Appendix 10.4a - Calculation of Active Area (Hourly and Daily)

Hourly and Daily - Year 2011 in Harcourt Garden area as the worst case scenario with heaviest construction activities.
Harcourt Garden Area (m²) = 10,000

From: 01-Jan To: 31-Mar Duration (months): 3					
Activity 1 Mobilisation, site set up, tree removal					
Plant/Activity	**% of usage**	**No. of Plant/ Acitivity**	**Plan Area (m²)**	**Total Plan Area (m²)**	**Area in terms of Time of Usage (m²)**
Breaker, hand-held breaker, 35kg	50%	3	1.0	3.0	1.5
Excavator (45kW)	50%	3	13.0	39.0	19.5
Concrete lorry mixer	20%	2	24.0	48.0	9.6
Crane, mobile/ barge mounted (diesel)	60%	1	36.0	36.0	21.6
Lorry with crane/grab	70%	2	24.0	48.0	33.6
				Total:	85.8
				Percentage of Usage Area to Works Area:	0.9

From: 01-Feb To: 31-Mar Duration (months): 2					
Activity 2 Demolition of Entrance e, Footbridge stairs, LCSD staff room					
Plant/Activity	**% of usage**	**No. of Plant/ Acitivity**	**Plan Area (m²)**	**Total Plan Area (m²)**	**Area in terms of Time of Usage (m²)**
Breaker, hand-held breaker, 35kg	60%	6	1.0	6.0	3.6
Breaker, excavator mounted (hydraulic), 73kW, 200kg	60%	3	13.0	39.0	23.4
Mobile crane	60%	1	36.0	36.0	21.6
Lorry with crane/grab	60%	2	24.0	48.0	28.8
Concrete lorry mixer	20%	1	24.0	24.0	4.8
				Total:	82.2
				Percentage of Usage Area to Works Area:	0.8

From: 01-Feb To: 30-Apr Duration (months): 3					
Activity 3 Works Area preparation: strip soil, instant wells, instrumentation					
Plant/Activity	**% of usage**	**No. of Plant/ Acitivity**	**Plan Area (m²)**	**Total Plan Area (m²)**	**Area in terms of Time of Usage (m²)**
Excavator (45kW)	70%	3	13.0	39.0	27.3
Lorry	50%	3	24.0	72.0	36.0
Breaker, hand-held, mass >= 20kg and <= 35kg	25%	3	0.5	1.5	0.4
Drill rig, rotary type (diesel)	70%	3	13.8	41.4	29.0
Concrete lorry mixer	20%	1	24.0	24.0	4.8
				Total:	97.5
				Percentage of Usage Area to Works Area:	1.0

From: 01-Feb To: 31-Jul Duration (months): 6					
Activity 4 Ground Investigation					
Plant/Activity	**% of usage**	**No. of Plant/ Acitivity**	**Plan Area (m²)**	**Total Plan Area (m²)**	**Area in terms of Time of Usage (m²)**
Drill rig, rotary type (diesel)	70%	2	13.8	27.6	19.3
Grout mixer	20%	1	6.0	6.0	1.2
				Total:	20.5
				Percentage of Usage Area to Works Area:	0.2

Appendix 10.4a - Calculation of Active Area (Hourly and Daily)

From: 01-Mar	To: 31-Jul	Duration (months): 5			
Activity 5 Cavern access shaft pipe piles					
Plant/Activity	**% of usage**	**No. of Plant/ Acitivity**	**Plan Area (m^2)**	**Total Plan Area (m^2)**	**Area in terms of Time of Usage (m^2)**
Piling, large diameter bored, reverse circulation drill	70%	3	36.0	108.0	75.6
Crane, mobile/ barge mounted (diesel)	50%	2	36.0	72.0	36.0
Drill rig, rotary type (diesel)	20%	3	13.8	41.4	8.3
Grout mixer	20%	3	6.0	18.0	3.6
				Total:	123.5
				Percentage of Usage Area to Works Area:	1.2

From: 01-Mar	To: 31-Jul	Duration (months): 5			
Activity 6 Temporary lateral support					
Plant/Activity	**% of usage**	**No. of Plant/ Acitivity**	**Plan Area (m^2)**	**Total Plan Area (m^2)**	**Area in terms of Time of Usage (m^2)**
Breaker, hand-held, mass >= 20kg and <= 35kg	50%	2	1.0	2.0	1.0
Mini backhoe	50%	1	25.6	25.6	12.8
Lorry with crane/grab	30%	1	24.0	24.0	7.2
Concrete lorry mixer	20%	1	24.0	24.0	4.8
Piling, large diameter bored, reverse circulation drill	70%	1	36.0	36.0	25.2
Crane, mobile/ barge mounted (diesel)	50%	1	36.0	36.0	18.0
Drill rig, rotary type (diesel)	20%	1	13.8	13.8	2.8
Grout mixer	20%	1	6.0	6.0	1.2
				Total:	73.0
				Percentage of Usage Area to Works Area:	0.7

From: 01-Mar	To: 31-May	Duration (months): 3			
Activity 7 CITIC pier underpinning H-piles					
Plant/Activity	**% of usage**	**No. of Plant/ Acitivity**	**Plan Area (m^2)**	**Total Plan Area (m^2)**	**Area in terms of Time of Usage (m^2)**
Piling, large diameter bored, reverse circulation drill	70%	2	36.0	72.0	50.4
Crane, mobile/ barge mounted (diesel)	50%	2	36.0	72.0	36.0
Grout mixer	20%	2	6.0	12.0	2.4
				Total:	88.8
				Percentage of Usage Area to Works Area:	0.9

From: 01-Feb	To: 31-Aug	Duration (months): 7			
Activity 8 Diaphragm wall					
Plant/Activity	**% of usage**	**No. of Plant/ Acitivity**	**Plan Area (m^2)**	**Total Plan Area (m^2)**	**Area in terms of Time of Usage (m^2)**
Piling, diaphragm wall, bentonite filtering plant	100%	1	36.0	36.0	36.0
Piling, diaphragm wall, hydraulic extractor	20%	1	36.0	36.0	7.2
Mobile crane	70%	3	36.0	108.0	75.6
Lorry	70%	3	24.0	72.0	50.4
Grout mixer	50%	1	6.0	6.0	3.0
Concrete lorry mixer	20%	1	24.0	24.0	4.8
				Total:	177.0
				Percentage of Usage Area to Works Area:	1.8

Duration (months): 6	
Activity 9 Temporary stockpiling	
Plant/Activity	**Area (m^2)**
Temporary stockpiling (Assume 2% of total works area are active stockpiling area)	200.0
Total:	200.0
Percentage of Usage Area to Works Area:	2.0

Maximum Percentage Active Area = **9.5**

Appendix 10.4a - Calculation of Active Area (Hourly and Daily)

Note:

Plant and activity with no dust emission during operation is not included (i.e. area = 0)

All plant that would generate dust emissions during their operation (e.g. excavator) have been included in estimating the active work areas whereas the plant without dust emission in the course of their operation (e.g. pumps, generators, air compressors) have been excluded from the calculation. Since the plants do not normally operate continuously throughout the 12-hour working period, an adjustment by "percentage of usage" was adopted for each plant/activity to reflect its estimated hours of operation on a typical working day. The actual dust emission area for each plant/activity was estimated and given as "Plan Area", by taking into account the maximum area of dust emissions which could be created by the plant/activity at any time instant. The duration (in months) of each construction activity in a year was factored into the annual active area calculation, but not in the hourly and daily calculation. It should be noted that haul roads within the construction site have not been included in the estimation of active work areas because all the haul roads will be paved and the dust emission from vehicular movements on paved roads would be minimal.

Justifications provided above are for the purpose of assessment predictions only. Actual figures would be defined by the Detailed Design Engineer.

Appendix 10.4b - Calculation of Active Area (Yearly)

Yearly - Year 2011 in Harcourt Garden area as the worst case scenario with heaviest construction activities.
Harcourt Garden Area (m²): 10,000

Advance Works

From: 01-Jan To: 31-Mar Duration (months): 3					
Activity 1 Mobilisation, site set up, tree removal					
Plant/Activity	**% of usage**	**No. of Plant/ Acitivity**	**Plan Area (m²)**	**Total Plan Area (m²)**	**Area in terms of Time of Usage (m²)**
Breaker, hand-held breaker, 35kg	50%	3	1.0	3.0	1.5
Excavator (45kW)	50%	3	13.0	39.0	19.5
Concrete lorry mixer	20%	2	24.0	48.0	9.6
Crane, mobile/ barge mounted (diesel)	60%	1	36.0	36.0	21.6
Lorry with crane/grab	70%	2	24.0	48.0	33.6
				Total:	85.8
				Percentage of Usage Area to Works Area:	0.9
				Percentage of Yearly Usage:	0.2

From: 01-Feb To: 31-Mar Duration (months): 2					
Activity 2 Demolition of Entrance e, Footbridge stairs, LCSD staff room					
Plant/Activity	**% of usage**	**No. of Plant/ Acitivity**	**Plan Area (m²)**	**Total Plan Area (m²)**	**Area in terms of Time of Usage (m²)**
Breaker, hand-held breaker, 35kg	60%	6	1.0	6.0	3.6
Breaker, excavator mounted (hydraulic), 73kW, 200kg	60%	3	13.0	39.0	23.4
Mobile crane	60%	1	36.0	36.0	21.6
Lorry with crane/grab	60%	2	24.0	48.0	28.8
Concrete lorry mixer	20%	1	24.0	24.0	4.8
				Total:	82.2
				Percentage of Usage Area to Works Area:	0.8
				Percentage of Yearly Usage:	0.1

From: 01-Feb To: 30-Apr Duration (months): 3					
Activity 3 Works Area preparation: strip soil, instant wells, instrumentation					
Plant/Activity	**% of usage**	**No. of Plant/ Acitivity**	**Plan Area (m²)**	**Total Plan Area (m²)**	**Area in terms of Time of Usage (m²)**
Excavator (45kW)	70%	3	13.0	39.0	27.3
Lorry	50%	3	24.0	72.0	36.0
Breaker, hand-held, mass >= 20kg and <= 35kg	25%	3	1.0	3.0	0.8
Drill rig, rotary type (diesel)	70%	3	13.8	41.4	29.0
Concrete lorry mixer	20%	1	24.0	24.0	4.8
				Total:	97.8
				Percentage of Usage Area to Works Area:	1.0
				Percentage of Yearly Usage:	0.2

From: 01-Feb To: 31-July Duration (months): 6					
Activity 4 Ground Investigation					
Plant/Activity	**% of usage**	**No. of Plant/ Acitivity**	**Plan Area (m²)**	**Total Plan Area (m²)**	**Area in terms of Time of Usage (m²)**
Drill rig, rotary type (diesel)	70%	2	13.8	27.6	19.3
Grout mixer	20%	1	6.0	6.0	1.2
				Total:	20.5
				Percentage of Usage Area to Works Area:	0.2
				Percentage of Yearly Usage:	0.1

Appendix 10.4b - Calculation of Active Area (Yearly)

From: 01-Mar	To: 31-Jul	Duration (months): 5			
Activity 5 Cavern access shaft pipe piles					
Plant/Activity	**% of usage**	**No. of Plant/ Acitivity**	**Plan Area (m²)**	**Total Plan Area (m²)**	**Area in terms of Time of Usage (m²)**
Piling, large diameter bored, reverse circulation drill	70%	3	36.0	108.0	75.6
Crane, mobile/ barge mounted (diesel)	50%	2	36.0	72.0	36.0
Drill rig, rotary type (diesel)	20%	3	13.8	41.4	8.3
Grout mixer	20%	3	6.0	18.0	3.6
				Total:	123.5
				Percentage of Usage Area to Works Area:	1.2
				Percentage of Yearly Usage:	0.5

From: 01-Mar	To: 31-Jul	Duration (months): 5			
Activity 6 Temporary lateral support					
Plant/Activity	**% of usage**	**No. of Plant/ Acitivity**	**Plan Area (m²)**	**Total Plan Area (m²)**	**Area in terms of Time of Usage (m²)**
Breaker, hand-held, mass >= 20kg and <= 35kg	50%	2	1.0	2.0	1.0
Mini backhoe	50%	1	25.6	25.6	12.8
Lorry with crane/grab	30%	1	24.0	24.0	7.2
Concrete lorry mixer	20%	1	24.0	24.0	4.8
Piling, large diameter bored, reverse circulation drill	70%	1	36.0	36.0	25.2
Crane, mobile/ barge mounted (diesel)	50%	1	36.0	36.0	18.0
Drill rig, rotary type (diesel)	20%	1	13.8	13.8	2.8
Grout mixer	20%	1	6.0	6.0	1.2
				Total:	73.0
				Percentage of Usage Area to Works Area:	0.7
				Percentage of Yearly Usage:	0.3

From: 01-Mar	To: 31-May	Duration (months): 3			
Activity 7 CITIC pier underpinning H-piles					
Plant/Activity	**% of usage**	**No. of Plant/ Acitivity**	**Plan Area (m²)**	**Total Plan Area (m²)**	**Area in terms of Time of Usage (m²)**
Piling, large diameter bored, reverse circulation drill	70%	2	36.0	72.0	50.4
Crane, mobile/ barge mounted (diesel)	50%	2	36.0	72.0	36.0
Grout mixer	20%	2	6.0	12.0	2.4
				Total:	88.80
				Percentage of Usage Area to Works Area:	0.89
				Percentage of Yearly Usage:	0.22

From: 01-Feb	To: 31-Aug	Duration (months): 7			
Activity 8 Diaphragm wall					
Plant/Activity	**% of usage**	**No. of Plant/ Acitivity**	**Plan Area (m²)**	**Total Plan Area (m²)**	**Area in terms of Time of Usage (m²)**
Piling, diaphragm wall, bentonite filtering plant	100%	1	36.0	36.0	36.0
Mobile crane	70%	3	36.0	108.0	75.6
Lorry	70%	3	24.0	72.0	50.4
Grout mixer	50%	1	6.0	6.0	3.0
Concrete lorry mixer	20%	1	24.0	24.0	4.8
				Total:	169.8
				Percentage of Usage Area to Works Area:	1.7
				Percentage of Yearly Usage:	1.0

Main Works

From: 01-Aug	To: 31-Oct	Duration (months): 3			
Activity 1 Mobilisation and site set up					
Plant/Activity	**% of usage**	**No. of Plant/ Acitivity**	**Plan Area (m²)**	**Total Plan Area (m²)**	**Area in terms of Time of Usage (m²)**
Breaker, hand-held, mass >= 20kg and <= 35kg	30%	2	1.0	2.0	0.6
Excavator/ loader, wheeled/ tracked	30%	2	13.0	26.0	7.8
Concrete lorry mixer	30%	2	24.0	48.0	14.4
Crane, mobile/ barge mounted (diesel)	70%	2	36.0	72.0	50.4
Lorry with crane/grab	70%	4	24.0	96.0	67.2
				Total:	140.4
				Percentage of Usage Area to Works Area:	1.4
				Percentage of Yearly Usage:	0.4

From: 01-Sep	To: 31-Dec	Duration (months): 4			
Activity 2 Cavern Access Shaft: Excavation in soft, Strutting and Decking					
Plant/Activity	**% of usage**	**No. of Plant/ Acitivity**	**Plan Area (m²)**	**Total Plan Area (m²)**	**Area in terms of Time of Usage (m²)**
Breaker, hand-held, mass >= 20kg and <= 35kg	50%	4	1.0	4.0	2.0
Excavator (45kW)	50%	4	13.0	52.0	26.0
Mini backhoe	50%	3	25.6	76.8	38.4
Lorry	50%	4	24.0	96.0	48.0
Mobile crane	60%	3	36.0	108.0	64.8
Piling, large diameter bored, reverse circulation drill	70%	1	36.0	36.0	25.2
Crane, mobile/ barge mounted (diesel)	50%	1	36.0	36.0	18.0
Drill rig, rotary type (diesel)	20%	1	13.8	13.8	2.8
Grout mixer	20%	1	6.0	6.0	1.2
				Total:	226.4
				Percentage of Usage Area to Works Area:	2.3
				Percentage of Yearly Usage:	0.8

Appendix 10.4b - Calculation of Active Area (Yearly)

From: 01-Oct To: 31-Dec Duration (months): 3					
Activity 3 CITIC piers C2 and C3 underpinning					
Plant/Activity	**% of usage**	**No. of Plant/ Acitivity**	**Plan Area (m²)**	**Total Plan Area (m²)**	**Area in terms of Time of Usage (m^2)**
Breaker, hand-held, mass >= 20kg and <= 35kg	60%	4	1.0	4.0	2.4
Breaker, excavator mounted (hydraulic), 73kW, 200kg	60%	2	13.0	26.0	15.6
Excavator/ loader, wheeled/ tracked	40%	1	13.0	13.0	5.2
Mini backhoe	50%	1	25.6	25.6	12.8
Lorry	20%	4	24.0	96.0	19.2
Crane, mobile/ barge mounted (diesel)	80%	2	36.0	72.0	57.6
Concrete lorry mixer	20%	1	24.0	24.0	4.8
				Total:	117.6
				Percentage of Usage Area to Works Area:	1.2
				Percentage of Yearly Usage:	0.3

From: 01-Dec To: 31-Dec Duration (months): 1					
Activity 4 Cavern Access Shaft : Excavation in rock under deck					
Plant/Activity	**% of usage**	**No. of Plant/ Acitivity**	**Plan Area (m²)**	**Total Plan Area (m²)**	**Area in terms of Time of Usage (m^2)**
Breaker, excavator mounted (hydraulic), 73kW, 200kg	30%	3	13.0	39.0	11.7
Excavator/ loader, wheeled/ tracked	70%	2	13.0	26.0	18.2
Mini backhoe	70%	2	25.6	51.2	35.8
Lorry with crane/grab	70%	4	24.0	96.0	67.2
				Total:	132.9
				Percentage of Usage Area to Works Area:	1.3
				Percentage of Yearly Usage:	0.1

Duration (months): 6	
Activity 5 Temporary Stockpiling	
Plant/Activity	**Area (m^2)**
Temporary stockpiling (Assume 2% of total works area are active stockpiling area)	200.0
Total:	200.0
Percentage of Usage Area to Works Area:	2.0
Percentage of Yearly Usage:	1.0

Combined Yearly Percentage for Activities = **5.2**

Note:
Plant and activity with no dust emission during operation is not included (i.e. area = 0)
All plant that would generate dust emissions during their operation (e.g. excavator) have been included in estimating the active work areas whereas the plant without dust emission in the course of their operation (e.g. pumps, generators, air compressors) have been excluded from the calculation. Since the plants do not normally operate continuously throughout the 12-hour working period, an adjustment by "percentage of usage" was adopted for each plant/activity to reflect its estimated hours of operation on a typical working day. The actual dust emission area for each plant/activity was estimated and given as "Plan Area", by taking into account the maximum area of dust emissions which could be created by the plant/activity at any time instant. The duration (in months) of each construction activity in a year was factored into the annual active area calculation, but not in the hourly and daily calculation. It should be noted that haul roads within the construction site have not been included in the estimation of active work areas because all the haul roads will be paved and the dust emission from vehicular movements on paved roads would be minimal.
Justifications provided above are for the purpose of assessment predictions only. Actual figures would be defined by the Detailed Design Engineer.

Appendix 10.6c: Calculation of Watering Efficiency

Equation (3-2) in the attached *Control of Open Fugitive Dust Sources Final Report* had been adopted for the watering efficiency with the assumptions as below:

p = Potential average hourly daytime evaporation rate, mm/hr = 0.25916

d = Average hourly daytime traffic rate per hour = 52/hr
i = Application intensity = 0.287 gal/yd^2 = 1.2989 L/m^2

Note:
p = 0.0049 x 52.8898 inch.
52.8898 inch referred to total evaporation of 1343.4 mm based on information in Hong Kong Observatory's website (http://www.weather.gov.hk/cis/normal/1971_2000/normals_e.htm).
d estimated by Engineer with a maximum of approximately 52 vehicles per hour at an active construction sites.
Justifications provided above are for the purpose of assessment predictions only. Actual figures would be defined by the Detailed Design.

EPA-450/3-88-008

CONTROL OF OPEN FUGITIVE DUST SOURCES

FINAL REPORT

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EPA Contract No. 68-02-4395
Work Assignment 14
MRI Project 8985-14

William L. Elmore, Project Officer
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September 1988

ACKNOWLEDGMENTS

We wish to acknowledge the significant contributions of a number of individuals to the success of this project. Much of the information contained in this report was developed at a cooperative working session attended by U. S. Environmental Protection Agency (EPA), State, local program, and contractor personnel. Without their cooperation in sharing data, discussing control strategies, and reviewing document drafts, this study would not have been possible. The individuals who made significant contributions and their organizational affiliations are listed below.

Frances Beyer, MRI
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1.0 INTRODUCTION

Fugitive particulate emissions are emitted by a wide variety of sources both in the industrial and in the nonindustrial sectors. Fugitive emissions refer to those air pollutants that enter the atmosphere without first passing through a stack or duct designed to direct or control their flow.

Sources of fugitive particulate emissions may be separated into two broad categories: process sources and open dust sources. Process sources of fugitive emissions are those associated with industrial operations that alter the chemical or physical characteristics of a feed material. Open dust sources are those that entail generation of fugitive emissions of solid particles by the forces of wind or machinery acting on exposed materials.

Open dust sources include industrial sources of particulate emissions associated with the open transport, storage, and transfer of raw, intermediate, and waste aggregate materials and nonindustrial sources such as unpaved roads and parking lots, paved streets and highways, heavy construction activities, and agricultural tilling. Generic categories of open dust sources are listed in Table 1-1. In some instances, the term fugitive dust may be further restricted to include only nonindustrial sources.

1.1 CONTROL OPTIONS

Typically, there are several options for control of fugitive particulate emissions from any given source. This is clear from the mathematical equation used to calculate the emission rate:

$$R = M\ e\ (1 - c)$$

where: R = estimated mass emission rate

M = source extent (i.e., surface area for most open dust sources)

e = uncontrolled emission factor, i.e., mass of uncontrolled emissions per unit of source extent

c = fractional efficiency of control

TABLE 1-1. GENERIC CATEGORIES OF OPEN DUST SOURCES

1. <u>Unpaved Travel Surfaces</u>
• Roads • Parking lots and staging areas • Storage piles
2. <u>Paved Travel Surfaces</u>
• Streets and highways • Parking lots and staging areas
3. <u>Exposed Areas</u> (wind erosion)
• Storage piles • Bare ground areas
4. <u>Materials Handling</u>
• Batch drop (dumping) • Continuous drop (conveyor transfer, stacking) • Pushing (dozing, grading, scraping) • Tilling

To begin with, because the uncontrolled emission rate is the product of the source extent and uncontrolled emission factor, a reduction in either of these two variables produces a proportional reduction in the uncontrolled emission rate.

Although the reduction of source extent results in a highly predictable reduction in the uncontrolled emission rate, such an approach in effect usually requires a change in the process operation. Frequently, reduction in the extent of one source may necessitate the increase in the extent of another, as in the shifting of vehicle traffic from an unpaved road to a paved road. The option of reducing source extent is beyond the scope of this manual and will not be discussed further.

The reduction in the uncontrolled emission factor may be achieved by process modifications (in the case of process sources) or by adjusted work practices (in the case of open sources). The degree of the possible reduction of the uncontrolled emission factor can be estimated from the known dependence of the factor on source conditions that are subject to alteration. For open dust sources, this information is embodied in the predictive emission factor equations for fugitive dust sources as presented in Section 11.2 of EPA's "Compilation of Air Pollutant Emission Factors" (AP-42).

The reduction of source extent and the incorporation of process modifications or adjusted work practices which reduce the amount of exposed dust-producing material are preventive techniques for control of fugitive dust emissions. This would include, for example, the elimination of mud/dirt carryout onto paved roads at construction and demolition sites.

On the other hand, mitigative measures involve the periodic removal of dust-producing material. Examples of mitigative measures include: cleanup of spillage on travel surfaces (paved and unpaved) and cleanup of material spillage at conveyor transfer points.

1.2 SCOPE OF THE DOCUMENT

Prior to the use of this manual, the reader should have a general idea of what sources within the specified jurisdictional boundary may require additional control programs to achieve desired air quality goals. This determination may be based on a prior total suspended particulate

(TSP) inventory of the area, discussions with field inspection personnel, or any other information source. Because the cost of many open dust source controls is directly related to the area of the source (e.g., surface area of a storage pile to be chemically stabilized, roadway area to be swept or flushed, etc.), the user may employ the ratio:

$$\frac{\text{Uncontrolled emission rate}}{\text{Source surface area}}$$

to prioritize sources for control. Regulatory personnel may wish to also combine this ratio with some measure of the affected population (e.g., zoning areas or population density within a certain distance of the source). This would be in keeping with guidance provided in a recent EPA draft urban dust policy.

The purpose of this document is to provide regulatory personnel with sufficient information to develop control plans for open dust sources of PM_{10} (i.e., particulate matter emissions no greater than 10 microns (μm) in aerodynamic diameter). Each section deals with a different source category:

- Section 2.0--Paved Roadways
  - a. Public
  - b. Industrial
- Section 3.0--Unpaved Roadways
  - a. Public
  - b. Industrial
- Section 4.0--Storage Piles
- Section 5.0--Construction/Demolition Activities
- Section 6.0--Open Area Wind Erosion
- Section 7.0--Agriculture

Each section begins with an overview of the source category, describing emission characteristics and mechanisms. Following this, available emission factors are presented to provide a basis for analyzing the operative nature of control measures. Next, demonstrated control techniques are discussed in terms of estimating efficiency and determining costs of implementation. Suggested regulatory formats explain the "philosophy" used in implementing the preceding technical discussions in viable regulations and compliance actions. Example regulations for each source category are presented in an appendix. These examples are predicated on a permit and penalty system as outlined in Table 1-2. Control agencies may issue construction, operation, and use permits to owners of many sources of fugitive PM_{10} emissions. These permits can be used to specify the conditions or activities that must be provided or undertaken by the source to ensure attainment of the PM_{10} emission reduction goals of the Agency's control plan. A permit system also may specify permit fees and compliance penalties which can be used to offset the costs of administering an inspection and enforcement program. Specific sources that may be appropriate for inclusion in a permit system include the following sources.

- Industrial roads
- Storage piles
- Construction/demolition sites
- Vacant lots
- Parking lots
- Feed lots
- Staging areas
- Off-road recreational areas
- Land disposal sites
- Landfills

In addition, a series of other appendices are also included which discuss terminology used in this manual, a general costing procedure used for open dust source controls and general recordkeeping/inspection procedures.

TABLE 1-2. PERMIT AND PENALTY SYSTEM

Permits

1. Any Control Agency may establish, by regulation, a permit that requires, except as provided below, that before any person engages in any activity which will cause the issuance of fugitive PM_{10} emissions, such person obtain a permit to do so from the control officer of the agency.

2. A permit system shall:

a. Ensure that the activity for which the permit was issued shall not prevent or interfere with the attainment or maintenance of the Federal PM_{10} standard. Attainment can be demonstrated through dispersion modeling of ambient concentrations resulting from source emissions.

b. Prohibit the issuance of a permit unless the control officer is satisfied, on the basis adopted by the Control Agency, that the activity will comply with all applicable orders, rules, and regulations of the agency.

3. The control officer may impose conditions on the permit to ensure that the provisions of 2(a) and (b) are met. The control officer, at any time, may require from an applicant, or the holder of a permit, such information, analyses, plans, or specifications which will disclose the nature, extent, quantity, or degree of fugitive PM_{10} emissions which are, or may be, discharged by the source for which a permit was issued or applied.

4. The Control Agency may adopt a schedule of fees for the evaluation, issuance, and renewal of permits to cover the cost of the agency programs related to the permitted sources.

5. Exemptions:

a. Size;
b. Duration; and
c. Location

Penalties

1a. Any person who violates any PM_{10} fugitive dust order, permit, rule, or regulation of the Control Agency is guilty of a misdemeaner and is subject to a fine of not more than one thousand dollars ($1,000), or imprisonment in the county jail for not more than 6 months, or both.

1b. Each infraction on each day during any portion of which a violation of paragraph 1(a) occurs is a separate offense.

(continued)

TABLE 1-2. (continued)

Penalties (continued)

2a. Any person who negligently emits an air contaminant in violation of any PM_{10} fugitive dust order, permit, rule, or regulation of the Control Agency pertaining to emission regulations or limitations is guilty of a misdemeanor and is subject to a fine of not more than ten thousand dollars ($10,000), or imprisonment in the county jail for not more than 9 months, or both.

2b. Each infraction on each day during any portion of which a violation occurs is a separate offense.

3a. Any person who emits PM_{10} fugitive dust in violation of any order, permit, rule, or regulation of the Control Agency pertaining to emission regulations or limitations, who knew of the emission and failed to take corrective action within a reasonable time under the circumstances, is guilty of a misdemeanor and is subject to a fine of not more than twenty five thousand dollars ($25,000), or imprisonment in the county jail for not more than 1 year, or both.

For the purposes of this paragraph, "corrective action" means the termination of the emission violation or the grant of a variance from the applicable order, permit, rule, or regulation.

3b. Any person who, knowingly and with intent to deceive, falsifies any document required to be kept pursuant to any order, permit, rule, or regulation of the Control Agency is guilty of a misdemeanor and is punishable as provided in paragraph 3(a).

3c. Each infraction on each day during any portion of which a violation occurs constitutes a separate offense.

2.0 PAVED ROADS

Particulate emissions occur whenever a vehicle travels 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), and that 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. Table 2-1 presents estimated deposition rates for paved roads. Note that these estimates date from a 1977 report and may not accurately reflect current trends.[1]

The following sections present a discussion of the various types of paved sources, available emission factors, viable control measures, and methods of determining controlled emission levels.

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, many public roads in industrial areas often are heavily loaded and traveled by heavy vehicles. In that instance, better emission estimates would be obtained by treating these roads as industrial roads. In an extreme case, a road or parking lot may have such a high surface loading that the paved surface is essentially

TABLE 2-1. ESTIMATED DEPOSITION RATES[a]

Deposition process	Typical rate, lb/curb-mi/day
Mud and dirt carryout	100
Litter	40
Biological debris	20
Ice control compounds	10
Dustfall	10
Pavement wear and decomposition	10
Vehicle-related (including tire wear)	17
Spills	<2
Erosion from adjacent areas	20

[a]Source: EPA-907/9-77-007.[1] As noted in the text, these estimates date from 1977 and may not accurately reflect current conditions or deposition at a specific location.

covered and is easily mistaken for an unpaved road. In that event, use of a paved road emission factor may actually result in a higher estimate than that obtained from the unpaved factor, and the road is better characterized as unpaved in nature rather than paved.[2]

As noted in the introduction, the reader, prior to using this manual, should have a general idea of what paved roads in his/her jurisdiction require additional controls. Furthermore, he/she should also have a general idea of what sources are contributing significantly to increased surface loadings on the roads requiring control. For example, heavy trucks may spill part of their load onto public roads in industrial areas, or large amounts of salt and sand may be applied during winter months. Prior to use of the information in this section, the reader should formulate preliminary answers to the following questions:

1. What paved roads are heavily loaded and thus likely to contribute a disproportionate share of emissions?
2. What sources are likely to contribute to these elevated surface loadings?
3. Who is the responsible party for each source identified in 2 above?
4. Can the carryout/deposition from each identified source be prevented or must the affected roadway be cleaned afterward?
5. Should any responsible party be granted an exclusion and on what basis?

2.1 PUBLIC PAVED ROADS

As discussed above, the term "public" is used in this manual to denote not only ownership of the road but also its surface and traffic characteristics. Roads in this class generally are fairly lightly loaded, are used primarily by light-duty vehicles, and usually have curbs and gutters. Examples are streets in residential and commercial areas and major thoroughfares (including freeways and arterials).

2.1.1 Estimation of Emissions

The current AP-42 PM_{10} emission factor for urban paved roads is:[3]

$$e = 2.28\ (sL/0.5)^{0.8}\ (g/VKT)$$

$$e = 0.0081\ (sL/0.7)^{0.8}\ (lb/VMT) \qquad (2\text{-}1)$$

where: e = PM_{10} emission factor, in units shown above
s = surface silt content, fraction of material smaller than 75 μm in diameter
L = total surface dust loading, g/m^2 ($grains/ft^2$)
VKT = vehicle kilometers traveled
VMT = vehicle miles traveled

The above equation is not rated in AP-42 (see Appendix A).

The product sL represents the mass of silt-size dust particles per unit area of the road surface and is usually termed the "silt loading." As is the case for all predictive models in AP-42, the use of site-specific (i.e., measured--using the methodology presented in Appendices D and E--for the sources under consideration) values of sL is strongly recommended. However, because measurement is not always feasible, AP-42 presents default values for use. Tables 2-2 and 2-3 present a summary of silt loadings as a function of roadway classification and the scheme used to classify roadways, respectively. In general, roads with a higher traffic volume tend to have lower surface silt loadings. This relationship is expressed in the empirical model presented in Reference 4:

$$sL = 21.3/(V^{0.41}) \qquad (2\text{-}2)$$

where: sL = surface silt loading (g/m^2)
V = average daily traffic volume (vehicles/d)

Several items should be noted about Table 2-2 and Equation (2-2). First, samples are restricted to the eastern and midwestern portions of the country. While these can be considered representative of most large urban areas of the United States, it is generally believed that surface silt loadings in the Southwest can be quite higher. Available data,

TABLE 2-2. SUMMARY OF SILT LOADINGS (sL) FOR PAVED URBAN ROADWAYS[a]

	Roadway category							
	Local streets		Collector streets		Major streets/highways		Freeways/expressways	
City	$\bar{X}_g$ (g/m²)	n	$\bar{X}_g$ (g/m²)	n	$\bar{X}_g$ (g/m²)	n	$\bar{X}_g$ (g/m²)	n
Baltimore	1.42	2	0.72	4	0.39	3	--	--
Buffalo	1.41	5	0.29	2	0.24	4	--	--
Granite City, Ill.	--	--	--	--	0.82	3	--	--
Kansas City	--	--	2.11	4	0.41	13	--	--
St. Louis	--	--	--	--	0.16	3	0.022	1
All	1.41	7	0.92	10	0.36	26	0.022	1

[a]Reference 3. $\bar{X}_g$ = geometric mean based on corresponding n sample size. Dash = not available. To convert g/m² to grains/ft² multiply g/m² by 1.4337.

TABLE 2-3. PAVED URBAN ROADWAY CLASSIFICATION[a]

Roadway category	Average daily traffic (vehicles)	Lanes
Freeways/expressways	>50,000	≥4
Major streets/highways	>10,000	≥4
Collector streets	500-10,000	2[b]
Local streets	<500	2[c]

[a]Reference 3.
[b]Road width ≥ 32 ft.
[c]Road width ≤ 32 ft.

however, do not necessarily support this suspicion; the following compares surface silt loadings from Table 2-2 and two counties in Arizona:

Street classification	Geometric mean sL (g/m²)		
	Table 2-2	Maricopa Co.[5]	Pima Co.[5]
Arterial/major	0.36	0.057	0.067
Collector	0.92	0.10	0.13

These differences may be partially the result of different measurement techniques and/or of lower measured silt fractions of materials on the Arizona roads. Once again, the use of site-specific data is stressed.

2.1.2 Demonstrated Control Techniques for Public Paved Roads

As mentioned in the introduction to this section, available control methods are largely designed either to prevent deposition of material on the roadway surface or to remove material which has been deposited in the driving lanes. Measurement-based efficiency values for control methods are presented in Table 2-4. Note that all values in this table are for mitigative measures applied to industrial paved roads.

In terms of public paved road dust control, only very limited field measurement data are available. One reference was found that could be used to indirectly quantify emission reductions and this, too, is for mitigative measures. Estimated PM_{10} control efficiencies (Table 2-5) were developed by applying Equation (2-1) to measurements before and after road cleaning.[6] Note that these estimates should be considered upper bounds on efficiencies obtained in practice because no redeposition after cleaning is considered. Note also that these estimated emission control efficiencies for urban roads compare fairly well with measurements at industrial roads. No airborne mass emission measurements quantifying control efficiency were found.

In general terms, one would expect that demonstrated control techniques applied to industrial paved roads could also be applied to public roads. One important point to note, however, is that it is generally recognized that mitigative measures decrease in effectiveness as

TABLE 2-4. MEASURED EFFICIENCY VALUES FOR PAVED ROAD CONTROLS[a]

Method	Cited efficiency	Comments
Vacuum sweeping	0-58 percent	Field emission measurement (PM-15) 12,000-cfm blower[b]
	46 percent	Reference 7, based on field measurement of 30 μm particulate emissions
Water flushing	69-0.231 $V^{c,d}$	Field measurement of PM-15 emissions[b]
Water flushing followed by sweeping	96-0.263 $V^{c,d}$	Field measurement of PM-15 emissions[b]

[a]Reference 8, except as noted. All results based on measurements of air emissions from industrial paved roads. Broom sweeping measurements presented in Section 2.3.2.1.
[b]PM_{10} control efficiency can be assumed to be the same as that tested.
[c]Water applied at 0.48 gal/yd².
[d]Equation yields efficiency in percent, V = number of vehicle passes since application.

TABLE 2-5. ESTIMATED PM_{10} EMISSION CONTROL EFFICIENCIES[a]

Method	Estimated PM_{10} efficiency, %
Vacuum sweeping	34
Improved vacuum sweeping[b]	37

[a]Reference 6. Estimated based on measured initial and residual ≤63 μm loadings on urban paved roads and Equation (2-1). Value reported represents the mean of 13 tests for each method. Broom sweeping mean (18 tests) given in Section 2.3.2.1.
[b]Sweeping improvements described in Refe-ence 6.

the surface loadings decrease. Because mitigative measures are less effective for public paved roads, a recent EPA draft urban dust policy stresses the importance of preventive measures, especially in instances where no dominant or localized source of road loading can be identified. Example sources would include: (1) unpaved areas adjacent to the road; (2) erosion due to storm water runoff; and (3) spillage from passing trucks. Corresponding examples of preventive measures include: (1) installing curbs, paving shoulders, or painting lines near the edge of the pavement; (2) controlling storm water or using vegetation to stabilize surrounding areas; and (3) requiring trucks to be covered and to maintain freeboard (i.e., distance between top of the load and top of truck bed sides). In instances where the source of loading can be easily identified (e.g., salt or sand spread during snow or ice storms) or the effects are localized (e.g., near the entrance to construction sites or unpaved parking lots), either preventive or mitigative measures could be prescribed. Table 2-6 summarizes Agency guidance on nonindustrial paved road preventive controls.

There are few efficiency values for any of the preventive measures presented in Table 2-6. Because these measures are designed to prevent deposition of additional material onto the paved surface, quantitative measurements before and after the control are generally not possible and interpretation of results are complicated. For example, based on ambient TSP monitoring results over a 3-month period, immediate and continuous manual cleaning of the access area to a construction site was estimated to result in ~30 percent control.[1] It is unclear, however, what effect seasonal variation in the monitoring data has on the estimate of 30 percent. Also, because this estimate is based on ambient air concentrations, use of the value may be inconsistent with the other efficiency estimates given in this chapter. Consequently, one very important further development deals with efficiency estimates for preventive measures.

A recent update of AP-42 Chapter 11.2 (Fugitive Dust Sources)--compared measured controlled emissions with estimates based on the reduced loading values, using the <u>industrial</u> paved road model presented in the next section.[2] Despite the fact that the reduced surface loadings were

TABLE 2-6. NONINDUSTRIAL PAVED ROAD DUST SOURCES AND PREVENTIVE CONTROLS

Source of deposit on road	Recommended controls
-- Sanding/salt	-- Make more effective use of abrasives through planning, uniform spreading, etc. -- Improve the abrasive material through specifications limiting the amount of fines and material hardness, etc. -- Rapid cleanup after streets become clear and dry
-- Spills from haul trucks	-- Require trucks to be covered -- Require freeboard between load and top of hopper -- Wet material being hauled
-- Construction carryout and entrainment	-- Clean vehicles before entering road -- Pave access road near site exit -- Semicontinuous cleanup of exit
-- Vehicle entrainment from unpaved adjacent areas	-- Pave/stabilize portion of unpaved areas nearest to paved road
-- Erosion from stormwater washing onto streets	-- Storm water control -- Vegetative stabilization -- Rapid cleanup after event
-- Wind erosion from adjacent areas	-- Wind breaks -- Vegetative stabilization or chemical sealing of ground -- Pave/treat parking areas, drive-ways, shoulders -- Limit traffic or other use that disturbs soil surface
-- Other	-- Case-by-case determination

often outside the range of the underlying data base, predictive accuracy was found to be quite good, both for vacuum sweeping and water flushing. For those two controls, the available data suggest that adequate estimates of controlled emission can be obtained from the predictive models. For flushing combined with broom sweeping, however, the estimates substantially overpredicted (by approximately a factor of 5) controlled emissions versus the measured values.

2.2 INDUSTRIAL PAVED ROADS

As noted earlier, emission estimation for paved roads depends less upon its ownership and more upon its surface material and traffic characteristics. In this manual, the term "industrial" paved road is used to denote those roads with higher surface loadings and/or are traveled by heavier vehicles. Consequently, some publicly owned roads are better characterized as industrial in terms of emissions. Examples would include city streets in heavily industrialized areas or areas of construction as well as paved roads in industrial complexes.

2.2.1 Estimation of Emissions

The current AP-42 PM_{10} emission factor for industrial paved roads is:[3]

$$e = 220\ (sL/12)^{0.3}\ (g/VKT)$$

$$e = 0.77\ (sL/0.35)^{0.3}\ (lb/VMT) \qquad (2\text{-}3)$$

where: e = emission factor, in units given above
sL = surface silt loading, g/m^2 (oz/yd^2)

The above equation is rated "A" in AP-42 (see Appendix A).

Alternatively, AP-42 presents a single-valued emission factor for use in lieu of Equation (2-3) for PM_{10} emissions from light-duty vehicles on heavily loaded industrial roads:

$$e = 93\ (g/VKT)$$

$$e = 0.33\ (lb/VMT) \qquad (2\text{-}4)$$

where e is as defined above. These single-valued emission factors are rated "C" (see Appendix A). Although no hard and fast rules can be provided, Table 2-7 summarizes a recommended decision process for selecting industrial paved road emission factors.

Table 2-8 presents a summary of silt loading values for industrial paved roads associated with a variety of industries. As is the case with all AP-42 Chapter 11.2 emission models, the use of site-specific data is strongly recommended.

2.2.2 Demonstrated Control Techniques for Industrial Paved Roads

As noted in Section 2.1.2, the vast majority of measured control efficiency values for paved roads are based on data from industrial roads. Consequently, the information presented earlier in Table 2-4 is more applicable to this class of road.

Mitigative measures may be more practical for industrial plant roads because (1) the responsible party is known; (2) the roads may be subject to considerable spillage and carryout from unpaved areas; and (3) all affected roads are in relatively close proximity, thus allowing a more efficient use of cleaning equipment. Preventive measures, of course, can be used in conjunction with plant cleaning programs and prevention is probably the preferred approach for city streets in industrialized areas with many potential sources of paved road dust. As before, the lack of efficiency values for preventive measures remains an important data gap and requires further investigation.

2.3 EVALUATION OF ALTERNATIVE CONTROL MEASURES

2.3.1 Preventive Measures

These types of control measures prevent the deposition of additional materials on a paved surface area. As a result, it is difficult to estimate their control effectiveness. For mitigative controls, before and after measurement (of surface loadings or of particulate emissions) is possible; clearly, this is not the case for preventive measures. Limited field data suggest that a 12-month construction project (without prevention programs) could result in an additional 18 tons/yr of TSP emissions from an adjacent paved road with 1,000 vehicle passes per day.[9] In this instance, one would expect that PM_{10} emissions would increase by approximately 10 tons/yr. As noted before, however, field data available to

TABLE 2-7. DECISION RULE FOR PAVED ROAD EMISSION ESTIMATES

Silt loading (sL), g/m^2	Average vehicle weight (W), Mg	Use model
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 > -300 to 400 g/m^2, it is recommended that the resulting estimate be compared to that from the unpaved road models (Section 3.0 of this manual), and the smaller of the two values used.

TABLE 2-8. INDUSTRIAL PAVED ROAD SILT LOADINGS[a]

Industry	No. of sites	No. of samples	Silt, percent w/w		No. of travel lanes	Silt loading, g/m^2	
			Range	Mean		Range	Mean
Copper smelting	1	3	[15.4-21.7]	[19.0]	2	[188-400]	[292]
Iron and steel production	6	20	1.1-35.7	12.5	2	0.09-79	12
Asphalt batching	1	3	[2.6-4.6]	[3.3]	1	[76-193]	[120]
Concrete batching	1	3	[5.2-6.0]	[5.5]	2	[11-12]	[12]
Sand and gravel processing	1	3	[6.4-7.9]	[7.1]	1	[53-95]	[70]

[a]Reference 3. Brackets indicate values based on only one plant visit.

estimate the effectiveness of preventive programs are extremely limited and often difficult to interpret. This data gap requires further development.

Instead of assigning control effectiveness values for preventive measures, regulatory personnel may choose to require all responsible parties (e.g., general contractors, street departments spreading salt and sand, businesses/homeowners with unpaved parking lots and driveways) to either submit control plans or agree to agency-supplied programs. Note that frequent watering of access areas should be discouraged (if possible) because that practice may compound carryout problems.

As early as 1971, EPA recommended reasonable mud/dirt carryout precautions including:

- Watering or use of suppressants at construction/demolition, road grading, and land clearing sites.
- Prompt removal of materials deposited upon paved roadways.
- Covering of open trucks transporting material likely to become airborne.

While most states have adapted many of EPA's recommendations to their own regulations, the vast number and spatial distribution of potential mud/dirt carryout points, as well as the large number of potentially responsible parties, make enforcement very difficult to plan and administer. Consequently, smaller jurisdictive areas (such as cities and counties) should be used in monitoring carryout enforcement.

Note that these local agencies include several other than those involved in air pollution per se. For example, building permits may be used to require carryout controls with building inspectors enforcing the regulations. Finally, it is clear that some agreement with the local public works department would be necessary to implement modifications in street salting and sanding procedures or to ensure prompt cleanup (see Appendix G).

2.3.1.1 Salting/Sanding for Snow and Ice. After winter snow and ice control programs, the heavy springtime street loadings found in certain areas of the country are known to adversely affect ambient PM_{10} concentrations. For example, data collected in Montana indicates that road sanding may produce early spring silt loadings 5 to 6 times higher than the mean loadings in Table 2-2.[3] Because that increase corresponds to roughly a fourfold increase in the emission level, it is clear that residual surface loadings represent an important source potentially requiring control. As indicated in Table 2-6, appropriate controls may include: (a) clean-up as soon as practical, (b) the use of improved materials, and (c) improvements in planning or application methods. Note that option (a) uses mitigative controls which are discussed in Section 2.3.2. The preventive options are discussed below.

Some municipalities have experimented by supplementing or replacing their usual snow/ice control materials with other harder and/or coarser materials. Because the choice of usual materials is based upon local availability (salt, sand, cinders) and price, it is clear that changes in materials applied will generally result in higher costs. However, the use of antiskid materials with either a lower initial silt content or greater resistance to forming silt-size particles will result in lower road surface silt loadings. Only limited field measurements comparing resultant silt contents and no measurements of silt loading values have been identified; consequently, it is not possible at this time to accurately estimate the control efficiency afforded by use of improved materials. Local agencies should design small-scale sampling programs (using the paved road sampling method presented in Appendix D) to estimate the differences in resulting silt loadings and then apply Equation (2-1) to determine a control efficiency value appropriate for their situation.

Improvements in planning and application techniques limit the amount of antiskid material applied to roads in an area. As was the case with improved materials, no field data are known to exist. However, an adequate estimate of area wide control efficiency can be obtained by (a) comparing the amounts of material applied, (b) assuming that both applications are equally subject to formation of fines, removal, etc., (c) assuming that both resultant silt loadings are substantially greater than the "baseline" (i.e., prewinter) value, and (d) using Equation (2-1). For example, if a community, through better planning, uses 30% less antiskid material, than the resultant silt loadings may be expected to be 30% lower. Use of Equation (2-1) would then indicate an effective PM_{10} control efficiency of 24.8%. Note that if assumption (c) above does not hold, the estimated control efficiency should be viewed only as an upper bound.

2.3.1.2 Carryout from Unpaved Areas and Construction Sites. Mud and dirt carryout from unpaved areas such as parking lots, construction sites, etc., often accounts for a substantial fraction of paved road silt loadings in many areas. The elimination of this carryout can significantly reduce paved road emissions.

As noted earlier, quantification of control efficiencies for preventive measures is essentially impossible using the standard before/after measurement approach. The methodology described below results in upper bounds of emission reductions. That is, the control afforded cannot be easily described in terms of percent but rather is discussed in terms of mass emissions prevented.

Furthermore, tracking of material onto a paved road results in substantial spatial variation in loading about the access point. This variation may complicate the modeling of emission reductions as well as their estimation, although these difficulties become less important as the number of unpaved areas in an area and their access points become larger.

For an individual access point from an unpaved area to a paved road, let N represent the daily number of vehicles entering or leaving the area. Let E be given by:

$$E = \begin{cases} 5.5 \text{ g/vehicle for } N \leq 25 \\ 13 \text{ g/vehicle for } N > 25 \end{cases}$$

where E is the unit PM_{10} emission increase in g/vehicle (see Section 5.1). Finally, if M represents the daily number of vehicle passes on the paved road, then the net daily emission reduction (g/d) is given by E x M, assuming complete prevention.

The emission reduction calculated above assumes that essentially all carryout from the unpaved area is controlled and, as such, is viewed as an upper limit. In use, a regulating agency may choose to assign an effective level of carryout control by using some fraction of the E values given above to calculate an emission reduction. Also, the regulatory agency could choose a percent control efficiency and substantiate compliance with testing data.

The methods used to control carryout consist of either mitigative measures on the paved road or preventive measures at the unpaved area or construction site. Discussion of these measures are presented in Sections 2.3.2, 3.3, and 5.3.

Finally, field measurements of the increased paved silt loadings around unpaved areas may also be used to gauge the effectiveness of control programs. A discussion of this is found in Section 2.5.

2.3.1.3 Other Preventive Control Measures. As shown in Table 2-6, numerous other preventive controls have been proposed for certain sources of paved road silt loadings. These controls range from wind fences in desert regions to keep sand off highways and other roads to measures designed to prevent losses of materials transported in trucks. No data are known to exist that quantify the PM_{10} emission reductions attributable to these controls. It is recommended that, if the use of one or more of these controls is contemplated in an area, the local control agency design small-scale field tests of the surface loadings (as described in Appendix D) before and after implementation to determine a reasonable estimate of the efficiency. Note that, in the design of any program of that type, particular attention must be paid to spatial variations in both sources and controls applied. For example, while a program for wind fences in desert areas would present few complications in assessing control, a program to assess the impact of, say, storm water control or haul truck restrictions, must include provisions for the localized (and possibly, random) nature of the source and its effects on surrounding roads.

2.3.2 Mitigative Measures

While preventive measures are to be preferred under the EPA urban dust policy, some sources of road dust loadings may not be easily controlled by prevention. Consequently, some mitigative measures may be necessary to achieve desired goals. This section discusses demonstrated mitigative measures.

TABLE 2-9. MISCELLANEOUS OPERATION/DESIGN AND COST DATA FOR BROOM SWEEPING PAVED ROADS[a]

Purchase price:	\$18,000 (1978) \$20,000 (1980)
Estimated life expectancy:	5 yr
Approximate annual operating cost during 1981:	\$65,100--No. 1 \$57,000--No. 2
Fuel consumption:	3 mi/gal
Cleaning capacity:	69,700 ft^2/h at 3 mph
Vehicle weight:	5,000 lb
Width of area cleaned per pass:	7.5 ft
Normal sweeping speed:	3 to 5 mile/h

[a]Reference 11. Purchase cost is actual cost in year purchased; other costs in 1981 dollars.

Records must be kept that document the frequency of broom sweeping applied to paved surfaces. Pertinent parameters to be specified in a control plan and to be regularly recorded include:

<u>General Information to be Specified in the Plan</u>

1. All road segments and parking locations referenced on a map available to both the responsible party and the regulatory agency
2. Length of each road and area of each parking lot
3. Type of control applied to each road/area and planned frequency of application
4. Any provisions for weather (e.g., ¼ in of rainfall will be substituted for one treatment)

<u>Specific Records for Each Road Segment/Parking Area Treatment</u>

1. Date of treatment
2. Operator's initials (note that the operator may keep a separate log whose information is transferred to the environmental staff's data sheets)
3. Start and stop times on a particular segment/parking lot, average speed, number of passes
4. Qualitative description of loading before and after treatment
5. Any areas of unusually high loadings, from spills, pavement deterioration

<u>General Records to be Kept</u>

1. Equipment maintenance records
2. Meteorological log (to the extent that weather influences the control program--see above)
3. Any equipment malfunctions or downtime.

In addition to those items related to control applications, some of the regulatory formats suggested in Section 2.5 require that additional records be kept. These records may include surface material samples or traffic counts. A suggested format for recording paved surface samples (following the sampling/analysis procedures given in Appendices D and E) is presented as Figure 2-1. Traffic counts may be recorded either manually or using automatic devices (low frequency, 1/season, 1/yr).

Type of Material Sampled: ______________________

Site of Sampling: ______________ No. of Traffic Lanes ______________

Type of Pavement: Asphalt/Concrete Surface Condition ______________

Sample No.	Vac. Bag	Time	Location*	Sample Area	Broom Swept (Y/N)

*Use code given on plant map for segment identification and indicate sample location on map.

Figure 2-1. Example paved road sample log.

2.3.2.2 Vacuum Sweeping of Roads. Vacuum sweepers remove material from paved surfaces by entraining particles in a moving air stream. A hopper is used to contain collected material and air exhausts through a filter system in a open loop. A regenerative sweeper functions in much the same way, although the air is continuously recycled. In addition to the vacuum pickup heads, a sweeper may also be equipped with gutter and other brooms to enhance collection.

Instantaneous control efficiency (cf. Appendix A) values were given earlier in Table 2-4. Available data show considerable scatter, ranging from a field measurement showing no effectiveness (over baseline uncontrolled emissions) to another field measurement of 58 percent. An average of the field measurements would indicate a efficiency of 34 percent. In addition, the estimated upper limits for PM_{10} control of urban roads (Table 2-5) compare fairly well with that average. Recall that very adequate controlled emission estimates were obtained using the industrial paved road model given as Equation (2-3). It is recommended that material loading samples be employed, if possible, in conjunction with the model to obtain a better estimate of control effectiveness.

Cost elements involved with vacuum sweeping include the following capital and operating/maintenance (O&M) expenses:

Capital: Purchase of truck or other device

O&M: Fuel, replacement parts, truck maintenance, operator labor cost data presented in Reference 10 provides the following estimates for a vacuum sweeping program

Initial capital expense: 36,800 $/truck

Annual O&M expense: 34,200 $/truck

All costs are based on April 1985 dollars. Determination of the number of trucks necessary can be made by assuming that 6 mi can be swept per unit per 12 h.[11] Additional cost data for a broom sweeping program is provided in Table 2-10.

Enforcement of a vacuum sweeping dust control program would ideally consist of two complementary approaches. The first facet would require the owner to maintain adequate records that would document to agency personnel's satisfaction that a regular cleaning program is in place. (See Appendix C for a suggested recordkeeping format.) The second

TABLE 2-10. MISCELLANEOUS OPERATION/DESIGN AND COST DATA FOR VACUUM SWEEPING PAVED ROADS[a]

Purchase price:	$72,000 (1980)
Estimated life expectancy:	5 yr
Approximate annual operating cost during 1981:	$214,000
Fuel consumption:	4 mi/gal
Hopper capacity:	10 yd^3
Vacuum blower capacity:	12,000 ft^3/min
Vehicle weight:	32,000 lb
Width of area cleaned per pass:[b]	5 ft
Normal sweeping speed:	5 mi/h
Velocity at suction head:	N/A
Type of dust control system (i.e., wet or dry):	Wet

[a]Reference 11. Purchase cost is actual cost in year purchased; other costs in 1981 dollars.
[b]Multiple passes required.

approach would involve agency spot checks of controlled roads by taking a material sample from the road. As before, the second approach is discussed in greater detail in Section 2.5. Note that some sample collection may be necessary to estimate control performance.

Records must be kept that document the frequency of vacuum sweeping paved surfaces. Pertinent parameters to be specified in a control plan and to be regularly recorded include:

General Information to be Specified in the Plan

1. All road segments and parking locations referenced on a map available to both the responsible party and the regulatory agency

2. Length of each road and area of each parking lot

3. Type of control applied to each road/area and planned frequency of application

4. Any provisions for weather (e.g., ¼ in of rainfall will be substituted for one treatment; no sprays during freezing periods, etc.)

Specific Records for Each Road Segment/Parking Area Treatment

1. Date of treatment

2. Operator's initials (note that the operator may keep a separate log whose information is transferred to the environmental staff's data sheets)

3. Start and stop times on a particular segment/parking lot, average speed, number of passes

4. Qualitative description of loading before and after treatment

5. Any areas of unusually high loadings, from spills, pavement deterioration, etc.

General Records to be Kept

1. Equipment maintenance records

2. Meteorological log (to the extent that weather influences the control program--see above)

3. Any equipment malfunctions or downtime

In addition to those items related to control applications, some of the regulatory formats suggested in Section 2.5 require that additional records be kept. These records may include surface material samples or traffic counts. A suggested format for recording paved surface samples (following the sampling/analysis procedures given in Appendices D and E) was presented in Figure 2-1. Traffic counts may be recorded either manually or using automatic devices.

2.3.2.3 Water Flushing of Roads. Street flushers remove surface materials from roads and parking lots using high pressure water sprays. Some systems supplement the cleaning with broom sweeping after flushing. Note that the purpose of the program is to remove material from the road surface; in some industries, water is regularly applied to roads to directly control emissions (i.e., as in unpaved roads). Unlike the two sweeping methods, flushing faces some obvious drawbacks in terms of water usage, potential water pollution, and the frequent need to return to the water source. However, flushing generally tends to be more effective in controlling particulate emissions.

Equations to estimate instantaneous control efficiency values are given in Table 2-3. Note that water flushing and flushing followed by broom sweeping represent the two most effective control methods (on the basis of field emission measurements) given in that table.

Cost elements involved with broom sweeping include the following capital and operating/maintenance (O&M) expenses:

Capital: Purchase of truck or other device

O&M: Fuel, replacement parts (possibly including brushes), truck maintenance, operator labor, water

Cost data presented in Reference 10 provides the following estimates for a flushing program;

Initial capital expense: 18,400 $/truck

Annual O&M expense: 27,600 $/truck

All costs are based on April 1985 dollars. Determination of the number of trucks required can be based on the assumption that 3 to 5 mi can be flushed or flushed and broom swept per unit per 8-h shift, respectively.[11] Additional cost/design data are provided as Table 2-11.

Enforcement of a road flushing (possibly supplemented by broom sweeping) program could consist of two approaches, as before. The first facet would require the owner to maintain adequate records that would document to agency personnel's satisfaction that a regular cleaning program is in place. (See Appendix C for a suggested recordkeeping format.) The second approach would involve agency spot checks of

TABLE 2-11. MISCELLANEOUS OPERATION/DESIGN AND COST DATA FOR FLUSHING PAVED ROADS[a]

Purchase price:	$68,000 (1976)
Estimated life expectancy:	10 yr
Approximate annual operating cost during 1981:	$57,000
Vehicle weight (dry):	N/A lb
Water tank capacity:	8,000 gal
Normal vehicle speed:	4 mi/h
Water pressure at nozzles:	50 psig
Vehicle weight (wet):	N/A lb
Fuel consumption:	7 mi/gal
Water flow at nozzles:	188 gal/min
Hopper capacity:	40 yd^3
Daily water consumption:	30,000 gal
Degree of water treatment:	1,800 gal/mil

[a]Reference 11. Purchase cost is actual cost in year purchased; other costs in 1981 dollars.

controlled roads by taking a material sample from the road. Recall that, while resulting estimates of controlled emissions should be adequate for a flushing program, the estimates are probably substantially overestimated in a flushing/broom sweeping program.

Records must be kept that document the frequency of broom sweeping applied to paved surfaces. Pertinent parameters to be specified in a control plan and to be regularly recorded include:

General Information to be Specified in the Plan

1. All road segments and parking locations referenced on a map available to both the responsible party and the regulatory agency
2. Length of each road and area of each parking lot
3. Type of control applied to each road/area and planned frequency of application
4. Provisions for weather (e.g., program suspended for periods of freezing temperatures)

Specific Records for Each Road Segment/Parking Area Treatment

1. Date of treatment
2. Operator's initials (note that the operator may keep a separate log whose information is transferred to the environmental staff's data sheets)
3. Start and stop times on a particular segment/parking lot, average speed, number of passes
4. Start and stop times for refilling tanks
5. Qualitative description of loading before and after treatment
6. Any areas of unusually high loadings, from spills, pavement deterioration, etc.

General Records to be Kept

1. Equipment maintenance records
2. Meteorological log (to the extent that weather influences the control program--see above)
3. Any equipment malfunctions or downtime

In addition to those items related to control applications, some of the regulatory formats suggested in Section 2.5 require that additional records be kept. These records may include surface material samples or traffic counts. A suggested format for recording paved surface samples (following the sampling/analysis procedures given in Appendices D and E) was presented in Figure 2-1. Traffic counts may be recorded either manually or using automatic devices.

2.4 EXAMPLE DUST CONTROL PLAN

To illustrate the use of material in this chapter, this section presents an example control plan. Unlike the other open dust sources considered in this manual, preventive control of paved roads (and especially public paved roads) requires that control be applied to a wide variety of contributing loading sources. Furthermore, the contribution of any individual loading source to the total silt loading on any roadway is, at present, impossible to determine. Consequently, the approach taken in this example will employ area wide silt loading reductions and will also use limited field sampling to gauge the effectiveness of the program.

Suppose a control agency determines that a 10% decrease in urban paved road emissions is necessary to meet some goal. Equation (2-1) shows that a 10 prcent decrease in the PM_{10} emission factor requires (a) a 10 percent reduction in traffic volume, (b) a 12% decrease in silt loading, or (c) some combination of traffic and silt loading reductions. Suppose that traffic reductions are not considered feasible and suppose further that the agency desires a uniform 12 percent decrease in area wide silt loadings rather than staggering loading decreases as a function of road lengths and traffic volumes.

The types of controls that could be applied to loading sources include: use of improved antiskid materials, rapid cleaning of snow/ice control methods, haul truck ordinances (e.g., covering, freeboard, etc.), and paving unpaved access points. Selection of sources to be controlled depend on a variety of factors, such as the perceived relative contribution of a source to an area's silt loading values, responsibility for enforcement of any new ordinances, etc.

In general, unless there is good reason to suspect that one source category is responsible for a substantial fraction of the paved road loading in an area, it is probable that a series of controls will be employed (see Section 2.5.2). Assessment of the (combined) effectiveness of the controls implemented will generally be based on the field sampling measurements discussed in Appendices D and E.

2.5 POTENTIAL REGULATORY FORMATS

2.5.1 General Guidelines

Clear and specific enforceable plan provisions are needed to gain credit for claimed emission reductions in State implementation plans (SIP's), which for paved road dust sources will likely rely on record-keeping, reporting, and surrogate factors rather than short-term mass emissions or opacity limits. Surrogate factors will include control program regulations, permits, or intergovernmental agreements to institute programs such as vacuum sweeping, mud/dirt carryout precautions, spill cleanup, erosion control, and/or measures to prevent or mitigate entrainment from unpaved adjacent areas. Record review of control programs (e.g., vacuum sweeping, road sand/salt application, etc.) and field checks (i.e., road silt loading sampling) will provide the likely means of compliance determination for these sources. Because paved road emissions are directly related to the surface silt loading, the most reliable regulatory formats are based on loading. Formats viable for other open dust sources--including opacity measurements, visible emissions at the property line--are generally not applicable for paved roads because of the lower unit emission levels involved (e.g., there are usually no visible plumes from a vehicle pass).

Many States currently have regulations related to the control of paved roads. Colorado, for example, may require a control plan from any party that repeatedly deposits materials which might create fugitive emissions from a public or private roadway. Note, however, that no quantitative determination of loading levels is specified.

An alternative format is presented below to suggest how a quantitative method could be incorporated in a regulation. Figure 2-2 presents a possible format for use with public paved road sources. In this example, if the silt loading on a road with an average traffic volume of 2,000 vehicles per day ever exceeds 2.9 g/m^2 (the "action level"), the regulatory agency may require the responsible party (e.g., a construction site with mud/dirt carryout) or the owner of the road to reduce the silt loading to a level less than the action level. The action level is an agency-supplied multiple of either baseline measurements or the surface silt loading predicted by Equation (2-2) and should correspond to

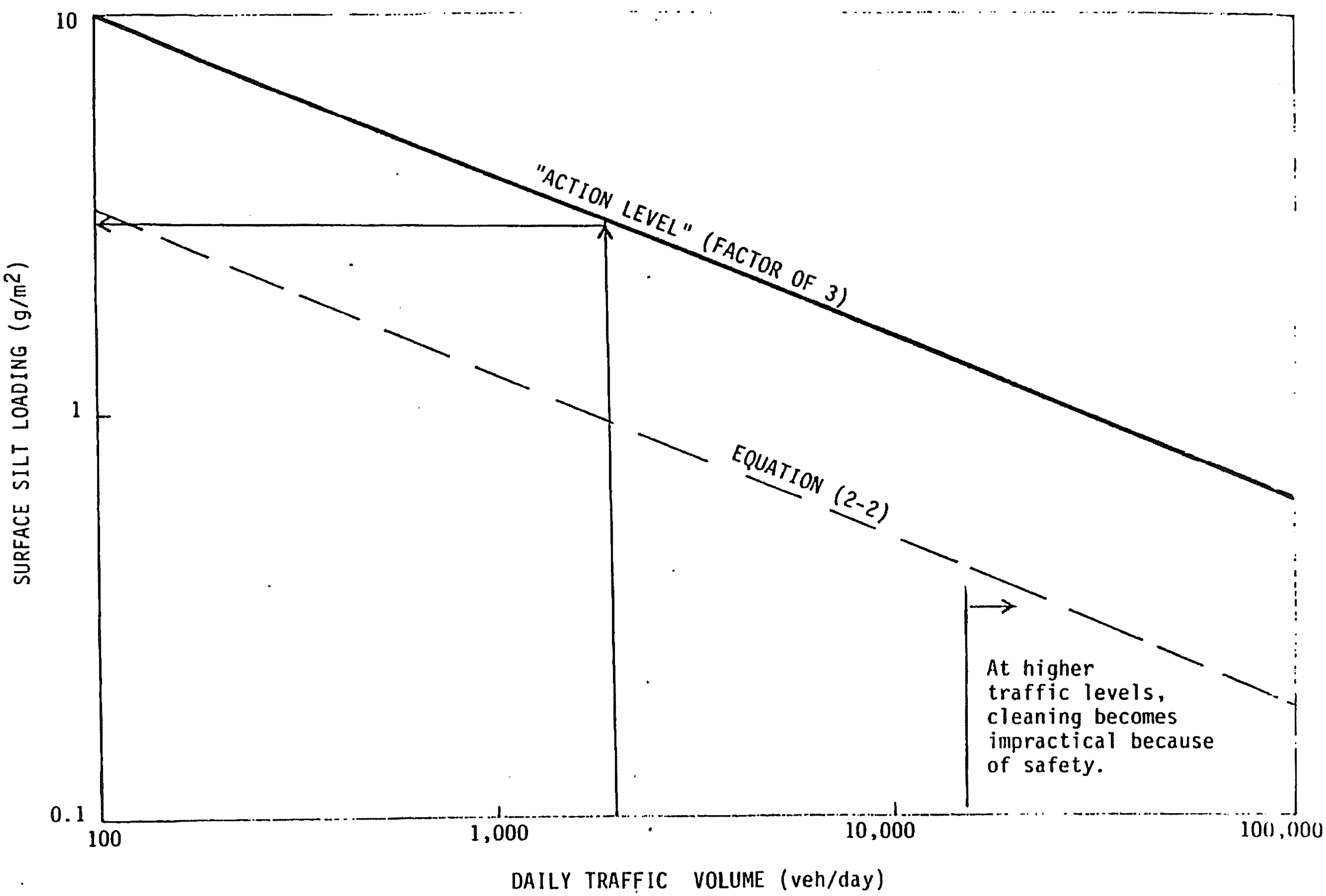

Figure 2-2. Possible use of "action levels" to trigger paved road controls.

minimum percent control efficiency level. The means of reduction will be left to the discretion of the responsible party and could consist of either preventive or mitigative controls. The maximum allowed silt loading requirement could be made part of a construction permit (as discussed in Section 5 of this manual) or an enforceable intergovernmental agreement. Note that additional traffic due to the construction activity should be included in the daily traffic volume used to determine the action level for the affected roadways. In addition, a request for permit should be accompanied with a description of the control technique(s) that will be employed. Similarly, intergovernmental agreements should clearly and specifically describe control techniques and associated recordkeeping and reporting requirements.

The field measurement of silt loading could either be made a requirement of the responsible party or be assigned to agency inspection personnel, or a combination of the two could be used. In either event, certain features of the measurement technique must be specified:

1. The sampling method used to determine silt loading for compliance inspection should conform to the technique used to develop the AP-42 urban paved road equation. That technique is specified in Appendix D and should be made part of an SOP for regulatory personnel or part of the construction permit.

2. Arrangements must be made to account for spatial variation of surface silt loading. Possible suggestions include (a) visually determining the heaviest loading on the road and selecting that spot for sampling, (b) sampling the midpoint of the road length segment of interest, and (c) sampling preselected (possibly on the basis of safety considerations) strips on the road surface (note that the samples may be aggregated).

3. Provision should be made to grant a "grace period" following a spill or other accidental increase in loading. An 8-h period is suggested to allow time for the responsible party to clean the affected area. This allowance should be made part of a construction or other permit.

For industrial paved roads, an approach similar to that described above could be applied as well, using agency-supplied action levels. Note that these levels could be specific to individual roads, apply to all roads in a plant, or be based on plant traffic levels. Because most plants will contain many roads, the regulatory agency may choose to set plant-wide goals (such as vacuum sweeping each road twice per week) rather than source-specific programs.

The control efficiency equations presented in Table 2-4 provide another potential regulatory format for industrial paved road sources. This approach involves inspection of both plant road cleaning records and traffic counts. By combining the two sets of information, regulatory personnel would be able to determine average efficiency values for the plant's controlled paved roads. Provision must be made to collect traffic information. The traffic data may require more frequent inspection visits than surface loading samples; however, analysis is more easily accomplished. Surface loading sampling provides an additional means for checking the success of achieving the estimated control efficiency.

2.5.2 Example SIP Language for Reduction of Public Paved Road Surface Contaminants

Public paved roads are important PM_{10} sources in areas across the country. Unlike the industrial sources described in this manual, control of municipal paved roads generally requires a close working agreement between various government bodies and the general public.

A number of States have developed enforceable regulations, permit conditions, or provisions in intergovernmental agreements (between State agencies, and with municipalities) that attempt to address sources contributing to the silt loading of paved roads. The following example regulations are drawn from existing State regulations and intergovernmental agreement provisions.

Material Transport

-- No person shall cause or permit the handling or transporting of any material in a manner which allows or may allow controllable particulate matter to become airborne. Visible dust emissions from the transportation of materials must be eliminated by covering stock loads in open-bodied trucks or other equivalently effective controls.

-- Earth or other material that is deposited by trucking and earth-moving equipment on paved streets shall be reported to the (local Department of Sanitation at _______) and removed immediately subject to safety considerations by the party or person responsible for such deposits.

Motor Vehicle Parking Areas

-- Effective ____________, no person shall cause, permit, suffer, or allow the operation, use, or maintenance of an unsealed or unpaved motor vehicle parking area.

Low use parking area exemption: Motor vehicle parking area requirements shall not apply to any parking area from which less than ___ (e.g., 10) vehicles exit on each day. Any person seeking such an exemption shall: (1) submit a petition to the Control Officer in writing identifying the location, ownership, and person(s) responsible for control of the parking area, and indicating the nature and extent of daily vehicle use; and (2) receive written approval from the regulating agency that a low use exemption has been granted.

Erosion and Entrainment From Nearby Areas

-- The City of __________ will revegetate, pave, or treat by using water, calcium chloride, or acceptable equivalent materials the following: paved road shoulders and approach aprons for unpaved roads and parking areas that connect to paved roads, which are within the City's right-of-ways or under the City's control and within X feet (e.g., 25) of roadways [specify location or entire roads by name], in amounts and frequencies as is necessary to effectively control PM_{10} emissions to a level of x percent control efficiency (e.g., paving--90 percent; vegetation per specified requirements--50 percent; chemical treatment per specified requirements--70 percent). [Include list of roads in memorandum of understanding and specify whether those areas will be revegetated, paved, or treated.]

-- If loose sand, dust, or dust particles are found to contribute to excessive silt loadings on nearby paved roads, the Control Officer shall notify the owner, lessee, occupant, operator, or user of said land that said situation is to be corrected within a specified period of time, dependent upon the scope and extent of the problem, but in no case may such a period of time exceed x (e.g., 2) days.

The Control Officer, or a designated agent, after due notice, may enter upon the subject land where said sand or dust problem exists, and take such remedial and corrective action as may be deemed appropriate to relieve, reduce, or remedy the existent dust condition, where the owner, occupant, operator, or any tenant, lessee, or holder of any possessory interest or right in the subject land, fails to do so.

Any cost incurred in connection with any such remedial or corrective action by the Control Officer shall be assessed against the owner of the involved property, and failure to pay the full amount of such costs shall result in a lien against said real property, which lien shall remain in full force and effect until any and all such costs shall have been fully paid, which shall include, but not be limited to, costs of collection and reasonable attorney's fee therefore.

Road Sanding/Salting and Traffic Reduction

-- The City of __________ will, beginning with the (year) winter season, restrict the use of sand used for anti skid operations to a material with greater than x percent (e.g., 95) grit retained by a number 100 mesh sieve screen and a degradation factor of x.

-- The City of __________ will provide alternative traffic flow patterns--such as a by-pass plan to reduce vehicular traffic (especially truck traffic) in the central business district to reduce the effects of vehicular reentrainment.

-- The City of __________ will conduct its vacuum street sweeping throughout the year with wintertime sweeping done whenever shaded pavement temperatures--as determined by the use of infrared thermometer--allow for the application of water spray from the vacuum sweeper without jeopardizing the safety of pedestrian and vehicular traffic on the swept areas. The street vacuuming program shall be designed to provide for maximum sweeping efforts throughout the winter and spring months and shall provide for adequate personnel and equipment to ensure thorough cleanup when possible within temperature and safety constraints. As soon as temperature conditions permit (melt periods), the City will begin vacuuming the road sand/salt loadings from streets per the following priority schedule: [include schedule in memo of understanding]. (Quality control provisions for recordkeeping/reporting requirements are presented in Section 2.3.2.2 and Appendix C.2.1. of this report.)

2.6 REFERENCES FOR SECTION 2

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3. U.S. Environmental Protection Agency. 1985. Compilation of Air Pollution Emission Factors, AP-42. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina.

4. Cowherd, C., Jr., and P. J. Englehart. 1984. Paved Road Particulate Emissions. EPA-600/7-84-077. U.S. Environmental Protection Agency, Washington, D.C.

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6. Duncan, M., et al. 1984. Performance Evaluation of an Improved Street Sweeper. EPA Contract No. 68-09-3902.

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

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9. Englehart, P. J., and J. S. Kinsey. 1983. Study of Construction Related Mud/Dirt Carryout. EPA Contract No. 68-02-3177, Work Assignment No. 21. July 1983.

10. Kinsey, J. S., et al. 1985. Control Technology for Sources of PM_{10}. Draft Final Report, EPA Contract No. 68-02-3891, Work Assignment No. 4. September 1985.

11. Cuscino, T., Jr., et al. 1983. 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.

to stockpile/reclaim activities in coal yards, compactor traffic in areas proximate to lifts at landfills, and travel related to open storage of finished products (such as coil at steel plants). These areas may often account for a substantial fraction of traffic-generated emissions from individual plants. In addition, these areas tend to be much more difficult to control than stretches of roadway (e.g., changing traffic patterns make semipermanent controls impractical, increased shear forces from cornering vehicles rapidly deteriorate chemically controlled surfaces, chemical suppressants may damage raw materials or finished products, etc.).

3.1 ESTIMATION OF EMISSIONS FROM UNPAVED ROADS

As was the case for paved roads, unpaved roads may be divided into the two classes of public and industrial. However, for the purpose of estimating emissions, there is no need to distinguish between the two, because the AP-42 emission factor equation takes source characteristics (such as average vehicle weight and road surface texture) into consideration:[1]

$$E = 0.61 \left(\frac{s}{12}\right) \left(\frac{S}{48}\right) \left(\frac{W}{2.7}\right)^{0.7} \left(\frac{w}{4}\right)^{0.5} \frac{(365-p)}{365} \text{ (kg/VKT)}$$

$$E = 2.1 \left(\frac{s}{12}\right) \left(\frac{S}{30}\right) \left(\frac{W}{3}\right)^{0.7} \left(\frac{w}{4}\right)^{0.5} \frac{(365-p)}{365} \text{ (lb/VMT)} \quad (3\text{-}1)$$

where: E = PM_{10} emission factor in units stated

s = silt content of road surface material, percent

S = mean vehicle speed, km/h (mil/h)

W = mean vehicle weight, Mg (ton)

w = mean number of wheels (dimensionless)

p = number of days with $\geq$0.254 mm (0.01 in.) of precipitation per year

Using the scheme given in Appendix A, the above equation is rated "A" in AP-42. Measured silt values are given in Table 3-1. As is the case with all AP-42 emission factors, <u>the use of site-specific data is strongly encouraged</u>.

Annual O&M costs: $6,600-$11,900/mile

These estimates are based on resurfacing every 5 years and "15 percent opportunity costs." Reference 7 estimates a cost of $140,000/mile (1983 dollars) to paved industrial unpaved roads. Because of the variety of cost estimates, it is strongly recommended that the reader obtain quotes from local paving contractors.

3.3.2.2 Gravel/Slag Improvements. As noted earlier, these types of improvements replace the present road surface material with a lower silt content material. Note that this method may increase road maintenance costs as the new aggregate fractures. This cost may be avoided by installing a "road carpet." Because Equation (3-1) indicates a linear relationship between silt content and emission levels, control efficiency can be estimated by determining the reduction in silt content. For example, if a road with a 12 percent silt content is recovered with a gravel (with an equilibrium silt content of 5 percent; see Table 3-1), then a 58 percent control efficiency would be expected.

Identified cost elements for these improvements follow:

Capital: Material (including "road carpet," if applicable), application equipment, and labor

O&M: Periodic grading including equipment and labor

No cost estimates were found in the reference documents used as the basis for this document. Because of the differences in local availability of cover materials (and civil engineering fabrics) and the amount of surface preparation, compaction, and maintenance required for various road types, it is recommended that the reader obtain quotes from local contractors.

3.3.2.3 Vegetative Cover. As noted by Turner et al., ". . . vegetative covers are obviously impractical for roads and facilities with construction activity . . . vegetative covering may be a practical control option for many inactive sites, but it is likely to be impractical for areas of continuing activity and areas that will not support a relatively dense vegetative cover."[5]

Consequently, vegetation is probably a viable control option only for inactive area wind erosion and is discussed elsewhere in this manual.

3.3.3 Surface Treatments

3.3.3.1 Watering. The control efficiency of unpaved road watering depends upon (a) the amount of water applied per unit area of road surface, (b) the time between reapplications, (c) traffic volume during that period, and (d) prevailing meteorological conditions during the period. While several investigations have estimated or studied watering efficiencies, few have specified all the factors listed above.

An empirical model for the performance of watering as a control technique has been developed.[8] The supporting data base consists of 14 tests performed in four states during five different summer and fall months. The model is:

$$C = 100 - \frac{0.8\ p\ d\ t}{i} \qquad (3\text{-}2)$$

where: C = average control efficiency, percent

P = potential average hourly daytime evaporation rate, mm/h

d = average hourly daytime traffic rate, (h^{-1})

i = application intensity, L/m^2

t = time between applications, h

Estimates of the potential average hourly daytime evaporation rate may be obtained from

$$p = \begin{cases} 0.0049 \times (\text{value in Figure 3-2}) \text{ for annual conditions} \\ 0.0065 \times (\text{value in Figure 3-2}) \text{ for summer conditions} \end{cases}$$

An alternative approach (which is potentially suitable for a regulatory format) is shown as Figure 3-3. This figure is adapted from 11 field tests conducted at a coal-fired power plant. Measured control efficiencies did not correlate well with either time or vehicle passes after application. However, this is believed due to reduced evening evaporation (logistics delayed the start of testing until 3 p.m. and testing continued through the early evening). Surface moisture grab samples were taken throughout the testing period, and not surprisingly, these show a strong correlation with control efficiency.

Figure 3-3 shows that between the average uncontrolled moisture content and a value of twice that, a small increase in moisture content results in a large increase in control efficiency. Beyond this point, control efficiency grows slowly with increased moisture content. Although

With regard to wind fences, only three studies have been identified for this particular control technique which attempt to quantify the degree of control achieved. Wind fences (and other types of barriers) are extremely cost effective in that they incur little or no operating and maintenance costs. For this reason wind fences are an attractive control alternative for windblown PM_{10} emissions.

Finally, both water injection and fabric filters have been used to control dust generation during drilling operations. Since this is a relatively minor source associated with construction operations, these controls do not offer significant emissions reductions. It should be noted, however, that drilling may be important at certain sites.

5.3 EVALUATION OF ALTERNATIVE CONTROL MEASURES

In this section, the various alternative control measures for fugitive PM_{10} at construction and demolition sites will be discussed in some detail. Included in this discussion will be the manner in which each technique controls emissions, methods for estimating control efficiency, an identification of cost elements to be considered, and available cost estimates for each in terms of capital and operating expenditures. Each control will be presented in the order shown previously in Section 5.2.

5.3.1 Watering of Unpaved Surfaces

5.3.1.1 Control Efficiency. Watering of unpaved roads is one form of wet dust suppression. This technique prevents (or suppresses) the fine particulate from leaving the surface and becoming airborne through the action of mechanical disturbance or wind. The water acts to bind the smaller particles to the larger material thus reducing emissions potential.

The control efficiency of watering of unpaved surfaces is a direct function of the amount of water applied per unit surface area (liters per square meter), the frequency of application (time between reapplication), the volume of traffic traveling over the surface between applications, and prevailing meteorological conditions (e.g., wind speed, temperature, etc.). As stated previously, a number of studies have been conducted with regard to the efficiency of watering to control dust, but few have quantified all parameters listed above.

The only specific control efficiency data which are available for construction and demolition involve the use of watering to control truck haulage emissions for a road construction project in Minnesota.[2] Using the geometric means of the important source characteristics (i.e., silt content, traffic volume, and surface moisture) and the regression equation developed from the downwind concentration data, a PM_{10} control efficiency of approximately 50 percent was obtained for a water application intensity of approximately 0.2 gal/yd²/hour.

It should be noted that truck travel at road construction sites is only somewhat similar to travel on unpaved roads. The road bed surface is generally not as compacted as a well-constructed unpaved road. There are also subtle differences in surface composition. Care should be taken, therefore, in estimating control efficiency for noncompacted surfaces.

For more compacted unpaved surfaces found in construction and demolition sites, an empirical model for the performance of a watering as a control technique has been developed. The supporting data base consists of 14 tests performed in four states during five different summer and fall months. The model is:[1]

$$C = 100 - \frac{0.8\ p\ d\ t}{i} \qquad (5\text{-}4)$$

where C = average control efficiency, in percent
p = potential average hourly daytime evaporation rate in mm/h
d = average hourly daytime traffic rate in vehicles per hour
i = application intensity in L/m²
t = time between applications in h

The term p in the above equation is determined using Figure 5-1 and the relationship:

$$p = \begin{cases} 0.0049\ e\ \text{(annual average)} & (5\text{-}5a) \\ 0.0065\ e\ \text{(worst case)} & (5\text{-}5b) \end{cases}$$

where p = potential average hourly daytime evaporation rate (mm/h)
e = mean annual pan evaporation (inches) from Figure 5-1

An alternative approach (which is potentially suitable for a regulatory format) is shown as Figure 5-2. This figure was presented earlier in Section 3.0.

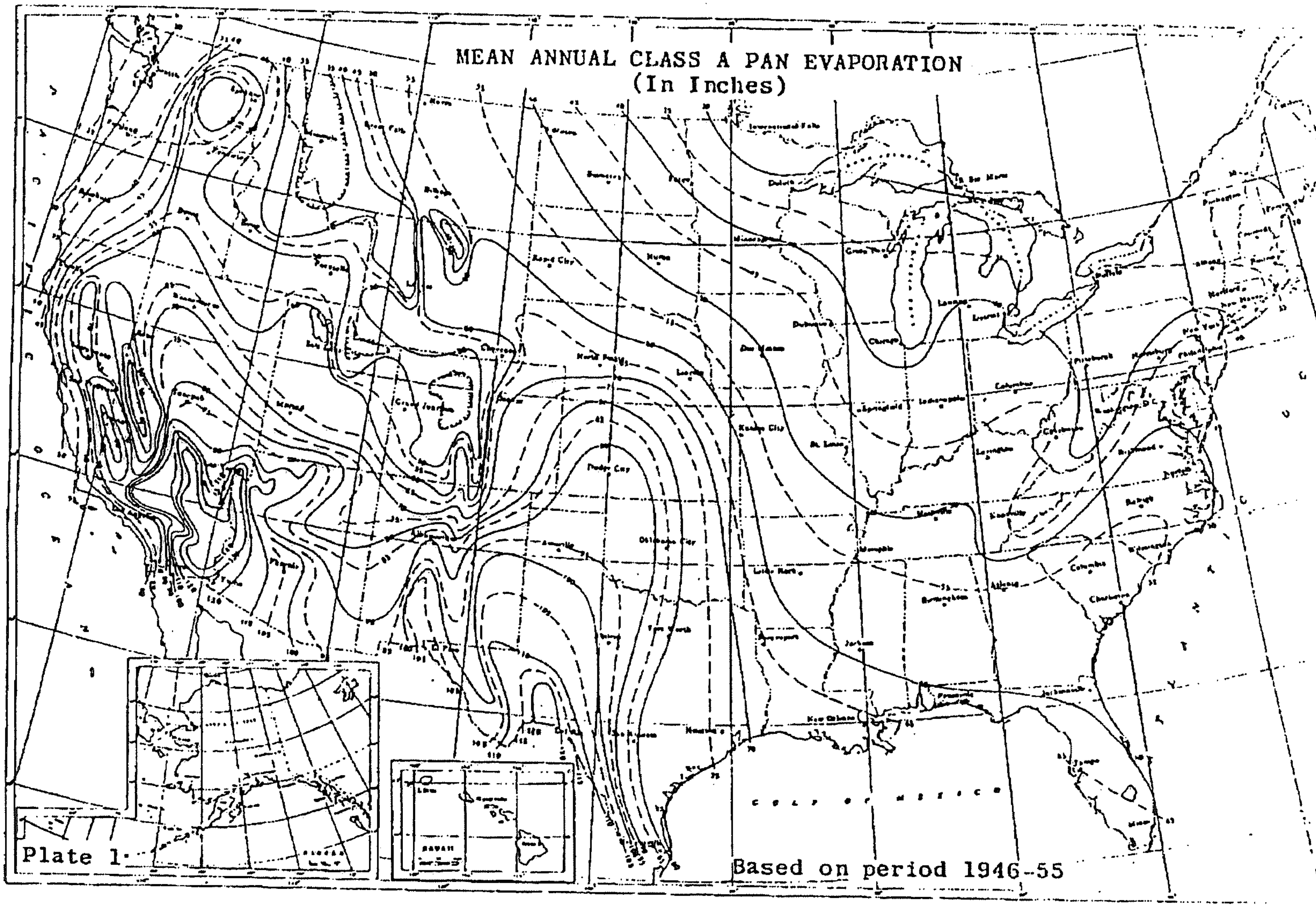

Figure 5-1. Mean evaporation for the United States.

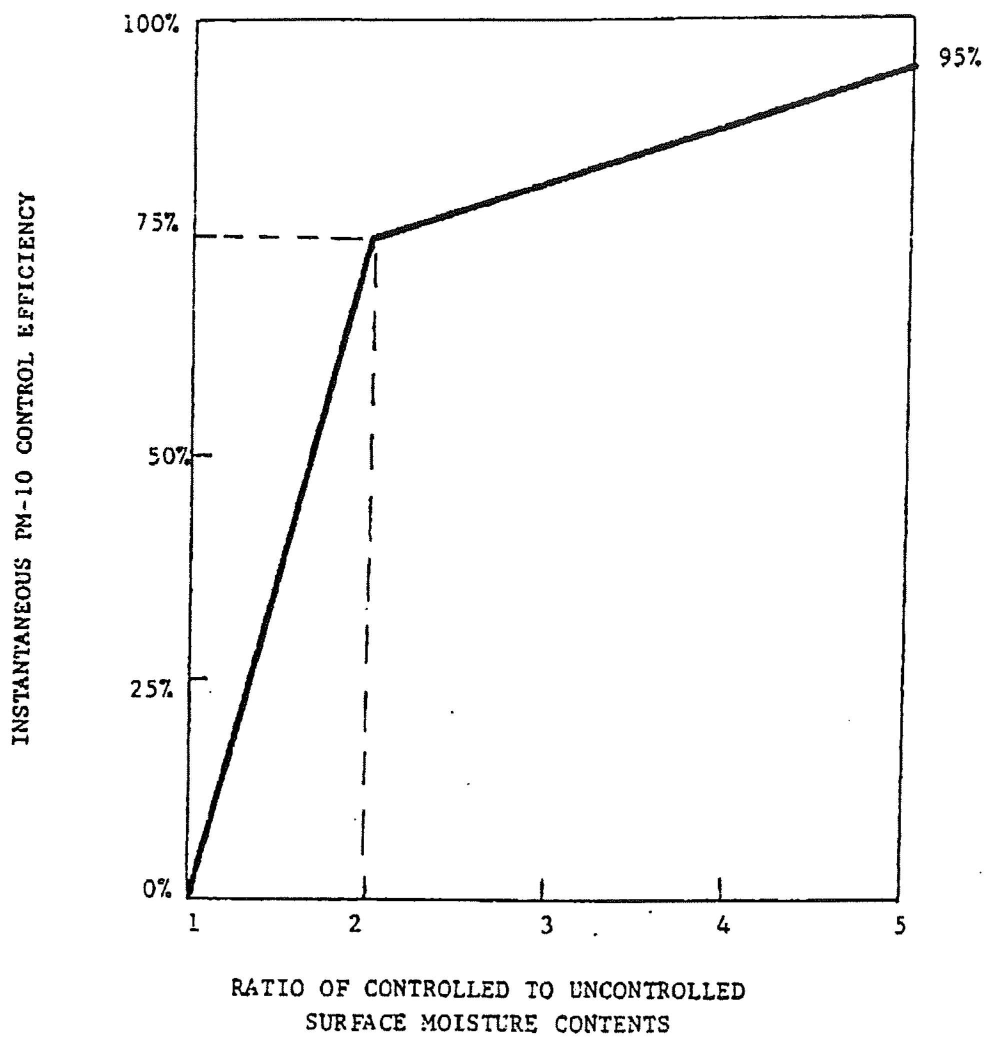

Figure 5-2. PM-10 control efficiency for watering unpaved roads.

Figure 5-2 shows that, between the average uncontrolled moisture content and a value of twice that, a small increase in moisture content results in a large increase in control efficiency. Beyond this point, control efficiency grows slowly with increased moisture content. Furthermore, this relationship is applicable to all size ranges considered:

$$c = \begin{cases} 75\,(M-1) & 1 \le M \le 2 \\ 62 + 6.7\,M & 2 \le M \le 5 \end{cases} \qquad (5\text{-}6)$$

where c = instantaneous control efficiency in percent

M = ratio of controlled to uncontrolled surface moisture contents

5.3.1.2 Control Costs. Costs for watering programs include the following elements:

- Capital: Purchase of truck or other device
- O&M: Fuel, water, truck maintenance, operator labor

Reference 6 estimates the following costs (1985 dollars):

Capital: $17,100/truck

O&M: $32,900/truck

The number of trucks required may be estimated by assuming that a single truck, applying water at 1 L/m^2, can treat roughly 4 acres of unpaved surface every hour.

5.3.1.3 Enforcement Issues. Enforcement of a watering program would ideally consist of two complementary approaches. The first facet would require the owner to maintain adequate records that would document to agency personnel's satisfaction that a regular program is in place. (See Appendix C for a suggested recordkeeping format.) The second approach would involve agency spot checks of controlled surfaces by taking material grab samples.

Records must be kept that document the frequency of water application to unpaved surfaces. Pertinent parameters to be specified in a control plan and rigorously recorded include:

General Information to be Specified.

1. All travel routes to be treated referenced on a plot plan available to both the site operator and regulatory personnel
2. Length and area of surfaces to be watered

3. Application intensity (gal/sq yd) and frequency (a minimum moisture content may be specified as an alternative)
4. Type of application vehicle, capacity of tank, and source of water

Specific Records to be Kept by Truck Operator

1. Date and time of treatment
2. Equipment used (this should be referred back to dust control plan specifications)
3. Operator's initials (a separate operators log may be kept and transferred later to permanent records by site operator)
4. Start and stop time, average speed, and number passes
5. Start and stop time for filling of water tank

Specific Records to be Kept by Site Operator

1. Equipment maintenance logs
2. Meteorological log of general conditions (e.g., sunny and warm vs. cloudy and cold)
3. Records of equipment breakdowns and downtime

An example permanent record form which may be used to record the above information is shown in Figure 5-3.

In addition to the above, some of the regulatory formats suggested in Section 5.4 require that records of surface samples or traffic counts also be kept. A suggested format for recording surface samples is shown in Figure 5-4. Traffic data may be recorded either manually or by automated counting devices.

5.3.2 Wet Suppression for Materials Storage and Handling

5.3.2.1 Control Efficiency. Wet suppression of materials storage and handling operations is similar to that used for unpaved surfaces. However, in addition to plain water this technique can also use water plus a chemical surfactant or micronized foam to control fugitive PM_{10}.

Surfactants added to the water supply allow particles to more easily penetrate the water droplet and increase the total number of droplets, thus increasing total surface area and contact potential. Foam is generated by adding a chemical (i.e., detergent-like substance) to a relatively small quantity of water which is then vigorously mixed to produce small bubble, high energy foam in the 100 to 200-μm size range.