DATA COLLECTION FOR THE HAZARDOUS WASTE IDENTIFICATION RULE

SECTION 3.0 WASTE MANAGEMENT UNIT DATA

Work Assignment Manager and Technical Direction:

Stephen M. Kroner
David A. Cozzie
U.S. Environmental Protection Agency
Office of Solid Waste
Washington, DC 20460

Prepared by:

Research Triangle Institute
3040 Cornwallis Road
Research Triangle Park, NC 27709-2194
Under Contract No. 68-W-98-085

U.S. Environmental Protection Agency
Office of Solid Waste
Washington, DC 20460

October 1999

ACKNOWLEDGMENTS

This work was performed by the Research Triangle Institute (RTI) under U.S. Environmental Protection Agency (EPA) contract 68-W-98-085 with the Office of Solid Waste. Stephen Kroner, the U.S. EPA Work Assignment Manager, provided overall technical direction and review throughout this work. Terry Pierson, the RTI Work Assignment Leader, along with Robert Truesdale, leader of the data collection task, provided day-to-day management and technical direction at RTI.

A number of individuals have been involved in the development of the data collection methodologies described herein. Jesse Baskir helped to direct the overall effort, and was responsible for quality control (QC) of the data compilation effort. Under his direction, the following engineers developed the waste management unit (WMU) model designs, collected and compiled data to develop the model inputs, and documented these activities: Subba Nishtala (landfills, land application units, and wastepiles) and Mark Bahner and Jeff Coburn (tanks and surface impoundments). Jenny Lloyd was responsible for assembling and processing the data and associated QC activities, and was assisted by Linda Andrews and Hilary Solomon in this regard. Jenny Lloyd, Debra Ackerman, Susie Tyndall, and Hilary Solomon assisted with document preparation, with Kathy Restivo serving as technical editor and Jesse Baskir and Robert Truesdale providing senior technical review and input. Cindi Salmons was the quality assurance officer.

DISCLAIMER

Table of Contents

Section **Page**

Table of Contents (continued)

Section **Page**

Figures

Tables

3.0 Waste Management Unit Data

The Hazardous Waste Identification Rule (HWIR) risk assessment was designed to estimate potential risks from the long-term management of HWIR waste by waste management facilities typically expected to handle exempted waste: Resource Conservation and Recovery Act (RCRA) Subtitle D nonhazardous industrial waste management units (WMUs). It employs an integrated, multimedia, multiple-exposure pathway, and multiple-receptor risk assessment model (3MRA model) to evaluate risks that may occur from the long-term, multimedia release of a chemical from these WMUs.

The 3MRA model includes 18 media-specific pollutant release, fate, transport, exposure, and risk modules. WMU input data are used explicitly by seven of these modules: the five source models, the air model, and the vadose zone model.[1] These WMU inputs describe the size and operation of the five land-based WMU types to be modeled as sources of contamination in the HWIR risk assessment: landfills, surface impoundments, wastepiles, land application units (LAUs), and aerated tanks. This section describes the derivation and use of values for the WMU data for each of these WMU types. Data sources are described along with data collection methodologies.

3.1 Parameters Collected

Table 3-1 presents the WMU model inputs as required by the source and media models. Three parameterization approaches were used for WMU inputs: site-specific, site-based and national. Site-specific data on WMU area, capacity, and waste loading rates were obtained from the Industrial D Screening Survey (Westat, 1987). Size-related WMU variables which were derived from these Industrial D data, are referred to as site-based data in this document. All other WMU inputs were developed on a national basis as either distributions or fixed values, depending on potential variability and model sensitivity.

3.2 Data Sources

The following documents are the primary data sources for the WMU data used for HWIR:

[1] WMU area also impacts site layout data by defining the area of interest (AOI) and, hence, implicitly affects other modules as well.

Table 3-1. WMU Inputs, by HWIR Model Component

Model Inputs	Source Models					Media Models	
	Aerated Tank	Land Application Unit	Landfill	Surface Impoundment	Waste Pile	Air Model	Vadose
Site-Specific							
area of source		!	!	!	!	!	
SettingID (SrcType+SiteID)						!	
waste loading rate (dry)					!		
WMU type (AT, SI, LAU, WP, or LF)	!	!	!	!	!	!	!
Site-Based							
depth of WMU (0 for AT, WP)		!	!	!			!
distance vehicle travels on active WMU surface		!	!		!		
fraction of SI occupied by sediments				!			
fraction organic carbon (cover soil)			!				
fraction surface area turbulent				!			
frequency of surface disturbance per month (active WMU)		!	!				
height (WP)					!		
impellers/aerators (number)				!			
impellers/aerators (total power)				!			
number of cultivations per application		!					
saturated hydraulic conductivity (LF cover soil)			!				
saturated water content (cover soil, total porosity)			!				
SCS curve number (WMU)		!			!		
soil moisture coefficient b (LF cover soil)			!				
source height						!	
spreading/compacting operations per day			!		!		
vehicle weight (mean)		!	!		!		
vehicles/day (mean annual)		!	!		!		
volumetric influent flow rate				!			
waste applications per year		!					
waste loading rate (dry)			!				
wet waste application rate		!					
wheels per vehicle (mean)		!	!		!		
National Tank Data (Correlated)							
area of source	!						
depth (liquid)	!						
fraction surface area-turbulent	!						
impellers/aerators (number)	!						
impellers/aerators (total power)	!						
volumetric flow rate (tank)	!						
National							
biologically active solids/total solids (ratio)	!			!			
biomass yield	!			!			
depth (tilling, LAU)		!					
digestion (sediments)	!			!			
dust suppression control efficiency		!	!		!		

(continued)

Table 3-1. (continued)

Model Inputs	Source Models					Media Models	
	Aerated Tank	**Land Application Unit**	**Landfill**	**Surface Impoundment**	**Waste Pile**	**Air Model**	**Vadose**
economic life of AT/SI	!			!			
fraction of unit occupied by sediments (max.)	!			!			
fraction vegetative cover (inactive WMU)		!	!				
impeller diameter	!			!			
impeller speed	!			!			
number of economic lifetimes (AT, SI)	!			!			
number of waste layers in a cell			!				
operating life (LAU, WP)		!			!		
optional soil cover thickness			!				
oxygen transfer correction factor	!			!			
oxygen transfer factor	!			!			
roughness height (inactive WMU)		!	!				
roughness ratio (LF waste zone surface)			!				
roughness ratio (till zone surface)		!					
saturated hydraulic conductivity (sediment layer)				!			
thickness of liner (or subsoil zone)			!				
USLE cover factor (WMU)		!			!		
USLE erosion control factor (WMU)		!			!		
vehicle speed (mean)		!	!		!		0

AT = aerated tank; LAU = land application unit; LF = landfill; SI = surface impoundment; USLE = universal soil loss equation; WMU = waste management unit; WP = wastepile.

- # *Landfills, wastepiles, LAUs, and surface impoundments* – Westat. 1987. *Screening Survey of Industrial Subtitle D Establishments. Draft Final Report.* Westat, Inc. EPA Contract No. 69-01-7359. U.S. EPA, Office of Solid Waste, Washington, DC.

- # *Aerated tanks* – U.S. EPA (Environmental Protection Agency). 1987. 1986 National Survey of Hazardous Waste Treatment, Storage, Disposal, and Recycling Facilities (TSDR) Database. Office of Solid Waste, Washington, DC.

Other data sources such as literature, site visits, and vendor information were used to supplement these sources as necessary. Table 3-2 lists the inputs for each model and includes the source code, units, parameterization (i.e., site-specific, site-based, or national), and data source for each input.

Table 3-2. WMU Data Sources

Model Input	Code	Units	Parameterization	Data Source
Landfill				
area of source	SrcArea	m^2	site-specific	Ind. D Screening Survey (Westat, 1987)
depth of source	SrcDepth	m	site-based	derived from Ind. D
distance vehicle travels on active LF cell surface	mt	m	site-based	derived from Ind. D
dust suppression control efficiency	effdust	unitless	national	U.S. EPA (1989)
fraction organic carbon (cover soil)	focC	mass fraction	site-specific	USSOILS (Schwarz and Alexander, 1995)
fraction vegetative cover (inactive LF cell)	veg	fraction	national	professional judgment
frequency of surface disturbance per month (active LF cell)	fd	1/mo	site-based	derived from Ind. D
number of waste layers in a cell	Nly	unitless	site-based	derived from Ind. D
optional soil cover thickness	zC	m	national	professional judgment
roughness height (inactive LF cell)	zruf	cm	national	U.S. EPA (1989)
roughness ratio (LF waste zone surface)	Lc	unitless	national	U.S. EPA (1989)
saturated hydraulic conductivity (LF cover soil)	KsatC	cm/h	site-specific	CONUS (Miller and White, 1998); Carsel and Parrish (1988)
saturated water content (cover soil, total porosity)	WCS_C	volume fraction	site-specific	CONUS (Miller and White, 1998); Carsel and Parrish (1988)
soil moisture coefficient b (LF cover soil)	SMbC	unitless	site-specific	CONUS (Miller and White, 1998); Carsel and Parrish (1988)
spreading/compacting operations per day	Nop	1/d	site-based	derived from Ind. D
thickness of liner (or subsoil zone)	zS	m	national	professional judgment
vehicle speed (mean)	vs	km/h	national	Overcash and Pal (1979)
vehicle weight (mean)	vw	Mg	site-based	derived from Ind. D
vehicles/day (mean annual)	nv	1/d	site-based	derived from Ind. D
waste loading rate (dry)	load	Mg/yr	site-based	derived from Ind. D
waste zone thickness	zW	m	site-based	derived from Ind. D
wheels per vehicle (mean)	nw	unitless	site-based	derived from Ind. D
WMU type (specified LF)	SrcType	unitless	site-specific	Ind. D Screening Survey (Westat, 1987)
Wastepile				
area of source	SrcArea	m^2	site-specific	Ind. D Screening Survey (Westat, 1987)
distance vehicle travels on WP surface	mt	m	site-based	derived from Ind. D
dust suppression control efficiency	effdust	unitless	national	U.S. EPA (1989)
height of WP above grade	zZ1WMU	m	site-based	derived from Ind. D
operating life	CutOffYr	yr	national	professional judgment
SCS curve number (WMU)	CNwmu	unitless	site-based	derived from Ind. D
spreading/compacting operations per day	Nop	1/d	site-based	derived from Ind. D
USLE cover factor (WMU)	Cwmu	unitless	national	Wanielista and Yousef (1993)
USLE erosion control factor (WMU)	Pwmu	unitless	national	Wanielista and Yousef (1993)
vehicle speed (mean)	vs	km/h	national	Overcash and Pal (1979)
vehicle weight (mean)	vw	Mg	site-based	derived from Ind. D
vehicles/day (mean annual)	nv	1/d	site-based	derived from Ind. D
waste loading rate (dry)	load	Mg/yr	site-specific	Ind. D Screening Survey (Westat, 1987)
wheels per vehicle (mean)	nw	unitless	site-based	derived from Ind D
WMU type (specified WP)	SrcType	unitless	site-specific	Ind. D Screening Survey (Westat, 1987)
Land Application Unit				
area of source	SrcArea	m^2	site-specific	Ind. D Screening Survey (Westat, 1987)
depth of tilling	zZ1WMU	m	national	literature

(continued)

Table 3-2. (continued)

Model Input	Code	Units	Parameterization	Data Source
depth of source	SrcDepth	m	national	= tilling depth
distance vehicle travels on LAU surface	mt	m	site-based	derived from Ind. D
dust suppression control efficiency	effdust	unitless	national	U.S. EPA (1989)
fraction vegetative cover	veg	fraction	national	professional judgment
frequency of surface disturbance per month (active LAU)	fd	1/mo	site-based	derived from Ind. D
number of cultivations per application	fcult	unitless	site-based	derived from Ind. D
operating life	CutOffYr	yr	national	professional judgment
roughness height	zruf	cm	national	U.S. EPA (1989)
roughness ratio (till zone surface)	Lc	unitless	national	U.S. EPA (1989)
SCS curve number (WMU)	CNwmu	unitless	site-based	derived from Ind. D
USLE cover factor (WMU)	Cwmu	unitless	national	Wanielista and Yousef (1993)
USLE erosion control factor (WMU)	Pwmu	unitless	national	Wanielista and Yousef (1993)
vehicle speed (mean)	vs	km/h	national	Overcash and Pal (1979)
vehicle weight (mean)	vw	Mg	site-based	derived from Ind. D
vehicles/day (mean annual)	nv	1/d	site-based	derived from Ind. D
waste applications per year	Nappl	1/yr	site-based	derived from Ind. D
wet waste application rate	Rappl	Mg/m^2-yr	site-based	derived from Ind. D
wheels per vehicle (mean)	nw	unitless	site-based	derived from Ind. D
WMU type (specified LAU)	SrcType	unitless	site-specific	Ind. D Screening Survey (Westat, 1987)
Surface Impoundment				
area of source	SrcArea	m^2	site-specific	Ind. D Screening Survey (Westat, 1987)
biologically active solids/total solids (ratio)	kba1	unitless	national	Tchobanoglous (1979)
biomass yield	bio_yield	g/g	national	Tchobanoglous (1979)
depth of source	SrcDepth	m	site-specific	Ind. D Screening Survey (Westat, 1987)
depth of WMU	d_wmu	m	site-based	derived from Ind. D
digestion (sediments)	k_dec	1/s	national	Tchobanoglous (1979)
economic life of AT/SI	EconLife	yr	national	professional judgment
fraction of SI occupied by sediments (max.)	d_setpt	fraction	site-based	derived from Ind. D
fraction surface area-turbulent	F_aer	fraction	site-based	derived from Ind. D
impeller diameter	d_imp	cm	national	U.S. EPA (1990)
impeller speed	w_imp	rad/s	national	U.S. EPA (1990)
impellers/aerators (number)	n_imp	unitless	site-based	derived from Ind. D
impellers/aerators (total power)	Powr	hp	site-based	derived from Ind. D
number of economic lifetimes	NumEcon	unitless	national	professional judgment
oxygen transfer correction factor	O2eff	unitless	national	Tchobanoglous (1979)
oxygen transfer factor	J	lb O_2/h-hp	national	Tchobanoglous (1979)
saturated hydraulic conductivity (sediment layer)	hydc_sed	m/s	national	professional judgment
volumetric influent flow rate	Q_wmu	m3/s	site-based	derived from Ind. D
WMU type (specified SI)	SrcType	unitless	site-specific	Ind. D Screening Survey (Westat, 1987)
Aerated Tank				
area of source	SrcArea	m^2	national_correlated	derived from TSDR Survey
biologically active solids/total solids (ratio)	kba1	unitless	national	Tchobanoglous (1979)
Aerated Tank (continued)				
biomass yield	bio_yield	g/g	national	Tchobanoglous (1979)
depth (liquid)	d_wmu	m	national_correlated	derived from TSDR Survey
digestion (sediments)	k_dec	1/s	national	Tchobanoglous (1979)
economic life of AT/SI	EconLife	yr	national	professional judgment
fraction of tank occupied by sediments (max.)	d_setpt	fraction	national	professional judgment

(continued)

Table 3-2. (continued)

Model Input	Code	Units	Parameterization	Data Source
fraction surface area-turbulent	F_aer	fraction	national_correlated	derived from TSDR Survey
impeller diameter	d_imp	cm	national	U.S. EPA (1990)
impeller speed	w_imp	rad/s	national	U.S. EPA (1990)
impellers/aerators (number)	n_imp	unitless	national_correlated	API/CMA/SOCMA (1998)
impellers/aerators (total power)	Powr	hp	national_correlated	professional judgment
number of economic lifetimes	NumEcon	unitless	national	professional judgment
oxygen transfer correction factor	O2eff	unitless	national	Tchobanoglous (1979)
oxygen transfer factor	J	lb O_2/h-hp	national	Tchobanoglous (1979)
volumetric flow rate (tank)	Q_wmu	m^3/s	national_correlated	TSDR Survey (U.S. EPA, 1987)
WMU type (specified AT)	SrcType	unitless	site-specific	specified for sites w/SI
Air Model				
area of source	SrcArea	m^2	site-specific	Ind. D Screening Survey (Westat, 1987)
source height	SHight	m	site-based	derived from Ind. D
SettingID (SrcType+SiteID)	SettingID	unitless	site-specific	Ind. D Screening Survey (Westat, 1987)
WMU type (AT, SI, LAU, WP, or LF)	SrcType	unitless	site-specific	Ind. D Screening Survey (Westat, 1987)
Vadose Zone				
depth of source (0 for AT, WP)	SrcDepth	m	site-based	derived from Ind. D
WMU type (AT, SI, LAU, WP, or LF)	SrcType	unitless	site-specific	Ind. D Screening Survey (Westat, 1987)

AT = aerated tank; LAU = land application unit; LF = landfill; SI = surface impoundment; USLE = universal soil loss equation; WMU = waste management unit; WP = wastepile

3.2.1 Industrial D Screening Survey

The primary source of data used to characterize waste sources is the 1985 *Screening Survey of Industrial Subtitle D Establishments*, referred to as the Industrial D Screening Survey or Ind D (Westat, 1987). This survey was designed to collect information about nonhazardous (RCRA Subtitle D) waste management practices at industrial facilities across the United States. Data were gathered for the following land-based WMU types: landfills, wastepiles, LAUs, and surface impoundments. The HWIR modeling effort used the facility address, dimensions of the WMUs, and annual waste volumes for the WMUs.

The Industrial D Screening Survey collected information on land-based Ind D waste management operations for 17 industry groups[2] defined by EPA. Data from this survey have been used to represent Ind D facility locations and WMU characteristics in a variety of RCRA regulatory initiatives, including the 1995 HWIR proposal. Although the Industrial D data are more than 10 years old, they are the largest consistent set of data available on Ind D WMU locations, dimensions, and waste volumes. Information on the survey design, response rates, and

[2] Industry groups as follows: (1) organic chemicals; (2) primary iron and steel; (3) fertilizer and agricultural chemicals; (4) electric power generation; (5) plastic and resins; (6) inorganic chemicals; (7) stone, clay, glass, and concrete; (8) pulp and paper; (9) primary nonferrous metals; (10) food and kindred products; (11) water treatment; (12) petroleum refining; (13) rubber and miscellaneous products; (14) transportation equipment; (15) selected chemical and allied products; (16) textiles; and (17) leather and leather products.

overall data quality and completeness may be found in Westat (1987), Clickner (1988), and Clickner and Craig (1988).

There were 15,844 total sites in the Ind D database. Of those, 2,850 reported that they managed waste in a landfill, LAU, surface impoundment, or wastepile. Only 2,839 sites, however, reported surface area, which is a required parameter for the HWIR model. Another 96 sites did not have address information because of confidential business information (CBI) claims, and 67 sites were outside of the contiguous United States (25 in Alaska and 37 in Hawaii). Some 201 sites (with a reported area and within the contiguous United States) were randomly selected for the HWIR modeling effort. When sites with no area or no address were selected, they were resampled. Table 3-3 shows the representativeness of the 201 sites selected for the HWIR model compared to the entire set of 2,850 facilities in the Industrial D Screening Survey. Section 2.0 provides general facility information, including industry group and location, for these 201 facilities.

Previous EPA Composite Model for leachate migration with Transformation Products (EPACMTP) (U.S. EPA, 1997) modeling efforts have uncovered issues associated with the internal consistency of the Industrial D data. For example, for certain facilities, the remaining capacity is greater than the total capacity of the unit. In other cases, depths calculated from site-specific data are unreasonably large or small. To address such problems, questionable data have been culled and/or replaced using procedures developed for EPACMTP (described in U.S. EPA, 1997). These replacement values were generated using random realizations from the probability distribution of quantity and/or capacity conditioned on area. Table 3-4 lists the number of WMU types for the entire Ind D data set and for the HWIR subset of 201 sites, as well as the number of replacement values calculated for each group.

In addition, the existing Ind D database contains some zero values for waste quantity and area that resulted from truncation of the third decimal place in the original database. When zero area or zero waste quantity was reported, a minimum bound of 0.005 acre (equal to 20.23 m^2) or 0.005 M ton (equal to 0.005 Mg) was used (U.S. EPA, 1997).

Calculations for replacement values and other site-based model inputs are explained further in the discussion sections for each of the WMU types. Appendix 3A shows raw data from the Industrial D Screening Survey (including replacement values) for the 201 Industrial D sites addressed in this analysis. This information includes the types and numbers of WMUs at each site, the average area, the waste quantity, and the total capacity for each WMU.

Table 3-3. WMU Type Distribution of 201 Sample Facilities

WMU Type	201 Sample Facilities		2,850 Industrial D Facilities	
	Number	Percentage	Number	Percentage
Landfill (LF)	56	27.9	801	28.1
Land Application Unit (LAU)	28	13.9	345	12.1
Surface Impoundment (SI)	137	68.2	1,869	65.6
Wastepile (WP)	61	30.3	829	29.1

Table 3-4. Number of Industrial D WMUs Used for HWIR Model

WMU Type	Sample Facilities			Industrial D Facilities			
	Selected for HWIR Modeling	Waste Quantity Replaced	Capacity Replaced	Manage Waste in WMU	Report Area for WMU	Waste Quantity Replaced	Capacity Replaced
LF	56	0	24	827	824	0 [a]	303
LAU	28	1	N/A	354	352	20	N/A
SI	137	4	21	1,930	1,926	57	268
WP	61	34	N/A	853	847	391	N/A
Total	201	39	45	2,850	2,839	468	571

[a] Waste quantity was missing for 6 landfills, but because they were not selected as part of the 201 subset, replacement values were not calculated.

N/A = Not applicable.

3.2.2 National Survey of Hazardous Waste Treatment, Storage, Disposal, and Recycling Facilities

The Industrial D Screening Survey (Westat, 1987) did not include tanks. Therefore, a tanks database was developed for this analysis that compiled flow rates and tank volumes. The primary source for these data was EPA's National Survey of Hazardous Waste Treatment, Storage, Disposal, and Recycling Facilities (TSDR Survey) (U.S. EPA, 1987). This comprehensive survey requested information from 2,626 TSDR facilities concerning their 1986 hazardous waste management practices and quantities. It also included a specific questionnaire regarding tanks used at each facility. Responses were received from 2,322 facilities. Of these, 1,700 facilities provided information on 18,773 tanks.

The TSDR Survey characterizes tanks containing hazardous (Subtitle C) wastes; extensive data were not available on tanks used for nonhazardous waste management. EPA believes, however, that from the perspective of basic tank design, hazardous waste tanks should adequately represent tanks designed for treating nonhazardous wastes.

3.2.2.1 Tank Data Set. The only subset of the original TSDR Survey currently available is for facilities that received any quantity of waste from an off-site source. This subset of data contains information on 8,511 tanks located at 710 facilities (approximately 45 percent of the tanks in the survey). This reduced data set was used to characterize tanks for the HWIR study. Although it would have been preferable to use the original complete data set, including tanks at facilities that treat only wastes generated on-site, these data are, unfortunately, no longer available electronically. The subset data, however, include a broad range of tank volumes – from less than 55 gal to more than 5,000,000 gal – and it is likely that the subset data represents the range of tank volumes reported for all tanks.

Several criteria were used to guide the development of the tanks database. These criteria were applied to the TSDR Survey data to determine which tanks should be included in the HWIR aerated tank data set:

- *Classification* – Only aerated treatment tanks were included in the database (see Section 3.2.2.2).

- *Flow rate* – Only those tanks reporting nonzero flow rates were included in the database.

- *Open versus covered tanks* – Only open tanks were included in the database; closed or covered tanks were omitted because emissions from covered tanks are likely to be significantly lower than emissions from open tanks. Therefore, results calculated for open tanks should also be protective for exposures associated with covered tanks.

- *Tank volume* – All tanks with a volume of 55 gal or less were excluded from the database. Inclusion of a relatively large number of smaller volume tanks could skew the risk results in the direction of lower risk because these smaller tanks would tend to have smaller surface areas and smaller aeration rates (where applicable), resulting in lower emission levels. It also can be argued that these smaller volume containers should be classified as drums and not tanks due to their size.

  Additionally, the two largest tanks (approximately 30,000,000 gal), one aerated treatment and one nonaerated treatment, were reviewed because these tanks were many times larger than the next largest tanks and appeared to be nonrepresentative. The facility that owns both tanks was contacted and it was determined that the tanks in question have volumes of 3,000,000 gal and 6,000,000 gal (Allswede, 1999), values within the range represented by the other tanks in the database. The tank volumes for these tanks were corrected in the database to the values provided by the facility.

3.2.2.2 Tank Classification. Industrial tanks can be used for either storage or treatment of wastes and can be further categorized as either aerated/agitated or quiescent (i.e., not aerated or agitated). Aeration or agitation is used in wastewater treatment systems to transfer air to the liquid in order to improve mixing or increase biodegradation. Storage tanks are, by definition, quiescent because they do not include aeration processes. Treatment tanks can belong to either group.[3] The HWIR analysis models only aerated tanks; therefore, storage tanks and any treatment tanks identified as quiescent were not included in the HWIR tank data set.

To determine which tanks were used for storage and which were used for aerated treatment, process codes from the TSDR Survey were evaluated. Tanks with process codes of either 2A (accumulation in tanks) or 2ST (storage in tanks) were classified as storage tanks. The

[3] Examples of quiescent treatment tanks are clarifiers and filters (such as sand or mixed-media filters).

TSDR Survey used a broad range of treatment codes (including codes for incinerators and belt filter presses); classification of treatment tanks was limited to those processes listed in Appendix 3B, Table 3B-1.

The process codes were evaluated further to determine the level of aeration used for treatment tanks. HI aeration was assigned to tanks that actively mix the liquid surface for the purpose of aeration or that add diffused air. LO aeration was assigned to tanks that are likely to have mixing devices used with chemical additions or other purposes. NO aeration was used for tanks that are purposefully operated to minimize mixing or agitation (e.g., a clarifier). The aeration level assignments for each process code are shown in Appendix 3B, Table 3B-1. The treatment tanks were subsequently divided into aerated tanks (tanks designated as HI or LO aeration) and nonaerated tanks (tanks designated as NO aeration).

The numbers of tanks included in each classification are summarized in Table 3-5. A few tanks reported multiple process codes that included both a storage code (2A or 2ST) and a treatment code. These tanks were classified as both storage and treatment tanks. The final tank data set used for HWIR modeling consists of 624 aerated treatment tanks.

3.2.2.3 <u>Additional Tank Data Used for Imputation</u>. To address tank-specific data gaps in the tanks database, additional data sources were identified. These data included information collected in 1985 and 1986 during EPA site visits to aerated treatment systems. These systems were selected to represent a range of aeration processes and reflect a variety of industries and waste types. To identify candidate facilities, numerous phone contacts were made with state and local environmental agencies. From these conversations, information on wastewater treatment systems at 54 facilities was collected. Site visits to these facilities were then conducted, and data on the individual tanks were provided by the facilities, including data on tank dimensions. Added to these data were five tanks from the TSDF background information document (U.S. EPA, 1991). This resulted in a supplemental database of 49 tanks (13 with high aeration, 9 with low aeration, and 27 with no aeration), presented in Appendix 3B, Table 3B-2.

Table 3-5. Numbers of Tanks, by Classification

Tank Classification	Number
Storage tanks	638
Aerated treatment tanks	624
High aeration	29
Low aeration	595
Nonaerated treatment tanks	273
Total	1,535

In addition to these data, several tank vendors were contacted to establish a reasonable high end for tank capacity and depth based on design principles. As a result, a reasonable maximum capacity for an open, partially or completely aboveground tank was defined to be approximately 3,000,000 gal and the depth of such a tank would not be expected to exceed 10 m (about 32 ft) (Pekar, 1999).

To maintain the integrity of the tank database, these site visit tanks and hypothetical tanks were used only as a basis for imputing values and were not modeled in this analysis.

3.2.3 National Data

When site-specific data were not available, WMU inputs were either imputed from site-specific data using national relationships or derived directly from national data. National data sources include literature, personal communication, and best engineering judgments. Data were collected first to derive general process diagrams for WMUs and then to develop specific parameter value estimates for design variables. When no information could be found, engineering calculations or judgments were used to generate design information or values for specific parameters.

Generally, in seeking information, multiple sources were consulted in order to identify and characterize potential variability in design aspects and specific parameter values. When the design and operation of WMUs were not well-standardized, parameters likely to show wide variability were flagged, and the variability was defined by distribution parameters used for the model inputs (e.g., distribution type, minimum, maximum, mean, and standard deviation).

3.3 Methodology

The general approach for WMU data collection was to develop model facility designs based on standard industry practices and scale the designs to the unit sizes extracted from the Industrial D data. These designs are general descriptions of the key unit features that determine the parameter values of interest for the source models. Based on these designs, the parameter values have been estimated, either as fixed values or value ranges. The following steps describe this approach:

1. **Collect information to define typical WMU designs.** Initially, information was collected from the Industrial D and TSDR databases and from the literature in order to define the typical designs for each WMU. For example, aerated tank design features (relating to unit depth, size and number of impellers, and aeration method) vary depending on unit size, flow rate of waste through the unit, and materials being treated. The collected information was then used to determine the number and general characteristics of the model facilities for each type of WMU.

2. **Collect detailed data for each WMU model design.** Once the general WMU model facility designs were reviewed, information was collected about the specific parameter values for each design. In general, multiple sources were consulted for each parameter in order to identify and characterize typical ranges

for parameter estimates. When no information was available in the literature for a parameter, engineering calculations were made, where possible, based on other aspects of facility design. As a final option, engineering judgment was used as a basis for developing data.

3.3.1 Site-Specific Data

Site-specific data describing waste management practices for landfills, wastepiles, LAUs, and surface impoundments were obtained from the Industrial D Screening Survey (Westat, 1987). Available data include the following:

- Landfills – Total area, total 1985 waste quantity, total capacity, remaining capacity, and number of units;
- Wastepiles – Total area, total 1985 waste quantity, and number of units;
- LAUs – Total area, total 1985 waste quantity, and number of units; and
- Surface impoundments – Total area, total 1985 waste quantity, total capacity, and number of units.

WMU total area and total 1985 waste quantity were available and used for all four WMU types. Total capacity was available only for landfills and surface impoundments. For all parameters, average values were calculated by dividing the total values by the number of units at a site.

In addition, site-specific data were obtained and used for landfill cover soil properties, LAU soil properties, and soil type underlying the wastepile. These properties were obtained from nationwide soil coverages as described in Section 7.0. Surface soil (top 20 cm) properties were used for LAUs and wastepiles, with the landfill cover soil assumed to have the average or predominant soil properties for the vadose zone underlying the WMU.

3.3.2 Site-Based Data

For model inputs based on the site-specific data described in Section 3.3.1 (e.g., Ind D WMU size or capacity), site-based data were derived using relationships based on the published literature and best engineering judgment. The data were processed using a combination of database and spreadsheet tools. As appropriate, Ind D data were used in a consistent fashion to previous HWIR and other Office of Solid Waste (OSW) modeling efforts (e.g., Air Characteristic/Industrial D modeling effort). Aspects of this approach include the following:

- When WMU dimensions (length and width) were needed, a square unit was assumed.
- For landfills and surface impoundments, depth was calculated based on area, total capacity, and typical waste bulk density.

- # Landfill loading rates were determined based on total capacity and fixed (30-yr) operating life.

- # Annual waste loading rates were estimated for surface impoundments, wastepiles, and LAUs based on waste generation rates for 1985 (i.e., total 1985 waste quantity).

3.3.3 National Tank Data (Correlated)

Because the TSDR sites could not be directly related to the sites in the Industrial D Screening Survey, for modeling purposes, the assumption was made that if one of the Ind D sites contained a surface impoundment, then it also contained an aerated tank. The HWIR model randomly picks an aerated tank from the TSDR data set, referred to as the national tank data set, using a tank index parameter (ATindex). It then correlates the data from the selected tank to the Industrial D facility being modeled.

To ensure that the selected tank is no larger than a surface impoundment at the site, a maximum source area (MaxSrcArea) is provided. MaxSrcArea is set equal to the source area for the surface impoundment being modeled. Surface impoundment areas range from 13.5 to 60,705,000 m^2. Aerated tank areas range from 0.06 to 4,694 m^2. The model loops through the selection process until an acceptable tank is chosen (i.e., tank area <= MaxSrcArea). Because the smallest tank is less than the smallest surface impoundment, a tank smaller than the MaxSrcArea will always be available. Once a tank is selected, all the parameters for that tank are assigned to the Industrial D site.

3.3.4 Other National Data

When site-based data were unavailable, inputs were derived on a national basis. Each of these inputs was defined by its type of distribution (e.g., constant, uniform, normal, lognormal). In addition, distribution parameters including mean, minimum, maximum, and standard deviation were provided where applicable.

3.4 Landfill Model Inputs

This section describes the approach used to develop inputs for the landfill source model. The landfill model design is described in Section 3.4.1. Sections 3.4.2 through 3.4.4 describe the development of input parameters for site-specific, site-based, and national data, respectively. For site-based variables, relationships between site-specific and site-based input parameters are identified and considered to ensure that related inputs are not randomly selected in a manner that would create physically impossible or unrealistic combinations.

Table 3-6 summarizes the data collected for landfill model inputs. It is organized by site-specific and site-based data, which are extracted directly or calculated from Industrial D Screening Survey data, and national data, which are based on relationships taken from books, reports, and professional judgment.

Table 3-6. WMU Data Collected for the Landfill Model

Variable	Units	Code	Value	Original Source
Site-Specific Data				
WMU type	unitless	SrcType	specified "LF"	Industrial D Screening Survey (Westat, 1987)
area of source	m^2	SrcArea	SrcArea = [total area]/[no. landfills]	Industrial D Screening Survey (Westat, 1987); average
fraction organic carbon (cover soil)	mass fraction	focC	depth-weighted average, entire soil column under WMU based on predominant soil texture for vadose zone soils underlying WMU (see Section 7.0)	USSOILS (Schwarz and Alexander, 1995)
saturated hydraulic conductivity (landfill cover soil)	cm/h	KsatC		CONUS (Miller and White, 1998); Carsel and Parrish (1988)
saturated water content (cover soil, total porosity)	volume fraction	WCS_C		CONUS (Miller and White, 1998); Carsel and Parrish (1988)
soil moisture coefficient b (landfill cover soil)	unitless	SMbC		CONUS (Miller and White, 1998); Clapp and Hornberger (1978)
Site-Based Data				
depth of source	m	SrcDepth	capacity/[area x bulk density] (Equation LF-1)	capacity (Mg) and area from Industrial D Screening Survey (Westat, 1987); assumed waste bulk density to get capacity in m^3
load	Mg/yr	---	capacity/30 (Equation LF-2)	calculated from Industrial D Screening Survey; assumes a 30-yr operating life
waste zone thickness	m	zW	zW = SrcDepth	calculated from Industrial D Screening Survey
distance vehicle travels on active landfill cell surface	m	mt	mt = width of landfill = sqrt(SrcArea) (Equation LF-3)	calculated from Industrial D Screening Survey; assumes a square landfill
vehicles per day (mean annual)	1/d	nv	nv = capacity/[operating life x payload x 365.25] (Equation LF-4)	best professional judgment, based on Industrial D capacity data
Site-Based Data				
spreading and compacting operations per day	1/d	Nop	Nop = nv (Equation LF-5) maximum value = 2	best professional judgment
frequency of surface disturbances per month (active landfill cell)	1/mo	fd	fd = Nop x 30 (Equation LF-6)	best professional judgment

(continued)

Table 3-6. (continued)

Variable	Units	Code	Value	Original Source
vehicle weight (mean)	Mg, m^3	vw	vw = payload/2 + w_{empty} (Equation LF-7)	Overcash and Pal (1979)
wheels per vehicle (mean)	unitless	nw	calculated site-specific depending on payload; 6 wheels for a small truck and 10 for a large truck	best professional judgment based on information from Overcash and Pal (1979) and MRI (1990)
number of waste layers in a cell	unitless	Nly	(Table LF-8) SrcDepth ≤ 1: Nly = 1 1 < SrcDepth ≤ 2: Nly = 2 SrcDepth > 2: Nly = Integer(SrcDepth)	best professional judgment
National Data				
optional soil cover thickness	m	zC	triangular distribution: minimum = 0.3 maximum = 0.9 mean = 0.6	best professional judgment, assuming a simple soil cover designed to support vegetative cover, based on Tchobanoglous (1993), Bagchi (1990), and McBean (1995)
thickness of liner (or subsoil zone)	m	zS	constant = 0	HWIR model scenario assumes an unlined landfill
National Data				
dust suppression control efficiency	unitless	effdust	normal distribution: minimum = 0 maximum = 1 mean = 0.5 standard deviation = 0.3	best professional judgment based on U.S. EPA (1989)
dust suppression control efficiency	unitless	effdust	normal distribution: minimum = 0 maximum = 1 mean = 0.5 standard deviation = 0.3	best professional judgment based on U.S. EPA (1989)
fraction vegetative cover (inactive LF cell)	unitless	veg	normal distribution: minimum = 0.8 maximum = 1 mean = 0.9 standard deviation = 0.1	best professional judgment, assuming landfill cover is vegetated once unit is closed

(continued)

Table 3-6. (continued)

Variable	Units	Code	Value	Original Source
roughness height (inactive landfill cell)	cm	zruf	normal distribution: minimum = 2 maximum = 4 mean = 3 standard deviation = 0.6	best professional judgment based on U.S. EPA (1989)
roughness ratio (landfill waste zone surface)	unitless	Lc	lognormal distribution: minimum = 1E-04 maximum = 1E-03 mean = 3E-04 standard deviation = 0.304	best professional judgment based on U.S. EPA (1989)
vehicle speed	km/h	vs	normal distribution: minimum = 20 maximum = 40 mean = 30 standard deviation = 6.1	Overcash and Pal (1979)

3.4.1 Landfill Model Design

Landfill data collection assumes that only one type of landfill is used for disposal of waste, (i.e., that there are no significant differences in the design of landfills depending on size or purpose). As with all other WMU parameters except aerated tanks, average landfill dimensions and capacity (i.e., total/number of units) are used from the Ind D database. Other significant assumptions are that the landfill is excavated below ground surface, the unit receives waste for 30 years, the landfill is capped with soil cover to establish a vegetative cover after a cell is filled, and there is no liner.

3.4.2 Landfill Site-Specific Data

Site-specific data for landfills were obtained from the Industrial D Screening Survey (Westat, 1987). These include total area, number of landfills at each site, total capacity, remaining capacity, and total 1985 annual waste quantity. Average values were calculated for use in the HWIR model by dividing the Ind D data for each of the parameters by the number of landfills at each site. Appendix 3A shows raw data from the Industrial D Screening Survey for the 201 Industrial D sites addressed in this analysis.

3.4.2.1 <u>Screening and Replacement of Ind D Data</u>. In accordance with previous EPA modeling efforts using the Industrial D Screening Survey, landfill capacities were screened from the Industrial D data when depth or capacity constraints were violated. Questionable data were screened using the following procedures (U.S. EPA, 1997):

> The landfill data were screened by placing constraints on the unit depth and unit volume to eliminate unrealistic observations. The unit depth, calculated by dividing the unit capacity by the unit area, was constrained to be either greater than or equal to 2 feet, or less than or equal to 33 feet. The unit depth bounds were adopted from the previous TC rule effort. In addition, the unit volume was constrained to be greater than the remaining capacity.

Of the 824 landfills (reporting surface area) in the Industrial D Screening Survey, 103 had a depth less than 2 ft, 87 had a depth greater than 33 ft, and 21 had remaining capacity that exceeded the total capacity. In addition, 92 facilities were missing data on total capacity, remaining capacity, or both. Thus, landfill capacity was missing or screened for 303 landfills.

Landfill capacities to replace the 303 missing or removed values were estimated based on the correlation between surface area and capacity of the remaining landfills in the Industrial D data. The procedure used to replace values was similar to the EPACMTP methodology (U.S. EPA, 1997):

> In cases where the unit depth or remaining capacity constraints were violated, the observed unit volume was replaced by generating a random realization from the volume probability distribution conditioned on area assuming that the unit area value was more likely to be correctly reported. The joint distribution was derived from the non-missing unit area/volume pairs that met the unit depth and

remaining capacity constraints and was assumed to be lognormal. Missing values were generated from the joint area/volume probability if both the area and volume were missing, and from the corresponding conditional distribution if only one of the two values was missing. Final depth values were calculated by dividing the unit volume by the area.

First, a statistical regression of log (average total capacity) versus log (average surface area) was done on the facilities with known capacities. The regression yielded an equation for a best-fit line through the known values. This equation gave the capacity as a function of area, so the missing or screened capacities could be estimated based on the known areas. To provide a more probabilistic sampling of average capacities, and because the known capacities seemed to be in a limited range above and below the best-fit line, a positive or negative random number was generated within that range and added to the calculated log (average total capacity) to replace each missing capacity with a random value that was reasonable with respect to landfill area. This value was then used to calculate landfill depth as described above. Figure 3-1 shows the regression plots, including the replaced (random capacity) values, for landfills.

3.4.2.2 <u>Cover Soil Properties</u>. For purposes of this analysis, it was assumed that the soil used to cover the landfill was obtained from soil at or very nearby the facility and, in many cases, could be soil excavated to construct the landfill itself. Thus, soil properties for the vadose zone directly underlying the landfill were used for cover soil properties. The following cover soil parameters have been collected for use by the landfill model: fraction organic carbon (focC), saturated hydraulic conductivity (KsatC), saturated water content (WCS_C), and soil moisture coefficient b (SmbC). See Section 7.0 for a discussion on vadose zone soil property data collection.

3.4.3 Landfill Site-Based Data

Site-based data are derived from Ind D data (notably average area and average capacity), using relationships based on the published literature and best engineering judgment.

3.4.3.1 <u>Depth (SrcDepth)</u>. Landfill depth (SrcDepth) was calculated consistent with previous EPACMTP modeling efforts using the Industrial D data (as described in U.S. EPA, 1997). The bulk density assumed for landfills was 1.09577 g/cm^3.

$$\text{depth (m)} = \frac{\text{landfill capacity (Mg)} \times 1\times10^6\ \text{g/Mg}}{\text{area (m}^2) \times \text{bulk density (g/cm}^3) \times (100\ \text{cm/m})^3} \qquad \text{(LF-1)}$$

3.4.3.2 <u>Waste Loading Rate (load)</u>. The waste loading rate (load) is the annual quantity of waste disposed at a landfill. Because data on the typical design life for landfills were not available, a 30-yr operating life was assumed as a reasonable value based on professional judgment.

$$\text{load (Mg/yr)} = \frac{\text{landfill capacity (Mg)}}{30\ \text{yr}} \qquad \text{(LF-2)}$$

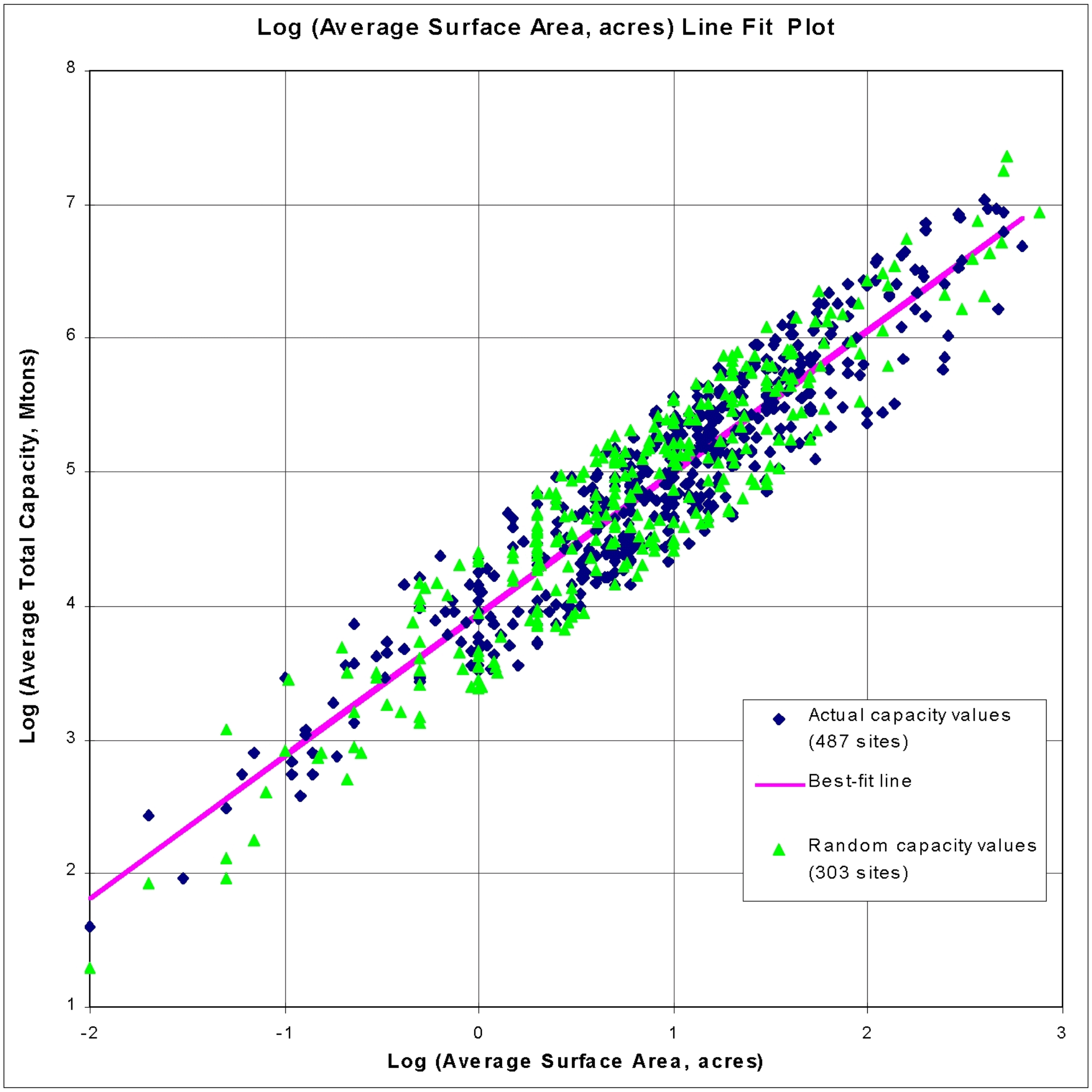

Figure 3-1. Correlation of total capacity to area for landfills.

3.4.3.3 <u>Distance Vehicle Travels on Active Landfill Cell Surface (mt)</u>. Assuming a square landfill unit configuration and assuming that a truck drives into the center of the landfill to deliver a load of waste, the length of unpaved road on the uncovered landfill is assumed to be equal to half the width of the landfill. The vehicle travels in and out on the road to deliver a load of waste, so the distance a vehicle travels on the active landfill surface (mt) is equal to the landfill width.

$$mt(m) = width(m) = \sqrt{area(m^2)} \qquad \text{(LF-3)}$$

3.4.3.4 <u>Average Number of Vehicles per Day (nv)</u>. The average number of vehicles per day (nv) is calculated assuming the landfill has a 30-yr operating life and that each truck carries a full payload.

$$nv(1/d) = \frac{\text{landfill capacity}(Mg)}{30\,yr \times \text{payload}(Mg) \times 365.25(d/yr)} \quad \text{(LF-4)}$$

where

payload = 35 Mg if landfill capacity >= 30,000 Mg/yr
payload = 15 Mg if landfill capacity < 30,000 Mg/yr.

3.4.3.5 <u>Number of Spreading and Compacting Operations per Day (Nop)</u>. The number of spreading and compacting operations (Nop) is the number of times that the whole landfill cell area is compacted with heavy equipment. The number of loads dropped off are equal to the average number of vehicles (nv) at the landfill. The number of spreading and compacting operations per day is specified by the following equation (with a maximum value of 2):

$$Nop(1/d) = nv(1/d) \quad \text{(LF-5)}$$

3.4.3.6 <u>Frequency of Disturbances per Month (fd)</u>. A disturbance is defined as an action that results in the exposure of fresh surface material. This can occur whenever material is added to the landfill cell or the waste is compacted or moved. The frequency of disturbances (fd) equals the number of spreading and compacting events per day (Nop) multiplied by the number of days per month.

$$fd(1/mo) = Nop(1/d) \times 30(d/mo) \quad \text{(LF-6)}$$

3.4.3.7 <u>Vehicle Weight (vw), Payload, and Number of Wheels (nw)</u>. Two typical truck sizes were developed for this analysis: small and large. Data on typical truck payloads and number of wheels per truck were obtained from Overcash and Pal (1979) and Midwest Research Institute (MRI) (1990). Data for determining the ratio of total to empty vehicle weight were obtained from Caterpillar (1994).

A small truck is assumed to have 6 wheels and a full weight of 30 Mg (15 Mg vehicle weight empty plus 15 Mg payload). The vehicle weight estimate is based on a payload size of 10 m^3 (roughly midrange for dump trucks in Overcash and Pal, 1979), a waste bulk density of about 1.5 Mg/m^3, and a ratio of weight loaded to weight unloaded of about 2.

A large truck is assumed to have 10 wheels and a full weight of 65 Mg (30 Mg vehicle weight empty plus 35 Mg payload). This vehicle weight estimate is based on a payload size of about 23 m^3 (the upper end of the dump truck sizes in Overcash and Pal, 1979), a waste density of about 1.5 Mg/m^3, and a ratio of weight loaded to weight unloaded of about 2.2.

For units managing less than 30,000 Mg/yr, a small truck is assumed. For units managing 30,000 Mg/yr or more, a large truck is assumed. Depending on the quantity of waste managed at the landfill, the appropriate truck payload is used in Equation LF-7.

The vehicle weight is used in particulate emission calculations. A full truck is assumed to drive onto the unit, dump its load, and then exit empty. The vehicle weight (vw) is the average of its weight full and empty. The weight of the vehicle is expressed as follows:

$$vw(Mg) = \frac{w_{full}(Mg) + w_{empty}(Mg)}{2} = \frac{payload(Mg)}{2} + w_{empty}(Mg) \qquad \text{(LF-7)}$$

where

vw	=	vehicle weight for a small or large truck (Mg)
payload	=	carrying capacity of the truck (Mg)
w_{full}	=	vehicle weight when full (Mg) = w_{empty} (Mg) + payload (Mg)
w_{empty}	=	vehicle weight when empty (Mg).

The vehicle weight depends on the size of the vehicle (large or small) and the vehicle payload. Small trucks are assumed to have a weight empty of 15 Mg, a payload of 15 Mg, and 6 wheels. Large trucks are assumed to have a weight empty of 30 Mg, a payload of 35 Mg, and 10 wheels.

In the absence of other data, the average fraction of a full load that a truck carries is assumed to be 1 (i.e., the truck carries a full load each time because operating the truck at less than a full load would be inefficient). A full load is considered to be a volume of waste equal to the volume of the truck dumper (rather than waste loaded in such a way as to mound above the sides of the truck dumper).

3.4.3.8 <u>Number of Waste Layers in a Cell (Nly)</u>. A waste layer in the landfill is a waste zone of uniform thickness within each landfill cell wherein initial constituent concentrations are assumed uniform by the landfill model. In other words, each annual landfill cell contains one or more uniform layers formed over time by the dumping of truck loads of waste in the landfill cell. For this analysis, the number of waste layers (Nly) is determined as follows:

Landfill Depth, m (SrcDepth)	Number of waste layers in a cell (Nly)
≤ 1	1
>1 and ≤ 2	2
>2	Integer (SrcDepth)

(LF-8)

3.4.4 Landfill National Data

National data were collected for input variables when site-specific data were not available and the variable was not correlated with other site-specific data. In most cases, a distribution was assumed to account for nationwide variability in parameter values.

3.4.4.1 Optional Soil Cover Thickness (zC). The Ind D landfill receiving exempted HWIR waste is assumed to have a simple soil cover designed to establish a vegetative cover on the closed landfill, not to limit infiltration into the landfill. This conservative assumption is consistent with the assumption of no engineered liner under the WMU. For the landfill model, the minimum depth of this soil cover is assumed to be 0.3 m and the maximum depth is 0.9 m. A triangular distribution is assumed, with a mean of 0.6 m.

3.4.4.2 Thickness of Liner (or Subsoil Zone) (zS). This parameter allows a liner to be used in the landfill model but was set at zero because HWIR assumes that modeled Ind D landfills are unlined.

3.4.4.3 Dust Suppression Control Efficiency (effdust). Dust suppression activities might include the watering of the landfill to reduce dust or the application of chemical dust suppressants (U.S. EPA, 1989). A value of zero corresponds to no dust suppression activity. Although information was available about types of dust suppression control activities, there is no definitive information quantifying the frequency of use or the effectiveness of these activities. Consequently, it is assumed that dust suppression control efficiency (effdust) has a normally distributed value between 0 and 1, with a mean of 0.5 and a standard deviation of 0.3.

3.4.4.4 Fraction Vegetative Cover (veg). After closure of the unit, it is assumed that the landfill is covered with vegetation. To allow for some variability in the extent of this cover, the fraction vegetative cover (veg) is specified as a normal distribution from 0.8 to 1, with a mean of 0.9 and a standard deviation of 0.1.

3.4.4.5 Roughness Height (zruf). This factor is the height aboveground at which the wind speed becomes zero due to obstructions (rocks, plants) on the ground surface (U.S. EPA, 1989). Roughness height (zruf) ranges from 0.1 cm to 1,000 cm for snow to urban settings. EPA provides some values for the roughness height for various sites in Arizona and for industrial aggregates, as well as a chart of values for different settings. After closure, the landfill is assumed to be similar to a grassland with a roughness height ranging from 2 cm to 4 cm, normally distributed, with a mean of 3 cm and a standard deviation of 0.6 cm.

3.4.4.6 Roughness Ratio (Lc). This factor is the ratio of the silhouette area of the roughness elements (>1 cm) in the soil to the total bare loose soil. Roughness ratio (Lc) can range from 0 to 0.01 (U.S. EPA, 1989). For HWIR, it is assumed to be lognormally distributed, with a minimum of 1×10^{-4}, a maximum of 1×10^{-3}, a mean of 3×10^{-4}, and a standard deviation of 0.304. Higher Lc values ($>2\times10^{-4}$) increase the threshold wind speed for the onset of wind erosion (causing lower particulate emissions). Therefore, assuming the mean and maximum Lc equal 3×10^{-4} and 1×10^{-3} is conservative with respect to particulate emissions (but not other emission processes).

3.4.4.7 Vehicle Speed (vs). Vehicle speed (vs) is the average speed that trucks travel on the landfill. For surface spreading, 20 to 40 km/h is a representative range (Overcash and Pal, 1979). Vehicle speed is specified as a normal distribution, with a mean of 30 km/h and a standard deviation of 6.1 km/h.

3.5 Wastepile Model Inputs

This section describes the approach used to develop inputs for the wastepile source models. The wastepile model design is described in Section 3.5.1. Sections 3.5.2 through 3.5.4 describe the development of input parameters for site-specific, site-based, and national data, including data sources, ranges, and assumptions. For site-based variables, relationships between site-specific and site-based input parameters are identified and considered to ensure that related inputs are not randomly selected in a manner that would create physically impossible or unrealistic combinations.

Table 3-7 summarizes the data collected for wastepile model inputs. It is organized by site-specific and site-based data, which are extracted directly or calculated from Industrial D Screening Survey data, and national data, which are based on relationships taken from books, reports, and professional judgment.

3.5.1 Wastepile Model Design

Wastepiles are essentially temporary units used for storing or accumulating waste prior to final treatment or disposal. Wastepiles are composed of solid waste materials that are dumped into a pile and may be subsequently moved or spread. Because a wastepile is a temporary unit, it is modeled so that the waste is deposited, remains in the wastepile for a period of time, and is then removed and replaced with a fresh wastepile with chemical concentrations equal to that of the original incoming waste. In this model, a waste is considered to be delivered by dump truck to the unit location and deposited to create a pile of uniform height throughout the area of the unit. The pile is assumed to be refreshed at least once every 5 yr, although a greater refresh frequency may occur for Industrial D facilities with large waste generation rates and relatively small wastepile areas.

The wastepile is assumed to be placed directly on native soil, with no compaction or liner underneath. There is no cover (engineered or otherwise) and no control practices are employed to limit water or wind erosion or volatile emissions from the pile.

3.5.2 Wastepile Site-Specific Data

Site-specific data for wastepiles were limited to data from the Industrial D Screening Survey (Westat, 1987). Ind D data included total area, number of wastepiles at each site, and total 1985 annual waste quantity (or waste loading). Average values were calculated for use in the HWIR model by dividing the total area and total annual waste quantity by the number of units at each site. Appendix 3A shows raw data from the Industrial D Screening Survey (including replacement values) for the 201 Industrial D sites addressed in this analysis.

Table 3-7. WMU Data Collected for the Wastepile Model

Variable	Units	Code	Value	Original Source
Site-Specific Variables				
WMU type	unitless	SrcType	specified "WP"	Industrial D Screening Survey (Westat, 1987)
area of source	m^2	SrcArea	SrcArea = [total area]/[no. wastepiles]	Industrial D Screening Survey (Westat, 1987); average values
waste loading rate (dry)	Mg/yr	load	load = [1985 total waste quantity]/[no. wastepiles]	Industrial D Screening Survey (Westat, 1987); average values; missing or inconsistent values replaced using the approach outlined in the EPACMTP model background document (U.S. EPA, 1997)
Site-Based Variables				
distance vehicle travels on wastepile surface (unpaved road)	m	mt	mt = width of WP = sqrt (SrcArea) (Equation WP-1)	calculated from Industrial D Screening Survey; assumes a square unit and that on average a vehicle drives into the middle of the unit and back out
height of wastepile above grade	m	zZ1WMU	calculated using Table WP-2	best professional judgment; heights determined using waste quantity and source area from Industrial D Screening Survey
vehicle weight (mean)	Mg, m^3	vw	based on facility size (Equation WP-4) *small truck*: weight (empty): 15 Mg payload: 15 Mg *large truck*: weight (empty): 30 Mg payload: 35 Mg	best professional judgment, based on information from Overcash and Pal (1979), MRI (1990), and Caterpillar (1994)
wheels per vehicle (mean)	unitless	nw	based on facility size *small truck*: 6 *large truck*: 10	best professional judgment, based on information from Overcash and Pal (1979) and MRI (1990)

(continued)

Table 3-7. (continued)

Variable	Units	Code	Value	Original Source
Site-Based Variables				
vehicles per day (mean annual)	1/d	nv	nv = load/[payload × 365.25] (Equation WP-5)	engineering calculation; load (i.e., waste application rate) calculated from Industrial D Screening Survey data; relationship of truck size to waste application rate based on best professional judgment; truck designs based on Overcash and Pal (1979) and Caterpillar (1994)
spreading/compacting operations per day	1/d	Nop	Nop = nv (Equation WP-6) maximum value = 2	best professional judgment
SCS curve number	unitless	CNwmu	assigned using a triangular distribution based on hydrologic soil group (see Table 3-8)	best professional judgment on range of wastepile cover effect; site-specific hydrologic soil groups obtained from STATSGO (USDA, 1994)
National Variables				
dust suppression control efficiency	unitless	effdust	normal distribution: minimum = 0 maximum = 1 mean = 0.5 standard deviation = 0.3	best professional judgment, based on information from U.S. EPA (1989)
operating life	yr	CutOffYr	constant = 30	best professional judgment
vehicle speed (mean)	km/hr	vs	normal distribution: minimum = 20 maximum = 40 mean = 30 standard deviation = 6.1	best professional judgment, based on information in Overcash and Pal (1979)
USLE cover factor	unitless	Cwmu	constant = 1	Wanielista and Yousef (1993); assumed no cover
USLE erosion control factor	unitless	Pwmu	constant = 1	Wanielista and Yousef (1993); assumed no erosion control

In some cases, the annual waste quantity was screened due to unrealistic values or missing data. Replacement values were calculated under two conditions: (1) if surface area data were reported for a given wastepile but the waste quantity was not provided or (2) if the minimum wastepile height constraint of 1 m was violated when the refresh rate was once every 5 yr.

The first condition for replacing waste quantities is consistent with previous EPACMTP efforts (U.S. EPA, 1997):

> Missing volume values were replaced by random realizations from the probability distribution of volume conditioned on area. The conditional distribution was assumed to be lognormal and was derived from the non-missing unit area/volume pairs.

The second condition (wastepile height constraint) was established because a wastepile is supposed to be a pile with some significant height and it is supposed to be a temporary unit. The minimum height and refresh frequency were selected based on judgment (see Sections 3.5.3.3 and 3.5.3.4). For a waste bulk density of 1.5 Mg/m^3, the 1-m height and once-per-5-yr refresh rate constraints correspond to an application rate of 0.3 $Mg/m^2/yr$. Of the 847 facilities reporting wastepiles (and surface area), 30 facilities did not provide data on waste quantity and 361 values were screened by the minimum height and refresh rate constraint.

To calculate replacement waste quantities, first a statistical regression of log (waste quantity) versus log (average surface area) was performed on facilities with known quantities. The regression yielded an equation for a best-fit line through the known values. This equation gave the waste quantity as a function of area, so the missing or screened waste quantities could be estimated based on the known areas. To provide a more probabilistic sampling of average waste quantities, and because the known quantities seemed to be in a limited range above and below the best-fit line (with some outliers), a positive or negative random number was generated within that range. This random number was then added to the calculated log (average waste quantity) to replace each missing waste quantity with a random value that was reasonable with respect to wastepile area. Figure 3-2 shows the regression plot, including the replaced (random waste quantity) values for wastepiles.

3.5.3 Wastepile Site-Based Data

Site-based data are derived from Ind D data (e.g., average area, width, and height of wastepiles), using relationships based on the published literature and best engineering judgment. In addition, the wastepile curve number (CNwmu) was derived from site-specific soil data and general assumptions about the water-holding properties of the waste.

3.5.3.1 Distance Vehicle Travels on Wastepile Surface (mt). Although the shape of a wastepile is likely irregular, for purposes of this analysis, all WMUs are assumed to be square in shape. It also is assumed that a truck drives into the center of the wastepile unit to deliver a load of waste (i.e., half the width of the wastepile). The vehicle travels in and out on the unpaved

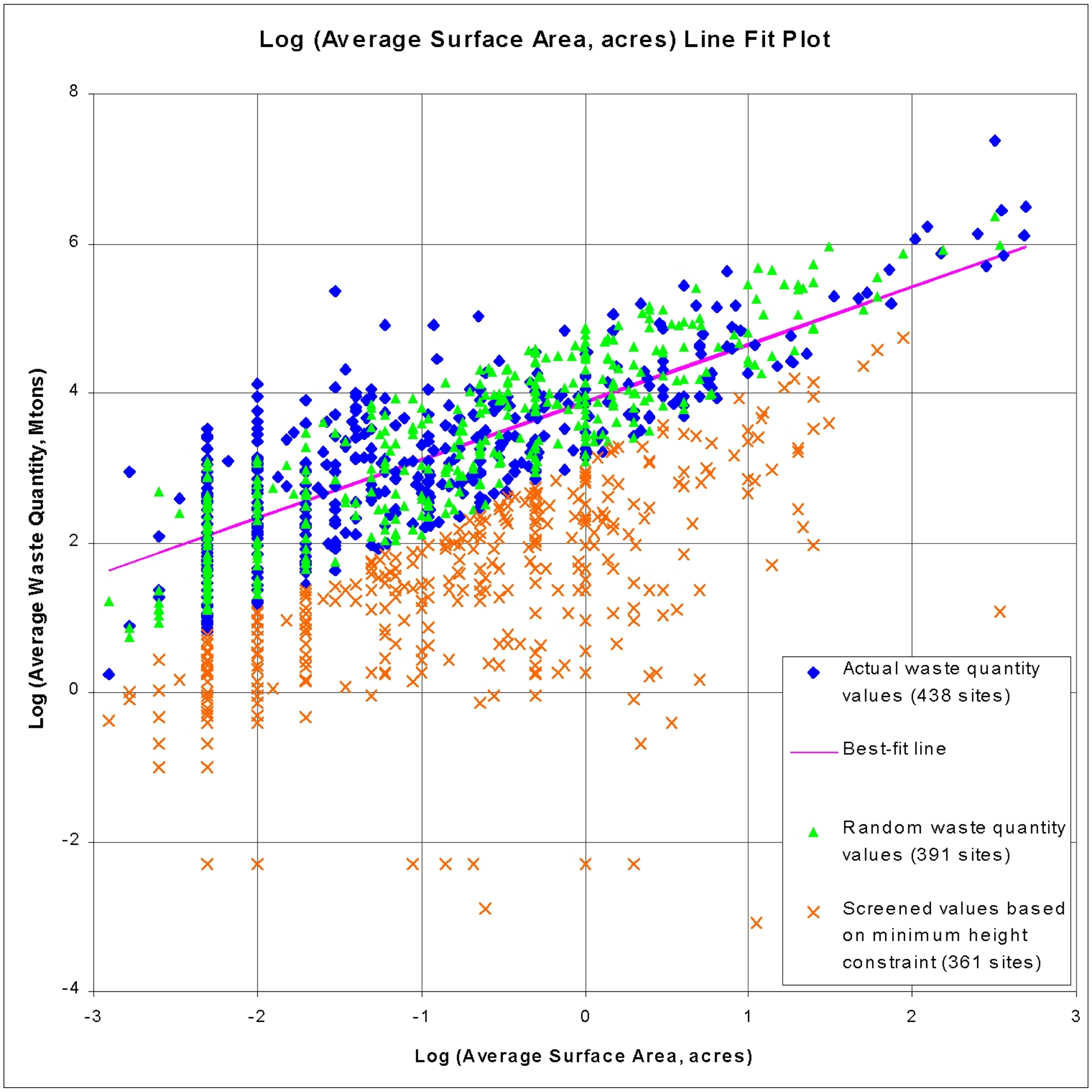

Figure 3-2. Correlation of waste quantity to area for wastepiles.

road to deliver a load of waste, so the distance traveled (mt) equals the width of the wastepile as follows:

$$mt(m) = width(m) = \sqrt{area(m^2)} \qquad \text{(WP-1)}$$

3.5.3.2 <u>Height of the Wastepile Above Grade (zZ1WMU, SHight)</u>. Wastepile height varies and will affect the rate at which waste in the unit is refreshed in the wastepile model. Site-specific wastepile height information was not available. In general, however, the height of a wastepile is a function of the area of the unit and the annual waste quantity managed in the unit.

Discrete pile height values ranging from 1 to 10 m were assumed in order to simplify the meteorological component of the data required for the wastepile model. In particular, a calculation was required to adjust the wind speed from the height of the measuring device to the height of the wastepile. The choice of heights was based on an interval over which the wind velocity differences would not be too large. The extremes were selected using best professional judgment. The relationships between pile height and the annual waste quantity per unit area were assumed based on best judgment. The following table lists the pile heights (zZ1WMU, SHight) as determined by the annual waste quantity to surface area ratio.

(WP-2)

Annual Waste Quantity/Surface Area ($Mg/m^2/yr$)	Pile Height (m)
≥0.3, <10	1
≥10, <20	2
≥20, <40	4
≥40, <60	6
≥60, <80	8
≥80	10

3.5.3.3 <u>Refresh Frequency</u>. The refresh frequency is used as a constraint for screening data (discussed in Section 3.5.2). The pile height, area, and annual waste loading determine the frequency of wastepile replacement, or the refresh frequency. This can be expressed as follows:

$$\text{refresh frequency (1/yr)} = \frac{\text{annual waste loading (Mg/yr)}}{\text{area}(m^2) \times \text{height}(m) \times \text{bulk density}(Mg/m^3)} \qquad \text{(WP-3)}$$

Because wastepiles are considered to be temporary units, the refresh frequency should not be too long. The minimum refresh frequency for a wastepile was assumed as once every 5 years, assuming a waste bulk density of 1.5 Mg/m^3. The Industrial D database contains combinations of waste loading and area data that, given the method used here for determining wastepile height, would lead to refresh frequencies of less than once every 5 yr. In these cases, the annual waste loading data were culled from the data set and replaced with a value randomly selected based on the distribution of valid wastepile area/annual waste loading combinations in the Industrial D database (see Section 3.5.2).

3.5.3.4 <u>Vehicle Weight (vw), Payload, and Number of Wheels (nw)</u>. Two typical truck sizes were developed: small and large. Data on typical truck payloads (and number of wheels per truck) were obtained from Overcash and Pal (1979) and MRI (1990). Data for determining the ratio of the total vehicle weight to the weight empty were obtained from Caterpillar (1994).

A small truck is assumed to have 6 wheels and a full weight of 30 Mg (15 Mg vehicle weight empty plus 15 Mg payload). The vehicle weight estimate is based on a payload size of

10 m^3 (roughly midrange for dump trucks in Overcash and Pal, 1979), a waste bulk density of about 1.5 Mg/m^3, and a ratio of weight loaded to weight unloaded of about 2.

A large truck is assumed to have 10 wheels and a full weight of 65 Mg (30 Mg vehicle weight empty plus 35 Mg payload). This vehicle weight estimate is based on a payload size of about 23 m^3 (the upper end of the dump truck sizes in Overcash and Pal, 1979), a waste density of about 1.5 Mg/m^3, and a ratio of weight loaded to weight unloaded of about 2.2.

The average number of vehicles used per waste application was not available from the literature. Instead, the average number of vehicles was calculated by assigning a truck size to the facility based on the amount of waste managed in the unit annually. For units managing less than 30,000 Mg/yr, a small truck was assumed. For units managing 30,000 Mg/yr or more, a large truck was assumed. For facilities managing just under 30,000 Mg/yr of waste, from Equation WP-3 we would calculate 2,000 trucks per year, or an average of about 5.5 trucks per day for year-round operation.

The vehicle weight (vw) is used in the particulate emission calculations. A full truck is assumed to drive onto the unit, dump its load, pick up waste from the old pile, and then exit full. The vehicle weight is its weight full, expressed as follows:

$$vw\,(Mg) = w_{empty}\,(Mg) + payload\,(Mg) \qquad \text{(WP-4)}$$

where

vw = vehicle weight for a small or large truck (Mg)
payload = carrying capacity of the truck (Mg)
w_{empty} = vehicle weight when empty (Mg).

The vehicle weight depends on the size of the vehicle (large or small) and the vehicle payload. Small trucks are assumed to have a weight empty of 15 Mg, a payload of 15 Mg, and 6 wheels. Large trucks are assumed to have a weight empty of 30 Mg, a payload of 35 Mg, and 10 wheels.

3.5.3.5 <u>Vehicles per Day (nv)</u>. The average number of vehicles per day (nv) is determined by the annual waste application rate and the size of the truck. The relationship can be expressed as follows:

$$nv\,(1/d) = \frac{load\,(Mg/yr)}{payload\,(Mg) \times 365.25\,(d/yr)} \qquad \text{(WP-5)}$$

where

nv = number of vehicles per day (1/d)
load = waste application rate (Mg/yr)
payload = carrying capacity of the truck (Mg).

3.5.3.6 <u>Spreading/Compacting Operations per Day (Nop)</u>. The number of spreading or compacting operations (Nop) is the number of times that the wastepile is spread and compacted with heavy equipment. The number of spreading and compacting operations per day is specified by the following equation (with a maximum value of 2):

$$Nop(1/d) = nv(1/d) \quad \text{(WP-6)}$$

3.5.3.7 <u>SCS Curve Number (CNwmu)</u>. Soil Conservation Survey (SCS) curve number (CNwmu) values appropriate for wastepiles could not be found in the open literature. To estimate this parameter, a scenario was developed in which the water percolates freely into the wastepile, with a portion of this infiltration running off once it hits the soil beneath the wastepile. Under this scenario, CNwmu is a function of the hydrologic group (A, B, C, or D) of the soil underlying the wastepile (as the infiltration limiting media) and the cover effect of the pile itself. The hydrologic group of the WMU soil was obtained from State Soil Geographic (STATSGO) data as described in Section 7.0.

Because CNwmu is primarily subject to variability with respect to the wastepile's cover effect, three cover conditions were selected from USDA (1986) to define the range and typical cover effect of the wastepile on the underlying soil as a triangular distribution. To represent wastepiles that would tend to hold water on the soil surface, minimizing runoff and maximizing infiltration, we selected "woods" in good hydrologic condition to define the minimum CNwmu value for a particular hydrologic soil group. To represent more granular wastepiles with minimum water-holding capacity, we selected "gravel roads (including right-of-way)" to define the maximum CNwmu value. Small-grain, contoured, and terraced row crops, with a crop residue cover and good hydrologic condition, were used to define a moderate water-holding condition (i.e., a wastepile on a leveled base) and the central tendency CNwmu for the triangular distribution. These minimum, central, and maximum values are shown in Table 3-8 by hydrologic soil groups A, B, C, and D.

To get the SCS curve number for the wastepile, the map unit with the largest area in the WMU was used to obtain the hydrologic soil group from processed STATSGO data (see Section 7.4.2 for more details). This hydrologic soil group was used to select the correct values for CNwmu from Table 3-8, which are passed as a triangular distribution.

3.5.4 Wastepile National Data

3.5.4.1 <u>Dust Suppression Control Efficiency (effdust)</u>. Dust suppression activities could include the watering of the wastepile to reduce dust or the application of chemical dust suppressants (U.S. EPA, 1989). A value of zero corresponds to no dust suppression activity. Although information was available about types of dust suppression control activities, no information was found on how often these activities are typically employed for Ind D wastepiles or their effectiveness. Consequently, it is assumed that dust suppression control efficiency (effdust) has a normally distributed value between 0 and 1, with a mean of 0.5 and a standard deviation of 0.3. A mean less than 0.5 (the value used for landfills) was selected because it is believed to be more likely that a facility would implement only limited dust suppression

Table 3-8. Wastepile Curve Numbers (CNwmu), by Hydrologic Soil Group

Hydrologic Soil Group	Curve Number (CNwmu)		
	Minimum	**Central Tendency**	**Maximum**
A	30	58	76
B	55	69	85
C	70	77	89
D	77	80	91
Source (USDA, 1986):	Woods/Good Table 2-2c	Small grain, contoured, and terraced + crop residue/Good Table 2-2b	Gravel streets and roads Table 2-2a

activities or that the dust suppression activities would have only limited effectiveness for wastepiles, which are not typically covered the way a landfill is.

3.5.4.2 Operating Life (CutOffYr). No information was found in the literature about the typical operating life of a wastepile. For purposes of this analysis, the operating life (CutOffYr) is assumed to be 30 yr.

3.5.4.3 Vehicle Speed (vs). The mean speed that trucks travel on the wastepile unit is assumed to range from 20 to 40 km/h, based on information in Overcash and Pal (1979) for LAUs. The vehicle speed (vs) is specified as normally distributed, with a mean of 30 km/h and a standard deviation of 6.1 km/h, again based on Overcash and Pal (1979).

3.5.4.4 USLE Cover Factor (Cwmu). For this analysis, it was assumed that wastepiles are bare. Therefore, the universal soil loss equation (USLE) cover factor (Cwmu) for wastepiles was fixed at a value of 1, indicating no cover (Wanielista and Yousef, 1993).

3.5.4.5 USLE Erosion Control Factor (Pwmu). For this analysis, it was assumed that no erosion control practices are implemented for the wastepiles. Therefore, the USLE erosion control factor (Pwmu) for wastepiles was fixed at a value of 1, indicating no erosion control (Wanielista and Yousef, 1993).

3.6 LAU Model Inputs

This section describes the approach used to develop inputs for the LAU source model. The LAU model design is described in Section 3.6.1. Sections 3.6.2, 3.6.3, and 3.6.4 describe the development of input parameters for site-specific, site-based, and national data, respectively. For site-based variables, relationships between site-specific and site-based input parameters are identified and considered to ensure that related inputs are not randomly selected in a manner that would create physically impossible or unrealistic combinations.

Table 3-9 summarizes the data collected for LAU model inputs. It is organized by site-specific and site-based data, which are extracted directly or calculated from Industrial D Screening Survey data, and national data, which are derived based on relationships taken from books, reports, and professional judgment.

3.6.1 LAU Model Design

3.6.1.1 <u>Unit Configuration</u>. Land treatment generally involves the application of wastes to an agricultural plot of land in either a liquid or semisolid form, tilling the wastes into the soil, and treatment through the biological degradation of the hazardous constituents in the soil zone. Typical land treatment unit designs include single plot, progressive plot, and rotating plot arrangements (U.S. EPA, 1989).

In single plot designs, wastes are spread uniformly over the available area. This design is typically used when applications occur only during one season or on a few specific occasions during the year. In progressive plot designs, the treatment unit is divided into smaller treatment cells, with only a single cell active at a given time. The other cells remain fallow and may be vegetated. Rotating plot designs also involve the division of the unit into smaller cells, with cells being used sequentially. The time frame during which waste is applied to a cell depends on the waste treatment requirements; however, rotation among cells is fast enough that all cells are essentially active.

For the HWIR LAU model, the single plot design was used and the entire LAU is modeled as a single unit. Application of the model to the single plot facility design is straightforward because this design assumes that waste is applied uniformly across the entire unit area. A rotating plot unit also could be modeled essentially in the same manner as a single plot operation. For the rotating plot facility, each cell would be assumed to be of equal size and operated in an identical manner, and each cell could be considered to be active throughout the year. The total waste quantity managed in the unit would be divided equally among all cells. Each cell would be modeled as receiving the same number of waste applications per year. This approach reduces the model of the rotating plot to that of a single plot design.

Modeling of a progressive plot facility would need to be based on application of the LAU model to a series of waste cells. For the progressive plot facility, each cell could be assumed to be used sequentially. The facility could be divided into a certain number of equally sized cells, where each cell would be used for a percentage of the total operating life of the facility. For example, if the facility was divided into 10 cells and operated for 40 yr, each cell would be considered to be active for 4 yr. The operation of each cell would be considered identical. During the time a cell was not being used, that cell would be fallow and would be assumed to be growing vegetation. For modeling, it would be necessary to track how many cells had been used and to model the contaminant transport from each. For example, in a 3-cell unit operating 30 yr and modeled for 30 yr, the first cell operating would have 30 yr of contaminant transport, the second cell 20 yr, and the last cell 10 yr. The progressive plot facility would effectively reduce the area of the active unit, for modeling purposes.

Table 3-9. WMU Data Collected for the LAU Model

Variable	Units	Code	Value	Data Source
Site-Specific Variables				
WMU type	unitless	SrcType	specified "LAU"	Industrial D Screening Survey (Westat, 1987)
area of source	m^2	SrcArea	SrcArea = [total area]/[no. LAUs]	Industrial D Screening Survey (Westat, 1987); average values
Site-Based Variables				
distance vehicle travels on LAU surface	m	mt	mt = width of LAU = sqrt(SrcArea) (Equation LAU-1)	calculated from Industrial D Screening Survey; assumes a square unit
wet waste application rate	Mg/m^2-yr	Rappl	Rappl = waste quantity/SrcArea (Equation LAU-2)	calculated using data from Industrial D Screening Survey
vehicle weight	Mg	vw	vw = payload/2 + w_{empty} (Equation LAU-3) *small truck*: weight (empty): 15 Mg payload: 15 Mg *large truck*: weight (empty): 30 Mg payload: 35 Mg	best professional judgment; based on information from Overcash and Pal (1979), MRI (1990), and Caterpillar (1994); small or large truck based on Ind. D annual waste quantity
wheels per vehicle (mean)	unitless	nw	*small truck*: 6 *large truck*: 10	best professional judgment; based on information from Overcash and Pal (1979) and MRI (1990); small or large truck based on Ind. D annual waste quantity
vehicles per day (mean annual)	1/d	nv	nv = [SrcArea x Rappl]/[payload × 365.25] (Equation LAU-4)	engineering calculation; relationship of truck size to waste application rate based on best professional judgment; truck designs based on Overcash and Pal (1979) and Caterpillar (1994)
waste applications per year	1/yr	Nappl	assigned using table LAU-5	best professional judgment; based on U.S. EPA (1989), ER&T (1983), and Reed and Crites (1984)

(continued)

Table 3-9. (continued)

Variable	Units	Code	Value	Data Source
Site-Based Variables (continued)				
frequency of cultivation	unitless	fcult	calculated using table LAU-6	best professional judgment; based on quantity of waste applied per unit area and information from ER&T (1983) and U.S. EPA (1989)
frequency of surface disturbances per month (active LAU)	1/mo	fd	fd = Nappl x fcult/12 (Equation LAU-7)	calculated from the number of applications per year and the frequency of cultivation per application
SCS curve number	unitless	CNwmu	triangular distribution assigned based on hydrologic soil group	CN range for row crops, meadow (USDA, 1986) assigned based on best professional judgment; hydrologic soil groups obtained from STATSGO (see Section 7.0)
National Variables				
depth of source, depth of tilling	m	SrcDepth, zZ1WMU	constant = 0.2 m	best professional judgment, based on information in Brown et al. (1983), ER&T (1983), Martin et al. (1986), and U.S. EPA (1996b).
dust suppression control efficiency	unitless	effdust	normal distribution: minimum = 0 maximum = 1 mean = 0.5 standard deviation = 0.3	best professional judgment; based on information in U.S. EPA (1989)
fraction vegetative cover	fraction	veg	normal distribution: minimum = 0.8 maximum = 1 mean = 0.9 standard deviation = 0.1	best professional judgment; assuming unit is vegetated during operation and after closure

(continued)

Table 3-9. (continued)

Variable	Units	Code	Value	Data Source
National Variables (continued)				
operating life	yr	CutOffYr	constant = 40	best professional judgment
roughness height	cm	zruf	normal distribution: minimum = 2 maximum = 4 mean = 3 standard deviation = 0.6	best professional judgment; based on values in U.S. EPA (1989) for grassland
roughness ratio	unitless	Lc	lognormal distribution: minimum = 1 E-04 maximum = 1 E-03 mean = 3 E-04 standard deviation = 0.304	best professional judgment; based on information in U.S. EPA (1989)
vehicle speed	km/h	vs	normal distribution: minimum = 20 maximum = 40 mean = 30 standard deviation = 6.1	best professional judgment; based on information in Overcash and Pal (1979)
mode of aggregate size distribution	mm		constant = 5	conservative value from *Soil Screening Guidance* (U.S. EPA, 1996a)
USLE cover factor	unitless	Cwmu	constant = 0.08	Wanielista and Yousef (1993); assumed land use was cropland
USLE erosion control factor	unitless	Pwmu	constant = 0.50	Wanielista and Yousef (1993); assumed land use was cropland

Because of the difficulties in applying the HWIR LAU model to this situation and the lack of additional model inputs that would be needed, development of input parameters based on the progressive plot facility design was not pursued. Applying the HWIR model for the LAU in this manner would be problematic because the location of the individual cells relative to each other, and to the local watershed, would need to be known to determine the appropriate transport of contaminants from runoff/erosion. Further, the number of plots into which a given site would be divided, and the frequency with which plots would be used, are likely to be site-specific variables dictated by factors such as the rate of metals buildup expected in the soil. No information was found in the literature on the typical frequency of plot rotation or size. Consequently, for a progressive plot model, these parameters would have to be assumed inputs for the model.

3.6.1.2 Waste Application. The assumed method of waste delivery to the unit is important for calculating the particulate emissions due to vehicles traveling over the surface of an LAU. The waste application method in LAUs depends on the solid content of the waste (Overcash and Pal, 1979). Application methods can be divided between those for semiliquid materials (up to 15 percent solids) and those for solid or low-moisture materials (>15 percent solids). Semiliquid systems are generally applied using mobile tanks. Mobile tanks may either be tractor-hauled or truck-mounted. For the HWIR analysis, truck-mounted tanks are assumed to deliver any liquid or sludge wastes. Truck-mounted tanks range from 5,000 to 22,500 L, with a typical size of 9,500 L (Overcash and Pal, 1979). For low-moisture materials, truck-trailers transport and spread waste at the site. The parameter selection for HWIR includes model unit designs based on these waste application methods.

Liquid wastes (<8 percent solids, particle size <2.5 cm) are generally applied by either surface irrigation (tank truck) or sprinkler irrigation. Although the application of wastes to LAUs at industrial facilities may occur through surface or sprinkler irrigation, these application methods are not the basis for the development of the LAU model in HWIR. Therefore, in the parameter selection approach, we have not attempted to simulate these types of unit designs.

3.6.2 LAU Site-Specific Data

Site-specific data for LAUs were obtained from the Industrial D Screening Survey (Westat, 1987). This includes total area, number of LAUs at each site, and total 1985 annual waste quantity. Average values were calculated for use in the HWIR model by dividing the total area and the total annual waste quantity by the number of units at each site. Appendix 3A shows raw data from the Industrial D Screening Survey for the 201 Industrial D sites addressed in this analysis.

In some cases, the LAU annual waste quantity was screened due to unrealistic values or missing data. Replacement values were calculated under two conditions: (1) if surface area data were reported for a given LAU but the waste quantity was not provided or (2) if the calculated application rate (based on waste quantity and area) exceeded the upper bound set at 10 Mg/m^2-yr. Questionable data were screened following EPACMTP methodology (U.S. EPA, 1997):

> The land application managed waste data were screened by constraining unit application rate to be less than 10,000 tons/acre/year to eliminate unrealistic values. The application rate was calculated by dividing the waste managed in 1985 by the site acreage. (The upper bound was derived by assuming a maximum application rate of 200 dry tons/acre/year with a 2% solids content.)

Of the 352 LAUs (reporting surface area), 8 facilities did not provide data on annual waste quantity. Waste quantities were replaced for 12 other facilities because the calculated application rate exceeded the upper bound. The procedure to replace values was consistent with EPACMTP methodology (U.S. EPA, 1997):

> Missing and screened values were replaced by random realizations from the joint area/volume probability distribution or the corresponding marginal distributions depending on where both or only one of either the waste volume or area observation was missing or screened. The joint distribution was assumed to be lognormal and was derived from the non-missing unit area/volume pairs that met the unit depth constraint.

In order to calculate replacement values for the screened and missing annual waste quantities, first a statistical regression of log (average 1985 waste quantity) versus log (average surface area) was performed on the facilities with a known annual waste quantity. The regression yielded an equation for a best fit line through the known values. This equation gave the waste quantity as a function of the area, so the missing or screened waste quantities could be estimated based on the known areas. To provide a more probabilistic sampling of average waste quantities, and because the known quantities seemed to be in a limited range above and below the best-fit line (with some outliers), a positive or negative random number was generated within that range. This random number was then added to the calculated log (average waste quantity) to replace each missing waste quantity with a random value that was reasonable with respect to LAU area. Figure 3-3 shows the regression plot, including the replaced (random waste quantity) values for Ind D LAUs.

3.6.3 LAU Site-Based Data

Site-based data are derived from Ind D data (e.g., average area and width of the LAU), using relationships based on the published literature and best engineering judgment.

3.6.3.1 <u>Distance Vehicle Travels on LAU Surface (mt)</u>. The HWIR model assumes that WMU are square in shape. In reality, the shape of LAUs is likely to be dictated by the available land; however, because data on length/width ratios in LAUs are absent from the literature, assuming a square unit is reasonable and allows the various models to be applied appropriately to the LAU. The distance traveled over the LAU (mt) by the truck is assumed to be equal to the width of the WMU, as given by Equation LAU-1:

$$\mathrm{mt}(\mathrm{m}) = \mathrm{width}(\mathrm{m}) = \sqrt{\mathrm{area}(\mathrm{m}^2)} \qquad \text{(LAU-1)}$$

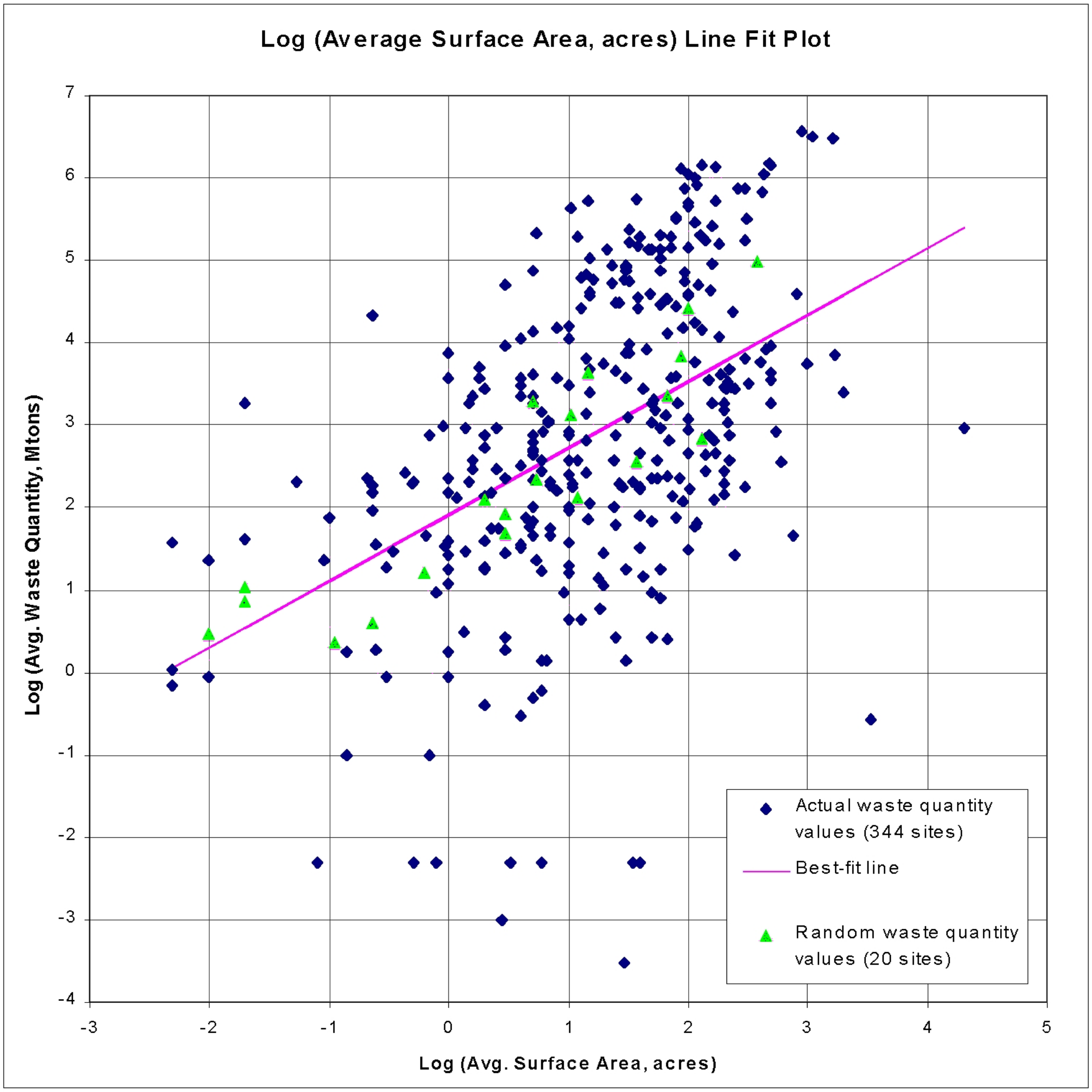

Figure 3-3. Correlation of waste quantity to area for LAUs.

3.6.3.2 <u>Wet Waste Application Rate (Rappl)</u>. The wet waste application rate (Rappl) is calculated as the average annual quantity of waste managed at the facility divided by the average LAU area as follows:

$$R_{appl}(Mg/m^2{-}yr) = \frac{\text{waste quantity}\,(Mg/yr)}{\text{area}\,(m^2)} \qquad \text{(LAU-2)}$$

3.6.3.3 <u>Vehicle Weight (vw), Payload, and Number of Wheels (nw)</u>. Two typical truck sizes were developed for this analysis: small and large. Data on typical truck payloads (and number of wheels per truck) were obtained from Overcash and Pal (1979) and MRI (1990). Data for determining the ratio of total to empty vehicle weight were obtained from Caterpillar (1994).

A small truck is assumed to have 6 wheels and a full weight of 30 Mg (15 Mg vehicle weight empty plus 15 Mg payload). The vehicle weight estimate is based on a payload size of 10 m^3 (roughly midrange for tank trucks in Overcash and Pal, 1979), a waste bulk density of about 1.5 Mg/m^3, and a ratio of weight loaded to weight unloaded of about 2.

A large truck is assumed to have 10 wheels and a full weight of 65 Mg (30 Mg vehicle weight empty plus 35 Mg payload). This vehicle weight estimate is based on a payload size of about 23 m^3 (the upper end of the tank truck sizes in Overcash and Pal, 1979), a waste density of about 1.5 Mg/m^3, and a ratio of weight loaded to weight unloaded of about 2.2.

The average number of vehicles used per waste application was not available from the literature. Instead, the average number of vehicles was calculated by assigning a truck size to the facility based on the amount of waste managed in the unit annually (i.e., waste quantity). For units managing less than 30,000 Mg/yr, a small truck is assumed. For units managing 30,000 Mg/yr or more, a large truck is assumed. Depending on the quantity of waste managed at the LAU, the appropriate truck payload is used in Equation LAU-4.

The vehicle weight is used in the particulate emission calculations. A full truck is assumed to drive onto the unit, dump its load while driving across the unit, and then exit empty. The vehicle weight is the average of its weight full and empty. The weight of the vehicle depends on the size of the vehicle (large or small) and the vehicle payload and is expressed as follows:

$$vw\,(Mg) = \frac{w_{full}\,(Mg) + w_{empty}\,(Mg)}{2} = \frac{payload\,(Mg)}{2} + w_{empty}\,(Mg) \qquad \text{(LAU-3)}$$

where

vw	=	vehicle weight for a small or large truck (Mg)
payload	=	carrying capacity of the truck (Mg)
w_{full}	=	vehicle weight when full (Mg) = w_{empty} (Mg) + payload (Mg)
w_{empty}	=	vehicle weight when empty (Mg).

3.6.3.4 <u>Vehicles per Day (nv)</u>. The average number of vehicles per day (nv) is determined by the average area of the LAU, the average annual waste application rate (Rappl from Equation LAU-2), and the carrying capacity (or payload) of the truck. The relationship is expressed as follows:

$$nv\,(1/d) = \frac{area\,(m^2) \times R_{appl}\,(Mg/m^2\text{-}yr)}{payload\,(Mg) \times 365.25\,(d/yr)} \qquad \text{(LAU-4)}$$

3.6.3.5 <u>Waste Applications per Year (Nappl)</u>. The following table shows how to determine the number of waste applications per year (Nappl) based on the annual waste quantity managed at the LAU. It was developed to keep the estimated number of applications at less than 100 per yr, based on information about typical applications per year found in U.S. EPA (1989), Environmental Research & Technology (ER&T) (1983), and Reed and Crites (1984). According to U.S. EPA (1989), the range for refineries is typically 2 to 52 applications per yr.

(LAU-5)

Annual Waste Quantity (Mg/yr)	Waste Applications per Year, Nappl (1/yr)
<1500	Waste quantity/15
>=1,500, <15,000	Waste quantity/150
>=15,000, <150,000	Waste quantity/1,500
>=150,000	Waste quantity/15,000

3.6.3.6 <u>Frequency of Cultivation (fcult)</u>. The frequency of cultivation (fcult) is determined based on the quantity of waste applied per unit area. In general, more cultivation per waste application is required for waste applied at a greater quantity per unit area (ER&T, 1983). According to U.S. EPA (1989), there are 1 to 5 cultivation events per application. The frequency of cultivation is calculated based on the following table, which was developed based on best professional judgment.

(LAU-6)

Annual Waste Application Rate ($Mg/m^2/yr$)	Frequency of Cultivation, f_{cult} (cultivations per waste application)
<0.01	1
>=0.01, <0.1	2
>=0.1, <1.0	3
>=1.0, <10.0	4
>=10.0	5

3.6.3.7 <u>Frequency of Surface Disturbances per Month (fd)</u>. A disturbance is defined as an action that results in the exposure of fresh surface material. This would occur whenever material is added to the surface or the surface is tilled. The frequency of surface disturbances per month (fd) equals the number of applications of waste per month multiplied by the number of cultivation events per application, as follows:

$$fd\,(1/mo) = \frac{N_{appl}\,(1/yr) \times f_{cult}}{12\,(mo/yr)} \qquad \text{(LAU-7)}$$

where

fd = frequency of surface disturbances per month (1/mo)
N_{appl} = number of waste applications per year (1/yr) (from table LAU-5)
f_{cult} = average frequency of cultivation of the plot, per application (from table LAU-6).

3.6.3.8 SCS Curve Number (CNwmu). The Soil Conservation Survey (SCS) curve number for the LAU (CNwmu) was based on the site-specific hydrologic soil group and the assumption that during operation and post-closure, the LAU would be actively cultivated with row crops, pasture, or meadow. To represent the potential variability in CNwmu under cultivation, a triangular distribution, based on three cover conditions, was selected from USDA (1986) and used to define the range and typical cover effect of agricultural cultivation. "Meadow – continuous grass, protected from grazing and generally mowed for hay" was used to represent conditions leading to minimum runoff and maximum infiltration, or minimum CNwmu, for a particular hydrologic soil group. To represent maximum CNwmu, or maximum runoff and minimum infiltration, straight row crops in poor hydrologic condition were used. Contoured row crops, with a crop residue cover and good hydrologic condition were used as the central tendency CNwmu for the triangular distribution, to represent a moderate water holding condition. These minimum, central and maximum values are shown in Table 3-10 by hydrologic soil groups A, B, C, and D.

To get the SCS curve number for the LAU, the map unit with the largest area in the WMU was used to obtain the hydrologic soil group from processed STATSGO data (see Section 7.4.2 for more details). This hydrologic soil group was used to select the correct values for CNwmu from Table 3-10, which were sent to the HWIR model as the parameters of a triangular distribution.

Table 3-10. LAU Curve Numbers (CNwmu), by Hydrologic Soil Group

Hydrologic Soil Group	Curve Number (CNwmu)		
	Minimum	Central Tendency	Maximum
A	30	64	72
B	58	74	81
C	71	81	88
D	78	85	91
Source (USDA, 1986):	Meadow Table 2-2c	Contoured row crops + crop residue/Good Table 2-2b	Straight row crops/Poor Table 2-2b

3.6.4 LAU National Data

3.6.4.1 Depth of Tilling (SrcDepth, zZ1WMU). The till depth is generally a function of the equipment used to conduct the tilling operation. Because this variable was sent both in the site layout (SrcDepth) and LAU (zZ1WMU) data groups, it was necessary to fix the value to ensure that the same value would be used for both variables. A tilling depth of 0.20 m was selected as a typical till depth based on a literature review (Brown et al., 1983; ER&T, 1983; Martin et al., 1986; U.S. EPA, 1996b). The limited range for this variable found in these data sources also supports the use of a constant value.

3.6.4.2 Dust Suppression Control Efficiency (effdust). Dust suppression activities might include watering the LAU to reduce dust or applying chemical dust suppressants (U.S. EPA, 1989). A value of zero corresponds to no dust suppression activity. Although information was available about types of dust suppression control activities, no information was found on how often these activities are typically employed or their effectiveness. Consequently, it is assumed that dust suppression control efficiency (effdust) has a normally distributed value between 0 and 1, with a mean of 0.5 and a standard deviation of 0.3. The mean value for dust suppression control efficiency for the LAU was set higher than that for the wastepile because the application of liquid waste in the LAU can suppress dust.

3.6.4.3 Fraction Vegetative Cover (veg). During LAU operation, fraction vegetative cover (veg) is assumed to be between 0.8 and 1, reflecting operation of the unit as agricultural cropland. The fraction vegetative cover is specified as a normal distribution, with a mean of 0.9 and a standard deviation of 0.1.

3.6.4.4 Operating Life (CutOffYr). For this analysis, LAU operating life was set at a constant value of 40 yr.

3.6.4.5 Roughness Height (zruf). This factor is the height aboveground at which the wind speed becomes zero (U.S. EPA, 1989). The range is 0.1 to 1,000 cm for snow to urban settings. U.S. EPA (1989) provides some values for the roughness height for various sites in Arizona and for industrial aggregates, as well as a chart of values for different settings. The roughness height for a closed LAU is assumed to be normally distributed from 2 to 4 cm (corresponding to grassland), with a mean of 3 cm and a standard deviation of 0.6 cm.

3.6.4.6 Roughness Ratio (Lc). This factor is the ratio of the silhouette area of the roughness elements (>1 cm) in the soil to the total bare loose soil. The roughness ratio (Lc) can range from 0 to 0.01 (U.S. EPA, 1989). Lc was assumed to be lognormally distributed, with a minimum of 1×10^{-4}, a maximum of 1×10^{-3}, a mean of 3×10^{-4}, and a standard deviation of 0.304. Higher Lc values ($>2\times10^{-4}$) increase the threshold wind speed for the onset of wind erosion (which means lower particulate emissions due to wind erosion). Therefore, assuming a value for Lc of 1×10^{-4} is conservative with respect to particulate emissions.

3.6.4.7 Vehicle Speed (vs). Vehicle speed is the mean speed that trucks travel on the LAU. For surface spreading, a range of 20 to 40 km/h is representative (Overcash and Pal 1979).

Vehicle speed (vs) is assumed to have a normal distribution from 20 to 40 km/h with a mean of 30 km/h and a standard deviation of 6.1 km/h.

3.6.4.8 Mode of Aggregate Size Distribution (asdm). This parameter is the mode value of the size of soil aggregates in an LAU. Because little data were available on this parameter, a conservative value of 0.5 mm is assumed for this parameter based on the *Soil Screening Guidance: Technical Background Document* (U.S. EPA, 1996a).

3.6.4.9 USLE Cover Factor (Cwmu) and Erosion Control Factor (Pwmu). For this analysis, it was assumed that the LAU is maintained as cropland. Therefore, the USLE cover factor (Cwmu) was fixed at a value of 0.08 and the erosion control factor (Pwmu) was fixed at a value of 0.50 (Wanielista and Yousef, 1993).

3.7 Surface Impoundment Model Inputs

This section describes the approach used to develop inputs for the surface impoundment source model. The model design is described in Section 3.7.1. Sections 3.7.2 through 3.7.4 describe the development of input parameters for site-specific, site-based, and national data, respectively. Relationships between site-specific and site-based input parameters are identified and considered to ensure that related inputs are not randomly selected in a manner that would create physically impossible or unrealistic combinations.

Table 3-11 summarizes the data collected for surface impoundment model inputs. It is organized by site-specific and site-based data, which are extracted directly or calculated from Industrial D Screening Survey data, and national data, which are derived based on relationships taken from books, reports, and professional judgment.

3.7.1 Surface Impoundment Model Design

A surface impoundment is an excavation or diked area typically used for the treatment, storage, or disposal of liquids or sludges containing free liquids. Liquids and solids typically separate in a surface impoundment by gravity settling. Liquids from surface impoundments are removed by draining, evaporation, or flow through an outlet structure. Accumulated solids are removed by dredging during impoundment operation or at the time of closure.

There are more than 180,000 surface impoundments in the United States (Hartley, 1992). Nearly 30,000 are used by industry, including chemical manufacturers, food processors, oil refineries, primary and fabricated metals, paper plants, and other commercial facilities.

For this analysis, surface impoundments were categorized depending on the waste composition, waste generation rate, and purpose of impoundment. Based on their purpose, the three generic impoundment types are storage, disposal, and treatment. Table 3-12 summarizes the distribution of surface impoundment applications.

Table 3-11. WMU Data Collected for the Surface Impoundment Model

Variable	Units	Code	Value	Data Source
Site-Specific Variables				
WMU type	unitless	SrcType	specified "SI"	Industrial D Screening Survey (Westat, 1987)
area of source	m^2	SrcArea	SrcArea = [total area]/[no. surface impoundments]	Industrial D Screening Survey (Westat, 1987); average values
Site-Based Variables				
depth of source	m	d_wmu, SrcDepth	capacity/[SrcArea × bulk density] (Equation SI-1)	derived from Industrial D Screening Survey; assumed bulk density of waste = 1.09577 g/cm^3; depth constraint 0.3 to 46 m (1 to 150 ft)
volumetric influent flow rate	m^3/s	Q_wmu	Q_wmu = waste quantity/[365.25 (d/y) x 86,400 (s/d) x bulk density] (Equation SI-2)	derived from Industrial D Screening Survey; assumed bulk density of waste = 1.0 g/cm^3
fraction of surface impoundment occupied by sediments	fraction	d_setpt	d_wmu < 1.5: d_setpt = 0.2 d_wmu >= 1.5 and <5: d_setpt = (d_wmu - 1.2)/d_wmu d_wmu >= 5: d_setpt = 0.76	best professional judgment; Tchobanoglous (1979)
impellers/aerators (number)	unitless	n_imp	SrcArea > 1,600 m^2: n_imp = integer(SrcArea/1,600) + 1 SrcArea < 1,600 m^2: n_imp = integer(SrcArea/160) + 1	U.S. EPA (1990); maximum number of impellers/aerators is 66 (4,950 hp)

(continued)

Table 3-11. (continued)

Variable	Units	Code	Value	Data Source
Site-Based Variables				
impellers/aerators (total power)	hp	Powr	SrcArea > 1,600 m^2: Powr = n_imp x 75 SrcArea < 1,600 m^2: Powr = n_imp x 7.5	U.S. EPA (1990); total power is assumed not to exceed 5,000 hp
turbulent area	m^2	---	turbulent area = n_imp x 5.22 x Powr	U.S. EPA (1990); assumed 5.22 m^2/hp turbulent area
fraction surface area turbulent	fraction	F_aer	F_aer = turbulent area/SrcArea	
National Variables				
biologically active solids/total solids (ratio)	unitless	kba1	uniform distribution: minimum = 0.7 maximum = 0.9	Tchobanoglous (1979)
biomass yield	g/g	bio_yield	uniform distribution: minimum = 0.4 maximum = 0.8	Tchobanoglous (1979)
digestion (sediments)	1/s	k_dec	uniform distribution: minimum = 4.6 E-07 maximum = 8.7 E-07	Tchobanoglous (1979)
economic life of a tank/surface impoundment	yr	EconLife	constant = 50	best professional judgment
impeller diameter	cm	d_imp	constant = 61	U.S. EPA (1990)
impeller speed	rad/s	w_imp	constant = 126	U.S. EPA (1990)
number of economic lifetimes	unitless	NumEcon	constant = 1.0	best professional judgment

(continued)

Table 3-11. (continued)

Variable	Units	Code	Value	Data Source
National Variables				
oxygen transfer correction factor	unitless	O2eff	uniform distribution: minimum = 0.80 maximum = 0.85	Tchobanoglous (1979)
oxygen transfer factor	lb O_2/h-hp	J	constant = 3	Tchobanoglous (1979)
saturated hydraulic conductivity (sediment layer)	m/s	hydc_sed	uniform distribution: minimum = 1 E-9 maximum = 1 E-6	best professional judgment

Table 3-12. Distribution of Surface Impoundment Applications

	Storage Percentage	Disposal Percentage	Treatment Percentage
Agricultural	55	26	19
Municipal	5	31	64
Industrial	17	31	52
Mining	18	27	56
Oil and gas	29	67	4

Source: Hartley, 1992.

3.7.2 Surface Impoundment Site-Specific Data

Site-specific data for surface impoundments were obtained from the Industrial D Screening Survey (Westat, 1987). The data include total area, number of surface impoundments at each site, total capacity, and total 1985 annual waste quantity. Average values were calculated for use in the HWIR model by dividing each of the parameters by the number of units at each site. Appendix 3A shows raw data from the Industrial D Screening Survey (including replacement values) for the 201 Industrial D sites addressed in this analysis.

In accordance with previous EPA modeling efforts using the Industrial D Screening Survey, surface impoundment capacities were screened from the Industrial D data when either the capacity was missing or the depth constraint was violated. As with landfills, the unit depth was calculated by dividing the unit capacity by the unit area. The depth constraint was described by EPACMTP documentation as follows (U.S. EPA, 1997):

> The surface impoundment volume data were screened by constraining the calculated unit depth to be between one and 150 feet in order to eliminate unrealistic values.

Some 1,926 Ind D surface impoundment facilities reported surface area. Missing waste quantity values were replaced for 57 of these facilities. Replacement capacity values were calculated for 268 of the facilities with either missing or screened capacities. The procedures to replace waste quantity and capacity are conditioned on area, as described for other WMU types, and are consistent with EPACMTP methodology (U.S. EPA, 1997).

In order to calculate replacement values for the screened and missing annual waste quantities, first a statistical regression of log (average annual waste quantity) versus log (average surface area) was performed on the facilities with known quantities. The regression yielded an equation for a best fit line through the known values. This equation gave the waste quantity as a function of area, so the missing or screened waste quantities could be estimated based on the known areas. To provide a more probabilistic sampling of average waste quantities, and because the known quantities seemed to be in a limited range above and below the best-fit line (with some outliers), a positive or negative random number was generated within that range. This random number was then added to the calculated log (average waste quantity) to replace each missing waste quantity with a random value that was reasonable with respect to the surface impoundment area. Figure 3-4 shows the regression plot, including the replaced (random waste quantity) values, for surface impoundments.

To calculate replacement values for capacity, first a statistical regression of log (average total capacity) versus log (average surface area) was performed on the facilities with known capacities. The regression yielded an equation for a best-fit line through the known values. This equation gave the capacity as a function of area, so the missing or screened capacities could be estimated based on the known areas. To provide a more probabilistic sampling of average capacities, and because the known capacities seemed to be in a limited range above and below the best-fit line (with some outliers), a positive or negative random number was generated within that range and added to the calculated log (average total capacity) to replace each missing capacity with a random value that was reasonable with respect to the surface impoundment area. This value was then used to calculate depth as described above. Figure 3-5 shows the regression plots, including the replaced (random capacity) values, for surface impoundments.

3.7.3 Surface Impoundment Site-Based Data

Surface impoundment variables related to site-specific surface impoundment area, capacity, or annual waste quantity were calculated as described below.

3.7.3.1 Depth of Surface Impoundment (d_wmu, SrcDepth). Surface impoundment depth (d_wmu or SrcDepth) was calculated consistent with previous EPA modeling efforts using the Industrial D capacity and area data (U.S. EPA, 1997). The bulk density used for surface impoundment was 1.0 g/cm^3. A range of 0.3 to 46 m (1 to 150 ft) was set as the depth constraint.

$$\text{depth (m)} = \frac{\text{SI capacity (Mg)} \times 1\times10^{6}\ \text{g/Mg}}{\text{area (m}^2) \times \text{bulk density (g/cm}^3) \times (100\ \text{cm/m})^3} \qquad \text{(SI-1)}$$

3.7.3.2 Volumetric Influent Flow Rate (Q_wmu). Volumetric influent flow rate (Q_wmu) is calculated based on the annual waste quantity from the Industrial D Screening Survey and an assumed bulk density of 1.0 Mg/m^3. Values ranged from 1×10^{-20} to 10 m^3/s. It was calculated as follows:

$$\text{Q\_wmu (m}^3\text{/s)} = \frac{\text{waste quantity (Mg/yr)}}{365.25\ \text{(d/yr)} \times 86{,}400\ \text{(s/d)} \times \text{bulk density (Mg/m}^3)} \qquad \text{(SI-2)}$$

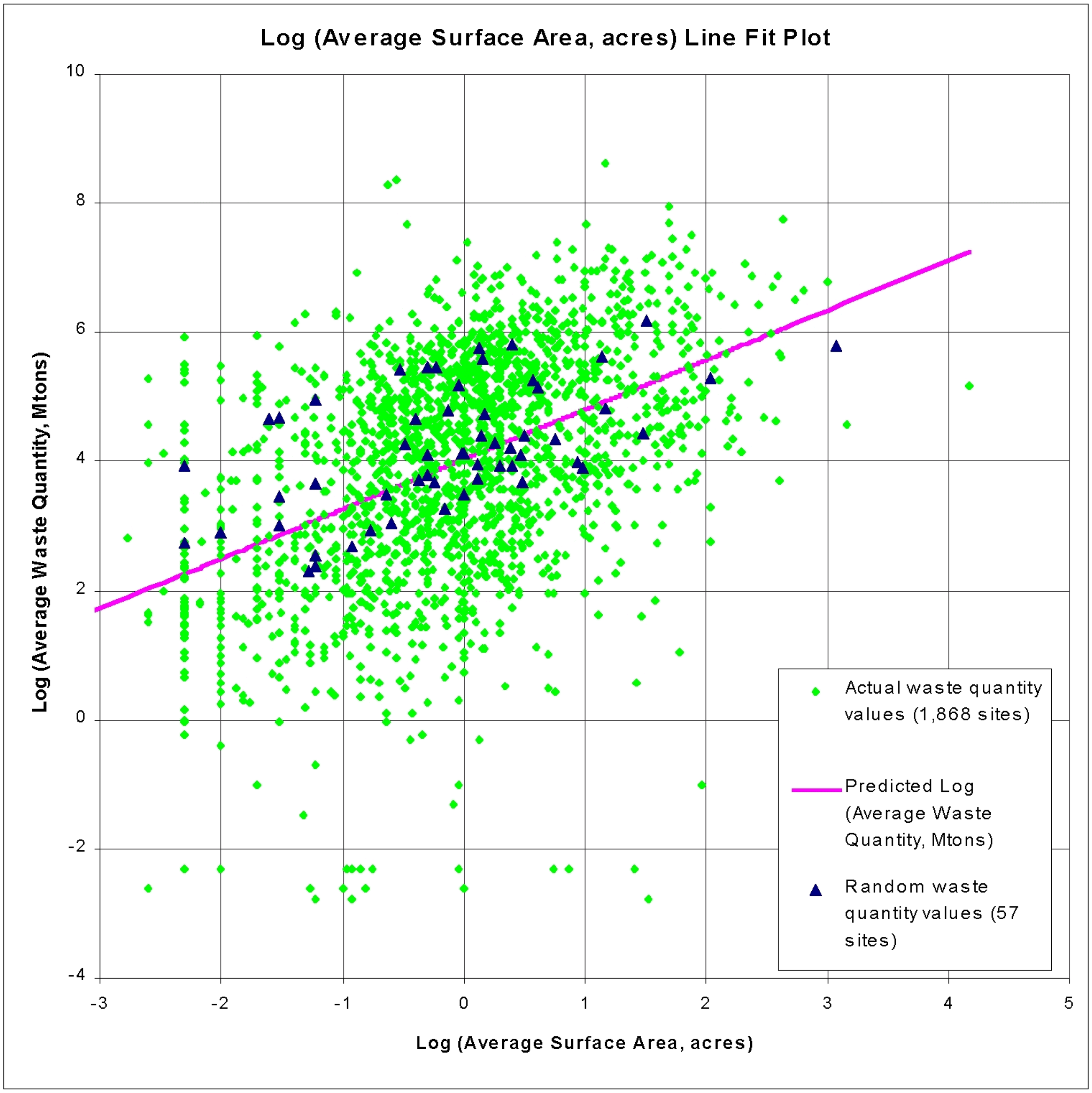

Figure 3-4. Correlation of waste quantity to area for surface impoundments.

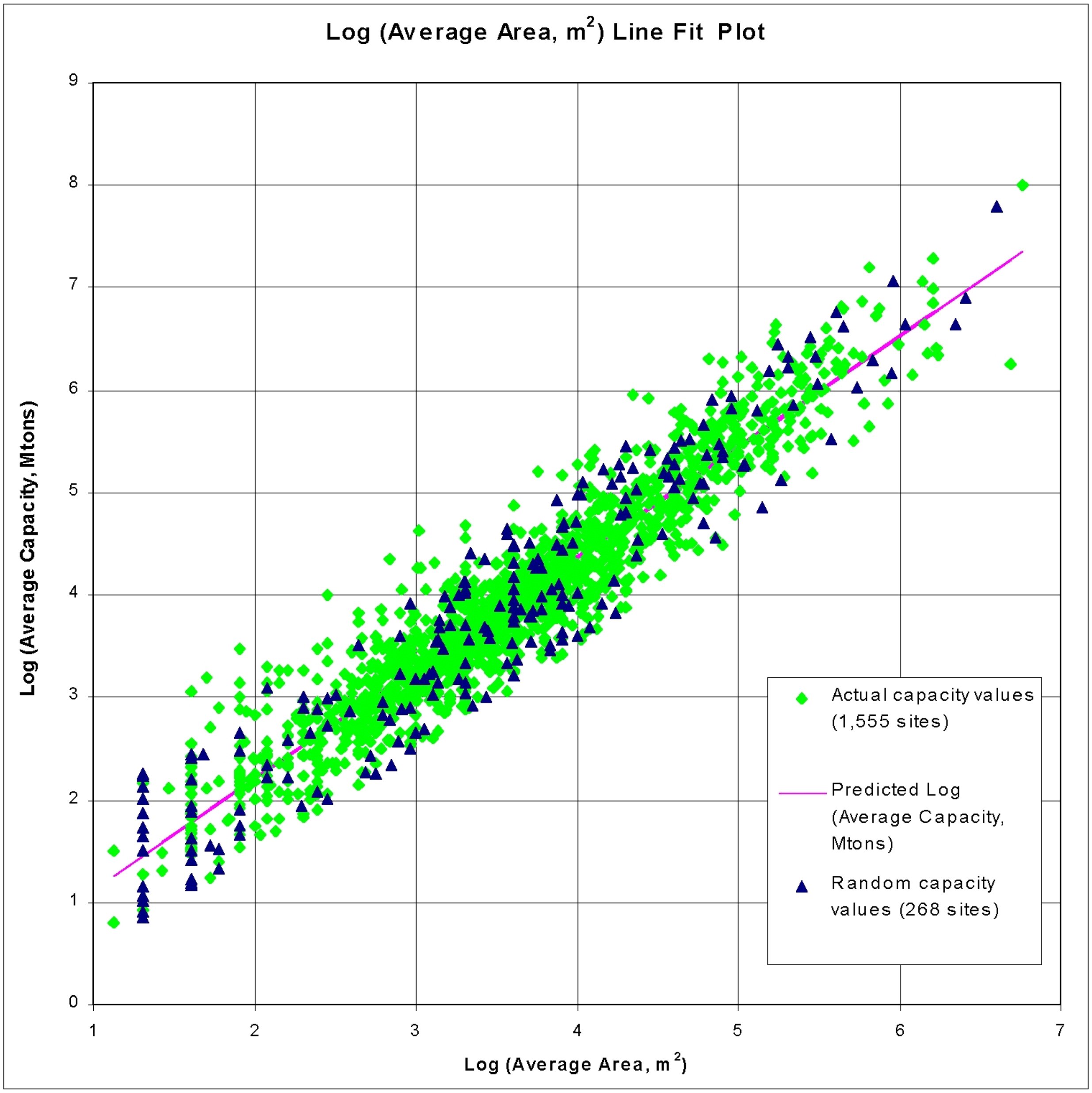

Figure 3-5. Correlation of total capacity to area for surface impoundments.

3.7.3.3 <u>Fraction of Unit Occupied by Sediments (d_setpt)</u>. To calculate the fraction of unit occupied by sediments (d_setpt), the following formula was developed based on best professional judgment, as follows:

For depths less than 1.5 m, d_setpt = 0.2
For depths less than 5 m, d_setpt = (depth - 1.2)/(depth)
For depths greater that 5 m, d_setpt = 0.76 (maximum value).

For depths less than 1.5 m, it is assumed the unit is cleaned whenever more than 20 percent of the unit depth is filled with sediment. For depths greater than 5 m, it is assumed the unit is cleaned whenever more than 76 percent of the unit is filled with sediment. For depths between 1.5 and 5 m, the set point is calculated as the percentage required to keep at least 1.2 m of clean depth. These values are based on engineering judgment and Tchobanoglous (1979).

3.7.3.4 <u>Impellers/Aerator Number (n_imp), Total Horsepower (Powr), and Fraction Surface Area Turbulent (F_aer)</u>. It is assumed that a one hp motor will agitate an area of 5.22 m^2 (U.S. EPA, 1990). Based on this assumption, we can calculate the total turbulent area using a 75- or 7.5-hp motor (turbulent area = ~392 m^2 for 75-hp motor). Typically, the turbulent area for a surface impoundment is about 25 percent of the total area of the unit (U.S. EPA, 1990). Therefore, a 75-hp motor will aerate about 25 percent of a 1,600 m^2 surface impoundment (392/1,600 = ~0.25). The number of impellers is taken to be equal to the number of motors. Two motor sizes were assumed: 7.5 hp and 75 hp. The smaller motor was assumed for smaller impoundments (area <1,600 m^2), while the larger motor was assumed for larger impoundments (area >=1,600 m^2).

- The number of impellers (n_imp) is calculated as follows:

  If source area >1,600 m^2, then n_imp = Integer [source area (m^2)/1,600 m^2] + 1.
  If source area <1,600 m^2, then n_imp = Integer [source area (m^2)/160 m^2] + 1.

- Total impeller power (Powr, hp) = n_imp × power per impeller (hp).

  If source area >1,600 m^2, then power per impeller = 75 hp.
  If source area <1,600 m^2, then power per impeller = 7.5 hp.

- Assuming 5.22 m^2/hp turbulent,

  turbulent area (m^2) = Powr (hp) × 5.22 (m^2/hp).

- Fraction turbulent area (F_aer) = turbulent area (m^2)/source area (m^2).

Total power is assumed not to exceed 5,000 hp. From the above calculations, therefore, the maximum number of impellers/aerators is 66 (4,950 hp).

3.7.4 Surface Impoundment National Data

Noncorrelated surface impoundment variables included in the national data tables are described below.

3.7.4.1 <u>Ratio of Biologically Active Solids to Total Solids (kba1)</u>. Values for the ratio of biologically active solids to total solids were assumed to be uniformly distributed between 0.7 and 0.9. The range is based on data from Tchobanoglous (1979).

3.7.4.2 <u>Biomass Yield (bio_yield)</u>. Values for biomass yield were assumed to vary uniformly, from 0.4 to 0.8 g/g. This is based on a range of 0.4 to 0.8 mg VSS/mg of biological oxygen demand for a 5-day test (BOD_5), reported by Tchobanoglous (1979).

3.7.4.3 <u>Digestion Rate (Sediments) (k_dec)</u>. Values for sediment digestion rate were assumed to be uniformly distributed between 4.6×10^{-7} s^{-1} and 8.7×10^{-7} s^{-1}. This is based on a range of 0.04 to 0.075 d^{-1} given for the parameter K_d (the endogenous decay coefficient) in Table 9-7 of Tchobanoglous (1979).

3.7.4.4 <u>Economic Life of Surface Impoundment (EconLife)</u>. The economic life of a surface impoundment was assumed to be 50 yr.

3.7.4.5 <u>Impeller Diameter (d_imp)</u>. The impeller diameter was fixed at 61 cm, based on U.S. EPA (1990).

3.7.4.6 <u>Impeller Speed (w_imp)</u>. The value for impeller speed was fixed at 126 rad/s. This is based on data from U.S. EPA (1990).

3.7.4.7 <u>Number of Economic Lifetimes (NumEcon)</u>. The number of economic lifetimes was fixed at 1.

3.7.4.8 <u>Oxygen Transfer Correction Factor (O2eff)</u>. Values for the oxygen transfer factor were assumed to be uniformly distributed between 0.80 and 0.85. The recommended range is based on data from Tchobanoglous (1979).

3.7.4.9 <u>Oxygen Transfer Factor (J)</u>. Values for the oxygen transfer factor were fixed at 3.0 lb O_2/hp h. This is the median of the recommended range of 2.0 and 4.0 O_2/hp h based on data from Tchobanoglous (1979).

3.7.4.10 <u>Saturated Hydraulic Conductivity of Sediment Layer (hydc_sed)</u>. The value of this parameter was assumed to be uniformly distributed between 1×10^{-9} and 1×10^{-6} m/s, based on engineering judgment that the sediment layer will be similar to a compacted soil.

3.8 Aerated Tank Model Inputs

This section describes the approach used to develop inputs for the aerated tank source model. The aerated tank model design is described in Section 3.8.1. Section 3.8.2 describes the use of tank data from the TSDR Survey (U.S. EPA, 1987) to derive correlated model input variables. Section 3.8.3 describes the collection of other, noncorrelated, nationally specified input parameters. These data were derived based on relationships taken from books, reports, and professional judgment. Table 3-13 summarizes the data collected for aerated tank model inputs.

3.8.1 Aerated Tank Model Design

Tanks are used to treat and/or store a variety of waste materials. Tanks may be enclosed, covered, or open to the atmosphere. This analysis focused on treatment tanks that were open to the atmosphere and had some agitation of material contained in the tank. Two levels of agitation (or aeration) were considered. Tanks that actively mix the liquid surface for the purpose of aeration (transferring oxygen from the atmosphere into the liquid) were classified as HI aeration because these units have a high degree of turbulence by design. Tanks that are likely to have mixing devices used with chemical additions or other purposes were classified as LO aeration. These tanks have convective currents and some degree of turbulence that increases volatile losses, but they are not designed specifically to enhance air-liquid mass transfer. Key parameters for any tank design are tank capacity and flow rate (which fixes the hydraulic retention time). For treatment tanks, the number, type, and power input to the aerators/mixers are important design parameters. For biological treatment tanks, the concentration of active biomass and the overall oxygen transfer rate (which is dependent on the aerator characteristics as well as the surface area to volume ratio) are also key design parameters.

Treatment tanks can be elevated (bottom of tank above ground level), on the ground (bottom of tank at ground level), or in-ground (bottom of tank below ground level). As the tank volume increases, so does the likelihood that the tank is on or in the ground. The elevation of the tank with respect to the ground level impacts the release height of the volatile emissions and the subsequent dispersion characteristics.

As described in Section 2.0, an aerated tank is assumed to be present at every HWIR facility that has a surface impoundment. This is based on the assumption that surface impoundments are an indication that a facility manages liquid wastes and that tanks are likely to be present at such facilities. During the execution of the HWIR modeling system, tanks were randomly selected for placement at aerated tank sites from a correlated data set of model tanks developed from the 624-tank TSDR database described in Section 3.2.2. The following section (Section 3.8.2) describes how this data set was developed.

3.8.2 Aerated Tank Correlated Data

Correlated tank data include size-related variables directly extracted or derived from the TSDR database described in Section 3.2.2. These variables are passed to the system as a data set of 624 model tanks. Correlated tank data and related parameters used in their derivation (such as aeration level, tank size, and tank capacity) are presented in Appendix 3B-3. As described in

Table 3-13. WMU Data Collected for the Aerated Tank Model

Variable	Units	Code	Value	Data Source
Site-Specific (Correlated) Variables				
aerated tank index	unitless	ATIndex	uniform distribution from 1 to 624 (number of tanks in national tank data set)	
volumetric flow rate (tank)	m^3/s	Q_wmu	converted from gallons	TSDR Survey (U.S. EPA, 1987)
depth (liquid)	m	d_wmu	calculated using tank capacity and HI/LO aeration designations; uses a random variation on calculated depths (Equation AT-1 and Section 3.8.2.3)	derived from TSDR Survey
area of source	m^2	SrcArea	calculated based on tank volume and projected tank depth (d_wmu)	derived from TSDR Survey
fraction surface area-turbulent	fraction	F_aer	assigned depending on HI/LO aeration designation HI aeration, normal distribution: minimum = 0 maximum = 1 mean = 0.75 standard deviation = 0.1 LO aeration, normal distribution: minimum = 0.2 maximum = 0.8 mean = 0.50 standard deviation = 0.2	derived from TSDR Survey

(continued)

Table 3-13. (continued)

Variable	Units	Code	Value	Data Source
Site-Specific (Correlated) Variables				
impellers/aerators (total power)	hp	Powr	assigned depending on HI/LO aeration designation (minimum = 0.25) HI aeration, normal distribution: 90 percent between 80 and 150 hp per million gallons of tank volume LO aeration, normal distribution: 90 percent between 15 and 45 hp per million gallons of tank volume	Tchobanoglous (1979), Adams and Eckenfelder (1974) and Water Pollution Control Federation (WPCF, 1988); minimum total power based on minimum size of commercially available mixers for containers holding 55 gal or more
impellers/aerators (number)	unitless	n_imp	Powr ≤25 hp: n_imp = 1 25 hp < Powr < 80 hp: randomly pick 1 or 2 (equal probability) Powr ≥80 hp: Integer (Powr/[random number between 60 and 100])	Adams and Eckenfelder (1974), Water Pollution Control Federation (WPCF, 1988)
National Variables				
biologically active solids/total solids (ratio)	unitless	kba1	uniform distribution: minimum = 0.7 maximum = 0.9	Tchobanoglous (1979)
biomass yield	g/g	bio_yield	uniform distribution: minimum = 0.4 maximum = 0.8	Tchobanoglous (1979)
digestion (sediments)	1/s	k_dec	uniform distribution: minimum = 4.6E-07 maximum = 8.7E-07	Tchobanoglous (1979)

(continued)

Table 3-l3. (continued)

Variable	Units	Code	Value	Data Source
National Variables				
economic life of AT/SI	yr	EconLife	constant = 20	best professional judgment
fraction of tank occupied by sediments (max.)	fraction	d_setpt	constant = 0.3	best professional judgment
impeller diameter	cm	d_imp	constant = 61	U.S. EPA (1990)
impeller speed	rad/s	w_imp	constant = 126	U.S. EPA (1990)
number of economic lifetimes	unitless	NumEcon	constant = 2.5	best professional judgment
oxygen transfer correction factor	unitless	O2eff	constant = 0.83	Tchobanoglous (1979)
oxygen transfer factor	lb O_2/h-hp	J	constant = 3.0	Tchobanoglous (1979)

Section 3.3.3, when the HWIR modeling system models an aerated tank site, one of these tanks is randomly selected and placed at the site. To avoid placing unreasonably large tanks at sites with small surface impoundments, tank selection is constrained so that the selected tank is no larger than the average surface impoundment area at the facility in question (i.e., the data set is resampled when this occurs).

3.8.2.1 <u>Aerated Tank Index (ATIndex) and Maximum Source Area (MaxSrcArea)</u>. The ATIndex and MaxSrcArea are used by the HWIR 3MRA model site definition processor in the selection of a tank to model at a facility. ATIndex is an integer with a uniform distribution from 1 to 624 that is randomly sampled to provide the tank to be modeled at a site. Each correlated tank variable is indexed on the ATIndex to allow the system to pick a consistent set of correlated values.

MaxSrcArea is simply the average surface impoundment area (SrcArea) for the site in question (see Section 3.7.2).

3.8.2.2 <u>Tank Throughput (Q_wmu)</u>. Values for tank throughput in the original TSDR Survey database were in units of gallons per year. These values were converted into units of cubic meters per second (m^3/s) based on the assumption of 8,766 h/yr operation.

3.8.2.3 <u>Preliminary Tank Depth</u>. The preliminary tank depth is used to estimate tank depth for the model as described in Section 3.8.2.4.

In 1985 and 1986, Research Triangle Institute (RTI) conducted numerous site visits to aerated treatment systems. Data extracted from site visit test reports is presented in Appendix 3B, Table 3B-2. Based on these data and the addition of a cubic 55-gal tank and a 3-million-gal/32-ft-deep tank (based on vendor information), the following log expression was derived:

$$\text{depth, m} = 10^{\left[0.1358 \times \log(\text{tank capacity, m}^3) + 0.2236\right]} \qquad \text{(AT-1)}$$

Using this expression, 55 gal tanks (the smallest tanks in the database) are approximately 4.4 ft tall and have a diameter less than 18 in. Consequently, for small tanks, a cubed-shaped tank was used as the central tendency value (i.e., depth = $\text{capacity}^{0.333}$). At a tank size of approximately 10 m^3, Equation AT-1 predicts approximately cubed-shaped tanks. Therefore, Equation AT-1 is used for tanks greater than 10 m^3.

The largest tank in the LO aeration category is 25,000 m^3, and the projected depth for this tank is 6.6 m (22 ft), which is acceptable for mixing tanks. The largest tank in the HI aeration category is 114,000 m^3, and the projected depth for this tank is 8.1 m (27 ft). In evaluating the depths of mechanically aerated tanks, however, the maximum depth was 6.1 m (20 ft). Even this depth appeared to be an outlier compared to the other HI aeration, mechanically aerated tanks. Data were available for eight tanks (two of which were the TSDF model tanks). The other seven tanks all had depths ranging from 3.35 m (11 ft) to 4.88 m (16 ft). The mid-range of the latter depths is approximately equivalent to a 1,000-m^3 tank as calculated using Equation AT-1.

Therefore, for HI aeration tanks greater than 1,000 m^3, a random (maximum) depth is set from the expected range of depths for HI aeration units.

3.8.2.4 <u>Estimating Tank Depth (d_wmu) from Tank Capacity</u>. In the following calculation algorithms the nomenclature random#(X to Y) indicates that a random number was selected based on a normal distribution, with 90 percent of the values falling within the range of X to Y.

<u>Estimating depth for LO aeration tanks, nonaerated tanks, and storage tanks:</u>

- If tank capacity is <10 m^3, depth = random#(0.8 to 1.2)*$capacity^{0.333}$.
- If tank capacity is >=10 m^3, use Equation AT-1 and then apply a random variation on the calculated depth [i.e., random#(0.8 to 1.2)].

<u>Estimating depth for HI aeration tanks:</u>

- If tank capacity is <10 m^3, depth = random#(0.8 to 1.2)*$capacity^{0.333}$.
- If 10 m^3 <= tank capacity <=1,000 m^3, use Equation AT-1 and then apply a random variation [i.e., random#(0.8 to 1.2)].
- Above 1,000 m^3, use random#(3.5 to 4.8) and then apply a random variation on the calculated depth [i.e., random#(0.8 to 1.2)].

3.8.2.5 <u>Surface Area (SrcArea)</u>. Tank surface area values were calculated, based on the database value for tank volume and the projected values for tank depth.

3.8.2.6 <u>Source Height (SHight)</u>. Because the heights of the tanks in the TSDR database were not provided, source height for tanks (SHight) was randomly generated for each tank in the 624-tank data set. Based on professional experience, it was assumed that tank heights do not exceed 20 m, that some tanks (especially larger ones) are buried beneath the ground surface, and that there can be some freeboard height (0.5 m aboveground) for every tank.

Given this perspective, SHight was randomly selected once for each of the 624 tanks in the data set from a uniform distribution ranging from 0 to 20 m. If the randomly selected value was less than the tank depth (d_wmu) + 0.5 m, the value was placed in the data set. Otherwise, SHight was set to d_wmu + 0.5 m.

3.8.2.7 <u>Fraction Surface Area Turbulent (F_aer)</u>. Three aeration levels were assumed to exist: (1) HI aeration when agitation is used for biological treatment or other high-energy processes, (2) LO aeration for mixing processes, and (3) NO aeration for complete quiescence. Aeration categories (HI/LO/NO) were assigned according to the waste treatment classification, as shown in Appendix 3B, Table 3B-3. The following aeration distributions were developed based on best engineering judgment:

- # The HI aeration was assumed to follow a normal distribution, centered on a fraction turbulent area of 0.75, with a standard deviation of 0.1 and no values above 1.0.

- # The LO aeration was assumed to follow a normal distribution, centered on a fraction turbulent of 0.50, with a standard deviation of 0.2 and no values above 0.8 or below 0.2.

3.8.2.8 <u>Total Aerator Horsepower (Powr)</u>. Total aerator horsepower was calculated based on the following algorithm:

- # The HI aeration power was assumed to follow a normal distribution, with 90 percent of the values falling between 80 and 150 hp per million gals of tank volume (Tchobanoglous, 1979).

- # The LO aeration power was assumed to follow a normal distribution, with 90 percent of the values between 15 and 45 hp per million gals of tank volume. This estimate was based on references that indicate surface aerators used for mixing typically have power levels of 15 to 20 hp/million gal (Adams and Eckenfelder, 1974) and that minimum surface aerator power to mix activated sludge tanks is 20 to 30 hp/million gal (WPCF, 1988). The upper value of 30 hp was multiplied by 1.5, with a resultant value of 45 hp/million gal, to provide values above the minimum.

- # Set the minimum Total Aerator Power to 0.25 hp, if the estimated value is less than 0.25 hp based on the minimum size of commercially available mixers for containers holding 55 gal or more.

3.8.2.9 <u>Number of Impellers/Aerators (n_imp)</u>. The number of impellers/aerators (n_imp) is determined based on the total aerator horsepower as follows:

- # For Total Power $\leq$25 hp, n_imp = 1.

- # For 25 hp < Total Power <80 hp, randomly pick 1 or 2 (equal probability).

- # For Total Power $\geq$80 hp, randomly pick a number between 60 and 100 (uniform distribution) and then divide the Total Power by the random number and round up to the next integer.

3.8.3 Aerated Tank National Data

Noncorrelated tank variables included in the national data tables for the HWIR modeling system are described below.

3.8.3.1 <u>Biologically Active Solids/Total Solids Ratio (kba1)</u>. Values for the ratio of biologically active solids to total solids were assumed to be uniformly distributed between 0.7 and 0.9. The range is based on data from Tchobanoglous (1979).

3.8.3.2 <u>Biomass Yield (bio_yield)</u>. Values for biomass yield are assumed to vary uniformly from 0.4 to 0.8 g/g. This is based on a range of 0.4 to 0.8 mg VSS/mg BOD_5 reported by Tchobanoglous (1979).

3.8.3.3 <u>Digestion (k_dec)</u>. Values for digestion of sediments are assumed to vary uniformly from 4.6×10^{-7} to 8.7×10^{-7}, based on data from Tchobanoglous (1979).

3.8.3.4 <u>Economic Life of AT (EconLife)</u>. The economic life of an aerated tank is assumed to be 20 yr.

3.8.3.5 <u>Fraction of Tank Occupied by Sediments (d_setpt)</u>. The maximum fraction of the tank occupied by sediments is set equal to 0.3.

3.8.3.6 <u>Impeller Diameter (d_imp)</u>. The impeller diameter was assumed to have a fixed value of 61 cm, based on U.S. EPA (1990).

3.8.3.7 <u>Impeller Speed (w_imp)</u>. The value for impeller speed was assumed to be fixed at 126 rad/s. This is based on data from U.S. EPA (1990).

3.8.3.8 <u>Number of Economic Lifetimes (NumEcon)</u>. The number of economic lifetimes for an aerated tank is fixed at 2.5. Combined with an EconLife value of 20 yr, this places a tank at each facility with a surface impoundment for the assumed lifetime of the surface impoundment (50 yr).

3.8.3.9 <u>Oxygen Transfer Correction Factor (O2eff)</u>. The value for the oxygen transfer factor was fixed at 0.83, based on data from Tchobanoglous (1979).

3.8.3.10 <u>Oxygen Transfer Factor (J)</u>. Values for the oxygen transfer factor were assumed to be fixed at 3.0 lb O_2/hp h. This is the median of the recommended range of 2.0 and 4.0 lb O_2/hp h based on data from Tchobanoglous (1979).

3.9 Quality Assurance/Quality Control

For the Industrial D data collection effort, manual calculations or data entry were checked 100 percent against their original references. Automated data extraction (or data processing) was checked for accuracy by checking approximately 10 percent of the values. Checks were conducted across WMU types to ensure that calculations in the database were correct.

Quality Assurance/quality control (QA/QC) of national data collection was based on a combination of internal and external review checks and collection of data from multiple sources for each parameter of interest. As described in Section 3.2.3, data for design parameters were generally sought from multiple sources. This helped to ensure that the data collected were representative of standard industry practice. When no standard industry practice existed and parameter values were found to be highly variable, using multiple data sources aided the characterization of parameter variability, which then became a consideration in the model unit designs.

Quality of the data sources was reviewed, and all data elements were entered into a database along with an indicator of the data source and the general estimated quality. Data quality was ranked as follows:

- In general, more recent literature sources were considered of higher quality than older sources.
- Standard reference texts were generally considered of higher quality than information collected by telephone or from the Internet.
- Engineering calculations were considered of lower quality than data from the literature.
- Engineering judgment was considered the lowest quality source.

Internal reviews consisted of senior engineering reviews of individual parameter values for realism and reviews of overall model system designs to ensure that parameter estimates within the model were internally consistent. For example, for an aerated tank, impeller parameter estimates, aerator requirements, flow rates, and biomass yield data should be consistent for a given facility design. External reviews of model facility designs and parameter estimates were also conducted to ensure that these were representative of typical industry practices.

Quality assurance was conducted to ensure that an adequate QC methodology was in place and correctly implemented and recorded. QA/QC records for WMU data processing can be provided on request.

3.10 Issues and Uncertainties

3.10.1 Age/Accuracy of Industrial D Data

For the nationally collected data, one issue of concern was the availability of recent data on actual Industrial D units (the Ind D data is more than 10 years old). Although significant data can be found on Subtitle C waste management units (e.g., permit records, design requirements), recent Ind D data are not compiled or readily available. In spite of its age, the Industrial D Screening Survey represents the largest consistent set of data available on facility locations and WMU dimensions. The 201-facility sample was selected from the survey to represent the types and geographical locations of WMUs at which exempt waste could be disposed. At some of the 201 facilities, there probably have been WMU additions or closures since the survey was conducted. We consider this approach of basing the assessment on actual WMU, land use, and population data, however, to be preferable to developing and evaluating hypothetical exposure scenarios.

Another issue that was identified during use of the Ind D data were whether to revisit the methodology used to screen out questionable entries in the Ind D database. For consistency, it was decided to use the methodology from previous EPACMTP modeling efforts, as described in U.S. EPA (1997).

3.10.2 Under Representation of Highly Aerated Tanks

The tank database does appear to under represent highly aerated tanks. This is probably due to a disproportionate number of aerated biological treatment systems being operated at facilities that only process on-site waste. This under representation introduces some uncertainty into the analysis, the result of which is that risks from highly aerated tanks may be underestimated.

3.11 References

Adams, C. E. and W. W. J. Eckenfelder (eds.). 1974. *Process Design Techniques for Industrial Waste Treatment.* Enviro Press, Inc., Nashville, TN.

Allswede, Sharon. 1999. "1986 Survey Corrections." Memorandum to Mark A. Bahner (Research Triangle Institute) from Sharon Allswede (Dow North America Michigan Environmental Operations), Midland, MI. March 25.

Bagchi, Amalendu. 1990. *Design, Construction, & Monitoring of Sanitary Landfill.* John Wiley & Sons, Inc., New York, NY.

Carsel, R. F., and R. S. Parrish. 1988. Developing joint probability distributions of soil water retention characteristics. *Water Resources Research,* 24(5):755-769. May.

Caterpillar, Inc. 1994. *Caterpillar Performance Handbook.* Caterpillar Inc., Peoria, IL. pp. 9-2.

Clapp, R. B., and G. M. Hornberger. 1978. Empirical equations for some soil hydraulic properties. *Water Resources Research,* 14:601-604.

Clickner, Robert. 1988. "Sampling weights for the industrial Subtitle D screening survey." Memorandum to Zubair Saleem (U.S. Environmental Protection Agency) from Robert Clickner (Westat, Inc.), Rockville, MD. July 28.

Clickner, Robert P., and Jim Craig. n.d. Using Business Establishment Size in an Environmental Survey (Unpublished).

Environmental Research & Technology (ER&T), Inc. 1983. *Land Treatment Practices in the Petroleum Industry*. The American Petroleum Institute. Environmental Research & Technology, Inc., Concord, MA. June.

Goldberg, Elliot (ed.). 1997. *Handbook of Downstream Processing.* 1st Edition. Chapman & Hall, London, UK.

Hartley, Robert P. 1992. *Surface Impoundments: Design, Construction and Operation.* Noyes Data Corporation, Park Ridge, NJ.

Martin, J. P., Ronald C. Sims, and John Matthews. 1986. Review and evaluation of current design and management practices for land treatment units receiving petroleum wastes. *Hazardous Waste & Hazardous Materials,* 3(3):261-280.

McBean, Edward A., Frank A. Rovers, and Grahame J. Farquhar . 1995. *Solid Waste Landfill Engineering and Design.* Prentice Hall PTR, Englewood Cliffs, NJ.

Midwest Research Institute (MRI). 1990. *Special Management Standards for Municipal Waste Combustion (MWC) Ash*. U.S. Environmental Protection Agency, Municipal Solid Waste Porgram. Midwest Research Institute, Falls Church, VA. June 29.

Miller, D. A., and R. A. White. 1998. *A Conterminous United States Multilayer Soil Characteristics Dataset for Regional Climate and Hydrology Modeling*. Website at http://www.essc.psu.edu/soil_info/index.cgi?soil_data&index.html.

Overcash, M. R., and D. Pal . 1979. *Design of Land Treatment Systems for Industrial Wastes - Theory and Practice.* Ann Arbor Science Publishers, Inc., Ann Arbor, MI. pp. 509-512.

Pekar, Zachary. 1999. "Personal Communication with Kendall Smith, Liquid Sales Manager for AO Smith Industrial." Information on the size and volume of large above-ground treatment/storage tanks. Memorandum from Zachary Pekar (Research Triangle Institute), Research Triangle Park, NC. March 16.

Reed, Sherwood C., and Ronald W. Crites. 1984. *Handbook of Land Treatment Systems for Industrial and Municipal Wastes.* Noyes Publications, Park Ridge, NJ. 219.

Reynolds, Tom D., and Paul A. Richards. 1996. *Unit Operations and Processes in Environmental Engineering.* 2nd Edition. PWS Publishing Company, Boston, MA.

Schwarz, G. E. and R. B. Alexander. 1995. *State Soil Geographic (STATSGO) Data Base for the Conterminous United States. Edition 1.1.* Open-File Report 95-449. U.S. Geological Survey, Reston, VA. Website at http://water.usgs.gov/GIS/metadata/usgswrd/ussoils.html. September 1.

Seaber, P. R., F. P. Kapinos, and G. L. Knapp. 1987. *Hydrologic Unit Maps*. U.S. Geological Survey Water-Supply Paper 2294. U.S. Government Printing Office, Washington, DC. pp. 1-13.

Tchobanoglous, George . Cerra, Frank J. and J. W. Maisel (eds.). 1979. *Wastewater Engineering: Treatment, Disposal, Reuse.* 2nd Edition. McGraw-Hill Book Company, New York, NY.

Tchobanoglous, George, Hilary Theisen, and Samuel Vigil. 1993. Integrated solid waste management: engineering principles and management issues. In: *McGraw-Hill Series in Water Resources and Environmental Engineering*. P.H.King and R.Eliassen (eds.). McGraw-Hill, Inc., New York, NY.

Treybal, Robert E. 1980. Mass-transfer operations. In: *McGraw-Hill Chemical Engineering Series*. J.J.Carberry, J.R.Fair, M.S.Peters, W.R.Schowalter, and J.Wei (eds.). 3rd Edition. McGraw-Hill, Inc., New York, NY.

U.S. EPA (Environmental Protection Agency). 1983. *Hazardous Waste Land Treatment.* EPA/530/SW-83/874. U.S. Environmental Protection Agency, Office of Research and Development, Cincinnati, OH. April.

U.S. EPA (Environmental Protection Agency). 1984. *Evaluation and Selection of Models for Estimating Air Emssions from Hazardous Waste Treatment, Storage, and Disposal Facilities.* EPA/450/3-84-020. U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, NC. December.

U.S. EPA(Environmental Protection Agency). 1987. 1986 National Survey of Hazardous Waste Treatment, Storage, Disposal, and Recycling Facilities (TSDR) Database. U.S. Environmental Protection Agency, Office of Solid Waste, Washington, DC.

U.S. EPA (Environmental Protection Agency). 1989. *Hazardous Waste TSDF (Treatment, Storage, and Disposal Facilities). Fugitive Particulate Matter Air Emissions Guidance Document.* EPA/450/3-89/019. U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, NC. May.

U.S. EPA (Environmental Protection Agency). 1990. *Background Document for the Surface Impoundment Modeling System (SIMS) Version 2.0.* EPA-450/4-90-019b. U.S. Environmental Protection Agency, Emission Standards Division, Office of Air Quality Planning and Standards, Research Triangle Park, NC. September.

U.S. EPA (Environmental Protection Agency). 1991. *Design, construction, and operation of hazardous and non-hazardous waste surface impoundments.* EPA/530/SW-91/054. U.S. Environmental Protection Agency, Risk Reduction Engineering Laboratory, Waste Minimization, Destruction, and Disposal Research Division, Cincinnati, OH. June.

U.S. EPA (Environmental Protection Agency). 1991. *Hazardous Waste TSDF - Background Information for Proposed RCRA Air Emission Standards. Volume 1, Chapters 1-8 and Appendices A-C.* (Draft EIS). EPA-450/3-89-023a. U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, NC. June.

U.S. EPA (Environmental Protection Agency). 1994. *1:250,000 Scale Quadrangles of Landuse/Landcover GIRAS Spatial Data in the Conterminous United States: Metadata.* Office of Information Resources Management, Washington, DC. Website at http://www.epa.gov/ngispgm3/nsdi/projects/giras.htm.

U.S. EPA (Environmental Protection Agency). 1996a. *Soil Screening Guidance Technical Background Document.* EPA/540/R/95/128. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Washington, DC. May.

U.S. EPA (Environmental Protection Agency). 1996b. *Technical Support Document for the Round Two Sewage Sludge Pollutants.* EPA-822-R-96-003. U.S. Environmental Protection Agency, Office of Water, Washington, DC. August.

U.S. EPA (Environmental Protection Agency). 1997. *EPA's Composite Model for Leachate Migration with Transformation Products. EPACMTP: User's Guide*. U.S. Environmental Protection Agency, Office of Solid Waste, Washington, DC.

USDA (Department of Agriculture). 1986. *Urban Hydrology for Small Watersheds.* TR-55. U.S. Department of Agriculture, Engineering Division, Soil Conservation Service, Washington, DC. pp. 2-5. June.

USDA (Department of Agriculture). 1994. *State Soil Geographic (STATSGO) Data Base. Data use information.* Miscellaneous Publication Number 1492. U.S. Department of Agriculture, Natural Resources Conservation Service, Fort Worth, TX. December.

Wanielista, M. P., and Y. A. Yousef. 1993. *Stormwater Management.* John Wiley & Sons, Inc., New York, NY. pp. 399-410.

Westat, Inc. 1987. *Screening Survey of Industrial Subtitle D Establishments. Draft Final Report.* U.S. Environmental Protection Agency. Westat, Inc., Rockville, MD. December 29.

WPCF, and ASCE. 1988. *Aeration, A Wastewater Treatment Process. Manual of Practice - No.FD-13.* Water Pollution Control Federation, Alexandria, VA.

Appendix 3A

WMU Data

Appendix 3A. WMU Data from the Industrial D Screening Survey

	Landfill Industrial D Data								Landfill Calculated FRAMES Inputs								
Idnum	Total LF	Depth (m) SrcDepth	Average surface area (acres)	Average surface area (m^2) SrcArea	Average capacity (Mg)	Capacity replaced ?	Average remaining capacity (Mg)	Average waste quantity (Mg)	Vehicles per day (1/d) nv	Vehicle weight (Mg) vw	Wheels per vehicle nw	Distance vehicle travels on LF (m) mt	Frequency of surface disturbance per month (1/mo) fd	Spreading/ compacting operations per day (1/d) Nop	Waste loading rate (dry, Mg/y) load	Waste zone thick-ness (m) zW	No. waste layers in a cell Nly
Count	56	56	56	56	56	24	52	56	56	56	56	56	56	56	56	56	56
Average	1.304	2.761071	27.1024	109683.5	405306		1.924E+09	192599.1	1.37139	25.625	6.5	248.2515	21.9339837	0.73113279	13510.2	2.7611	2.9821
Minimum	1	0.63	0.03	121.41	90.7		0.005	0.005	0.000552	22.5	6	11.01862	0.01655487	0.00055183	3.02333	0.63	1
Maximum	4	7.68	293	1185771	3746855		1E+11	9353232	9.769838	47.5	10	1088.931	60	2	124895	7.68	8
0114001																	
0130207																	
0131104																	
0131207																	
0131508	1	7.68	110	445170	3746855		2412037.9	140507.1	9.769838	47.5	10	667.2106	60	2	124895	7.68	8
0136703																	
0220102																	
0221207																	
0223504	1	4.42	0.5	2023.5	9797.8		8164.8	136.1	0.059611	22.5	6	44.98333	1.78832763	0.05961092	326.593	4.42	4
0224002																	
0231002	1	0.84	3.3	13355.1	12247.2		4536	1020.6	0.074513	22.5	6	115.5643	2.23540041	0.07451335	408.24	0.84	1
0231106	1	0.87	15	60705	58060.8		14515.2	3011.9	0.353248	22.5	6	246.3838	10.5974538	0.35324846	1935.36	0.87	1
0231407	1	1.93	7.1	28733.7	60782.4		1360.8	14515.2	0.369807	22.5	6	169.5102	11.0942094	0.36980698	2026.08	1.93	2
0231610																	
0231911																	
0231914																	
0232305																	
0232313	3	4.09	33.3333	134900	604800		604800	5911.8	3.679671	22.5	6	367.2874	60	2	20160	4.09	4
0232402	1	0.76	11.3	45731.1	38138.1	yes	330946	16547.3	0.232036	22.5	6	213.8483	6.96109037	0.23203635	1271.27	0.76	1
0232415																	
0232501	1	1.25	0.8	3237.6	4417.1	yes	15603.8	0.005	0.026874	22.5	6	56.89991	0.80622353	0.02687412	147.237	1.25	2
0232705																	
0233601																	
0233603	1	0.83	2	8094	7395.74	yes		13608	0.044997	22.5	6	89.96666	1.34989562	0.04499652	246.525	0.83	1
0234904	1	3.07	4	16188	54432		18144	9072	0.33117	22.5	6	127.2321	9.93511294	0.33117043	1814.4	3.07	3
0235301	1	6.07	100	404700	2691120	yes	12700.8	1262.8	7.017034	47.5	10	636.1604	60	2	89704	6.07	6
0312301																	
0314202	1	5.54	0.2	809.4	4912.15	yes	7.3	1.5	0.029886	22.5	6	28.44996	0.8965815	0.02988605	163.738	5.54	6
0321802																	
0331006																	
0331902																	
0332104																	
0332707	1	5.37	5	20235	119077	yes	181.4	13.6	0.724478	22.5	6	142.2498	21.7343541	0.72447847	3969.24	5.37	5
0332811																	
0430108																	
0430412	1	5.25	5	20235	116425	yes	362.9	72.6	0.708343	22.5	6	142.2498	21.2502764	0.70834255	3880.83	5.25	5
0431912	1	5.66	137	554439	3441593	yes	6054652.8	9353232	8.973873	47.5	10	744.6066	60	2	114720	5.66	6
0432011	1	2.25	2	8094	19952.2	yes		108.9	0.121392	22.5	6	89.96666	3.64175123	0.12139171	665.075	2.25	2
0432106																	
0432716																	
0433201	1	2.86	3.61	14609.67	45771.4	yes	5151925.7	175633.8	0.278478	22.5	6	120.8705	8.3543545	0.27847848	1525.71	2.86	3
0433204																	
0433404	2	5.11	13.5	54634.5	305726		109589.75	161028	1.860074	22.5	6	233.7402	55.8022177	1.86007392	10190.9	5.11	5
0433408																	
0434505																	
0434804																	
0435510																	

(continued)

Appendix 3A. (continued)

	Landfill Industrial D Data								Landfill Calculated FRAMES Inputs								
Idnum	Total LF	Depth (m)	Average surface area (acres)	Average surface area (m^2)	Average capacity (Mg)	Capacity replaced ?	Average remaining capacity (Mg)	Average waste quantity (Mg)	Vehicles per day (1/d)	Vehicle weight (Mg)	Wheels per vehicle	Distance vehicle travels on LF (m)	Frequency of surface disturbance per month (1/mo)	Spreading/ compacting operations per day (1/d)	Waste loading rate (dry, Mg/y)	Waste zone thick-ness (m)	No. waste layers in a cell
		SrcDepth		SrcArea					nv	vw	nw	mt	fd	Nop	load	zW	Nly
0436007																	
0436108																	
0530901																	
0531301																	
0531502																	
0531702	2	1.39	22	89034	136080		13608	798.35	0.827926	22.5	6	298.3857	24.8377823	0.82792608	4536	1.39	2
0531902																	
0534504																	
0613402																	
0620401																	
0620604																	
0621603																	
0621902																	
0622902																	
0625002	1	3.57	0.34	1375.98	5376		4032	299.4	0.032708	22.5	6	37.0942	0.98124572	0.03270819	179.2	3.57	4
0625501																	
0631701																	
0631903	1	1.31	20	80940	116122		79833.6	36.3	0.706497	22.5	6	284.4996	21.1949076	0.70649692	3870.72	1.31	2
0632003	1	1.14	3.4	13759.8	17236.8		3991.7	5806.1	0.104871	22.5	6	117.3022	3.1461191	0.10487064	574.56	1.14	2
0632606	3	0.63	22.9567	92905.63	63789.4	yes	5685.1333	5140.8	0.388102	22.5	6	304.8042	11.6430565	0.38810188	2126.31	0.63	1
0632608	1	1.06	9.99	40429.53	46771.2		44768.6	10.9	0.284561	22.5	6	201.071	8.53683778	0.28456126	1559.04	1.06	2
0634001																	
0635301																	
0713618																	
0713705	2	3.57	5	20235	79059.2	yes	3628800	2903.05	0.481005	22.5	6	142.2498	14.430153	0.4810051	2635.31	3.57	4
0715007																	
0715216																	
0716701																	
0720506																	
0720803	1	1.02	3	12141	13592	yes	1E+11	22.7	0.082695	22.5	6	110.1862	2.48085559	0.08269519	453.066	1.02	2
0721305																	
0722107																	
0722503																	
0722505																	
0722705	1	2.6	0.07	283.29	806.4		645.1	121	0.004906	22.5	6	16.83122	0.14718686	0.00490623	26.88	2.6	3
0723607																	
0724206																	
0724301																	
0724804																	
0724909																	
0730407	1	1.53	2.87	11614.89	19438	yes	272.2	272.2	0.118263	22.5	6	107.7724	3.54788617	0.11826287	647.933	1.53	2
0730502																	
0730914	1	3.27	2	8094	29030.4		20680	206.8	0.176624	22.5	6	89.96666	5.2987269	0.17662423	967.68	3.27	3
0731111																	
0731405																	
0731411																	
0731412																	
0731501																	
0731507																	
0731514	1	3.78	65	263055	1088640		290304	14515.2	2.838604	47.5	10	512.8889	60	2	36288	3.78	4
0731703	1	3.01	0.34	1375.98	4536		1360.8	90.7	0.027598	22.5	6	37.0942	0.82792608	0.02759754	151.2	3.01	3
0732110	1	7.07	4.5	18211.5	141120		63806.3	3774	0.858588	22.5	6	134.95	25.7576454	0.85858818	4703.99	7.07	7

(continued)

Appendix 3A. (continued)

	Landfill Industrial D Data								Landfill Calculated FRAMES Inputs								
Idnum	Total LF	Depth (m)	Average surface area (acres)	Average surface area (m^2)	Average capacity (Mg)	Capacity replaced ?	Average remaining capacity (Mg)	Average waste quantity (Mg)	Vehicles per day (1/d)	Vehicle weight (Mg)	Wheels per vehicle	Distance vehicle travels on LF (m)	Frequency of surface disturbance per month (1/mo)	Spreading/ compacting operations per day (1/d)	Waste loading rate (dry, Mg/y)	Waste zone thick-ness (m)	No. waste layers in a cell
		SrcDepth		SrcArea					nv	vw	nw	mt	fd	Nop	load	zW	Nly
0732405																	
0732510																	
0733203																	
0733210	1	2.61	3	12141	34746.2	yes	725760	7257.6	0.2114	22.5	6	110.1862	6.34199423	0.21139981	1158.21	2.61	3
0733302																	
0733404	1	5.59	5.7	23067.9	141349	yes	1003	0.005	0.859982	22.5	6	151.8812	25.7994673	0.85998224	4711.63	5.59	6
0733501																	
0733606																	
0734604																	
0735309	3	2.28	6.66667	26980	67374.7		30119.033	1372.9	0.409915	22.5	6	164.2559	12.2974644	0.40991548	2245.82	2.28	2
0826707																	
0830601	2	2.89	10	40470	128097		47900.15	13608	0.779354	22.5	6	201.1716	23.3806343	0.77935448	4269.89	2.89	3
0830903	1	0.84	45	182115	166925		161844.5	5080.3	1.015589	22.5	6	426.7493	30.4676797	1.01558932	5564.16	0.84	1
0831102																	
0831406	2	1.32	36	145692	210833		141341.75	25054.15	1.282734	22.5	6	381.6962	38.4820078	1.28273359	7027.78	1.32	2
0831904	1	6.14	40	161880	1088640		997920	54432	2.838604	47.5	10	402.3431	60	2	36288	6.14	6
0832304	1	2.61	293	1185771	3396194		2358720	504907.6	8.855497	47.5	10	1088.931	60	2	113206	2.61	3
0832510																	
0832903																	
0832904																	
0832909																	
0833001	2	2.73	180	728460	2177280		1415232	108864	5.677207	47.5	10	853.4987	60	2	72576	2.73	3
0833007	1	0.82	50	202350	181440		105235.2	3810.2	1.103901	22.5	6	449.8333	33.1170431	1.10390144	6048	0.82	1
0834009																	
0923004																	
0930205																	
0930301	1	2.57	2.8	11331.6	31933.4		17563.4	544.3	0.194286	22.5	6	106.45	5.82859229	0.19428641	1064.45	2.57	3
0930702	4	5.87	23.875	96622.125	621254	yes		6804	3.779779	22.5	6	310.841	60	2	20708.5	5.87	6
0932103	1	1.73	4	16188	30767.9	yes	725.8	181.4	0.187195	22.5	6	127.2321	5.61585527	0.18719518	1025.6	1.73	2
0932507																	
0932509	2	1.31	20.405	82579.035	118846	yes	1197504	96163.2	0.723075	22.5	6	287.3657	21.6922596	0.72307532	3961.55	1.31	2
0932903	1	0.91	75	303525	301553		284135	12236	1.834684	22.5	6	550.931	55.0405293	1.83468431	10051.8	0.91	1
0933704																	
1010805																	
1012203	1	2.41	0.5	2023.5	5342.31	yes	326.6	27.2	0.032503	22.5	6	44.98333	0.97509591	0.0325032	178.077	2.41	2
1013209																	
1014805	1	0.67	30	121410	89795.8	yes	0.005	18.1	0.546328	22.5	6	348.4394	16.3898279	0.5463276	2993.19	0.67	1
1015510	1	0.68	0.03	121.41	90.7		68	9.1	0.000552	22.5	6	11.01862	0.01655487	0.00055183	3.02333	0.68	1
1023705																	
1031503																	
1031507																	
1032715																	
1032802	1	0.8	16	64752	56609.3		37739.5	3774	0.344417	22.5	6	254.4641	10.3325211	0.34441737	1886.98	0.8	1
1033107																	
1033114																	
1033202																	
1033602																	
1034005																	
1034210																	
1034406																	
1034805																	

(continued)

Appendix 3A. (continued)

	Landfill Industrial D Data								Landfill Calculated FRAMES Inputs									
Idnum	Total LF	Depth (m)	Average surface area (acres)	Average surface area (m^2)	Average capacity (Mg)	Capacity replaced ?	Average remaining capacity (Mg)	Average waste quantity (Mg)	Vehicles per day (1/d)	Vehicle weight (Mg)	Wheels per vehicle	Distance vehicle travels on LF (m)	Frequency of surface disturbance per month (1/mo)	Spreading/ compacting operations per day (1/d)	Waste loading rate (dry, Mg/y)	Waste zone thick-ness (m)	No. waste layers in a cell
		SrcDepth		SrcArea					nv	vw	nw	mt	fd	Nop	load	zW	Nly
1035117																	
1035405																	
1035508																	
1120904																	
1122705																	
1131103																	
1131802																	
1133902																	
1134405																	
1212301																	
1221704																	
1223404																	
1230111																	
1230206																	
1230517																	
1230919																	
1231101																	
1231705																	
1233101																	
1235205																	
1236637																	
1236652																	
1236732																	
1236810																	
1236820																	
1331103																	
1333001																	
1333701																	
1415407																	
1421506																	
1430107	2	2.67	33.65	136181.55	398463	yes	20412	2721.6	2.424291	22.5	6	369.0278	60	2	13282.1	2.67	3
1430404																	
1430602																	
1431515																	
1434022																	
1434802																	
1435317	1	2.02	7.5	30352.5	67199.9		47040	1633	0.408852	22.5	6	174.2197	12.2655533	0.40885178	2240	2.02	2
1522504																	
1530605	1	4.29	13	52611	247399	yes	1814.4	2721.6	1.505206	22.5	6	229.3709	45.1561906	1.50520635	8246.65	4.29	4
1530808																	
1532401																	
1621808																	
1630106	1	1.24	4.5	18211.5	24677.7		16554.9	4644.9	0.150142	22.5	6	134.95	4.50425736	0.15014191	822.59	1.24	2
1630401																	
1631701																	
1632106																	
1632703	1	0.82	2	8094	7242.79	yes		4.5	0.044066	22.5	6	89.96666	1.3219792	0.04406597	241.426	0.82	1
1633404																	
1633405																	
1635404																	
1721603																	

Appendix 3A. (continued)

	Waste Pile Industrial D Data					Waste Pile Calculated FRAMES Inputs						
Idnum	Total WP	Average surface area (acres)	Average surface area (m^2)	Average waste quantity (Mg)	Waste quantity replaced?	Height of waste pile above grade (m)	Distance vehicle travels on WP (m)	Vehicles per day (1/d)	Vehicle weight (Mg)	Wheels per vehicle	Spreading/ compacting operations per day (1/d)	Waste loading rate (dry, Mg/y)
			SrcArea			zZ1WMU	mt	nv	vw	nw	Nop	load
Count	61	61	61	61	34	61	61	61	61	61	61	61
Average	1.672	2.8814344	11661.17	17980.848		1.8032787	52.01723	1.759575	34.59016	6.52459	0.774448173	17980.848
Minimum	1	0.0016667	6.745	7.5666667		1	2.597114	0.001381	30	6	0.001381094	7.5666667
Maximum	20	75	303525	295634.8		10	550.931	23.12583	65	10	2	295634.8
0114001	2	0.025	101.175	4131.5737	yes	6	10.05858	0.754109	30	6	0.754108817	4131.5737
0130207	1	0.11	445.17	11249.3		4	21.09905	2.05326	30	6	2	11249.3
0131104												
0131207												
0131508	1	0.08	323.76	4536		2	17.99333	0.827926	30	6	0.827926078	4536
0136703												
0220102	1	1.2	4856.4	2449.4		1	69.68788	0.447073	30	6	0.447072781	2449.4
0221207	1	0.005	20.235	453.6		4	4.498333	0.082793	30	6	0.082792608	453.6
0223504	1	6.5	26305.5	43091.72	yes	1	162.1897	3.37082	65	10	2	43091.72
0224002	1	0.04	161.88	128.4		1	12.72321	0.023436	30	6	0.023436003	128.4
0231002												
0231106												
0231407												
0231610												
0231911	3	5.3333333	21584	60480		1	146.9149	4.731006	65	10	2	60480
0231914												
0232305	1	0.52	2104.44	17611.619	yes	1	45.87418	3.214532	30	6	2	17611.619
0232313	1	1.55	6272.85	4195.1789	yes	1	79.20133	0.765718	30	6	0.765718265	4195.1789
0232402												
0232415	1	0.06	242.82	81648		10	15.58268	6.386858	65	10	2	81648
0232501	1	0.16	647.52	275.29268	yes	1	25.44641	0.050247	30	6	0.050247353	275.29268
0232705												
0233601												
0233603												
0234904												
0235301												
0312301												
0314202												
0321802	1	1.38	5584.86	27779.166	yes	1	74.73192	5.070347	30	6	2	27779.166
0331006												
0331902	1	0.45	1821.15	37776.6	yes	4	42.67493	2.955048	65	10	2	37776.6
0332104	3	0.23	930.81	5517.2631	yes	1	30.50918	1.00703	30	6	1.007029535	5517.2631
0332707	2	75	303525	158760		1	550.931	12.41889	65	10	2	158760
0332811	1	0.005	20.235	107		1	4.498333	0.01953	30	6	0.019530002	107
0430108	1	0.21	849.87	1002.6722	yes	1	29.15253	0.183011	30	6	0.18301113	1002.6722
0430412												
0431912												
0432011												
0432106												
0432716												
0433201												
0433204												
0433404												
0433408												
0434505												
0434804												
0435510												

(continued)

Appendix 3A. (continued)

	Waste Pile Industrial D Data					Waste Pile Calculated FRAMES Inputs						
Idnum	Total WP	Average surface area (acres)	Average surface area (m^2)	Average waste quantity (Mg)	Waste quantity replaced?	Height of waste pile above grade (m)	Distance vehicle travels on WP (m)	Vehicles per day (1/d)	Vehicle weight (Mg)	Wheels per vehicle	Spreading/ compacting operations per day (1/d)	Waste loading rate (dry, Mg/y)
			SrcArea			zZ1WMU	mt	nv	vw	nw	Nop	load
0436007												
0436108												
0530901												
0531301												
0531502												
0531702												
0531902												
0534504												
0613402												
0620401												
0620604												
0621603												
0621902												
0622902												
0625002												
0625501												
0631701												
0631903												
0632003												
0632606												
0632608												
0634001												
0635301												
0713618												
0713705												
0715007	1	0.5	2023.5	896.64784	yes	1	44.98333	0.163659	30	6	0.163659199	896.64784
0715216	1	0.005	20.235	45.224774	yes	1	4.498333	0.008255	30	6	0.008254579	45.224774
0716701												
0720506	1	0.1	404.7	3818.4122	yes	1	20.11716	0.69695	30	6	0.696949522	3818.4122
0720803												
0721305	1	0.17	687.99	4536		1	26.22956	0.827926	30	6	0.827926078	4536
0722107	1	0.06	242.82	1097.1236	yes	1	15.58268	0.200251	30	6	0.200250719	1097.1236
0722503												
0722505												
0722705												
0723607												
0724206	1	2	8094	2721.6		1	89.96666	0.496756	30	6	0.496755647	2721.6
0724301	1	0.01	40.47	1088.6		4	6.361604	0.198695	30	6	0.198694958	1088.6
0724804	1	0.005	20.235	121.72405	yes	1	4.498333	0.022217	30	6	0.022217486	121.72405
0724909	1	0.02	80.94	53.844793	yes	1	8.996666	0.009828	30	6	0.009827934	53.844793
0730407												
0730502	2	0.61	2468.67	9986.9261	yes	1	49.68571	1.822848	30	6	1.822847561	9986.9261
0730914	6	0.0133333	53.96	756		2	7.345747	0.137988	30	6	0.13798768	756
0731111												
0731405												
0731411	1	0.01	40.47	499		2	6.361604	0.091079	30	6	0.09107917	499
0731412	1	3	12141	17563.757	yes	1	110.1862	3.205796	30	6	2	17563.757
0731501												
0731507	20	0.12	485.64	1723.68		1	22.03724	0.314612	30	6	0.31461191	1723.68
0731514												
0731703												
0732110												
0732405	1	0.01	40.47	1134		4	6.361604	0.206982	30	6	0.20698152	1134

(continued)

Appendix 3A. (continued)

	Waste Pile Industrial D Data					Waste Pile Calculated FRAMES Inputs						
Idnum	Total WP	Average surface area (acres)	Average surface area (m^2)	Average waste quantity (Mg)	Waste quantity replaced?	Height of waste pile above grade (m)	Distance vehicle travels on WP (m)	Vehicles per day (1/d)	Vehicle weight (Mg)	Wheels per vehicle	Spreading/ compacting operations per day (1/d)	Waste loading rate (dry, Mg/y)
			SrcArea			zZ1WMU	mt	nv	vw	nw	Nop	load
0732510	1	0.37	1497.39	2721.6		1	38.69612	0.496756	30	6	0.496755647	2721.6
0733203												
0733210												
0733302	1	0.09	364.23	3601.5029	yes	1	19.08481	0.657359	30	6	0.657358509	3601.5029
0733404	1	0.09	364.23	8250.5666	yes	4	19.08481	1.505921	30	6	1.505921345	8250.5666
0733501												
0733606	1	50	202350	131785.43	yes	1	449.8333	10.30882	65	10	2	131785.43
0734604	2	0.0025	10.1175	18.15		1	3.180802	0.003313	30	6	0.003312799	18.15
0735309												
0826707												
0830601												
0830903												
0831102	1	4	16188	15895.451	yes	1	127.2321	2.901292	30	6	2	15895.451
0831406												
0831904												
0832304	1	0.12	485.64	81179.9		10	22.03724	6.350242	65	10	2	81179.9
0832510	1	0.01	40.47	1360.8		4	6.361604	0.248378	30	6	0.248377823	1360.8
0832903	3	16.666667	67450	295634.8	yes	1	259.7114	23.12583	65	10	2	295634.8
0832904												
0832909												
0833001												
0833007												
0834009												
0923004	1	0.005	20.235	156.81096	yes	1	4.498333	0.028622	30	6	0.028621667	156.81096
0930205	1	0.2	809.4	10345.857	yes	2	28.44996	1.888361	30	6	1.888360806	10345.857
0930301	1	0.25	1011.75	3175.2		1	31.80802	0.579548	30	6	0.579548255	3175.2
0930702												
0932103	1	2.07	8377.29	9771.1888	yes	1	91.52754	1.78347	30	6	1.783470468	9771.1888
0932507	1	0.25	1011.75	323.39869	yes	1	31.80802	0.059028	30	6	0.059027823	323.39869
0932509	1	0.57	2306.79	9072		1	48.02905	1.655852	30	6	1.655852156	9072
0932903												
0933704												
1010805												
1012203	1	0.5	2023.5	10780.078	yes	1	44.98333	1.967616	30	6	1.967616345	10780.078
1013209												
1014805												
1015510												
1023705												
1031503												
1031507												
1032715												
1032802												
1033107												
1033114												
1033202												
1033602												
1034005	1	0.4	1618.8	2498.3318	yes	1	40.23431	0.456004	30	6	0.456003978	2498.3318
1034210												
1034406												
1034805												
1035117												
1035405												
1035508												

(continued)

Appendix 3A. (continued)

	Waste Pile Industrial D Data					Waste Pile Calculated FRAMES Inputs						
Idnum	**Total WP**	**Average surface area (acres)**	**Average surface area (m^2)**	**Average waste quantity (Mg)**	**Waste quantity replaced?**	**Height of waste pile above grade (m)**	**Distance vehicle travels on WP (m)**	**Vehicles per day (1/d)**	**Vehicle weight (Mg)**	**Wheels per vehicle**	**Spreading/ compacting operations per day (1/d)**	**Waste loading rate (dry, Mg/y)**
			SrcArea			**zZ1WMU**	**mt**	**nv**	**vw**	**nw**	**Nop**	**load**
1120904												
1122705												
1131103												
1131802												
1133902												
1134405												
1212301												
1221704	1	0.18	728.46	811.64744	yes	1	26.99	0.148145	30	6	0.14814464	811.64744
1223404												
1230111												
1230206												
1230517												
1230919	1	0.04	161.88	231.22105	yes	1	12.72321	0.042203	30	6	0.042203248	231.22105
1231101												
1231705												
1233101												
1235205	1	0.23	930.81	907.2		1	30.50918	0.165585	30	6	0.165585216	907.2
1236637												
1236652												
1236732	1	0.005	20.235	49.9		1	4.498333	0.009108	30	6	0.009107917	49.9
1236810	3	0.0016667	6.745	7.5666667		1	2.597114	0.001381	30	6	0.001381094	7.5666667
1236820												
1331103												
1333001												
1333701	4	0.0125	50.5875	528.72744	yes	2	7.112489	0.096505	30	6	0.096505122	528.72744
1415407	1	0.005	20.235	13.346777	yes	1	4.498333	0.002436	30	6	0.002436099	13.346777
1421506	2	0.115	465.405	276.7		1	21.57325	0.050504	30	6	0.050504221	276.7
1430107												
1430404												
1430602												
1431515												
1434022												
1434802												
1435317												
1522504												
1530605												
1530808												
1532401	2	0.0025	10.1175	15.57732	yes	1	3.180802	0.002843	30	6	0.002843225	15.57732
1621808												
1630106	1	0.02	80.94	51		1	8.996666	0.009309	30	6	0.009308693	51
1630401	1	0.07	283.29	132.44853	yes	1	16.83122	0.024175	30	6	0.024174953	132.44853
1631701												
1632106												
1632703												
1633404												
1633405												
1635404												
1721603												

Appendix 3A. (continued)

	LAU Industrial D Data					Land Application Unit Calculated FRAMES Inputs							
Idnum	Total LAU	Average surface area (acres)	Average surface area (m^2)	Average waste quantity (Mg)	Waste quantity replaced ?	Wet waste application rate (Mg/m-y)	Vehicles per day (1/d)	Vehicle weight (Mg)	Wheels per vehicle	Waste applications per year (1/y)	Distance vehicle travels on LAU (m)	Frequency of surface disturbance per month (1/mo)	Number of cultivations per application
			SrcArea			Rappl	nv	vw	nw	Nappl	mt	fd	fcult
Count	28	28	28	28	1	28	28	28	28	28	28	28	28
Average	1.8571	46.679762	188913	65070.27		0.221371738	5.319935	28.75	7	29.17213056	341.0428	5.790122884	2.107142857
Minimum	1	0.02	80.94	1.4		5.32208E-05	0.000256	22.5	6	0.093333333	8.996666	0.007777778	1
Maximum	10	300	1214100	754780		1.258899185	59.04214	47.5	10	88.05766667	1101.8621	18.03925	4
0114001													
0130207													
0131104													
0131207													
0131508													
0136703	2	67.5	273172.5	13208.65		0.048352781	2.410888	22.5	6	88.05766667	522.65907	14.67627778	2
0220102													
0221207													
0223504	2	5	20235	217.75		0.010761058	0.039744	22.5	6	14.51666667	142.24978	2.419444444	2
0224002													
0231002													
0231106													
0231407													
0231610													
0231911													
0231914													
0232305													
0232313													
0232402													
0232415													
0232501													
0232705													
0233601													
0233603													
0234904													
0235301													
0312301	2	10	40470	37.75		0.00093279	0.00689	22.5	6	2.516666667	201.17157	0.209722222	1
0314202													
0321802													
0331006													
0331902													
0332104	1	100	404700	509476.5		1.258899185	39.85345	47.5	10	33.9651	636.16036	11.3217	4
0332707													
0332811													
0430108													
0430412													
0431912													
0432011													
0432106													
0432716													
0433201													
0433204													
0433404													
0433408													
0434505													
0434804													

(continued)

Appendix 3A. (continued)

	LAU Industrial D Data					Land Application Unit Calculated FRAMES Inputs							
Idnum	Total LAU	Average surface area (acres)	Average surface area (m^2)	Average waste quantity (Mg)	Waste quantity replaced ?	Wet waste application rate (Mg/m-y)	Vehicles per day (1/d)	Vehicle weight (Mg)	Wheels per vehicle	Waste applications per year (1/y)	Distance vehicle travels on LAU (m)	Frequency of surface disturbance per month (1/mo)	Number of cultivations per application
			SrcArea			Rappl	nv	vw	nw	Nappl	mt	fd	fcult
0435510	1	6.5	26305.5	1.4		5.32208E-05	0.000256	22.5	6	0.093333333	162.1897	0.007777778	1
0436007													
0436108													
0530901	1	5	20235	4126		0.203904127	0.753091	22.5	6	27.50666667	142.24978	6.876666667	3
0531301													
0531502													
0531702													
0531902													
0534504													
0613402													
0620401													
0620604													
0621603													
0621902													
0622902													
0625002													
0625501	1	33	133551	7547.8		0.056516237	1.37765	22.5	6	50.31866667	365.4463	8.386444444	2
0631701	1	1	4047	39.6		0.009785026	0.007228	22.5	6	2.64	63.616036	0.22	1
0631903													
0632003													
0632606													
0632608													
0634001													
0635301													
0713618													
0713705													
0715007													
0715216													
0716701													
0720506													
0720803	3	1.3333333	5396	3.033333		0.000562145	0.000554	22.5	6	0.202222222	73.457471	0.016851852	1
0721305													
0722107													
0722503													
0722505													
0722705													
0723607													
0724206													
0724301													
0724804													
0724909													
0730407													
0730502													
0730914													
0731111													
0731405													
0731411													
0731412													
0731501													
0731507													
0731514													
0731703													

(continued)

Appendix 3A. (continued)

	LAU Industrial D Data					Land Application Unit Calculated FRAMES Inputs							
Idnum	Total LAU	Average surface area (acres)	Average surface area (m^2)	Average waste quantity (Mg)	Waste quantity replaced ?	Wet waste application rate (Mg/m-y)	Vehicles per day (1/d)	Vehicle weight (Mg)	Wheels per vehicle	Waste applications per year (1/y)	Distance vehicle travels on LAU (m)	Frequency of surface disturbance per month (1/mo)	Number of cultivations per application
			SrcArea			Rappl	nv	vw	nw	Nappl	mt	fd	fcult
0732110													
0732405													
0732510													
0733203													
0733210													
0733302													
0733404													
0733501													
0733606													
0734604													
0735309													
0826707													
0830601													
0830903													
0831102													
0831406													
0831904	1	300	1214100	754780		0.62167861	59.04214	47.5	10	50.31866667	1101.8621	12.57966667	3
0832304													
0832510													
0832903													
0832904													
0832909													
0833001													
0833007													
0834009													
0923004													
0930205													
0930301													
0930702													
0932103													
0932507													
0932509													
0932903													
0933704													
1010805	1	0.5	2023.5	192.5		0.095132197	0.035136	22.5	6	12.83333333	44.98333	2.138888889	2
1012203													
1013209													
1014805													
1015510													
1023705													
1031503	2	31.5	127480.5	1235.95		0.009695208	0.22559	22.5	6	82.39666667	357.04411	6.866388889	1
1031507													
1032715													
1032802	1	60	242820	207564.5		0.854808088	16.23659	47.5	10	13.83763333	492.76769	3.459408333	3
1033107													
1033114													
1033202	3	5	20235	505.6		0.02498641	0.092284	22.5	6	33.70666667	142.24978	5.617777778	2
1033602	1	230	930810	2903		0.003118789	0.529865	22.5	6	19.35333333	964.78495	1.612777778	1
1034005	1	13	52611	62269.3		1.18357948	4.870973	47.5	10	41.51286667	229.37088	13.83762222	4
1034210	1	40	161880	170		0.001050161	0.031029	22.5	6	11.33333333	402.34314	0.944444444	1
1034406													
1034805													
1035117													

(continued)

Appendix 3A. (continued)

	LAU Industrial D Data					Land Application Unit Calculated FRAMES Inputs							
Idnum	Total LAU	Average surface area (acres)	Average surface area (m^2)	Average waste quantity (Mg)	Waste quantity replaced ?	Wet waste application rate (Mg/m-y)	Vehicles per day (1/d)	Vehicle weight (Mg)	Wheels per vehicle	Waste applications per year (1/y)	Distance vehicle travels on LAU (m)	Frequency of surface disturbance per month (1/mo)	Number of cultivations per application
			SrcArea			Rappl	nv	vw	nw	Nappl	mt	fd	fcult
1035405													
1035508	1	58.68	237478	108235.5		0.455770717	8.466647	47.5	10	72.157	487.3171	18.03925	3
1120904													
1122705													
1131103													
1131802	1	5	20235	754.8		0.037301705	0.137769	22.5	6	50.32	142.24978	8.386666667	2
1133902	1	4	16188	36.6		0.002260934	0.00668	22.5	6	2.44	127.23207	0.203333333	1
1134405	8	25	101175	61.0125		0.000603039	0.011136	22.5	6	4.0675	318.08018	0.338958333	1
1212301													
1221704													
1223404													
1230111													
1230206													
1230517													
1230919													
1231101	1	5	20235	439.9		0.02173956	0.080292	22.5	6	29.32666667	142.24978	4.887777778	2
1231705	10	14	56658	6415.63		0.113234318	1.171003	22.5	6	42.77086667	238.02941	10.69271667	3
1233101													
1235205													
1236637													
1236652													
1236732													
1236810													
1236820													
1331103													
1333001	1	115	465405	17895.8		0.038452101	3.266402	22.5	6	11.93053333	682.20598	1.988422222	2
1333701													
1415407													
1421506													
1430107													
1430404													
1430602													
1431515													
1434022													
1434802													
1435317													
1522504	1	0.02	80.94	10.73	yes	0.132567334	0.001958	22.5	6	0.715333333	8.996666	0.178833333	3
1530605													
1530808													
1532401													
1621808	1	30	121410	86799.7		0.714930401	6.789846	47.5	10	57.86646667	348.43938	14.46661667	3
1630106													
1630401													
1631701	1	114	461358	5903.9		0.012796787	1.0776	22.5	6	39.35933333	679.23339	6.559888889	2
1632106	1	27	109269	31134.7		0.284936258	2.43549	47.5	10	20.75646667	330.55862	5.189116667	3
1632703													
1633404													
1633405													
1635404													
1721603													

Appendix 3A. (continued)

Idnum	Total SI	Depth (m)	Average surface area (acres)	Average surface area (m^2)	Average total capacity (Mg)	Total capacity replaced ?	Average waste quantity (Mg)	Waste quantity replace d?	Fraction of SI occupied by sediments	Depth of SI (m)	Number of impellers/ aerators	Total power to impellers (HP)	Fraction surface area turbulent	Volumetric influent flow rate (m3/s)
	Surface Impoundment Industrial D Data								Surface Impoundment Calculated FRAMES Inputs					
		SrcDepth		SrcArea					d_setpt	d_WMU	n_imp	Powr	F_aer	Q_wmu
Count	137	137	137	137	137	21	137	4	137	137	137	137	137	137
Average	3.131	3.0193	15.409904	62363.88	273698.3		394927.36		0.42851753	3.01927	14.9927007	1030.3467	0.29675531	0.012522714
Minimum	1	0.31	0.007	28.329	15.64125		0.0025		0.2	0.31	1	7.5	0.01596182	7.92723E-11
Maximum	20	29.86	400	1618800	9681638		12972781		0.76	29.86	66	4950	1	0.411352677
0114001														
0130207														
0131104	6	4.3	0.0216667	87.685	377.3833		138376.33		0.72093023	4.3	1	7.5	0.44648458	0.004387762
0131207	3	1.26	0.2233333	903.83	1139.733		91831.567		0.2	1.26	6	45	0.25989401	0.002911878
0131508	11	11.16	2.5454545	10301.45	114923.8		77193.409		0.76	11.16	7	525	0.26603039	0.002447718
0136703	1	2.03	1.38	5584.86	11321.7		37739		0.408867	2.03	4	300	0.28040094	0.001196662
0220102														
0221207														
0223504														
0224002														
0231002														
0231106														
0231407														
0231610	1	1.05	0.02	80.94	84.7		1067.3		0.2	1.05	1	7.5	0.48369162	3.38429E-05
0231911														
0231914	4	2.49	0.895	3622.065	9033.825		12972781		0.51807229	2.49	3	225	0.32426254	0.411352677
0232305														
0232313	1	3.61	0.13	526.11	1896.7		10119.1		0.66759003	3.61	4	30	0.29765638	0.000320866
0232402	8	4.63	0.665	2691.255	12453.88		688736.75		0.74082073	4.63	2	150	0.29094233	0.021839088
0232415	2	2.56	0.015	60.705	155.25		14061.6		0.53125	2.56	1	7.5	0.64492216	0.000445878
0232501														
0232705	2	1.22	6.5	26305.5	32078.15		6302413		0.2	1.22	17	1275	0.25300793	0.199842609
0233601	1	1.88	0.01	40.47	76.2		76.2		0.36170213	1.88	1	7.5	0.96738325	2.41622E-06
0233603														
0234904														
0235301														
0312301	1	1.78	0.03	121.41	216.2629	yes	75.5		0.3258427	1.78	1	7.5	0.32246108	2.39402E-06
0314202														
0321802	4	3.74	0.25	1011.75	3787.15		120204		0.67914439	3.74	7	52.5	0.27086731	0.003811537
0331006	3	3.25	1.1466667	4640.56	15095.6		21385.433		0.63076923	3.25	3	225	0.25309445	0.000678109
0331902	6	1.15	1.2466667	5045.26	5826.783		83654.783		0.2	1.15	4	300	0.31039035	0.002652602
0332104	3	0.95	1.7966667	7271.11	6918.8		471737.5		0.2	0.95	5	375	0.26921612	0.014958279
0332707														
0332811														
0430108	1	2.09	0.14	566.58	1185.7		43203.6		0.42583732	2.09	4	30	0.27639521	0.001369939
0430412	2	2.7	0.345	1396.215	3773.9		943.45		0.55555556	2.7	9	67.5	0.25236085	2.99158E-05
0431912	1	5.98	400	1618800	9681638		463579.2		0.76	5.98	66	4950	0.01596182	0.014699588
0432011														
0432106	4	2.33	10	40470	94347.5		9072000		0.48497854	2.33	26	1950	0.25151964	0.287663178
0432716	6	4.56	100	404700	1844594		43545.6		0.73684211	4.56	66	4950	0.06384729	0.001380783
0433201	6	2.68	58	234726	629740		3673.2667		0.55223881	2.68	66	4950	0.11008154	0.000116475
0433204	7	6.96	57.342857	232066.5	1614459		88586.414		0.76	6.96	66	4950	0.11134306	0.002808978
0433404	9	5.47	18.455556	74689.63	408482.7		3944773.8		0.76	5.47	47	3525	0.24635949	0.125084454
0433408	6	11.27	87.533333	354247.4	3993750		35252.233		0.76	11.27	66	4950	0.07294055	0.00111781
0434505	1	1.83	0.9	3642.3	6668.5		167		0.3442623	1.83	3	225	0.32246108	5.29539E-06
0434804	1	3.56	145	586815	2090540		42094.1		0.66292135	3.56	66	4950	0.04403262	0.001334758

(continued)

Appendix 3A. (continued)

	Surface Impoundment Industrial D Data								Surface Impoundment Calculated FRAMES Inputs					
Idnum	Total SI	Depth (m)	Average surface area (acres)	Average surface area (m^2)	Average total capacity (Mg)	Total capacity replaced ?	Average waste quantity (Mg)	Waste quantity replace d?	Fraction of SI occupied by sediments	Depth of SI (m)	Number of impellers/ aerators	Total power to impellers (HP)	Fraction surface area turbulent	Volumetric influent flow rate (m3/s)
		SrcDepth		SrcArea					d_setpt	d_WMU	n_imp	Powr	F_aer	Q_wmu
0435510	2	6.68	25	101175	676351		1887327.4		0.76	6.68	64	4800	0.24765011	0.059845084
0436007	2	0.74	48	194256	143878.3		18098.65		0.2	0.74	66	4950	0.1330152	0.000573888
0436108	1	7.51	176	712272	5352480		2630880		0.76	7.51	66	4950	0.03627687	0.083422322
0530901	3	1.88	0.45	1821.15	3419.167		926.1		0.36170213	1.88	2	150	0.42994811	2.93656E-05
0531301	12	1.85	0.6366667	2576.59	4775.7		1016.4333		0.35135135	1.85	2	150	0.30389003	3.223E-05
0531502	2	0.56	0.025	101.175	56.6		33965.1		0.2	0.56	1	7.5	0.3869533	0.001076996
0531702														
0531902	7	2.58	0.0242857	98.28429	253.3857		37739		0.53488372	2.58	1	7.5	0.39833428	0.001196662
0534504	1	0.62	0.06	242.82	151		88337.7	yes	0.2	0.62	2	15	0.32246108	0.002801092
0613402	2	0.38	0.12	485.64	185.6831	yes	37.75		0.2	0.38	4	30	0.32246108	1.19701E-06
0620401	1	0.93	1	4047	3773.9		20379.1		0.2	0.93	3	225	0.29021497	0.000646199
0620604	1	1.16	300	1214100	1411537		49060.7		0.2	1.16	66	4950	0.02128243	0.001555661
0621603	1	8.05	0.39	1578.33	12703.8		237000.9		0.76	8.05	10	75	0.24804699	0.007515039
0621902	2	0.42	0.48	1942.56	816.5		299.4		0.2	0.42	2	150	0.40307635	9.49365E-06
0622902	1	1.08	0.69	2792.43	3019.1		754.8		0.2	1.08	2	150	0.28040094	2.39339E-05
0625002	2	0.34	0.23	930.81	312.3802	yes	145.15		0.2	0.34	6	45	0.25236085	4.60255E-06
0625501														
0631701														
0631903	7	0.55	71.428571	289071.4	158108		571476.29		0.2	0.55	66	4950	0.08938621	0.018120887
0632003	5	6.87	6.954	28142.84	193442.6		101735.5		0.76	6.87	18	1350	0.25040119	0.003225921
0632606	5	1.22	36.732	148654.4	180676.7		471737.5		0.2	1.22	66	4950	0.17381927	0.014958279
0632608	5	1.97	0.424	1715.928	3383.88		92.9		0.39086294	1.97	2	150	0.45631285	2.94576E-06
0634001	1	0.48	14	56658	27216		9072		0.2	0.48	36	2700	0.24875569	0.000287663
0635301	1	1.66	0.8	3237.6	5363.8		6.8		0.27710843	1.66	3	225	0.36276872	2.15621E-07
0713618	2	0.36	0.07	283.29	101.5484	yes	1500.15		0.2	0.36	2	15	0.27639521	4.75681E-05
0713705	1	0.91	2	8094	7378.4		63945.9		0.2	0.91	6	450	0.29021497	0.002027654
0715007														
0715216														
0716701	1	3.16	5.96	24120.12	76232.8		381.2		0.62025316	3.16	16	1200	0.2597002	1.20874E-05
0720506														
0720803	1	0.56	0.02	80.94	45.09036	yes	15095.6		0.2	0.56	1	7.5	0.48369162	0.000478665
0721305														
0722107														
0722503	1	2.12	0.02	80.94	171.5		76.2		0.43396226	2.12	1	7.5	0.48369162	2.41622E-06
0722505	1	3.5	2.3	9308.1	32588.98	yes	152.5		0.65714286	3.5	6	450	0.25236085	4.83561E-06
0722705														
0723607	1	1.09	0.3	1214.1	1326.8		262078.04	yes	0.2	1.09	8	60	0.25796887	0.008310207
0724206	2	2.8	4	16188	45360		4536		0.57142857	2.8	11	825	0.26603039	0.000143832
0724301														
0724804														
0724909														
0730407	2	0.31	0.14	566.58	177.3944	yes	2.25		0.2	0.31	4	30	0.27639521	7.1345E-08
0730502	2	6.33	0.38	1537.86	9727.602	yes	1.3		0.76	6.33	10	75	0.25457454	4.12216E-08
0730914	2	0.78	0.3	1214.1	952.9		57.15		0.2	0.78	8	60	0.25796887	1.81216E-06
0731111	2	2	0.07	283.29	566.1		200016.7		0.4	2	2	15	0.27639521	0.00634231
0731405	1	1.66	0.45	1821.15	3019.1		27.2		0.27710843	1.66	2	150	0.42994811	8.62482E-07
0731411														
0731412	1	0.71	45.45	183936.2	131381.1	yes	22680		0.2	0.71	66	4950	0.1404781	0.000719158
0731501	4	0.35	0.015	60.705	21.03648	yes	13.2		0.2	0.35	1	7.5	0.64492216	4.18558E-07
0731507	2	2.41	11.82	47835.54	115104		1041.6		0.50207469	2.41	30	2250	0.24552874	3.3028E-05
0731514	7	2.45	8.1428571	32954.14	80869.29		754780		0.51020408	2.45	21	1575	0.24948305	0.023933247
0731703														
0732110														

(continued)

Appendix 3A. (continued)

	Surface Impoundment Industrial D Data								Surface Impoundment Calculated FRAMES Inputs					
Idnum	Total SI	Depth (m)	Average surface area (acres)	Average surface area (m^2)	Average total capacity (Mg)	Total capacity replaced ?	Average waste quantity (Mg)	Waste quantity replace d?	Fraction of SI occupied by sediments	Depth of SI (m)	Number of impellers/ aerators	Total power to impellers (HP)	Fraction surface area turbulent	Volumetric influent flow rate (m3/s)
		SrcDepth		SrcArea					d_setpt	d_WMU	n_imp	Powr	F_aer	Q_wmu
0732405														
0732510														
0733203	4	1.52	0.2575	1042.103	1587.975		125		0.21052632	1.52	7	52.5	0.26297797	3.96361E-06
0733210	1	0.49	18	72846	36003		1000.1		0.2	0.49	46	3450	0.24722016	3.17121E-05
0733302	3	0.72	0.0766667	310.27	224.6667		259.2		0.2	0.72	2	15	0.25236085	8.21895E-06
0733404														
0733501	1	1.85	0.07	283.29	524.9418	yes	9.1		0.35135135	1.85	2	15	0.27639521	2.88551E-07
0733606	1	12.23	11	44517	544320		22680		0.76	12.23	28	2100	0.24624301	0.000719158
0734604														
0735309	3	3.99	0.3333333	1349	5384.1		125796.67		0.69924812	3.99	9	67.5	0.26119348	0.003988874
0826707	1	0.39	0.01	40.47	15.64125	yes	2.7		0.2	0.39	1	7.5	0.96738325	8.5614E-08
0830601														
0830903	4	3.76	14.075	56961.53	214168.8		1390682.2		0.68085106	3.76	36	2700	0.24743017	0.044097007
0831102														
0831406	1	2.13	8	32376	68990.7		5717.5		0.43661972	2.13	21	1575	0.2539381	0.000181296
0831904	10	1.17	80	323760	377691.9		1132170		0.2	1.17	66	4950	0.07980912	0.03589987
0832304														
0832510	3	2.62	1.8366667	7432.99	19498.47		500041.73		0.54198473	2.62	5	375	0.26335297	0.015855775
0832903	3	2.77	40.333333	163229	451691.8		13608		0.566787	2.77	66	4950	0.15829908	0.000431495
0832904	2	2.53	0.92	3723.24	9434.75		94.35		0.5256917	2.53	3	225	0.31545106	2.99174E-06
0832909	2	1.39	0.745	3015.015	4192.8		4139.1		0.2	1.39	2	150	0.2597002	0.000131246
0833001														
0833007	1	1.71	2.72	11007.84	18869.5		1320.9		0.29824561	1.71	7	525	0.24895892	4.18843E-05
0834009	1	6.39	2.01	8134.47	51990.8		2103.3		0.76	6.39	6	450	0.28877112	6.66933E-05
0923004														
0930205	1	3.67	1	4047	14832.33	yes	113217		0.67302452	3.67	3	225	0.29021497	0.003589987
0930301	1	1.88	10	40470	76204.8		3810.2		0.36170213	1.88	26	1950	0.25151964	0.000120817
0930702	9	5.05	45.555556	184363.3	931734		88704		0.76	5.05	66	4950	0.1401526	0.002812707
0932103	3	4.31	2.1666667	8768.5	37800		302400		0.72157773	4.31	6	450	0.26789075	0.009588773
0932507	4	1.66	0.425	1719.975	2853.65		44.35		0.27710843	1.66	2	150	0.45523917	1.40629E-06
0932509	4	3.34	3.2775	13264.04	44343.33		1487.675		0.64071856	3.34	9	675	0.265643	4.71725E-05
0932903	7	9.25	110.71429	448060.7	4145562	yes	189521.63	yes	0.76	9.25	66	4950	0.05766852	0.006009523
0933704	1	1.52	0.92	3723.24	5660.8		18.9		0.21052632	1.52	3	225	0.31545106	5.99298E-07
1010805														
1012203	8	1.79	1.5	6070.5	10849.96		14152.125		0.32960894	1.79	4	300	0.25796887	0.000448748
1013209	2	0.45	0.25	1011.75	451.2919	yes	264.15		0.2	0.45	7	52.5	0.27086731	8.37591E-06
1014805														
1015510														
1023705	1	2.21	4.64	18778.08	41512.9		294364.2		0.45701357	2.21	12	900	0.25018532	0.009333966
1031503														
1031507	9	3.04	17.777778	71946.67	218618.5		1677.2889		0.60526316	3.04	45	3375	0.24486888	5.3185E-05
1032715	3	1.27	7.3333333	29678	37751.57		314491.67		0.2	1.27	19	1425	0.2506402	0.009972186
1032802	1	1.31	16	64752	84912.7		180015		0.2	1.31	41	3075	0.24789196	0.005708078
1033107	2	0.47	1	4047	1886.95		60005		0.2	0.47	3	225	0.29021497	0.001902693
1033114	1	2.26	3.3	13355.1	30191.2		1037822.5		0.46902655	2.26	9	675	0.26383179	0.032908214
1033202														
1033602	6	2.31	1.5833333	6407.75	14781.1		94347.5		0.48051948	2.31	5	375	0.30548945	0.002991656
1034005														
1034210	5	29.86	1.8	7284.6	217503.7	yes	52834.6		0.76	29.86	5	375	0.26871757	0.001675327
1034406	2	1.52	7.5	30352.5	46114.85		131143		0.21052632	1.52	19	1425	0.24507042	0.004158401
1034805	1	5.62	0.44	1780.68	10000.8		200016.7		0.76	5.62	2	150	0.43971966	0.00634231
1035117	1	1.75	0.4	1618.8	2830.4		291345.1		0.31428571	1.75	2	150	0.48369162	0.009238234
1035405	3	2.21	0.21	849.87	1875.467		37739		0.45701357	2.21	6	45	0.27639521	0.001196662

(continued)

Appendix 3A. (continued)

	Surface Impoundment Industrial D Data								Surface Impoundment Calculated FRAMES Inputs					
Idnum	Total SI	Depth (m)	Average surface area (acres)	Average surface area (m^2)	Average total capacity (Mg)	Total capacity replaced ?	Average waste quantity (Mg)	Waste quantity replace d?	Fraction of SI occupied by sediments	Depth of SI (m)	Number of impellers/ aerators	Total power to impellers (HP)	Fraction surface area turbulent	Volumetric influent flow rate (m3/s)
		SrcDepth		SrcArea					d_setpt	d_WMU	n_imp	Powr	F_aer	Q_wmu
1035508	4	4.55	1.8375	7436.363	33870.75		38493.775		0.73626374	4.55	5	375	0.26323354	0.001220595
1120904	1	1.3	5.74	23229.78	30191.2		109443.1		0.2	1.3	15	1125	0.2528005	0.003470321
1122705	2	16.43	0.03	121.41	1995.1		14520.1		0.76	16.43	1	7.5	0.32246108	0.000460416
1131103	1	1.52	1.03	4168.41	6351.9		721.2		0.21052632	1.52	3	225	0.28176211	2.28685E-05
1131802														
1133902														
1134405														
1212301	2	5.85	0.575	2327.025	13608		13608		0.76	5.85	2	150	0.33648113	0.000431495
1221704	2	6.37	0.03	121.41	773.778	yes	47817.703	yes	0.76	6.37	1	7.5	0.32246108	0.001516247
1223404	6	0.44	0.0483333	195.605	86.44089	yes	0.0333333		0.2	0.44	2	15	0.40029652	1.05696E-09
1230111	3	2.03	1.3766667	5571.37	11292.3		185976		0.408867	2.03	4	300	0.28107988	0.005897095
1230206	4	0.99	1.0625	4299.938	4245.625		707606.25		0.2	0.99	3	225	0.2731435	0.022437419
1230517	12	1.76	0.5741667	2323.653	4088.392		43242.6		0.31818182	1.76	2	150	0.33696949	0.001371175
1230919														
1231101	2	1.17	1	4047	4717.35		349085.75		0.2	1.17	3	225	0.29021497	0.011069127
1231705	4	3.86	1.9925	8063.648	31134.68		468907.08		0.68911917	3.86	6	450	0.29130738	0.014868529
1233101	1	3.07	0.38	1537.86	4717.4		26.8		0.60912052	3.07	10	75	0.25457454	8.49799E-07
1235205	1	1.32	0.28	1133.16	1499.114	yes	15095.6		0.2	1.32	8	60	0.27639521	0.000478665
1236637	1	0.56	0.02	80.94	45.4		181.4		0.2	0.56	1	7.5	0.48369162	5.752E-06
1236652	1	1.71	0.03	121.41	207.6		100		0.29824561	1.71	1	7.5	0.32246108	3.17089E-06
1236732														
1236810														
1236820	1	9.59	4	16188	155269		27216		0.76	9.59	11	825	0.26603039	0.00086299
1331103	3	1.06	0.2666667	1079.2	1144.3		42.333333		0.2	1.06	7	52.5	0.2539381	1.34234E-06
1333001														
1333701														
1415407														
1421506														
1430107	2	1.15	0.5	2023.5	2320.95		275.5		0.2	1.15	2	150	0.3869533	8.7358E-06
1430404	1	0.91	0.41	1659.27	1510.1		1377473.5		0.2	0.91	2	150	0.47189427	0.043678175
1430602	2	1.12	0.25	1011.75	1132.15		49060.7		0.2	1.12	7	52.5	0.27086731	0.001555661
1431515	20	1.25	0.007	28.329	35.51722	yes	566.085		0.2	1.25	1	7.5	1	1.79499E-05
1434022	1	2.18	0.03	121.41	264.2		943.5		0.44954128	2.18	1	7.5	0.32246108	2.99174E-05
1434802	1	0.88	0.15	607.05	536.4		2145.2		0.2	0.88	4	30	0.25796887	6.80219E-05
1435317														
1522504														
1530605	6	4.05	1.9166667	7756.75	31449.17		377390		0.7037037	4.05	5	375	0.25236085	0.011966623
1530808	4	0.86	0.225	910.575	783.55		30191.2		0.2	0.86	6	45	0.25796887	0.00095733
1532401														
1621808	2	2.03	1.5	6070.5	12304.52	yes	32502.7		0.408867	2.03	4	300	0.25796887	0.001030625
1630106	16	3.24	0.794375	3214.836	10425.4		161805.96		0.62962963	3.24	3	225	0.3653375	0.00513069
1630401														
1631701	2	1.87	0.54	2185.38	4094.7		634232.2		0.35828877	1.87	2	150	0.35829009	0.020110808
1632106	1	1.92	4	16188	31134.7		31134.7		0.375	1.92	11	825	0.26603039	0.000987247
1632703														
1633404	1	2.13	2	8094	17216.2		245303.5		0.43661972	2.13	6	450	0.29021497	0.007778305
1633405	2	9.11	0.155	627.285	5717.45		0.0025		0.76	9.11	4	30	0.24964729	7.92723E-11
1635404	1	8.5	0.5	2023.5	17209		250020.9		0.76	8.5	2	150	0.3869533	0.007927889
1721603	2	0.93	0.25	1011.75	943.45		25002.1		0.2	0.93	7	52.5	0.27086731	0.000792789

Appendix 3B

Aerated Tank Data

Table 3B-1. TSDR Survey Wastewater Treatment Codes Used in Identifying Treatment Tanks

Process Code/Process Level		Aeration	Process Code/Process		Aeration Level
Equalization			**Filtration**		
1WT	Equalization	LO	34WT	Diatomaceous earth	NO
Cyanide oxidation			35WT	Sand	NO
2WT	Alkaline chlorination	LO	36WT	Multimedia	NO
3WT	Ozone	LO	37WT	Other filtration	NO
4WT	Electrochemical	LO	**Sludge dewatering**		
5WT	Other cyanide oxidation	LO	38WT	Gravity thickening	NO
General oxidation (including disinfection)			**Air flotation**		
6WT	Chlorination	LO	43WT	Dissolved air flotation	HI
7WT	Ozonation	LO	44WT	Partial aeration	HI
8WT	UV radiation	LO	45WT	Air dispersion	HI
9WT	Other general oxidation	LO	46WT	Other air flotation	HI
Chemical precipitation			**Oil skimming**		
10WT	Lime	LO	47WT	Gravity separation	NO
11WT	Sodium hydroxide	LO	48WT	Coalescing plate separation	NO
12WT	Soda ash	LO	49WT	Other oil skimming	NO
13WT	Sulfide	LO	**Other liquid-phase separation**		
14WT	Other chemical precipitation	LO	50WT	Decanting	NO
Chromium reduction			51WT	Other liquid phase-separation	NO
15WT	Sodium bisulfite	LO	**Biological treatment**		
16WT	Sulfur dioxide	LO	52WT	Activated sludge	HI
17WT	Ferrous sulfate	LO	54WT	Fixed film – rotating contactor	LO
18WT	Other chromium reduction	LO	57WT	Anaerobic	NO
19WT	Complexed metals treatment	LO	58WT	Other biological treatment	HI
Emulsion breaking			**Other wastewater treatment**		
20WT	Thermal	NO	60WT	Neutralization	LO
21WT	Chemical	LO	61WT	Nitrification	LO
22WT	Other emulsion breaking	LO	62WT	Denitrification	LO
Evaporation			63WT	Flocculation and/or coagulation	NO
31WT	Solar	NO	64WT	Settling (clarification)	NO
Fuel blending			66WT	Other wastewater treatment	LO
1FB	Fuel blending	LO	**Other Processes**		
			1TR	Other treatment	LO

Table 3B-2. Summary of Tank Information Collected by EPA on Aerated Wastewater Treatment

Company	Type of Unit	Type of Aerator	Aeration Level	Volume (m^3)	Area (m^2)	Depth (m)	Total hp	# Aer.	d_imp (cm)	w_imp (rad/s)	Q_air (m^3/s)	O_2 transfer rate (lb/hp-h)	hp/m^3 Tank Volume	Q_air/m^3 Tank Volume (1/s)	hp/Aer. for hp>100
Rielly Tar	Aerated lagoon	Mechanical	SI	3,369	2,109	1.60	30	2	14.0	367			0.009		
Texaco, IL	Bubbling pit	Diffused	HI	453	74	6.10					2.17			0.00479	
EWR	So eq. basin	Mechanical	LO	240	109	2.21	30	2	106.7	7.1			0.125		
EWR	No eq. basin	Mechanical	LO	191	84	2.29	20	1	152.4	5.9			0.105		
Summit	Mixing tank	Mechanical	LO	68	9	7.32	1.5	1	182.9	1.0			0.022		
Leaman	Mixing tank	Mechanical	LO	112	34	3.35	3	1					0.027		
Leaman	Aeration tank	Mechanical	HI	112	34	3.35	7.5	1					0.067		
Texaco, TX	Aerated lagoon	Mechanical	SI	45,425			1,800	28					0.040		64
LNVA	Eq. basin	Mechanical	LO	41,261	11,241	3.66	150	5	121.9	7.1			0.004		30
LNVA	Aeration tank	Mechanical	HI	41,261	11,241	3.66	900	9	259.1	188.5		3.0	0.022		100
LNVA	Aux. Aer. tank	Mechanical	HI	21,804	4,459	4.88	450	6	259.1	125.7		3.0	0.021		75
Neches	Aeration tank	Mechanical	HI	26,546	5,806	4.57	900	6	274.3				0.034		150
Shell, IL	Aerated lagoon	Mechanical	SI	24,975	5,853	4.27	270	6	41.9	123.0			0.011		45
Sun, OK	Aeration tank	Mechanical	HI	3,367	910	3.70	150	2	50	123.6		3.0	0.045		75
Plant A3	Aeration tank	Diffused	HI	5,764	1,051	5.49					2.35			0.00041	
Plant A2	Aeration tank	Diffused	HI	5,830							3.78			0.00065	
Plant A2	Aeration tank	Mechanical	HI	1,211											
Plant A1	Eq. basin	Mechanical	LO	681	200	3.40									
Plant A1	Aeration tank	Diffused	HI	1,666	159	10.46					0.80			0.00048	
Amoco	Aeration tank	Mechanical	HI	5,678	931	6.10	300	3					0.053		100
EI DuPont	Aeration tank	Diffused	HI	4,542	618	7.36									
Mobay	Aeration tank	Diffused	HI	3,785	730	5.19									
Borg-Warner	Aeration tank	Diffused	HI	6,814							4.72			0.00069	
TSDF -T01G	Aerated trt. tank	Mechanical	HI	108	27	4.00	7.5						0.069		
TSDF -T01H	Aerated trt. tank	Mechanical	HI	1,600	430	3.70	120						0.075		
TSDF -T01A	Treatment tank		LO	30	13	2.40									
TSDF -T01B	Treatment tank		LO	76	26	2.70									
TSDF -T01C	Treatment tank		LO	800	65	12.00									
Average									146.2	105.4			0.0416	0.0014	79.9
Median									137.2	123.0			0.0303	0.0006	75.0

Table 3B-3. Correlated Tank Data from TSDR Survey

Tank Index	Aeration Level	Size (gal)	Capacity (m^3)	Through-put (m^3/s)	Depth (m)	Surface Area (m^2)	Source Height (m)	Fraction Aerated	Total Aerator Horse-power	Number of Impellers/ Aerators
ATIndex				**Q_wmu**	**d_wmu**	**SrcArea**	**SHight**	**F_aer**	**Powr**	**n_imp**
1	HI	300	1.14	8.15E-05	1.03	1.11	1.53	0.691	0.250	1
2	HI	400	1.51	1.62E-03	1.25	1.21	0.90	0.633	0.250	1
3	HI	850	3.22	2.40E-07	1.28	2.51	1.78	0.929	0.250	1
4	HI	1,000	3.79	7.20E-07	1.44	2.62	1.94	0.787	0.250	1
5	HI	3,200	12.11	2.24E-04	2.90	4.18	3.40	0.691	0.259	1
6	HI	5,125	19.40	1.26E-04	2.47	7.87	2.97	0.800	0.847	1
7	HI	5,880	22.26	1.49E-03	2.16	10.31	2.66	0.834	0.922	1
8	HI	10,200	38.61	1.63E-04	3.27	11.81	3.77	0.558	1.031	1
9	HI	10,200	38.61	1.70E-03	2.66	14.51	3.16	0.761	1.133	1
10	HI	15,000	56.78	8.15E-05	3.26	17.39	1.40	0.783	1.544	1
11	HI	13,900	52.62	3.51E-04	2.90	18.16	3.40	0.647	1.447	1
12	HI	20,000	75.71	1.02E-03	2.97	25.51	3.47	0.762	2.357	1
13	HI	30,370	114.96	8.40E-04	4.01	28.65	0.80	0.922	2.129	1
14	HI	21,000	79.49	3.56E-03	2.76	28.79	3.26	0.630	2.250	1
15	HI	31,300	118.48	5.97E-03	3.21	36.94	3.71	0.707	3.331	1
16	HI	196,000	741.94	1.70E-03	4.87	152.50	5.10	0.785	18.478	1
17	HI	225,000	851.71	2.40E-06	3.58	237.62	4.08	0.811	22.185	1
18	HI	415,600	1,573.21	3.92E-03	3.70	424.73	4.20	0.765	32.900	1
19	HI	640,000	2,422.65	2.06E-01	4.16	582.44	4.66	0.651	48.541	1
20	HI	640,000	2,422.65	2.06E-01	3.39	714.37	3.89	0.745	58.856	2
21	HI	1,800,000	6,813.72	8.64E-02	5.17	1,319.02	5.67	0.898	273.136	4
22	HI	3,000,000	11,356.19	9.15E-01	5.54	2,049.16	6.04	0.706	330.106	4
23	HI	6,000,000	22,712.39	9.15E-01	4.80	4,734.60	5.30	0.849	829.287	9
24	HI	4,624,000	17,503.68	4.71E-01	5.06	3,455.96	5.56	0.655	649.233	7
25	HI	4,624,000	17,503.68	4.71E-01	3.77	4,644.58	4.27	0.732	555.704	9
26	HI	4,624,000	17,503.68	4.71E-01	3.46	5,054.12	0.60	0.585	317.706	4
27	HI	8,200,000	31,040.27	3.88E-01	3.68	8,430.73	4.18	0.810	890.808	12
28	HI	8,200,000	31,040.27	3.29E-01	3.67	8,452.59	4.17	0.713	1,164.902	13
29	HI	3,000,000	11,356.19	9.15E-01	3.38	3,361.45	1.50	0.720	263.739	3
30	LO	120	0.45	5.15E-04	0.90	0.50	1.40	0.342	0.250	1
31	LO	100	0.38	1.34E-04	0.74	0.51	1.24	0.582	0.250	1
32	LO	150	0.57	2.75E-05	1.04	0.55	1.54	0.760	0.250	1
33	LO	100	0.38	8.30E-05	0.69	0.55	1.19	0.553	0.250	1
34	LO	100	0.38	8.30E-05	0.69	0.55	1.19	0.393	0.250	1
35	LO	110	0.42	1.78E-07	0.75	0.55	1.25	0.506	0.250	1
36	LO	120	0.45	5.15E-04	0.76	0.60	1.26	0.678	0.250	1
37	LO	100	0.38	1.80E-08	0.63	0.60	1.13	0.797	0.250	1
38	LO	150	0.57	2.40E-07	0.92	0.62	1.42	0.631	0.250	1
39	LO	150	0.57	2.40E-07	0.90	0.63	1.40	0.786	0.250	1
40	LO	125	0.47	1.49E-08	0.72	0.65	1.22	0.287	0.250	1
41	LO	200	0.76	2.55E-04	1.14	0.66	1.64	0.368	0.250	1
42	LO	200	0.76	5.48E-04	1.09	0.69	0.80	0.292	0.250	1
43	LO	150	0.57	2.40E-07	0.80	0.71	1.30	0.518	0.250	1
44	LO	180	0.68	1.80E-07	0.95	0.72	1.45	0.659	0.250	1
45	LO	215	0.81	1.64E-06	1.08	0.75	1.58	0.471	0.250	1
46	LO	150	0.57	1.50E-05	0.72	0.79	1.22	0.319	0.250	1
47	LO	200	0.76	2.55E-04	0.91	0.83	1.41	0.274	0.250	1
48	LO	230	0.87	1.64E-06	1.01	0.86	1.51	0.200	0.250	1
49	LO	185	0.70	5.48E-04	0.81	0.86	1.31	0.640	0.250	1

(continued)

Table 3B-3. (continued)

Tank Index	Aeration Level	Size (gal)	Capacity (m^3)	Through-put (m^3/s)	Depth (m)	Surface Area (m^2)	Source Height (m)	Fraction Aerated	Total Aerator Horse-power	Number of Impellers/ Aerators
ATIndex				Q_wmu	d_wmu	SrcArea	SHight	F_aer	Powr	n_imp
50	LO	235	0.89	1.44E-08	0.99	0.90	1.10	0.551	0.250	1
51	LO	200	0.76	1.64E-06	0.83	0.91	1.33	0.622	0.250	1
52	LO	400	1.51	2.40E-05	1.64	0.92	2.14	0.730	0.250	1
53	LO	210	0.79	1.44E-08	0.84	0.94	1.34	0.311	0.250	1
54	LO	210	0.79	1.44E-08	0.82	0.96	1.32	0.584	0.250	1
55	LO	200	0.76	1.20E-07	0.76	0.99	1.26	0.268	0.250	1
56	LO	250	0.95	1.46E-06	0.93	1.01	1.43	0.716	0.250	1
57	LO	350	1.32	6.72E-07	1.28	1.04	1.78	0.591	0.250	1
58	LO	350	1.32	6.72E-07	1.23	1.07	0.50	0.316	0.250	1
59	LO	300	1.14	6.10E-05	1.05	1.08	1.55	0.371	0.250	1
60	LO	350	1.32	6.72E-07	1.22	1.08	1.72	0.407	0.250	1
61	LO	400	1.51	1.40E-04	1.32	1.15	1.82	0.414	0.250	1
62	LO	350	1.32	6.72E-07	1.14	1.16	1.64	0.461	0.250	1
63	LO	350	1.32	6.72E-07	1.08	1.23	1.58	0.567	0.250	1
64	LO	350	1.32	6.72E-07	1.06	1.24	1.56	0.253	0.250	1
65	LO	450	1.70	9.31E-06	1.37	1.25	1.87	0.367	0.250	1
66	LO	450	1.70	2.24E-04	1.30	1.31	1.80	0.669	0.250	1
67	LO	550	2.08	2.15E-06	1.56	1.33	2.06	0.443	0.250	1
68	LO	500	1.89	7.65E-05	1.41	1.34	1.91	0.557	0.250	1
69	LO	475	1.80	4.80E-07	1.33	1.35	1.70	0.800	0.250	1
70	LO	530	2.01	1.68E-04	1.42	1.41	1.92	0.430	0.250	1
71	LO	400	1.51	2.40E-05	1.07	1.42	0.50	0.771	0.250	1
72	LO	500	1.89	1.45E-07	1.33	1.42	0.50	0.285	0.250	1
73	LO	450	1.70	2.24E-04	1.17	1.46	1.67	0.310	0.250	1
74	LO	500	1.89	1.09E-03	1.29	1.47	1.79	0.480	0.250	1
75	LO	550	2.08	1.67E-06	1.42	1.47	1.92	0.441	0.250	1
76	LO	550	2.08	2.15E-06	1.40	1.49	1.90	0.521	0.250	1
77	LO	500	1.89	3.60E-07	1.26	1.51	1.76	0.800	0.250	1
78	LO	500	1.89	1.67E-06	1.26	1.51	1.76	0.415	0.250	1
79	LO	600	2.27	7.48E-07	1.50	1.51	2.00	0.482	0.250	1
80	LO	600	2.27	2.57E-03	1.50	1.51	2.00	0.232	0.250	1
81	LO	435	1.65	1.20E-07	1.08	1.52	1.58	0.551	0.250	1
82	LO	500	1.89	7.80E-06	1.24	1.53	1.74	0.495	0.250	1
83	LO	500	1.89	1.10E-04	1.23	1.54	1.73	0.633	0.250	1
84	LO	475	1.80	1.67E-06	1.17	1.54	0.50	0.472	0.250	1
85	LO	636	2.41	2.56E-03	1.53	1.57	2.03	0.594	0.250	1
86	LO	500	1.89	7.20E-07	1.20	1.58	1.70	0.200	0.250	1
87	LO	430	1.63	2.40E-10	1.03	1.59	1.53	0.256	0.250	1
88	LO	600	2.27	1.71E-03	1.43	1.59	1.93	0.683	0.250	1
89	LO	500	1.89	2.40E-05	1.16	1.64	1.66	0.284	0.250	1
90	LO	500	1.89	6.00E-07	1.15	1.65	1.65	0.800	0.250	1
91	LO	500	1.89	3.68E-05	1.14	1.66	0.80	0.589	0.250	1
92	LO	500	1.89	1.09E-03	1.13	1.67	1.63	0.800	0.250	1
93	LO	327	1.24	1.44E-08	0.73	1.71	1.23	0.667	0.250	1
94	LO	500	1.89	3.60E-06	1.11	1.71	1.61	0.200	0.250	1
95	LO	670	2.54	2.77E-06	1.48	1.71	1.98	0.384	0.250	1
96	LO	600	2.27	7.48E-07	1.32	1.73	1.82	0.210	0.250	1
97	LO	500	1.89	2.71E-04	1.10	1.73	1.60	0.455	0.250	1
98	LO	600	2.27	5.33E-04	1.30	1.74	1.80	0.346	0.250	1

(continued)

Table 3B-3. (continued)

Tank Index	Aeration Level	Size (gal)	Capacity (m^3)	Through-put (m^3/s)	Depth (m)	Surface Area (m^2)	Source Height (m)	Fraction Aerated	Total Aerator Horse-power	Number of Impellers/ Aerators
ATIndex				Q_wmu	d_wmu	SrcArea	SHight	F_aer	Powr	n_imp
99	LO	500	1.89	4.68E-05	1.07	1.77	1.57	0.235	0.250	1
100	LO	600	2.27	5.62E-04	1.24	1.83	1.74	0.733	0.250	1
101	LO	650	2.46	1.09E-03	1.34	1.83	0.60	0.271	0.250	1
102	LO	670	2.54	4.08E-06	1.37	1.86	1.87	0.714	0.250	1
103	LO	600	2.27	7.48E-07	1.22	1.86	1.72	0.273	0.250	1
104	LO	500	1.89	1.29E-06	1.00	1.90	1.50	0.589	0.250	1
105	LO	800	3.03	2.13E-05	1.59	1.91	2.09	0.358	0.250	1
106	LO	1,000	3.79	5.62E-05	1.96	1.93	2.46	0.564	0.250	1
107	LO	900	3.41	4.80E-07	1.74	1.96	0.50	0.623	0.250	1
108	LO	600	2.27	2.57E-03	1.15	1.97	1.65	0.363	0.250	1
109	LO	750	2.84	9.00E-06	1.42	2.00	1.92	0.258	0.250	1
110	LO	500	1.89	8.16E-04	0.94	2.01	1.44	0.535	0.250	1
111	LO	600	2.27	5.49E-04	1.12	2.02	1.62	0.200	0.250	1
112	LO	800	3.03	1.86E-03	1.49	2.03	1.99	0.569	0.250	1
113	LO	790	2.99	1.64E-06	1.47	2.04	1.97	0.446	0.250	1
114	LO	1,000	3.79	3.60E-03	1.85	2.05	2.35	0.598	0.250	1
115	LO	636	2.41	1.62E-04	1.17	2.05	1.67	0.220	0.250	1
116	LO	800	3.03	4.42E-03	1.47	2.06	1.97	0.466	0.250	1
117	LO	1,000	3.79	1.01E-06	1.82	2.08	2.32	0.431	0.250	1
118	LO	800	3.03	2.13E-05	1.45	2.09	1.95	0.289	0.250	1
119	LO	1,160	4.39	1.50E-05	2.09	2.10	2.59	0.305	0.250	1
120	LO	1,000	3.79	1.20E-05	1.79	2.11	2.29	0.671	0.250	1
121	LO	748	2.83	2.69E-05	1.32	2.15	1.82	0.519	0.250	1
122	LO	748	2.83	2.69E-05	1.32	2.15	1.82	0.257	0.250	1
123	LO	675	2.56	1.38E-04	1.14	2.24	1.64	0.444	0.250	1
124	LO	1,008	3.82	3.92E-03	1.65	2.31	2.15	0.611	0.250	1
125	LO	1,041	3.94	9.60E-07	1.68	2.35	2.18	0.702	0.250	1
126	LO	934	3.54	9.23E-05	1.50	2.36	2.00	0.237	0.250	1
127	LO	1,000	3.79	1.10E-04	1.59	2.38	2.09	0.363	0.250	1
128	LO	1,000	3.79	3.60E-03	1.54	2.46	2.04	0.505	0.250	1
129	LO	1,000	3.79	6.69E-03	1.53	2.47	2.03	0.511	0.250	1
130	LO	1,041	3.94	7.50E-06	1.57	2.50	2.07	0.547	0.250	1
131	LO	800	3.03	4.29E-05	1.21	2.51	1.71	0.200	0.250	1
132	LO	1,000	3.79	6.90E-06	1.50	2.53	2.00	0.524	0.250	1
133	LO	1,200	4.54	6.00E-07	1.78	2.55	2.28	0.780	0.250	1
134	LO	1,000	3.79	3.60E-03	1.46	2.59	1.96	0.800	0.250	1
135	LO	1,100	4.16	1.38E-04	1.59	2.63	2.09	0.297	0.250	1
136	LO	1,400	5.30	5.76E-02	2.01	2.64	0.90	0.200	0.250	1
137	LO	1,100	4.16	9.02E-04	1.57	2.65	2.07	0.200	0.250	1
138	LO	1,500	5.68	6.00E-05	2.13	2.67	2.63	0.663	0.250	1
139	LO	1,000	3.79	4.08E-07	1.42	2.67	1.92	0.203	0.250	1
140	LO	1,000	3.79	2.88E-06	1.41	2.68	1.91	0.260	0.250	1
141	LO	1,000	3.79	2.32E-06	1.40	2.70	1.90	0.624	0.250	1
142	LO	1,050	3.97	1.10E-04	1.47	2.71	1.97	0.234	0.250	1
143	LO	1,000	3.79	1.08E-03	1.37	2.75	1.87	0.646	0.250	1
144	LO	1,400	5.30	6.52E-04	1.92	2.77	2.42	0.520	0.250	1
145	LO	1,000	3.79	1.58E-05	1.36	2.79	1.86	0.334	0.250	1
146	LO	1,500	5.68	1.62E-04	2.01	2.82	2.51	0.450	0.250	1
147	LO	1,615	6.11	1.35E-03	2.12	2.88	2.62	0.287	0.250	1

(continued)

Table 3B-3. (continued)

Tank Index	Aeration Level	Size (gal)	Capacity (m^3)	Through-put (m^3/s)	Depth (m)	Surface Area (m^2)	Source Height (m)	Fraction Aerated	Total Aerator Horse-power	Number of Impellers/ Aerators
ATIndex				Q_wmu	d_wmu	SrcArea	SHight	F_aer	Powr	n_imp
148	LO	950	3.60	1.08E-03	1.25	2.88	1.75	0.393	0.250	1
149	LO	1,500	5.68	6.24E-03	1.95	2.91	2.45	0.684	0.250	1
150	LO	1,400	5.30	1.20E-08	1.81	2.93	0.50	0.773	0.250	1
151	LO	1,269	4.80	2.07E-02	1.63	2.95	2.13	0.368	0.250	1
152	LO	1,200	4.54	1.89E-04	1.53	2.97	2.03	0.496	0.250	1
153	LO	1,800	6.81	2.30E-07	2.23	3.05	2.73	0.524	0.250	1
154	LO	2,000	7.57	6.24E-03	2.48	3.06	2.98	0.552	0.250	1
155	LO	1,270	4.81	4.37E-03	1.55	3.11	2.05	0.540	0.250	1
156	LO	1,800	6.81	2.30E-07	2.18	3.12	2.68	0.592	0.250	1
157	LO	1,350	5.11	4.80E-07	1.64	3.12	2.14	0.742	0.250	1
158	LO	1,800	6.81	2.30E-07	2.16	3.15	2.66	0.200	0.250	1
159	LO	1,870	7.08	3.15E-03	2.23	3.17	2.73	0.627	0.250	1
160	LO	1,800	6.81	2.30E-07	2.15	3.17	2.65	0.528	0.250	1
161	LO	1,450	5.49	1.33E-04	1.72	3.19	2.22	0.292	0.250	1
162	LO	1,000	3.79	1.45E-03	1.17	3.23	1.67	0.378	0.250	1
163	LO	2,000	7.57	6.40E-06	2.29	3.30	2.79	0.491	0.250	1
164	LO	1,650	6.25	2.76E-03	1.86	3.36	0.60	0.295	0.250	1
165	LO	1,800	6.81	1.44E-05	2.02	3.38	2.52	0.352	0.250	1
166	LO	1,600	6.06	1.24E-03	1.79	3.39	2.29	0.427	0.250	1
167	LO	1,400	5.30	3.54E-05	1.56	3.40	1.40	0.545	0.250	1
168	LO	1,800	6.81	1.73E-04	1.99	3.42	2.49	0.529	0.250	1
169	LO	2,150	8.14	9.01E-04	2.35	3.46	2.85	0.790	0.250	1
170	LO	1,800	6.81	2.30E-07	1.96	3.48	2.30	0.542	0.250	1
171	LO	1,500	5.68	6.15E-03	1.58	3.59	2.08	0.289	0.250	1
172	LO	2,550	9.65	5.48E-04	2.65	3.64	3.15	0.273	0.250	1
173	LO	2,000	7.57	1.82E-03	2.05	3.69	2.55	0.495	0.250	1
174	LO	1,800	6.81	2.30E-07	1.82	3.74	2.32	0.312	0.250	1
175	LO	2,000	7.57	1.80E-05	1.97	3.84	1.90	0.350	0.250	1
176	LO	3,000	11.36	6.24E-06	2.94	3.86	3.44	0.538	0.250	1
177	LO	2,000	7.57	1.09E-03	1.95	3.88	2.45	0.493	0.250	1
178	LO	2,000	7.57	1.53E-04	1.95	3.89	2.45	0.726	0.250	1
179	LO	2,000	7.57	1.44E-06	1.93	3.92	2.43	0.599	0.250	1
180	LO	2,000	7.57	4.80E-07	1.93	3.92	2.43	0.443	0.250	1
181	LO	2,290	8.67	4.99E-05	2.19	3.97	2.69	0.416	0.250	1
182	LO	2,000	7.57	2.19E-02	1.90	3.99	2.40	0.501	0.250	1
183	LO	2,100	7.95	2.16E-06	1.99	4.00	2.49	0.286	0.250	1
184	LO	2,000	7.57	2.40E-05	1.88	4.03	2.38	0.323	0.250	1
185	LO	2,000	7.57	1.39E-05	1.86	4.06	2.36	0.800	0.250	1
186	LO	2,300	8.71	1.35E-03	2.13	4.08	2.63	0.548	0.250	1
187	LO	2,200	8.33	4.42E-03	2.03	4.10	1.30	0.436	0.250	1
188	LO	3,000	11.36	4.80E-05	2.76	4.11	3.00	0.276	0.250	1
189	LO	1,800	6.81	2.16E-06	1.62	4.21	2.12	0.639	0.250	1
190	LO	2,000	7.57	2.44E-05	1.79	4.23	2.29	0.546	0.250	1
191	LO	2,500	9.46	2.80E-02	2.22	4.26	2.72	0.684	0.250	1
192	LO	2,800	10.60	5.61E-06	2.48	4.28	1.20	0.552	0.250	1
193	LO	2,150	8.14	9.01E-04	1.88	4.33	2.38	0.478	0.250	1
194	LO	2,500	9.46	3.43E-03	2.17	4.36	2.67	0.306	0.250	1
195	LO	2,000	7.57	4.80E-06	1.69	4.47	1.20	0.321	0.250	1
196	LO	3,230	12.23	6.67E-04	2.69	4.55	2.60	0.350	0.250	1

(continued)

Table 3B-3. (continued)

Tank Index	Aeration Level	Size (gal)	Capacity (m^3)	Through-put (m^3/s)	Depth (m)	Surface Area (m^2)	Source Height (m)	Fraction Aerated	Total Aerator Horse-power	Number of Impellers/ Aerators
ATIndex				Q_wmu	d_wmu	SrcArea	SHight	F_aer	Powr	n_imp
197	LO	3,000	11.36	1.44E-06	2.49	4.57	2.99	0.507	0.250	1
198	LO	2,400	9.08	6.67E-04	1.96	4.64	2.46	0.800	0.250	1
199	LO	2,500	9.46	1.44E-05	2.03	4.66	2.53	0.480	0.250	1
200	LO	3,000	11.36	1.01E-02	2.43	4.67	2.93	0.465	0.250	1
201	LO	2,000	7.57	1.15E-04	1.62	4.67	1.90	0.593	0.250	1
202	LO	2,500	9.46	2.80E-02	2.02	4.68	1.10	0.453	0.250	1
203	LO	2,500	9.46	1.38E-07	2.02	4.68	2.52	0.474	0.250	1
204	LO	3,100	11.73	1.33E-02	2.50	4.69	3.00	0.470	0.250	1
205	LO	3,000	11.36	1.09E-03	2.42	4.69	2.92	0.561	0.250	1
206	LO	2,220	8.40	1.35E-03	1.79	4.70	2.29	0.555	0.250	1
207	LO	3,000	11.36	4.80E-05	2.38	4.76	2.88	0.355	0.250	1
208	LO	2,400	9.08	1.73E-04	1.89	4.79	0.50	0.527	0.250	1
209	LO	2,550	9.65	5.48E-04	2.01	4.81	0.50	0.678	0.250	1
210	LO	3,800	14.38	7.32E-06	2.94	4.89	3.44	0.574	0.250	1
211	LO	3,300	12.49	2.55E-04	2.54	4.92	3.04	0.675	0.250	1
212	LO	3,000	11.36	3.66E-05	2.31	4.92	2.81	0.472	0.250	1
213	LO	2,700	10.22	2.64E-06	2.08	4.92	2.58	0.592	0.250	1
214	LO	3,000	11.36	1.01E-02	2.30	4.93	0.60	0.623	0.250	1
215	LO	3,000	11.36	1.44E-06	2.29	4.96	2.79	0.555	0.250	1
216	LO	2,400	9.08	5.22E-03	1.81	5.01	2.31	0.380	0.250	1
217	LO	3,100	11.73	4.96E-03	2.33	5.04	2.83	0.472	0.250	1
218	LO	4,000	15.14	1.36E-06	2.99	5.06	3.49	0.434	0.250	1
219	LO	3,300	12.49	2.55E-04	2.47	5.06	2.97	0.746	0.250	1
220	LO	2,400	9.08	1.40E-04	1.79	5.09	2.29	0.603	0.250	1
221	LO	3,100	11.73	1.98E-05	2.30	5.10	2.80	0.441	0.250	1
222	LO	3,800	14.38	6.14E-06	2.81	5.12	3.31	0.322	0.250	1
223	LO	3,400	12.87	1.90E-03	2.50	5.14	3.00	0.482	0.250	1
224	LO	3,100	11.73	5.01E-03	2.25	5.21	0.90	0.514	0.250	1
225	LO	3,100	11.73	1.98E-05	2.24	5.23	2.74	0.330	0.250	1
226	LO	3,500	13.25	1.09E-02	2.50	5.31	3.00	0.608	0.250	1
227	LO	3,384	12.81	2.07E-02	2.40	5.33	2.90	0.754	0.250	1
228	LO	3,000	11.36	1.08E-04	2.13	5.34	2.63	0.617	0.250	1
229	LO	2,500	9.46	3.43E-03	1.76	5.37	2.26	0.360	0.250	1
230	LO	4,000	15.14	1.50E-05	2.80	5.40	3.30	0.512	0.250	1
231	LO	3,000	11.36	1.82E-03	2.09	5.44	0.50	0.800	0.250	1
232	LO	3,000	11.36	7.20E-06	2.09	5.44	2.59	0.527	0.250	1
233	LO	3,000	11.36	1.08E-04	2.06	5.51	2.56	0.475	0.250	1
234	LO	3,000	11.36	6.24E-03	2.05	5.53	2.55	0.712	0.250	1
235	LO	2,200	8.33	4.42E-03	1.50	5.54	0.90	0.665	0.250	1
236	LO	4,000	15.14	2.11E-04	2.71	5.59	3.21	0.255	0.250	1
237	LO	4,100	15.52	8.17E-03	2.77	5.60	3.27	0.515	0.250	1
238	LO	4,000	15.14	1.36E-06	2.67	5.68	3.17	0.200	0.250	1
239	LO	3,350	12.68	2.49E-01	2.21	5.73	2.71	0.304	0.250	1
240	LO	4,200	15.90	9.86E-03	2.73	5.83	3.23	0.455	0.250	1
241	LO	4,200	15.90	9.86E-03	2.73	5.83	3.23	0.257	0.250	1
242	LO	2,000	7.57	1.90E-03	1.27	5.96	1.77	0.514	0.250	1
243	LO	3,400	12.87	8.17E-03	2.15	5.98	2.65	0.376	0.250	1
244	LO	4,320	16.35	9.23E-05	2.73	5.98	3.23	0.200	0.250	1
245	LO	4,000	15.14	4.71E-05	2.49	6.08	2.99	0.631	0.250	1

(continued)

Table 3B-3. (continued)

Tank Index	Aeration Level	Size (gal)	Capacity (m^3)	Through-put (m^3/s)	Depth (m)	Surface Area (m^2)	Source Height (m)	Fraction Aerated	Total Aerator Horse-power	Number of Impellers/ Aerators
ATIndex				Q_wmu	d_wmu	SrcArea	SHight	F_aer	Powr	n_imp
246	LO	5,000	18.93	1.92E-05	3.11	6.09	3.61	0.622	0.250	1
247	LO	4,000	15.14	1.50E-05	2.47	6.13	2.30	0.273	0.250	1
248	LO	4,000	15.14	1.80E-05	2.47	6.13	2.97	0.469	0.250	1
249	LO	3,500	13.25	7.75E-05	2.16	6.14	2.66	0.493	0.250	1
250	LO	4,000	15.14	6.04E-05	2.45	6.17	2.95	0.439	0.250	1
251	LO	3,600	13.63	4.29E-04	2.19	6.21	2.69	0.200	0.250	1
252	LO	4,200	15.90	9.86E-03	2.53	6.28	3.03	0.526	0.250	1
253	LO	3,945	14.93	1.53E-04	2.37	6.31	2.87	0.800	0.250	1
254	LO	3,600	13.63	4.29E-04	2.15	6.33	2.65	0.217	0.250	1
255	LO	4,600	17.41	1.38E-03	2.72	6.39	3.22	0.575	0.250	1
256	LO	4,000	15.14	1.36E-06	2.34	6.48	2.84	0.800	0.250	1
257	LO	4,000	15.14	6.24E-03	2.32	6.53	2.82	0.425	0.250	1
258	LO	4,700	17.79	2.18E-05	2.70	6.59	1.60	0.251	0.250	1
259	LO	4,000	15.14	1.36E-06	2.29	6.61	2.79	0.369	0.250	1
260	LO	3,445	13.04	4.20E-03	1.93	6.74	2.43	0.321	0.250	1
261	LO	4,000	15.14	5.61E-06	2.24	6.77	2.74	0.795	0.250	1
262	LO	4,300	16.28	1.40E-02	2.40	6.78	2.90	0.586	0.250	1
263	LO	4,400	16.66	3.60E-03	2.41	6.90	2.91	0.290	0.250	1
264	LO	5,000	18.93	1.23E-04	2.74	6.91	3.24	0.552	0.250	1
265	LO	4,500	17.03	9.36E-06	2.44	6.99	2.94	0.573	0.250	1
266	LO	5,000	18.93	3.00E-05	2.70	7.02	2.10	0.200	0.250	1
267	LO	3,780	14.31	1.38E-07	2.02	7.10	2.52	0.433	0.250	1
268	LO	4,200	15.90	4.68E-07	2.20	7.24	2.70	0.295	0.250	1
269	LO	5,800	21.96	4.80E-04	3.02	7.27	3.50	0.200	0.250	1
270	LO	5,000	18.93	2.76E-06	2.59	7.30	3.09	0.347	0.250	1
271	LO	5,800	21.96	2.52E-02	3.00	7.31	3.50	0.620	0.250	1
272	LO	4,700	17.79	2.42E-05	2.42	7.34	2.92	0.238	0.250	1
273	LO	5,000	18.93	1.23E-04	2.56	7.40	3.06	0.381	0.250	1
274	LO	4,000	15.14	9.60E-05	2.04	7.41	2.54	0.273	0.250	1
275	LO	5,800	21.96	2.52E-02	2.93	7.49	3.43	0.800	0.274	1
276	LO	5,400	20.44	1.84E-04	2.68	7.62	3.18	0.304	0.250	1
277	LO	5,500	20.82	8.11E-03	2.70	7.70	3.20	0.467	0.250	1
278	LO	4,320	16.35	9.23E-05	2.11	7.74	2.60	0.694	0.250	1
279	LO	4,320	16.35	9.23E-05	2.10	7.78	2.60	0.610	0.250	1
280	LO	4,500	17.03	1.82E-03	2.19	7.79	0.50	0.427	0.250	1
281	LO	5,600	21.20	3.15E-04	2.67	7.94	1.90	0.338	0.250	1
282	LO	5,000	18.93	4.99E-05	2.38	7.95	0.50	0.536	0.250	1
283	LO	5,000	18.93	7.41E-05	2.34	8.10	2.84	0.654	0.254	1
284	LO	6,000	22.71	1.07E-02	2.78	8.18	3.28	0.784	0.250	1
285	LO	5,000	18.93	7.41E-05	2.31	8.20	0.90	0.403	0.250	1
286	LO	5,000	18.93	4.37E-03	2.27	8.34	2.77	0.402	0.250	1
287	LO	7,500	28.39	1.78E-05	3.34	8.50	3.84	0.413	0.250	1
288	LO	5,000	18.93	4.68E-05	2.21	8.56	2.71	0.323	0.250	1
289	LO	5,000	18.93	1.92E-05	2.21	8.58	2.71	0.445	0.250	1
290	LO	7,100	26.88	3.53E-06	3.12	8.61	3.62	0.460	0.250	1
291	LO	4,500	17.03	6.79E-03	1.97	8.66	2.47	0.403	0.250	1
292	LO	5,000	18.93	2.76E-06	2.18	8.69	2.68	0.492	0.250	1
293	LO	6,000	22.71	4.80E-06	2.56	8.86	3.06	0.411	0.250	1
294	LO	6,000	22.71	8.01E-04	2.51	9.05	3.01	0.466	0.275	1

(continued)

Table 3B-3. (continued)

Tank Index	Aeration Level	Size (gal)	Capacity (m^3)	Through-put (m^3/s)	Depth (m)	Surface Area (m^2)	Source Height (m)	Fraction Aerated	Total Aerator Horse-power	Number of Impellers/ Aerators
ATIndex				Q_wmu	d_wmu	SrcArea	SHight	F_aer	Powr	n_imp
295	LO	6,000	22.71	8.01E-04	2.50	9.07	3.00	0.561	0.250	1
296	LO	6,390	24.19	4.64E-03	2.65	9.11	3.15	0.624	0.250	1
297	LO	6,850	25.93	5.04E-03	2.80	9.25	3.30	0.349	0.250	1
298	LO	4,700	17.79	2.42E-05	1.92	9.27	2.42	0.316	0.250	1
299	LO	8,000	30.28	2.27E-05	3.27	9.27	3.77	0.442	0.283	1
300	LO	4,000	15.14	2.74E-05	1.63	9.28	2.13	0.750	0.250	1
301	LO	6,500	24.61	4.77E-03	2.60	9.47	3.10	0.483	0.250	1
302	LO	7,000	26.50	1.24E-03	2.77	9.56	0.70	0.598	0.250	1
303	LO	4,000	15.14	1.80E-04	1.56	9.72	2.06	0.494	0.250	1
304	LO	7,500	28.39	1.87E-05	2.91	9.77	3.41	0.251	0.250	1
305	LO	7,000	26.50	8.20E-05	2.64	10.05	3.14	0.613	0.250	1
306	LO	9,000	34.07	7.74E-04	3.36	10.15	3.86	0.545	0.280	1
307	LO	7,500	28.39	1.78E-05	2.77	10.25	3.27	0.347	0.250	1
308	LO	8,000	30.28	2.68E-02	2.86	10.58	3.36	0.581	0.348	1
309	LO	7,000	26.50	9.72E-06	2.51	10.58	3.01	0.479	0.250	1
310	LO	7,500	28.39	1.46E-05	2.68	10.58	3.18	0.734	0.302	1
311	LO	7,680	29.07	2.41E-03	2.74	10.60	3.24	0.533	0.279	1
312	LO	8,500	32.18	4.48E-03	3.02	10.67	3.52	0.302	0.306	1
313	LO	6,171	23.36	1.60E-01	2.18	10.72	2.68	0.695	0.250	1
314	LO	7,000	26.50	2.93E-03	2.47	10.74	2.97	0.445	0.250	1
315	LO	7,000	26.50	1.09E-02	2.46	10.77	2.96	0.627	0.250	1
316	LO	6,800	25.74	2.81E-03	2.38	10.83	1.00	0.583	0.250	1
317	LO	7,500	28.39	1.73E-03	2.61	10.88	3.11	0.620	0.250	1
318	LO	7,000	26.50	1.87E-05	2.43	10.92	2.93	0.456	0.300	1
319	LO	5,800	21.96	4.80E-04	2.01	10.94	2.51	0.368	0.250	1
320	LO	9,000	34.07	7.74E-04	3.11	10.95	3.61	0.303	0.327	1
321	LO	7,500	28.39	1.87E-05	2.59	10.96	3.09	0.541	0.311	1
322	LO	7,000	26.50	2.93E-03	2.41	11.00	2.91	0.516	0.250	1
323	LO	6,800	25.74	2.81E-03	2.33	11.06	1.50	0.765	0.250	1
324	LO	7,500	28.39	6.55E-06	2.56	11.07	3.06	0.538	0.285	1
325	LO	7,500	28.39	1.46E-05	2.55	11.12	3.05	0.478	0.314	1
326	LO	8,000	30.28	1.60E-01	2.70	11.23	3.20	0.738	0.250	1
327	LO	11,200	42.40	1.34E-03	3.75	11.29	4.25	0.553	0.250	1
328	LO	9,000	34.07	2.88E-03	2.99	11.38	3.49	0.347	0.250	1
329	LO	9,000	34.07	1.48E-05	2.96	11.53	2.20	0.658	0.336	1
330	LO	9,300	35.20	1.98E-05	3.05	11.55	3.55	0.498	0.284	1
331	LO	7,500	28.39	6.55E-06	2.45	11.58	2.95	0.351	0.250	1
332	LO	7,500	28.39	1.78E-05	2.44	11.64	2.94	0.780	0.292	1
333	LO	8,000	30.28	9.95E-04	2.59	11.70	3.09	0.800	0.250	1
334	LO	9,000	34.07	1.51E-02	2.88	11.83	2.90	0.800	0.303	1
335	LO	9,000	34.07	1.51E-02	2.87	11.87	3.37	0.768	0.374	1
336	LO	10,000	37.85	9.60E-04	3.11	12.17	3.61	0.369	0.417	1
337	LO	9,100	34.45	1.46E-03	2.82	12.20	3.32	0.565	0.282	1
338	LO	9,900	37.48	3.03E-03	3.06	12.25	3.56	0.466	0.360	1
339	LO	8,000	30.28	7.52E-05	2.46	12.29	2.96	0.470	0.424	1
340	LO	10,000	37.85	7.82E-05	3.08	12.30	3.58	0.578	0.423	1
341	LO	8,000	30.28	6.79E-05	2.45	12.35	2.95	0.536	0.250	1
342	LO	9,000	34.07	1.48E-05	2.74	12.45	3.24	0.567	0.261	1
343	LO	9,000	34.07	1.51E-02	2.72	12.51	3.22	0.570	0.389	1

(continued)

Table 3B-3. (continued)

Tank Index	Aeration Level	Size (gal)	Capacity (m^3)	Through-put (m^3/s)	Depth (m)	Surface Area (m^2)	Source Height (m)	Fraction Aerated	Total Aerator Horse-power	Number of Impellers/ Aerators
ATIndex				Q_wmu	d_wmu	SrcArea	SHight	F_aer	Powr	n_imp
344	LO	6,850	25.93	5.04E-03	2.07	12.53	2.57	0.579	0.250	1
345	LO	10,000	37.85	1.20E-04	3.01	12.57	3.51	0.758	0.260	1
346	LO	10,000	37.85	4.05E-04	2.99	12.64	3.30	0.297	0.354	1
347	LO	10,000	37.85	4.08E-05	2.98	12.69	3.48	0.234	0.316	1
348	LO	7,680	29.07	2.41E-03	2.27	12.83	2.77	0.463	0.273	1
349	LO	9,000	34.07	2.67E-02	2.62	13.00	3.12	0.477	0.250	1
350	LO	10,000	37.85	1.50E-03	2.91	13.00	3.41	0.719	0.338	1
351	LO	8,000	30.28	9.95E-04	2.32	13.04	2.82	0.578	0.278	1
352	LO	10,000	37.85	4.08E-05	2.88	13.13	3.38	0.710	0.250	1
353	LO	10,000	37.85	2.19E-02	2.86	13.25	3.36	0.204	0.420	1
354	LO	11,000	41.64	3.42E-04	3.14	13.27	3.64	0.510	0.250	1
355	LO	10,000	37.85	6.60E-05	2.85	13.28	3.35	0.384	0.250	1
356	LO	10,885	41.20	2.70E-03	3.09	13.34	3.59	0.427	0.314	1
357	LO	9,000	34.07	1.51E-02	2.55	13.38	3.05	0.372	0.276	1
358	LO	10,000	37.85	4.08E-05	2.79	13.59	3.29	0.577	0.336	1
359	LO	12,000	45.42	1.50E-04	3.33	13.65	3.83	0.466	0.313	1
360	LO	9,000	34.07	1.51E-02	2.49	13.66	2.99	0.438	0.250	1
361	LO	9,300	35.20	1.98E-05	2.56	13.77	0.50	0.750	0.250	1
362	LO	9,000	34.07	7.74E-04	2.47	13.77	2.97	0.442	0.250	1
363	LO	12,000	45.42	2.40E-03	3.28	13.87	3.78	0.592	0.399	1
364	LO	10,000	37.85	9.12E-06	2.72	13.94	3.22	0.408	0.250	1
365	LO	10,000	37.85	7.82E-05	2.69	14.06	3.10	0.772	0.273	1
366	LO	10,000	37.85	1.09E-02	2.68	14.11	3.18	0.708	0.479	1
367	LO	12,800	48.45	3.74E-04	3.40	14.26	3.90	0.553	0.440	1
368	LO	10,000	37.85	4.08E-05	2.65	14.26	3.15	0.527	0.307	1
369	LO	10,000	37.85	9.72E-06	2.65	14.29	3.15	0.564	0.363	1
370	LO	10,000	37.85	9.60E-04	2.64	14.35	3.14	0.550	0.446	1
371	LO	10,000	37.85	9.60E-04	2.63	14.39	3.13	0.707	0.250	1
372	LO	10,000	37.85	4.80E-04	2.61	14.48	3.11	0.315	0.331	1
373	LO	12,600	47.70	1.51E-02	3.24	14.72	3.74	0.617	0.250	1
374	LO	10,000	37.85	1.50E-03	2.57	14.74	3.07	0.690	0.250	1
375	LO	10,000	37.85	3.81E-03	2.56	14.76	3.06	0.515	0.250	1
376	LO	11,000	41.64	3.42E-04	2.80	14.86	3.30	0.631	0.250	1
377	LO	10,000	37.85	5.45E-03	2.52	15.05	3.02	0.200	0.250	1
378	LO	12,000	45.42	5.06E-03	2.99	15.18	3.49	0.279	0.689	1
379	LO	10,640	40.28	2.70E-03	2.65	15.20	3.15	0.648	0.370	1
380	LO	15,000	56.78	1.19E-03	3.72	15.28	4.22	0.645	0.639	1
381	LO	13,400	50.72	2.80E-02	3.31	15.32	3.81	0.685	0.250	1
382	LO	12,000	45.42	1.50E-04	2.96	15.35	3.46	0.459	0.250	1
383	LO	11,360	43.00	2.70E-03	2.79	15.43	3.29	0.700	0.410	1
384	LO	12,000	45.42	5.52E-03	2.91	15.59	3.41	0.367	0.250	1
385	LO	15,000	56.78	4.66E-03	3.62	15.67	3.20	0.476	0.479	1
386	LO	12,500	47.32	1.50E-04	3.02	15.68	3.52	0.662	0.250	1
387	LO	12,800	48.45	3.74E-04	3.08	15.74	3.58	0.279	0.299	1
388	LO	8,000	30.28	1.50E-05	1.92	15.78	2.42	0.321	0.336	1
389	LO	13,500	51.10	8.08E-03	3.21	15.90	3.71	0.689	0.312	1
390	LO	8,700	32.93	1.09E-05	2.07	15.90	2.57	0.225	0.254	1
391	LO	10,000	37.85	4.05E-04	2.34	16.16	2.84	0.615	0.564	1
392	LO	12,000	45.42	6.24E-05	2.81	16.18	3.31	0.325	0.450	1

(continued)

Table 3B-3. (continued)

Tank Index	Aeration Level	Size (gal)	Capacity (m^3)	Through-put (m^3/s)	Depth (m)	Surface Area (m^2)	Source Height (m)	Fraction Aerated	Total Aerator Horse-power	Number of Impellers/ Aerators
ATIndex				Q_wmu	d_wmu	SrcArea	SHight	F_aer	Powr	n_imp
393	LO	12,000	45.42	3.86E-04	2.79	16.27	3.29	0.736	0.359	1
394	LO	11,000	41.64	3.42E-04	2.55	16.36	3.05	0.453	0.340	1
395	LO	8,500	32.18	4.48E-03	1.94	16.57	2.44	0.200	0.250	1
396	LO	12,500	47.32	1.50E-04	2.81	16.84	3.31	0.588	0.513	1
397	LO	12,000	45.42	1.57E-01	2.65	17.17	3.15	0.487	0.284	1
398	LO	12,000	45.42	1.25E-03	2.63	17.24	3.13	0.800	0.506	1
399	LO	12,000	45.42	1.44E-06	2.63	17.24	3.13	0.764	0.342	1
400	LO	11,200	42.40	1.34E-03	2.45	17.31	2.95	0.745	0.399	1
401	LO	11,200	42.40	1.34E-03	2.44	17.39	2.94	0.495	0.250	1
402	LO	12,000	45.42	1.19E-03	2.61	17.39	3.11	0.445	0.347	1
403	LO	10,000	37.85	1.09E-03	2.18	17.40	2.68	0.205	0.250	1
404	LO	15,000	56.78	2.85E-05	3.25	17.46	3.75	0.800	0.551	1
405	LO	12,000	45.42	3.86E-04	2.60	17.47	3.10	0.405	0.387	1
406	LO	12,000	45.42	6.24E-05	2.58	17.59	3.08	0.458	0.357	1
407	LO	11,000	41.64	3.42E-04	2.36	17.68	2.86	0.538	0.286	1
408	LO	15,000	56.78	1.37E-02	3.18	17.88	3.68	0.496	0.464	1
409	LO	15,000	56.78	2.19E-03	3.16	17.96	3.66	0.498	0.264	1
410	LO	11,200	42.40	1.34E-03	2.34	18.09	2.84	0.739	0.373	1
411	LO	11,500	43.53	4.80E-06	2.37	18.36	2.87	0.442	0.250	1
412	LO	14,490	54.85	9.37E-03	2.98	18.41	2.70	0.200	0.691	1
413	LO	13,500	51.10	8.08E-03	2.77	18.44	3.27	0.499	0.343	1
414	LO	12,000	45.42	1.44E-01	2.44	18.61	2.94	0.282	0.329	1
415	LO	16,000	60.57	1.44E-03	3.24	18.68	3.74	0.646	0.250	1
416	LO	12,000	45.42	1.25E-03	2.42	18.78	2.92	0.286	0.250	1
417	LO	14,950	56.59	2.70E-03	3.01	18.79	3.51	0.505	0.608	1
418	LO	12,800	48.45	3.74E-04	2.57	18.83	3.07	0.515	0.379	1
419	LO	13,500	51.10	9.23E-05	2.70	18.90	3.20	0.200	0.351	1
420	LO	15,000	56.78	3.86E-04	2.98	19.03	3.48	0.461	0.349	1
421	LO	13,400	50.72	2.80E-02	2.65	19.14	3.15	0.493	0.389	1
422	LO	15,000	56.78	3.42E-04	2.95	19.27	3.45	0.600	0.411	1
423	LO	14,950	56.59	2.70E-03	2.91	19.43	3.41	0.557	0.648	1
424	LO	13,400	50.72	2.80E-02	2.61	19.43	3.11	0.451	0.312	1
425	LO	15,000	56.78	1.19E-03	2.91	19.51	3.41	0.200	0.620	1
426	LO	13,400	50.72	4.99E-05	2.56	19.84	3.06	0.780	0.250	1
427	LO	15,000	56.78	3.42E-04	2.86	19.85	3.36	0.784	0.400	1
428	LO	14,000	53.00	2.94E-04	2.65	19.96	2.20	0.512	0.289	1
429	LO	12,000	45.42	3.86E-04	2.27	20.03	2.77	0.628	0.455	1
430	LO	15,000	56.78	3.42E-04	2.80	20.29	3.30	0.657	0.544	1
431	LO	15,000	56.78	7.24E-07	2.80	20.29	1.10	0.469	0.452	1
432	LO	15,000	56.78	3.42E-04	2.79	20.35	3.29	0.465	0.513	1
433	LO	13,000	49.21	4.82E-03	2.41	20.43	2.91	0.443	0.310	1
434	LO	20,000	75.71	1.85E-04	3.70	20.44	4.20	0.800	0.399	1
435	LO	12,800	48.45	3.81E-04	2.35	20.66	2.85	0.563	0.349	1
436	LO	15,000	56.78	1.19E-03	2.72	20.88	3.22	0.455	0.372	1
437	LO	15,000	56.78	3.42E-04	2.71	20.94	3.21	0.654	0.260	1
438	LO	17,000	64.35	2.52E-05	3.05	21.11	3.55	0.613	0.404	1
439	LO	20,000	75.71	1.85E-04	3.52	21.53	4.02	0.660	0.781	1
440	LO	20,000	75.71	5.42E-04	3.50	21.66	4.00	0.283	0.581	1
441	LO	15,500	58.67	4.46E-04	2.69	21.80	3.19	0.513	0.609	1

(continued)

Table 3B-3. (continued)

Tank Index	Aeration Level	Size (gal)	Capacity (m^3)	Through-put (m^3/s)	Depth (m)	Surface Area (m^2)	Source Height (m)	Fraction Aerated	Total Aerator Horse-power	Number of Impellers/ Aerators
ATIndex				Q_wmu	d_wmu	SrcArea	SHight	F_aer	Powr	n_imp
442	LO	13,400	50.72	2.80E-02	2.32	21.87	2.82	0.416	0.297	1
443	LO	20,000	75.71	3.60E-05	3.45	21.91	3.95	0.356	0.431	1
444	LO	20,000	75.71	1.14E-04	3.44	22.00	3.94	0.572	0.528	1
445	LO	15,000	56.78	2.26E-05	2.56	22.21	3.06	0.200	0.550	1
446	LO	15,000	56.78	1.50E-05	2.54	22.34	3.04	0.321	0.250	1
447	LO	15,000	56.78	1.19E-03	2.51	22.64	3.01	0.232	0.345	1
448	LO	20,000	75.71	1.14E-04	3.33	22.72	3.83	0.250	0.250	1
449	LO	20,000	75.71	2.06E-01	3.30	22.93	3.80	0.375	0.457	1
450	LO	15,000	56.78	1.50E-03	2.46	23.05	2.96	0.687	0.535	1
451	LO	15,000	56.78	8.15E-04	2.46	23.08	2.96	0.744	0.576	1
452	LO	20,000	75.71	6.24E-03	3.25	23.30	3.75	0.503	0.801	1
453	LO	20,000	75.71	1.85E-04	3.21	23.56	3.71	0.320	0.538	1
454	LO	21,600	81.76	3.00E-04	3.44	23.79	3.94	0.452	0.697	1
455	LO	24,000	90.85	1.80E-05	3.79	23.99	4.29	0.525	0.480	1
456	LO	20,000	75.71	1.06E-03	3.15	24.02	3.65	0.496	0.329	1
457	LO	20,000	75.71	5.42E-04	3.14	24.11	3.64	0.538	0.570	1
458	LO	15,000	56.78	4.66E-03	2.35	24.20	2.85	0.529	0.250	1
459	LO	15,000	56.78	1.50E-04	2.33	24.33	1.70	0.569	0.582	1
460	LO	21,000	79.49	3.02E-07	3.25	24.46	3.75	0.253	0.665	1
461	LO	15,000	56.78	2.23E-05	2.30	24.68	2.80	0.800	0.250	1
462	LO	20,000	75.71	5.04E-03	3.03	24.99	3.53	0.550	0.614	1
463	LO	21,000	79.49	1.44E-03	3.17	25.06	3.20	0.519	0.563	1
464	LO	20,000	75.71	1.85E-04	3.02	25.11	3.52	0.372	0.289	1
465	LO	20,000	75.71	3.60E-05	3.00	25.23	3.50	0.408	0.808	1
466	LO	21,000	79.49	3.02E-07	3.15	25.25	3.65	0.611	0.720	1
467	LO	20,000	75.71	5.04E-03	2.99	25.28	3.49	0.402	0.286	1
468	LO	20,000	75.71	3.79E-05	2.97	25.46	2.30	0.554	0.636	1
469	LO	20,000	75.71	1.06E-03	2.86	26.51	3.36	0.501	0.495	1
470	LO	20,000	75.71	3.57E-04	2.84	26.66	3.34	0.581	0.871	1
471	LO	23,540	89.11	2.70E-03	3.28	27.13	3.78	0.200	0.742	1
472	LO	26,930	101.94	5.06E-06	3.74	27.24	2.50	0.308	1.269	1
473	LO	20,000	75.71	5.04E-03	2.78	27.25	3.28	0.800	0.766	1
474	LO	25,000	94.63	9.00E-04	3.43	27.57	3.93	0.500	0.975	1
475	LO	20,000	75.71	1.14E-04	2.71	27.90	1.10	0.557	0.790	1
476	LO	23,000	87.06	1.46E-02	3.07	28.37	3.57	0.370	0.719	1
477	LO	20,948	79.30	7.32E-05	2.78	28.52	3.28	0.800	0.730	1
478	LO	21,000	79.49	4.48E-03	2.78	28.59	3.28	0.429	0.717	1
479	LO	25,000	94.63	5.46E-03	3.25	29.14	3.75	0.548	1.079	1
480	LO	15,000	56.78	1.78E-05	1.94	29.25	2.44	0.339	0.331	1
481	LO	25,000	94.63	5.96E-02	3.24	29.25	2.80	0.394	0.832	1
482	LO	14,360	54.36	6.79E-03	1.85	29.42	2.35	0.558	0.499	1
483	LO	25,000	94.63	5.46E-03	3.19	29.70	1.50	0.284	0.891	1
484	LO	24,000	90.85	1.46E-02	3.03	29.98	3.53	0.555	0.739	1
485	LO	20,000	75.71	5.42E-04	2.52	30.07	3.02	0.530	0.547	1
486	LO	25,000	94.63	9.00E-04	3.11	30.44	3.61	0.424	0.532	1
487	LO	20,000	75.71	4.80E-06	2.48	30.58	2.98	0.528	0.864	1
488	LO	30,000	113.56	1.09E-05	3.71	30.58	4.21	0.580	1.345	1
489	LO	26,930	101.94	5.06E-06	3.30	30.89	3.80	0.200	0.250	1
490	LO	21,000	79.49	4.50E-04	2.56	31.09	3.06	0.537	0.537	1

(continued)

Table 3B-3. (continued)

Tank Index	Aeration Level	Size (gal)	Capacity (m^3)	Through-put (m^3/s)	Depth (m)	Surface Area (m^2)	Source Height (m)	Fraction Aerated	Total Aerator Horse-power	Number of Impellers/ Aerators
ATIndex				Q_wmu	d_wmu	SrcArea	SHight	F_aer	Powr	n_imp
491	LO	20,000	75.71	5.42E-04	2.34	32.29	2.84	0.739	0.649	1
492	LO	20,000	75.71	3.79E-05	2.34	32.32	2.84	0.567	0.446	1
493	LO	26,000	98.42	1.87E-03	2.96	33.28	0.50	0.541	0.641	1
494	LO	30,000	113.56	4.65E-04	3.40	33.42	3.90	0.546	1.330	1
495	LO	25,000	94.63	2.87E-03	2.83	33.49	3.33	0.650	0.895	1
496	LO	26,000	98.42	1.86E-05	2.92	33.71	3.42	0.421	0.452	1
497	LO	26,930	101.94	5.06E-06	3.02	33.80	1.90	0.327	0.660	1
498	LO	22,000	83.28	1.36E-03	2.46	33.90	2.96	0.800	0.630	1
499	LO	35,000	132.49	5.51E-05	3.81	34.77	4.31	0.432	0.910	1
500	LO	25,000	94.63	9.00E-04	2.71	34.95	3.21	0.751	0.492	1
501	LO	26,930	101.94	5.06E-06	2.91	35.05	3.41	0.800	1.295	1
502	LO	28,000	105.99	3.23E-03	3.01	35.21	3.51	0.436	1.147	1
503	LO	33,000	124.92	1.07E-01	3.53	35.41	4.03	0.554	1.352	1
504	LO	29,000	109.78	5.04E-03	3.08	35.66	3.58	0.597	0.933	1
505	LO	20,000	75.71	1.30E-05	2.11	35.83	2.61	0.527	0.804	1
506	LO	34,000	128.70	9.26E-04	3.51	36.72	4.01	0.478	0.729	1
507	LO	33,000	124.92	2.25E-03	3.32	37.64	3.82	0.518	1.312	1
508	LO	37,300	141.20	5.57E-06	3.74	37.77	4.24	0.359	1.200	1
509	LO	21,200	80.25	5.14E-03	2.12	37.77	2.62	0.598	0.688	1
510	LO	25,000	94.63	2.87E-03	2.47	38.30	2.97	0.388	1.021	1
511	LO	28,000	105.99	1.06E-03	2.74	38.65	3.24	0.652	1.054	1
512	LO	34,000	128.70	3.86E-06	3.33	38.67	3.83	0.584	1.395	1
513	LO	35,000	132.49	4.66E-05	3.42	38.74	1.20	0.272	1.142	1
514	LO	30,000	113.56	3.84E-03	2.93	38.76	3.43	0.468	0.721	1
515	LO	26,930	101.94	5.06E-06	2.62	38.89	3.12	0.524	1.169	1
516	LO	26,930	101.94	5.06E-06	2.60	39.27	1.40	0.800	0.909	1
517	LO	24,300	91.99	1.44E-06	2.31	39.85	2.81	0.784	0.589	1
518	LO	35,000	132.49	2.49E-03	3.28	40.39	3.78	0.541	0.793	1
519	LO	25,000	94.63	9.00E-04	2.34	40.47	2.84	0.473	0.788	1
520	LO	36,000	136.27	1.80E-05	3.34	40.84	0.50	0.293	1.847	1
521	LO	40,000	151.42	7.64E-05	3.69	41.00	0.50	0.204	1.180	1
522	LO	37,300	141.20	5.57E-06	3.43	41.18	3.93	0.495	1.070	1
523	LO	41,000	155.20	2.79E-03	3.75	41.36	4.25	0.705	1.458	1
524	LO	41,000	155.20	2.28E-03	3.72	41.70	4.22	0.449	1.925	1
525	LO	40,000	151.42	2.96E-02	3.61	41.92	4.11	0.358	0.988	1
526	LO	40,465	153.18	6.76E-03	3.49	43.89	3.99	0.523	1.385	1
527	LO	40,000	151.42	2.16E-05	3.40	44.50	3.90	0.389	1.925	1
528	LO	40,933	154.95	2.57E-01	3.46	44.79	3.96	0.684	1.428	1
529	LO	50,000	189.27	7.44E-04	4.12	45.96	4.62	0.403	1.820	1
530	LO	30,000	113.56	7.20E-03	2.46	46.12	2.96	0.691	0.836	1
531	LO	40,000	151.42	2.87E-05	3.28	46.20	3.78	0.453	1.625	1
532	LO	40,000	151.42	2.96E-02	3.27	46.24	3.77	0.200	0.560	1
533	LO	37,000	140.06	1.07E-01	3.01	46.55	3.51	0.458	1.599	1
534	LO	47,300	179.05	2.05E-03	3.80	47.10	4.30	0.641	1.775	1
535	LO	41,000	155.20	2.79E-03	3.17	48.95	3.67	0.307	1.204	1
536	LO	37,300	141.20	5.57E-06	2.88	49.00	3.38	0.626	0.906	1
537	LO	46,000	174.13	2.28E-03	3.55	49.04	1.30	0.598	0.788	1
538	LO	41,000	155.20	2.79E-03	3.11	49.97	3.61	0.640	1.530	1
539	LO	47,000	177.91	1.07E-01	3.50	50.79	0.90	0.449	1.674	1

(continued)

Table 3B-3. (continued)

Tank Index	Aeration Level	Size (gal)	Capacity (m^3)	Through-put (m^3/s)	Depth (m)	Surface Area (m^2)	Source Height (m)	Fraction Aerated	Total Aerator Horse-power	Number of Impellers/ Aerators
ATIndex				Q_wmu	d_wmu	SrcArea	SHight	F_aer	Powr	n_imp
540	LO	48,600	183.97	6.67E-04	3.60	51.09	4.10	0.650	1.772	1
541	LO	55,000	208.20	7.08E-03	4.00	52.08	4.50	0.616	1.779	1
542	LO	46,000	174.13	2.41E-03	3.33	52.31	3.83	0.720	1.205	1
543	LO	40,000	151.42	7.64E-05	2.87	52.78	3.37	0.630	1.196	1
544	LO	40,000	151.42	2.96E-02	2.87	52.81	3.37	0.440	1.743	1
545	LO	54,000	204.41	1.63E-02	3.84	53.20	4.34	0.710	0.761	1
546	LO	55,000	208.20	2.72E-03	3.85	54.11	4.35	0.389	1.328	1
547	LO	55,000	208.20	2.72E-03	3.83	54.38	4.33	0.697	1.706	1
548	LO	50,000	189.27	2.68E-02	3.46	54.70	3.96	0.442	1.064	1
549	LO	55,000	208.20	2.81E-03	3.78	55.14	4.28	0.492	1.905	1
550	LO	37,300	141.20	5.57E-06	2.56	55.18	3.06	0.200	1.039	1
551	LO	61,500	232.80	1.34E-03	4.17	55.84	4.67	0.344	2.283	1
552	LO	55,000	208.20	2.81E-03	3.72	55.97	4.22	0.402	2.169	1
553	LO	57,000	215.77	2.24E-02	3.81	56.61	4.31	0.562	1.701	1
554	LO	50,000	189.27	4.80E-04	3.31	57.10	3.81	0.290	1.585	1
555	LO	61,500	232.80	1.34E-03	3.98	58.50	4.48	0.800	1.552	1
556	LO	48,500	183.59	4.50E-04	3.08	59.61	3.58	0.800	1.670	1
557	LO	50,000	189.27	4.02E-02	3.08	61.37	3.58	0.800	1.387	1
558	LO	50,000	189.27	2.72E-02	3.05	62.01	3.55	0.361	1.073	1
559	LO	61,500	232.80	1.34E-03	3.65	63.70	4.15	0.498	1.344	1
560	LO	50,000	189.27	8.77E-05	2.96	63.90	3.46	0.626	2.093	1
561	LO	48,500	183.59	4.50E-04	2.82	65.11	3.10	0.640	2.705	1
562	LO	67,000	253.62	5.80E-03	3.69	68.79	0.90	0.249	2.977	1
563	LO	65,000	246.05	7.84E-06	3.53	69.77	1.10	0.200	1.722	1
564	LO	65,000	246.05	1.05E-02	3.51	70.17	4.01	0.229	2.586	1
565	LO	46,000	174.13	5.04E-04	2.44	71.34	2.30	0.385	1.307	1
566	LO	48,000	181.70	3.47E-03	2.51	72.51	3.01	0.342	1.253	1
567	LO	80,000	302.83	5.04E-03	4.11	73.67	3.70	0.378	3.230	1
568	LO	80,000	302.83	5.04E-03	3.92	77.17	4.42	0.633	1.738	1
569	LO	55,000	208.20	2.81E-03	2.66	78.37	3.16	0.800	1.723	1
570	LO	65,000	246.05	7.84E-06	3.13	78.53	3.63	0.406	2.017	1
571	LO	80,000	302.83	8.07E-03	3.79	79.95	4.29	0.533	3.450	1
572	LO	80,000	302.83	5.04E-03	3.65	82.88	1.00	0.612	3.799	1
573	LO	75,830	287.05	4.37E-03	3.41	84.11	3.91	0.479	2.570	1
574	LO	72,000	272.55	2.42E-05	3.14	86.88	3.64	0.354	0.473	1
575	LO	100,000	378.54	2.89E-04	4.30	88.03	4.80	0.297	2.237	1
576	LO	87,000	329.33	1.07E-01	3.57	92.35	0.60	0.574	1.206	1
577	LO	125,000	473.17	3.00E-03	4.70	100.68	5.20	0.781	4.376	1
578	LO	117,800	445.92	9.02E-04	4.32	103.30	4.82	0.505	4.034	1
579	LO	120,000	454.25	4.96E-03	4.36	104.29	2.90	0.289	2.480	1
580	LO	80,000	302.83	8.07E-03	2.89	104.65	2.90	0.259	2.951	1
581	LO	92,400	349.77	3.22E-03	3.22	108.70	3.72	0.781	3.220	1
582	LO	120,000	454.25	7.20E-05	4.13	110.05	4.63	0.200	3.337	1
583	LO	92,400	349.77	3.22E-03	3.17	110.23	3.67	0.711	2.796	1
584	LO	120,000	454.25	7.56E-03	4.01	113.18	0.50	0.385	3.602	1
585	LO	100,000	378.54	2.89E-04	3.31	114.29	3.80	0.401	3.772	1
586	LO	119,700	453.11	1.51E-02	3.77	120.17	4.27	0.553	3.545	1
587	LO	100,000	378.54	2.68E-02	3.10	122.12	3.60	0.504	3.415	1
588	LO	110,000	416.39	1.89E-02	3.40	122.59	3.90	0.550	3.623	1

(continued)

Table 3B-3. (continued)

Tank Index	Aeration Level	Size (gal)	Capacity (m^3)	Through-put (m^3/s)	Depth (m)	Surface Area (m^2)	Source Height (m)	Fraction Aerated	Total Aerator Horse-power	Number of Impellers/ Aerators
ATIndex				Q_wmu	d_wmu	SrcArea	SHight	F_aer	Powr	n_imp
589	LO	119,700	453.11	1.51E-02	3.59	126.25	4.09	0.358	2.031	1
590	LO	103,600	392.17	1.05E-02	3.06	128.25	3.56	0.598	3.176	1
591	LO	150,000	567.81	1.55E-03	3.96	143.23	4.46	0.391	4.456	1
592	LO	200,000	757.08	4.71E-01	4.70	161.09	5.20	0.326	2.832	1
593	LO	210,000	794.93	1.89E-02	4.88	162.74	4.30	0.678	5.052	1
594	LO	200,000	757.08	4.71E-01	4.61	164.14	5.00	0.404	9.990	1
595	LO	225,000	851.71	2.86E-04	4.88	174.58	5.38	0.674	6.577	1
596	LO	200,000	757.08	4.71E-01	4.30	176.20	4.80	0.757	2.150	1
597	LO	135,000	511.03	2.68E-02	2.74	186.84	3.24	0.469	2.278	1
598	LO	250,000	946.35	4.88E-05	4.71	200.88	5.21	0.437	5.826	1
599	LO	250,000	946.35	4.88E-05	4.67	202.57	5.17	0.586	4.592	1
600	LO	250,000	946.35	2.44E-02	4.58	206.53	3.00	0.585	5.402	1
601	LO	187,000	707.87	8.64E-02	3.36	210.47	2.20	0.670	1.963	1
602	LO	300,000	1,135.62	2.67E-02	4.87	233.15	5.37	0.601	4.749	1
603	LO	250,000	946.35	4.88E-05	3.98	238.02	4.48	0.606	8.768	1
604	LO	320,000	1,211.33	6.00E-04	4.68	258.69	1.50	0.354	7.695	1
605	LO	300,000	1,135.62	8.17E-04	4.31	263.38	4.81	0.513	12.948	1
606	LO	320,000	1,211.33	6.07E-04	4.38	276.61	2.80	0.466	11.313	1
607	LO	420,000	1,589.87	1.07E-01	5.74	276.85	6.24	0.551	8.451	1
608	LO	312,000	1,181.04	1.45E-03	4.25	278.17	4.75	0.315	14.275	1
609	LO	395,300	1,496.37	6.96E-04	5.29	282.79	5.79	0.559	9.977	1
610	LO	395,300	1,496.37	6.96E-04	5.15	290.36	5.65	0.420	14.353	1
611	LO	320,000	1,211.33	6.07E-04	4.12	294.27	4.62	0.794	8.523	1
612	LO	450,000	1,703.43	6.15E-03	5.23	325.81	5.73	0.665	10.896	1
613	LO	415,000	1,570.94	1.86E-03	4.74	331.54	4.50	0.200	6.073	1
614	LO	460,000	1,741.28	1.07E-01	4.89	355.95	5.39	0.717	17.351	1
615	LO	543,300	2,056.61	6.26E-03	5.30	388.02	5.80	0.648	7.178	1
616	LO	500,000	1,892.70	5.40E-02	4.59	412.37	5.09	0.638	11.484	1
617	LO	900,000	3,406.86	3.18E-05	5.73	594.96	6.23	0.200	21.511	1
618	LO	543,300	2,056.61	6.26E-03	3.46	595.02	3.96	0.692	11.471	1
619	LO	900,000	3,406.86	2.72E-02	4.51	755.52	5.01	0.567	9.136	1
620	LO	1,500,000	5,678.10	2.03E-02	6.29	902.31	0.50	0.380	24.253	2
621	LO	1,500,000	5,678.10	8.35E-03	5.51	1,031.00	6.01	0.648	39.801	2
622	LO	1,500,000	5,678.10	2.03E-02	5.13	1,107.74	5.63	0.330	35.589	1
623	LO	3,000,000	11,356.19	4.02E-02	6.18	1,837.68	6.68	0.744	55.158	1
624	LO	6,720,000	25,437.88	2.36E-03	7.03	3,616.24	1.10	0.200	183.260	2