction was made between public and industrial roads or controlled/uncontrolled tests. However, on page 3-2, the top paragraph indicates that "earlier controlled industrial road test data were reexamined in addition to new data." Which is it? In section 4, it looks like all data were reviewed. Be consistent.	5. Please see the discussion in response 6 regarding independent calculation of exposure profiling test results. MRI does not see the two statements as contradictory; however, there may be some confusion about the meaning of terms such as "reexamined" or "reviewed". The background document does not make any hard and fast distinctions between terms such as "considered," "(re)examined," or "reviewed." Simply put, data are first examined -- or equivalently, "reviewed" or "considered" -- to decide from which data emission factors will be developed. New data (from test reports I, II and III) were examined. In addition, MRI reconsidered field test results that had been available during the earlier updates of this section (in 1983 and, to a lesser extent, 1987) but not used (because of the "controlled" nature of the surface) to develop an emission factor. The reasons for including the controlled tests in the current update are described in the background document and in the previous response.

COMMENT	RESPONSE
6. Page 3-2, item #2 in the section 3-2 list. What do EPA method 5 front-half and back-half have to do with fugitives? A better example of incompatible methods should be found. A great deal of the discussion on upwind-downwind tends to deal with drawbacks to using this method. However, it can be utilized with standardized, wind tunnel certified sampling devices and really requires little more meteorological data than exposure profiling (wind speed and direction vs. wind speed). Equal time should be devoted towards drawbacks/uncertainties associated with exposure profiling. For instance, the samplers used for exposure profiling have never been wind tunnel certified for size cutpoints to the best of my knowledge (i.e., never published). Also, I have never been able to successfully duplicate the "spatial integration of measurements" even when data and example calculations have been provided. In the case of PM-10, how can you truly estimate the visual extent of the plume to insure that at least 90% is captured? I believe that visually estimating the extent of 10 micron particles (mainly invisible) would be extremely difficult. Finally, the discussion of exposure profiling should discuss the relative error (as was done for upwind-downwind). The overall tone of the discussion tends to sound "heavy-handed" and biased towards the method that MRI developed rather than an objective presentation of the two methodologies which is what an objective review should do.	6. This text is drawn verbatim from the EPA guideline document for development of AP-42 sections. MRI will revise this passage to better reflect the particulars involved with paved road testing procedures in any new version of the background document. It is important to recall that exposure profiling represents a sampling approach rather than any specific type of sampler. In other words, "standardized, wind tunnel certified samplers" can (and have been) used in exposure profiling programs. The reviewer is quite right in stating that upwind/downwind (UW/DW) approach requires little more meteorlolgical data than exposure profiling. As a matter of fact, MRI requires that wind direction be monitored throughout any exposure profiling test. The important distinction to be drawn between the UW/DW and the exposure profiling methods involves how data are used to characterize the source. The background document discusses basic limitations of using uncalibrated dispersion models to estimate emission strength. Beyond the relatively simple discussion presented in the background document, UW/DW suffers other fundamental limitations. For example, traffic on many roads is too low to pose a steady, uniformly emitting line source as required in dispersion models. A better representation would view the source as a series of discrete moving point source. Even assuming the source is reasonably steady in nature, the modeled line source/wind geometry does not necessarily properly account for dispersion from the moving point sources. As the plume is released, dispersion occurs in all three cartestian coordinate directions. Only dispersion in the direction parallel to the plume centerline would be negligible. Depending on the direction a vehicle is traveling, an oblique wind would appear to "dilute" or "concentrate" the plume as seen by the UW/DW samplers. Correction for each plume depends upon the magnitude and direction of the wind relative to vehicle velocity vector. In other words, if two vehicles passed in opposite directions at the same time, one plume would be concentrated and the other diluted. Because the exposure profiling approach focuses on the mass flux through a plane, concentration/dilution issues are not a concern. As noted earlier, standardized samplers can be and have been readily used in the exposure profiling arrays. Because of the interest in total particulate and size-specific factors, MRI has traditionally used directional samplers operated isokinetically, together with aerodynamic particle sizing instruments. (In addition to manufacturer tests for the cascade impactors, the cyclone preseparator has been wind tunnel tested. Results are reported in Baxter et al 1986.) The Southern Research Institute (SoRI) collaborative study (Pyle and McClain 1986) examined many issues associated with exposure profiling. The authors duplicated MRI's and four other organization's calculations from 11 test runs on a "simulated" unpaved road. In addition, SoRI investigated potential errors associated with isokinetic tracking, different particle sizing approaches, maximum sampling height, spatial integration schemes, etc.

RESPONSE TO COMMENTS MADE IN ATTACHMENTS TO WILLIAM R. BARNARD LETTER OF MAY 12, 1993
PAVED ROADS (continued)

COMMENT	RESPONSE
7. Page 3-9, next to last sentence says, "sin specific source parameters" should say "in specific source parameters" Page 3-11, top of page "virtual point source missions" should be "virtual point source emissions"	7. These changes will be made to any subsequent version of the background document.
8. On page 3-11, one of the criteria used for evaluating emission factor data is "industry representativeness." Why are we concerned about industry representativeness as a criteria in developing a new emission factor when the new emission factor is to be reflective of emissions from any paved road, regardless of whether industrial or public?	8. As stated above, this text is drawn verbatim from the EPA guideline document. The passage will be revised in any subsequent version of the background document.
9. Page 4-7, 1st full paragraph indicates that the Test Report I does not fully meet the minimum requirements for upwind-downwind sampling (i.e., a minimum of 4 samplers). The description of the sampling set-up says that even when 6 samplers were used they were set up identically with one at 20 m and a pair at 5 m on each side of the road. This means 3 samplers on upwind side at 2 distances and 3 on downwind at 2 distances. On page 3-10, next to last paragraph, the minimum test requirements for upwind-downwind are stated as 1 device upwind (satisfied here by 3 at 2 distances) and the others at 2 downwind (satisfied here by the 5 m and 20 m distances) and 3 crosswind. The requirement for crosswind distances is waived for line sources. A paved road is a line source, thus this report does meet the minimum requirements for sampling and should be included in the analysis.	9. MRI mistakenly stated in the background document that "neither" sampling configuration met minimum requirements. Only the <u>second</u> configuration (described on page 4-4) failed to meet minimum requirements because the sources tested were not truly line sources. Instead, the halves of each road segment were considered separately. Test Report I did not explain how far samplers were separated from the end of segments nor did it describe any attempt to prevent tracking of material from one segment to another. (See, for example, Figure 2-3 of Test Report I.) Thirty-two of the 69 emission tests used the second configuration.
10 In the discussion of Test Report II, the text indicates that only 1 particle size device is used to determine a PM-10 emission factor. Are the investigators really sure that there is no variability in the distribution of the PM-10 concentration (flux) with height? Unpaved road studies performed as part of NAPAP indicate otherwise.	10. Test Report II's use of single height for particle sizing measurements resulted from the limited number of devices available. MRI has found in numerous past studies and one would certainly expect the PM-10 fraction to increase with height in the plume. To at least partially account for this, the single height was selected to approximate the height in a dust plum at which half the mass emissions pass above and half below.
11. Figure 4-3 is really a table.	11. MRI called this a "figure" because it is a photocopy of two different outputs from a computer program. No change is planned.
12. Table 4-5, the multiple R^2 for PM-15 = .765, but "Figure" 4-3 indicates it should be .772.	12. To ensure that the different size fractions had functional forms similar to that for PM-10, all final models were "forced" to have the same exponents for silt loading and weight. Thus, the ℓn-transformed emission factors were regressed against the term $0.65 \ell n\ sL + 1.5 \ell n\ W$ with the line-of-fit forced to pass through the origin to determine the final form. The lower R^2 results from the fact that the final factor is not "best" in an independent least-squares sense.

RESPONSE TO COMMENTS MADE IN ATTACHMENTS TO WILLIAM R. BARNARD LETTER OF MAY 12, 1993
PAVED ROADS (continued)

COMMENT	RESPONSE
13. Based upon the discussion above concerning inclusion of Test Report I and due to the fact that it was considered good enough for validation, what would the emission factor equation look like if that data was included?	13. Inclusion of the Test Report I data could be expected to lower the exponent for "sL" for the PM-10 equation from 0.65 to approximately 0.5. At a summer 1992 meeting with the commentor, Chuck Masser, Tom Pace, and Robin Dunkins, we discussed how, the discussion in Zimmer 1991 notwithstanding, Test Report I emission rates exhibited a strong dependence on silt loading. (Figure 4-2 of the background document clearly shows this.) It is also important to recall that primary reason for not including Test Report I data was that only PM-10 factors were available.
14. On page 4-23, the validation results indicate that at least 50% of the data are outside the factor of 3 range. Does this mean that the factor of 2 used for rating (see Table 3-1) is unrealistic for rating emission factors and that a more appropriate lower end would be 3 rather than 2?	14. Page 4-23 states that "a little over half" of the quasi-independent values are within a factor of 3. This certainly does not indicate that "at least 50% ... are outside" that range. A rough scaling of Figure 4-4 on page suggests that approximately 57% ≈ 60% are within a factor of 3. Table 3-1 pertains to single-valued emission factors. The quality ratings for predictive equations are assigned following the scheme presented in Table 3-2.
15. Why is the equation on the first page of the proposed new section 11.2.x different from the new one derived in the report (equation on page 4-22). Specifically, why is sL divided by 2 and W by 3? Why doesn't the equation on page 4-22 have an equation number as earlier equations did?	15. The background document discusses a "working" form for the model. By that is meant all emission factors are measured in g/VMT, all silt loadings are in g/m^2, and so on. For example, in order to be exactly precise, one must either • consider silt loading and weight "nondimensionalized" by implicit division by 1 g/m^2 and 1 ton respectively or $\frac{g \cdot m^{1.3}}{g^{0.65} \cdot tons^{1.5} \cdot veh\text{-}mile} = \frac{g^{0.35} \cdot m^{1.3}}{tons^{1.5} \cdot veh\text{-}mile}$ The working versions of models are used to establish properties of candidate emission factors. On the other hand, once a factor has been selected, the AP-42 section must present a final product. In the AP-42 sections, nondimensionalization occurs through the explicit division by the "default" values of 2 g/m^2 and 3 tons. Furthermore, k is expressed in a variety of compatible units. One can readily verify that all working and final expressions result in the same emission factor for the same input values. An equation number will be added on page 4-22 in any subsequent version of the background document.

References

Baxter, T. E. et al. 1986. "Calibration of Cyclone for Monitoring Inhalable Particles," Journal of Environmental Engineering, 112, 3, pp. 468-478.

Pyle, B. E. and J. D. McCain 1986. Critical Review of Open Source Particulate Emission Measurements -- Part II: Field Comparison. Work Assignment 002, EPA Contract 68-02-3936. February 1986.

Zimmer, R. A. 1991."Evaluation of PM10 Emission Factors for Paved Streets." Harding Lawson and Associates report for the Regional Air Quality Council (Denver). October 1991.

RESPONSE TO COMMENTS MADE IN ATTACHMENTS TO WILLIAM R. BARNARD LETTER OF MAY 12, 1993
CONSTRUCTION ACTIVITIES

COMMENT	RESPONSE
Specific comments	
1. On page v, there is a superscript 8 in the Section 3.3 line of the Table of Contents. On page vi, there is a superscript in #2-3 line of Tables list	1. These all address typographical errors or recommended wording changes to the background document. These changes will be made in any subsequent version of the background document.
2. As with the Paved Roads document, I'd probably flip-flop Sections 2 and 3, although the reason for switching them is less compelling in this document, since there are few if any references to the previous AP-42 emission factor quality rating.	2. MRI will consider the merit of reorganizing the background document prior to any revision to the report.
Comments on Section 2	
3. Page 2-1 In the discussion of the number of construction industries, you list 2.0 million, instead of 2 million. The decimal point implies some level of significant figures. Is that level really there?	3. Reference 1 in the background document should not be the Statistical Abstract but rather the 1987 Census of Construction Industries. This will be corrected in any revision. The 1987 Census uses the expression "nearly 2.0 million construction establishments." Any subsequent version of the background document will incorporate that phrasing.
4. Unless total value of business done is the way that Statistical Abstract describes the information presented on page 2-1 and 2-2, I'd say total revenue.	4. The Statistical Abstract reports "value of construction [contract]." The Census of Construction Industries uses the term "value of construction work." Subsequent version of the background document will use "value of construction work."
5. Page 2-5 "unpaved travel rates"? - middle of last paragraph	5. This is a typographical error and should read "travel routes." The change will be made in a subsequent revision to the background document.
Comments on Section 3	
6. I think another criteria should be added to all reviews and AP-42 chapter development efforts. All primary source reports should contain sufficient information and data so that all data reduction procedures and/or calculations can be verified. Frequently, even when information has been given in fugitive emission factor development reports, the data cannot be used to give reproducible results using the data reduction/calculation methods presented.	6. Please see response 6 in the paved road comment log regarding independent calculation of exposure profiling test results.
7. Page 3-1 near the bottom. The 1987 Censu s of Construction Industries, United States Summary is *listed as reference 1, however, reference 1 is the* Statistical Abstract of the U.S. for 1992.	7. As noted in response 3, Reference 1 should read *U.S. Department of Commerce, Bureau of the Census. "1987 Census of Construction Industries."* Geographic Area Series, CC87-A-10. Washington, D. C. October 1990.
8. Page 3-6, change "unless the plume can be draw..." to "unless the plume can be drawn" Page 3-9, next to last sentence change "when characterize source conditions" to "which characterize source conditions"	8. These changes will be made in any subsequent version of the background document.

RESPONSE TO COMMENTS MADE IN ATTACHMENTS TO WILLIAM R. BARNARD LETTER OF MAY 12, 1993
CONSTRUCTION ACTIVITIES (continued)

COMMENT	RESPONSE
Comments on Section 4	
9. All discussions of reviewed emission factors should clearly delineate whether the emission factor being discussed is for TSP or PM-10. Page 4-5, last paragraph, says that upwind-downwind sampling was used to determine TSP emission factors in Table 4-2, but the table caption says they are PM-10 emission factors.	9. The background document will be reviewed to identify points where PM10/TSP could be confused. The entries are in fact PM-10 emission factors based on Referernce 12's reanalysis of TSP emission factors contained in Test Report III. Statements will be corrected in any subsequent version of the background document.
10. Page 4-6, last sentence of first paragraph, says that a minimum of 4 samplers are required but on Page 3-11 the minimum number is specified as 5.	10. MRI does not see the two statements as contradictory. Page 3-11 calls for "at least five ... with one device located upwind." Consequently at least 4 should be deployed downwind. Page 4-6 states that "two samplers ... were used downwind rather than the minimum of four."
11. Page 4-6, last paragraph before section 4.2.2, either give it a B or a C rating. Probably deserves a C	11. MRI agrees that "C" is appropriate.
12. In the revised section for AP-42, the discussion concerning equation 1 indicates that the emission factor can be used for PM-10, but this is a TSP emission factor. No discussion is provided to indicate what factor should be applied to provide PM-10 emission estimates.	12. The intention in the revised AP-42 section is to allow readers to use Equation (1) to not only estimate TSP emissions but also to conservatively estimate PM-10 emissions. The discussion on page 11.2.4-2 recognizes that this approach may result in too high a PM-10 estimate and recommends estimating emissions on the basis of component operations.

COMMENTS MADE IN MAY 24, 1992, LETTER FROM DOUGLAS P. COLLINS, IDAHO DEQ PAVED ROADS

COMMENT	RESPONSE
The 90th percentile, as a worst case scenario, appears to overestimate emissions, especially if used to generate a daily total emission rate. To assume that all streets, on any day, would be carrying a 90th percentile silt loading seems unlikely.	MRI agrees that it is highly unlikely that all roads in an area will be at the 90th percentile at once. As noted in the AP-42 section and the comments below, sL values specific to the site and situation of interest would be preferred.
The temporal scale of January to June, and July to December, does not reflect annual increase and decrease of silt loadings in Idaho. Increased silt loadings from the application of anti skid materials starts with the first significant snow fall, usually in November, and lasts until about April, when many road departments mechanically remove excess road debris.	During the preparation of the AP-42 Section, MRI considered using different groupings, such as winter/spring vs. summer/fall or November-through-March vs. April-through-October. The other grouping schemes all failed to adequately account for differences seen in the sL values; furthermore, the other schemes called for a subjective decision -- such as: When does "winter" begin at a specific site? -- or failed to take into account weather patterns during a particular sampling year -- such as: Was November 1991 particularly snowy or warm? Because the sL data base was a secondary objective in the program, project resources were insufficient to devote much effort in resolving weather patterns. Consequently, calendar year halves were selected to avoid subjective decisions.
Not all counties in Idaho require vehicle weights to be recorded with the title or registration. Therefore it is a best guess as to what the average vehicle weight might be. Some guidelines, references, or suggested values, or range of values would be helpful.	For most public roads with "normal" mixes of cars, trucks and buses, one can probably expect the average weight not vary outside the range of 2.0 to 2.5 tons.
The preferred method for determining silt loading value is to collect your own representative samples. Appendices, in the past, have addressed how to take and analyze the samples, but do not provide a methodology to set up a sampling study. A methodology that lays out guidelines on the number of sites, number of samples, precision and accuracy, QA/QC, meterological considerations, and other parameters needed to conduct an adequate road silt sampling project would be of help. These guidelines could address both larger studyies for determining specific silt loading values, an a limited study for trying to narrow down the options presented in using the 50th to 90th percentile used in the revised AP-42.	MRI agrees that some sort of "case study" would be quite useful to the regulatory community. The current version of Appendix D to AP-42 is necessarily vague on where and how many samples should be collected and even on the type of equipment to be used in sampling, because site-specific considerations may affect decisions. A case study that considered • three different size cities (e.g., Phoenix, Reno, and Pocatello) and, • and 2 or 3 levels of effort (for example, a two-month long program for $10,000 versus a multiyear program for $70,000). would be of great practical benefit.
Use of the public paved road sL data base (not yet provided) would seem to be a good intermediate choice between getting site specific data and using the the revised AP-42 values, providing the selection criteria used can adequately reflect the area of interest. Selection information might include: the amount of anti-skid material used, percent of silt in anti skid material, average number of applications per season, application equipment used, application rate, and the size and location of the area where the data was collected.	At present, the revised paved road section recognizes that end users of AP-42 are the most capable in selecting roads in the data base that are similar to roads of interest in their jurisdictions. Although site-specific sL values would be most preferred, MRI believes that the new approach represents an improvement.
When compared to the current AP-42 section in use, selecting a winter time silt loading value from the revised section feels more comfortable. The 50th to 90th percentile range appears to accurately reflect the range of silt loadings that can be found on Idaho roads, and even though the value range is fairly large, it does let you know when you are in the ball park.	MRI agrees.

COMMENTS MADE IN MAY 27, 1992, LETTER FROM GARY NEUROTH, ARIZONA DEQ PAVED ROADS

COMMENT	RESPONSE
The "MRI accepted" data base contains little, if any, data for relatively high volume, high speed roads typically found in urban areas. For example, roads with daily traffic volumes over 10,000 with speeds over 35 mph.	Figures 1 and 2 compare the speed/silt loading ranges in the AP-42 data base and data from the PEI Denver study (Test Report I in the background document). As can be seen, the AP-42 data contains slightly more tests within the range of the PEI data. This is not to say that the current paved road emission factor data base does not suffer from certain limitations. As MRI has pointed out, the present paved road emission factor models do not explicitly reference characteristics that are likely to influence emission levels, such as • Vehicle mix -- It is likely that particulate matter emission levels are higher for roads/areas where diesel and/or poorly maintained older vehicles are prevalent. At present, however, neither the current Section 11.2.5 or Section 11.2.6 PM_{10} emission factor distinguishes between roads with different vehicle mixes. The recommended revision, on the other hand, at least partially accounts for vehicle mix by the inclusion of the "weight term." Still, no direct distinction is made for different diesel/gasoline ratios, etc. • Vehicle speed -- As the comment points out, it is likely that, all other factors being equal, high ADT roads should have different emission characteristics than low ADT roads. However, both the AP-42 and the PEI baseline data bases show a very strong interrelationship between silt loading and vehicle speed. Thus, the effects of high-speed (and, by inference, high-ADT) are at least partially accounted for by the inclusion of silt loading as an input parameter. (Also, please see the response to comment 4 in the log for the letter from Pechan and Associates. • Traffic flow characteristics -- The AP-42 paved road data base and all current or revised emission factor models apply only to freely flowing traffic; no provision is made for the presumably higher emissions due to stop-and-go traffic.
As you are probably aware, the Federal Highway Administration is presentaly funding research conducted by Desert Research Institute (DRI) to characterize emissions from paved roads. My staff is currently assisting DRI conducting roadside testing in Scottsdale, Arizona. In October 1993, our Department plans to conduct roadside PM_{10} sampling at several locations in the Phoenix metro area using a 3-dimensional sampling array similar to the MRI configuration. I've enclosed a copy of our proposed study plan, which I believe has two inherent advantages that promise to yield a better data base than that used to derive the AP-42 emission factors for urban areas: (1) saqmpling will be conducted on roads selected to represent a majority of the urban VMT (2) PM_{10} samples will be collected continuously using Tapedred Element Oscillating Microbalance (TEOM) samplers which will provide a larger number of data points with shorter averaging times allowing tighter specification on variables such as wind and traffic.	In light of the above response, MRI certainly recognizes the need for additional field investigation. Furthermore, MRI also recognizes the need that, as new information becomes available, the paved road emission factor should be evaluated in terms of its performance in estimatin • evaluated in terms of its performance in estimating independent emissions data • reformulated, as needed, depending upon the results of the evaluation

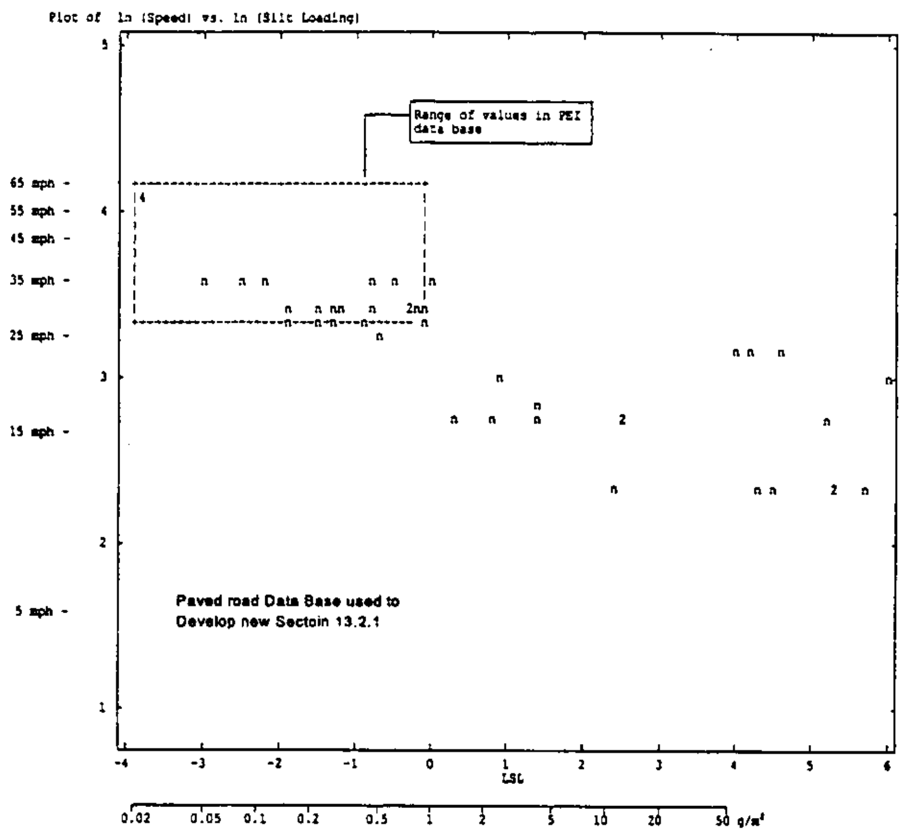


Figure 1. PLOT OF AVERAGE VEHICLE SPEED vs. SILT LOADING IN THE AP-42 PAVED ROAD EMISSION FACTOR DATA BASE (Fully logarithmic)

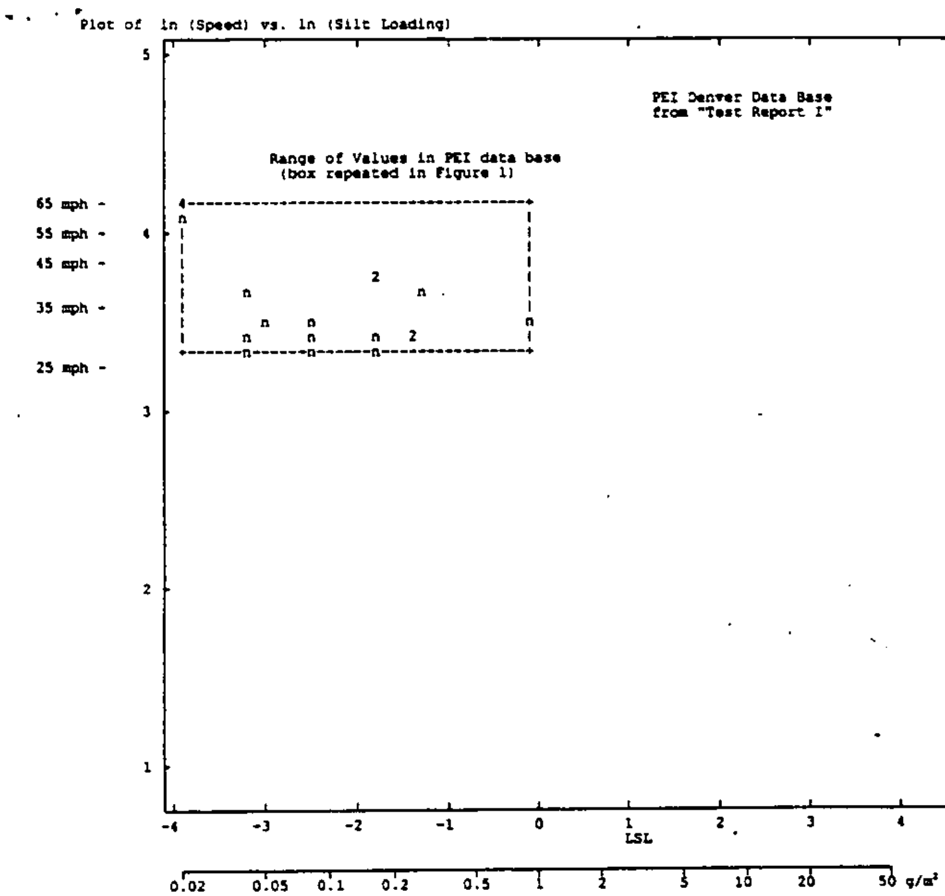


Figure 2. PLOT OF AVERAGE VEHICLE SPEED vs. SILT LOADING IN THE PEI BASELINE EMISSION FACTOR DATA BASE (Fully logarithmic)

Attachment 2.

Public Paved Road Surface Loading
Presented as Appendix X in March 8, 1993
Paved Road Background Document

TABLE A2-1. PUBLIC PAVED ROAD SURFACE LOADING DATA BASE (DETAILED INFORMATION)

STATE	CITY	STREET	CLASS	DATE	ADT	SILT LOADING (g/m*m)	SILT %	TOTAL LOADING (g/m*m)	SILT LOADING SUMMARY
The following data from		Reference 1							
MT	Billings	-----	Rural	Apr-78	50	0.6	18.5	3.4	
MT	Billings	Yellowstone	Residential	Apr-78	115	0.5	14.3	3.5	
MT	Missoula	Bancroft	Residential	Apr-78	4000	8.4	33.9	24.9	
MT	Butte	1st St	Residential	Apr-78	679	24.6	10.6	232.4	
MT	Butte	N Park Pl	Residential	Apr-78	60	103.7	7	1480.8	
MT	Billings	Grand Ave	Collector	Apr-78	6453	1.6	19.1	13.05	2 samples, range: 1.0 - 2.2
MT	Billings	4th Ave E	Collector	Apr-78	3328	7.7	7.7	99.5	
MT	Missoula	6th St	Collector	Apr-78	3655	26	62.9	6	
MT	Butte	Harrison	Arterial	Apr-78	22849	1.9	5	37.3	
MT	Missoula	Hiway 93	Arterial	Apr-78	18870	1.9	55.9	3.3	
MT	Butte	Montana	Arterial	Apr-78	13529	0.8	6.6	11.9	
MT	East Helena	Thurman	Residential	Apr-83	140	13.1	4.3	305.2	
MT	East Helena	1st St	Local	Apr-83	780	4	13.6	29	
MT	East Helena	Montana	Collector	Apr-83	2700	8.2	9.4	86.6	
MT	East Helena	Main St	Collector	Apr-83	1360	4.7	8.4	55.3	
MT	Libby	6th	Local	Mar-88	1310	-----	14.8	-----	
MT	Libby	5th	Local	Mar-88	331	-----	16.5	-----	
MT	Libby	Champion Int So g	Collector	Mar-88	800	-----	27.5	-----	
MT	Libby	Mineral Ave	Collector	Mar-88	5900	7	16	43.5	
MT	Libby	Main Ave btwn 6th	Collector	Mar-88	536	61	20.4	299.2	
MT	Libby	California	Collector	Mar-88	4500	-----	12.1	-----	
MT	Libby	US 2	Arterial	Mar-88	10850	-----	12.3	-----	
MT	Butte	Garfield Ave	Residential	Apr-88	562	2.1	10.9	19.3	
MT	Butte	Continental Dr	Arterial	Apr-88	5272	0.9	10.1	8.8	
MT	Butte	Garfield Ave	Residential	Jun-89	562	1	8.7	11.2	
MT	Butte	So Park Ave	Residential	Jun-89	60	2.8	10.9	25.5	
MT	Butte	Continental Dr	Arterial	Jun-89	5272	7.2	3.6	197.6	
MT	East Helena	Morton St	Local	Aug-89	250	1.7	6.8	24.6	
MT	East Helena	Main St	Collector	Aug-89	2316	0.7	4.1	17	
MT	East Helena	US 12	Arterial	Aug-89	7900	2.1	12.5	16.5	
MT	Columbia Fall	7th St	Residential	Mar-90	390	-----	9.5	-----	
MT	Columbia Fall	4th St	Residential	Mar-90	400	18.8	14.3	131.5	
MT	Columbia Fall	3rd Ave	Residential	Mar-90	50	-----	14.3	-----	
MT	Columbia Fall	4th Ave	Residential	Mar-90	1720	-----	5.4	-----	

TABLE A2-1. (continued)

STATE	CITY	STREET	CLASS	DATE	ADT	SILT LOADING (g/m*m)	SILT %	TOTAL LOADING (g/m*m)	SILT LOADING SUMMARY
MT	Columbia Fall	CF Forest	Local	Mar-90	240	-----	16.3	-----	
MT	Columbia Fall	12th Ave	Collector	Mar-90	1510	-----	8.8	-----	
MT	Columbia Fall	3rd St	Collector	Mar-90	1945	-----	7	-----	
MT	Columbia Fall	Nucleus	Collector	Mar-90	4730	15.4	10	153.9	
MT	Columbia Fall	Plum Creek	Collector	Mar-90	316	-----	6.2	-----	
MT	Columbia Fall	6th Ave	Collector	Mar-90	1764	-----	4.2	-----	
MT	Columbia Fall	US 2	Arterial	Mar-90	13110	2.7	18.7	14.6	
MT	East Helena	Morton	Residential	Jul-90	250	1.6	17	9.3	
MT	East Helena	Main St	Collector	Jul-90	2316	5.6	10.6	52.5	
MT	East Helena	US 12	Arterial	Jul-90	7900	3.2	15.4	20.9	
MT	Columbia Fall	4th Ave	Local	Aug-90	400	1.5	4	37.7	
MT	Libby	Main Ave 4th &	Collector	Aug-90	530	2.4	17.9	13.2	
MT	Columbia Fall	Nucleus	Collector	Aug-90	5730	0.8	5.3	16	
MT	Columbia Fall	US 2	Arterial	Aug-90	13039	0.2	7	2.9	
MT	East Helena	Morton	Local	Oct-90	250	3.4	10.2	33.6	
MT	East Helena	Main	Collector	Oct-90	2316	4.5	5.6	81.3	
MT	East Helena	US 12	Arterial	Oct-90	7900	0.6	13.9	4.3	
MT	Columbia Fall	Nucleus	Collector	11/6/90	5670	5.2	13.5	38	
MT	Columbia Fall	US 2	Arterial	11/6/90	15890	1.7	24.1	7.2	
MT	Libby	US 2	Arterial	12/8/90	10000	21.5	9.6	223.9	
MT	Libby	Main Ave 4th &	Collector	12/9/90	530	13.6	27.1	50.3	
MT	Butte	Texas	Collector	12/13/90	3070	1	15.4	6.4	
MT	East Helena	King	Local	Jan-91	75	1	3.4	30.6	
MT	East Helena	Prickly Pear	Local	Jan-91	425	12	1.8	666.5	
MT	East Helena	Morton	Local	Jan-91	250	14.1	3.5	402.3	
MT	East Helena	Main St	Collector	Jan-91	2316	36.7	12.1	303.4	
MT	East Helena	US 12	Arterial	Jan-91	7900	0.8	14	5.6	
MT	Thompson Fall	Preston	Local	1/23/90	920	9.2	9.9	93	
MT	Thompson Fall	Highway 200	Collector	1/23/90	5000	33.3	27.2	122.2	
MT	East Helena	Seaver Park Rd	Local	Feb-91	150	21.6	7.1	304.7	
MT	East Helena	New Lake Helena D	Collector	Feb-91	2140	19.2	9	213.4	
MT	East Helena	Porter	Collector	Feb-91	850	74.4	7.7	966.8	
MT	Libby	Main Ave 4th &	Collector	2/14/91	530	33.3	18.7	178.2	
MT	Libby	US 2	Arterial	2/17/91	10000	69.3	21	330.3	
MT	Butte	Texas	Collector	2/21/91	3070	1.2	11	10.9	

TABLE A2-1. (continued)

STATE	CITY	STREET	CLASS	DATE	ADT	SILT LOADING (g/m*m)	SILT %	TOTAL LOADING (g/m*m)	SILT LOADING SUMMARY
MT	Butte	Harrison	Arterial	2/21/91	22849	2.9	7.9	36.6	
MT	Kalispell	3rd btwn Main & 1	Collector	2/24/91	2653	30.5	24.8	122.9	
MT	Kalispell	Main	Arterial	2/24/91	14730	17.4	20.4	85.2	
MT	Thompson Fall	Preston	Local	2/25/91	920	35.7	17.9	199.6	
MT	Thompson Fall	Highway 200	Collector	2/25/91	5000	66.8	17.8	375.3	
MT	Helena	Montana	Arterial	Mar-91	21900	15.4	6.2	248.3	
MT	Kalispell	3rd btwn Main & 1	Collector	3/9/91	2653	39.1	29.1	134.5	
MT	Columbia Fall	Nucleus	Collector	Mar-91	5670	30.1	17	174.6	2 samples, range: 0.8 - 0.8
MT	Kalispell	Main	Arterial	3/9/91	14730	17.6	24.7	71.4	
MT	Thompson Fall	Preston	Local	Mar-91	920	4.4	8.3	51	2 samples, range: 2.8 - 5.9
MT	Thompson Fall	Highway 200	Collector	Mar-91	5000	4.3	15.5	28.9	2 samples, range: 1.0 - 7.5
MT	Libby	Main Ave 4th &	Collector	Mar-91	530	14.8	33.1	44.9	2 samples, range: 13.5 - 16.1
MT	Libby	US 2	Arterial	Mar-91	11963	20	19.5	111.9	3 samples, range: 11.4 - 32.4
MT	East Helena	Morton	Local	Apr-91	250	4.3	8.8	48.7	
MT	East Helena	US 12	Arterial	Apr-91	7900	0.5	8.7	5.7	
MT	Thompson Fall	Preston	Local	Apr-91	920	1.2	15.7	6.3	4 samples, range: 0.3 - 4.0
MT	Thompson Fall	Highway 200	Collector	4/4/91	5000	2	13.4	14.7	2 samples, range: 1.1 - 2.2
MT	Libby	Main Ave 4th &	Collector	Apr-91	530	3.5	44	7.8	2 samples, range: 2.5 - 4.4
MT	Libby	US 2	Arterial	Apr-91	12945	11.8	20.5	57.2	4 samples, range: 1.2 - 22.9
MT	Kalispell	3rd btwn Main & 1	Collector	4/14/91	2653	15.1	37.1	40.9	
MT	Columbia Fall	Nucleus	Collector	Apr-91	5670	9	19.8	47.6	
MT	Kalispell	Main	Arterial	4/14/91	14730	13	44.5	29.4	
MT	Columbia Fall	Nucleus	Collector	May-91	5670	2.4	17.5	15.9	4 samples, range: 1.3 - 3.8
MT	Columbia Fall	US 2	Arterial	May-91	14712	5.5	20.7	24.8	5 samples, range: 1.5 - 14.2
MT	Libby	Main Ave 4th &	Collector	5/19/91	530	1.7	31	5.7	
MT	Libby	Main Ave 4th &	Collector	6/27/91	530	1.7	24.3	7.1	
MT	Libby	US 2	Arterial	6/27/91	10000	3.8	12.6	30.6	
MT	East Helena	Morton	Local	Jul-91	250	1.7	11.4	15.3	
MT	East Helena	Main	Collector	Jul-91	2316	8.8	11	79.7	
MT	Thompson Fall	Preston	Local	7/9/91	920	10.9	11	98.7	
MT	Thompson Fall	Highway 200	Collector	7/9/91	5000	2.1	8.1	25.9	
MT	Helena	Montana	Arterial	7/17/91	21900	0.9	4.7	19.4	
MT	Butte	Texas	Collector	7/26/91	3070	2.5	28.2	8.9	
MT	Butte	Harrison	Arterial	7/26/91	22849	1.6	28.2	5.8	
MT	Kalispell	3rd btwn Main & 1	Collector	8/3/91	2653	5.8	23	25.3	

TABLE A2-1. (continued)

STATE	CITY	STREET	CLASS	DATE	ADT	SILT LOADING (g/m*m)	SILT %	TOTAL LOADING (g/m*m)	SILT LOADING SUMMARY
MT	Kalispell	Main	Arterial	8/3/91	14730	4	21	19.3	
MT	Columbia Fall	US 2	Arterial	8/11/91	15890	0.1	5.6	2.3	
MT	Missoula	Russel btwn 4th &	Road	8/30/91	5270	1.6	8.3	19.3	
MT	East Helena	US 12	Arterial	8/30/91	7900	7	20.5	34.3	
MT	Butte	Texas	Collector	10/3/91	3070	1	17.7	5.4	
MT	Butte	Harrison	Arterial	10/3/91	22849	2.1	23.1	9.1	
MT	Kalispell	3rd btwn Main & 1	Collector	10/6/91	2653	10	31.3	31.9	
MT	Kalispell	Main	Arterial	10/6/91	14730	4.3	27.7	15.7	
MT	East Helena	Morton	Local	10/16/91	250	1.8	31	5.9	
MT	East Helena	Main St	Collector	10/16/91	2316	1.6	20.5	7.7	
MT	East Helena	US 12	Arterial	10/16/91	7900	1	6.7	14.9	
MT	Columbia Fall	Nucleus	Collector	10/20/91	5670	1.9	13.9	13.3	
MT	Columbia Fall	US 2	Arterial	10/20/91	15890	1.2	11.3	10.2	
MT	Kalispell 3r	d btwn Main & 1	Collector	11/6/91	2653	2.2	12.3	17.8	
MT	Kalispell	Main	Arterial	11/28/91	14730	2.7	8.6	30.8	
MT	Thompson Fall	Preston	Local	12/17/91	920	4	18.1	22.5	
MT	Thompson Fall	Highway 200	Collector	12/17/91	5000	1.5	13.2	11.6	
MT	Butte	Texas	Collector	2/2/92	3070	19.1	11.6	164.5	
MT	Butte	Harrison	Arterial	2/2/92	22849	8.3	12	69.3	
MT	East Helena	Morton	Local	2/3/92	250	78.3	9.5	824.7	
MT	Libby	W 4th St	Local	2/3/92	350	36.3	56.3	64.5	
MT	Libby	Main Ave 4th &	Collector	2/3/92	530	10.7	49.9	21.4	
MT	East Helena	Main St	Collector	2/3/92	2316	57.9	14.8	391	
MT	Columbia Fall	Nucleus	Collector	2/3/92	5670	29.2	20.1	145.4	
MT	Columbia Fall	US 2	Arterial	Feb-92	12945	51.3	32.2	143.1	2 samples, range: 13.0 - 89.5
MT	East Helena	US 12	Arterial	2/3/92	7900	2.9	14.3	20.7	
MT	Thompson Fall	Preston	Local	2/22/92	920	0.5	18	2.6	
MT	Thompson Fall	Highway 200	Collector	2/22/92	5000	1.2	14.6	8.1	
MT	Kalispell	3rd btwn 2nd & 3r	Local	3/15/92	450	40.2	11.9	338	
MT	Kalispell	3rd btwn Main & 1	Collector	3/15/92	2653	81.1	37.3	217.3	
MT	Kalispell	Main	Arterial	3/15/92	14730	16.5	32.1	51.3	
MT	Thompson Fall	Preston	Local	Apr-92	920	0.43	14.9	3.2	
MT	Thompson Fall	Highway 200	Collector	Apr-92	5000	0.8	18.2	4.7	3 samples, range: 0.4 - 1.0
MT	Kalispell	3rd btwn 2nd & 3r	Local	4/26/92	450	20.9	45.8	45.5	
MT	Kalispell	3rd btwn Main & 1	Collector	4/26/92	2653	19.2	50.9	37.7	

TABLE A2-1. (continued)

STATE	CITY	STREET	CLASS	DATE	ADT	SILT LOADING (g/m*m)	SILT %	TOTAL LOADING (g/m*m)	SILT LOADING SUMMARY
MT	Kalispell	Main	Arterial	4/26/92	14730	10.7	33.5	32.1	
MT	Kalispell	3rd btwn 2nd & 3r	Local	May-92	450	8.3	35.6	23.5	3 samples, range: 6.6 - 10.3
MT	Kalispell	3rd btwn Main & 1	Collector	May-92	2653	8.5	32.4	25.8	3 samples, range: 6.3 - 11.4
MT	Kalispell	Main	Arterial	May-92	14730	5.1	23.6	21.7	3 samples, range: 3.8 - 5.9
MT	Libby	W 4th St	Local	5/11/92	350	13.4	56.5	23.7	
MT	Libby	Main Ave 4th &	Collector	5/11/92	530	5.6	58.9	9.4	
MT	Libby	US 2	Arterial	May-92	12945	10.4	25.6	29.4	
MT	East Helena	Morton	Local	5/15/92	250	6.9	6.7	103	
MT	East Helena	Main St	Collector	5/15/92	2316	6.4	10.2	62.8	
MT	East Helena	US 12	Arterial	5/15/92	7900	1.2	6.9	17	
MT	Columbia Fall	Nucleus	Collector	5/25/92	5670	1	21.7	4.5	
MT	Missoula	Inez btwn 4th & 5	Local	6/4/92	500	1	17.4	5.6	
MT	Missoula	Russel btwn 3rd &	Collector	6/4/92	5270	15.2	14	108.4	
MT	Missoula	3rd btwn Prince &	Arterial	6/4/92	12000	2	13.1	15.7	
The following data from		Reference 2 & 3							
CO	Denver	E. Colfax	Principal Arte	Mar-89	1994 *	0.21	2	19.9	4 samples, range: 0.04-0.47
CO	Denver	E. Colfax	Principal Arte	Apr-89	2228 *	0.73	1.7	106.7	18 samples, range: 0.08-1.78
CO	Denver	York St	Principal Arte	Apr-89	780 *	0.86	1.2	74.8	2 samples, range: 0.83 - 0.89
CO	Denver	E. Belleview	Principal Arte	Apr-89	-----	0.07	4.2	2	3 samples, range: 0.03-0.09
CO	Denver	I-225	Expressway +	Apr-89	4731 *	0.02	3.6	0.4	3 samples, range: 0.01-0.02
CO	Denver	W. Evans	Principal Arte	May-89	1905 *	0.76	1.9	74	11 samples, range: 0.03 - 2.24
CO	Denver	W. Evans	Principal Arte	Jun-89	1655 *	0.71	1.2	66.1	12 samples, range: 0.07 - 3.34
CO	Denver	E. Louisiana	Minor Arterial	Jun-89	515 *	0.14	4.66	3.5	5 samples, range: 0.08 - 0.24
The following data from		Reference 4 & 3							
CO	Denver	E. Louisiana	Minor Arterial	Jan-90	-----	1.44 *	-----	-----	6 samples, range: 0.12-2.0
CO	Denver	E. Jewell Ave	Collector +	1/24/90	-----	2.24 *	-----	-----	
CO	Denver St	ate Highway 36	Expressway +	1/30/90	-----	0.56 *	-----	-----	2 samples, range: 0.56 - 0.56
CO	Denver St	ate Highway 36	Expressway +	2/1/90	--;--	1.92 *	-----	-----	4 samples, range: 1.92-1.92
CO	Denver	W. Evans Ave	Principal Arte	2/3/90	-----	1.64 *	-----	-----	2 samples, range: 1.64-1.64

TABLE A2-1. (continued)

STATE	CITY	STREET	CLASS	DATE	ADT	SILT LOADING (g/m*m)	SILT %	TOTAL LOADING (g/m*m)	SILT LOADING SUMMARY
CO	Denver	E. Mexico St	Local +	2/7/90	-----	2.58 *	-----	-----	3 samples, range: 2.58 - 2.58
CO	Denver	E. Colfax Ave	Principal Arte	Feb-90	-----	0.09 *	-----	-----	16 samples, range: 0.02 - 0.17
CO	Denver St	ate Highway 36	Expressway +	Mar-90	-----	-----	-----	-----	7 samples
CO	Denver E.	Louisiana Ave	Minor Arterial	3/10/90	-----	-----	-----	-----	3 samples
CO	Denver	W. Evans Ave	Principal Arte	Mar-90	-----	1.27 *	-----	-----	5 samples, range: 0.07 - 3.38
CO	Denver	W. Colfax Ave	Principal Arte	Mar-90	-----	0.41 *	-----	-----	21 samples, range: 0.04 - 2.61
CO	Denver	Parker Rd	Local +	Apr-90	-----	0.05 *	-----	-----	6 samples, range: 0.01 - 0.11
CO	Denver	W. Byron Pl	Principal Arte	Apr-90	-----	0.3 *	-----	-----	6 samples, range: 0.21 - 0.35
CO	Denver	E. Colfax Ave	Principal Arte	4/18/90	-----	0.21 *	-----	-----	
The following data from		Reference 5							
UT	Salt Lake Cou	700 East	Arterial	*	42340	0.137	11.5	1.187	4 samples, range: 0.107-0.162
UT	Salt Lake Cou	State St	Collector	*	27140	0.288	17	1.692	4 samples, range: 0.212-0.357
UT	Salt Lake Cou	I-80	Freeway	*	77040	0.023	21.4	0.1	5 samples, range: 0.011 - 0.034
UT	Salt Lake Cou	I-15	Freeway	*	146180	0.096	23.5	0.419	6 samples, range: 0.078 - 0.126
UT	Salt Lake Cou	400 East	Local	*	5000	1.967	4.07	46.043	14 samples, range: 0.177 - 5.772
The following data from		Reference 6							
NV	Las Vegas	Lake Mead	Major	7/15/87	-----	0.81	12.4	6.51	
NV	Las Vegas	Perliter	Local	7/15/87	-----	2.23	31.2	7.14	
NV	Las Vegas	Bruce	Collector	7/15/87	-----	1.64	26.1	6.3	
NV	Las Vegas	Stewart	Major	9/29/87	-----	0.38	24	1.63	3 samples, range: 0.24 - 0.46
NV	Las Vegas	Ambler	Local	9/29/87	-----	1.38	23	6.32	3 samples, range: 0.64 - 2.00
NV	Las Vegas	28th St	Collector	9/29/87	-----	0.52	15.8	3.4	3 samples, range: 0.51 - 0.54
NV	Las Vegas	Lake Mead	Major	10/7/87	-----	0.19	14.9	1.26	2 samples, range: 0.17 - 0.20

TABLE A2-1. (continued)

STATE	CITY	STREET	CLASS	DATE	ADT	SILT LOADING (g/m*m)	SILT %	TOTAL LOADING (g/m*m)	SILT LOADING SUMMARY
NV	Las Vegas	Perliter	Local	10/7/87	-----	1.5	31.9	4.76	2 samples, range: 1.48 - 1.52
NV	Las Vegas	Bruce	Collector	10/7/87	-----	0.9	24.1	3.74	2 samples, range: 0.76 - 1.03
The following data from		Reference 7							
AZ	Phoenix	Broadway	Arterial	*	-----	0.127	12.2	1.071	
AZ	Phoenix	South Central	Arterial	*	-----	0.085	5	1.726	
AZ	Phoenix	Indian School & 2	Arterial	*	-----	0.035	3.1	1.021	
AZ	Glendale	43rd & Vista	Arterial	*	-----	0.042	3.9	1.049	
AZ	Glendale	59th & Peoria	Arterial	*	-----	0.099	8.2	1.183	
AZ	Mesa	Mesa Drive	Arterial	*	-----	0.099	8.9	1.085	
AZ	Mesa	E. McKellips & Ol	Arterial	*	-----	0.014	17	0.092	
AZ	Phoenix	17th & Highland	Collector	*	-----	0.028	13.4	0.232	
AZ	Mesa	3rd & Miller	Collector	*	-----	0.07	11.8	0.627	
AZ	Phoenix	Avalon & 25th	Collector	*	-----	0.528	11.1	4.79	
AZ	Phoenix	Apache	Collector	*	-----	0.282	6.4	4.367	
AZ	Phoenix	28th St & E. G	Collector	*	-----	0.035	2.3	1.479	
AZ	Pima County	6th Ave	Collector	*	-----	1.282	6.417	19.961	
AZ	Pima County	Speedway Blvd	Arterial	*	-----	0.401	8.117	4.937	
AZ	Pima County	22nd St	Arterial	*	-----	0.028	16.529	0.176	
AZ	Pima County	Amklam Rd	Collector	*	-----	0.014	5.506	0.197	
AZ	Pima County	Fort Lowel Rd	Arterial	*	-----	0.113	3.509	3.268	
AZ	Pima County	Oracle Rd	Arterial	*	-----	0.014	1.556	0.725	
AZ	Pima County	Inn Rd	Arterial	*	-----	0.021	18.756	0.127	
AZ	Pima County	Orange Grove	Arterial	*	-----	0.162	21.989	0.725	
AZ	Pima County	La Canada	Arterial	*	-----	0.106	3.975	2.571	
The following data from		Reference 8							
KS	Kansas City	7th	Arterial	Feb-80	-----	0.29	6.8	4.2	3 samples, range: 0.15 - 0.46
MO	Kansas City	Volker	Arterial	Feb-80	-----	0.67	20.1	3.5	3 samples, range: 0.43 -1.00
MO	Kansas City	Rockhill	Arterial	Feb-80	-----	0.68	21.7	3.3	
KS	Tonganoxie	4th	Collector	Mar-80	-----	2.5	14.5	17.1	
KS	Kansas City	7th	Arterial	Mar-80	-----	0.29	12.2	2.4	
MO	St. Louis	I-44	Expressway	May-80	-----	0.02	-----	-----	4 samples, range: 0.02

TABLE A2-1. (continued)

STATE	CITY	STREET	CLASS	DATE	ADT	SILT LOADING (g/m*m)	SILT %	TOTAL LOADING (g/m*m)	SILT LOADING SUMMARY
MO	St. Louis	Kingshighway	Collector	May-80	-----	0.08	10.9	0.7	3 samples, range: 0.05 - 0.11
IL	GraniteCity	24th	Arterial	May-80	-----	0.78	6.4	12.3	2 samples, range: 0.73 - 0.83
IL	GraniteCity	Benton	Collector	May-80	-----	0.93	8.6	10.8	
The following data from		Reference 9							
MN	Duluth	US53north	Highway	3/19/92	5000	0.23	28	1.94	8 samples, range: 0.04 - 0.77
MN	Duluth	US53south	Highway	2/26/92	5000	0.24	13.4	2.3	5 samples, range: 0.05 - 0.37
The following data from		Reference 10							
CO	Aspen	Aspen	Local	3/18/92	-----	3.56 *	24	14.81	* Samples said to be wet sieved
CO	Aspen	Aspen	Collector	3/30/92	-----	12.05 *	24	50.23	
CO	Aspen	Aspen	Collector	4/1/92	-----	5.97 *	21.1	29.16	8 samples, range: 2.65 - 9.10
CO	Aspen	Highway 82	Major Arterial	-4/6/92	-----	6.1 *	12	50.08	2 samples, range: 4.55 - 7.65
CO	Aspen	Knollwood	Local	4/1/92	-----	7.9 *	8	96.01	2 samples, range: 5.21 - 10.59
CO	Aspen	Main	Major Arterial	4/2/92	-----	7.68 *	21.7	35.9	3 samples, range: 5.58 - 9.30
CO	Aspen	Maroon Creek Rd	Minor Arterial	3/30/92	-----	2.07 *	9	23.03	
CO	Aspen	Maroon Creek Rd	Minor Arterial	4/1/92	-----	2.78 *	8.9	30.35	7 samples, range: 0.96 - 6.41
CO	Aspen	South Mill	Collector	4/1/92	-----	9.05 *	25	36.21	

"-----" denotes missing information.

TABLE A2-2. PUBLIC PAVED ROAD SURFACE LOADING DATA BASE

STATE	CLASS	DATE	ADT	SL	SILT	TL	# SAMPLES
MT	1	Apr-78	50	0.6	18.5	3.4	1
MT	2	Apr-78	115	0.5	14.3	3.5	1
MT	2	Apr-78	4000	8.4	33.9	24.9	1
MT	2	Apr-78	679	24.6	10.6	232.4	1
MT	2	Apr-78	60	103.7	7	1480.8	1
MT	3	Apr-78	6453	1.6	19.1	13.05	2
MT	3	Apr-78	3328	7.7	7.7	99.5	1
MT	3	Apr-78	3655	26	62.9	6	1
MT	4	Apr-78	22849	1.9	5	37.3	1
MT	4	Apr-78	18870	1.9	55.9	3.3	1
MT	4	Apr-78	13529	0.8	6.6	11.9	1
MT	2	Apr-83	140	13.1	4.3	305.2	1
MT	5	Apr-83	780	4	13.6	29	1
MT	3	Apr-83	2700	8.2	9.4	86.6	1
MT	3	Apr-83	1360	4.7	8.4	55.3	1
MT	5	Mar-88	1310	.	14.8	.	1
MT	5	Mar-88	331	.	16.5	.	1
MT	3	Mar-88	800	.	27.5	.	1
MT	3	Mar-88	5900	7	16	43.5	1
MT	3	Mar-88	536	61	20.4	299.2	1
MT	3	Mar-88	4500	.	12.1	.	1
MT	4	Mar-88	10850	.	12.3	.	1
MT	2	Apr-88	562	2.1	10.9	19.3	1
MT	4	Apr-88	5272	0.9	10.1	8.8	1
MT	2	Jun-89	562	1	8.7	11.2	1
MT	2	Jun-89	60	2.8	10.9	25.5	1
MT	4	Jun-89	5272	7.2	3.6	197.6	1
MT	5	Aug-89	250	1.7	6.8	24.6	1
MT	3	Aug-89	2316	0.7	4.1	17	1
MT	4	Aug-89	7900	2.1	12.5	16.5	1
MT	2	Mar-90	390	.	9.5	.	1
MT	2	Mar-90	400	18.8	14.3	131.5	1
MT	2	Mar-90	50	.	14.3	.	1
MT	2	Mar-90	1720	.	5.4	.	1

TABLE A2-2. (continued)

STATE	CLASS	DATE	ADT	SL	SILT	TL	# SAMPLES
MT	5	Mar-90	240	.	16.3	.	1
MT	3	Mar-90	1510	.	8.8	.	1
MT	3	Mar-90	1945	.	7	.	1
MT	3	Mar-90	4730	15.4	10	153.9	1
MT	3	Mar-90	316	.	6.2	.	1
MT	3	Mar-90	1764	.	4.2	.	1
MT	4	Mar-90	13110	2.7	18.7	14.6	1
MT	2	Jul-90	250	1.6	17	9.3	1
MT	3	Jul-90	2316	5.6	10.6	52.5	1
MT	4	Jul-90	790	3.2	15.4	20.9	1
MT	5	Aug-90	400	1.5	4	37.7	1
MT	3	Aug-90	530	2.4	17.9	13.2	1
MT	3	Aug-90	5730	0.8	5.3	16	1
MT	4	Aug-90	13039	0.2	7	2.9	1
MT	5	Oct-90	250	3.4	10.2	33.6	1
MT	3	Oct-90	2316	4.5	5.6	81.3	1
MT	4	Oct-90	7900	0.6	13.9	4.3	1
MT	3	11/6/90	5670	5.2	13.5	38	1
MT	4	11/6/90	15890	1.7	24.1	7.2	1
MT	4	12/8/90	10000	21.5	9.6	223.9	1
MT	3	12/9/90	530	13.6	27.1	50.3	1
MT	3	12/13/90	3070	1	15.4	6.4	1
MT	5	Jan-91	75	1	3.4	30.6	1
MT	5	Jan-91	425	12	1.8	666.5	1
MT	5	Jan-91	250	14.1	3.5	402.3	1
MT	3	Jan-91	2316	36.7	12.1	303.4	1
MT	4	Jan-91	7900	0.8	14	5.6	1
MT	5	1/23/91	920	9.2	9.9	93	1
MT	3	1/23/91	5000	33.3	27.2	122.2	1
MT	5	Feb-91	150	21.6	7.1	304.7	1
MT	3	Feb-91	2140	19.2	9	213.4	1
MT	3	Feb-91	850	74.4	7.7	966.8	1
MT	3	2/14/91	530	33.3	18.7	178.2	1
MT	4	2/17/91	10000	69.3	21	330.3	1

TABLE A2-2. (continued)

STATE	CLASS	DATE	ADT	SL	SILT	TL	# SAMPLES
MT	3	2/21/91	3070	1.2	11	10.9	1
MT	4	2/21/91	22849	2.9	7.9	36.6	1
MT	3	2/24/91	2653	30.5	24.8	122.9	1
MT	4	2/24/91	14730	17.4	20.4	85.2	1
MT	5	2/25/91	920	35.7	17.9	199.6	1
MT	3	2/25/91	5000	66.8	17.8	375.3	1
MT	4	Mar-91	21900	15.4	6.2	248.3	1
MT	3	3/9/91	2653	39.1	29.1	134.5	1
MT	3	Mar-91	5670	30.1	17	174.6	2
MT	4	3/9/91	14730	17.6	24.7	71.4	1
MT	5	Mar-91	920	4.4	8.3	51	2
MT	3	Mar-91	5000	4.3	15.5	28.9	2
MT	3	Mar-91	530	14.8	33.1	44.9	2
MT	4	Mar-91	11963	20	19.5	111.9	3
MT	5	Apr-91	250	4.3	8.8	48.7	1
MT	4	Apr-91	7900	0.5	8.7	5.7	1
MT	5	Apr-91	920	1.2	15.7	6.3	4
MT	3	4/4/91	5000	2	13.4	14.7	2
MT	3	Apr-91	530	3.5	44	7.8	2
MT	4	Apr-91	12945	11.8	20.5	57.2	4
MT	3	4/14/91	2653	15.1	37.1	40.9	1
MT	3	Apr-91	5670	9	19.8	47.6	1
MT	4	4/14/91	14730	13	44.5	29.4	1
MT	3	May-00	5670	2.4	17.5	15.9	4
MT	4	50	14712	5.5	20.7	24.8	5
MT	3	5/19/91	530	1.7	31	5.7	1
MT	3	6/27/91	530	1.7	24.3	7.1	1
MT	4	6/27/91	10000	3.8	12.6	30.6	1
MT	5	Jul-91	250	1.7	11.4	15.3	1
MT	3	Jul-91	2316	8.8	11	79.7	1
MT	5	7/9/91	920	10.9	11	98.7	1
MT	3	7/9/91	5000	2.1	8.1	25.9	1
MT	4	7/17/91	21900	0.9	4.7	19.4	1
MT	3	7/26/91	3070	2.5	28.2	8.9	1

TABLE A2-2. (continued)

STATE	CLASS	DATE	ADT	SL	SILT	TL	# SAMPLES
MT	4	7/26/91	22849	1.6	28.2	5.8	1
MT	3	8/3/91	2653	5.8	23	25.3	1
MT	4	8/3/91	14730	4	21	19.3	1
MT	4	8/11/91	15890	0.1	5.6	2.3	1
MT	3	8/3/91	5270	1.6	8.3	19.3	1
MT	4	8/3/91	7900	7	20.5	34.3	1
MT	3	10/3/91	3070	1	17.7	5.4	1
MT	4	10/3/91	22849	2.1	23.1	9.1	1
MT	3	10/6/91	2653	10	31.3	31.9	1
MT	4	10/6/91	14730	4.3	27.7	15.7	1
MT	5	10/16/91	250	1.8	31	5.9	1
MT	3	10/16/91	2316	1.6	20.5	7.7	1
MT	4	10/16/91	7900	1	6.7	14.9	1
MT	3	10/20/91	5670	1.9	13.9	13.3	1
MT	4	10/20/91	15890	1.2	11.3	10.2	1
MT	3	11/6/91	2653	2.2	12.3	17.8	1
MT	4	11/28/91	14730	2.7	8.6	30.8	1
MT	5	12/17/91	920	4	18.1	22.5	1
MT	3	12/17/91	5000	1.5	13.2	11.6	1
MT	3	2/2/92	3070	19.1	11.6	164.5	1
MT	4	2/2/92	22849	8.3	12	69.3	1
MT	5	2/3/92	250	78.3	9.5	824.7	1
MT	5	2/3/92	350	36.3	56.3	64.5	1
MT	3	2/3/92	530	10.7	49.9	21.4	1
MT	3	2/3/92	2316	57.9	14.8	391	1
MT	3	2/3/92	5670	29.2	20.1	145.4	1
MT	4	Feb-92	12945	51.3	32.2	143.1	2
MT	4	2/3/92	7900	2.9	14.3	20.7	1
MT	5	Feb-92	920	0.5	18	2.6	1
MT	3	2/22/92	5000	1.2	14.6	8.1	1
MT	5	3/15/92	450	40.2	11.9	338	1
MT	3	3/15/92	2653	81.1	37.3	217.3	1
MT	4	3/15/92	14730	16.5	32.1	51.3	1
MT	5	Apr-92	920	0.43	14.9	3.2	1

TABLE A2-2. (continued)

STATE	CLASS	DATE	ADT	SL	SILT	TL	# SAMPLES
MT	3	Apr-92	5000	0.8	18.2	4.7	3
MT	5	4/26/92	450	20.9	45.8	45.5	1
MT	3	4/26/92	2653	19.2	50.9	37.7	1
MT	4	4/26/92	14730	10.7	33.5	32.1	1
MT	5	May-92	450	8.3	35.6	23.5	3
MT	3	May-92	2653	8.5	32.4	25.8	3
MT	4	May-92	14730	5.1	23.6	21.7	3
MT	5	5/11/92	350	13.4	56.5	23.7	1
MT	3	5/11/92	530	5.6	58.9	9.4	1
MT	4	May-92	12945	10.4	25.6	29.4	1
MT	5	5/15/92	250	6.9	6.7	103	1
MT	3	5/15/92	2316	6.4	10.2	62.8	1
MT	4	5/15/92	7900	1.2	6.9	17	1
MT	3	5/25/92	5670	1	21.7	4.5	1
MT	5	6/4/92	500	1	17.4	5.6	1
MT	3	6/4/92	5270	15.2	14	108.4	1
MT	4	6/4/92	12000	2	13.1	15.7	1
CO	6	Mar-89	1994	0.21	2	19.9	4
CO	6	Apr-89	2228	0.73	1.7	106.7	18
CO	6	Apr-89	780	0.86	1.2	74.8	2
CO	6	Apr-89	.	0.07	4.2	2	3
CO	7	Apr-89	4731	0.02	3.6	0.4	3
CO	6	May-89	1905	0.76	1.9	74	11
CO	6	Jun-89	1655	0.71	1.2	66.1	12
CO	8	Jun-89	515	0.14	4.66	3.5	5
CO	8	Oct-90	.	1.44	.	.	6
CO	3	1/24/90	.	2.24	.	.	1
CO	7	1/30/90	.	0.56	.	.	2
CO	7	2/1/90	.	1.92	.	.	4
CO	6	2/3/90	.	1.64	.	.	2
CO	5	2/7/90	.	2.58	.	.	3
CO	6	Feb-90	.	0.9	.	.	16
CO	7	Mar-90	.	.	.	.	7
CO	8	3/10/90	.	.	.	.	3

TABLE A2-2. (continued)

STATE	CLASS	DATE	ADT	SL	SILT	TL	# SAMPLES
CO	6	Mar-90	.	1.27	.	.	5
CO	6	Mar-90	.	0.41	.	.	21
CO	5	Apr-90	.	0.05	.	.	6
CO	6	Apr-90	.	0.3	.	.	6
CO	6	4/18/90	.	0.21	.	.	1
UT	4	.	42340	0.137	11.5	1.187	4
UT	3	.	27140	0.288	17	1.692	4
UT	9	.	77040	0.023	21.4	0.1	5
UT	9	.	146180	0.096	23.5	0.419	6
UT	5	.	5000	1.967	4.07	46.043	14
NV	10	7/15/87	.	0.81	12.4	6.51	1
NV	5	7/15/87	.	2.23	31.2	7.14	1
NV	3	7/15/87	.	1.64	26.1	6.3	1
NV	10	9/29/87	.	0.38	24	1.63	3
NV	5	9/29/87	.	1.38	23	6.32	3
NV	3	9/29/87	.	0.52	15.8	3.4	3
NV	10	10/7/87		0.19	14.9	1.26	2
NV	5	10/7/87	.	1.5	31.9	4.76	2
NV	3	10/7/87	.	0.9	24.1	3.74	2
AZ	4	.	.	0.127	12.2	1.071	1
AZ	4	.	.	0.085	5	1.726	1
AZ	4	.	.	0.035	3.1	1.021	1
AZ	4	.	.	0.042	3.9	1.049	1
AZ	4	.	.	0.099	8.2	1.183	1
AZ	4	.	.	0.099	8.9	1.085	1
AZ	4	.	.	0.014	17	0.092	1
AZ	3	.	.	0.028	13.4	0.232	1
AZ	3	.	.	0.07	11.8	0.627	1
AZ	3	.	.	0.528	11.1	4.79	1
AZ	3	.	.	0.282	6.4	4.367	1
AZ	3	.	.	0.035	2.3	1.479	1
AZ	3	.	.	1.282	6.417	19.961	1
AZ	4	.	.	0.401	8.117	4.937	1
AZ	4	.	.	0.028	16.529	0.176	1

TABLE A2-2. (continued)

STATE	CLASS	DATE	ADT	SL	SILT	TL	# SAMPLES
AZ	3	.	.	0.014	5.506	0.197	1
AZ	4	.	.	0.113	3.509	3.268	1
AZ	4	.	.	0.014	1.556	0.725	1
AZ	4	.	.	0.021	18.756	0.127	1
AZ	4	.	.	0.162	21.989	0.725	1
AZ	4	.	.	0.106	3.975	2.571	1
KS	4	Feb-80	.	0.29	6.8	4.2	3
MO	4	Feb-80	.	0.67	20.1	3.5	3
MO	4	Feb-80	.	0.68	21.7	3.3	1
KS	3	Mar-80	.	2.5	14.5	17.1	1
KS	4	Mar-80	.	0.29	12.2	2.4	1
MO	7	May-80		0.02	.	.	4
MO	3	May-80		0.08	10.9	0.7	3
IL	4	May-80		0.78	6.4	12.3	2
IL	3	May-80		0.93	8.6	10.8	1
MN	11	3/19/92	5000	0.23	28	1.94	8
MN	11	2/26/92	5000	0.24	13.4	2.3	5
CO	5	3/18/92		3.56	24	14.81	1
CO	3	3/30/92	.	12.05	24	50.23	1
CO	3	4/1/92	.	5.97	21.1	29.16	8
CO	10	4/6/92	.	6.1	12	50.08	2
CO	5	4/1/92		7.9	8	96.01	2
CO	10	4/2/92	.	7.68	21.7	35.9	3
CO	8	3/30/92	.	2.07	9	23.03	1
CO	8	4/1/92	.	2.78	8.9	30.35	7
CO	3	4/1/92	.	9.05	25	36.21	1

Attachment 3

New Silt Loading Data Set Used to Develop Revised Default Silt Loading Values

TABLE A3-1. NEW PUBLIC PAVED ROAD SILT LOADING DATA SET

State	Reference	Location	Date	Silt loading, g/m2	ADT	Posted speed limit	Road/Comments
NV	BACM11	Las Vegas	Apr-95	0.084	LOW	NA	Composite of 4 roads of the same class
NV	BACM11	Las Vegas	Jun-95	0.097	LOW	NA	Repeat sample of above roads
NV	BACM11	Las Vegas	Apr-95	0.052	HIGH	NA	Composite of 4 roads of the same class
NV	BACM11	Las Vegas	Jun-95	0.033	HIGH	NA	Repeat sample of above roads
NV	BACM12	Las Vegas	Jun-95	1.270	LOW	NA	Composite of 4 roads of the same class
NV	BACM12	Las Vegas	Jun-95	0.029	HIGH	NA	Composite of 4 roads of the same class
NV	BACM13	Las Vegas	Jun-95	0.280	LOW	NA	Composite of 4 roads of the same class
NV	BACM13	Las Vegas	Jun-95	0.200	HIGH	NA	Composite of 4 roads of the same class
CA	BACM21	South Coast	Apr-95	0.184	LOW	NA	Composite of 4 roads of the same class
CA	BACM21	South Coast	Jun-95	0.054	LOW	NA	Repeat sample of above roads
CA	BACM21	South Coast	Apr-95	0.012	HIGH	NA	Composite of 4 roads of the same class
CA	BACM21	South Coast	Jun-95	0.015	HIGH	NA	Repeat sample of above roads
CA	BACM22	South Coast	Jun-95	0.170	LOW	NA	Composite of 4 roads of the same class
CA	BACM22	South Coast	Jun-95	0.011	HIGH	NA	Composite of 4 roads of the same class
CA	BACM23	South Coast	Jun-95	0.140	LOW	NA	Composite of 4 roads of the same class
CA	BACM23	South Coast	Jun-95	0.046	HIGH	NA	Composite of 4 roads of the same class
CA	BACM31	Bakersfield	Apr-95	0.520	LOW	NA	Composite of 4 roads of the same class
CA	BACM31	Bakersfield	Jul-95	0.190	LOW	NA	Repeat sample of above roads
CA	BACM31	Bakersfield	Apr-95	0.054	HIGH	NA	Composite of 4 roads of the same class
CA	BACM31	Bakersfield	Jul-95	0.015	HIGH	NA	Repeat sample of above roads
CA	BACM32	Bakersfield	Jul-95	0.940	LOW	NA	Composite of 4 roads of the same class
CA	BACM32	Bakersfield	Jul-95	0.051	HIGH	NA	Composite of 4 roads of the same class
CA	BACM33	Bakersfield	Jul-95	0.410	LOW	NA	Composite of 4 roads of the same class
CA	BACM33	Bakersfield	Jul-95	0.039	HIGH	NA	Composite of 4 roads of the same class
CA	BACM41	Coachella Valley	Apr-95	2.040	LOW	NA	Composite of 4 roads of the same class, visible trackout signs present
CA	BACM41	Coachella Valley	Jul-95	0.420	LOW	NA	Repeat sample of above roads
CA	BACM41	Coachella Valley	Apr-95	0.027	HIGH	NA	Composite of 4 roads of the same class
CA	BACM41	Coachella Valley	Jul-95	0.037	HIGH	NA	Repeat sample of above roads
CA	BACM42	Coachella Valley	Jul-95	0.350	LOW	NA	Composite of 4 roads of the same class
CA	BACM42	Coachella Valley	Jul-95	0.082	HIGH	NA	Composite of 4 roads of the same class
CA	BACM43	Coachella Valley	Jul-95	0.200	LOW	NA	Composite of 4 roads of the same class
CA	BACM43	Coachella Valley	Jul-95	0.030	HIGH	NA	Composite of 4 roads of the same class

TABLE A3-1. (continued)

State	Reference	Location	Date	Silt loading, g/m2	ADT	Posted speed limit	Road/Comments
CA	SCAQMD	South Coast	Mar-90	0.117	MIXED	NA	Composite of 10 to 12 roads within a 5 km x 5 km area
CA	SCAQMD	South Coast	Mar-90	0.236	MIXED	NA	Composite of 10 to 12 roads within a 5 km x 5 km area
CA	SCAQMD	South Coast	Mar-90	0.720	MIXED	NA	Composite of 10 to 12 roads within a 5 km x 5 km area
CA	SCAQMD	South Coast	Mar-90	0.207	MIXED	NA	Composite of 10 to 12 roads within a 5 km x 5 km area
CA	SCAQMD	South Coast	Mar-90	0.438	MIXED	NA	Composite of 10 to 12 roads within a 5 km x 5 km area
CA	SCAQMD	South Coast	Mar-90	0.139	MIXED	NA	Composite of 10 to 12 roads within a 5 km x 5 km area
CA	SCAQMD	South Coast	Mar-90	0.180	MIXED	NA	Composite of 10 to 12 roads within a 5 km x 5 km area
CA	SCAQMD	South Coast	Mar-90	0.348	MIXED	NA	Composite of 10 to 12 roads within a 5 km x 5 km area
CA	SCAQMD	South Coast	Mar-90	0.112	MIXED	NA	Composite of 10 to 12 roads within a 5 km x 5 km area
CA	SCAQMD	South Coast	Mar-90	0.283	MIXED	NA	Composite of 10 to 12 roads within a 5 km x 5 km area
CA	SCAQMD	South Coast	Mar-90	1.830	MIXED	NA	Composite of 10 to 12 roads within a 5 km x 5 km area
CA	SCAQMD	South Coast	Mar-90	0.907	MIXED	NA	Composite of 10 to 12 roads within a 5 km x 5 km area
CA	SCAQMD	South Coast	Mar-90	0.260	MIXED	NA	Composite of 10 to 12 roads within a 5 km x 5 km area
OR	LAGRD	La Grande	May-91	0.770	MIXED	NA	Composite of 10 to 12 roads within the inventory area
OR	KFALLS	Klamath Falls	May-91	0.370	MIXED	NA	Composite of 10 to 12 roads within the inventory area
OR	GRPASS	Grants Pass	May-91	0.810	MIXED	NA	Composite of 10 to 12 roads within the inventory area
NV	RENO	Reno	Jan-95	0.520	2778	25	Purina
NV	RENO	Reno	Feb-95	0.810	2778	25	Purina
NV	RENO	Reno	Mar-95	0.400	2778	25	Purina
NV	RENO	Reno	Apr-95	0.690	2778	25	Purina
NV	RENO	Reno	May-95	0.890	2778	25	Purina
NV	RENO	Reno	Jun-95	0.910	2778	25	Purina
NV	RENO	Reno	Jul-95	0.550	2778	25	Purina
NV	RENO	Reno	Aug-95	1.520	2778	25	Purina
NV	RENO	Reno	Sep-95	0.920	2778	25	Purina
NV	RENO	Reno	Oct-95	0.290	2778	25	Purina
NV	RENO	Reno	Nov-95	0.390	2778	25	Purina
NV	RENO	Reno	Dec-95	0.330	2778	25	Purina
NV	RENO	Reno	Jan-95	0.300	511	25	Lonetree
NV	RENO	Reno	Feb-95	0.100	511	25	Lonetree
NV	RENO	Reno	Mar-95	0.330	511	25	Lonetree
NV	RENO	Reno	Apr-95	0.270	511	25	Lonetree
NV	RENO	Reno	May-95	0.200	511	25	Lonetree

TABLE A3-1. (continued)

State	Reference	Location	Date	Silt loading, g/m2	ADT	Posted speed limit	Road/Comments
NV	RENO	Reno	Jun-95	0.120	511	25	Lonetree
NV	RENO	Reno	Jul-95	0.120	511	25	Lonetree
NV	RENO	Reno	Aug-95	0.120	511	25	Lonetree
NV	RENO	Reno	Sep-95	0.090	511	25	Lonetree
NV	RENO	Reno	Oct-95	0.130	511	25	Lonetree
NV	RENO	Reno	Nov-95	0.170	511	25	Lonetree
NV	RENO	Reno	Dec-95	1.050	511	25	Lonetree
NV	RENO	Reno	Jan-95	0.260	1978	25	Forest
NV	RENO	Reno	Feb-95	0.160	1978	25	Forest
NV	RENO	Reno	Mar-95	0.100	1978	25	Forest
NV	RENO	Reno	Apr-95	0.180	1978	25	Forest
NV	RENO	Reno	May-95	0.250	1978	25	Forest
NV	RENO	Reno	Jun-95	0.140	1978	25	Forest
NV	RENO	Reno	Jul-95	0.190	1978	25	Forest
NV	RENO	Reno	Aug-95	0.110	1978	25	Forest
NV	RENO	Reno	Sep-95	0.280	1978	25	Forest
NV	RENO	Reno	Oct-95	0.160	1978	25	Forest
NV	RENO	Reno	Nov-95	0.110	1978	25	Forest
NV	RENO	Reno	Dec-95	0.110	1978	25	Forest
NV	RENO	Reno	Jan-95	0.230	1978	25	Forest
NV	RENO	Reno	Feb-95	1.310	2155	25	Freeport
NV	RENO	Reno	Mar-95	0.420	2155	25	Freeport
NV	RENO	Reno	Apr-95	2.890	2155	25	Freeport
NV	RENO	Reno	May-95	0.330	2155	25	Freeport
NV	RENO	Reno	Jun-95	0.720	2155	25	Freeport
NV	RENO	Reno	Jul-95	0.810	2155	25	Freeport
NV	RENO	Reno	Aug-95	1.030	2155	25	Freeport
NV	RENO	Reno	Sep-95	0.850	2155	25	Freeport
NV	RENO	Reno	Oct-95	0.420	2155	25	Freeport
NV	RENO	Reno	Nov-95	0.910	2155	25	Freeport
NV	RENO	Reno	Dec-95	0.680	2155	25	Freeport
NV	RENO	Reno	Jan-95	1.510	1578	25	Cashill
NV	RENO	Reno	Feb-95	6.820	1578	25	Cashill

TABLE A3-1. (continued)

State	Reference	Location	Date	Silt loading, g/m2	ADT	Posted speed limit	Road/Comments
NV	RENO	Reno	Mar-95	0.630	1578	25	Cashill
NV	RENO	Reno	Apr-95	0.480	1578	25	Cashill
NV	RENO	Reno	May-95	0.340	1578	25	Cashill
NV	RENO	Reno	Jun-95	0.340	1578	25	Cashill
NV	RENO	Reno	Jul-95	0.270	1578	25	Cashill
NV	RENO	Reno	Aug-95	0.140	1578	25	Cashill
NV	RENO	Reno	Sep-95	0.150	1578	25	Cashill
NV	RENO	Reno	Oct-95	0.190	1578	25	Cashill
NV	RENO	Reno	Nov-95	0.430	1578	25	Cashill
NV	RENO	Reno	Dec-95	0.550	1578	25	Cashill
NV	RENO	Reno	Feb-95	5.090	509	25	Ralston
NV	RENO	Reno	Mar-95	2.100	509	25	Ralston
NV	RENO	Reno	Apr-95	1.340	509	25	Ralston
NV	RENO	Reno	May-95	1.630	509	25	Ralston
NV	RENO	Reno	Jun-95	1.630	509	25	Ralston
NV	RENO	Reno	Jul-95	2.170	509	25	Ralston
NV	RENO	Reno	Aug-95	1.730	509	25	Ralston
NV	RENO	Reno	Sep-95	2.250	509	25	Ralston
NV	RENO	Reno	Oct-95	0.790	509	25	Ralston
NV	RENO	Reno	Nov-95	1.120	509	25	Ralston
NV	RENO	Reno	Dec-95	1.000	509	25	Ralston
NV	RENO	Reno	Jan-95	0.240	2396	25	Mayberry
NV	RENO	Reno	Apr-95	0.200	2396	25	Mayberry
NV	RENO	Reno	Jul-95	0.220	2396	25	Mayberry
NV	RENO	Reno	Oct-95	0.320	2396	25	Mayberry
NV	RENO	Reno	Jan-95	0.110	5135	25	Patriot
NV	RENO	Reno	Feb-95	0.860	5135	25	Patriot
NV	RENO	Reno	Mar-95	0.340	5135	25	Patriot
NV	RENO	Reno	Apr-95	0.460	5135	25	Patriot
NV	RENO	Reno	May-95	0.710	5135	25	Patriot
NV	RENO	Reno	Jun-95	0.230	5135	25	Patriot
NV	RENO	Reno	Jul-95	0.400	5135	25	Patriot
NV	RENO	Reno	Aug-95	0.370	5135	25	Patriot

TABLE A3-1. (continued)

State	Reference	Location	Date	Silt loading, g/m2	ADT	Posted speed limit	Road/Comments
NV	RENO	Reno	Sep-95	0.520	5135	25	Patriot
NV	RENO	Reno	Oct-95	0.450	5135	25	Patriot
NV	RENO	Reno	Nov-95	0.550	5135	25	Patriot
NV	RENO	Reno	Dec-95	0.460	5135	25	Patriot
NV	RENO	Reno	Jan-95	0.630	5135	25	W. 4th
NV	RENO	Reno	Apr-95	1.020	5135	25	W. 4th
NV	RENO	Reno	Jul-95	0.380	5135	25	W. 4th
NV	RENO	Reno	Oct-95	0.280	5135	25	W. 4th
NV	RENO	Reno	Jan-95	0.140	10170	35	Mill
NV	RENO	Reno	Apr-95	0.290	10170	35	Mill
NV	RENO	Reno	Jul-95	0.140	10170	35	Mill
NV	RENO	Reno	Oct-95	0.200	10170	35	Mill
NV	RENO	Reno	Jan-95	0.170	10521	45	Vista
NV	RENO	Reno	Apr-95	0.190	10521	45	Vista
NV	RENO	Reno	Jul-95	0.090	10521	45	Vista
NV	RENO	Reno	Oct-95	0.080	10521	45	Vista
NV	RENO	Reno	Jan-95	0.050	14441	45	N. McCarran
NV	RENO	Reno	Apr-95	0.050	14441	45	N. McCarran
NV	RENO	Reno	Jul-95	0.020	14441	45	N. McCarran
NV	RENO	Reno	Oct-95	0.010	14441	45	N. McCarran
NV	RENO	Reno	Jan-95	0.400	15566	50	Kietzke-G
NV	RENO	Reno	Apr-95	0.250	15566	50	Kietzke-G
NV	RENO	Reno	Jul-95	0.080	15566	50	Kietzke-G
NV	RENO	Reno	Oct-95	0.250	15566	50	Kietzke-G
NV	RENO	Reno	Jan-95	0.210	17425	25	Prater
NV	RENO	Reno	Apr-95	0.070	17425	25	Prater
NV	RENO	Reno	Jul-95	0.040	17425	25	Prater
NV	RENO	Reno	Oct-95	0.110	17425	25	Prater
NV	RENO	Reno	Jan-95	0.110	17854	40	S. McCarran
NV	RENO	Reno	Apr-95	0.250	17854	40	S. McCarran
NV	RENO	Reno	Jul-95	0.160	17854	40	S. McCarran
NV	RENO	Reno	Oct-95	0.330	17854	40	S. McCarran
NV	RENO	Reno	Jan-95	0.470	25199	40	Kietzke-P

TABLE A3-1. (continued)

State	Reference	Location	Date	Silt loading, g/m2	ADT	Posted speed limit	Road/Comments
NV	RENO	Reno	Apr-95	0.530	25199	40	Kietzke-P
NV	RENO	Reno	Jul-95	0.210	25199	40	Kietzke-P
NV	RENO	Reno	Oct-95	0.200	25199	40	Kietzke-P
NV	PM2.5 Study	Reno	Jun-96	0.082	HIGH	45	Virginia, North of Parr
NC	PM2.5 Study	Raleigh	May-96	0.060	HIGH	45	Western (3600 block)

NA = not applicable; shown for composite samples from several roads

SECTION 5

DRAFT AP-42 SECTION

A proposed new AP-42 section for paved roads is presented on the following pages as it would appear in the document.

11.2.x GENERIC PAVED ROADS

11.2.x.1 General

Particulate emissions occur whenever vehicles travel over a paved surface such as a road or parking lot. In general terms, particulate emissions from paved roads originate from the loose material present on the surface. In turn, that surface loading is continuously replenished by other sources. At industrial sites, surface loading is replenished by spillage of material and trackout from unpaved roads and staging areas. Figure 11.2.x-1 illustrates several transfer processes occurring on public streets.

Various field studies have found that public streets and highways as well as roadways at industrial facilities can be major sources of the atmospheric particulate matter within an area. Of particular interest in many parts of the United States are the increased levels of emissions from public paved roads when equilibrium between deposition and removal processes is upset. This situation can occur for various reasons, including application of snow and ice controls; carryout from construction activities in the area; and wind and/or water erosion from surrounding unstabilized areas.

11.2.x.2 Emissions And Correction Parameters

Dust emissions from paved roads have been found to vary with what is termed the "silt loading" present on the road surface as well as the average weight of vehicles traveling the road. The term "silt loading" refers to the mass of silt-size material (equal to or less than 75 microns in physical diameter) per unit area of the travel surface. The total road surface dust loading consists of loose material which can be collected by broom sweeping and vacuuming of the traveled portion of the paved road. The silt fraction is determined by measuring the proportion of the loose dry surface dust that passes a 200 mesh screen, using the ASTM-C-136 method. The product of the silt fraction and the total loading constitutes the "silt loading" and is abbreviated as "sL." Additional details on the sampling and analysis are provided in Appendices D and E.

The surface silt loading provides a reasonable means of introducing seasonal variability in a paved road emission inventory. In many areas of the country, road surface loadings are heaviest during the late winter and early spring months when the residual loading from snow/ice controls is greatest.

11.2.x.3 Predictive Emission Factor Equations

The quantity of dust emissions from vehicle traffic on a paved road may be estimated using the following empirical expression:

$$E = k\ (sL/2)^{0.65}\ (W/3)^{1.5} \qquad (1)$$

where:

	E	=	Particulate emission factor
	k	=	base emission factor for particle size range and units of interest (see below)
	sL	=	road surface silt loading (g/m^2)
	W	=	average weight (tons) of the vehicles traveling the road

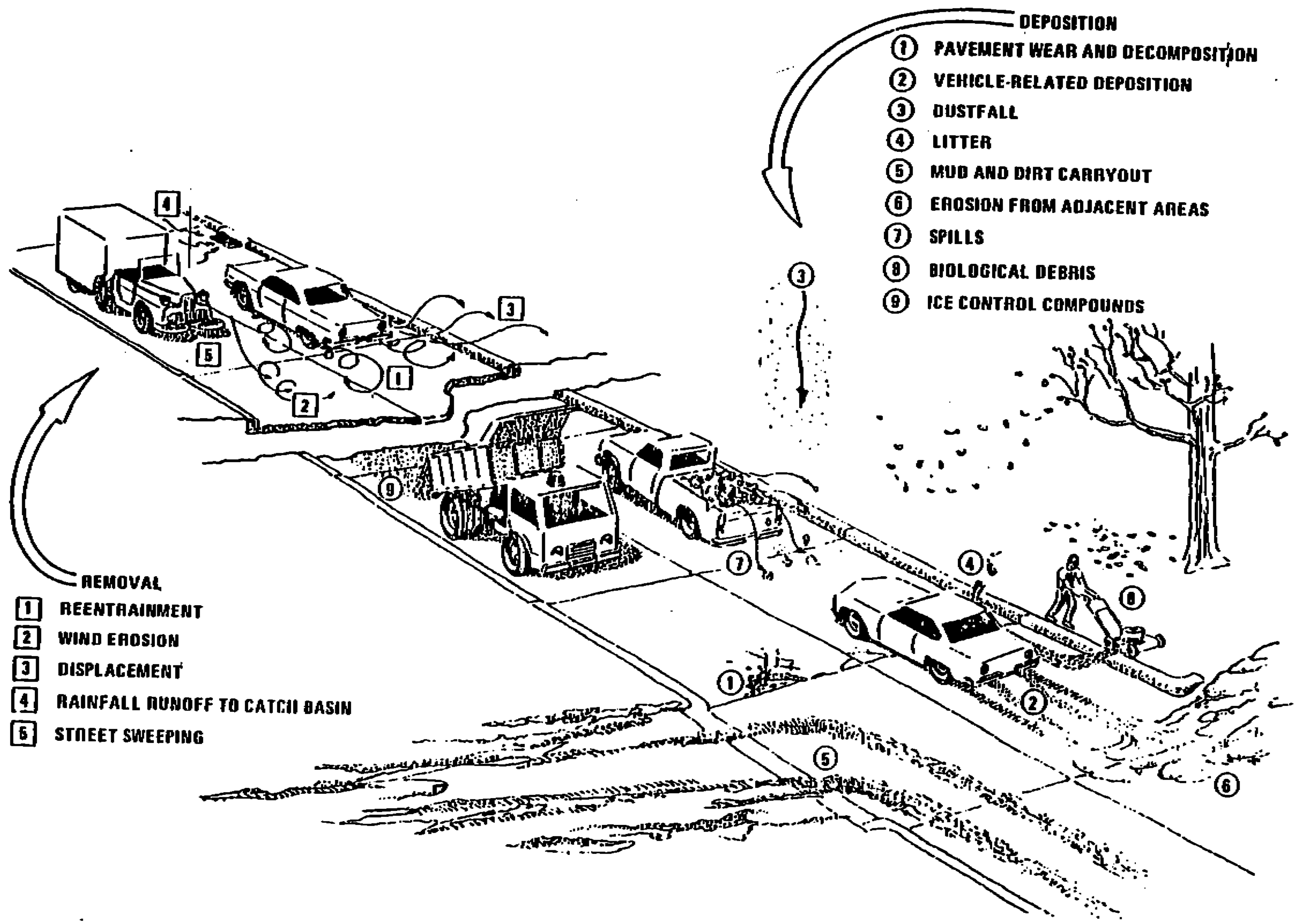


Figure 11.2.x-1. Deposition and removal processes.

The particle size multiplier (k) above varies with aerodynamic size range as follows:

Size	Multiplier k[b]		
Range[a]	g/VKT	g/VMT	lb/VMT
PM-2.5	2.1	3.3	0.0073
PM-10	4.6	7.3	0.016
PM-15	5.5	9.0	0.020
PM-30[c]	24	38	0.082

[a] Refers to airborne particulate matter (PM-x) with an aerodynamic diameter less than or equal to x microns.

[b] Units shown are grams per vehicle kilometer traveled (g/VKT), grams per vehicle mile traveled (g/VMT), and pounds per vehicle mile traveled (lb/VMT).

[c] PM-30 is sometimes termed "suspendable particulate" (SP) and is often used as a surrogate for TSP.

To determine particulate emissions for a specific particle size range, use the appropriate value of k above.

The above equations are based on a regression analysis of numerous emission tests, including 65 tests for PM-10. Sources tested include public paved roads as well as controlled and uncontrolled industrial paved roads. The equations retain the quality rating of A (B for PM-2.5) if applied within the range of source conditions that were tested in developing the equation as follows:

Silt loading:	0.02 - 400 g/m^2 0.03 - 570 $grain/ft^2$
Mean vehicle weight:	2 - 42 tons 1.8 - 38 Mg
Mean vehicle speed:	10 - 55 mph 16 - 88 kph

To retain the quality rating for the emission factor equation when applied to a specific paved road, it is necessary that reliable correction parameter values for the specific road in question be determined. The field and laboratory procedures for determining surface material silt content and surface dust loading are given in Reference __ and are summarized in Appendices D and E. In the event that site-specific values cannot be obtained, an appropriate value for an industrial road may be selected from the mean values given in Table 11.2.x-1, but the quality ratings of the equation should be reduced by one level.

TABLE 11.2.x-1. TYPICAL SILT CONTENT AND LOADING VALUES FOR PAVED ROADS AT INDUSTRIAL FACILITIES[a]

Industry	No. of sites	No. of samples	Silt content (%)		No. of travel lanes	Total loading x 10^{-3}			Silt loading (g/m^2)	
			Range	Mean		Range	Mean	Units[b]	Range	Mean
Copper smelting	1	3	15.4-21.7	19.0	2	12.9-19.5 45.8-69.2	15.9 55.4	kg/km lb/mi	188-400	292
Iron and steel production	9	48	1.1-35.7	12.5	2	0.006-4.77 0.020-16.9	0.495 1.75	kg/km lb/mi	0.09-79	9.7
Asphalt batching	1	3	2.6-4.6	3.3	1	12.1-18.0 43.0-64.0	14.9 52.8	kg/km lb/mi	76-193	120
Concrete batching	1	3	5.2-6.0	5.5	2	1.4-1.8 5.0-6.4	1.7 5.9	kg/km lb/mi	11-12	12
Sand and gravel processing	1	3	6.4-7.9	7.1	1	2.8-5.5 9.9-19.4	3.8 13.3	kg/km lb/mi	53-95	70
Municipal solid waste landfill	2	7	–	–	2	–	–	–	1.1-32.0	7.4
Quarry	1	6	–	–	2	–	–	–	2.4-14	8.2

[a] References 1-5.
[b] Multiply entries by 1,000 to obtain stated units.

With the exception of limited access roadways which are difficult to sample, collection and use of site-specific sL data for public paved road emission inventories are strongly recommended. Although hundreds of public paved road silt loading measurements have been made since 1980, uniformity has been lacking in sampling equipment and analysis techniques, in roadway classification schemes, and in the types of data reported. The assembled data set (described below) does not yield any readily identifiable, coherent relationship between silt loading and road class, average daily traffic (ADT), etc. Further complicating the analysis is the fact that, in many parts of the country, paved road silt loading varies greatly over the course of the year. For example, repeated sampling of the same roads over a period three calendar years at four Montana municipalities indicate a noticeable annual cycle, with a decline in sL during the first two calendar quarters together with an increase during the fourth calendar quarter.

Figures 11.2.x-2 and 11.2.x-3 present the cumulative frequency distribution for the public paved road sL data base assembled during the preparation of this AP-42 section. The data base includes samples taken from roads that have treated with sand and other snow/ice controls. Roadways are grouped into high and low ADT sets, with 5000 vehicles per day being the approximate cutoff. Figures 11.2.x.-2 and 11.2.x.-3 present the cumulative frequency distributions for high and low ADT roads, respectively.

In the absence of site-specific sL data to serve as input to a public paved road inventory, one may obtain conservatively high emission estimates by using the following values taken from the figures. For annual conditions, one may use the median sL values of 0.4 g/m^2 for high-ADT roads (excluding limited access roads, which are discussed below) and 2.5 g/m^2 for low-ADT roads. One may estimate worst-case loadings for high-ADT (excluding limited access roads) and low-ADT roads with the 90th percentile values of 7 and 25 g/m^2, respectively. Figures 11.2.x-4 through 11.2.x-7 present similar cumulative frequency distribution information for high- and low-ADT roads, except that the sets have been divided based on whether the sample was collected during the first or second half of the year. Information on the 50th and 90th percentile values are summarized in Table 11.2.x-2.

TABLE 11.2.X-2. PERCENTILES FOR NONINDUSTRIAL SILT LOADING (g/m^2) DATA BASE

	High ADT		Low ADT	
Averaging period	50th	90th	50th	90th
Annual	0.4	7	2.5	25
January-June	0.5	14	3	30
July-December	0.3	3	1.5	5

In the event that sL values are taken from any of the cumulative frequency distribution figures, the quality ratings for the emission estimates should be downgraded two letters.

As an alternative method of selecting sL values in the absence of site-specific data, users may review the public paved road sL data base (presented in Appendix ___) and select values that they deem appropriate for the roads and seasons of interest.

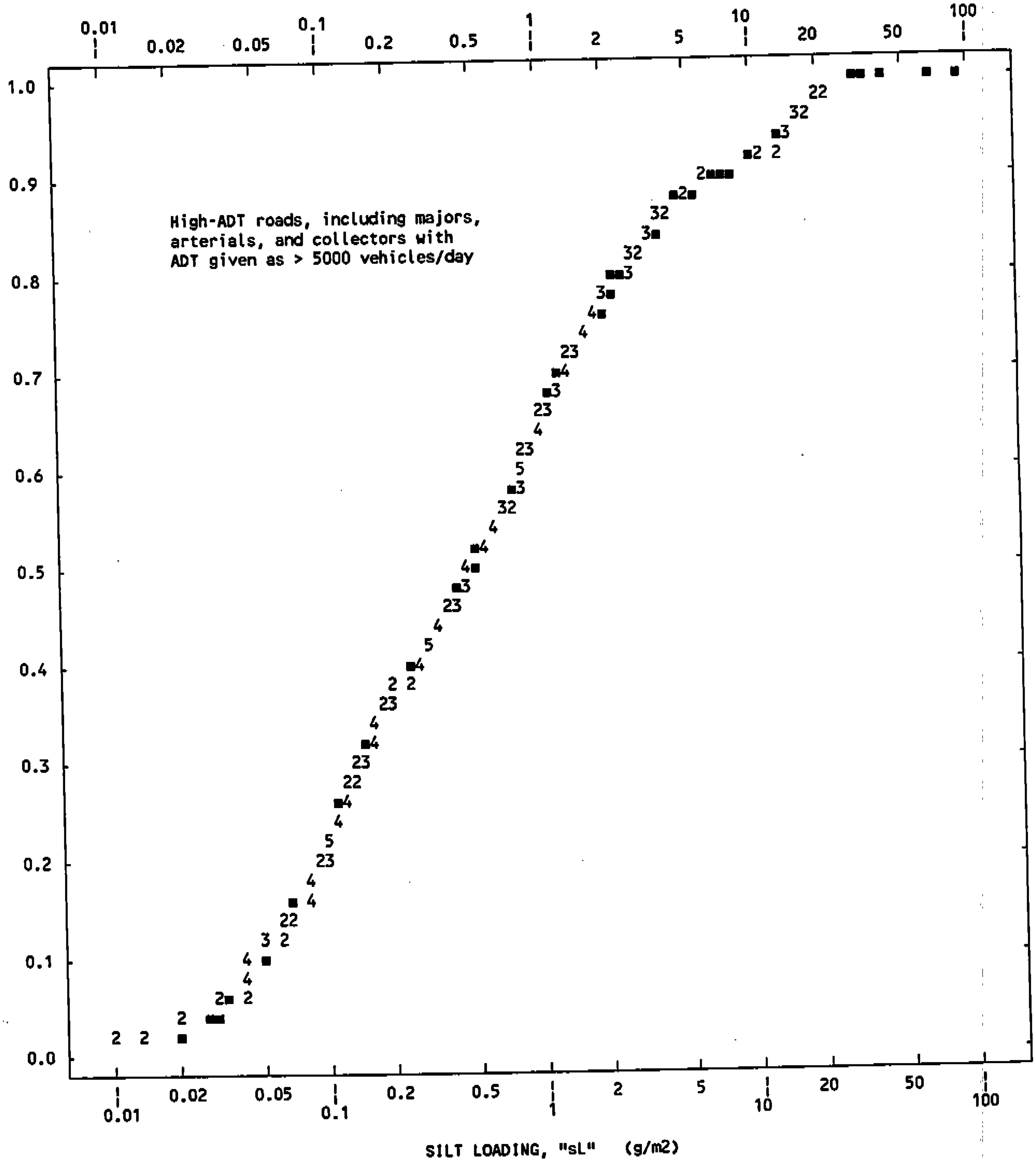


Figure 11.2.x-2. Cumulative frequency distribution for surface silt loading on high-ADT roadways.

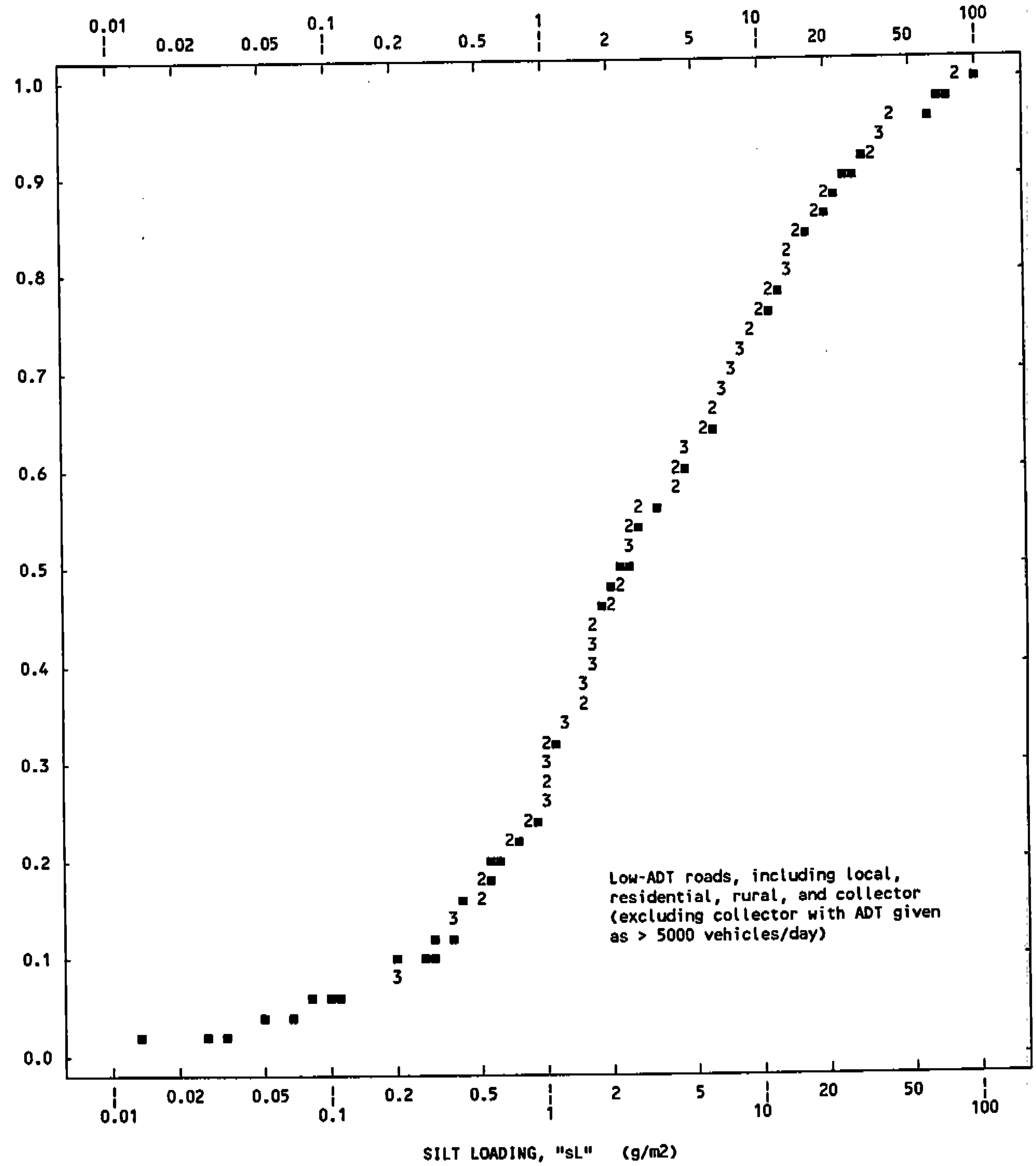


Figure 11.2.x-3. Cumulative frequency distribution for surface silt loading on low-ADT roadways.

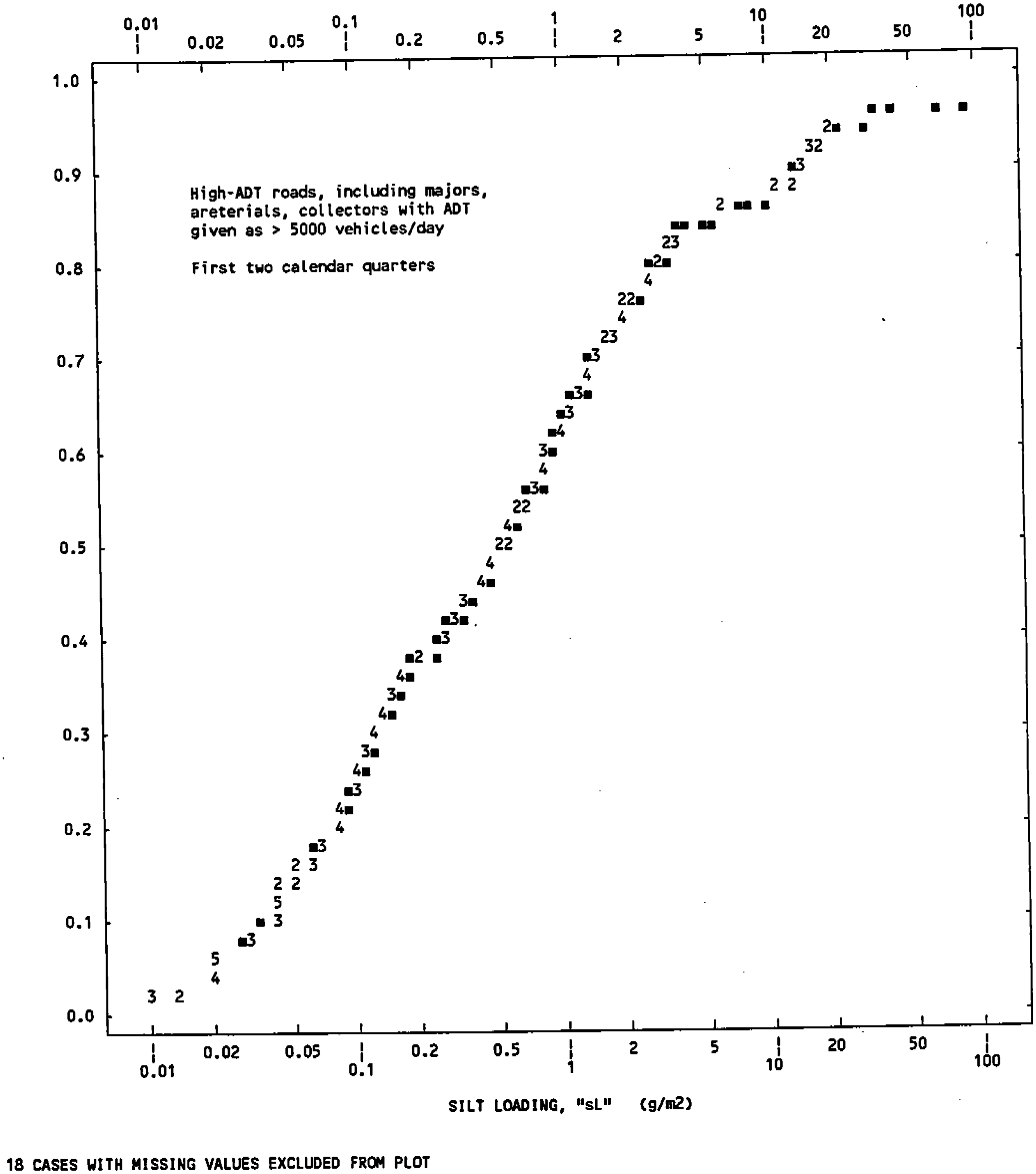
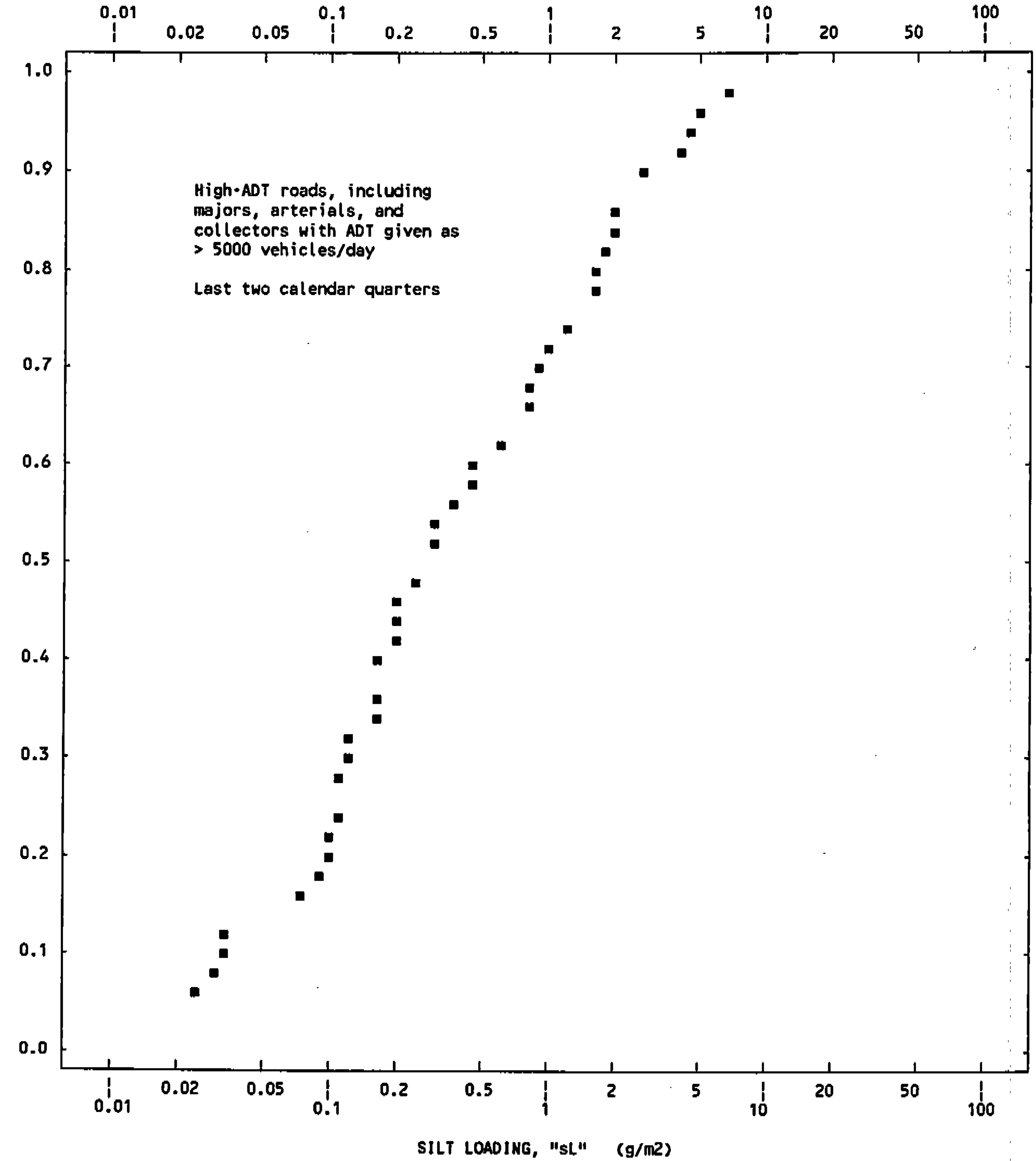
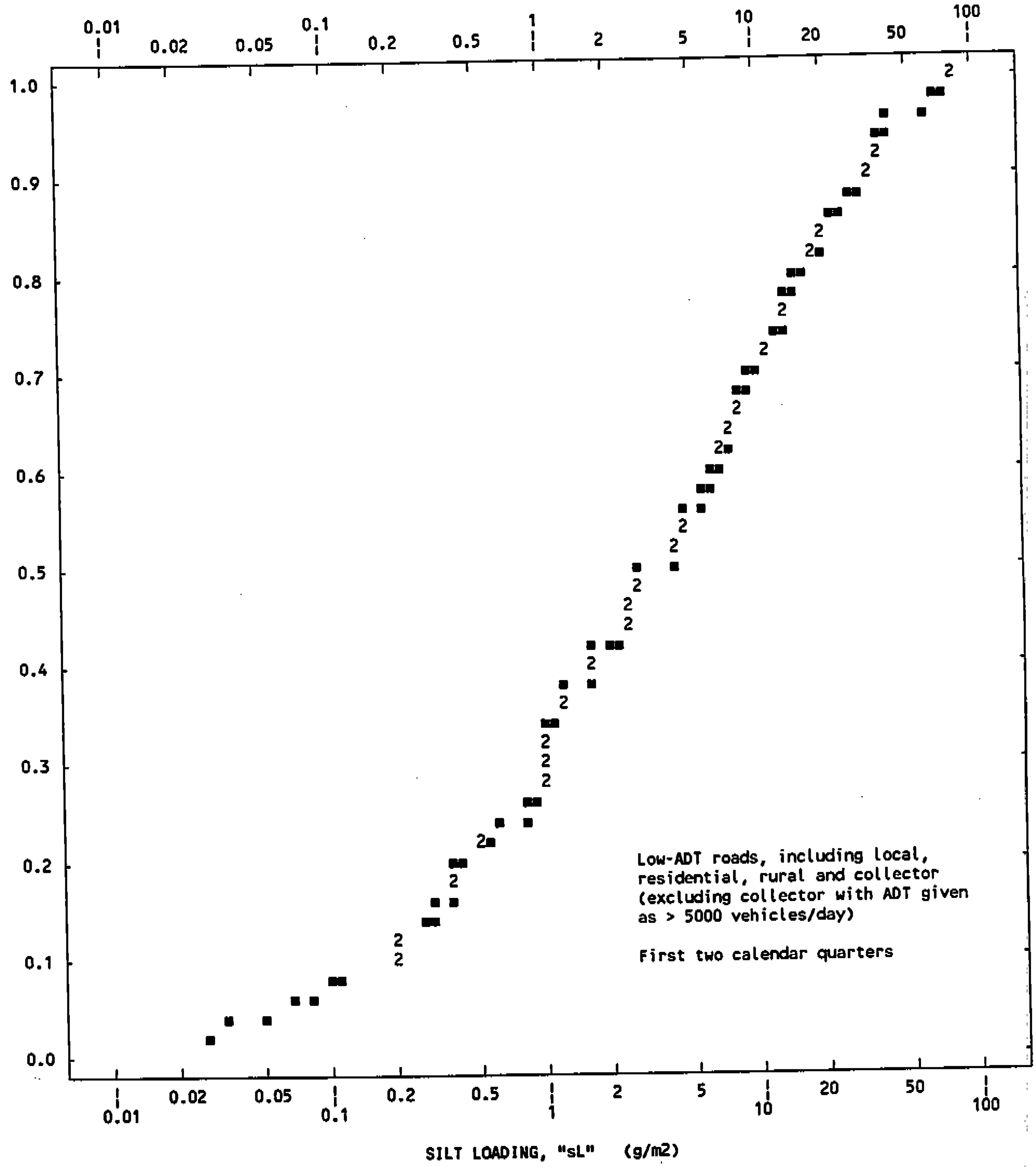


Figure 11.2.x-4. Cumulative frequency distribution for surface silt loading on high-ADT roadways, based on samples collected during the first half of the calendar year.



3 CASES WITH MISSING VALUES EXCLUDED FROM PLOT

Figure 11.2.x-5. Cumulative frequency distribution for surface silt loading on high-ADT roadways, based on samples collected during the second half of the calendar year.



16 CASES WITH MISSING VALUES EXCLUDED FROM PLOT

Figure 11.2.x-6. Cumulative frequency distribution for surface silt loading on low-ADT roadways, based on samples collected during the first half of the calendar year.

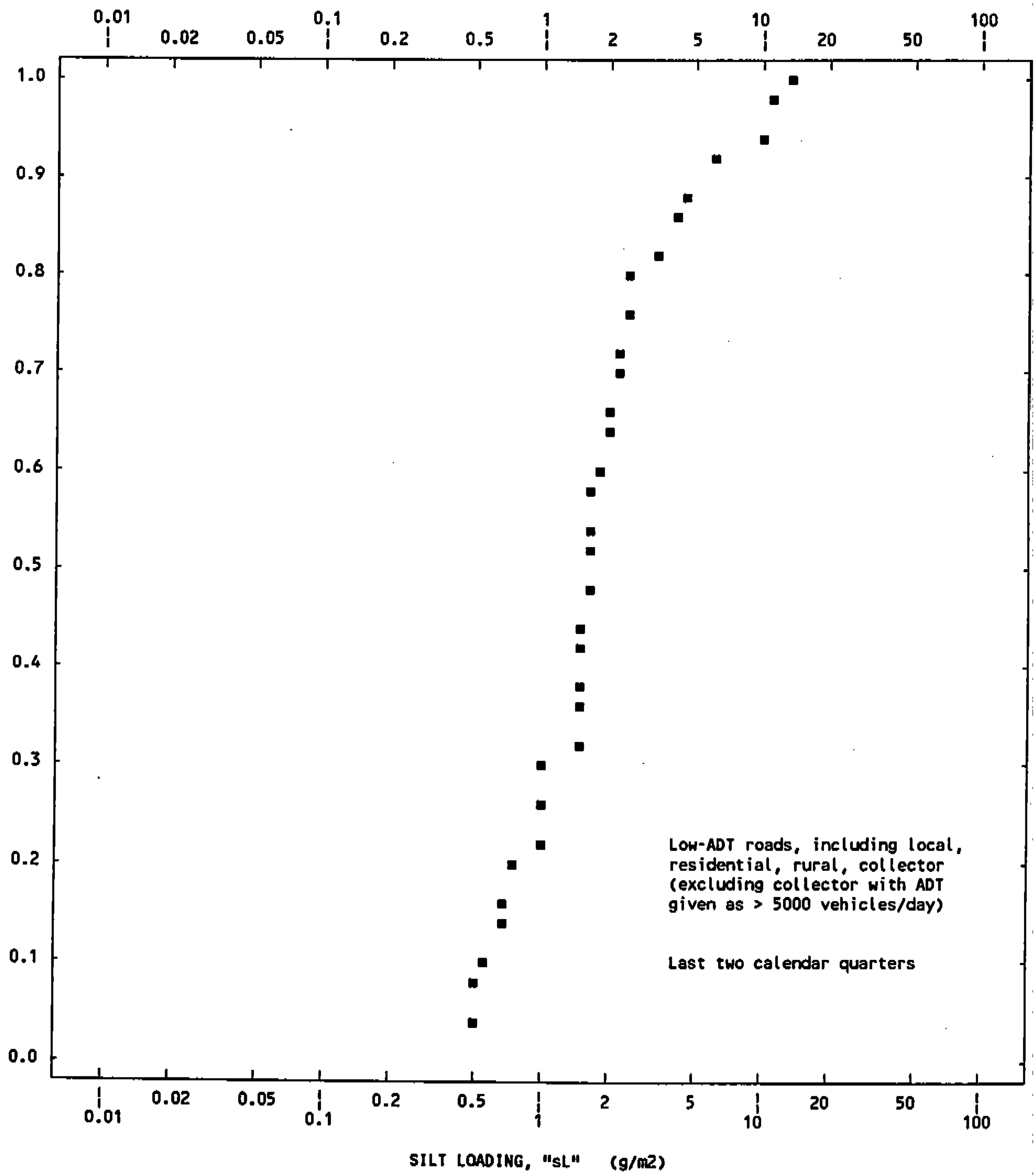


Figure 11.2.x-7. Cumulative frequency distribution for surface silt loading on low-ADT roadways, based on samples collected during the second half of the calendar year.

The appendix presents paved road surface loading values together with the city, state, road name, collection date (samples collected from the same road during the same month are averaged), road ADT if reported, classification of the roadway, etc. Recommendation of this approach recognizes that end users of AP-42 are the most capable in identifying roads in the data base that are similar to roads in the area being inventoried. In the event that sL values are developed in this way and the selection process is fully described, then the quality ratings for the emission estimates should be downgraded only one letter.

Limited access roadways pose severe logistical difficulties in terms of surface sampling, and few sL data are available. Nevertheless, the data that are available do not suggest great variation in sL for limited access roadways from one part of the country to another. For annual conditions, a default value of 0.02 g/m^2 is recommended for limited access roadways. Even fewer of the available data correspond to worst-case situations, and elevated loadings are observed to be quickly depleted because of high ADT rates. A default value of 0.1 g/m^2 is recommended for short periods of time following application of snow/ice controls to limited access roads.

11.2.x.4 Controls

Because of the importance of the surface loading, control techniques for paved roads either attempt to prevent material from being deposited onto the surface ("preventive" controls) or to remove from the travel lanes any material that has been deposited ("mitigative" controls). Regulations requiring covered loads in trucks or paving access areas to unpaved lots or construction sites are examples of preventive measures. Examples of mitigative controls include vacuum sweeping, water flushing, and flushing combined with broom sweeping.

In general, preventive controls are usually more cost-effective than mitigative controls; the cost-effectiveness for mitigative controls falls off dramatically as the size of an area to be treated grows. That is to say, the number and length of public roads within most areas of interest preclude any widespread and routine use of mitigative controls. On the other hand, due to the more limited scope of roads at an industrial site, mitigative measures may be used quite successfully (especially in situations where truck spillage occurs). Note, however, that public agencies could make effective use of mitigative controls to remove sand/salt from roads after winter.

Because available controls affect the silt loading, controlled emission factors may be obtained by substituting controlled loading values into Equation 1. (Emission factors from controlled industrial roads were used in the development of the equation.) The collection of surface loading samples from the treated as well as baseline (untreated) roads thus provides a means to track effectiveness of the controls over time.

References for Section 11.2.x

[TO BE PROVIDED]