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Incident Waste Decision Support Tool - Waste Materials Estimator Version 6.4

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Incident Waste Decision Support Tool - Waste Materials Estimator Version 6.4

Prepared for:

U.S. Environmental Protection Agency
Office of Research and Development
National Homeland Security Research Center
Research Triangle Park, NC 27711

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DISCLAIMERS

The U.S. Environmental Protection Agency through its Office of Research and Development managed the research described here. This work was performed by Eastern Research Group under Contract No. EP-D-11-006 Work Assignment 5-10. It has been subjected to the Agency's review and has been approved for publication. Note that approval does not signify that the contents necessarily reflect the views of the Agency.

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LIST OF ACRONYMS

AHA	American Hospital Association
APME	Association of Plastics Manufacturers in Europe
ASHES	American Society for Healthcare Environmental Services
BDR	Building Decontamination Residue
BoEE	Back-of-the-envelope Estimator
CPU	Central Processing Unit
CT	Computerized Tomography (CT scanners)
DF	Debris Factor
DST	Decision Support Tool
EOC	Emergency Operations Center
EPA	U.S. Environmental Protection Agency
ERG	Eastern Research Group, Inc.
FEMA	Federal Emergency Management Agency
GLA	Gross leasable area
GOC	General Occupancy Class
HAZUS-MH	Hazards U.S.-Multi-Hazard Loss Estimation Software
HR	High rise; a type of height range for model building types
HSRP	Homeland Security Research Program
ICER	Industry Council for Electronic Equipment Recycling
ICSC	International Council of Shopping Centers
IV	Intravenous
I-WASTE DST	Incident Waste Decision Support Tool
LR	Low rise, a type of height range for model building types
MBT	Model Building Type
MR	Mid-rise; a type of height range for model building types
MRI	Magnetic resonance imaging (MRI machines)
NRF	National Retail Federation
PET	Polyethylene terephthalate
PMF	Packaging Materials Factor
PRF	Paper and Office or School Supplies Removal Factor
PVC	Polyvinyl chloride
RCRA	Resource Conservation and Recovery Act
SF	Square footage
SOC	Specific Occupancy Class

LIST OF ACRONYMS (Continued)

SPI	Society of the Plastics Industry
UCSF	University of California, San Francisco
WCF	Waste Category Factor
WEEE	Waste Electronic Electrical Equipment
WME	Waste Materials Estimator

LIST OF SYMBOLS AND NOTATION

b_{wc-i}	Intercept for waste category *i*
DF_i	Debris factor for debris type i, mass or volume
DF_{MBT-i}	Debris factor for MBT type i
E_{wc-i}	Estimate of waste for waste category *i*, tons or yd^3
F Intercept	Intercept for foundation
F Slope	Slope for foundation
G	Gutted Single-Family Residences
G Intercept	Intercept for structure gutting (from Table 2-48)
G Slope	Slope for structure gutting (from Table 2-48)
IP_x	Input parameter value for *x*
$IP_{x, y}$	Input parameter value for structure type *x* and hotel area fraction *y*
$IP_{x,z}$	Input parameter value for structure type *x* and input parameter *z*
M	Percent of brick/masonry-faced exterior walls, %
$M_{0\%}$	0% Masonry-Faced Exterior Walls
$M_{0\%}$ Intercept	Intercept for 0% masonry-faced exterior walls
$M_{0\%}$ Slope	Slope for 0% masonry-faced exterior walls
$M_{100\%}$	100% Masonry-Faced Exterior Walls
$M_{100\%}$ Intercept	Intercept for 100% masonry-faced exterior walls
$M_{100\%}$ Slope	Slope for 100% masonry-faced exterior walls
$MBTf_i$	Fraction of SOC comprised of MBT type i
m_{wc-i}	Slope for waste category *i*
n	Number of single-family residences
NF	Single-family residences with no foundation
NF Intercept	Intercept for no foundation
NF Slope	Slope for no foundation
SA_t	*S*pace allocation for store type *t*, % of GLA
SF	Square footage, ft^2
$SF_{single-family\ residence}$	Square footage of single-family residence
WCF_i	Waste category factor for waste category *i*, tons/bed or yd^3/bed
$WCF_{i, y}$	Waste category factor for waste category *i* and hotel area fraction *y*
$WCF_{i,t}$	Waste category factor for waste category *i* and store type *t*
$WCF_{i,z}$	Waste category factor for waste category *i* and input parameter *z*

LIST OF UNITS

BTU	British thermal unit(s)
ft^3	Cubic foot (feet)
in^3	Cubic inch(es)
m^3	Cubic meter(s)
yd^3	Cubic yard(s)
ft	Foot (feet)
in	Inch(es)
kg	Kilogram(s)
MJ	Megajoule(s)
tons	U.S. ton(s)
oz	Ounce(s)
lb	Pound(s)
ft^2	Square foot (feet)
m	Meter(s)
m^2	Square meter(s)
mi^2	Square mile(s)
yd^2	Square yard(s)

1. INTRODUCTION

This document outlines the methodology and data used to develop the Waste Materials Estimator (WME) contained in the Incident Waste Decision Support Tool (I-WASTE DST).

The WME is both a standalone calculator that generates waste estimates in terms of broad waste categories and is also integrated into the Incident Planning and Response section of the tool where default inventories of specific waste items are provided in addition to the estimates for the broader waste categories. The WME can generate waste estimates for both common materials found in open spaces (soil, vegetation, concrete, and asphalt) and for a vast array of items and materials found in common structures.

Waste estimates are designed to be order of magnitude estimates of the weight and volume of materials found in open spaces or materials and items found in a structure.

The terminology used in this document is contextual. Under normal circumstances, EPA differentiates between "materials' and "wastes" along the waste management continuum. The term *waste* used in this document refers to incident-generated wastes, some of which may be materials that can be treated or diverted to recycling if appropriate. For additional information, please see EPA's Managing Materials and Wastes for Homeland Security Incidents website (https://www.epa.gov/homeland-security-waste, last accessed September 20, 2016).

For structures, the input parameter values are multiplied by Waste ***Category Factors*** to generate weight and volume estimates for several waste categories specific for each structure type. See Section 2.1. For open spaces, the input parameters define the volume of material that may be removed from an area. Those volumes are then multiplied by the respective material density to generate mass-based waste estimates. See Section 5.

Default structure inventories provide a basic estimate of the quantity of material that may require disposal based on a few simple input parameters. However, instead of just providing an estimate for broad categories of items or materials (e.g., patient care furniture), the default structure inventories provide a specific list of items (e.g., patient beds, infant cribs, exam tables, wheel chairs) by multiplying the input parameter values by Waste ***Item Factors***.

Default structure inventories are not designed to be an all-inclusive list for every specific item in a structure; rather, they provide a starting point for the user to identify oversized items and other items that may have special disposal considerations. See Section 2.2.

Currently, waste estimates can be generated for seven general types of structures: hospitals, hotels, offices, single-family residences, K-12 schools, shopping malls, and movie theaters.

The estimates generated by the WME are divided according to several Waste ***Categories***. For structures, the Waste Categories are broad groupings of individual Waste Items found in a structure. The waste items are grouped into waste categories according to ***Non-Structural/Interior*** items and materials and ***Structural*** items and materials. Non-structural/interior items and materials are divided between building materials and all other non-structural/interior items. Structural items and materials are divided between brick, wood, and other structural building materials; and reinforced concrete and steel. Details on each individual waste category, including which waste items are included in the estimate, and related assumptions are provided in Section 2.2. All estimates for interior and non-structural items and waste categories are based on factors developed from site visits and other research conducted by ERG.

2. NON-STRUCTURAL/INTERIOR ITEMS AND MATERIALS

A general overview of the methodology for estimating non-structural and building interior waste items and materials is described Sections 2.1 and 2.2. Examples of non-structural waste items include drywall, ceiling tiles, and flooring materials. Examples of interior waste items include furniture, bathroom fixtures, electronic equipment, and personal effects. Non-structural and interior waste items are assigned and grouped to a Waste Category that is specific to the structure type. Many of the Waste Categories (e.g., Drywall) apply to multiple structure types, although the specific non-structural and interior waste items may vary. The detailed methodologies and data sources for each structure type are provided in Sections 2.3 through 2.9 that follow.

2.1 Methodology and Factor Development

The waste category factors used by the WME for interior and non-structural weight and volume estimates for all structure types, except for single-family residences, were developed based on site visits conducted by ERG. During the development of earlier versions of I-WASTE, ERG conducted site visits to commercial businesses and establishments representing all structure types found in the WME, except for single-family residences. At each site visited, a thorough inventory was conducted of all furniture, electronic equipment, etc. The quantity of duct work, ventilation systems, drywall, and other non-structural building materials was estimated by reviewing the structure’s floor plans. In total, over 500 individual items were cataloged in a database. These items were broadly grouped according to general type of item or use.

Using the collected inventory information, the weight and volume for each item were estimated (see Section 2.2). The items were then grouped into several categories and the total weight and volume for the waste category were calculated by summing the individual volumes and weights of all items in the category. Additionally:

- All items are assumed to be fully assembled prior to being shipped for disposal.
- All weights are dry weights; the additional weight of any water that may be added to an item (e.g., water from decontamination activities) is not accounted for.

Floor plans were reviewed to estimate the square footage of the structure, and factors for estimating the quantity of items and materials based on square footage were generated by dividing the total volume and weight for the waste category by the total structure square footage. For some structures, a correlation exists between the amount of items and materials and the number of occupants in an office building, number of students in a school, number of beds in a hospital, etc.

To generate estimates for the quantity of items or materials requiring disposal, the WME multiplies the respective waste category factor by the input parameter value on which the factors are based. The specific parameters that are associated with each structure type are described in detail later in this section.

2.2 Waste Item Database, Item Properties, and Default Item Inventories

The inventories of items completed during site visits by ERG (see Section 2.1 were compiled into a database to which additional information for and properties of each item were added. This section describes the Waste Item Database in detail. The Waste Item Database is available in I-WASTE and can be accessed either through the Incident Planning section of the tool, or through the Chem/Bio Guidance Section of the tool. Additionally, the Waste Item Database is used when developing an Incident Record to supplement the waste estimation results by providing users a detailed inventory of items that is generated based on the user inputs to the WME. The Waste Item Database is not available to users in the WME section of the tool. The Waste Item Database and Default Item Inventories are intended only to provide details on potentially contaminated items that may be present in structures and that may require decontamination and/or disposal. The Waste Item Database does not include decontamination equipment, decontamination residues, or decontamination wastewater.

2.2.1 Methodology for Item Data Collection and Database Creation [1]

The current Waste Item Database contains items that may be found in many types of structures, including (but not limited to) offices, schools, restaurants, hotels, and movie theaters.

The creation of the database was broken up into two tasks. The first task was to brainstorm larger items that may be found in the buildings and provide approximate dimensions, weights, and material content for each item. The brainstorming was primarily completed based on the personal experiences of visiting these sites. Online catalogs were also searched and served as the primary source for dimensions and weights. Table 2-1 through Table 2-8 outline the sources for each item in the database.

Using the weight and material content, the second task was to determine the heat content, residual ash, and potential water weight of each item. To complete this task, literature was searched to generate a table of material properties (Table 2-9). Since the specific type of wood, plastic, or metal used in the items would generally be unknown by the user of the database, generic categories were created for each of these groups. Two other material categories, electronics and carpet, were also created to model the numerous materials in these items as one composite material. Table 2-10 through Table 2-12 outline the assumptions and sources used for the generation of Table 2-9.

2.2.2 Waste Items

The Waste Item Database includes default dimensions and properties values associated with each item, along with other characteristics calculated from the default values stored in the database. Default weights and dimensions for items were found in online catalogs such as www.bestbuy.com or www.acemart.com (both last accessed December 21, 2015), or estimated by visual inspection and/or measurement. The defaults were designed to give reasonable estimates for the items that may be found at a site. However, due to the variety of shapes and

[1] Information presented in this section was originally documented in the ERG memorandum entitled, “BDR Database Assumptions,” from Aaron Osborne (ERG) to Andy Miller (EPA), dated February 16, 2004.

sizes of the items, these dimensions may be modified by the tool user. These dimensions include the following:

- Height (inches);
- Width (inches);
- Depth (inches); and
- Weight (pounds).

Table 2-1 through Table 2-8 contain a list of sources and assumptions used for the dimensions, weight, and material contents for items in the database. If a website is listed as the basis, it implies the following:

- An item or items matching the description were found on the website;
- If dimensions for the item were listed, they were rounded up to the nearest inch;
- If a weight was listed, it was rounded to two significant digits; and
- If a shipping weight was listed, it was reduced by 5-10% and rounded to two significant digits.

If “visual inspection and measurement” is listed as the basis, it implies the following:

- An item or items matching the description were found during the visit;
- The item was measured using a tape measure or ruler;
- The weight was estimated by lifting the item or by the density of the material;
- The item may have been scaled up or down to generate dimensions and weights for other items in its group (e.g., a medium plastic blind was used to estimate the weight of a small and large blind.)

All dimensions were rounded up to the nearest inch. Weights were generally rounded to two significant digits. Material content was rounded to the nearest 5%. Unless otherwise noted, all assumptions for material content are based on visual inspection. User-defined items are addressed in Section 2.2.3.

Table 2-1. Sources and Basis for Bathroom and Janitorial Items

Group	Specific Item	Source/Basis[a]
Carts	All Items	www.officedepot.com and www.acemart.com
Equipment	Brooms & Mops	www.acemart.com
Equipment	Steam Cleaner & Vacuums	www.bestbuy.com
Mirror	All Items	Visual inspection and measurement
Miscellaneous	All Items	www.acemart.com
Paper Towels	All Items	Visual inspection, measurement, and www.acemart.com

Table 2-1. Sources and Basis for Bathroom and Janitorial Items

Group	Specific Item	Source/Basis[a]
Showers	All Items	Visual inspection, measurement, and www.shop.toohome.com[2]
Sinks	Kitchen	www.acemart.com
Sinks	All Others	Visual inspection, measurement, and www.shop.toohome.com[3]
Stall Dividers	All Items	www.moss-engineering.com
Toilet Paper	All Items	Visual inspection, measurement, and www.acemart.com
Toilets	All Items	Visual inspection, measurement, and www.shop.toohome.com[3]
Trash Cans	Particle Board	Weight based on construction with 5/8" particle board.
Trash Cans	All Others	www.janisan.com
Washers/Dryers	All Items	www.bestbuy.com

[a] All websites last accessed on December 21, 2015 unless otherwise noted.

Table 2-2. Sources and Basis for Building Materials

Group	Specific Item	Source / Basis[a]
Blinds	All Items	Visual inspection and www.blinds.com
Carpet and Padding	Carpet	Most carpet sold in 12 foot (ft) wide rolls. Weight of 4.75 pounds per square yard (lb/yd^2) based on www.maslandcontract.com.
Carpet and Padding	Padding	Most padding sold in 6 ft wide rolls. Generally sold in ¼ inch (in), $^5/_{16}$ in, and $^3/_8$ in gauge. Weight of 34 ounces ($oz)/yd^2$ based on $^5/_{16}$ in http://www.maslandcontract.com/[3]
Ceiling Tiles	All Items	Dimensions, weight, and material content all based on www.usg.com
Doors	All Items	Dimensions and weights vary greatly. Standard sizes were chosen based on visual inspection and measurement for estimates. Metal fire doors are based on www.cecodoor.com
Drywall	All Items	www.usg.com. All estimations based on $^3/_8$ in thick drywall.
Floor Tiles	All Items	Visual inspection and tile estimator from www.homestore.com[4]
Insulation	All Items	Visual inspection and www.owenscorning.com

2 The website and URL are not valid as of January 7, 2011. At the time this website was referenced, it was a valid URL, and this reference remains the source of the information or data currently used in the WME.

3 The website and URL are not valid as of July 31, 2015. At the time this website was referenced, it was a valid URL and this reference remains the source of the information or data currently used in the WME.

4 At the time this website was referenced, it was a valid URL and this reference remains the source of the information or data currently used in the WME. This URL now redirects to www.move.com.

Table 2-2. Sources and Basis for Building Materials

Group	Specific Item	Source / Basis[a]
Linoleum	All Items	Can be made from either linen seed oil or polyvinyl chloride (PVC). Generally made in 6 ft wide rolls. Assumed a weight of 2.1kilograms per square meter (kg/m^2) based on www.stylepark.com and www.magnafabrics.com

[a] All websites last accessed on December 21, 2015 unless otherwise noted.

Table 2-3. Sources and Basis for Electronic Equipment and Office Machines

Group	Specific Item	Source/Basis[a]
Cameras	All Items	www.bestbuy.com
Clocks	All Items	Visual inspection and measurement
Computers	Laptop and CPU	www.bestbuy.com
Computers	Mac (Monitor and CPU)	www.apple.com
Computers	Servers	www.ibm.com
Disks	All Items	Visual inspection and measurement
Fans	Ceiling	www.hansenwholesale.com
Fans	Floor	www.husan.com
Fans	Industrial	www.vestilmfg.com
Fax Machines	All Items	www.canon.com
Light Fixtures	All Items	Visual inspection, measurements, and www.officedepot.com
Metal Detectors	Handheld	www.detection.com
Metal Detectors	Walk Through	www.securitydetectors.com[5]
Monitors	All Items	www.bestbuy.com
Paper Folders	All Items	www.abc-i.com
Phones	Video Phones	www.polycom.com
Phones	All Others	www.bestbuy.com
Photocopiers	All Items	www.canon.com
Printers	Large	www.canon.com
Printers	All Others	www.bestbuy.com
Projectors	All Items	www.bestbuy.com
Retail Equipment	Cash Register	www.cashregisterstore.com
Retail Equipment	Neon Sign	www.acemart.com
Scanners	All Items	www.bestbuy.com
Shredders	All Items	www.abc-i.com
Soda/Snack Machines	All Items	www.vending4freedom.com[5]
Space Heaters	All Items	www.heatershop.com[6]

5 At the time this website was referenced, it was a valid URL and this reference remains the source of the information or data currently used in the WME. This URL now redirects to www.adt.com.

6 The website and URL are not valid as of July 31, 2015. At the time this website was referenced, it was a valid URL and this reference remains the source of the information or data currently used in the WME.

Table 2-3. Sources and Basis for Electronic Equipment and Office Machines

Group	Specific Item	Source/Basis[a]
Televisions	All Items	www.bestbuy.com
VCR/DVD Players	All Items	www.bestbuy.com
Video Arcade Games	All Items	www.quarterarcade.com
X-ray Machines	All Items	www.bombdetection.com

[a] All websites last accessed on December 21, 2015 unless otherwise noted.

Table 2-4. Sources and Basis for Office and School Furniture and Supplies

Group	Specific Item	Source/Basis[a]
Archive Storage	All Items	Visual inspection and measurement
Book Cases	All Items	www.officefurniture.com
Bulletin Boards	All Items	www.ahutton.com
Carts	All Items	www.officefurniture.com
Chairs	All Items	Visual inspection, measurements, and www.officefurniture.com
Chalk Board	All Items	www.ahutton.com
Coat Racks	Floor Trees	www.thehomestore.com[7]
Coat Racks	All Others	www.keysan.com[8]
Cubicle Dividers	All Items	Visual inspection and www.officefurniture.com
Desks	School	www.schooloutfitters.com
Desks	All Others	www.officefurniture.com
Filing Cabinets	All Items	www.officefurniture.com
Mail Sorters	All Items	www.cleansweepsupply.com[9]
Paper	All Items	Weight based on 20 lb paper.
Plants	All Items	www.silkplantscanada.com
Projection Screen	All Items	www.draperinc.com
Storage Cabinets	All Items	Visual inspection, measurements, and www.officefurniture.com
Storage Shelves	All Items	Visual inspection and measurements
Tables	End Tables	Based on construction with 5/8 in wood or particle board
Tables	Folding	www.officefurniture.com. Material content based on top made out of 5/8 in particle board
Tables	All Others	www.officefurniture.com
Whiteboard	All Items	www.ahutton.com

[a] All websites last accessed on December 21, 2015 unless otherwise noted.

7 The website and URL are not valid as of January 7, 2011. At the time this website was referenced, it was a valid URL and this reference remains the source of the information or data currently used in the WME.

8 The website and URL are not valid as of July 31, 2015. At the time this website was referenced, it was a valid URL and this reference remains the source of the information or data currently used in the WME.

9 At the time this website was referenced, it was a valid URL and this reference remains the source of the information or data currently used in the WME. This URL now redirects to www.officezilla.com.

Table 2-5. Sources and Basis for Other School Equipment

Group	Specific Item	Source/Basis[a]
Bleachers	Retractable	Generally custom designed, and would require disassembling prior to shipment. Estimates based on www.interkal.com
Bleachers	Stationary	www.theparkcatalog.com
Display (Trophy) Cases	All Items	www.sun-rise.com[10]
Gym Equipment	Basketball Hoops	www.basketballgoals.com
Gym Equipment	Benches	www.lasteelcraft.com
Gym Equipment	Wrestling Mat	www.cartwheelfactory.com
Gym Equipment	Balance Beam Pommel Horse	www.olympic-usa.org/sports2/gy/az_equip.html[11]
Gym Equipment	Wall Padding	Visual inspection
Laboratory Equipment	All Items	Visual inspection and measurement
Lockers	All Items	www.corcraft.com[7]
Music	Harp	www.lyonhealy.com
Music	All Others	www.yamaha.com
Podium	All Items	www.impact-displays.com[12] and www.heavenlywood.com
Risers	All Items	Visual Inspection and measurement
Room Dividers	All Items	www.draperinc.com
Weightlifting Equipment	All Items	www.megafitness.com

[a] All websites last accessed on December 21, 2015 unless otherwise noted.

Table 2-6. Sources and Basis for Restaurant and Cafeteria Items

Group	Specific Item	Source/Basis[a]
Bar	All Items	Visual inspection and measurement
Cafeteria Line	All Items	www.acemart.com
Cooking Equipment	All Items	www.acemart.com and www.bestbuy.com
Other Kitchen Equipment	All Items	www.acemart.com, www.bestbuy.com , and www.hobart.com[13]
Refrigerated Beverage Displays	All Items	www.acemart.com
Seating	All Items	www.acemart.com

10 The website and URL are not valid as of July 31, 2015. At the time this website was referenced, it was a valid URL and this reference remains the source of the information or data currently used in the WME.

11 The website and URL are not valid as of January 7, 2011. At the time this website was referenced, it was a valid URL and this reference remains the source of the information or data currently used in the WME.

12 The website and URL are not valid as of July 31, 2015. At the time this website was referenced, it was a valid URL and this reference remains the source of the information or data currently used in the WME.

13 The website and URL are not valid as of July 31, 2015. At the time this website was referenced, it was a valid URL and this reference remains the source of the information or data currently used in the WME.

Table 2-6. Sources and Basis for Restaurant and Cafeteria Items

Group	Specific Item	Source/Basis[a]
Tables	Folding Cafeteria	www.classroomfurniture.com
Tables	All Others	Dimensions, weight, and material content based on www.tableandbaseworld.com[13]

[a] All websites last accessed on December 21, 2015 unless otherwise noted.

Table 2-7. Sources and Basis for Movie Theater Specific Items

Group	Specific Item	Source/Basis[a]
Acoustic Tiles	All Items	Based on a density of 3 kg/m^2 from www.soundservice.co.uk
Concession Stand Counter	All Items	Based on construction from 5/8 in particle board
Concession Stand Items	All Items	www.acemart.com
Crowd Control Lines	All Items	www.gocrown.com[14]
Drapes/Curtains	All Items	Based on a density of 18 oz/yd^2 from www.tapestria.com[15]
Movie Screens	All Items	Based on estimate of 0.6 lb/ft^2 from www.draperinc.com. Screens are vinyl with glass beads.
Row of Seating	All Items	Seats are generally custom made. Sections vary greatly in number of seats, material content, and size. Estimates based on www.ki.com and visual inspection.
Sound Equipment	Speakers	www.peavey.com
Sound Equipment	All Others	www.zzounds.com

[a] All websites last accessed on December 21, 2015 unless otherwise noted.

2.2.3 User-Defined Waste Items

Due to the vast array of items that could be found in any given structure type, *User-Defined* Waste Items were created to model objects not specified elsewhere in the database. Six different shapes are included for each material. Small, medium, and large, objects were designed to model items such as a statue or other piece of furniture. The small and large tubs were designed to model the tubs of smaller items packaged together. The panel was designed to model items such as decorative wood panels or glass panes. The shapes and dimensions are as follows:

- Small object, 24 in × 48 in ×18 in;
- Medium object, 36 in × 72 in × 27 in;
- Large object, 48 in × 96 in × 36 in;

14 At the time this website was referenced, it was a valid URL and this reference remains the source of the information or data currently used in the WME. This URL now redirects to www.4rails.com.

15 The website and URL are not valid as of January 7, 2011. At the time this website was referenced, it was a valid URL and this reference remains the source of the information or data currently used in the WME.

- Small tub, 18 in × 36 in × 18 in;
- Large tub, 24 in × 48 in × 24 in; and
- Panel, 36 in × 72 in × 1 in.

The weight of each object was calculated based on the density of the material. Since it would be unrealistic to assume that the entire volume of the object or tub was filled with the material, the following assumptions were made:

- Objects were six sided boxes with a wall thickness listed in Table 2-8;
- Tubs have a void fraction of 0.5; and
- Panels were of the thickness listed in Table 2-8. Note that a panel thickness of 1 in is listed in the database because all dimensions were rounded up to the nearest inch.

The thicknesses are based on the relative strength of the material and typical construction practices with the material. The weights were rounded to two significant figures.

Table 2-8. Wall Thickness of User-Defined Objects

Material	Wall Thickness (in)
Metal	0.1
Plastics, Polyvinyl Chloride, Glass	0.25
Wood, Particle Board, Paper, Fabric, Ceramic, Gypsum, Fiberglass Board	0.5
Masonry, Marble, Foam	1.0

2.2.4 Waste Item Properties

Table 2-9 is a summary of the material properties used for the calculation of the heat content, residual ash, and potential water weight for the items in the Waste Item Database. The weight and material content, in conjunction with the material properties listed in Table 2-9, are used to calculate the heat content, residual ash, and potential water weight for each item. The assumptions and sources used to generate Table 2-9 are detailed in this section.

2.2.4.1 Volume

The volume is calculated by simply multiplying the height by the width and the depth. All items were assumed to be box-shaped because of packaging prior to shipment.

2.2.4.2 Heat of Combustion

The sources and assumptions used to generate the heats of combustion in Table 2-9 are listed in Table 2-10. Most values are from literature sources. While most items will have coatings, screws, and other pieces made from other materials (combustible or non-combustible), these coatings or pieces are assumed not to have a significant effect on the overall heat content of the item. The heat content for each item was calculated by multiplying its weight by the heat of combustion value for the corresponding material.

2.2.4.3 Density

The densities for all materials unless otherwise noted are from Incorpera[16]. The following additional assumptions and sources were used:

- The density of an unknown wood was assumed to be the average of the density of hardwood and softwood.
- The density of an unknown metal was assumed to be that of steel.
- Because the densities of electronics vary widely, none are given.
- The densities of polyethylene, polypropylene, polyester, polyvinyl chloride, and nylon are from the NAUE Dictionary[17].
- The density of polystyrene is from CPS Instruments[18].
- The density of an unknown plastic was assumed to be the density of polyethylene.
- The densities of carpet, fabric, and linoleum were calculated by dividing the weight per square yard (see Table 2-2 and Table 2-7) by the thickness and converting units.

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16 Incropera, F. and Dewitt, D. *Fundamentals of Heat and Mass Transfer, 5th editionEedition*. John Wiley and Sons, New York, 2002.

17 Naue Fasertechnik Dictionary. http://www.naue.com/english/lexikon/frame/index.html. Viewed January 2004. The website and URL are not valid as of January 7, 2011. At the time this website was referenced, it was a valid URL and this reference remains the source of the information or data currently used in the WME.

18 CPS Instruments. “Analysis of Low Density Particles Using Differential Centrifugal Sedimentation.” http://www.cpsinstruments.com/TechLibrary/LowDensity.PDF. Viewed January 2004. The website and URL are not valid as of July 31, 2015.

Table 2-9. Summary of Properties for Waste Items

Material	Heat of Combustion (Megajoules (MJ)/kg)	Heat of Combustion (British Thermal Units (BTU)/lb)[a]	Density (kg/cubic meter (m^3))	Density (lb/ft^3)[b]	Ash Weight (%)	Damp Water Weight (lb H_2O/ lb Material)	Soaked Water Weight (lb H_2O / lb Material)
Wood	20	8610	615	38	10	0	0
Hardwood (oak, maple)	20	8610	720	45	10	0	0
Softwood (fir, pine)	20	8610	510	32	10	0	0
Particle Board	18.6	8000	800	50	10	0	0
Paper	19.7	8480	930	58	6	0.41	0.8
Metal	0	0	8000	500	95	0	0
Steel	0	0	8000	500	95	0	0
Aluminum	0	0	2750	170	95	0	0
Copper	0	0	8800	550	95	0	0
Polyethylene	46.3	19900	950	59	5	0	0
Polypropylene	46.4	20000	910	57	5	0	0
Polystyrene	41.4	17800	1050	66	5	0	0
Polyethylene terephthalate (PET)	26.0	11200	1380	86	5	0	0
Polyvinyl Chloride	18.0	7750	1380	86	5	0	0
Plastic	46.3	19900	950	59	5	0	0
Electronics	9.5	4090	–[c]	–[c]	70	0	0
Carpet	21.1	9080	400	25	18	0.68	1.21
Nylon	35.8	15400	1140	71	5	0	0

Table 2-9. Summary of Properties for Waste Items

Material	Heat of Combustion (Megajoules (MJ)/kg)	Heat of Combustion (British Thermal Units (BTU)/lb)[a]	Density (kg/cubic meter (m^3))	Density (lb/ft^3)[b]	Ash Weight (%)	Damp Water Weight (lb H_2O/ lb Material)	Soaked Water Weight (lb H_2O / lb Material)
Fabric (Wool or Cotton)	20	8610	550	34	5	1.52	2.85
Foam (Polyurethane)	41.8[d]	18000	70	4.4	5	0.6	1.03
Rubber	29.7[d]	12800	1100	69	5	0	0
Linoleum	20	8610	700	44	5	0	0
Fiberglass (Insulation)	0	0	40	2.5	95	5.84	6.27
Fiberglass (Board)	13	5600	105	6.6	50	0	0
Masonry	0	0	1900	119	95	0	0
Gypsum	0	0	800	50	95	0	0
Glass	0	0	2300	144	95	0	0
Marble	0	0	2680	167	95	0	0
Ceramic	0	0	2000	125	95	0	0
Slate	0	0	2700	169	95	0	0

[a] Heats of combustion were converted from MJ/kg to BTU/lb using a conversion factor of 430.28. The results were rounded to three significant figures.

[b] Densities were converted from kg/m^3 to lb/ft^3 using a conversion factor of 0.0624302. The results were rounded to two significant figures.

[c] A density for electronics was not determined.

[d] These values were listed in BTU/lb and converted to MJ/kg using a conversion factor of 0.0023241. The results were rounded to three significant figures.

Table 2-10. Basis of the Heat of Combustion Values for Waste Items

Material	Heat of Combustion (MJ/kg)	Heat of Combustion (BTU/lb)[a]	Basis / Rationale
Wood, Hardwood, Softwood	20.0	8610	Kittle[b] The value is an average for dry wood. Most types of wood have approximately the same heat of combustion per kilogram; however, there is a wide variance in density.
Particle Board	18.6	8000	BIOBIB[c]
Paper	19.7	8480	Kittle[b]
Metal, Steel, Copper, Aluminum	0	0	These materials are assumed not to combust, and the heat of combustion is negligible.
Polyethylene	46.3	19900	Kittle[b]
Polypropylene	46.4	20000	Kittle[b]
Polystyrene	41.4	17800	Kittle[b]
Polyester (PET)	26	11200	Kittle[b]
Polyvinyl Chloride	18.0	7750	Kittle[b]
Plastic	46.3	19900	For unknown plastics, the heat of combustion of polyethylene or polypropylene is chosen. Polyethylene or polypropylene are the most common plastics used for consumer items.
Electronics	9.5	4090	ICER[d] states that the typical computer is 27% plastic, and the balance is non-combustible (metal and glass). The plastics in electronics will also generally have lower heat content because 26% of plastics used in electronics is PVC[e], and flame retardants may make up as much as 20% of the plastic[f]. A heat content of 35 MJ/kg was assumed for the plastic and multiplied by 27% plastics in electronics.
Carpet	12.1	9080	Lemieux et al.[g]. Carpet is approximately 50% fibers and 50% fines (backing) by weight. The heat of combustion is 29.31 MJ/kg for carpet fibers and 12.97 MJ/kg for carpet fines.
Nylon	35.8	15400	Calculated based on method from Walters[h].
Fabric	20	8610	Larsson[i] estimates the heat of combustion for wool and organic fibers (cotton) to be approximately 20 MJ/kg.
Foam (polyurethane)	41.8	18000	Hankins[j]
Rubber	29.7	12800	SPI[k]
Linoleum	20.0	8610	Linoleum may be made of PVC or linseed oil. For linseed oil, Larsson[i] estimates the heat of combustion for natural organic material such as wool and wood to be approximately 20 MJ/kg.

Table 2-10. Basis of the Heat of Combustion Values for Waste Items

Material	Heat of Combustion (MJ/kg)	Heat of Combustion (BTU/lb)[a]	Basis / Rationale
Fiberglass (Insulation)	0	0	Insulation is typically greater than 90% fibrous glass. Heat of combustion from other additives assumed to be negligible.
Fiberglass (Board)	13.0	5600	Fiberglass board is typically polyester with approximately 30-50% inorganic materials. Assumed 50% polyester.
Masonry, Glass, Marble, Ceramic, Slate, Gypsum	0	0	These materials are assumed not to combust, and the heat of combustion is negligible.

[a] Heats of combustion were converted from MJ/kg to BTU/lb using a conversion factor of 430.28. The results were rounded to three significant figures.

[b] Kittle, P. “Flammability of Plastics and Polymers Used as Alternate Daily Covers.” Rusmar Incorporated, West Chester, PA, 1993.

[c] Hofbauer, H. “BIOBIB Database for Biofuels.” University of Technology, Vienna. http://www.vt.tuwien.ac.at/biobib/biobib.html. Viewed January 2004. The website and URL are not valid as of July 31, 2015.

[d] Industry Council for Electronic Equipment Recycling (ICER). *Status Report on* Waste *Electronic and Electrical Equipment(WEEE).* March 2000.

[e] Silicon Valley Toxics Coalition. *Poison PCs and Toxic TVs.* June 2003.

[f] John Wiley and Sons, Inc. *Kirk-Othmer Encyclopedia of Chemical Technology*. 4th edition. Volume 10, page 930. 1993.

[g] Lemieux, P., Stewart, E. Realff, M., and Mulholland, J. “Emissions Study of Co-Firing Waste Carpet in a Rotary Kiln.” *J Environ Manage*. 2004 Jan; 70(1): 27-33.

[h] Walters, R., *Federal Aviation Administration. Molar Heat Contributions to Heat of Combustion.* DOT/FAA/AR-TN01/75. U.S. Department of Transportation, Springfield, VA. September 2001.

[i] Larsson, Y. *Recycling of* Materials *in Rail Vehicles*. Lulea Tekniska University, 2001.

[j] Hankins, J. “Hazards Associated with the Storage of Flexible Polyurethane Foam in Warehouse Situations” In: *Proceedings of the Polyurethane Foam Association*. Factory Mutual Research, October 9 and 10, 1997.

[k] The Society of the Plastics Industry (SPI). “Community Involvement - Incineration.” http://www.plasticsindustry.org/outreach/environment/2110.htm. Viewed January 2004. The website and URL are not valid as of January 7, 2011. At the time this website was referenced, it was a valid URL and this reference remains the source of the information or data currently used in the WME.

2.2.4.4 Residual Ash

The amount of residual ash left after combustion was determined based on the assumptions made in Table 2-11. These assumptions account for the small percentage of the weight from coatings, screws, and other pieces made from other materials. The amount of residual ash was calculated by multiplying the weight of the object by the ash weight percent listed in Table 2-9 and Table 2-11.

Total ash will often be some combination of bottom ash and fly ash. For example, the incineration of a wooden desk will result in some ash contribution to the material discharged from the grate (bottom ash) and some ash contribution to the particulate "catch" by the electrostatic precipitator, baghouse, and/or scrubber. In the case of the incineration of a metal desk, virtually all of the residual material would end up as bottom ash.

Table 2-11. Basis of the Residual Ash for Materials

Material	% Weight Ash Residue	Basis / Rationale
Wood, Hardwood, Softwood, Particle Board	10	BIOBIB[a] estimates the ash content of waste wood is 5.82%. 10% is assumed to account for screws, nails, handles and other non-combustible items.
Paper	6	BIOBIB[a]
Metal, Steel, Copper, Aluminum	95	The metal is assumed to remain in the ash; however, 95% is assumed to account for the paints, coatings, and other attached plastic pieces that will combust.
Polyethylene, Polypropylene, Polystyrene, Polyester (PET), Polyvinyl Chloride, Plastic	5	APME[b] lists the ash residue to be 0.1% of the original weight; however, plastics may contain large quantities of inorganic fillers. 5% ash assumed as an average.
Electronics	70	ICER[c] states the typical computer is 27% plastic and the balance non-combustible (metal and glass). 70% ash estimated.
Carpet	18	Lemieux et al.[d]. Carpet is approximately 50% fibers and 50% fines (backing) by weight. The ash residue is 7.7% for carpet fibers and 29.2% for carpet fines.
Nylon, Fabric, Foam, Rubber, Linoleum	5	Organic material. 5% assumed.
Fiberglass (Insulation)	95	Insulation is typically greater than 90% fibrous glass. Assumed that 5% of weight combusts.
Fiberglass (Board)	50	Fiberglass board is typically polyester with approximately 30-50% inorganic materials. Assumed 50% non-combustible inorganics.
Masonry, Glass, Marble, Ceramic, Slate, Gypsum	95	The material is assumed to remain in the ash; however, 95% is assumed to account for the paints, coatings, and other attached plastic pieces that will combust.

[a] Hofbauer, H. "BIOBIB Database for Biofuels." University of Technology, Vienna. http://www.vt.tuwien.ac.at/biobib/biobib.html. Viewed January 2004. The website and URL are not valid as of July 31, 2015.

[b] Association of Plastics Manufacturers in Europe (APME). "Incineration of PET Packaging Article and of Municipal Solid Waste Containing PET." March, 2001.

[c] Industry Council for Electronic Equipment Recycling (ICER). *Status Report on* Waste *Electronic and Electrical Equipment (WEEE).* March, 2000.

[d] Lemieux, P., Stewart, E. Realff, M., and Mulholland, J. "Emissions Study of Co-Firing Waste Carpet in a Rotary Kiln." *Journal of Environmental Management* 70(1), January 2004, 27-33.

2.2.4.5 Water Weight

Water weights were determined by an experiment performed on January 20, 2004 by Aaron Osborne of ERG. The purpose of the experiment was to determine the water retention (amount of water a material can hold) of carpet, fabric, foam, insulation, and paper for use in the Waste Item Database. The following samples were collected:

- Carpet, 28 ounces per square yard (oz/yd^2) fiber weight, approximately one square foot (ft^2);
- Cotton fabric, similar to t-shirt fabric, approximately five ft^2;
- Cotton fabric, similar to towel fabric, approximately 2.5 ft^2;
- Foam pad from an office chair, approximately 16 in × 22 in × 2 in;
- Fiberglass insulation with paper backing, approximately 6 in × 10 in × 8 in; and
- Paper, 250 sheets of 20 lb office paper.

The following procedure was performed on each sample:

- The samples were weighed dry.
- The samples were sprayed with a hose until completely saturated.
- Excess water was allowed to flow off the samples until water no longer dripped rapidly.
- The soaked samples were weighed.
- The samples were mechanically wrung (as possible) and beaten in the air for one minute.
- The damp samples were weighed.
- The damp and soaked weights were divided by the dry weight to determine the water retention of the sample.

The results are presented in Table 2-12.

Table 2-12. Water Retention of Various Samples

Sample	Dry Weight (lb)	Total Damp Weight (lb)	Damp Water Retention (lb water/ lb material)[a]	Total Soaked Weight (lb)	Soaked Water Retention (lb water/ lb material)
Carpet	0.49	0.82	0.68	1.08	1.21
Cotton Fabric, T-shirt	0.39	0.93	1.37	1.27	2.22
Cotton Fabric, Towel	0.39	1.03	1.66	1.74	3.48
Foam	1.32	2.11	0.60	2.68	1.03
Fiberglass Insulation	0.23	1.58	5.84	1.68	6.27

Table 2-12. Water Retention of Various Samples

Sample	Dry Weight (lb)	Total Damp Weight (lb)	Damp Water Retention (lb water/ lb material)[a]	Total Soaked Weight (lb)	Soaked Water Retention (lb water/ lb material)
Paper	2.53	3.57	0.41	4.54	0.80

[a] Designed to simulate wet-vacuumed or otherwise de-watered material.

2.2.5 Default Waste Item Inventories

Default structure inventories are similar to the WME in that they provide a basic estimate of the quantity of material that may require disposal in the event of an incident based on a few simple input parameters (e.g., square footage, number of employees). However, instead of just providing an estimate for broad categories of material (e.g., furniture), the default structure inventories include a specific list of items that comprise the broad waste category (e.g., number of desks, office chairs, folding tables). Default structure inventories are available for all structure types in the WME and can be accessed either through the Incident Planning section of the tool, or through the Chem/Bio Guidance Section of the tool.

Default structure inventories were generated based on information collected during the development of the WME. The user-supplied inputs entered into the WME are multiplied by waste ***item factors*** (e.g., offices have approximately 1.1 computers per employee) to create a sample inventory for the structure.

If multiple input parameters are entered into the WME for schools, offices, or movie theaters (e.g., total office square footage *and* number of office employees), the WME will select the preferred parameter when creating the default structure inventories. Additional information on the preferential estimates for each structure type can be found in Sections 2.5.6, 2.6.3, and 2.7.3.

When using a default inventory within an incident planning and response record, the user can specify the type of treatment facility or disposal facility for each category of waste by selecting the facility type from the drop down list beside each waste category. For example, the user can specify that all electronic equipment is sent to a large landfill and all paper is sent to a large municipal waste combustion facility. Additionally, the user may choose to remove a waste category from the default structure inventory (e.g., if drywall is not being removed from the structure). After the inventory is generated, the user may modify the default structure inventory to add or remove items specific to the structure, as appropriate (e.g., aluminum siding may be selected over the default vinyl siding). The default structure inventories are designed to be a starting point for the user, not an authoritative list.

The default item inventories for each structure type do not currently include individual building structural items and materials. Therefore, the default inventories generated include only items that comprise the non-structural/interior waste categories. Because of rounding errors, the total weight and volume of the items in the default structure inventories may vary slightly from estimates generated by the WME. Additionally, because the tool always assumes at least one of each item, it may not be appropriate for small facilities (e.g., one copier is estimated for a cubical office arrangement ranging from 1 to 50 employees).

To minimize the number of and variation of items, items of similar materials, weights, and dimensions were combined. For example, a desktop fax machine is very similar in dimensions and material content to a desktop printer. Additionally, while a structure may have five-foot, six-foot, and eight-foot folding tables, the default structure inventory contains only six-foot folding tables. In all cases, the user can add or remove items to further refine and tailor the inventory.

Note that while users can select to account for the additional weight and volume of packaging materials in the WME estimates, packaging material is not accounted for in the default inventories. Similarly, all paper is assumed to be removed from furniture prior to shipment, regardless of the specifications defined when generating the WME estimate. However, the default inventories do account for the extensive decorations/marble that may be found in a luxury hotel, the removal of residential foundations, and material found in common areas at shopping malls if specified for inclusion. In a future version of the tool, structural materials will also be included in the default inventories. Although structural materials are estimated in the WME, only non-structural materials are included in the item inventories in version 6.1.

2.3 Hospitals

This section discusses the data sources, methodology, and assumptions used to generate the waste category factors and the waste item factors for hospitals, including a description of each waste category, and a brief analysis of the data quality. This information was originally presented in a memorandum dated January 4, 2008.[19]

2.3.1 Data Sources

The factors for hospitals were generated based on a site visit to a hospital, partial hospital inventories, national hospital statistical data, a report on medical waste generation, and weights and dimensions of items from hospital equipment supplier catalogs.

2.3.1.1 Site Visit

INOVA Health System allowed ERG to visit a 900 bed hospital in Northern Virginia. At the hospital, an inventory was conducted of all furniture, electronic equipment, fixtures, and other items. Note that only one set of similar item rooms was inventoried. For example, only one patient room on each floor (e.g., emergency, labor and delivery, cardiac, intensive care) was inventoried, because all rooms of each type were similar. Inventories were recorded on appropriate checklists. The quantity of duct work, ventilation systems, drywall, and other building materials was estimated by reviewing the structure’s floor plans.

[19] Memorandum from Aaron Osborne (ERG) to Susan Thorneloe and Paul Lemieux (EPA), *Summary of Methodology and Data Collection for the Hospital WME (WME) and Default Structure Inventories*, January 4, 2008.

2.3.1.2 Hospital Inventories

While INOVA did not have a master inventory of all items at the hospital, the following inventories were available for the hospital visited and used for the development of the Hospital WME factors:

- Patient care equipment (e.g., patient beds, IV pumps, ventilators);
- Laboratory and surgical equipment (e.g., anesthesia units, drills, blood analyzers);
- Imaging equipment (e.g., CT scanners, X-ray machines);
- Standard pharmaceuticals kept in stock; and
- Linens.

2.3.1.3 National Hospital Statistical Data

The American Hospital Association (AHA) provided comprehensive national statistics on the size and breakdown (i.e., number of beds per specialty) of hospitals.[20] These data are based on extensive national surveys conducted by AHA from 1980-2004 and were used to ensure that the model hospital developed by ERG to calculate the Hospital WME factors was consistent with a typical hospital in the United States. Additionally, the American Society for Healthcare Environmental Services (ASHES) of AHA provided a guidance document on recommended practices for disaster readiness and recovery for hospitals.[21] While this document was used to develop the disposal guidance presented in the tool, it was not used to develop the WME factors.

2.3.1.4 Medical Waste Generation Rates

The Florida Center for Solid and Hazardous Waste Management conducted a survey to estimate the quantity of medical waste generated in Florida. Based on survey responses from 35 hospitals in the state of Florida, an average metropolitan community hospital generates 189 pounds of medical waste per occupied bed per month (rural community hospitals averaged 134 pounds per occupied bed per month).[22] The estimate includes medical waste Types A through H.[23] The tool uses the data for metropolitan hospitals and assumes 90% occupancy and a maximum of three days of medical waste remaining at the hospital at any given time (one day's worth in patient care areas and two additional days' worth in storage for transport was provided

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20 American Hospital Association (AHA). *2006 AHA Hospital Statistics*. Health Forum, LLC, 2006.

21 American Society for Healthcare Environmental Services (ASHES). *Recommended Practice Series: Disaster Readiness & Recovery*. Metalog, Inc., 2006.

22 Sengupta, S. *Medical Waste Generation, Treatment and Disposal Practices in the State of Florida*, Florida Center for Solid and Hazardous Waste Management, Report #90-3, June 1990. http://www.hinkleycenter.com/publications/sengupta_90-3.pdf. The website and URL are not valid as of January 7, 2011. At the time this website was referenced, it was a valid URL and this reference remains the source of the information or data currently used in the WME.

23 For a definition of the types of medical waste, see U.S. Environmental Protection Agency. *Characterization of Medical Waste Generation and Treatment and Disposal Practices in New York and New Jersey*. USEPA Region 2 and Office of Solid Waste. January 30, 1989. http://www.p2pays.org/ref%5C02/01260/01260.pdf (last accessed September 9, 2015).

as conservative estimates by hospital contacts) to generate medical waste estimates (i.e., 189 lb/occupied bed-month × 0.9 occupied beds/total beds × 3 days/30 days/month = 17 lb/bed).

2.3.1.5 Item Weights and Dimensions

To estimate the total weight and volume of all items at a structure, the weight and volume of each item must be known. Weights and dimensions for many items at a hospital were already included in the Waste Item Database located within the I-WASTE DST. Additional hospital items were added to the database based on weights and dimensions found in catalogs of common hospital equipment vendors (e.g., Med1Online - www.med1online.com[24], GE Healthcare - www.gehealthcare.com[25]).

2.3.2 Methodology

The methodology used to develop estimates for hospitals is similar to the methodology used for other structure types (e.g., offices, schools, hotels, movie theaters; see later sections). For hospitals, estimates are based on the number of beds in the hospital. While other parameters could apply (e.g. total structure square footage, number of intensive care beds versus non-critical care beds), the number of beds is the most common metric in the industry and most broadly applicable for community hospitals. Additionally, number of beds was recommended as the best metric by hospital management personnel consulted for the development of this tool.

2.3.2.1 Model Hospital Inventory

ERG used the data sources previously described to create an inventory of a model hospital. This inventory was primarily based on the inventories provided by INOVA and supplemented with data collected during the site visit. Additionally, the structure floor plans were reviewed to estimate the quantities of building materials. The distribution of beds between hospital wards (e.g., emergency, labor and delivery, cardiac, intensive care) was normalized based on national hospital statistics provided by AHA. Smaller items were placed in “boxes” based on the approximate weight of each item (e.g., keyboards, security cameras, extension cords, etc., were placed in “boxes of electronics”). Additionally, similar items were grouped (e.g., gauze, bandages, casting material, etc., were placed in “boxes of medical supplies”). The inventory for the model hospital was divided between patient care areas (e.g., patient rooms, nurse’s stations, operating rooms, waiting rooms, cafeterias) and non-patient care areas (e.g., management offices, maintenance offices, food preparation areas, laboratories, storage areas). This model inventory was used to create the waste item factors for the default structure inventories and the waste category factors for the WME.

2.3.2.2 Default Structure Inventories

To create the parameters used to generate default structure inventories, each item on the master inventory was divided by the number of beds of the model hospital to generate the Item

[24] The website and URL are not valid as of January 7, 2011. At the time this website was referenced, it was a valid URL and this reference remains the source of the information or data currently used in the WME.

[25] Last accessed December 21, 2015.

Factors (e.g., the hospital had 179 ventilators and 900 beds, which equals 0.2 ventilators per bed). Separate Item Factors were developed for items in the entire hospital and items located in patient care areas (see Section 2.3.3). To minimize the number of items and resulting complexity, items of similar materials, weights, and dimensions were combined. For example, a desktop fax machine is very similar in dimensions and material content to a desktop printer. Additionally, while a hospital may have multiple types of CT and MRI machines, the default structure inventories only contain an estimate for the number of Computerized Tomography (CT)/magnetic resonance imaging (MRI) scanners. In all cases, the user can add or remove items to further refine and tailor the inventory to the user's specific needs.

To generate default structure inventories, the tool multiplies each waste item factor by the number of beds (e.g., 0.2 ventilators per bed × 500 beds = 100 ventilators).

2.3.2.3 Waste Category Estimates

Similar items in the inventories were grouped into the waste categories described in greater detail in Section 2.3.5. A weight and volume were assigned to each item in the waste category based on information in the waste item database. The total weight and volume for the waste category were calculated by summing the individual weights and volumes of all items in the category. The total weight and volume of each waste category was divided by the number of beds for the model hospital. Separate waste category factors were developed for items in the entire hospital and items located in patient care areas (see Section 2.3.3).

To generate waste estimates for the quantity of items and material that may require disposal, the tool multiplies the respective waste category factor by each input parameter according to the following equation:

$$E_{wc\text{-}i} = (WCF_i)(IP_x)(1 + PMF) \qquad \textbf{(Eq. 2-1)}$$

where:

$E_{wc\text{-}i}$	=	Estimate of waste for waste category *i*, tons or cubic yards (yd^3)
WCF_i	=	Waste category factor for waste category *i*, tons/bed or yd^3/bed (from Table 2-13)
IP_x	=	Input parameter value for structure type *x*, beds
PMF	=	Packaging materials factor (from Table 2-14)

For hospitals, the only input parameter required to generate waste estimates is the number of beds.

2.3.3 Waste Category Factors

Based on the data and methodology presented above, Table 2-13 presents the factors used by the WME to generate order of magnitude estimates of the quantity of items and materials that may require disposal from a hospital. A description of the items that are included in each waste category is presented in Section 2.3.5, below. The tool also allows the user to account for the additional weight and volume added by packaging materials. Additionally, estimates are available that account for only materials in patient care areas. These available adjustments are described further, below.

Table 2-13. WME Interior/Non-Structural Waste Category Factors (WCFs) for Hospitals

Waste **Category**	**WCF** (tons/bed)	**WCF** (yd^3/bed)	**WCF** (tons/bed) *Patient Care Areas Only*	**WCF** (yd^3/bed) *Patient Care Areas Only*
Total Non-Structural Building Materials	3.09[a]	13.8[a]	1.91[a]	8.53[a]
Drywall	1.74	5.74	1.05	3.44
Ceiling Tiles	0.37	4.81	0.23	3.08
Carpet	0.13	0.65	0.01	0.05
Other Non-Structural Building Materials	0.85	2.57	0.62	1.97
Electronic Equipment	1.20[b]	13.2[b]	0.77[b]	8.46[b]
Patient Care Equipment	0.24	2.89	0.23	2.86
Imaging Equipment	0.05	0.52	0.05	0.52
Laboratory/Surgery Equipment	0.24	1.58	0.13	0.64
Industrial Electronic Equipment	0.21	1.75	0.08	0.52
Other Electronic Equipment	0.46	6.48	0.28	3.93
Furniture	1.61[c]	20.5[c]	0.62[c]	10.5[c]
Patient Care Furniture	0.21	3.39	0.19	3.04
Office and Other Furniture	1.40	17.12	0.43	7.41
Medical Supplies	0.17	1.46	0.11	0.93
Pharmaceuticals	0.02	0.18	0.01	0.05
Linens	0.02	0.04	0.02	0.04
Food	0.11	0.31	0.00	0.01
Paper/Office Supplies	0.36	3.29	0.02	0.18
Medical Waste	0.01	0.19	0.00	0.06
Other Items & Equipment	0.07	1.56	0.03	0.98
TOTAL	**6.66[d]**	**54.5[d]**	**3.49[d]**	**29.7[d]**

[a] Represents a calculated value. The estimate for *Total Non-Structural Building* Materials is calculated by adding the individual waste category estimates for the *Drywall, Ceiling Tiles, Carpet, and Other Non-Structural Building* Materials waste categories.

[b] Represents a calculated value. The estimate for *Electronic Equipment* is calculated by adding the individual waste quantity estimates for the *Patient Care, Imaging, Laboratory/Surgery, Industrial, and Other Electronic Equipment* waste categories.

[c] Represents a calculated value. The estimate for *Furniture* is calculated by adding the individual waste quantity estimates for the *Patient Care* and *Office and Other Furniture* waste categories.

[d] The Total estimated waste quantity is calculated by adding the individual estimates for *Total Non-Structural Building* Materials, *Electronic Equipment,* and *Furniture,* and the individual waste quantity estimates for the

Medical Supplies, Pharmaceuticals, Linens, Food, Paper/Office Supplies, Medical Waste*, and Other* Items *and Equipment* waste categories.

2.3.3.1 Additional Weight and Volume Added by Packaging Materials

If items are packaged prior to shipment, the packing material will increase the volume and weight. If the user chooses to account for this increase in volume and weight, the volume of the estimate for each waste material category will increase by 10% and the weight of the each estimate will increase by 5%. Actual increases in weight and volume due to packing material may vary based on the type and shape of the item, the type of packing material used, and the packing requirements for the various contaminants. Note that packaging material is not accounted for in the default structure inventories.

Table 2-14. Packaging Materials Factors (PMFs) for Hospitals

Waste **Category Estimate Based On…**	**PMF**
Weight	0.05
Volume	0.10

2.3.3.2 Materials in Patient Care Areas

In the event of a contamination incident at a hospital, contamination may be isolated to patient care areas (e.g., a contaminated patient infects only the emergency room). Therefore, only a portion of the hospital may require decontamination and disposal. Patient care areas include patient rooms, nurses' stations, operating rooms, waiting rooms, cafeterias, and other areas that patients commonly pass through. Non-patient care areas include management offices, maintenance offices, food preparation areas, laboratories, and storage areas. If the box is checked, only waste generated from patient care areas will be included in the estimate. If the box is not checked, items and materials from the entire hospital will be included in the estimate. Note that items and materials from non-patient care rooms located within patient care areas (e.g., an office on the same hall as a patient room) will still be included in the estimate if the box is checked.

2.3.4 Assumptions and Key Notes

The following assumptions are made when estimating the amount of waste materials from a hospital:

- All weights are dry weights. Additional weight of water from any decontamination fluid is not accounted for.
- Drywall and ceiling tiles will not be neatly stacked when packaged for shipment. The base volume of drywall and ceiling tiles (i.e., length × width × height) is multiplied by a factor of 1.3 to determine the total volume including void space.
- Since some buildings may be constructed without one or more of the listed building materials (i.e., drywall, ceiling tiles, carpet), or because these materials may not be removed during a decontamination process, estimates for drywall, ceiling tiles, and

carpet are broken out separately within the Non-Structural Building Materials category.

- All items are assumed to be shipped for disposal fully assembled. The volume for each item is determined by multiplying its maximum overall dimensions. Only minimum size reduction is assumed (e.g., folding tables and chairs are folded).

2.3.5 Category Descriptions

Descriptions, additional details, and assumptions for each interior/non-structural waste category are described in Table 2-15 below.

Table 2-15. Interior/Non-Structural Waste Categories and Descriptions for Hospitals

Waste Category	Description
Total Non-Structural Building Materials	This estimate assumes the hospital is gutted and includes the estimates for drywall, ceiling tiles, and carpet, as well as restroom equipment (i.e., toilets, sinks, stall dividers, etc.), doors, other floor coverings (e.g., ceramic tiles, linoleum), and ventilation systems. Sprinkler systems, piping, and frames supporting the drywall are assumed to remain in place and are also not included in this estimate. Since some buildings may be constructed without using drywall, ceiling tiles, and carpet, or because these materials may not be removed during the decontamination process, estimates for these materials are broken out separately within the building materials category.
Drywall	This estimate includes drywall on walls and ceilings. Frames supporting the drywall are not included in this estimate. This estimate is based on hospitals where approximately 90% of the interior walls are covered with drywall (only utility and back storage room walls were not covered with drywall). Ceiling heights used to generate the drywall estimate are 9 feet for patient care areas, hallways, and offices and 12 feet for lobbies and cafeterias. Only minimal use of drywall on ceilings was observed in the hospital visited (e.g., vaulted ceilings in atria). Because drywall will not be neatly stacked when removed from a building, the base volume of drywall (i.e., length × width × height) is multiplied by a factor of 1.3 to arrive at the total volume including void spaces.
Ceiling Tiles	This estimate includes ceiling tiles and frames. Almost all ceilings in the hospital visited were covered with ceiling tiles (only ceilings in utility and back storage room walls were not covered with ceiling tiles). Because tiles will not be neatly stacked when removed from a building, the base volume of tiles (i.e., length × width × height) is multiplied by a factor of 1.3 to arrive at the total volume including void spaces.
Carpet	This estimate includes only carpet on floors. Carpet padding is not included because padding was not found at the hospital visited. Carpet was used in waiting rooms, staff lounges, gift shops, dining areas, and approximately 70% of the offices. Carpet was assumed to be rolled and dry.

Table 2-15. Interior/Non-Structural Waste Categories and Descriptions for Hospitals

Waste Category	Description
Other Non-Structural Building Materials	This estimate includes all building material not included in other building material subcategories (Drywall, Ceiling Tiles, and Carpet). The building materials in this estimate include restroom equipment, doors, glass panes, other floor coverings, duct work, and vents.
Electronic Equipment	Included in this category is the estimate for Patient Care Equipment, Imaging Equipment, Laboratory/Surgery Equipment, Industrial Electronic Equipment, and Other Electronic Equipment. While this estimate includes air handlers, it does not include boilers and other climate control equipment located on the exterior of the hospital. Additional types of materials that were not included are wiring, elevators, and escalators.
Patient Care Equipment	This estimate includes intravenous (IV) pumps, vital statistics monitors, ventilators, incubators, and other electrical patient care equipment.
Imaging Equipment	This estimate includes x-ray machines, CT scanners, MRI machines, and other associated imaging electronic equipment.
Laboratory/Equipment	This estimate includes electronic equipment used in hospital laboratories (e.g., blood analyzers, centrifuges) and electronic surgical equipment (e.g., blood transfusion units, anesthesia units, scopes/surgical cameras).
Industrial Electronic Equipment	This estimate includes all kitchen electronic equipment (i.e., industrial ovens, freezers, etc.), air handlers, laundry equipment, circuit breaker boxes, and telephone routing boxes.
Other Electronic Equipment	This estimate includes all electrical items not listed in the categories above, including computers, televisions, telephones, vacuums, and lights and light fixtures.
Furniture	This estimate includes all items in the Patient Care Furniture and Office and Other Furniture categories presented below. The volume for each item was determined by multiplying the overall dimensions. All items are assumed to still be fully assembled. Only minimum size reduction is assumed (e.g., folding tables and chairs are folded).
Patient Care Furniture	This estimate includes patient beds, infant cribs, examining tables, wheel chairs, and other furniture used for patient care.
Office and Other Furniture	This estimate includes office furniture (e.g., desks, office chairs, filing cabinets) found at nurses' stations, registration, and other offices throughout the hospital. The estimate also includes all other non-patient care furniture (e.g., storage cabinets, storage shelves, trash cans).
Supplies	This estimate includes all items in the Medical Supplies, Pharmaceuticals, Linens, Food, and Paper/Office Supplies categories presented below.
Medical Supplies	This estimate includes all of the disposable medical supplies throughout the hospital including gauze, medical tape, tongue depressors, bed pans, IV bags, needles, etc.

Table 2-15. Interior/Non-Structural Waste Categories and Descriptions for Hospitals

Waste Category	Description
Pharmaceuticals	This estimate includes all pharmaceuticals and associated liquid reagents and solvents in the hospital. The estimate is based on the quantity of storage space for pharmaceuticals at a hospital. Please note that many pharmaceuticals are regulated hazardous waste under the Resource Conservation and Recovery Act (RCRA). Additional guidance is provided in the tool on safely disposing of pharmaceuticals.
Linens	This estimate is based on data on the standard hospital use rate of linens, including sheets, pillow cases, towels, and patient gowns.
Food	This estimate is based on inventories of all standard food kept on hand. The amount of food on hand may be significantly lower between deliveries.
Paper/Office Supplies	This estimate is based on the assumption that all office filing cabinets, bookshelves, etc., are 75% full of paper and office supplies. Additionally, phone books, toilet paper, janitorial paper products, food service paper products (e.g., plates, napkins), and other paper products are also included in this estimate.
Medical Waste	The estimate includes medical waste Types A through H[a]. The tool uses the data for metropolitan hospitals and assumes 90% occupancy and a maximum of three days of medical waste remaining at the hospital at any given time to generate medical waste estimates (i.e., 189 lb/occupied bed-month × 0.9 occupied beds/total beds × 3 days/30 days/month = 17 lb/bed). Additional guidance is provided in the tool on medical waste handling and disposal.
Other Items and Equipment	This estimate includes all other materials found at hospitals, including dishes and cookware, pictures and posters, janitorial carts, cleaning supplies, maintenance supplies (e.g., cans of paint, tools), and plants.

[a] For a definition of the types of medical waste, see U.S. Environmental Protection Agency. *Characterization of Medical* Waste *Generation and* Treatment *and* Disposal *Practices in New York and New Jersey*. USEPA Region 2 and Office of Solid Waste. January 30, 1989. http://www.p2pays.org/ref%5C02/01260/01260.pdf

2.3.6 Data Analysis and Quality

The estimates are based on community hospitals. While specialized hospitals (e.g., cardiovascular centers, orthopedic hospitals) are expected to contain similar quantities of items, the applicability of the estimates to these types of facilities is uncertain.

Because only one site visit was conducted, it is impossible to perform a statistical analysis of the data used to generate the waste and item category factors. However, the model hospital was normalized based on national hospital statistics collected through a large national survey conducted by AHA. Additionally, based on conversations with the AHA and its members, the contents of most patient care areas are fairly typical and standard among community hospitals (i.e., patient rooms are fairly standard among hospitals). Therefore, ERG believes that estimates made based on these factors are appropriate for the order of magnitude estimations required for the WME.

2.4 Hotels

This section discusses the data sources, methodology, and assumptions used to generate the waste category factors and the waste item factors for hotels, including a description of each waste category, and a brief analysis of the data quality. This information was originally presented in a memorandum dated October 14, 2005.[26]

2.4.1 Data Sources

The factors for hotels were generated based on site visits to two hotels, information from and discussions with Marriott International management personnel, partial hotel inventories, and weights and dimensions of items from the American Hotel Register catalog.

2.4.1.1 Site Visits

Marriott International allowed ERG to visit two of their hotels for the development of the Hotel WME. The first hotel was a large conference center hotel with:

- 322 standard guest rooms (261 with two queen-size beds and 61 with one king-size bed);
- 8 suite guest rooms;
- 32,500 ft^2 of meeting rooms; and
- 548 restaurant seats.

The second hotel visited was an extended-stay type hotel with 123 suite rooms (81 studio suites, 30 one-bedroom suites, and 12 two-bedroom suites). The hotel also contained one small 500 ft^2 meeting room and a continental breakfast area with 48 seats.

At each site visited, an inventory was conducted of all furniture, electronic equipment, fixtures, and other items. Note that only one guest room of each room type (e.g., studio suite, one-bedroom suite, two-bedroom suite) was inventoried, because all rooms of each type are identical. Inventories were recorded on appropriate checklists. The quantity of duct work, ventilation systems, drywall, and other building materials, was estimated by reviewing the structure's floor plans.

2.4.1.2 Hotel Inventories

While Marriott Hotels did not have master inventories of all items in the hotel, the following inventories were available for the hotels visited and used for the development of the waste category factors:

- Standard food kept in stock for most restaurant and conference activities (note that additional food may be ordered for large conferences and events);

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[26] Memorandum from Aaron Osborne (ERG) to Susan Thorneloe and Paul Lemieux (EPA), *Summary of Methodology and Data Collection for the Hotel* Back-of-the-envelope *Estimator (*BoEE*)*, October 14, 2005.

- Electronic equipment for conference and event support;
- Dishware, silverware, and serving items;
- Toiletries, paper products, and cleaning products;
- Conference and event tables, chairs, etc., and associated linens; and
- Standard items purchased for the startup of a new hotel.

2.4.1.3 Information from Marriott International

In addition to allowing the site visits and providing inventories, Marriott International also provided ERG with extensive information on the hotel industry including the following:

- Standard designs and floor plans. Many new chain hotels are designed based on standard floor plans and built at multiple locations. Standard floor plans for several Marriott brand hotels (e.g., Residence Inn, Fairfield Inn) are available at http://marriott.com/development/default.mi?WT_Ref=mi_left and were reviewed to gain an understanding of typical hotel proportions (e.g., how the number of guest rooms compares to laundry structure size). The extended-stay type hotel visited is very similar to the standard plans reviewed.
- Standard hotel practices. Many items are kept in proportion to the number of rooms or beds. For example, four sets of sheets are kept for each bed (i.e., one dirty sheet is on a bed, one clean sheet is ready to be put on the bed, one sheet is being cleaned, and one sheet is in transit or extra), and 16 sets of towels are kept for each room (i.e., four clean sets, etc.).
- Back room and office association. Several back rooms and offices (e.g., laundry, administrative offices, marketing, etc.) may be associated with both serving the guest rooms and conference or restaurant portions of the hotel (e.g., the laundry washes both sheets and towels for the guest room beds, as well as table cloths and napkins for the restaurant). The percentage of each back room or office associated with guest rooms, conference structure, and restaurant was determined based on discussions with Marriott management personnel.

2.4.1.4 Item Weights and Dimensions

To estimate the total weight and volume of items and materials at a structure, the weight and volume of each item must be known. Weights and dimensions for many items at a hotel were already included in the waste item database located within the I-WASTE DST. Additional hotel items were added to the database based on weights and dimensions found in the American Hotel Register 2005/2006 Catalog (most weights and dimensions are also available online at www.americanhotelregister.com). Marriott and several other hotel companies use American Hotel Register to supply many of the items found in their hotels.

2.4.2 Methodology

The extensive differences between hotels posed a unique challenge for the WME. For schools and offices, variations within a structure type are accounted for by multiple sub-structure types (i.e., elementary, middle, and high schools) requiring only one parameter to generate estimates within an order of magnitude. While two parameters may be entered for offices and schools, waste material estimates are made independently for each parameter. However, this approach was not the most appropriate for generating estimates within an order of magnitude for hotels. While hotels could be broken down into several sub-structure types to represent the differences between hotels (e.g., interstate hotels with no restaurant or meeting space, large inner-city hotels with multiple restaurants, shops, and meeting rooms) and estimates made based on number of guest rooms or total square footage, hotels within each class may still vary significantly within each sub-structure type. For example, Marriott facilities with 40,000 ft^2 of meeting rooms may have between 300 and 1,500 guest rooms. Therefore, instead of different input parameters providing independent WME estimates, the WME allows users to "build" their own hotel by entering the following multiple independent input parameters for each *hotel area fraction:* standard guest rooms, suite guest rooms, meeting rooms, and restaurant space.

- *Number of standard guest rooms*. Standard guest rooms are typically one room with one or two beds, a desk and a few chairs, a few end tables, a dresser or bureau, a television and telephone, several lamps and lights, and a bathroom. Based on the number of standard guest rooms, the estimator calculates the quantity of items and materials for all standard guest rooms, hallways associated with the guest rooms, main lobby, exercise rooms, and equipment for indoor pools (the pool itself is not included). The estimate also includes the portions of offices (e.g., janitorial office, administrative office), kitchen, laundry rooms, and utility rooms associated with lodging.
- *Number of suite guest rooms*. Suite guest rooms are typically several rooms with a kitchenette, dining area, couches with an additional television in addition to the items in a standard guest room. Because of the significant differences in the quantity of items and materials between the different types of guest rooms, specifically, the additional furniture and electronic equipment in a suite room, the tool requests both the number of standard guest rooms and the number of suite guest rooms. While separating standard and suite rooms may not result in a significant difference in total items and materials if only two percent of the hotel's rooms are suites, the separation does represent a significant difference for extended-stay type hotels with all suite rooms. Additionally, during the site visits to develop these factors, larger hotels with conference facilities tended to have drywall ceilings in most rooms. However, in newer extended-stay type hotels with all suite guest rooms, ceilings were not covered with drywall. Therefore, estimates for standard rooms include drywall on ceilings and estimates for suite rooms do not. This estimate also includes the appropriate portion of the items and materials in rooms associated with lodging, discussed above for standard guest rooms (e.g., hallways, janitorial rooms).
- *Square footage of meeting rooms*, not including foyer space in front of the meeting rooms or other square footage associated with the meeting rooms, the most common way hotels measure their meeting space. The information is available on most hotel websites. The estimator may not provide accurate estimates for hotels with limited meeting space (e.g., one 20 ft × 20 ft meeting room). The quantity of items and materials associated with one small meeting room of this size is minimal compared to the quantity of items and materials associated with the guest rooms. Based on the

square footage of meeting rooms, the estimator calculates the quantity of waste from all meeting rooms, storage rooms, restrooms, hallways, and lobbies associated with the conference structure. The estimate also includes the portions of offices (e.g., marketing office, administrative office), kitchen, laundry rooms, and utility rooms associated with the conference space.

- *Total number of restaurant seats*, including bar seats. While a hotel may have multiple restaurants, using the total number of seats is the easiest value to use for estimating the waste. Using the square footage associated with the restaurants may cause confusion of what square footage to include and would require the use of the building floor plans. Based on the total number of restaurant seats, the estimator calculates the quantity of items and materials from the dining rooms, storage rooms, and hallways associated with the restaurants and bars. The estimate also includes the portions of offices (e.g., marketing office, administrative office), kitchen, laundry rooms, and utility rooms associated with the restaurant.

ERG used the data sources previously described to create model inventories for each part of the hotel (i.e., standard guest rooms, suite guest rooms, meeting space, and restaurants). The three data sources were combined to create the model inventories with actual hotel inventories used first, followed by hotel standards, and finally inventories taken during site visits (i.e., if the hotel had a known inventory of 124 six-foot round meeting tables, that value would be used over the number of tables counted during the site visit). Model inventories for standard guest rooms, conference space, and restaurants were based mainly on information from the large conference center hotel, while the model inventory for suite guest rooms was based mainly on the extended-stay suite hotel visited.

2.4.2.1 Waste Category Estimates

Similar items in the model inventory were grouped into the waste material categories, described in greater detail in Section 2.4.5. A weight and volume was assigned to each item in the waste material category based on information in the Waste Item Database. The total weight and volume for the waste material category was calculated by summing the individual weights and volumes of all items in the category. The total weight and volume of each waste material category was divided by the parameter appropriate for the model inventory (e.g., the model inventory for conference space was for a structure with 32,500 ft^2 of meeting room space) to generate the waste material factors for hotels.

To generate estimates for the quantity of items and materials, the tool multiplies the respective waste category factor (listed in Table 2-17 through Table 2-20) by each input parameter for each hotel sub-structure. The waste estimate from each input parameter is summed and presented to the user (i.e., 100 tons of drywall associated with standard guest rooms plus 30 tons of drywall associated with meeting rooms equals 130 tons of drywall for the structure). This approach allows the estimator to better account for the differences between hotels. If a hotel does not have meeting space, the user could simply enter “0” for square footage of meeting rooms, and no items or materials associated with meeting rooms would be included in the estimate.

$$E_{wc-i} = \sum (WCF_{i,y})(IP_{x,y})(1 + PMF) \qquad \textbf{(Eq. 2-2)}$$

where:

$E_{wc\text{-}i}$	=	Estimate of waste for waste category *i*, tons or yd^3
$WCF_{i,\,y}$	=	Waste category factor for waste category *i* and hotel area fraction *y* (from Table 2-17 through Table 2-20)
$IP_{x,\,y}$	=	Input parameter value for structure type *x* and hotel area fraction *y* (from Table 2-16)
PMF	=	Packaging materials factor (from Table 2-21)

As discussed above, there are four independent input parameters for hotels, one parameter for each hotel area fraction. At least one of the four parameters is required to generate waste estimates for hotels.

Table 2-16. Input Parameters for Hotels

WME Structure Type	**Hotel Area Fraction**	**Hotel Area Fraction Input Parameter**
Hotel	Standard guest rooms Suite guest rooms Conference rooms Restaurant(s)	Number of standard guest rooms Number of suite guest rooms Square feet of conference rooms Number of restaurant seats

2.4.3 Waste Category Factors

Based on the data and methodology presented above, Table 2-17 through Table 2-20 present the factors used by the WME to generate order of magnitude estimates of the quantity of non-structural items and materials from a non-luxury hotel. A description of the items that are included in each waste category is presented in Section 2.4.5, below.

The tool also allows the user to make two adjustments to the estimates. First, the user can account for the additional weight and volume added by packaging materials. Also, the user can account for the additional items and materials in luxury hotels. These adjustments are further described below.

Table 2-17. WME Interior/Non-Structural Factors for Estimating the Weight of Items for Non-Luxury Hotels

Waste Category	**WCF** (tons/standard guest room)	**WCF** (tons/suite guest room)	**WCF** (tons/ft^2 of meeting rooms)	**WCF** (tons/restaurant seat)
Total Non-Structural Building Materials	2.05[a]	1.77[a]	0.00785[a]	0.0944[a]
Drywall	1.43	1.09	0.00519	0.0570
Ceiling Tiles	0.00667	0.00933	0.000231	0.00541
Carpet	0.113	0.185	0.000532	0.00709
Marble and Ceramic Tiles	0.103	0.105	0.000538	0.00740

Table 2-17. WME Interior/Non-Structural Factors for Estimating the Weight of Items for Non-Luxury Hotels

Waste Category	**WCF** (tons/standard guest room)	**WCF** (tons/suite guest room)	**WCF** (tons/ft^2 of meeting rooms)	**WCF** (tons/restaurant seat)
Other Non-Structural Building Materials	0.397	0.381	0.00136	0.0175
Electronic Equipment	0.185[b]	0.441[b]	0.00129[b]	0.0259[b]
Industrial Electronic Equipment	0.0269	0.0374	0.000605	0.0187
Other Electronic Equipment	0.158	0.403	0.000687	0.00726
Furniture	0.714	0.779	0.00230	0.0345
Paper	0.0343	0.0372	0.000835	0.0134
Food	0.00398	0.0108	0.000683	0.017
Linens	0.0531	0.0613	0.0000512	0.00159
Dishware	0.003	0.0195	0.000207	0.00542
Other Items and Equipment	0.00903	0.0218	0.000165	0.00937
Personal Effects	0.0234	0.0234	0	0
TOTAL	**3.07[c]**	**3.17[c]**	**0.0134[c]**	**0.202[c]**

[a] Represents a calculated value. The estimate for *Total Non-Structural Building* Materials is calculated by adding the individual waste category estimates for the *Drywall, Ceiling Tiles, Carpet, Marble and Ceramic Tiles*, and *Other Non-Structural Building* Materials waste categories.

[b] Represents a calculated value. The estimate for *Electronic Equipment* is calculated by adding the individual waste quantity estimates for the *Industrial Electronic Equipment* and *Other Electronic Equipment* waste categories.

[c] The Total estimated waste quantity is calculated by adding the individual estimates for *Total Non-Structural Building* Materials, *Electronic Equipment*, and the individual waste quantity estimates for the *Furniture, Paper, Food, Linens, Dishware, Other* Items *and Equipment, and Personal Effects* waste categories.

Table 2-18. WME Interior/Non-Structural Factors for Estimating the Volume of Items for Non-Luxury Hotels

Waste Category	**WCF** (yd^3/standard guest room)	**WCF** (yd^3/suite guest room)	**WCF** (yd^3/ft^2 of meeting rooms)	**WCF** (yd^3/restaurant seat)
Total Non-Structural Building Materials	9.64[a]	10.4[a]	0.0488[a]	0.534[a]
Drywall	4.12	3.16	0.0150	0.165
Ceiling Tiles	0.0711	0.0993	0.00246	0.0576
Carpet	0.994	1.63	0.00467	0.0622
Marble and Ceramic Tiles	0.226	0.194	0.00171	0.0235
Other Non-Structural Building Materials	4.23	5.28	0.0250	0.225
Electronic Equipment	1.53[b]	4.61[b]	0.0151[b]	0.215[b]

Table 2-18. WME Interior/Non-Structural Factors for Estimating the Volume of Items for Non-Luxury Hotels

Waste Category	**WCF** (yd^3/standard guest room)	**WCF** (yd^3/suite guest room)	**WCF** (yd^3/ft^2 of meeting rooms)	**WCF** (yd^3/restaurant seat)
Industrial Electronic Equipment	0.375	0.462	0.00515	0.160
Other Electronic Equipment	1.16	4.15	0.00997	0.0557
Furniture	10.7	13.8	0.0383	0.906
Paper	0.131	0.120	0.00311	0.0500
Food	0.0246	0.0665	0.00422	0.107
Linens	0.226	0.316	0.000200	0.00586
Dishware	0.0148	0.165	0.00139	0.0359
Other Items and Equipment	0.0610	0.174	0.00113	0.0173
Personal Effects	0.141	0.141	0	0
TOTAL	**22.5[c]**	**29.7[c]**	**0.112[c]**	**1.87[c]**

[a] Represents a calculated value. The estimate for *Total Non-Structural Building* Materials is calculated by adding the individual waste category estimates for the *Drywall, Ceiling Tiles, Carpet, Marble and Ceramic Tiles,* and *Other Non-Structural Building* Materials waste categories.

[b] Represents a calculated value. The estimate for *Electronic Equipment* is calculated by adding the individual waste quantity estimates for the *Industrial Electronic Equipment* and *Other Electronic Equipment* waste categories.

[c] The Total estimated waste quantity is calculated by adding the individual estimates for *Total Non-Structural Building* Materials, *Electronic Equipment,* and the individual waste quantity estimates for the *Furniture, Paper, Food, Linens, Dishware, Other* Items *and Equipment, and Personal Effects* waste categories.

2.4.3.1 Luxury Hotels

In luxury hotels, marble may cover the floor and walls of all bathrooms and cover large spaces in the lobby. Additionally, extensive molding and décor is typically present in lavish hotels. If the user wants to account for additional items and materials in luxury hotels, marble is assumed to be used in all bathrooms and in large spaces in the lobby, and additional décor is included. If the user does not want to account for additional items and materials in luxury hotels, linoleum or ceramic tiles are assumed to be used in all bathrooms and in large spaces in the lobby instead of marble. Additional décor is also not included. Accounting for additional items and materials in luxury hotels increases the weight and volume of items in the Marble and Ceramic Tiles, Other Building Materials, and Furniture waste categories. For these categories, the factors presented in Table 2-19 and Table 2-20 are used to generate waste estimates instead of the values presented in Table 2-17 and Table 2-18.

Table 2-19. Alternative WME Interior/Non-Structural Factors for Estimating the Weight of Items for Luxury Hotels

Waste Category	**WCF** (tons/standard guest room)	**WCF** (tons/suite guest room)	**WCF** (tons/ft^2 of meeting rooms)	**WCF** (tons/restaurant seat)
Marble and Ceramic Tiles	0.365	0.370	0.00206	0.0189
Other Non-Structural Building Materials	0.401	0.489	0.00176	0.0228
Furniture	0.786	0.857	0.00253	0.0379

Table 2-20. Alternative WME Interior/Non-Structural Factors for Estimating the Volume of Items for Luxury Hotels

Waste **Category**	**WCF** (yd^3/standard guest room)	**WCF** (yd^3/suite guest room)	**WCF** (yd^3/ft^2 of meeting rooms)	**WCF** (yd^3/restaurant seat)
Marble and Ceramic Tiles	0.534	0.527	0.0029	0.0363
Other Non-Structural Building Materials	4.44	5.55	0.0257	0.237
Furniture	11.3	14.5	0.0402	0.951

2.4.3.2 Additional Weight and Volume Added by Packaging Materials

If items are packaged prior to shipment, the packing material will increase the volume and weight. If the user chooses to account for this increase in volume and weight, the volume of the estimate for each waste category will increase by 10% and the weight of the each estimate will increase by 5%. Actual increases in weight and volume due to packing material may vary based on the type and shape of the item, the type of packing material used, and the packing requirements for the various contaminants.

Table 2-21. Packaging Materials Factors for Hotels

Waste **Category Estimate Based On…**	**PMF**
Weight	0.05
Volume	0.10

2.4.4 Assumptions and Key Notes

The following assumptions are made when estimating the amount of waste materials requiring disposal from a hotel:

- Items and materials located outside the hotel (e.g., outdoor pools, tennis courts, and picnic areas) are not included in the estimate.

- All weights are dry weights. Additional weight of water from decontamination fluid is not accounted for.
- Drywall and ceiling tiles will not be neatly stacked when packaged for shipment. The base volume of drywall and ceiling tiles (i.e., length × width × height) is multiplied by a factor of 1.3 to determine the total volume including void space.
- Since some buildings may be constructed without using drywall, ceiling tiles, carpet, and marble and ceramic tiles, or because these materials may not be removed during the decontamination process, estimates for these materials are broken out separately within the building materials category.
- Estimates are based on hotels with 90% walls covered with drywall, 5% to 15% of ceilings covered with ceiling tiles, and carpet in all guest rooms, guest hallways, meeting rooms, dining rooms, and offices.
- All items are assumed to be shipped for disposal fully assembled. The volume for each item is determined by multiplying its maximum overall dimensions. Only minimum size reduction is assumed (e.g., folding tables and chairs are folded).
- The amount of paper is based on inventories of toilet paper, tissues, etc. and the assumption that all filing cabinets, bookshelves, etc. are 50% full of paper and office supplies.

2.4.5 Category Descriptions

Details and assumptions for each waste category for which estimates are generated are described in Table 2-22 below.

Table 2-22. Interior/Non-Structural Waste Categories and Descriptions for Hotels

Waste Category	Description
Total Non-Structural Building Materials	This category includes the estimates for drywall, ceiling tiles, carpet, and marble and ceramic tiles as well as restroom equipment (e.g., toilets, sinks, stall dividers), doors, blinds and window coverings, other floor coverings (e.g., linoleum), and ventilation systems. Ventilation systems estimates include only duct work and vents. Air handlers and other mechanical ventilation equipment are not included. Sprinkler systems, piping, and frames supporting the drywall are assumed to remain in place and also are not included in this estimate. Since some buildings may be constructed without using drywall, ceiling tiles, carpet, and marble and ceramic tiles, and because these materials, even if present, may not be removed during the decontamination process, estimates for these materials are broken out separately within the building materials category.

Table 2-22. Interior/Non-Structural Waste Categories and Descriptions for Hotels

Waste Category	Description
Drywall	This estimate includes drywall on walls and ceilings. Frames supporting the drywall are not included in this estimate. This estimate is based on hotels where 90% of the interior walls are covered with drywall (only some back utility room walls were not covered with drywall). During the site visits to develop these factors, larger hotels with conference facilities tended to have drywall ceiling in most rooms; however, in newer extended-stay type hotels with all suite guest rooms, ceilings were exposed concrete ceilings. Therefore, estimates for standard rooms include drywall on ceilings and estimates for suite rooms do not. Because drywall will not be neatly stacked when removed from a building, the base volume of drywall (i.e., length × width × height) is multiplied by a factor of 1.3 to arrive at the total volume including void spaces.
Ceiling Tiles	This estimate includes ceiling tiles and frames. Hotels visited had between 5 and 15% of their ceilings covered with ceiling tiles (mostly back offices and work space). Because tiles will not be neatly stacked when removed from a building, the base volume of tiles (i.e., length × width × height) is multiplied by a factor of 1.3 to arrive at the total volume including void spaces.
Carpet	This estimate includes only carpet on floors. Carpet padding is not included because padding was not found at the hotels visited. Carpet was found in all guest rooms, guest hallways, meeting rooms, dining rooms, and offices. Bathrooms, lobbies, and most back areas other than offices were not carpeted. Carpet was assumed to be rolled and dry.
Marble and Ceramic Tiles	In lavish hotels, marble may cover the floor and walls of all bathrooms and cover large spaces in the lobby. If the lavish hotel box is checked, this estimate includes the marble in all of these locations. If the lavish hotel box is not checked, it assumes that all of these floors and walls are covered with ceramic tiles.
Other Non-Structural Building Materials	This estimate includes all building material not included in other building material subcategories (Drywall, Ceiling Tiles, Carpet, and Marble and Ceramic Tiles). The building materials in this estimate include restroom equipment, doors, blinds and window coverings, other floor coverings, duct work, and vents.
Electronic Equipment	Included in this category is the estimate for industrial electronic equipment, as well as all computers, televisions, electronic janitorial equipment (i.e., vacuum cleaners, floor cleaners, etc.), cooking equipment in guest rooms, and lights and light fixtures. Two potential types of waste materials that were not included are wiring and mechanical ventilation and climate control equipment (e.g., air handlers, boilers).
Industrial Electronic Equipment	This estimate includes all kitchen electronic equipment (e.g., industrial ovens, freezers), water heaters, laundry equipment, circuit breaker boxes, and telephone routing boxes.
Other Electronic Equipment	This estimate includes all items listed above in the Electronics Equipment category with the exception of industrial electronic equipment.
Furniture	This estimate includes all furniture, divider panels, and pictures. Cabinetry and counter tops are also included. The volume for each item was determined by multiplying the overall dimensions. All items are assumed to still be fully assembled. Only minimum size reduction is assumed (e.g., folding tables and chairs are folded).

Table 2-22. Interior/Non-Structural Waste Categories and Descriptions for Hotels

Waste Category	Description
Paper	This estimate is based on the assumption that all filing cabinets, bookshelves, etc., are 50% full of paper and office supplies. Phone books, toilet paper, and other paper products are also included in this estimate.
Food	This estimate is based on detailed inventories of all standard food kept on hand. If a large conference is in session, significant quantities of additional food may also require disposal.
Linens	This estimate includes all towels, sheets, pillow cases, blankets, table cloths, and linen napkins. The estimate is based on standard hotel practices (i.e., for each bed, one dirty sheet is on a bed, one clean sheet is ready to be put on the bed, one sheet is being cleaned, and one sheet is in transit or extra).
Dishware	This estimate includes all glasses, plates, silverware, cookware, pitchers, etc. The estimate is based on detailed inventories of purchased equipment.
Other Items and Equipment	This estimate includes all other materials found at the hotel, including toiletries, cleaning supplies, maintenance supplies (e.g., cans of paint, rock salt, tools), and plants.
Personal Effects	This estimate includes luggage and personal items that will be in the hotel. The estimate assumes one large suitcase and one backpack/briefcase per guest room and 85% occupancy.

2.4.6 Data Analysis and Quality

Because site visits were conducted at only two hotels, it is impossible to perform a statistical analysis of the data. However, based on the extensive information provided by Marriott International, ERG believes that estimates made based on these factors are appropriate for the order of magnitude estimations required for the WME. Because of the standard designs used for most new and non-conference hotels, data collected for the extended-stay type hotel should be very similar to other hotels in this category. If future refinements to the tool are performed, ERG recommends additional site visits to large conference center hotels because of the potential considerable variability in hotels of this type.

2.5 Movie Theaters

This section discusses the data sources, methodology, and assumptions used to generate the waste category factors and the waste item factors for movie theaters, including a description of each waste category and a brief analysis of the data quality. This information was originally presented in a memorandum dated April 6, 2006.[27]

[27] Memorandum from Aaron Osborne (ERG) to Susan Thorneloe and Paul Lemieux (EPA), *Summary of Methodology and Data Collection for the Theater WME (WME) and Default Structure Inventories*, April 6, 2006.

2.5.1 Data Sources

The factors for movie theaters were generated based on site visits to three movie theaters and weights and dimensions of items obtained from Christie's Digital Systems (projection equipment manufacturer) and various other vendor catalogs.

2.5.1.1 Site Visits

Regal Cinemas allowed ERG to visit the following three movie theaters:

- Ten-screen theater with 2,009 theater seats located within a suburban strip mall;
- Fourteen-screen theater with 2,788 theater seats located within a downtown mall; and
- Twenty-screen theater with 3,678 theater seats located in its own separate building.

At each site visited, an inventory was conducted of all furniture, projection equipment, concession equipment, fixtures, and other items. Only one set of similar items or rooms was inventoried. For example, identical sets of projection and sound equipment were used for each screen. The inventoried set was multiplied by the number of screens to calculate the total for the structure. Inventories were recorded on the appropriate checklists. The quantity of duct work, ventilation systems, drywall, and other building materials was estimated by reviewing the floor plans of the structure.

The facilities did not keep detailed inventories of the items in the movie theater. However, some limited inventories (e.g., amount of food kept in stock) were obtained and used.

2.5.1.2 Item Weights and Dimensions

To estimate the total weight and volume of items and materials at a structure, the weight and volume of each item must be known. Weights and dimensions for many items at a movie theater were already included in the waste item database located within the I-WASTE DST. Additional movie theater projection equipment items were added to the database based on weights and dimensions from Christie's Digital Systems (www.christiedigital.com, last accessed December 21, 2015). Christie's manufactured the majority of the projection equipment used at the movie theaters visited. Weights and dimensions for many movie theater concession items were found through the Ace Mart Supply Company (www.acemart.com, last accessed December 21, 2015), a common vendor.

2.5.2 Methodology

The methodology used to develop estimates for movie theaters is similar to the methodology used for schools and offices. For these facilities, the tool accounts for variations between facilities by using multiple sub-structure types (i.e., elementary, middle, and high schools) and generates estimates based on each input parameter (i.e., number of seats, number of screens). While two parameters may be entered for these facilities, waste category estimates are made independently for each parameter. Because the factors for movie theaters were generated based on multiplex movie theaters, the applicability of these factors to estimates to other types of theaters (e.g., performing arts) is uncertain.

Because of the standard designs and proportions of most movie theaters currently being operated, it was not necessary to allow the users to “build” their own movie theater by entering the multiple independent input parameters (i.e., number of screens, concession booths). This approach is necessary only for facilities that may have extensive differences between facilities of similar size.

Instead, the WME can generate order of magnitude estimates of the quantity of items and materials from movie theaters based on the total number of seats in every auditorium *or* on the total number of screens. Estimates based on the total structure square footage were also investigated. Estimates based on square footage were found to be more accurate for many of the waste categories (additional discussion presented in Section 2.5.6); however, most establishments did not know this parameter off-hand and did not know how to find the value. Corporate staff also had difficulty determining the square footage of the establishment. Additionally, there were questions on how to calculate the total square footage. For example, the square footage found on the structure’s lease was based on the square footage of the main floor and did not include the square footage of the upper floor with the projection room and many offices. While ERG could roughly estimate the square footage based on the floor plans of the facilities, because the parameter would not likely be readily available as an input value, it was not used in the WME.

2.5.2.1 Individual Movie Theater Inventories

ERG used the data sources previously described to create inventories for each movie theater visited. These inventories were based primarily on the data collected during the site visit. ERG notes that the movie theater inventories were much less complex than the inventories for schools and hotels (i.e., hotel inventories included items in guest rooms, conference rooms, lobbies, offices, swimming pools, exercise rooms, storage rooms, etc., whereas movie theaters consist *primarily* of auditoriums, lobby/concession areas, projection rooms, and a few offices). Smaller items were placed in “boxes” based on the approximate weight of each item (e.g., calculators, security cameras, extension cords, etc., were placed in “boxes of electronics”). These master inventories for each structure were used to create the factors for the default structure inventories and for the WME.

2.5.2.2 Default Structure Inventories

To create the parameters used to generate default structure inventories, each item on the master inventories was divided by the appropriate parameter to generate the waste item factors for each movie theater (e.g., movie theater #1 had 10 film projectors and 2,009 seats, which equals 0.005 film projectors per seat). The waste item factors from each movie theater were averaged to create the factors used in the WME.

To minimize the number of items and resulting complexity, items of similar materials, weights, and dimensions were combined. For example, a desktop fax machine is very similar in dimensions and material content to a desktop printer. Additionally, while a structure may have five-foot, six-foot, and eight-foot folding tables, the default structure inventories contain only six foot folding tables. In all cases, the user can add or remove items to further refine and tailor the inventory to the user’s specific needs.

To generate default structure inventories, the tool multiplies each waste item factor by the preferred input parameter (see Section 2.5.6 for additional discussion on preferred input parameter). While the user may enter both number of seats and number of screens, the default structure inventories are made based only on the preferred input parameter.

2.5.2.3 Waste Category Estimates

Similar items in the inventories were grouped into the waste categories, described in greater detail in Section 2.5.5. A weight and volume were assigned to each item in the waste category based on information in the waste item database. The total weight and volume for the category were calculated by summing the individual weights and volumes of all items in the category. The total weight and volume of each category were divided by the parameter appropriate for each movie theater (e.g., movie theater #1 had 2,009 seats) to generate the waste category factors for each movie theater. The factors from each of the three theaters were averaged to create the factors used in the WME.

To generate waste estimates for movie theaters, the tool multiplies the respective waste category factor (listed in Table 2-23) by each input parameter value. While the user may enter both number of seats and number of screens, waste estimates are made independently for each parameter. While waste estimates may be generated based on the number of seats and/or the number of screens, each waste material category may have a stronger correlation to one factor over the other. If *both* the number of screens and the number of seats are entered into the WME, a preferential estimate is chosen when generating estimates.

Estimates are generated according to the following equation:

$$E_{wc\text{-}i} = (WCF_{i,z})(IP_{x\,z})(1 + PMF) \qquad \textbf{(Eq. 2-3)}$$

where:

$E_{wc\text{-}I}$	=	Estimate of waste for waste category *i*, tons or yd^3
$WCF_{i,z}$	=	Waste category factor for waste category *i* and input parameter *z*; tons/seat, tons/screen, yd^3/seat, or yd^3/seat (from Table 2-23)
$IP_{x,z}$	=	Input parameter value for structure type *x* and input parameter *z*, seats or screens
PMF	=	Packaging materials factor (from Table 2-24).

Because a movie theater's square footage is more closely dependent on the number of seats than the number of screens, the Total Non-Structural Building Materials waste categories (e.g., Carpet, Ceiling Tiles, Drywall) have a stronger correlation to the number of seats than the number of screens (movie theaters visited had approximately 20-24 ft^2/seat). Similarly, the major component of the Furniture category is the movie theater seats; therefore, the Furniture category also has a stronger correlation to the number of seats.

However, a set amount of equipment is required for each screen mostly independent of the auditorium's size. Therefore, the Theater Electronic Equipment and Other Electronic Equipment categories have a stronger correlation to the number of screens. Based on the sites visited, the other categories (Concession Electronic Equipment, Food, and Other Theater Items) had a slightly stronger but not significant correlation to the number of seats over the number of screens mainly because each movie theater has a certain set of equipment and rooms regardless of the size of the theater. For example, the concession area of the largest movie theater visited was only slightly larger than the concession area for the smallest movie theater visited, because the same pieces of equipment (e.g., popcorn machine, soda fountains, and cash registers) are required. Additionally, the quantity of food in the movie theaters visited was more dependent on the date of the last delivery than on the theater's size. For the purposes of estimates in the tool where only one value can be used, if both number of seats and number of screens are entered, all estimates are based on the number of seats, except for the estimate for Theater Electronic Equipment.

2.5.3 Waste Category Factors

Based on the data and methodology presented above, Table 2-23 presents the factors used by the WME to generate order of magnitude estimates of the quantity of waste that may require disposal from a movie theater. A description of the items that are included in each waste category is presented in Section 2.5.5. The tool also allows the user to account for the additional weight and volume added by packaging materials, which is further described below.

Table 2-23. WME Interior/Non-Structural Factors for Movie Theaters

Waste **Category**	**WMF** (tons/seat)	**WMF** (yd^3/seat)	**WMF** (tons/screen)	**WMF** (yd^3/screen)
Total Non-Structural Building Materials	0.0684[a]	0.658[a]	13.3[a]	128[a]
Carpet	0.00316	0.0277	0.615	5.39
Ceiling Tiles	0.00907	0.0966	1.77	18.8
Drywall	0.0343	0.0991	6.69	19.3
Curtains and Acoustical Material	0.0106	0.352	2.07	68.4
Other Non-Structural Building Materials	0.00421	0.0716	0.822	14.0
Electronic Equipment	[b]	[b]	[b]	[b]
Theater Electronic Equipment	0.00988	0.0871	1.920	16.9
Concession Electronic Equipment	0.00114	0.0123	0.221	2.39
Other Electronic Equipment	0.00151	0.00728	0.295	1.42
Furniture	0.0179	0.719	3.478	1402
Food	0.00147	0.00674	0.286	1.31
Other Theater Items	0.0118	0.113	2.305	22.0

[a] Represents a calculated value. The estimate for *Total Non-Structural Building* Materials is calculated by adding the individual waste category estimates for the *Drywall, Ceiling Tiles, Carpet, Curtains and Acoustical Material,* and *Other Non-Structural Building* Materials waste categories. The *Other Non-Structural Building Material* waste category includes floor tiles.

[b] Represents a calculated value. The estimate for *Electronic Equipment* is calculated by adding the individual waste quantity estimates for the *Theater Electronic Equipment, Concession Electronic Equipment,* and *Other*

Electronic Equipment waste categories. If *both* the number of seats and the number of screens is entered by a user, then the total quantity of *Electronic Equipment* is calculated by adding the estimates generated for *Theater Electronic Equipment* and *Other Electronic Equipment* (based on number of screens) and the estimate for *Concession Electronic Equipment* (based on the number of seats).

2.5.3.1 Additional Weight and Volume Added by Packaging Materials

If items are packaged prior to shipment, the packing material will increase the volume and weight. If the user chooses to account for this increase in volume and weight, the volume of the estimate for each waste category will increase by 10% and the weight of the each estimate will increase by 5%. Actual increases in weight and volume due to packaging material may vary based on the type and shape of the item, the type of packaging material used, and the packaging requirements for the various contaminants. Note that packaging material is not accounted for in the default structure inventories.

Table 2-24. Packaging Materials Factors for Movie Theaters

Waste Category Estimate Based On…	PMF
Weight	0.05
Volume	0.10

2.5.4 Assumptions and Key Notes

The following assumptions are made when estimating the amount of waste materials requiring disposal from a movie theater:

- Estimates only include items and materials from the movie theater and do not include items and materials from an attached mall or shopping center.
- Estimates are based on the entire building, not just one room. Estimates include items and materials found in the auditoriums, hallways, lobby, concessions area, projection room, arcade, administrative offices, employee break rooms, storage rooms, and restrooms.
- All weights are dry weights. Additional weight of water from any decontamination fluid is not accounted for.
- Drywall and ceiling tiles will not be neatly stacked when packaged for shipment. The base volume of drywall and ceiling tiles (i.e., length × width × height) is multiplied by a factor of 1.3 to determine the total volume including void space.
- Since some buildings may be constructed without one or more of the listed building materials (i.e., drywall, ceiling tiles, carpet, floor tiles, and curtains and acoustical material), or because these materials may not be removed during the decontamination process, estimates for drywall, ceiling tiles, carpet, floor tiles, and curtains and acoustical material are broken out separately within the building materials category. Additionally, users can exclude these categories when generating a default structure inventory.

- All items are assumed to be shipped for disposal fully assembled. The volume for each item is determined by multiplying its maximum overall dimensions. Only minimum size reduction is assumed (e.g., folding tables and chairs are folded).

2.5.5 Category Descriptions

Details and assumptions for each waste category for which estimates are generated are described in Table 2-25 below.

Table 2-25. Interior/Non-Structural Waste Categories and Descriptions for Movie Theaters

Waste Category	Description
Total Non-Structural Building Materials	This estimate includes the estimates for drywall, ceiling tiles, carpet, floor tiles, and curtains and acoustical material as well as restroom equipment (i.e., toilets, sinks, stall dividers, etc.), doors, ventilation systems. Note that ventilation systems estimates include only duct work and vents. Air handlers and other mechanical ventilation equipment are not included. Sprinkler systems, piping, and frames supporting the drywall are assumed to remain in place and are also not included in this estimate. Since some buildings may be constructed without one or more of the listed building materials (i.e., drywall, ceiling tiles, carpet, floor tiles, and curtains and acoustical material), or because these materials may not be removed during the decontamination process, estimates for drywall, ceiling tiles, carpet, floor tiles, and curtains and acoustical material are broken out separately within the building materials category.
Drywall	This estimate includes drywall on walls. Frames supporting the drywall are not included in this estimate. This estimate is based on movie theaters with 95% of interior walls covered with drywall (only some back utility room walls were not covered with drywall). The use of drywall for ceilings was not observed in the site visits. Because drywall will not be neatly stacked when removed from a building, the base volume of drywall (i.e., length × width × height) is multiplied by a factor of 1.3 to arrive at the total volume including void spaces.
Ceiling Tiles	This estimate includes ceiling tiles and frames. Movie theaters visited had between 90 and 95% of their ceilings covered with ceiling tiles, with the exception of some lobby areas. Because tiles will not be neatly stacked when removed from a building, the base volume of tiles (i.e., length × width × height) is multiplied by a factor of 1.3 to arrive at the total volume including void spaces.
Carpet	This estimate includes carpet on floors and walls. Carpet padding is not included because padding was not found at the movie theaters visited. Carpet was found in all offices, hallways, lobby/concession areas, and in the auditorium walkways. In the auditoriums, carpet was also found on the lower three feet of the auditorium walls, for acoustical purposes. Bathrooms, kitchens, storage rooms, projection rooms, lobbies, floor underneath the auditorium seats, and most back areas other than offices were not carpeted. Approximately 30-35% of the total square footage of the facilities was carpeted. Carpet was assumed to be rolled and dry.

Table 2-25. Interior/Non-Structural Waste Categories and Descriptions for Movie Theaters

Waste Category	Description
Curtains and Acoustical Materials	This estimate includes acoustic tiles, acoustical wall padding, and curtains. Because of the acoustical requirements of the auditoriums, all auditorium walls were covered with acoustical materials. Typically, the lowest three feet of the walls around the auditoriums were covered with carpet (accounted for in the Carpet category). Acoustical padding covered by a fixed curtain covered the remaining height of the side walls. Acoustical tiles were used on the rear walls. A retractable curtain covered the front wall.
Other Non-Structural Building Materials	This estimate includes all building material not included in other building material subcategories (Drywall, Ceiling Tiles, Carpet, and Curtains and Acoustical Materials). Building materials in this estimate include restroom equipment, doors, duct work, and vents and floor tiles. Floor tiles include floor tiles and other floor coverings (e.g., linoleum) from bathrooms, kitchens, storage rooms, projection rooms, lobbies, floor underneath the auditorium seats, and most back areas other than offices were covered with floor tiles and other types of floor coverings.
Electronic Equipment	Included in this category are the estimates for Theater Electronic Equipment and Concession Electronic Equipment, as well as all computers, televisions, electronic janitorial equipment (i.e., vacuum cleaners, floor cleaners, etc.), and lights and light fixtures. Two potential types of waste materials that were not included are wiring and mechanical ventilation and climate control equipment (i.e., air handlers, boilers, etc.).
Theater Electronic Equipment	This estimate includes all electronic equipment used to play movies in the theaters. Equipment includes film and digital projectors, winding machines, sound units, speakers, and electrical panels.
Concession Electronic Equipment	This estimate includes all electronic equipment used for concessions and food preparation purposes. Equipment includes popcorn poppers, food warmers, soda fountains, microwaves, and freezers.
Other Electronic Equipment	This estimate includes all items listed above in the Electronics Equipment category with the exception of items included in the Theater and Concession Electronic Equipment categories.
Furniture	This estimate includes all seating, cabinets, desks, chairs, tables, trash cans, and other furniture items. The volume for each item was determined by multiplying the overall dimensions. All items are assumed to still be fully assembled. Only minimum size reduction is assumed (e.g., folding tables and chairs are folded).
Food	This estimate includes all chips, popcorn, soda, ice cream, and other food served at a movie theater. This estimate does not include items associated with food preparation (e.g., popcorn popper) or food serving (e.g., paper cup). The estimate is based on food in stock at the time of the site visits and may vary significantly based on delivery schedules.
Other Theater Supplies	This estimate includes all other materials found at a movie theater, including movie screens, cleaning supplies, maintenance supplies, paper cups and plates, and movie posters and other movie advertisements.

2.5.6 Data Analysis and Quality

The following input parameters for movie theaters (i.e., the parameters the user would enter into the tool to generate the estimates) were investigated:

- Total number of seats in all auditoriums;
- Number of screens; and,
- Total structure square footage.

The methodology previously described was used to generate estimates for each waste category for each of the three movie theaters visited. The average of the three movie theaters for each waste category was calculated. For each category, the greatest difference between an individual movie theater estimate and the average of all three theaters was used to estimate the percent error, presented in Table 2-13. Additionally, the preferred input parameter (i.e., if both number of seats and number of screens are entered, the preferred input parameter is used when generating a default structure inventory) for each category is also included in Table 2-13.

ERG notes that these data are based on only three facilities. Based on discussions with Regal Cinemas and the National Association of Theater Owners, these movie theaters should be representative of the industry. Based on the data shown in Table 2-26, ERG believes that estimates made based on these factors are appropriate for the order of magnitude estimations required for the WME and the default structure inventories. The data collected and presented in Table 2-26 are appropriate for determining which factor has the better correlation to each waste category; however, additional data would be required to perform a complete statistical analysis.

Table 2-26. Movie Theater WME Input Parameter Error Analysis Results

Waste Category	Percent Error Based on Per Seat Estimations	Percent Error Based on Per Screen Estimations	Percent Error Based on Per Square Foot Estimations	Preferred Input Parameter
Total Non-Structural Building Materials	NA	NA	NA	NA
Carpet	6.54%	9.83%	4.81%	Seats
Ceiling Tiles	8.07%	12.58%	2.06%	Seats
Drywall	10.86%	16.05%	2.62%	Seats
Floor Tiles	12.36%	17.48%	5.22%	Seats
Curtains and Acoustical Material	2.17%	3.41%	10.93%	Seats
Other Non-Structural Building Materials	19.59%	22.98%	12.06%	Seats
Electronic Equipment	NA	NA	NA	NA
Theater Electronic Equipment	6.49%	0.79%	15.39%	Screens
Concession Electronic Equipment	22.94%	26.71%	20.97%	Seats

Table 2-26. Movie Theater WME Input Parameter Error Analysis Results

Waste Category	Percent Error Based on Per Seat Estimations	Percent Error Based on Per Screen Estimations	Percent Error Based on Per Square Foot Estimations	Preferred Input Parameter
Other Electronic Equipment	33.37%	37.03%	25.35%	Seats
Furniture	2.03%	6.93%	7.18%	Seats
Food	34.39%	35.31%	35.19%	Seats
Other Theater Items	5.85%	9.69%	4.27%	Seats

NA – Not Applicable. Value is calculated by summing sub-categories as described in Table 2-7. Percent error is not estimated for these values.

Item estimates may be generated in the tool based on the number of seats and/or the number of screens. However, Table 2-26 shows that each waste category may have a stronger correlation to one of the two input parameters.

For the Total Non-Structural Building Materials category and subcategories (i.e., Carpet, Ceiling Tiles, Drywall), Table 2-26 shows that these categories had the strongest correlation to the square footage of the facilities (except for Curtains and Acoustical Materials). Curtains and Acoustical Materials probably had the strongest correlation to the number of seats, because these materials are found only in the auditoriums. Therefore, the size of the auditoriums (which correlates well to the number of seats) is more important than the overall size of the movie theater (i.e., structure square footage). However, as discussed in Section 2.5.2, because movie theaters typically do not know their total square footage, and there is confusion on how to estimate the structure's square footage, it was decided to not use square footage as an input parameter. Because the movie theater's square footage more closely dependent on the number of seats than the number of screens, the Building Materials categories (e.g., Carpet, Ceiling Tiles, Drywall) have a stronger correlation to the number of seats than the number of screens (the movie theaters visited had approximately 20-24 ft^2/seat).

Table 2-26 also shows that the number of screens is the least accurate input parameter for all waste categories except Theater Electronic Equipment. A set amount of equipment is required for each screen mostly independent of the auditorium's size. Therefore, the Theater Electronic Equipment category has a stronger correlation to the number of screens over the other input parameters. Similarly, the major component of the Furniture category is the movie theater seats; therefore, the Furniture category has the strongest correlation to the number of seats.

Concession Electronic Equipment, Other Electronic Equipment, and Food did not have a strong correlation to any of the three input parameters, mainly because each movie theater has a certain set of equipment and rooms regardless of the size of the theater. For example, the concession area of the largest movie theater visited was only slightly larger than the concession area for the smallest theater visited, because the same pieces of equipment (e.g., popcorn machine, soda fountains, and cash registers) are required. Additionally, the quantity of Food in the theaters visited was more dependent on the date of the last delivery than on the size of the movie theater. Based on the movie theaters visited, these categories had a slightly stronger, but not significant, correlation to the number of seats over the number of screens.

For the purposes of estimates in the tool where only one value can be used (e.g., when creating default structure inventories), if both number of seats and number of screens are entered, all estimates are based on the number of seats, except for the estimate for Theater Electronic Equipment.

2.6 Offices

This section discusses the data sources, methodology, and assumptions used to generate the waste category factors and the waste item factors for offices, including a description of each waste category, and a brief analysis of the data quality. The waste category factors were revised with the release of version 6.4 of I-WASTE. The data sources, methodology, and assumptions used to generate the office waste category factors prior to version 6.4 were originally presented in the document: *Draft Documentation for Version 1 of the Building* Decontamination Residue *(*BDR*)* Disposal *Decision Support Tool* dated September 30, 2004.[28] The documentation for the I-WASTE office factors revisions for version 6.4 were originally presented in the document: *Revised I-*WASTE Waste Materials *Estimator (WME)* Waste *Category Weight and Volume Factors for Offices* dated January 16, 2015.[29]

2.6.1 Data Sources

The estimates provided are divided into the several waste categories. Details on each individual category, including what items are included in the estimate and the assumptions related to the category are provided in Section 2.6.5. All estimates are based on factors developed from a site visit conducted by EPA.

Several other factors may affect the amount of waste materials requiring disposal, as described in Section 2.6.6. These factors will be considered in generating an estimate based on a user’s selections. Additional factors considered can include:

- Additional weight and volume added by packaging materials; and
- Removal of paper and office supplies from furniture prior to shipment and disposal.

Additional limitations of the estimates are presented in Section 2.6.7.

[28] Draft Documentation for Version 1 of the Building Decontamination Residue (BDR) Disposal Decision Support Tool, September 30, 2004.

[29] Memorandum from Colin Hayes and Molly Rodgers, ERG, to Paul Lemieux and Susan Thorneloe, US EPA, Subject: Revised I-WASTE Waste Materials Estimator (WME) Waste Category Weight and Volume Factors for Offices, January 16, 2015.

2.6.2 Methodology

The waste category factors used by the WME were generated based on an EPA survey conducted in 2014 of the contents of the 290 Broadway building in New York City, NY, a thirty (30)-story building that houses the EPA Region 2 offices on thirteen (13) of those floors.

EPA collected data on the number of rooms, room footprints (square feet per room, or ft^2/room), average material loading per room for each room type (pounds per room, or lb/room) and by material type. From those data, EPA calculated total room areas (ft^2) and total material loading quantities for each room type and by material type (in pounds, or lbs). Part of the EPA survey included determining the amount of paper that was found inside various items of office furniture located in each of the room types surveyed. The total amount of paper located inside furniture was included in EPA's estimate for the "average paper loading" per room by room type, in lbs/room, and the total "average paper loading" for all rooms by room type, in lbs. Based on those data, ERG calculated the average paper loading in furniture per room and the average paper loading in furniture for all rooms of each room type based on the total number of rooms.

2.6.2.1 Distribution of Material Loadings to WME Input Categories

Since the WME estimates for offices are based on either the number or square footage of cubicle offices or the number or square footage of individual-walled offices, the material loadings and the "Average Paper in Furniture Loading (lb)" values for all room types other than "cube" and "walled office" were distributed between "cube" and "walled office" based on the relative number of occupants in each office type. Based on those results, the average fraction of paper located inside furniture is 0.7571 and 0.7547 for cubicle offices and walled offices, respectively. The individual survey category loadings were added together according to the WME Waste Material Category to generate the WME Waste Category weights and volumes.

2.6.2.2 Waste Category Estimates

To generate Waste Materials Estimates for the quantity of materials requiring disposal, the tool multiplies the respective waste category factor by the number of occupants or the total square footage entered by the user. The WME allows users to input either the number of occupants or the square footage for both individual walled office configurations and cubicle office configurations since many office buildings are comprised of one or both of those configurations. Additional factors affecting the quantity of material requiring disposal that may be accounted for by the tool are presented in Section 2.6.4.

For all waste categories except for weight estimates for the "Furniture" waste category and weight and volume estimates for the "Paper and Office Supplies" waste category, estimates are generated according to the following equation:

$$E_{wc-i} = (WCF_{i,z})(IP_{x\ z})(PMF) \qquad \textbf{(Eq. 2-4a)}$$

where:

E_{wc-i} = Estimate of waste for waste category *i*, tons or yd^3

$WCF_{i,z}$	=	Waste category factor for waste category *i* and input parameter *z*; tons/ft^2, tons/occupant, yd^3/ft^2, or yd^3/occupant (from Table 2-27 and Table 2-28)
$IP_{x,z}$	=	Input parameter value for structure type *x* and input parameter *z*, ft^2 or occupants
PMF	=	Packaging materials factor (from Table 2-30)

For the "Furniture" waste category, weight estimates are generated according to the following equation:

$$E_F = [WCF_F + (WCF_P)(PLF)](IP_{x\,z})(PMF) \qquad \textbf{(Eq. 2-4b)}$$

where:

E_F	=	Estimate of waste for the Furniture waste category, tons
WCF_F	=	Waste category factor for Furniture and input parameter *z*; tons/ft^2 or tons/occupant (from Table 2-27 and Table 2-28)
WCF_P	=	Waste category factor for Paper and Office Supplies and input parameter *z*; tons/ft^2 or tons/occupant (from Table 2-27 and Table 2-28)
PLF	=	Paper loading factor (from Table 2-31)
$IP_{x,z}$	=	Input parameter value for structure type *x* and input parameter *z*, ft^2 or occupants
PMF	=	Packaging materials factor (from Table 2-30)

The volume of furniture will not change regardless of whether paper is inside the furniture or complete removed, therefore, the volume estimates for the "Furniture" waste category are generated according to Equation 2-4a.

For the "Paper and Office Supplies" waste category, weight and volume estimates are generated according to the following equation:

$$E_P = (IP_{x\,z})(PMF)(WCF_P)(1 - PLF) \qquad \textbf{(Eq. 2-4c)}$$

where:

E_P	=	Estimate of waste for the Paper and Office Supplies waste category, tons or yd^3
$IP_{x,z}$	=	Input parameter value for structure type *x* and input parameter *z*, ft^2 or occupants
PMF	=	Packaging materials factor (from Table 2-30)
WCF_P	=	Waste category factor for Paper and Office Supplies and input parameter *z*; tons/ft^2, tons/occupant, yd^3/ft^2, or yd^3/occupant (from Table 2-27 and Table 2-28)
PLF	=	Paper loading factor (from Table 2-31)

2.6.3 Waste Category Factors

Although office configurations and layouts may vary widely, two general configurations are:

- Individual walled offices; and
- Cubicle offices.

Individual walled offices are generally those where most employees work in a room shared by only one or two employees. Cubicle offices are generally those where most employees work in rooms shared by three or more employees, where desks are separated by cubicle divider panels. The major difference between the two office layouts is the square footage of office space per employee. Based on EPA survey data, individual walled offices (including common areas such as lobbies, hallways, restrooms) have approximately 628 square feet per employee; cubicle configurations have approximately 525 square feet per employee.

Table 2-27 and Table 2-28 present the factors used by the WME to generate estimates.

Table 2-27. WME Interior/Non-Structural Factors for Individual Walled Offices

Waste **Category**	**WCF** (ton/ft^2)	**WCF** (ton/occupant)	**WCF** (yd^3/ft^2)	**WCF** (yd^3/occupant)
Total Non-Structural Building Materials	0.00239[a]	1.50[a]	0.0164 [a]	10.3[a]
Drywall	0.00115	0.721	0.00331	2.08
Ceiling Tiles	0.000386	0.242	0.00418	2.62
Carpet	0.000669	0.420	0.00584	3.67
Other Non-Structural Building Material	0.000184	0.116	0.00306	1.92
Electronic Equipment	0.0000447	0.0281	0.00034	0.215
Furniture	0.0178	11.2	0.233	147
Paper and Office Supplies	0.0115	7.25	0.0355	22.3

[a] The Total Non-Structural Building Materials waste quantity is calculated by adding the individual estimates for *Drywall, Ceiling Tiles, Carpet, and Other Non-Structural Building* Materials.

Table 2-28. WME Interior/Non-Structural Factors for Cubicle Offices

Waste Category	**WCF** (ton/ft^2)	**WCF** (ton/occupant)	**WCF** (yd^3/ft^2)	**WCF** (yd^3/occupant)
Total Non-Structural Building Materials	0.00181[a]	0.949 [a]	0.0140 [a]	7.37 [a]
Drywall	0.000700	0.367	0.00202	1.06
Ceiling Tiles	0.000310	0.162	0.00329	1.73
Carpet	0.000480	0.252	0.00427	2.24

Other Non-Structural Building Material	0.000320	0.168	0.00445	2.34
Electronic Equipment	0.0000300	0.0161	0.000220	0.113
Furniture	0.0209	11.0	0.188	98.6
Paper and Office Supplies	0.0136	7.15	0.0412	21.6

[a] The Total Non-Structural Building Materials waste quantity is calculated by adding the individual estimates for *Drywall, Ceiling Tiles, Carpet, and Other Non-Structural Building* Materials.

2.6.3.1 Total Square Footage and Number of Employees

Total square footage includes the square footage from all areas, not just work areas, including common areas. Common areas may include kitchens, restrooms, lobbies, hallways, and storage areas. Common areas are accounted for in the waste estimates.

2.6.3.2 Estimations Based on Square Footage versus Estimations Based on Number of Employees

While waste estimates may be generated based on the total square footage and/or the number of employees, each Office waste category has a stronger correlation to one factor over the other. Because the square footage per employee may vary widely between office buildings, estimates are more accurate if both parameters are entered. There is a more accurate correlation between the amount of building materials, including drywall, ceiling tiles, and carpet, and the total square footage than there is between the amount of building materials and the number of employees. However, because employees generally each require a similar amount of electronic equipment and furniture, there is a more accurate correlation between these values and the number of employees than there is between these values and the total square footage. The amount of paper varies with other factors not accounted for by this estimator (e.g., type/products of the office, length of occupancy, number of archive rooms, etc.). However, in general, there is a better correlation between the amount of paper and the total square footage because companies tend to store more paper if they have more space.

If both the square footage and the number of occupants are entered into the WME, a preferential parameter is chosen when generating estimates or creating default structure inventories (see Section 2.2 for a discussion of Default Item Inventories). For example, there is a better correlation between the amount of building materials and the total square footage than there is between the amount of building materials and the number of occupants. Therefore, in this example, the estimates for building materials are based on the WME results using the total square footage if both parameters are entered. A summary of which factor is used for preferential estimates is presented below.

Table 2-29. Preferred Input Parameters for Office Interior/Non-Structural Waste Categories

Preferential Estimates Based on Total Square Footage	**Preferential Estimates Based on** Number of Occupants
All Building Materials Categories	Electronic Equipment
Paper and Office Supplies[a]	Furniture

[a] Offices tend to have a better correlation between the square footage and the amount of paper than between the number of employees and the amount of paper, because companies tend to store more files if they have additional space.

2.6.4 Additional Factors Affecting the Quantity of Items

While several factors may affect the quantity of items requiring disposal, two additional factors that may be accounted for by the tool are the additional weight and volume added by packaging materials and the removal of paper and office supplies from furniture prior to shipment and disposal.

2.6.4.1 Additional Weight and Volume Added by Packaging Materials

If waste items are packaged prior to shipment, the packaging material will increase the volume and weight. If you chose to account for this increase in volume and weight, the volume of the estimate for each waste category will increase by 10% and the weight of the each estimate will increase by 5%. Actual increases in weight and volume due to packaging material may vary based on the type and shape of the item, the type of packaging material used, and the packaging requirements for the various contaminants.

Table 2-30. Packaging Materials Factors (PMF) for Offices

Waste Category Estimate Based On…	PMF
Weight	1.05
Volume	1.10

2.6.4.2 Removal of Paper and Office Supplies from Furniture Prior to Shipment and Disposal

When furniture is packaged for shipment, the paper and office supplies in the furniture piece (i.e., filing cabinets, desk drawers, etc.) may be removed and packaged separately or left in the furniture piece. At the site surveyed, the following percentages of the total paper in a building were found stored in drawers, cabinets, or other enclosed pieces of furniture:

- 75.4% for individual walled offices; and
- 75.7% for cubicle configurations.

If the "*Remove paper and office supplies from the furniture*" option is selected, the estimates for the *Paper and Office Supplies* waste category will not include paper stored in enclosed furniture. Paper stored in enclosed furniture will be included the *Furniture* waste category estimate, but only for the additional weight (the volume of furniture will not change). Selecting the "remove paper and office supplies from the furniture" option will increase the volume and weight of the Paper and Office Supplies estimate. The weight (not the volume) of furniture will also decrease corresponding to the increase in paper.

Table 2-31. Paper Loading Factors (PLF) for Offices

Paper Removed from Furniture	Paper Not Removed from Furniture (Individual Walled Offices)	Paper Not Removed from Furniture (Cubicle Offices)
0	0.754	0.757

2.6.5 Assumptions and Key Notes

The following assumptions are made when estimating the amount of waste materials requiring disposal from an office:

- All weights are dry weights. Additional weight of water from decontamination fluid is not accounted for.
- Since some buildings may be constructed without using drywall, ceiling tiles, and carpet, or because these materials may not be removed during the decontamination process, estimates for drywall, ceiling tiles, and carpet are broken out separately within the building materials category.
- All items are assumed to be shipped for disposal fully assembled. The volume for each item is determined by multiplying its maximum overall dimensions. Only minimum size reduction is assumed (e.g., folding tables and chairs are folded).

2.6.6 Category Descriptions

There are seven primary waste categories for offices. Each of these categories is described in Table 2-32 below.

Table 2-32. Interior/Non-Structural WME Waste Categories and Descriptions for Offices

Waste Category	Description
Total Non-Structural Building Materials	The Building Materials category for offices includes the estimates for drywall, ceiling tiles, and carpet, as well as restroom equipment (i.e., toilets, sinks, stall dividers, etc.), doors, blinds and window coverings, other floor coverings (e.g., linoleum), and ventilation systems. Ventilation systems estimates include only duct work and vents. Air handlers and other mechanical ventilation equipment are not included. Sprinkler systems and frames supporting the drywall are also not included in this estimate. Since some buildings may be constructed without using drywall, ceiling tiles, and carpet, or because these materials may not be removed during the decontamination process, estimates for drywall, ceiling tiles, and carpet are broken out separately within the building materials category.

Table 2-32. Interior/Non-Structural WME Waste Categories and Descriptions for Offices

Waste Category	Description
Drywall	The Drywall category estimate for offices includes only drywall on walls. Drywall covering ceilings and frames supporting the drywall are not included in this estimate. This estimate is based on the assumption that all interior walls are covered with drywall. If some walls in the building are made of other materials such as cinder blocks an overestimate may occur.
Ceiling Tiles	The Ceiling Tile category estimate for offices includes ceiling tiles and frames. If some ceilings are covered with other materials, an overestimate may occur.
Carpet	The Carpet category estimate for offices includes carpet only on floors. Carpet padding is not included because padding was not found at the offices visited. Bathrooms, kitchens, and some other common areas may not be carpeted. If floors are covered with other materials, this may be an overestimate. Carpet was assumed to be rolled and dry.
Other Non-Structural Building Materials	This estimate includes all building materials not included in other building material subcategories. The building materials in this estimate may include restroom equipment, doors, glass panes, blinds and window coverings, other floor coverings, duct work, and vents.
Electronic Equipment	The Electronic Equipment estimate for offices includes all computers, telephones, servers and routers, office machine, lights and light fixtures, kitchen equipment, etc. Two potential areas of waste materials excluded are wiring and mechanical ventilation equipment (e.g., air handlers). Two other factors that may result in additional electronic equipment are offices that do not dispose of outdated computers and electronic equipment, and offices that are heavily based on electronics (e.g., graphics design, hardware design, and publishing).
Furniture	The Furniture category estimate for offices includes all furniture, divider panels, plants, and pictures. Cabinetry and counter tops are also included. The volume for each item was determined by multiplying the overall dimensions. Folding table and chairs are assumed to be folded, and all other items are assumed to still be fully assembled.
Paper and Office Supplies	The Paper and Office Supplies category estimates are highly dependent on the type/product of office, the amount of archive storage, and the length of occupancy. The amount of paper and office supplies may vary significantly between facilities of similar size.

2.6.7 Data Analysis and Quality

The WME is designed to provide only an order of magnitude estimate for the amount of waste that may be generated. Each structure is unique, and the amount of waste may vary significantly between facilities of similar size. Several limitations of the tool include:

- Currently, enough data points are not available to calculate the accuracy of the tool;
- The age of the structure is not accounted for (e.g., older facilities tend to have more paper stored and may be constructed differently);

- The type of office/office product is not accounted for (e.g., software development companies will have more electronics but less paper); and
- Several other office configurations exist.

2.7 Schools

This section discusses the data sources, methodology, and assumptions used to generate the waste category factors and the waste item factors for schools, including a description of each waste category, and a brief analysis of the data quality. This information was originally presented in the document: *Draft Documentation for Version 1 of the Building* Decontamination Residue *(*BDR*)* Disposal *Decision Support Tool* dated September 30, 2004.[30]

2.7.1 Data Sources

The estimates provided are divided into several waste categories based on the structure type. Table 2-20 lists the waste categories for schools. Details on each individual category, including what items are included in the estimate and the assumptions related to the category are provided in Section 2.7.5. All estimates are based on factors developed from site visits conducted by ERG.

Several other factors may affect the amount of residue requiring disposal, as described in Section 2.7.6. These factors will be considered in generating an estimate based on a user's selections. Additional factors considered can include:

- Additional weight and volume added by packaging materials; and
- Removal of paper and school supplies from furniture prior to shipment and disposal.

Additional limitations of the estimates are presented in Section 2.7.7.

2.7.2 Methodology

The waste category factors used by the WME were generated based on site visits conducted by ERG. The factors are based on three schools (one elementary, one middle, and one high school). The factors may be refined in future releases of the tool if additional information becomes available.

At each site visited, a thorough inventory was conducted of all furniture, electronic equipment, etc. The quantity of duct work, ventilation systems, drywall, and other building materials was estimated by reviewing the structure's floor plans. Using the collected information, the volume, and weight for each item was estimated. The items were grouped in several categories, as described in Section 2.7.6. The total weight and volume for the category were calculated by summing the individual volumes and weights of all items in the category. All items are assumed to be shipped for disposal fully assembled. The volume for each item is determined by multiplying its maximum overall dimensions. Only minimum size reduction is assumed (e.g.,

30 Draft Documentation for Version 1 of the Building Decontamination Residue (BDR) Disposal Decision Support Tool, September 30, 2004.

folding tables and chairs are folded). Note that all weights are dry weights. Additional weight of water from decontamination fluid was not accounted for.

Structure floor plans were reviewed to estimate the square footage of the structure, and factors for estimating the quantity of items and materials based on square footage were generated by dividing the total volume and weight for the waste category by the total square footage. The number of students attending the school was found in school records. Factors for estimating the quantity of items and materials based on the number of students were generated by dividing the total volume and weight for the category by the actual number of students.

2.7.2.1 Waste Category Estimates

To generate waste estimates for the quantity of items and materials requiring disposal, the tool multiplies the respective waste category factor by the inputted number of students or the total school square footage. Additional factors affecting the quantity of material requiring disposal that may be accounted for by the tool are presented in Section 2.7.5.

Estimates are generated according to the following equation:

$$E_{wc\text{-}i} = (WCF_{i,z})(IP_{x\ z})(1 + PMF)(PLF) \qquad \textbf{(Eq. 2-5)}$$

where:

$E_{wc\text{-}I}$	=	Estimate of waste for waste category *i*, tons or yd^3
$WCF_{i,z}$	=	Waste category factor for waste category *i* and input parameter *z* (tons/ft^2, tons/student, yd^3/ft^2, or yd^3/student) (from Table 2-34 through Table 2-36)
$IP_{x,z}$	=	Input parameter value for structure type *x* (elementary school, middle school, or high school) and input parameter *z* (ft^2 or number of students)
PMF	=	Packaging materials factor (from Table 2-37)
PLF	=	Paper/school supplies loading factor (from Table 2-38).

2.7.3 Factors

Waste category factors have been generated for the following three types of schools:

- Elementary schools;
- Middle schools; and
- High schools.

While the transition year between schools varies, elementary schools may be attended by students grades K through 6; middle schools by grades 6 through 9; and high schools by grades 9 through 12. For secondary schools (i.e., combined middle and high schools), waste category factors for high schools are expected to be generally applicable. While there are several differences in the designs of the different school types, the principal difference in waste quantity results from differences in the amount of space devoted to extracurricular activities (i.e., gymnasiums, auditoriums, music rooms, career centers, etc.).

Schools inherently contain a large number of special-purpose rooms (e.g., gymnasiums, auditoriums, cafeterias, weight rooms). Due to the size of these rooms, residue estimates may not be accurate for small schools (less than 200 students). Attendance at schools visited ranged from 450 to 1,600 students.

2.7.3.1 Total Square Footage and Number of Students

Estimates are based on the Total Square Footage of the building, including gymnasiums, auditoriums, mechanical rooms, multi-purpose rooms, cafeterias, bathrooms, hallways, and closets. Estimates are based on the entire school building being decontaminated, not just a wing, or a few classrooms.

All estimation factors for the Number of Students are based on the actual attendance of the school. Waste category factors were generated from elementary schools with approximately 150 square feet per student and from middle and high schools with approximately 200 square feet per student. Applying these factors to under- or over-crowded schools may give less accurate results.

2.7.3.2 Trailers and Other Buildings

Estimates do not include items and materials from trailers and other buildings (e.g., press boxes, outdoor storage sheds) not attached to the main school building. The number of students should be reduced if a significant number of classrooms are in trailers. Schools visited did not have trailers or other classrooms not attached to the main school building.

2.7.3.3 Estimations Based on Square Footage versus Estimations Based on Number of Students

While waste estimates may be generated based on the total square footage and/or the number of students, each School waste category may have a stronger correlation to one factor over the other. Because the square footage per student may vary widely between schools, estimates are more accurate if both parameters are entered. There is a better correlation between the amount of building materials, including drywall, ceiling tiles, carpet, and wood flooring, and the total square footage than there is between the amount of building materials and the number of students.

If both the square footage and the number of students are entered into the WME, a preferential estimate is chosen when generating estimates using default parameters or creating default structure inventories. For example, there is a better correlation between the amount of building materials and the total square footage than there is between the amount of building materials and the number of students. Therefore, in this example, the weight and volume estimates for building materials are based on the WME estimates using the total square footage if both parameters are entered. A summary of which factor is used for preferential estimates is presented below:

Table 2-33. Preferred Input Parameters for School Interior/Non-Structural Waste Categories

Preferential Estimates Based on Total Square Footage	**Preferential Estimates Based on** Number of Students
All Building Materials Categories	All Electronic Equipment Categories Furniture Gym and Sports Equipment Art and Music Equipment Paper and School Supplies[a]

[a] For schools, there tends to be a better correlation between the number of students and the amount of paper, because if one school has more space per student than another, it is generally for larger gyms, theaters, workshops, etc.

Table 2-34 through Table 2-36 present the factors used by the WME to generate mass and volume estimates for each waste category.

Table 2-34. WME Interior/non-Structural Factors for Elementary Schools

Waste **Category**	**WCF** (ton/ft^2)	**WCF** (yd^3/ft^2)	**WCF** (ton/student)	**WCF** (yd^3/student)
Total Non-Structural Building Materials	0.000885[a]	0.00999[a]	0.132 [a]	1.49 [a]
Drywall	0.0000930	0.000269	0.0139	0.0402
Ceiling Tiles	0.000338	0.00361	0.0505	0.540
Carpet	0.000131	0.00115	0.0196	0.172
Other Non-Structural Building Materials	0.000324	0.00496	0.0485	0.742
Electronic Equipment	0.000358[b]	0.00313 [b]	0.0536[b]	0.469[b]
Industrial Electronic Equipment	0.000112	0.000854	0.0168	0.128
Other Electronic Equipment	0.000246	0.00228	0.0368	0.341
Furniture	0.00143	0.0211	0.214	3.15
Paper and School Supplies	0.00158	0.0131	0.236	1.96
Gym and Sports Equipment	0.0000550	0.00103	0.00816	0.153
Art and Music Equipment	0.0000400	0.000516	0.00595	0.0772

[a] Represents a calculated value. The estimate for *Total Non-Structural Building* Materials is calculated by adding the individual waste quantity estimates for the *Drywall, Ceiling Tiles, Carpet,* and *Other Non-Structural Building* Materials waste categories.

[b] Represents a calculated value. The estimate for *Electronic Equipment* is calculated by adding the individual waste quantity estimates for the *Industrial Electronic Equipment* and *Other Electronic Equipment* waste categories.

Table 2-35. WME Interior/Non-Structural Factors for Middle Schools

Waste Category	WCF (ton/ft^2)	WCF (yd^3/ft^2)	WCF (ton/student)	WCF (yd^3/student)
Total Non-Structural Building Materials	0.000918[a]	0.00886 [a]	0.178[a]	1.72[a]
Drywall	0.0000470	0.000136	0.00916	0.0265
Ceiling Tiles	0.000319	0.00341	0.0618	0.661
Carpet	0.0000330	0.000291	0.00644	0.0565
Other Non-Structural Building Materials	0.000322	0.00466	0.0624	0.904
Wood Flooring	0.000197	0.000364	0.0382	0.0707
Electronic Equipment	0.000323[b]	0.00276[b]	0.0627 [b]	0.535[b]
Industrial Elec. Equip.	0.0000720	0.000529	0.0140	0.103
Other Elec. Equip.	0.000251	0.00223	0.0487	0.432
Furniture	0.00123	0.0189	0.238	3.66
Paper and School Supplies	0.00111	0.00966	0.215	1.87
Gym and Sports Equipment	0.000168	0.00221	0.0327	0.428
Art and Music Equipment	0.000132	0.00112	0.0258	0.217

[a] Represents a calculated value. The estimate for *Total Non-Structural Building* Materials is calculated by adding the individual waste quantity estimates for the *Drywall, Ceiling Tiles, Carpet, Wood Flooring*, and *Other Non-Structural Building* Materials waste categories.

[b] Represents a calculated value. The estimate for *Electronic Equipment* is calculated by adding the individual waste quantity estimates for the *Industrial Electronic Equipment* and *Other Electronic Equipment* waste categories.

Table 2-36. WME Interior/Non-Structural Factors for High Schools

Waste Category	WCF (ton/ft^2)	WCF (yd^3/ft^2)	WCF (ton/student)	WCF (yd^3/student)
Building Materials	0.000988[a]	0.00916 [a]	0.199[a]	1.84 [a]
Drywall	0.0000330	0.0000960	0.00669	0.0193
Ceiling Tiles	0.000300	0.00321	0.0603	0.646
Carpet	0.0000320	0.000279	0.00639	0.0561
Other Non-Structural Building Materials	0.000357	0.00509	0.0717	1.02
Wood Flooring	0.000266	0.000493	0.0535	0.0992
Electronic Equipment	0.000320[b]	0.00261 [b]	0.0645[b]	0.525 [b]
Industrial Electronic Equipment	0.0000730	0.000457	0.0148	0.0920
Other Electronic Equipment	0.000247	0.00216	0.0497	0.433
Furniture	0.00132	0.0205	0.266	4.12

Table 2-36. WME Interior/Non-Structural Factors for High Schools

Waste Category	WCF (ton/ft^2)	WCF (yd^3/ft^2)	WCF (ton/student)	WCF (yd^3/student)
Paper and School Supplies	0.00124	0.0110	0.249	2.21
Gym and Sports Equipment	0.000193	0.00241	0.0389	0.484
Art and Music Equipment	0.000179	0.00139	0.0359	0.280

[a] Represents a calculated value. The estimate for *Total Non-Structural Building* Materials is calculated by adding the individual waste quantity estimates for the *Drywall, Ceiling Tiles, Carpet, Wood Flooring*, and *Other Non-Structural Building* Materials waste categories.

[b] Represents a calculated value. The estimate for *Electronic Equipment* is calculated by adding the individual waste quantity estimates for the *Industrial Electronic Equipment* and *Other Electronic Equipment* waste categories.

2.7.4 Additional Factors Affecting the Waste Estimates

While several factors may affect the amount of waste requiring disposal, two additional factors that may be accounted for by the tool are the additional weight and volume added by packaging materials and the removal of paper and school supplies from furniture prior to shipment and disposal.

2.7.4.1 Additional Weight and Volume Added by Packaging Materials

If waste items are packaged prior to shipment, the packaging material will increase the volume and weight. If you chose to account for this increase in volume and weight, the volume of the estimate for each waste material category will increase by 10% and the weight of the each estimate will increase by 5%. Actual increases in weight and volume due to packaging material may vary based on the type and shape of the item, the type of packaging material used, and the packing requirements for the various contaminants.

Table 2-37. Packaging Materials Factors (PMF) for Schools

Waste Category Estimate Based On…	PMF
Weight	0.05
Volume	0.10

2.7.4.2 Removal of Paper and School Supplies from Furniture Prior to Shipment and Disposal

When furniture is packaged for shipment, the paper and school supplies in the furniture piece (i.e., filing cabinets, desk drawers, etc.) may be removed and packaged separately or left in the furniture piece. At the elementary, middle, and high schools visited, approximately 30% of the total paper in the buildings was found stored in drawers, cabinets, or other enclosed pieces of furniture.

If the *Remove paper and school supplies from the furniture* option is selected, estimates for the *Paper and School Supplies* waste material category will not include paper stored in enclosed furniture. Paper stored in enclosed furniture is included the Furniture waste category estimate. Selecting the remove paper and school supplies from furniture option will increase the volume and weight of the paper and school supplies estimate. The weight (not the volume) of furniture will also decrease corresponding to the increase in paper.

Table 2-38. Paper Loading Factors (PLF) for Schools

	Paper Removed from Furniture		**Paper Not Removed from Furniture**	
School Structure Sub-Type	*Furniture* Waste Category **(weight estimates only)**	*Paper and Office Supplies* Waste Category **(weight and volume estimates)**	*Furniture* Waste Category **(weight estimates only)**	*Paper and Office Supplies* Waste Category **(weight and volume estimates)**
Elementary Schools	0	1	0.3	0.7
Middle Schools	0	1	0.3	0.7
High Schools	0	1	0.3	0.7

2.7.5 Assumptions and Key Notes

The following assumptions are made when estimating the amount of items and materials requiring disposal from a school:

- All estimation factors for the number of students are based on the actual attendance of the schools visited.
- Estimates do not include items and materials from trailers or other buildings not attached to the main school building.
- All weights are dry weights. Additional weight of water from decontamination fluid is not accounted for.
- Drywall and ceiling tiles will not be neatly stacked when packaged for shipment. The base volume of drywall and ceiling tiles (i.e., length × width × height) is multiplied by a factor of 1.3 to determine the total volume including void space.
- Since some buildings may be constructed without using drywall, ceiling tiles, carpet, and wood flooring, or because these materials may not be removed during the decontamination process, estimates for drywall, ceiling tiles, carpet, and wood flooring are broken out separately within the building materials category.
- All items are assumed to be shipped for disposal fully assembled. The volume for each item is determined by multiplying its maximum overall dimensions. Only minimum size reduction is assumed (e.g., folding tables and chairs are folded).

- The amount of paper and school supplies is based on the assumption that all filing cabinets, bookshelves, lockers, etc. are 75% full of paper and school supplies.

2.7.6 Category Descriptions

There are eleven primary waste categories for schools. Each of these categories is described in Table 2-39 below.

Table 2-39. Interior/Non-Structural Waste Categories and Descriptions for Schools

Waste Category	Description
Total Non-Structural Building Materials	The Building Materials category for schools includes the estimates for drywall, ceiling tiles, carpet, and wood flooring, as well as restroom equipment (i.e., toilets, sinks, stall dividers, etc.), doors, blinds and window coverings, other floor coverings (e.g., linoleum), acoustic tiles, and ventilation systems. Ventilation system estimates include only duct work and vents. Air handlers and other mechanical ventilation equipment are not included. Sprinkler systems and frames supporting the drywall are also not included in this estimate. Since some buildings may be constructed without using drywall, ceiling tiles, carpet, and wood flooring, or because these materials may not be removed during the decontamination process, estimates for drywall, ceiling tiles, carpet, and wood flooring are broken out separately within the building materials category.
Drywall	Walls in schools are made primarily of cinderblock. Of the schools visited, less than twenty walls per school were constructed with drywall. If more walls in the school are constructed with drywall, the WME factors for drywall in schools may provide an underestimate. This estimate does not include frames that support the drywall. Because drywall will not be neatly stacked when removed from a building, the base volume of drywall (i.e., length × width × height) is multiplied by a factor of 1.3 to arrive at the total volume including void spaces.
Ceiling Tiles	The Ceiling Tiles category estimate for schools includes ceiling tiles and frames. The size and number of rooms without tiled ceilings (e.g., gymnasiums, auditoriums, and mechanical rooms) increases from elementary to middle to high schools. Estimates are based on elementary schools with approximately 90%, middle schools with 85%, and high schools with 80% of the total square footage of the school covered with ceiling tiles. If more ceilings are exposed or covered with other materials, this may be an overestimate. Because tiles will not be neatly stacked when removed from a building, the base volume of tiles (i.e., length × width × height) is multiplied by a factor of 1.3 to arrive at the total volume including void spaces.
Carpet	The Carpet category estimate for schools includes only carpet on floors. Carpet padding is not included because padding was not found at the schools visited. The estimate is based on middle and high schools where approximately 20% of the floor space is carpeted (libraries, multi-purpose rooms, and offices were carpeted). For elementary schools, approximately 50% of the floor space is carpeted (most classrooms, gymnasiums, libraries, multi-purpose room, and offices were carpeted). Elementary school floors are more likely to be carpeted to cushion children’s falls. Carpet was assumed to be rolled and dry.

Table 2-39. Interior/Non-Structural Waste Categories and Descriptions for Schools

Waste Category	Description
Wood Flooring (middle and high schools only)	The Wood Flooring category estimate for schools includes the wood and padding underneath the wood flooring. Wood floors are not expected at elementary schools (gymnasiums were carpeted). In the middle and high schools visited, wooden-floored gymnasiums and stages accounted for between 8 and 12% of the total square footage of the school, depending on the size and number of gymnasiums. Estimates based on 7/8 inch thick wood flooring with appropriate padding and support structure underneath.
Electronic Equipment	The Electronic Equipment category for schools includes the estimate for industrial electronic equipment, as well as all computers, televisions, electronic laboratory equipment, electronic janitorial equipment (i.e., vacuum cleaners, floor cleaners, etc.), cooking equipment in teacher's lounges, and cooking classrooms, and lights and light fixtures. Two potential types of waste materials that were not included are wiring and mechanical ventilation and climate control equipment (i.e., air handlers, boilers, etc.). This estimate is based on schools with a television in every classroom, multiple computer laboratories, and one computer for every staff member.
Industrial Electronic Equipment	The Industrial Electronic Equipment category estimate for schools includes all cafeteria electronic equipment (i.e., industrial ovens, freezers, etc.), circuit breaker boxes, and telephone routing boxes.
Other Electronic Equipment	This category excludes industrial electronic equipment.
Furniture	The Furniture category estimate for schools includes all furniture, cabinetry, counter tops, lockers, divider panels, plants, chalkboards, and bulletin boards. Also included in this estimate are non-electronic laboratory equipment (i.e., metal stands, glassware, hoses, etc.) and auditorium items (i.e., theater seating, curtains, podiums, risers, etc.). The volume for each item was determined by multiplying the overall dimensions. All items are assumed to still be fully assembled. Only minimum size reduction is assumed (e.g., folding tables and chairs are folded).
Music and Art Equipment	The Music and Art Equipment category estimate for schools includes all musical instruments and cases, music stands, theatrical props and sets, and art supplies. The amount of theatrical props and sets and art supplies may vary widely between schools, depending on storage space available.
Gym and Sports Equipment	The Gym and Sports Equipment category estimate for schools includes basketball hoops and mounts, gym lockers, gym dividers, wall and floor pads, workout equipment, gymnastics equipment, wrestling mats, and sports equipment (i.e., football pads, basketballs, etc.) This estimate also includes large gymnasium bleachers. Main high school gymnasium bleachers from schools visited could hold between 1,000 and 1,500 people. The size and capacity of bleachers may vary widely between schools.

Table 2-39. Interior/Non-Structural Waste Categories and Descriptions for Schools

Waste Category	Description
Paper and School Supplies	The Paper and School Supplies estimate for schools is based on the assumption that all filing cabinets, bookshelves, lockers, etc., are 75% full of paper and school supplies. This estimation is consistent with the schools visited; however, the quantity of paper and school supplies may vary based on the age of the school (quantity of archived student records and other accumulated material), point in the school year (paper slowly builds up in the school throughout the year), and the size of the library. School libraries visited had between 5,000 (elementary school library) and 15,000 books (high school library).

2.7.7 Data Analysis and Quality

The WME is designed to provide only an order of magnitude estimate for the amount of waste that may be generated. Each structure is unique, and the amount of waste may vary significantly between facilities of similar size. Several limitations of the tool include:

- Currently enough data points are not available to calculate the accuracy of the tool;
- The age of the structure is not accounted for (e.g., older facilities tend to have more paper stored and may be constructed differently); and
- No estimations for secondary schools (combined middle and high schools) or for smaller private schools are available.

2.8 Shopping Malls

This section discusses the data sources, methodology, and assumptions used to generate the waste category factors and the waste item factors for shopping malls, including a description of each waste category, and a brief analysis of the data quality. This information was originally presented in the document: *Summary of Methodology and Data Collection for the Shopping Mall* Back-of-the-envelope *Estimator (*BoEE*) and Default Facility Inventories* dated January 12, 2007.[31]

2.8.1 Data Sources

The factors for shopping mall waste estimates were generated based on a site visit to a shopping mall, merchandise inventories from several retailers, mall tenant space allocation data, and weights and dimensions of items from retail furniture catalogs.

[31] *Summary of Methodology and Data Collection for the Shopping Mall Back-of-the-envelope Estimator (*BoEE*) and Default Facility Inventories*. Memorandum from Aaron Osborne (ERG) to Paul Lemieux and Susan Thorneloe (EPA), January 12, 2007.

2.8.1.1 Site Visit

Through the International Council of Shopping Centers (ICSC), the leading trade association representing owners of shopping malls and centers, General Growth Properties, allowed ERG to visit a 969,000 ft^2 gross leasable area (GLA) shopping mall in Northern Virginia.

At the shopping mall, ERG conducted an inventory of all furniture, electronic equipment, decorations, fixtures, and other items within the common areas of the mall (i.e., janitorial storage, loading docks, hallways, kiosks, public restrooms, food court seating, and other areas not associated with a specific store). Only one set of similar items or rooms was inventoried. For example, an inventory was taken of only one set of restrooms. The inventoried set was multiplied by the number of restrooms to calculate the total for the shopping mall. Inventories were recorded on the appropriate checklists. The quantity of duct work, ventilation systems, drywall, and other building materials was estimated by reviewing the floor plans of the shopping mall.

While the individual stores typically had inventories of their merchandise, they did not have inventories of their retail equipment (e.g., display furniture, cash registers). During the site visit, equipment inventories were also conducted of 14 retailers within several different store types (e.g., apparel, furniture, and electronics). These equipment inventories were paired with available merchandise inventories.

2.8.1.2 Merchandise Inventories

At the shopping mall visited, several stores provided available inventories of their merchandise. Specific items were grouped into general categories of items (e.g., the number of medium Nike red hooded sweatshirts was not recorded; rather, the total number of sweaters and sweatshirts at the store was recorded). The National Retail Federation (NRF), the leading trade association representing retailers, assisted ERG in obtaining these inventories.

2.8.1.3 Mall Tenant Space Allocation Data

ICSC provided May, 2004, data on mall tenant space allocation based on a national survey they conduct monthly. The data represent the percent of the GLA leased by each of the different store types (e.g., apparel, furniture, and electronics). Table 2-40 presents the national average data that are used in the tool as default values.

Table 2-40. Default Values for Mall Tenant Space Allocation

Type of Store	Percent of GLA Associated with Store Type
Department Stores/Anchors	56%
Apparel	22%
Furniture	3%
Electronics	3%
Services/Specialty Stores	5%
Books/Toys	5%

Table 2-40. Default Values for Mall Tenant Space Allocation

Type of Store	Percent of GLA Associated with Store Type
Jewelry	2%
Restaurants	2%
Fast Food/Food Court	2%

Source: ICSC Research, *Monthly Mall Merchandise Index*, May 2004.

2.8.1.4 Item Weights and Dimensions

To estimate the total weight and volume of waste at a structure, the weight and volume of each item must be known. Weights and dimensions for many items at a shopping mall were already included in the waste item database located within the WME. Additional retail display items were added to the database based on weights and dimensions found in catalogs of common retail display vendors (e.g., Trio Retail Design & Equipment, www.triodisplay.com, last accessed December 21, 2015).

2.8.2 Methodology

The methodology used to develop estimates for shopping malls is similar to the methodology used for other structure types previously developed (e.g., offices, schools, hotels, movie theaters). However, because the type and quantity of waste may vary significantly among the different types of stores, the Shopping Mall WME allows the user to assign the percentage of retail space associated with each type of store to properly model the affected structure (e.g., one mall may have a significantly greater percentage of the GLA occupied by electronics stores). Default values for the percentage of the GLA occupied by each store type based on 2004 national averages are included in the tool. However, these defaults may be modified by the user if more specific data are available. For example, if a shopping mall contains no department stores, the percent for department stores could be changed to 0 and the other store types increased as appropriate. Additionally, if only a few stores within the shopping center are affected, the percentages may be modified. Note that these values are the percentage of the GLA, not the percentage of the number of stores. Using these percentages, the mall is essentially broken up into several smaller areas by type of store to estimate the total quantity of waste.

The only parameter the user must provide is the gross leasable area (GLA) of the shopping mall. The GLA includes only the portion of the mall that may be leased to tenant retailers. Common areas (e.g., hallways, public restrooms) are specifically excluded. Other parameters such as the total square footage of the mall and the number of stores were investigated however, GLA was selected because it is the most common metric used in the industry, is available on most mall websites, and is known by almost all mall managers. In discussions with mall managers and from reviewing floor plans, the total square footage of the mall was not readily available and is difficult to determine quickly. The number of stores also did not provide accurate estimates because the average store size may vary widely.

2.8.2.1 Individual Store Inventories

ERG used the data sources previously described to create inventories for each of the 14 stores inventoried in detail. These inventories merged the merchandise inventories provided by the retailers, inventories of retail equipment collected during the site visit, and estimates of building materials based on the structure floor plans. Note smaller items were placed in “boxes” based on the approximate weight of each item (e.g., calculators, security cameras, extension cords, etc., were placed in “boxes of electronics”). Additionally, similar items were grouped (e.g., all clothing was placed in “boxes of apparel”). Inventories were also created for the common areas (e.g., mall management offices, hallways) based mainly on data collected during the site visit. These master inventories for each type of store or common area were used to create the waste item factors for the default structure inventories and the waste category factors for the WME.

2.8.2.2 Default Structure Inventories

To create the parameters used to generate default structure inventories, each item on the master inventories was divided by the square footage of the retail store to generate the waste item factors for each store (e.g., Apparel Store #1 had three computers for 8,032 sq ft, which equals 0.00037 computers per ft^2). The item factors from stores within the same store type were averaged to create the factors used in the WME.

To minimize the number of items and the resulting complexity, items of similar materials, weights, and dimensions were combined. For example, a desktop fax machine is very similar in dimensions and material content to a desktop printer. Additionally, while a structure may have five-foot, six-foot, and eight-foot folding tables, the default structure inventories contain only six-foot folding tables. In all cases, the user can add or remove items to further refine and tailor the inventory to the user’s specific needs.

To generate default structure inventories, the tool multiplies each item factor for each type of store by the square footage associated with each type of store (e.g., number of computers associated with apparel stores = GLA × % of GLA associated with apparel stores × number of computers per sq ft of apparel stores) and then sums the values for all store types (e.g., total number of computers = number of computers associated with apparel stores + number of computers associated with electronics stores + …).

2.8.2.3 Waste Category Estimates

Similar items in the inventories were grouped into the waste categories, described in greater detail in Section 2.8.5. A weight and volume were assigned to each item in the waste category based on information in the waste item database. The total weight and volume for the waste category were calculated by summing the individual weights and volumes of all items in the category. The total weight and volume of each waste category were divided by the parameter appropriate for each type of store to generate the waste category factors for each type of store (e.g., Apparel Store #1 had 1 ton of Other Electronic Equipment for 8,032 ft^2, which equals 0.000124 tons of Other Electronic Equipment per ft^2). The waste category factors from stores within the same store type were averaged to create the factors used in the WME.

To generate estimates for the quantity of waste requiring disposal, a methodology similar to the methodology previously described for the default structure inventories is used to make estimates for each waste category:

(Eq. 2-6)

where:

$E_{wc\text{-}i}$	=	Estimate of waste for waste category *i* for all store types, tons or yd^3
$WCF_{i,t}$	=	Waste category factor for waste category *i* and store type *t* ($tons/ft^2$ or yd^3/ft^2) (from Table 2-41 and Table 2-42)
IP_x	=	Input parameter value *x* (Gross Leasable Area, GLA), ft^2
SA_t	=	Space allocation for store type *t*, % of GLA

2.8.3 Waste Category Factors

Based on the data and methodology presented above, Table 2-41 and Table 2-42 present the factors used by the WME to generate order of magnitude estimates of the quantity of waste that may require disposal from a shopping mall. Note that the tool does not present estimates for each type of store, rather presents an estimate for the entire shopping mall. A description of the items that are included in each waste category is presented in Section 2.8.5. The tool also allows the user to account for the additional weight and volume added by packaging materials and for material found in common areas, which are further described below.

Table 2-41. WME Interior/Non-Structural Factors for Shopping Malls

Store Type, *t*	**Anchor**		**Apparel**		**Furniture**		**Electronics**		**Services/Specialty**	
Waste **Category**	**WCF** (ton/ft^2)	**WCF** (yd^3/ft^2)	**WCF** (ton/ft^2)	**WCF** (yd^3/ft^2)	**WCF** (ton/ft^2)	**WCF** (yd^3/ft^2)	**WCF** (ton/ft^2)	**WCF** (yd^3/ft^2)	**WCF** (ton/ft^2)	**WCF** (yd^3/ft^2)
Total Non-Structural Building Materials	1.42E-03[a]	6.72E-03[a]	2.35E-03[a]	9.82E-03[a]	1.97E-03[a]	9.56E-03[a]	1.78E-03[a]	9.95E-03[a]	3.78E-03[a]	1.35E-02[a]
Drywall	8.85E-04	2.56E-03	6.97E-04	2.01E-03	5.54E-04	1.60E-03	6.96E-04	2.01E-03	1.22E-03	3.54E-03
Ceiling Tiles	2.82E-04	3.45E-03	3.86E-04	4.11E-03	4.06E-04	4.33E-03	4.07E-04	4.34E-03	3.72E-04	3.96E-03
Carpet	8.40E-05	4.15E-04	3.91E-05	1.93E-04	2.14E-04	1.06E-03	2.12E-04	1.05E-03	8.95E-05	4.42E-04
Marble and Ceramic Tiles	1.17E-04	2.61E-04	1.87E-04	2.80E-04	5.40E-05	1.20E-04	1.36E-04	3.03E-04	9.43E-04	1.27E-03
Other Non-Structural Building Materials	4.93E-05	3.95E-05	1.04E-03	3.23E-03	7.38E-04	2.46E-03	3.26E-04	2.24E-03	1.15E-03	4.33E-03
Electronic Equipment	3.00E-04[b]	1.95E-03[b]	1.30E-04[b]	7.32E-04[b]	2.36E-04[b]	3.47E-03[b]	2.15E-03[b]	1.46E-02[b]	5.93E-04[b]	4.02E-03[b]
Industrial Electronic Equipment	9.73E-06	1.41E-05	6.18E-06	8.48E-06	5.00E-08	2.22E-04	1.13E-05	1.55E-05	1.99E-05	2.73E-05
Other Electronic Equipment	2.91E-04	1.94E-03	1.24E-04	7.23E-04	2.36E-04	3.25E-03	2.14E-03	1.46E-02	5.73E-04	3.99E-03
Furniture	1.37E-03[c]	3.22E-02[c]	1.27E-03[c]	3.69E-02[c]	1.76E-03[c]	3.11E-02[c]	1.96E-03[c]	2.47E-02[c]	1.44E-03[c]	2.21E-02[c]
Retail Furniture	1.30E-03	3.13E-02	1.24E-03	3.65E-02	1.72E-03	3.05E-02	1.90E-03	2.40E-02	1.13E-03	1.76E-02
Office Furniture	6.57E-05	9.10E-04	2.59E-05	3.32E-04	3.95E-05	6.31E-04	5.49E-05	7.02E-04	3.05E-04	4.52E-03
Paper/Office Supplies	4.72E-05	4.26E-04	2.06E-05	1.86E-04	5.00E-05	4.51E-04	1.13E-04	1.02E-03	1.92E-04	1.74E-03
Food	3.72E-09	1.78E-08	0	0	0	0	0	0	0	0
Apparel	8.61E-04	1.18E-02	1.23E-03	1.69E-02	0	0	0	0	0	0
Other Merchandise and Supplies	2.88E-04	2.24E-03	1.19E-04	1.58E-03	5.15E-05	1.09E-03	7.80E-05	8.05E-04	1.55E-03	9.44E-03

[a] Represents a calculated value. The estimate for *Total Non-Structural Building* Materials is calculated by adding the individual waste category estimates for the *Drywall*, *Ceiling Tiles*, *Carpet*, *Marble and Ceramic Tiles*, and *Other Non-Structural Building* Materials waste categories.

[b] Represents a calculated value. The estimate for *Electronic Equipment* is calculated by adding the individual waste quantity estimates for the *Industrial Electronic Equipment*, and *Other Electronic Equipment* waste categories.

[c] Represents a calculated value. The estimate for *Furniture* is calculated by adding the individual waste quantity estimates for the *Retail Furniture* and *Office Furniture* waste categories.

Table 2-42. WME Interior/Non-Structural Factors for Shopping Malls

Store Type, *t*	**Books/Toys**		**Jewelry**		**Restaurant**		**Food Court**		**Common Areas**	
Waste **Category**	**WCF** (ton/ft^2)	**WCF** (yd^3/ft^2)	**WCF** (ton/ft^2)	**WCF** (yd^3/ft^2)	**WCF** (ton/ft^2)	**WCF** (yd^3/ft^2)	**WCF** (ton/ft^2)	**WCF** (yd^3/ft^2)	**WCF** (ton/ft^2)	**WCF** (yd^3/ft^2)
Total Non-Structural Building Materials	1.36E-03[a]	8.83E-03[a]	5.51E-03[a]	1.23E-02[a]	3.42E-03[a]	1.38E-02[a]	4.55E-03[a]	2.12E-02[a]	2.21E-04[a]	7.24E-04[a]
Drywall	5.77E-04	1.67E-03	2.06E-03	5.96E-03	8.97E-04	2.59E-03	1.38E-03	4.00E-03	1.28E-04	3.69E-04
Ceiling Tiles	4.11E-04	4.38E-03	0	0	4.06E-04	4.33E-03	3.94E-04	4.20E-03	1.19E-05	1.26E-04
Carpet	2.64E-04	1.30E-03	2.64E-04	1.30E-03	0	0	0	0	4.06E-07	2.01E-06
Marble and Ceramic Tiles	0	0	2.81E-03	2.07E-03	4.88E-04	1.09E-03	4.04E-04	9.02E-04	5.09E-05	1.05E-04
Other Non-Structural Building Materials	1.11E-04	1.48E-03	3.77E-04	2.92E-03	1.63E-03	5.83E-03	2.37E-03	1.21E-02	3.07E-05	1.22E-04
Electronic Equipment	9.59E-04[b]	9.10E-03[b]	2.96E-04[b]	1.36E-03[b]	1.49E-03[b]	1.45E-02[b]	4.22E-03[b]	3.83E-02[b]	1.74E-05[b]	1.27E-04[b]
Industrial Electronic Equipment	7.03E-06	9.64E-06	2.51E-05	3.45E-05	1.29E-03	1.39E-02	3.99E-03	3.63E-02	3.68E-06	1.95E-05
Other Electronic Equipment	9.51E-04	9.09E-03	2.71E-04	1.33E-03	2.02E-04	5.70E-04	2.34E-04	2.06E-03	1.37E-05	1.07E-04
Furniture	2.87E-03[c]	4.43E-02[c]	1.52E-03[c]	1.37E-02[c]	1.78E-03[c]	3.71E-02[c]	1.32E-03[c]	2.52E-02[c]	3.46E-05[c]	7.69E-04[c]
Retail Furniture	2.83E-03	4.37E-02	1.39E-03	1.21E-02	1.71E-03	3.63E-02	1.32E-03	2.52E-02	3.00E-05	7.13E-04
Office Furniture	4.02E-05	5.88E-04	1.22E-04	1.56E-03	6.33E-05	8.43E-04	0	0	4.55E-06	5.53E-05
Paper/Office Supplies	4.25E-03	7.97E-03	5.03E-05	4.54E-04	4.17E-05	3.76E-04	1.35E-03	1.22E-02	7.33E-06	6.61E-05
Food	0	0	0	0	6.13E-04	3.42E-03	1.01E-03	5.96E-03	7.43E-08	3.57E-07
Apparel	0	0	0	0	3.13E-05	4.63E-04	0	0	2.58E-07	3.82E-06
Other Merchandise and Supplies	1.55E-03	2.09E-02	4.25E-04	8.29E-04	3.93E-04	2.26E-03	4.34E-04	2.81E-03	9.35E-06	1.35E-04

[a] Represents a calculated value. The estimate for *Total Non-Structural Building* Materials is calculated by adding the individual waste category estimates for the *Drywall*, *Ceiling Tiles*, *Carpet*, *Marble and Ceramic Tiles*, and *Other Non-Structural Building* Materials waste categories.

[b] Represents a calculated value. The estimate for *Electronic Equipment* is calculated by adding the individual waste quantity estimates for the *Industrial Electronic Equipment*, and *Other Electronic Equipment* waste categories.

[c] Represents a calculated value. The estimate for *Furniture* is calculated by adding the individual waste quantity estimates for the *Retail Furniture* and *Office Furniture* waste categories.

2.8.3.1 Additional Weight and Volume Added by Packaging Materials

If waste items are packaged prior to shipment, the packaging material will increase the volume and weight. If the user chooses to account for this increase in volume and weight, the volume of the estimate for each waste material category will increase by 10% and the weight of the each estimate will increase by 5%. Actual increases in weight and volume due to packaging material may vary based on the type and shape of the item, the type of packaging material used, and the packaging requirements for the various contaminants. Note that packaging material is not accounted for in the default structure inventories.

Table 2-43. Packaging Materials Factors for Shopping Malls

Waste Category Estimate Based On…	PMF
Weight	0.05
Volume	0.10

2.8.3.2 Materials in Common Areas

Common areas in shopping malls include mall management offices, janitorial storage, loading docks, hallways, kiosks, public restrooms, food court seating, and other areas not associated with a specific store. The tool allows the user to exclude items that may be generated from common areas by selecting a check box. If the box within the tool is checked, only the waste generated from within a store or shop will be included and waste estimates for the Common Areas will not be included. This omission may be appropriate if only a particular store or group of stores is contaminated, or most materials in the common areas do not require disposal. Additionally, not accounting for waste generated from common areas may more appropriately model open shopping centers that do not have these types of areas; however, open shopping centers were outside the scope of this effort, and the applicability of the tool to these facilities is unknown. If this box within the tool is not checked, waste that may be generated from these areas is included in the estimate. This inclusion is appropriate if the entire mall is contaminated and all material will require disposal.

2.8.4 Assumptions and Key Notes

The following assumptions are made when estimating the amount of waste materials requiring disposal from a shopping mall:

- 100% of the GLA is assumed to be occupied.
- All weights are dry weights. Additional weight of water from any decontamination fluid is not accounted for.
- Drywall and ceiling tiles will not be neatly stacked when packaged for shipment. The base volume of drywall and ceiling tiles (i.e., length × width × height) is multiplied by a factor of 1.3 to determine the total volume including void space.
- Since some buildings may be constructed without one or more of the listed building materials (i.e., drywall, ceiling tiles, carpet, and marble and ceramic tiles), or because these materials may not be removed during the decontamination process, estimates

for drywall, ceiling tiles, carpet, and marble and ceramic tiles are broken out separately within the Non-Structural Building Materials waste material category. Additionally, users can exclude these categories when generating a default structure inventory.

- All items are assumed to be shipped for disposal fully assembled. The volume for each item is determined by multiplying its maximum overall dimensions. Only minimum size reduction is assumed (e.g., folding tables and chairs are folded).
- Movie theaters are not included in the waste estimates for Shopping Malls. If a movie theater is located within the Shopping Mall, the GLA should be reduced to exclude the portion associated with the theater.

2.8.5 Category Descriptions

WME estimates for shopping malls are broken into the following waste categories. Details and assumptions for each waste category for which estimates are generated are described in Table 2-44 below.

Table 2-44. Interior/Non-Structural Waste Categories and Descriptions for Shopping Malls

Waste Category	Description
Total Non-Structural Building Materials	This estimate includes the estimates for drywall, ceiling tiles, carpet, and marble and ceramic tiles as well as restroom equipment (i.e., toilets, sinks, stall dividers, etc.), doors, other floor coverings (e.g., wood floors, linoleum), and ventilation systems. Note that ventilation systems estimates include only duct work and vents. Air handlers and other mechanical ventilation equipment are not included. Sprinkler systems, piping, and frames supporting the drywall are assumed to remain in place and are also not included in this estimate. Since some buildings may be constructed without using drywall, ceiling tiles, carpet, and marble and ceramic tiles, or because these materials may not be removed during the decontamination process, estimates for these materials are broken out separately within the building materials category.
Drywall	This estimate includes drywall on walls and ceilings. Frames supporting the drywall are not included in this estimate. This estimate is based on shopping malls with approximately 90% of the interior walls covered with drywall (only some back utility and storage room walls were not covered with drywall). Additionally, approximately 10% of the ceilings were covered with drywall (vaulted ceilings in the hallways, and a few stores). Because drywall will not be neatly stacked when removed from a building, the base volume of drywall (i.e., length × width × height) is multiplied by a factor of 1.3 to arrive at the total volume including void spaces.
Ceiling Tiles	This estimate includes ceiling tiles and frames. Most ceilings within the retail stores at the mall visited were covered with ceiling tiles. Additionally, the ceilings in the mall management offices and back hallways were also covered with ceiling tiles. Because tiles will not be neatly stacked when removed from a building, the base volume of tiles (i.e., length × width × height) is multiplied by a factor of 1.3 to arrive at the total volume including void spaces.

Table 2-44. Interior/Non-Structural Waste Categories and Descriptions for Shopping Malls

Waste Category	Description
Carpet	This estimate includes only carpet on floors. Carpet padding is not included because padding was not found at the shopping mall visited. Carpet was found in the mall management office and in approximately 70% of the floors within the retail stores. Carpet was assumed to be rolled and dry.
Marble and Ceramic Tiles	This estimate includes all marble and ceramic tiles on the floors and around fountains. Most hallways of the shopping mall visited were covered with tiles.
Other Non-Structural Building Materials	This estimate includes all building material not included in other building material subcategories (Drywall, Ceiling Tiles, Carpet, and Marble and Ceramic Tiles). The building materials in this estimate include restroom equipment, doors, glass panes, other floor coverings, duct work, and vents.
Electronic Equipment	Included in this category is the estimate for industrial electronic equipment, as well as all computers, televisions, and other electronic merchandise, electronic janitorial equipment (i.e., vacuum cleaners, floor cleaners, etc.), and lights and light fixtures. Potential sources of BDR that were not included are wiring, mechanical ventilation and climate control equipment (i.e., air handlers, boilers, etc.), and elevators and escalators.
Industrial Electronic Equipment	This estimate includes all kitchen electronic equipment (i.e., industrial ovens, freezers, etc.), water heaters, laundry equipment, circuit breaker boxes, and telephone routing boxes. Most of the industrial electronic equipment identified at shopping malls was found in restaurants.
Other Electronic Equipment	This estimate includes all items listed above in the Electronics Equipment category with the exception of industrial electronic equipment.
Furniture	This estimate includes all items in the Retail Furniture and Office Furniture Categories presented below. The volume for each item was determined by multiplying the overall dimensions. All items are assumed to still be fully assembled. Only minimum size reduction is assumed (e.g., folding tables and chairs are folded).
Retail Furniture	This estimate includes all furniture for retail displays (e.g., clothes racks, shelving). The estimate also includes checkout counters, seating and tables in restaurants, furniture for sale in furniture stores and trash cans.
Office Furniture	This estimate includes only office furniture in the management office and in back rooms in the retail stores (e.g., desks, office chairs, filing cabinets).
Paper/Office Supplies	This estimate is based on the assumption that all office filing cabinets, bookshelves, etc. are 50% full of paper and office supplies. Additionally, books and other paper/office supply merchandise, phone books, toilet paper, janitorial paper products, food service paper products (e.g., plates, napkins), and other paper products are also included in this estimate.
Food	This estimate is based on detailed inventories of all standard food kept on hand. The food on hand may be significantly lower between deliveries or after several busy nights.

Table 2-44. Interior/Non-Structural Waste Categories and Descriptions for Shopping Malls

Waste Category	Description
Apparel	This estimate includes all shoes, shirts, pants, ties, towels, sheets, and other linens and apparel. This estimate is based on available merchandise inventories at several apparel stores.
Other Merchandise and Supplies	This estimate includes all other materials found at the shopping mall, including dishes at restaurants, jewelry, plastic toys, pots and other cooking supplies, cleaning supplies, perfumes, soaps, sporting goods, maintenance supplies (e.g., cans of paint, rock salt, tools), and plants.

2.8.6 Data Analysis and Quality

The default values for the mall tenant space allocation provided in the tool are based on a large national survey conducted by ICSC and should be appropriate for the order of magnitude estimations required for the WME.

Because only one site visit was conducted, it is impossible to perform a statistical analysis of the data used to generate the Shopping Mall WME Category and Item Factors. However, based on conversations with the NRF and its members, the contents and design of most stores of the same brand are fairly typical and standard (i.e., two Gap stores of a similar size would contain a similar quantity of items and materials). Therefore, ERG believes that estimates made based on these factors are appropriate for the order of magnitude estimations required for the WME. Because of the standard designs used for most chain stores, data collected should be very similar to other stores within the same category. If future refinements to the tool were to be performed, ERG recommends additional site visits to other malls to determine the potential variation between waste materials that may be generated from common areas (e.g., hallways, mall management offices).

2.9 Single-Family Residences

Estimates are currently available for single-family residences. The estimates are based on the Building Deconstruction and Assessment Tool[32] and standard industry floor plans and building materials lists. The estimates are based on homes ranging from 1,000 to 3,500 ft^2 (basements excluded). The applicability of these estimates to homes outside this range is uncertain. Additionally, the estimates are based mainly on wood-framed houses. The applicability of these estimates to alternative construction methods is also uncertain.

[32] The Building Deconstruction and Assessment Tool (Decon 2.0) was developed by the National Defense Center for Environmental Excellence. The tool is designed to provide estimates of the quantity and value of material that may be salvaged from deconstructing a building to determine if deconstruction is a viable alternative to demolition. While the Residential WME may be used to generate order of magnitude estimates, more specific estimates may be generated using Decon 2.0. Please contact Dr. Edgar Smith at Edgar.d.smith@erdc.usace.army.mil for additional information on the tool or to obtain a copy of the tool.

The estimates for single-family residences differ from estimates for other structure types in that pipes, wiring, and climate control equipment are included in this estimator, but are excluded for other structure types.

2.9.1 Average Square Footage of the Affected Residences and Number of Affected Residences

Estimates for each single-family residence waste material category are based on the square footage of the affected residence(s) and the WME generates an estimate for an average house of that size. Some estimates are more dependent on one parameter than another. For example, a house with 2,000 ft^2 and a house with 5,000 ft^2 will both typically have only one dishwasher. However, a house with 2,000 ft^2 will likely have fewer bathrooms than a house with 5,000 ft^2. Therefore, an estimate for five affected residences with an average square footage of 1,000 ft^2 will be different from an estimate for one affected residence with 5,000 ft^2.

2.9.2 Percent of Brick/Masonry-Faced Exterior Walls

Exterior walls in single-family residences may be covered with bricks, aluminum siding, vinyl siding, wood siding, and other materials. The weight of building materials required for houses with brick/masonry exterior walls may be more than double the weight of building material required for houses with vinyl siding. Therefore, if structural material estimates are desired, then the percent of brick/masonry-faced exterior walls must be specified. Brick/masonry-faced exterior walls are more likely in older and more expensive neighborhoods or in regions of the country where wood-framed houses are not typical and are less likely in newer or middle-class neighborhoods. As the percentage of brick/masonry-faced exterior walls increases, the quantity of concrete/masonry will increase. However, the quantity of wood and wood sheathing under siding and other building materials (siding) will decrease. Please note that even if the percent of brick/masonry-faced exterior walls is set to 0, some masonry may be estimated from brick or stone fireplaces.

2.9.3 Additional Weight and Volume Added by Packaging Materials

If items are packaged prior to shipment, the packaging material will increase the volume and weight. If you chose to account for this increase in volume and weight, the volume of the estimate for each category will increase by 10% and the weight of the each estimate will increase by 5%. Actual increases in weight and volume due to packaging material may vary based on the type and shape of the item, the type of packaging material used, and the packaging requirements for the various contaminants.

2.9.4 Structural Materials

Due to the extent of the damage or contamination, a single-family residence may require complete demolition or may only require gutting. If the *Include estimates for building structural* materials option is selected, the entire structure and all of its contents are included in the estimate. Alternatively, if this option is not selected, only the contents of the structure are included in the estimate. Gutting assumes all structural wood and masonry, siding, foundation, roofing, pipes, and exterior doors and windows would not be included in the waste estimate; however, all drywall, carpet and other interior flooring, duct work, bathroom and kitchen equipment, appliances and electronic equipment (including all wiring), furniture, and personal effects would be included. If structural material estimates are included, the structural materials are divided into two categories: brick, wood, and other materials; and reinforced concrete and steel. Any of those materials that are not structural will appear in the non-structural/interiors category. To match the two Structural Materials categories across all structure types into "brick, wood, and other" and "reinforced concrete and steel," the factors and calculations used to estimate Structural Materials for single-family residences were revised to be able to segregate the individual item estimates into the two categories. The total estimated Structural Materials amount will not change, just the presentation of the individual item estimates and how those items are grouped together for the purposes of presentation in the results page of the WME.

2.9.5 Foundations

The WME assumes single-family residences are built on a concrete slab or have concrete basement foundations. Depending on the reason for demolition, the concrete foundation may be removed or left in place for future construction. Concrete foundations may account for up to 70% of the total weight of material that may require disposal. This option is available only if the *Include estimates for building structural* materials option is selected.

2.9.6 Factors and Calculations

Because the Building Deconstruction and Assessment Tool (Decon 2.0) was used to model single-family residences, the waste category factor approach used for the other structures available in the WME was not used. The output of Decon 2.0 was a set of linear equations with the structure square footage as the independent variable and the mass or volume of items comprising the waste category as the dependent variable.

Because the WME divides estimates into structural and interior/non-structural waste categories, additional equations were developed by ERG that allows fractions of certain waste categories to be partitioned across either structural or interior/non-structural categories. The equations and tables presented in the following sections are divided between non-building materials (interiors and contents) and building materials (structural and non-structural building materials).

2.9.6.1 Non-Building Materials

Estimates for the Drywall, Carpet, Bathroom/Kitchen, Electronic Equipment, Furniture, and Personal Effects/Other Items waste categories are not affected by:

- The percent of brick/masonry-faced exterior walls,
- Whether the building structural materials are included in the estimates, or
- Whether the foundations are accounted for.

Therefore, Equation 2-7 is used to estimate waste for each non-building material category:

$$E_{wc\text{-}i} = ((m_{wc\text{-}i})(SF_{\text{single-family residence}}) + b_{wc\text{-}i})\ (1\ \textit{or}\ 0.037) \qquad \textbf{(Eq. 2-7)}$$

where:

$E_{wc\text{-}i}$ = Estimate of waste for waste category *i*, tons or yd^3

$m_{wc\text{-}i}$ = Slope for waste category *i* (from Table 2-45)

$SF_{single\text{-}family\ residence}$ = Square footage of single-family residence

$b_{wc\text{-}i}$ = Intercept for waste category *i* (from Table 2-45)

0.037 = Conversion from ft^3 to yd^3

When estimating weight using Equation 2-7, the conversion factor of 1 is used. When estimating volume, the conversion factor from ft^3 to yd^3 must be used (0.037). If $E_{wc\text{-}i}$ <0.5, then the result is rounded to zero. Also, some values may end up negative. If the values are negative, the number of items will be zero.

Table 2-45. WME Factors for Non-Building Materials from Single-Family Residences

	Weight (tons)		**Volume** (ft^3)	
Waste Category	$\mathbf{m_{wc\text{-}i}}$	$\mathbf{b_{wc\text{-}i}}$	$\mathbf{m_{wc\text{-}i}}$	$\mathbf{b_{wc\text{-}i}}$
Drywall	0.00462	0.321	0.360	25.1
Carpet	0.000276	–0.0342	0.0564	–7.00
Bathroom/Kitchen	0.000444	0.360	0.0724	233
Electronic Equipment	0.000273	0.562	0.0859	176
Furniture	0.000780	0.365	0.318	208
Personal Effects/Other Household Items	0.000295	0.451	0.0905	181

2.9.6.2 Building Materials

2.9.6.2.1 Wood and Other Building Materials

The Percent Masonry specified affects the estimates for the *Wood* and *Other Building* Materials waste categories; however, the inclusion or exclusion of the residence foundation does not affect the estimates for these categories. Estimates for the wood and other building materials from a single-family residence are made separately for *structural* and *non-structural* items. To estimate the structural and non-structural wood and other building materials waste categories, the following equations are used:

2.9.6.2.1.1 Structural Wood and Structural Other Building Materials

Waste from *structural* wood and other building materials is estimated using Equation 2-8:

$$\begin{aligned} E_{wc\text{-}i} = (n \times ((M / 100 \times (SF \times M_{100\%}\ \text{Slope} + M_{100\%}\ \text{Intercept})\ ) \ + \\ (\ (100 - M) / 100 \times (SF \times M_{0\%}\ \text{Slope} + M_{0\%}\ \text{Intercept})\ ) - \\ (n \times (SF \times G\ \text{Slope} + G\ \text{Intercept})\ )\ (1\ \textit{or}\ 0.037) \end{aligned} \qquad \textbf{(Eq. 2-8)}$$

where:

$E_{wc\text{-}i}$	=	Estimate of waste for waste category *i*, tons or yd^3
n	=	Number of single-family residences
M	=	Percent of brick/masonry-faced exterior walls, %
SF	=	Square footage, ft^2
$M_{100\%}$ Slope	=	Slope for 100% masonry-faced exterior walls (from Table 2-46)
$M_{100\%}$ Intercept	=	Intercept for 100% masonry-faced exterior walls (from Table 2-46)
$M_{0\%}$ Slope	=	Slope for 0% masonry-faced exterior walls (from Table 2-47)
$M_{0\%}$ Intercept	=	Intercept for 0% masonry-faced exterior walls (from Table 2-47)
G Slope	=	Slope for structure gutting (from Table 2-48)
G Intercept	=	Intercept for structure gutting (from Table 2-48)
0.037	=	Conversion from ft^3 to yd^3

When estimating weight using Equation 2-7, the conversion factor of 1 is used. When estimating volume, the conversion factor from ft^3 to yd^3 must be used (0.037).

2.9.6.2.1.2 Non-Structural Wood and Non-Structural Other Building Materials

Waste from *non-structural* wood and other building materials is estimated using Equation 2-9:

$$E_{wc\text{-}i} = n \times (\, SF \times G\ Slope + G\ Intercept\,)\ (1\ \mathit{or}\ 0.037) \qquad \textbf{(Eq. 2-9)}$$

where:

$E_{wc\text{-}i}$	=	Estimate of waste for waste category *i*, tons or yd^3
n	=	Number of single-family residences
SF	=	Square footage, ft^2
G Slope	=	Slope for structure gutting (from Table 2-48)
G Intercept	=	Intercept for structure gutting (from Table 2-48)
0.037	=	Conversion from ft^3 to yd^3

When estimating weight using Equation 2-7, the conversion factor of 1 is used. When estimating volume, the conversion factor from ft^3 to yd^3 must be used (0.037).

Table 2-46. WME Factors for Building Materials from Single-Family Residences with 100% Masonry-Faced Exterior Walls

	$M_{100\%}$			
	Weight (tons)		Volume (ft^3)	
Waste Category	$M_{100\%}$ Slope	$M_{100\%}$ Intercept	$M_{100\%}$ Slope	$M_{100\%}$ Intercept
Wood	0.00399	2.54	0.221	150
Other Building Materials	0.00252	2.94	0.848	244

Table 2-47. WME Factors for Building Materials from Single-Family Residences with 0% Masonry-Faced Exterior Walls

	$M_{0\%}$			
	Weight (tons)		Volume (ft^3)	
Waste **Category**	$M_{0\%}$ Slope	$M_{0\%}$ Intercept	$M_{0\%}$ Slope	$M_{0\%}$ Intercept
Wood	0.00452	4.74	0.252	279
Other Building Materials	0.00275	3.32	0.891	315

Table 2-48. WME Factors for Building Materials from Gutted Single-Family Residences

	G			
	Weight (tons)		Volume (ft^3)	
Waste **Category**	G Slope	G Intercept	G Slope	G Intercept
Wood	0.000733	–0.873	0.0407	–48.5
Other Building Materials	0.00180	0.354	0.750	137

2.9.6.2.2 Concrete and Masonry

The estimates for concrete and masonry are dependent on both the specified percent masonry and whether the residence foundation is included. No concrete or masonry is included as part of the non-structural estimates and therefore, these two waste categories appear in the estimate results only if structural material estimates are included in the calculation.

If the foundation *IS NOT* included in the estimates, then the following equations are used:

2.9.6.2.2.1 Structural Concrete and Masonry Materials – Foundation Not Included

For estimates that do not include the structure foundation, estimates are generated using Equations 2-10 and 2-11 and Table 2-49:

Concrete:

$$E_{wc\text{-}i} = (n \times ((100 - M) / 100) \times (SF \times \text{NF Slope} + \text{NF Intercept})) (1 \textit{ or } 0.037) \qquad \textbf{(Eq. 2-10)}$$

where:

$E_{wc\text{-}i}$	=	Estimate of waste for waste category *i*, tons or yd^3
n	=	Number of single-family residences
M	=	Percent of brick/masonry-faced exterior walls, %
SF	=	Square footage, ft^2
NF Slope	=	Slope for no foundation (from Table 2-49)
NF Intercept	=	Intercept for no foundation (from Table 2-49)
0.037	=	Conversion from ft^3 to yd^3

When estimating weight using Equation 2-7, the conversion factor of 1 is used. When estimating volume, the conversion factor from ft^3 to yd^3 must be used (0.037).

Masonry:

$$E_{wc\text{-}i} = (n \times (M / 100) \times (SF \times NF\ Slope + NF\ Intercept)\ )\ (1\ \textit{or}\ 0.037) \qquad \textbf{(Eq. 2-11)}$$

where:

$E_{wc\text{-}i}$	=	Estimate of waste for waste category *i*, tons or yd^3
n	=	Number of single-family residences
M	=	Percent of brick/masonry-faced exterior walls, %
SF	=	Square footage, ft^2
NF Slope	=	Slope for no foundation (from Table 2-49)
NF Intercept	=	Intercept for no foundation (from Table 2-49)
0.037	=	Conversion from ft^3 to yd^3

When estimating weight using Equation 2-7, the conversion factor of 1 is used. When estimating volume, the conversion factor from ft^3 to yd^3 must be used (0.037).

Table 2-49. WME Factors for Structural Concrete and Masonry Materials From Single-Family Residences Where Foundations Are Not Included

Waste **Category**	**NO FOUNDATION**			
	Weight (tons)		**Volume (ft^3)**	
	NF Slope	**NF Intercept**	**NF Slope**	**NF Intercept**
Concrete	0.000881	-0.173	0.026	-5.18
Masonry	0.0105	14.8	0.315	444

2.9.6.2.2.2 Structural Concrete and Masonry Materials – Foundation Included

For estimates that do include the structure foundation, estimates are generated using Equations 2-12 and 2-13 and Table 2-50:

Concrete:

$$E_{wc\text{-}i} = (n \times (100 - M) \times (F\ Intercept + F\ Slope \times SF)\ )\ (1\ \textit{or}\ 0.037) \qquad \textbf{(Eq. 2-12)}$$

where:

$E_{wc\text{-}i}$	=	Estimate of waste for waste category *i*, tons or yd^3
n	=	Number of single-family residences
M	=	Percent of brick/masonry-faced exterior walls, %
SF	=	Square footage, ft^2
F Slope	=	Slope for foundation (from Table 2-50)
F Intercept	=	Intercept for foundation (from Table 2-50)

0.037	=	Conversion from ft^3 to yd^3

When estimating weight using Equation 2-7, the conversion factor of 1 is used. When estimating volume, the conversion factor from ft^3 to yd^3 must be used (0.037).

Masonry:

$$E_{wc\text{-}i} = (n \times M \times (F\ Intercept + F\ Slope \times SF)\ )\ (1\ \textit{or}\ 0.037) \qquad \textbf{(Eq. 2-13)}$$

where:

$E_{wc\text{-}i}$	=	Estimate of waste for waste category *i*, tons or yd^3
n	=	Number of single-family residences
M	=	Percent of brick/masonry-faced exterior walls, %
SF	=	Square footage, ft^2
F Slope	=	Slope for foundation (from Table 2-50)
F Intercept	=	Intercept for foundation (from Table 2-50)
0.037	=	Conversion from ft^3 to yd^3

When estimating weight using Equation 2-7, the conversion factor of 1 is used. When estimating volume, the conversion factor from ft^3 to yd^3 must be used (0.037).

Table 2-50. WME Factors for Structural Concrete and Masonry Materials From Single-Family Residences Where Foundations Are Included

	FOUNDATION			
	Weight (tons)		Volume (ft^3)	
Waste Category	F Slope	F Intercept	F Slope	F Intercept
Concrete	0.0165	43.6	0.286	725
Masonry	0.0261	58.6	0.575	1170

2.9.7 Assumptions and Key Notes

The following assumptions are made when estimating the amount of materials requiring disposal from a single-family residence:

- The estimates are based on homes ranging from 1,000 to 3,500 ft^2 (basements excluded).
- The estimates are mainly based on wood-framed homes.
- All weights are dry weights. Additional weight of water from any decontamination fluid is not accounted for.
- Drywall will not be neatly stacked when packaged for shipment. The base volume of drywall and ceiling tiles (i.e., length × width × height) is multiplied by a factor of 1.3 to determine the total volume including void space.

- Since some houses may be constructed without one or more of the listed building materials (i.e., drywall, wood, concrete/masonry, and carpet), or because these materials may not be removed during the decontamination process, estimates for drywall, wood, concrete/masonry, and carpet are broken out separately within the building materials category.
- All items are assumed to be shipped for disposal fully assembled. The volume for each item is determined by multiplying its maximum overall dimensions. Only minimum size reduction is assumed (e.g., folding tables and chairs are folded).

2.9.8 Category Descriptions

WME estimates for single-family residences are broken into the following waste categories. Details and assumptions for each category for which estimates are generated are described in Table 2-51, below.

Table 2-51. Waste Categories and Descriptions for Single-Family Residences

Waste Category	Description
Total Non-Structural Building Materials	This estimate includes the estimates for drywall, wood, concrete/masonry, carpet, and other building materials, as discussed below. Since some houses may be constructed without using drywall, wood, concrete/masonry, and carpet, or because these materials may not be removed during the decontamination process, estimates for these materials are broken out separately within the building materials category.
Drywall	This estimate includes drywall on walls and ceilings. Wood frames supporting the drywall are not included in this estimate. This estimate is based on residences with over 90% of the interior walls covered with drywall (only some back utilities and garages were not covered with drywall). Because drywall will not be neatly stacked when removed from a building, the base volume of drywall (i.e., length × width × height) is multiplied by a factor of 1.3 to arrive at the total volume including void spaces.
Wood	This estimate includes all wood used for framing walls, ceilings, and roofs, as well as plywood used for floors and sheathing under shingles and siding. Wood framing is assumed to be behind most brick/masonry-faced exterior walls. This estimate does not include wood furniture. Because wood will not be neatly stacked when removed from a building, the base volume of wood (i.e., length × width × height) is multiplied by a factor of 1.3 to arrive at the total volume including void spaces.
Concrete/ Masonry	This estimate includes concrete slab foundations (including concrete basements), brick/masonry exterior walls, and brick/masonry used for chimneys. The percent of brick/masonry-faced exterior walls will affect this estimate as will the inclusion of concrete foundations. Due to the weight of these materials, the concrete/masonry category may comprise over 80% of the total waste materials that may require disposal.
Carpet	This estimate includes only carpet and carpet padding on floors. Carpet padding is assumed to be under all carpet in residences. Carpet and padding are assumed to be rolled and dry.

Table 2-51. Waste Categories and Descriptions for Single-Family Residences

Waste Category	Description
Other Non-Structural Building Materials	This estimate includes all building material not included in other building material subcategories (Drywall, Wood, Carpet/Masonry, and Carpet). The building materials in this estimate include windows and doors, siding and shingles, pipes, electrical wiring, duct work, insulation, and other floor coverings (e.g., linoleum, tiles). Please note that these estimates differ from estimates for other structure types (e.g., offices, schools, movie theaters), in that pipes and wiring are included.
Kitchen/ Bathroom	This estimate includes all kitchen and bathroom items, including toilets, showers, sinks, faucets and knobs, cabinets, and counter tops. Appliances are excluded from this estimate.
Electronic Equipment	This estimate included all electronic equipment and appliances. Included in this category are laundry washers and dryers, kitchen appliances (e.g., refrigerators, dishwashers, ovens, microwaves, toasters, and garbage disposals), televisions, computers, stereos, clocks, water heaters, heat pumps, and all other electronic items. Please note that these estimates differ from estimates for other structure types (e.g., offices, schools, movie theaters), in that climate control equipment is included.
Furniture	This estimate includes all residential furniture including beds, couches, recliners, dining room tables, chairs, desks, coffee tables, end tables, and night stands. The volume for each item was determined by multiplying the overall dimensions. All items are assumed to still be fully assembled. Only minimum size reduction is assumed (e.g., folding tables and chairs are folded).
Personal Effects and Other Household Items	This estimate includes all other materials found in a residence, including personal items, food, toiletries, pots, pans, dishes, linens, clothes, plants, pictures, paper, and window coverings.

3. STRUCTURAL BUILDING MATERIALS

This section discusses the methodology for estimating quantities of building structural materials in the WME for all structure types except single-family residences.

As discussed in Section 2.9, the structural material estimates for single-family residences are based on the Building Deconstruction and Assessment Tool[33] and standard industry floor plans and building materials lists. The estimates are based on homes ranging from 1,000 to 3,500 ft^2 (basements excluded). We believe those estimates provide greater accuracy over estimates that would be generated based on the Hazards U.S. – Multi-Hazard Loss Estimation Software (HAZUS-MH) debris factors (discussed in detail below) for single family residences.

As discussed in Section 2, the WME allows users to generate first order estimates of the quantities of interior and non-structural items and materials for several types of building structures. The estimates are generated based on factors that were developed for various items and categories of materials.

The methodology for estimating the mass and volume of building structural materials is based almost entirely on data developed by the Federal Emergency Management Agency (FEMA) for use in the FEMA-developed HAZUS-MH program for estimating potential losses from natural disasters[34]. Unless otherwise noted or referenced in this section, all data used in the development of this methodology were taken either from the HAZUS-MH databases or from the HAZUS-MH technical and user manuals available from the HAZUS website[33]. During the development of this methodology, it was necessary to supplement the HAZUS-MH data to enable its use in the tool. The supplemental data consisted primarily of data obtained by ERG during the initial development of the structure-specific WMEs. Additional secondary data sources were identified and utilized in this methodology where it was necessary to fill remaining data gaps.

The HAZUS-MH program contains the ability for users of the program to estimate the quantity of building debris that could result from a natural disaster. The program utilizes a set of debris factors to estimate the amount of debris based on the degree of damage to a structure. One set of debris factors included in the program's methodology is based on 100% building damage, which essentially equates to complete demolition of the structure. The debris factors vary according to the type of building construction (not the occupancy/structure type or intended use) and are grouped into structural and non-structural categories. Furthermore, the factors are in terms of mass per area of building floor space.

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33 The Building Deconstruction and Assessment Tool (Decon 2.0) was developed by the National Defense Center for Environmental Excellence. The tool is designed to provide estimates of the quantity and value of material that may be salvaged from deconstructing a building to determine if deconstruction is a viable alternative to demolition.

34 Federal Emergency Management Agency, *HAZUS-MH Multi-Hazard Loss Estimation Software*, Version 1.3 (September 2007) and Version 1.4 (August 2009). http://www.fema.gov/plan/prevent/hazus/ and http://www.fema.gov/plan/prevent/hazus/hz_manuals.shtm. The website and URL are not valid as of July 31, 2015. At the time this website was referenced, it was a valid URL and this reference remains the source of the information or data currently used in the WME

For the development of the methodology outlined in the sections below, the general approach was as follows:

1. Match the structure types in the tool to the occupancy types used by HAZUS-MH. See Section 3.2.
2. Using averaged HAZUS-MH data for a selected number of States, determine the percentage of each HAZUS-MH occupancy type comprised of various types of construction. See Section 3.3.
3. Convert the HAZUS-MH debris factors from a construction type basis to an occupancy type/structure type basis and develop additional factors for debris volumes. See Section 3.4.
4. Develop additional correlations between the tool's structure input parameters and structure square footage based on data collected during initial development of the WMEs and additional research as needed. See Section 3.5.

3.1 HAZUS-MH Building Types

FEMA's HAZUS-MH loss estimation program allows users to generate estimates of building structural and non-structural debris that may result from an earthquake, hurricane, or flood. The program utilizes aggregated total square footage data for general building stock based on occupancy, or Specific Occupancy Classes (SOC) in conjunction with various factors to calculate direct and indirect losses from the three event types previously mentioned. The aggregated square footage data are based on U.S. Census data for each Census tract in the geographic region being studied. The HAZUS-MH debris estimation methodology utilizes structural and non-structural debris factors, in tons of debris per 1,000 square feet of structure, which vary depending on the type of construction of the structure, which is referred to as the Model Building Type, or MBT. The debris factors also vary according to the degree of damage to the structure as a result of the natural hazard being modeled.

The building structural material estimates in the WME utilize the HAZUS-MH debris factors only for *structural* components. The structural components include one or more of brick, wood, concrete, steel, and other components, and the primary building structural materials can be generally correlated to the MBT. HAZUS-MH also contains factors for non-structural materials, but those factors are not utilized in the tool. Examples of the non-structural building components that are not included are listed below. The HAZUS-MH structural debris factors facilitated the estimation of debris for all possible building materials except for those items and materials listed in Table 3-1, below. Some of the items listed in Table 3-1 are already accounted for by the WME, notably major mechanical and electrical components, and of course building contents. We believe that the non-structural items currently not estimated by the WME or by the methodology presented in this section (i.e., the architectural components listed in Table 3-1 and certain mechanical/electrical items) do not represent a significant percentage of all non-structural materials. However, we may want to assess the non-structural debris factors in the future to assess how closely they align with similar debris materials that are already included in the tool.

Table 3-1. List of Typical Nonstructural Components and Contents of Buildings

Type of Nonstructural Component	Item
Architectural	Non-bearing Walls/Partitions
	Cantilever Elements and Parapets
	Exterior Wall Panels
	Veneer and Finishes
	Penthouses
	Racks and Cabinets
	Access Floors
	Appendages and Ornaments
Mechanical and Electrical	General Mechanical (boilers, etc.)
	Manufacturing and Process Machinery
	Piping Systems
	Storage Tanks and Spheres
	Heating, Ventilation and Air Conditioning (HVAC) systems (chillers, ductwork, etc.)
	Elevators
	Trussed Towers
	General Electrical (switchgear, ducts, etc.)
	Lighting Fixtures
Contents	File Cabinets, Bookcases, etc.
	Office Equipment and Furnishings
	Computer/Communication Equipment
	Non-permanent Manufacturing Equipment
	Manufacturing/Storage Inventory
	Art and other Valuable Objects

General building stock in HAZUS-MH is classified in two different ways: 1) according to MBT (type of construction) and 2) according to SOC (type of building occupancy or building use); that is, each building is characterized by both MBT and SOC. The MBTs and SOC utilized in HAZUS-MH are found in Table 3-2 and Table 3-3, respectively. Descriptions of each MBT can be found in Appendix B.

Table 3-2. HAZUS-MH Specific Occupancy Classes (SOCs) for General Building Stock

Specific Occupancy Class (SOC)	**SOC Description**	**General Occupancy Class (GOC)** Description	**Example Descriptions**
RES1	Single Family Dwelling	Residential	House
RES2	Mobile Home		Mobile Home
RES3	Multi-Family Dwelling		Apartment/Condominium
RES4	Temporary Lodging		Hotel/Motel

Table 3-2. HAZUS-MH Specific Occupancy Classes (SOCs) for General Building Stock

Specific Occupancy Class (SOC)	**SOC Description**	**General Occupancy Class (GOC)** Description	**Example Descriptions**
RES5	Institutional Dormitory		Group Housing (military, college), Jails
RES6	Nursing Home		
COM1	Retail Trade	Commercial	Store
COM2	Wholesale Trade		Warehouse
COM3	Personal and Repair Services		Service Station/Shop
COM4	Professional/Technical Services		Offices
COM5	Banks		
COM6	Hospital		
COM7	Medical Office/Clinic		
COM8	Entertainment & Recreation		Restaurants/Bars
COM9	Theaters		Theaters
COM10	Parking		Garages
IND1	Heavy	Industrial	Factory
IND2	Light		Factory
IND3	Food/Drugs/Chemicals		Factory
IND4	Metals/Minerals Processing		Factory
IND5	High Technology		Factory
IND6	Construction		Office
AGR1	Agriculture	Agriculture	
REL1	Church/Non-Profit	Religion/Non-Profit	
GOV1	General Services	Government	Office
GOV2	Emergency Response		Police/Fire Station/Emergency Operations Centers (EOC)
EDU1	Grade Schools	Education	
EDU2	Colleges/Universities		Does not include group housing

Table 3-3. HAZUS-MH Model Building Types (MBTs) for General Building Stock

Model Building Type (MBT)	**MBT Description**	**Height**			
		Range		**Typical**	
		Name	**Stories**	**Stories**	**Feet**
W1	Wood, Light Frame (< 5,000 sq. ft.)		1-2	1	14
W2	Wood, Commercial, and Industrial (> 5,000 sq. ft.)		All	2	24
S1L	Steel Moment Frame	LR	1-3	2	24
S1M	Steel Moment Frame	MR	4-7	5	60
S1H	Steel Moment Frame	HR	8+	13	156
S2L	Steel Braced Frame	LR	1-3	2	24

Table 3-3. HAZUS-MH Model Building Types (MBTs) for General Building Stock

Model Building Type (MBT)	MBT Description	Height			
		Range		Typical	
		Name	Stories	Stories	Feet
S2M	Steel Braced Frame	MR	4-7	5	60
S2H	Steel Braced Frame	HR	8+	13	156
S3	Steel Light Frame		All	1	15
S4L	Steel Frame with Cast-in-Place Concrete Shear Walls	LR	1-3	2	24
S4M	Steel Frame with Cast-in-Place Concrete Shear Walls	MR	4-7	5	60
S4H	Steel Frame with Cast-in-Place Concrete Shear Walls	HR	8+	13	156
S5L	Steel Frame with Unreinforced Masonry Infill Walls	LR	1-3	2	24
S5M	Steel Frame with Unreinforced Masonry Infill Walls	MR	4-7	5	60
S5H	Steel Frame with Unreinforced Masonry Infill Walls	HR	8+	13	156
C1L	Concrete Moment Frame	LR	1-3	2	20
C1M	Concrete Moment Frame	MR	4-7	5	50
C1H	Concrete Moment Frame	HR	8+	12	120
C2L	Concrete Shear Walls	LR	1-3	2	20
C2M	Concrete Shear Walls	MR	4-7	5	50
C2H	Concrete Shear Walls	HR	8+	12	120
C3L	Concrete Frame with Unreinforced Masonry Infill Walls	LR	1-3	2	20
C3M	Concrete Frame with Unreinforced Masonry Infill Walls	MR	4-7	5	50
C3H	Concrete Frame with Unreinforced Masonry Infill Walls	HR	8+	12	120
PC1	Precast Concrete Tilt-Up Walls		All	1	15
PC2L	Precast Concrete Frames with Concrete Shear Walls	LR	1-3	2	20
PC2M	Precast Concrete Frames with Concrete Shear Walls	MR	4-7	5	50
PC2H	Precast Concrete Frames with Concrete Shear Walls	HR	8+	12	120
RM1L	Reinforced Masonry Bearing Walls with Wood or Metal Deck Diaphragms	LR	1-3	2	20
RM1M	Reinforced Masonry Bearing Walls with Wood or Metal Deck Diaphragms	MR	4+	5	50
RM2L	Reinforced Masonry Bearing Walls with Precast Concrete Diaphragms	LR	1-3	2	20
RM2M	Reinforced Masonry Bearing Walls with Precast Concrete Diaphragms	MR	4-7	5	50
RM2H	Reinforced Masonry Bearing Walls with Precast Concrete Diaphragms	HR	8+	12	120
URML	Unreinforced Masonry Bearing Walls	LR	1-2	1	15
URMM	Unreinforced Masonry Bearing Walls	MR	3+	3	35
MH	Mobile Homes		All	1	10

LR – Low rise.

MR – Mid rise.

HR – High rise.

Buildings categorized in one SOC may be of one or more MBTs. For instance, a single family dwelling (RES1) will likely be light frame wood construction (W1), but some residences may be constructed differently. Construction types vary according to geographic regions so that the distribution of MBTs for each SOC varies not only within a specific city, county, or State, but also nationwide.

3.2 HAZUS-MH Debris Factors

The HAZUS-MH debris factors are listed in Table 3-4. These debris factors include both structural and non-structural debris for 100% damage to the building. As mentioned in Section 3.0, the debris factors are in terms of tons of debris per 1,000 ft^2 of building and are based on the MBT.

Table 3-4. HAZUS-MH Default Building Debris Factors

MBT	Brick, Wood, and Other Structural (tons/1,000 ft^2)	Brick, Wood, and Other Non-structural (tons/1,000 ft^2)	Reinforced Concrete and Steel Structural (tons/1,000 ft^2)	Reinforced Concrete and Steel Non-structural (tons/1,000 ft^2)
W1	6.5	12.1	15.0	0.0
W2	4.0	8.1	15.0	1.0
S1L	0.0	5.3	44.0	5.0
S1M	0.0	5.3	44.0	5.0
S1H	0.0	5.3	44.0	5.0
S2L	0.0	5.3	44.0	5.0
S2M	0.0	5.3	44.0	5.0
S2H	0.0	5.3	44.0	5.0
S3	0.0	0.0	67.0	1.5
S4L	0.0	5.3	65.0	4.0
S4M	0.0	5.3	65.0	4.0
S4H	0.0	5.3	65.0	4.0
S5L	20.0	5.3	45.0	4.0
S5M	20.0	5.3	45.0	4.0
S5H	20.0	5.3	45.0	4.0
C1L	0.0	5.3	98.0	4.0
C1M	0.0	5.3	98.0	4.0
C1H	0.0	5.3	98.0	4.0
C2L	0.0	5.3	112.0	4.0
C2M	0.0	5.3	112.0	4.0
C2H	0.0	5.3	112.0	4.0
C3L	20.0	5.3	90.0	4.0
C3M	20.0	5.3	90.0	4.0

Table 3-4. HAZUS-MH Default Building Debris Factors

MBT	Brick, Wood, and Other Structural (tons/1,000 ft^2)	Brick, Wood, and Other Non-structural (tons/1,000 ft^2)	Reinforced Concrete and Steel Structural (tons/1,000 ft^2)	Reinforced Concrete and Steel Non-structural (tons/1,000 ft^2)
C3H	20.0	5.3	90.0	4.0
PC1	5.5	5.3	40.0	1.5
PC2L	0.0	5.3	100.0	4.0
PC2M	0.0	5.3	100.0	4.0
PC2H	0.0	5.3	100.0	4.0
RM1L	17.5	5.3	28.0	4.0
RM1M	17.5	5.3	28.0	4.0
RM2L	17.5	5.3	78.0	4.0
RM2M	24.5	5.3	78.0	4.0
RM2H	24.5	5.3	78.0	4.0
URML	35.0	10.5	41.0	4.0
URMM	35.0	10.5	41.0	4.0
MH	10.0	18.0	22.0	0.0

Since the debris factors are based on MBT and not on SOC, the distribution of MBT for each SOC had to be determined. Mapping schemes are utilized in HAZUS-MH to specify the distribution of MBTs for each SOC. The mapping schemes are State-specific and account for regional building practices and the vintage of construction. The default mapping schemes for selected states contained in the HAZUS-MH databases (see Appendix A) were utilized in the WME to calculate a representative national distribution of MBTs for each SOC. Because the WME currently contains a subset of the types of buildings contained in HAZUS-MH (based on SOC), the mapping of SOC to MBT needed only to utilize those SOCs for which a similar structure type currently exists in the WME.

The WME structure types that could be matched to the HAZUS-MH SOCs are shown in Table 3-5, below.

Table 3-5. WME Structure Types Matched to HAZUS-MH Specific Occupancy Class (SOC)

WME Structure Type	HAZUS-MH SOC
Residence – Single-Family Home	RES1
Hotels	RES4
Shopping Mall	COM1
Office - Individual Walled Office - Cubicle	COM4
Hospitals	COM6
Movie Theater	COM9

School – Elementary School – Middle School – High	EDU1

3.3 Mapping Specific Occupancy Class (SOC) to Model Building Type (MBT)

The default mapping schemes were generated from the HAZUS-MH databases for nine states: California, Colorado, Georgia, Illinois, Missouri, New York, Oregon, Pennsylvania, and Texas. The distribution of MBTs for each SOC was then averaged across all nine states to generate a single mapping scheme of SOCs to MBTs. As an example, the mapping scheme for the COM4 SOC is shown in Table 3-6. This table shows the distribution of MBTs for the COM4 SOC based on total building square footage and is an average for all nine states listed above. For any single state, the total square footage is based on aggregated building data and represents the total square footage comprised of COM4 building types.

Table 3-6. Average Distribution of Model Building Type (MBT) Floor Area within the COM4 Specific Occupancy Class (SOC)

MBT	MBT Description	Fraction of COM4 SOC Floor Area
W1	Wood, Light Frame (< 5,000 sq. ft.)	0.00
W2	Wood, Commercial, and Industrial (> 5,000 sq. ft.)	0.31
S1L	Steel Moment Frame – Low Rise	0.04
S1M	Steel Moment Frame – Mid Rise	0.00
S1H	Steel Moment Frame – High Rise	0.00
S2L	Steel Braced Frame – Low Rise	0.04
S2M	Steel Braced Frame – Mid Rise	0.00
S2H	Steel Braced Frame – High Rise	0.00
S3	Steel Light Frame	0.07
S4L	Steel Frame with Cast-in-Place Concrete Shear Walls – Low Rise	0.04
S4M	Steel Frame with Cast-in-Place Concrete Shear Walls – Mid Rise	0.00
S4H	Steel Frame with Cast-in-Place Concrete Shear Walls – High Rise	0.00
S5L	Steel Frame with Unreinforced Masonry Infill Walls – Low Rise	0.06
S5M	Steel Frame with Unreinforced Masonry Infill Walls – Mid Rise	0.00
S5H	Steel Frame with Unreinforced Masonry Infill Walls – High Rise	0.00
C1L	Concrete Moment Frame – Low Rise	0.02
C1M	Concrete Moment Frame – Mid Rise	0.00
C1H	Concrete Moment Frame – High Rise	0.00
C2L	Concrete Shear Walls – Low Rise	0.07
C2M	Concrete Shear Walls – Mid Rise	0.00
C2H	Concrete Shear Walls – High Rise	0.00
C3L	Concrete Frame with Unreinforced Masonry Infill Walls – Low Rise	0.00
C3M	Concrete Frame with Unreinforced Masonry Infill Walls – Mid Rise	0.00
C3H	Concrete Frame with Unreinforced Masonry Infill Walls – High Rise	0.00
PC1	Precast Concrete Tilt-Up Walls	0.05

Table 3-6. Average Distribution of Model Building Type (MBT) Floor Area within the COM4 Specific Occupancy Class (SOC)

MBT	MBT Description	Fraction of COM4 SOC Floor Area
PC2L	Precast Concrete Frames with Concrete Shear Walls – Low Rise	0.01
PC2M	Precast Concrete Frames with Concrete Shear Walls – Mid Rise	0.00
PC2H	Precast Concrete Frames with Concrete Shear Walls – High Rise	0.00
RM1L	Reinforced Masonry Bearing Walls with Wood or Metal Deck Diaphragms – Low Rise	0.06
RM1M	Reinforced Masonry Bearing Walls with Wood or Metal Deck Diaphragms – Mid Rise	0.00
RM2L	Reinforced Masonry Bearing Walls with Precast Concrete Diaphragms – Low Rise	0.01
RM2M	Reinforced Masonry Bearing Walls with Precast Concrete Diaphragms – Mid Rise	0.00
RM2H	Reinforced Masonry Bearing Walls with Precast Concrete Diaphragms – High Rise	0.00
URML	Unreinforced Masonry Bearing Walls – Low Rise	0.22
URMM	Unreinforced Masonry Bearing Walls – Mid Rise	0.00
MH	Mobile Homes	0.00

Utilizing the mapping scheme above, the percentage of total COM4 floor area (for all COM4 buildings) comprised of each MBT (Table 3-7) was determined.

Table 3-7. Default Distribution of Model Building Types (MBTs) for COM4 Specific Occupancy Class (SOC)

MBT	Percentage of COM4 Floor Area
W2	31%
S1L	4%
S2L	4%
S3	7%
S4L	4%
S5L	6%
C1L	2%
C2L	7%
PC1	5%
PC2L	1%
RM1L	6%
RM2L	1%
URML	22%

3.4 Utilizing HAZUS-MH Debris Factors

To convert the debris factors from tons per ft^2 of MBT to tons per ft^2 of SOC, we assumed 1 ft^2 per SOC building and multiplied the fraction of MBT by the default debris factor for that MBT. This procedure was followed for each of the two structural debris types to generate a set of debris factors that are then based on 1 ft^2 of the building and based on SOC. The factors were then summed to generate a total debris factor for each debris type. The Hazus structural materials debris types are “Brick, Wood, and Other Materials” and “Reinforced Concrete and Steel.”

$$DF_i = \sum (MBTf_i)(DF_{MBT-i}) \qquad \textbf{(Eq. 3-1)}$$

where:

DF_i = Debris factor for debris type i, mass or volume

$MBTf_i$ = Fraction of SOC comprised of MBT type i

DF_{MBT-i} = Debris factor for MBT type i

The result of this calculation is shown in Table 3-8 below, for the COM4 SOC and in Table 3-9 for all WME structure types. As mentioned in Section 3, the “debris” factors used by HAZUS-MH equate to “structural materials” for the purposes of the WME, as the HAZUS-MH debris factors utilized by the methodology presented here are those for 100% building damage. Additionally, the values and factors developed for this methodology and presented throughout the remainder of this section retain a relatively large number of significant figures. The significant figures were retained as these values are utilized in intermediate calculations. The final structural debris estimates generated using these intermediate factors and values (and presented in the WME) have an appropriately smaller number of significant figures retained, consistent with the number of figures shown by the WME for the non-structural/interior estimates.

Table 3-8. MBT Debris Factors (Mass) for COM4 SOC

MBT	Brick, Wood, and Other Structural (tons/ft^2)	Reinforced Concrete and Steel Structural (tons/ft^2)
W2	0.0012229	0.0045857
S1L	0	0.0018612
S2L	0	0.0017952
S3	0	0.0045225
S4L	0	0.0002309
S5L	0.0011040	0.0024840
C1L	0	0.0019425
C2L	0	0.0080992
PC1	0.0002986	0.0021717
PC2L	0	0.0008571
RM1L	0.0011039	0.0017662

Table 3-8. MBT Debris Factors (Mass) for COM4 SOC

MBT	Brick, Wood, and Other Structural (tons/ft^2)	Reinforced Concrete and Steel Structural (tons/ft^2)
RM2L	0.0002233	0.0009951
URML	0.0076708	0.0089857
TOTAL	**0.011623**	**0.040297**

Table 3-9. Calculated Building Structural Materials Factors (Mass) Based on Specific Occupancy Class (SOC)

WME Structure Type	HAZUS-MH SOC	Structural Material Factor (tons/ft^2)	
		Brick, Wood, and Other	Reinforced Concrete and Steel
Residence - Single-Family Home	RES1	0.010633	0.019144
Hotels	RES4	0.014672	0.033150
Shopping Mall	COM1	0.011100	0.041721
Office - Individual Walled	COM4	0.011623	0.040297
Office - Cubicle	COM4	0.011623	0.040297
Hospitals	COM6	0.009114	0.055697
Movie Theater	COM9	0.008530	0.053459
School - Elementary	EDU1	0.014930	0.046378
School - Middle	EDU1	0.014930	0.046378
School - High	EDU1	0.014930	0.046378

Where a single HAZUS-MH SOC applies to multiple WME structure types, we assumed that the single structural material factor for the corresponding SOC applied to all similar WME structure types.

To determine the volume for structural materials based on the mass factors calculated above, we assumed the structural densities found in Table 3-10, and we further assumed the distribution of structural materials found in Table 3-11. Using the densities and assumed volumetric distribution of materials, the volumetric debris factors were then calculated in cubic feet (ft^3) per ft^2 of MBT as shown in Table 3-12 for the COM4 SOC. The debris factors for each MBT within each SOC were then summed to arrive at a total volumetric debris factor for the entire SOC.

Table 3-10. Assumed Structural Material Densities

Structural Material	lb/ft^3
Brick	128
Wood	40

Table 3-10. Assumed Structural Material Densities

Structural Material	lb/ft^3
Other (Glass is assumed)	162
Concrete	144
Steel	489

Source: Perry's Chemical Engineers Handbook, 7th Ed, Table 2-118.

Table 3-11. Assumed Volumetric Distribution (Percentage of Total) of Structural Materials by MBT

MBT	MBT Description	Brick	Wood	Glass	Concrete	Steel
W1	Wood, Light Frame (<5,000 sq. ft.)	20	60	10	10	0
W2	Wood, Commercial and Industrial (>5,000 sq. ft.)	20	60	10	10	0
S1	Steel Moment Frame	0	0	25	15	60
S2	Steel Braced Frame	0	0	25	15	60
S3	Steel Light Frame	0	0	25	15	60
S4	Steel Frame with Cast-in-Place Concrete Shear Walls	0	0	20	40	40
S5	Steel Frame with Unreinforced Masonry Infill Walls	40	0	20	0	40
C1	Concrete Moment Frame	0	0	20	65	15
C2	Concrete Shear Walls	0	0	20	65	15
C3	Concrete Frame with Unreinforced Masonry Infill Walls	40	0	20	30	10
PC1	Precast Concrete Tilt-Up Walls	0	0	20	65	15
PC2	Precast Concrete Frames with Concrete Shear Walls	0	0	20	65	15
RM1	Reinforced Masonry Bearing Walls with Wood or Metal Deck Diaphragms	40	20	20	10	10
RM2	Reinforced Masonry Bearing Walls with Precast Concrete Diaphragms	50	0	20	20	10
URM	Unreinforced Masonry Bearing Walls	55	5	20	10	10
MH	Mobile Homes	0	85	10	0	5

Table 3-12. MBT Debris Factors (Volume) for COM4 SOC

MBT	Brick, Wood, and Other Structural (ft^3/ft^2)	Reinforced Concrete and Steel Structural (ft^3/ft^2)
W2	0.033452	0.063690
S1L	0	0.008863
S2L	0	0.008549
S3	0	0.021536
S4L	0	0.001459
S5L	0.015847	0.010160
C1L	0	0.018616
C2L	0	0.077620
PC1	0.003687	0.020813
PC2L	0	0.008215
RM1L	0.019282	0.011161
RM2L	0.003242	0.007684
URML	0.117111	0.056782
TOTAL	**0.192620**	**0.315147**

Based on the procedure outlined above, the volumetric factors for each SOC were calculated for each of the two materials categories. Table 3-13 shows the results of those calculations for all WME structure types.

Table 3-13. Calculated Building Structural Materials Factors (Volume) Based on Specific Occupancy Class (SOC)

WME Structure Type	HAZUS-MH SOC	Structural Material Factor (ft^3/ft^2)	
		Brick, Wood, and Other	Reinforced Concrete and Steel
Residence - Single-Family Home	RES1	0.229149	0.218714
Hotels	RES4	0.265218	0.294474
Shopping Mall	COM1	0.181330	0.313234
Office - Individual Walled	COM4	0.192620	0.315147
Office - Cubicle			
Hospitals	COM6	0.141946	0.468278
Movie Theater	COM9	0.129606	0.383945
School - Elementary	EDU1	0.240285	0.34878
School - Middle			
School - High			

For building structural materials estimates, we are not proposing to further subdivide each of the two main materials categories; that is, for “brick, wood, and other” materials, we will not estimate the amount of the aggregated material that is comprised of brick, wood, and other materials. Estimating individual components would require some knowledge or ability to reasonably estimate the fractional distribution of those individual material types according to the type of building construction. Although we have assumed distributions of each material component for the purposes of estimating a composite density for each of the two aggregated materials categories, additional research would be needed to validate the distributions shown in Table 3-11.

3.5 Additional Correlations Needed for Certain WME Structure Types

A complicating factor with the methodology outlined thus far is that the majority of the input parameters for the WME structure types are not total building square footage. Only the single-family residence structure type has square footage as the sole input parameter, while offices and schools have square footage as an optional input parameter.

To utilize the debris factors based on the HAZUS-MH data and developed according to the methodology outlined in previous sections, an additional correlation needed to be developed between the building square footage and the WME input parameters. The required correlations between current WME input parameters and structure square footage are shown in Table 3-14 below.

Table 3-14. WME Input Parameters Requiring Correlations to Structure Square Footage

WME Structure Type	Input Parameter
Hospitals	Number of Beds
Hotels	Number of Standard Guest Rooms Number of Suites Number of Restaurant Seats
Shopping Malls	Gross Leasable Area (GLA)
Movie Theaters	Number of Screens Number of Seats
Schools	Number of Students
Offices	Number of Occupants

3.6 Correlating WME Input Parameters to Structure Square Footage

3.6.1.1 Hospitals

During the early development of the WME, a single site visit was performed to develop waste estimates and waste factors for hospitals. For the purposes of developing this methodology, additional research was performed to identify a design correlation for the number of hospital beds and total hospital square footage. A design correlation between number of beds and hospital square footage that seemed suitable for our purposes was located on the University of California, San Francisco (UCSF) Campus Planning website[35].

$$SF_{hospital} = (\text{Number of Beds})(2{,}100\ ft^2/bed) \qquad \textbf{(Eq. 3-2)}$$

3.6.1.2 Hotels

Based on one of the two site visits by ERG, the data collected from two hotels was utilized to calculate the necessary correlations between square footage and the four input parameters for hotels. Based on the data obtained for each hotel, total square footage values were determined for all guestrooms, suites, and restaurant space. These values are found in Table 3-15.

Table 3-15. Available Hotel Data

Hotel	**Number of Guest Rooms** (rooms/hotel)	**Number of Suites** (rooms/hotel)	**Total Room Square Footage** (ft^2/hotel)	**Number of Restaurant Seats** (seats/hotel)	**Total Restaurant Square Footage** (ft^2/hotel)
A	123	0	93,441	48	2,998
B	322	8	163,592	548	101,614

For Hotel B, the total guest room square footage includes the floor area of the eight suites. The Total Guest Room Square Footage was plotted against the sum of the number of guest rooms and number of suites and a regression analysis was performed that resulted in the following two regression equations:

$$SF_{hotel\text{-}guest\ rooms} = (\text{Number of Standard Guest Rooms})(528\ ft^2/room) \qquad \textbf{(Eq. 3-3)}$$

$$SF_{hotel\text{-}seats} = (\text{Number of Restaurant Seats})(184\ ft^2/seat) \qquad \textbf{(Eq. 3-4)}$$

Since we did not have information on the square footage of all suites for Hotel B, the number of suites was included in the total number of standard guest rooms in the regression analysis, and we therefore assumed that Eq. 3-2 above can also be used to reasonably estimate the square footage of the total of all suites.

$$SF_{hotel\text{-}suites} = (\text{Number of Suites})(528\ ft^2/suite) \qquad \textbf{(Eq. 3-5)}$$

If multiple inputs for a hotel are entered, then the square footage estimates for each input parameter are additive, resulting in a total estimated square footage value for the hotel.

[35] http://campusplanning.ucsf.edu/pdf/MTZionPlan-Guidelines.pdf, Accessed July 2, 2009.

3.6.1.3 Shopping Malls

ERG visited and inventoried a 969,000 ft^2 GLA suburban shopping mall. Based on data collected during the site visit and through information submitted by the mall owner, the square footage of the mall that is comprised of non-leasable area was determined. Non-leasable spaces included hallways, atria, management offices, and food court seating space. ERG estimated that the non-leasable floor space accounted for approximately 8.6% of the GLA. Therefore, for shopping malls, the GLA can be correlated to total mall square footage according to Equation 3-5:

$$SF_{\text{shopping mall}} = \frac{\text{Gross Leasable Area (GLA)}}{0.9142} \qquad \textbf{(Eq. 3-6)}$$

3.6.1.4 Movie Theaters

Correlations were developed for both number of seats to movie theater square footage (Figure 3-1) and number of screens to theater square footage (Figure 3-2).

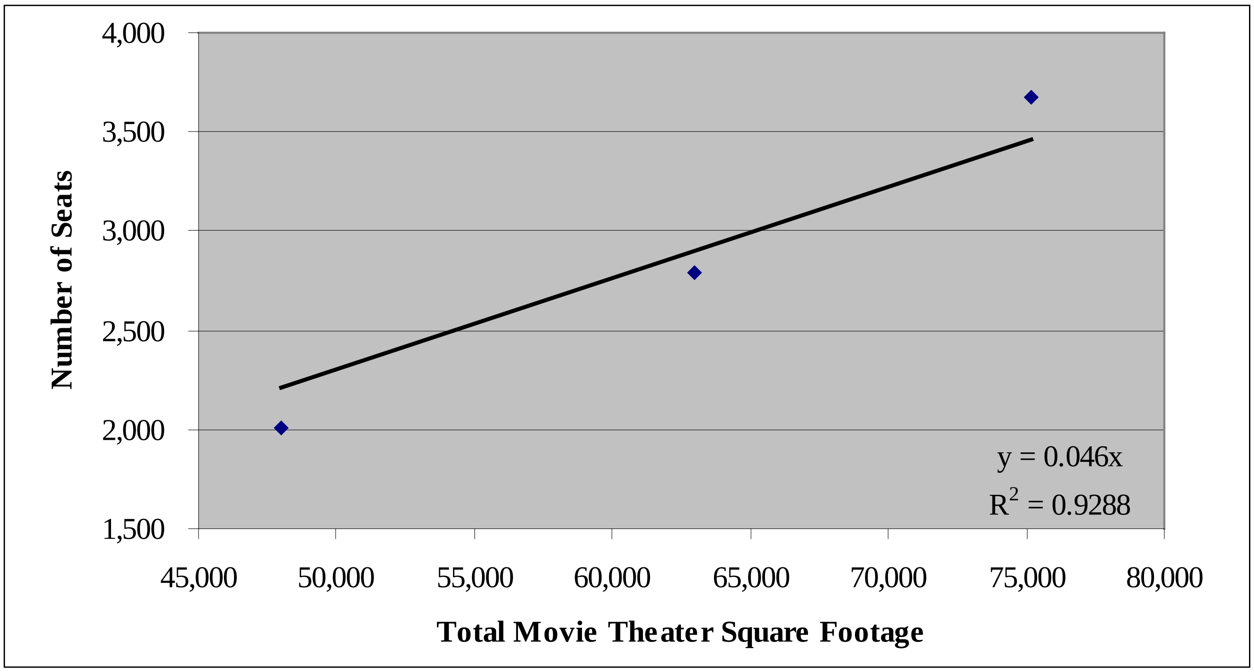

Figure 3-1. Movie Theater Seats as a Function of Total Square Footage

A regression analysis results in the following equation:

$$\text{Seats per Square Foot} = (0.046)\ (\text{Total Theater Square Footage}) \qquad \textbf{(Eq. 3-7)}$$

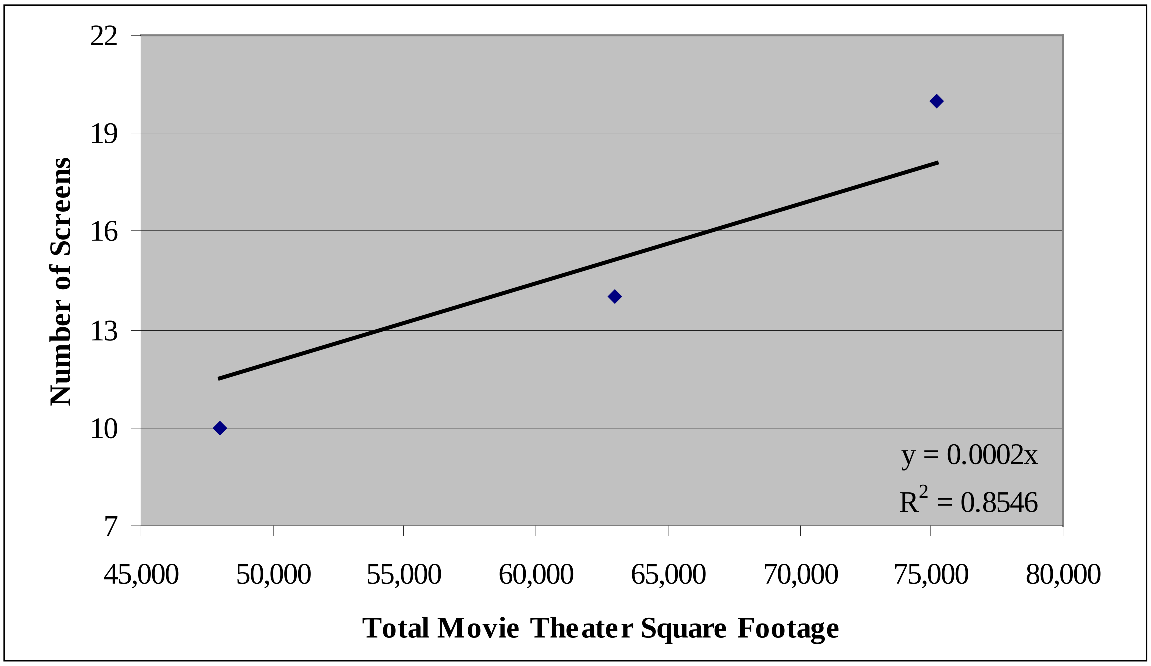

Figure 3-2. Movie Theater Screens as a Function of Total Square Footage

A regression analysis results in the following equation:

Screens per Square Foot = (2.0E-04)(Total Movie Theater Square Footage) **(Eq. 3-8)**

Building replacement cost models are used in HAZUS-MH[36]. These data are based on industry-standard cost-estimation models published in RS Means Square Foot Costs (RS Means, 2002) and are based on typical square footages for each type of building found in HAZUS-MH. Using the RS Means value of 12,000 ft^2 for an average size movie theater with Equations 3-6 and 3-7, we calculated an average of 552 seats and two screens for a 12,000 ft^2 theater. From those results, we then developed the following equations:

$SF_{\text{movie theater}}$ = (Number of Screens) (6,000 ft^2/screen) **(Eq. 3-9)**

$SF_{\text{movie theater}}$ = (Number of Seats) (22 ft^2/seat) **(Eq. 3-10)**

3.6.1.5 Schools

ERG visited an elementary school, a middle school, and a high school. Based on data collected from these three schools, we developed factors for the square footage of each school per student. We then developed correlation equations for the school square footage based on the number of students.

$SF_{\text{elementary school}}$ = (Number of Students) (150 ft^2/student) **(Eq. 3-11)**

36 See HAZUS-MH MR4 Earthquake Technical Manual, p. 3-18.

$$SF_{\text{middle school}} = (\text{Number of Students})\ (194\ \text{ft}^2/\text{student}) \quad \textbf{(Eq. 3-12)}$$

$$SF_{\text{high school}} = (\text{Number of Students})\ (201\ \text{ft}^2/\text{student}) \quad \textbf{(Eq. 3-13)}$$

Table 3-16. Summary of Correlation Equations

WME Structure Type	Input Parameter/Structure Square Footage Correlation Equation	Equation Number
Hospital	SF_{hospital} = (Number of Beds)(2,100)	3.2
Hotel	$SF_{\text{hotel-guest rooms}}$ = (Number of Standard Guest Rooms)(528)	3.3
	$SF_{\text{hotel-seats}}$ = (Number of Restaurant Seats)(184)	3.4
	$SF_{\text{hotel-suites}}$ = (Number of Suites)(528)	3.5
Shopping Mall	$SF_{\text{shopping mall}} = \frac{\text{Gross Leasable Area (GLA)}}{0.9142}$	3.6
Movie Theater	$SF_{\text{movie theater}}$ = (Number of Screens)(6,000)	3.9
	$SF_{\text{movie theater}}$ = (Number of Seats)(22)	3.10
Schools	$SF_{\text{elementary school}}$ = (Number of Students)(150)	3.11
	$SF_{\text{middle school}}$ = (Number of Students)(194)	3.12
	$SF_{\text{high school}}$ = (Number of Students)(201)	3.13

4. DEFAULT PARAMETERS AND PARAMETER VALUES

This section discusses the methodology for developing default structure input parameter values for the WME. The WME allows users to calculate potential waste amounts for more than one structure type at a time with minimal inputs. The calculations are based on pre-populated default input parameter values that can be modified by the user. By using default parameter values, users can generate waste estimates quickly by entering only the number of structures. Default parameters can be viewed and modified by users if desired.

The methodology presented in this section for estimating the mass and volume of building structural materials is based almost entirely on RS Means Square Foot Costs data used by the Federal Emergency Management Agency (FEMA) for use in the FEMA-developed HAZUS-MH program for estimating potential losses from natural disasters[37]. Unless otherwise noted or referenced in this section, all data used in the development of this methodology were taken from the HAZUS-MH technical and user manuals and supplemented with data collected by ERG during site visits conducted during the early development of the tool.

During the development of this methodology, it was necessary to supplement the HAZUS-MH data to enable their use in the WME. The supplemental data consisted primarily of data obtained by ERG during the initial development of the structure-specific WMEs and the building structural materials estimation methodology. Additional secondary data sources were identified and used in this methodology where it was necessary to fill remaining data gaps.

Table 4-2 summarizes the default parameter values for each WME structure type and Table 4-3 summarizes the various correlations used or developed in conjunction with the methodology outlined in this section.

4.1 Methodology

The majority of the default parameter values are based on building replacement cost models used in FEMA's HAZUS-MH Multi-Hazard Loss Estimation Program[38]. The data are based on industry-standard cost-estimation models published in RS Means Square Foot Costs (RS Means, 2002) and are based on typical square footages for each type of building. Default parameter values for those WME structures that have square footage as an input parameter utilize the typical square footage data used in the RS Means valuation models and found in HAZUS-MH. For structures that have input parameters in addition to or other than square footage, additional equations and factors were developed to correlate the default RS Means (2002) square footage to a particular input parameter. Additional research was conducted to determine a default square footage value for single-family residences and shopping malls. The default RS Means values for the remaining WME structure types can be found in Table 4-1.

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[37] Federal Emergency Management Agency, *HAZUS-MH Multi-Hazard Loss Estimation Software*, Version 1.3 (September 2007) and Version 1.4 (August 2009). http://www.fema.gov/plan/prevent/hazus/ and http://www.fema.gov/plan/prevent/hazus/hz_manuals.shtm. The website and URL are not valid as of July 31, 2015. At the time this website was referenced, it was a valid URL and this reference remains the source of the information or data currently used in the WME.

[38] See HAZUS-MH MR4 Earthquake Technical Manual, p. 3-18.

Table 4-1. Selected HAZUS-MH Default Full Replacement Cost Models (RS Means, 2002)

HAZUS-MH SOC	HAZUS-MH SOC Description	Sub-Category	RS Means Model Description	RS Means Model Number
RES4	Temporary Lodging	Hotel, medium	Hotel, 4-7 st., 135,000 SF	M.350
		Hotel, large	Hotel, 8-24 st., 450,000 SF	M.360
		Motel, small	Motel, 1 st., 8,000 SF	M.420
		Motel, medium	Motel, 2-3 st., 49,000 SF	M.430
COM4	Professional/ Technical/Business Services	Office, small	Office, 2-4 st., 20,000 SF	M.460
		Office, medium	Office, 5-10 st., 80,000 SF	M.470
		Office, large	Office, 11-20 st., 260,000 SF	M.480
COM6	Hospital	Hospital, medium	Hospital, 2-3 st., 55,000 SF	M.330
		Hospital, large	Hospital, 4-8 st., 200,000 SF	M.340
COM9	Theaters	Movie Theater	Movie Theater, 12,000 SF	M.440
EDU1	Schools/Libraries	Elementary School	School, Elementary, 45,000 SF	M.560
		Jr. High School	School, Jr. High, 110,000 SF	M.570
		High School	School, High, 130,000 SF	M.580

Source: HAZUS-MH MR4 Earthquake Technical Manual, Table 3.6.

Some of the structure types in the WME have input parameters that do not include the square footage of the structure, including hospitals, hotels, and movie theaters. To utilize the RS Means/HAZUS default square footage values for those three structure types, correlations were needed between the input parameter and the structure square footage. For hospitals and movie theaters, these correlations were developed during the development of the methodology to estimate building structural materials. The detailed development of these correlations is discussed in Sections 3.5 and 3.6. For hotels, data obtained from site visits conducted during the initial development of the WME were used to develop additional factors needed to correlate the default RS Means square footage to the structure input parameter.

The remaining structure types (offices, schools, single-family residences, and shopping malls) include square footage as an input parameter. However, offices and schools also allow users to specify the number of occupants and number of students, respectively. RS Means default square footage values were available for offices and schools, but additional correlations were needed to develop default values for number of occupants and number of students based on the structure square footage. As with hotels, data obtained from site visits conducted during the initial development of the WME were used to develop additional factors needed to correlate the default RS Means square footage to the structure input parameter.

For single-family residences, a single RS Means default square footage value was not readily available and additional research was conducted to determine a default value. Additional research was also conducted for shopping malls, as the input parameter is gross leasable area (GLA) and not the total mall square footage. Information obtained during a site visit to a shopping mall was not used as it represents only a single data point and was insufficient for the purposes of developing a reasonable default value for GLA.

Details and additional descriptions of the default parameters developed for each WME structure type are discussed below.

4.2 Hospitals

Estimates are based on the number of beds in the hospital. Research was performed to identify a design correlation for the number of hospital beds and total hospital square footage. A design correlation of 2,100 ft^2/bed (4.76E-04 beds/ft^2) was located on the UCSF Campus Planning website[39]. Using the design correlation and the default RS Means average square footage values for a medium and large hospital, the following default numbers of beds can be calculated:

Hospital, Medium

$$\text{Default Beds} = \text{Default SF} \times 4.76\text{E-}04\ (\text{beds/ft}^2) = 55{,}000 \times 4.76\text{E-}04 = \underline{26\text{ beds}} \qquad \textbf{(Eq. 4-1)}$$

Hospital, Large

$$\text{Default Beds} = \text{Default SF} \times 4.76\text{E-}04\ (\text{beds/ft}^2) = 200{,}000 \times 4.76\text{E-}04 = \underline{95\text{ beds}} \qquad \textbf{(Eq. 4-2)}$$

4.3 Hotels

The current WME factors for hotels were generated based on site visits to two hotels, information from and discussions with Marriott International management personnel, partial hotel inventories, and weights and dimensions of items from the American Hotel Register catalog. At each site visited, an inventory was conducted to account for all furniture, electronic equipment, fixtures, and other items. Only one guest room of each room type (e.g., studio suite, one-bedroom suite) was inventoried, because all rooms of each type are identical. The quantity of duct work, ventilation systems, drywall, and other building materials was estimated by reviewing the structure's floor plans.

Based on the site visit to the hotel with 322 standard guestrooms, a factor was developed to estimate the number of standard guest rooms per square foot of the hotel (1.00E-03 guest rooms/ft^2). Additional factors based on the total number of standard guestrooms were developed to estimate the number of suites (2.48E-02 suites/guest room), square feet of conference space

[39] http://campusplanning.ucsf.edu/pdf/MTZionPlan-Guidelines.pdf, Accessed July 2, 2009.

(101 ft^2/guest room), and number of restaurant seats (1.70 seats/guest room). Using the RS Means model square footage for a medium and large hotel and a medium motel (representing a “small” hotel), the standard guest rooms per square foot factor was applied to each hotel size and default numbers of standard guest rooms were developed. Based on the number of standard guest rooms, the additional factors for number of suites, square feet of conference space, and number of restaurant seats were then applied to generate default values for those three parameters.

Hotel, Small

Default Number of Guest Rooms = Default SF × 1.00E-03 (guest rooms/ft^2)
= 49,000 × 1.00E-03 = <u>49 guest rooms</u>

Default Number of Suites = Default Number of Guest Rooms
× 2.48E-02 (suites/guest room) = 49 × 2.48E-02 = <u>1 suite</u>

Default Square Footage of Conference Space = Default Number of Guest Rooms × 101 (ft^2 conference space/guest room) = 49 × 101 = <u>4961 ft^2</u>

Default Number of Restaurant Seats = Default Number of Guest Rooms × 1.70 (seats/guest room) = 49 × 1.70 = <u>84 seats</u>

Hotel, Medium

Default Number of Guest Rooms = Default SF × 1.00E-03 (guest rooms/ft^2)
= 135,000 × 1.00E-03 = <u>135 guest rooms</u>

Default Number of Suites = Default Number of Guest Rooms × 2.48E-02 (suites/guest room)
= 135 × 2.48E-02 = <u>3 suites</u>

Default Square Footage of Conference Space = Default Number of Guest Rooms × 101 (ft^2 conference space/guest room) = 135 × 101 = <u>13,668 ft^2</u>

Default Number of Restaurant Seats = Default Number of Guest Rooms × 1.70 (seats/guest room) = 135 × 1.70 = <u>230 seats</u>

Hotel, Large

Default Number of Guest Rooms = Default SF × 1.00E-03 (guest rooms/ft^2)
= 450,000 × 1.00E-03 = <u>451 guest rooms</u>

Default Number of Suites = Default Number of Guest Rooms × 2.48E-02 (suites/guest room)
= 451 × 2.48E-02 = <u>11 suites</u>

Default Square Footage of Conference Space = Default Number of Guest Rooms × 101 (ft^2 conference space/guest room) = 451 × 101 = <u>45,561 ft^2</u>

Default Number of Restaurant Seats = Default Number of Guest Rooms × 1.70 (seats/guest room) = 451 × 1.70 = 768 seats

4.4 Movie Theaters

Similar to hotels, offices, and schools, existing site visit information was used to develop factors for the number of seats per square foot of movie theater. Two input parameters are available for movie theaters (number of seats and number of screens). As discussed in Section 3, based on existing data collected for the WME, factors were developed for the number of seats per theater square foot and number of screens per square foot for three movie theaters. These factors were plotted against the movie theater square footage and a regression equation was developed for the number of seats per square foot and screens per square foot as a function of total square footage. The RS Means model square footage for a theater was then used with the equations to develop a default number of seats and a default number of screens (see Structural Materials memo).

Movie Theater

Default Seats = Default SF × 0.046 (seats/ft^2) =
12,000 × 0.046 = 552 seats

Default Screens = Default SF × 2.0E-04 (screens/ft^2) =
12,000 × 2.0E-04 = 2 screens

4.5 Offices

A similar approach was used to develop default parameter values for offices. Factors were developed to estimate the number of occupants per square foot for the individual walled offices and cubicle office portions of a surveyed commercial office building. The R.S. Means model square footage for a small, medium, and large office building were each multiplied by the fraction of the surveyed building square footage consisting of individual walled offices and cubicle offices to determine the default square footage values for the individual walled and cubicle portions of a small, medium, and large office buildings. Each of those default square footage values were then multiplied by the number of occupants per square foot for the respective office configuration to determine the default number of occupants for individual walled office spaces and cubicle office spaces.

Office, Small

Individual Walled:

Default Occupants = Default SF × Average Occupancy Density (occupants/ft^2)
= 5,000 × 1.59E-03 = 8 occupants

Cubicles:

Default Occupants = Default SF × Average Occupancy Density (occupants/ft^2)
= 15,000 × 1.90E-03 = 29 occupants

Office, Medium

Individual Walled:

Default Occupants = Default SF × Average Occupancy Density (occupants/ft^2)
= 20,000 × 1.59E-03 = 32 occupants

Cubicles:

Default Occupants = Default SF × Average Occupancy Density (occupants/ft^2)
= 60,000 × 1.90E-03 = 115 occupants

Office, Large

Individual Walled:

Default Occupants = Default SF × Average Occupancy Density (occupants/ft^2)
= 65,000 × 1.59E-03 = 104 occupants

Cubicles:

Default Occupants = Default SF × Average Occupancy Density (occupants/ft^2)
= 195,000 × 1.90E-03 = 372 occupants

4.6 Schools

Similar to hotels and offices, existing site visit information was used to develop factors for the number of students per square foot of school. These factors were developed for elementary, middle, and high schools and are 6.68E-03, 5.16E-03, and 4.97E-03 students/ft^2, respectively. Using the RS Means model square footage for an elementary, middle, and high school, the number of students per square foot factors were applied to each school type and default numbers of students were developed.

School, Elementary

Default Students = Default SF × Student Density (students/ft^2)
= 45,000 × 6.68E-03 = 301 students

School, Middle

Default Students = Default SF × Student Density (students/ft^2)
= 110,000 × 5.16E-03 = 567 students

School, High

Default Students = Default SF × Student Density (students/ft^2)
= 130,000 × 4.97E-03 = 646 students

4.7 Single-Family Residences

The default parameter value for single-family residences utilizes a representative value for the square footage of the residence. Data obtained from the U.S. Census Bureau[40] for the average square footage of single-family residences sold in the United States in 2007 was used as the basis for the default parameter. In 2007, the average single-family home sold in the U.S. was 2,479 ft^2. Therefore, a default parameter value of 2,500 ft^2 is used.

4.8 Shopping Malls

Estimates are based on the gross leasable area (GLA) of the shopping mall rather than total square footage. GLA is the most common metric in the industry and includes all areas that may be leased to tenants. GLA does not include mall management offices, janitorial storage, loading docks, hallways, kiosks, public restrooms, food court seating, and other areas not associated with a specific store. The estimates assume 100% occupancy of the GLA.

Because different types of stores (e.g., furniture, apparel, and electronics) will carry different merchandise, the tool currently allows the user to model the breakdown of stores by GLA. Default percentages for shopping malls are included based on U.S. shopping mall averages provided by the ICSC. The percentages are based on GLA, not the total number of stores in one category versus another. The percent of the total GLA associated with each store type may be modified by the user to properly model the affected structure.

The GLA of the mall is used as the default parameter value for shopping malls in addition to the default percentages that model representative store types that are already available in the WME. Square footage data for the fourteen largest enclosed shopping malls in the U.S.[41] indicates an average GLA of 2,516,529 ft^2. Based on these data and best engineering judgment, default parameter values of 250,000 ft^2, 500,000 ft^2, and 1,000,000 ft^2 for shopping malls were determined to be likely to be representative of small, medium, and large malls, respectively.

Table 4-2. Summary of WME Default Parameters and Values

Structure Type	Default Parameter	Default Parameter Value		
Hospital		*Medium*	*Large*	
	Number of beds	26	95	
Hotel		*Small*	*Medium*	*Large*
	Number of standard guest rooms Number of suite guest rooms Square feet of conference rooms Number of restaurant seats	49 rooms 1 suite 4,961 ft^2 84 seats	135 rooms 3 suites 13,668 ft^2 230 seats	451 rooms 11 suites 45,561 ft^2 768 seats
Office	*Individual Walled:*	*Small*	*Medium*	*Large*

40 http://www.census.gov/const/C25Ann/soldmedavgsf.pdf.

41 *Largest Shopping Malls in the United States*. American Studies at East Connecticut State University, Shopping Mall and Shopping Center Studies. http://www.easternct.edu/depts/amerst/MallsLarge.htm.

Table 4-2. Summary of WME Default Parameters and Values

Structure Type	Default Parameter	Default Parameter Value		
	Total square footage Number of occupants	5,000 ft^2 8 occupants	20,000 ft^2 32 occupants	65,000 ft^2 104 occupants
		Small	*Medium*	*Large*
	Cubicles: Total square footage Number of occupants	15,000 ft^2 29 occupants	60,000 ft^2 115 occupants	195,000 ft^2 372 occupants
Single-Family Residence	Average square footage of affected residences	2,500 ft^2		
Elementary School	Total square footage Number of students	45,000 ft^2 301 students		
Middle School	Total square footage Number of students	110,000 ft^2 567 students		
High School	Total square footage Number of students	130,000 ft^2 646 students		
Shopping Mall		*Small*	*Medium*	*Large*
	Gross leasable area (GLA)	250,000 ft^2	500,000 ft^2	1,000,000 ft^2
Movie Theater	Number of seats	552 seats 2 screens		

Table 4-3. Summary of WME Correlations Between Structure Square Footage and Input Parameter(s)

Structure Type	Factor/Equation
Hospital	4.76E-04 beds/ft^2
Hotel	1.00E-03 guest rooms/ft^2 2.48E-02 suites/guest room 101 ft^2/guest room 1.70 seats/guest room
Office	Individual Walled: 1.59E-03 occupants/ft^2 Cubicles: 1.90E-03 occupants/ft^2
Elementary School	6.68E-03 students/ft^2
Middle School	5.16E-03 students/ft^2
High School	4.97E-03 students/ft^2
Movie Theater	0.046 seats/ft^2 2.00E-04 screens/ft^2

5. OPEN SPACE

The WME includes functionality for users to estimate the amount of waste that may result from decontamination and/or remediation activities. Open space is any area that is not otherwise occupied by one or more buildings or vehicles. Examples of open spaces include parking lots, sidewalks, parks, greenways, roadways, and plazas. For the purposes of the WME, bodies of water (lakes, rivers, streams, etc.) can be included as open space, but waste estimates resulting from removal or remediation of these features are currently not available in the WME. Additionally, the WME does not currently estimate vehicles or vehicle counts that might be present in or on parking lots or roadways. Because of the wide variety of items and materials that can be found in large open space areas across the U.S., the open space estimation feature of the WME provides only mass and volume estimates of soil, vegetation, asphalt, and concrete.

5.1 Methodology

The amount of waste estimated for each of the four waste categories above is dependent entirely upon the size of the affected area, the percentage of the affected area that is open space, and the quantity (or depth) of materials removed from the ground surface as a result of decontamination and/or remediation activities. Users can model an entire area based on a single set of characteristics or model specific parcels to reflect significant differences within an affected area of open space.

Inputs required to generate an open space estimate are:

- The total affected area, in square miles;
- The percentage of the total affected area that is comprised of open space;
- The percentage of open space that is comprised of soil, vegetation, asphalt, and concrete;
- The depth of removal for each surface material.

Soil includes any area covered by grass, vegetation, or other landscaping and that is not covered by asphalt, concrete, or another improved surface type. The percentage of vegetation in an affected area can, and will, overlap with the percentage of soil. For example, a city park with an area of one square mile may consist of 70% soil, 5% water, 15% asphalt, and 10% concrete. The same square mile may contain various types of vegetation (trees, shrubs, etc.) that make up approximately 60% of the total park area, or 0.6 square miles.

Depending upon the nature of the incident, different decontamination and/or remediation strategies may be employed to decontaminate soils, asphalt, and concrete surfaces. Some of those strategies may include removing only the uppermost layers of the surface, deeper excavation, or complete removal. For soil, asphalt, and concrete, users can enter an estimate of how much of the material will be removed from the surface. For decontamination of some materials, this may involve removing only an inch or two from the surface. Soils may require deeper excavation (e.g., 15 inches) to remove contamination, and to completely remove asphalt from a parking lot, for example, several inches of asphalt may be involved.

5.2 Waste Category Estimates

To generate waste estimates for open spaces, the tool performs a series of multiplication calculations on each input parameter value. Volumetric waste estimates for asphalt, concrete, and soil are generated according to the following equation:

$$E_{wc\text{-}i} = (TAA)(OSP/100)(PM_i/100)(4{,}014{,}489{,}600)(DM_i)(2.14E\text{-}05) \qquad \textbf{(Eq. 5-1)}$$

where:

$E_{wc\text{-}i}$	=	Estimate of waste for waste category *i*, yd^3
TAA	=	Total affected area, square miles (mi^2)
OSP	=	Percent of total affected area that is open space
PM_i	=	Percent of open space that is comprised of material *i*
DMi	=	Depth of material *i* that is removed, inches
4,014,489,600	=	Conversion factor for mi^2 to in^2
2.14E-05	=	Conversion factor for cubic inches (in^3) to yd^3

The soil, asphalt, and concrete densities used by the WME to generate mass-based waste estimates for those materials are listed in Table 5-1.

Table 5-1. Summary of Open Space Material Densities

Material	Density (kg/m^3)
Soil	1,521[a]
Asphalt	819[b]
Concrete	2,160[c]

[a] Source: Perry's Chemical Engineer's Handbook, 7th Ed., 1997, Table 2-118. Earth, dry, packed: 95 lb/ft^3.

[b] Source: "Standard Volume-to-Weight Conversion Factors." http://www.epa.gov/osw/partnerships/wastewise/pubs/conversions.pdf

[c] Source: Perry's Chemical Engineer's Handbook, 7th Ed., 1997, Table 2-118. Portland cement: 94-135 lb/ft^3.

Volumetric waste estimates for vegetation are generated according to the following equation:

$$E_{wc\text{-}i} = (TAA)(OSP/100)(PV/100)(640)(16{,}117) \qquad \textbf{(Eq. 5-2)}$$

where:

$E_{wc\text{-}i}$	=	Estimate of waste for waste category *i*, cubic yards (yd^3)
TAA	=	Total affected area, mi^2
OSP	=	Percent of total affected area that is open space
PV	=	Percent of open space that is comprised of vegetation
640	=	Conversion factor for mi^2 to acres

16,117 = Volumetric vegetation debris factor, yd^3/acre[42]

To obtain mass-based waste estimates for vegetation, the volumetric waste result is multiplied by 4.[43]

[42] FEMA 325, p.60. 1 acre of debris at 3.33 yards high equals 16,117 yd^3

[43] FEMA 325; p.60. For mixed debris, 4 yd^3 equals 1 ton.

Appendix A
Calculated Representative Mapping Scheme – Model Building Types (MBTs) to Specific Occupancy Classes (SOCs) for WME Structure Types

Table A-1. Calculated Representative Mapping Scheme – Fraction of Model Building Types (MBTs) That Comprise Each Specific Occupancy Class (SOC) for WME Structure Types[44]

MBT[45]	COM1	COM4	COM6	COM9	EDU1	RES1	RES4
W1	0.00	0.00	0.00	0.00	0.07	0.85	0.50
W2	0.25	0.31	0.09	0.03	0.08	0.00	0.00
S1L	0.08	0.04	0.06	0.13	0.09	0.00	0.02
S1M	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S1H	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S2L	0.05	0.04	0.05	0.11	0.11	0.00	0.01
S2M	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S2H	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S3	0.07	0.07	0.02	0.10	0.00	0.00	0.01
S4L	0.03	0.04	0.03	0.05	0.02	0.00	0.01
S4M	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S4H	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S5L	0.07	0.06	0.05	0.09	0.03	0.00	0.01
S5M	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S5H	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C1L	0.02	0.02	0.06	0.04	0.04	0.00	0.03
C1M	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C1H	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C2L	0.06	0.07	0.15	0.10	0.09	0.00	0.05
C2M	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C2H	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C3L	0.00	0.00	0.02	0.01	0.01	0.00	0.00
C3M	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C3H	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PC1	0.07	0.05	0.20	0.13	0.02	0.00	0.01
PC2L	0.01	0.01	0.04	0.03	0.01	0.00	0.01
PC2M	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PC2H	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RM1L	0.06	0.06	0.07	0.06	0.11	0.00	0.06
RM1M	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RM2L	0.01	0.01	0.01	0.02	0.02	0.00	0.02
RM2M	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RM2H	0.00	0.00	0.00	0.00	0.00	0.00	0.00
URML	0.20	0.22	0.14	0.13	0.32	0.15	0.28
URMM	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MH	0.00	0.00	0.00	0.00	0.00	0.00	0.00

[44] See Table 3-13 for the correlation of WME structure types to HAZUS-MH SOCs.

[45] Model Building Type definitions and descriptions are provided in Appendix B. The sum of fractions for each SOC equals 1. None of the seven SOCs is composed of all 35 MBTs.

Appendix B
Model Building Type (MBT) Descriptions

The following MBT descriptions were taken directly from the HAZUS-MH MR4 Earthquake Model *Technical Manual*, pages 5-8 to 5-12.

B.1 Wood, Light Frame (W1)

These are typically single-family or small, multiple-family dwellings of not more than 5,000 square feet of floor area. The essential structural feature of these buildings is repetitive framing by wood rafters or joists on wood stud walls. Loads are light and spans are small. These buildings may have relatively heavy masonry chimneys and may be partially or fully covered with masonry veneer. Most of these buildings, especially the single-family residences, are not engineered but constructed in accordance with “conventional construction” provisions of building codes. Hence, they usually have the components of a lateral-force-resisting system even though it may be incomplete. Lateral loads are transferred by diaphragms to shear walls. The diaphragms are roof panels and floors that may be sheathed with sawn lumber, plywood, or fiberboard sheathing. Shear walls are sheathed with boards, stucco, plaster, plywood, gypsum board, particle board, or fiberboard, or interior partition walls sheathed with plaster or gypsum board.

B.2 Wood, Greater than 5,000 Sq. Ft. (W2)

These buildings are typically commercial or industrial buildings, or multi-family residential buildings with a floor area greater than 5,000 square feet. These buildings include structural systems framed by beams or major horizontally spanning members over columns. These horizontal members may be glue-laminated (glu-lam) wood, solidsawn wood beams, or wood trusses, or steel beams or trusses. Lateral loads usually are resisted by wood diaphragms and exterior walls sheathed with plywood, stucco, plaster, or other paneling. The walls may have diagonal rod bracing. Large openings for stores and garages often require post-and-beam framing. Lateral load resistance on those lines may be achieved with steel rigid frames (moment frames) or diagonal bracing.

B.3 Steel Moment Frame (S1)

These buildings have a frame of steel columns and beams. In some cases, the beam column connections have very small moment resisting capacity but, in other cases, some of the beams and columns are fully developed as moment frames to resist lateral forces. Usually the structure is concealed on the outside by exterior nonstructural walls, which can be of almost any material (curtain walls, brick masonry, or precast concrete panels), and on the inside by ceilings and column furring. Diaphragms transfer lateral loads to moment-resisting frames. The diaphragms can be almost any material. The frames develop their stiffness by full or partial moment connections. The frames can be located almost anywhere in the building. Usually the columns have their strong directions oriented so that some columns act primarily in one direction while the others act in the other direction. Steel moment frame buildings are typically more flexible than shear wall buildings. This low stiffness can result in large interstory drifts that may lead to relatively greater nonstructural damage.

B.4 Steel Braced Frame (S2)

These buildings are similar to steel moment frame buildings except that the vertical components of the lateral-force-resisting system are braced frames rather than moment frames.

B.5 Steel Light Frame (S3)

These buildings are pre-engineered and prefabricated with transverse rigid frames. The roof and walls consist of lightweight panels, usually corrugated metal. The frames are designed for maximum efficiency, often with tapered beam and column sections built up of light steel plates. The frames are built in segments and assembled in the field with bolted joints. Lateral loads in the transverse direction are resisted by the rigid frames with loads distributed to them by diaphragm elements, typically rod-braced steel roof framing bays. Tension rod bracing typically resists loads in the longitudinal direction.

B.6 Steel Frame with Cast-In-Place Concrete Shear Walls (S4)

The shear walls in these buildings are cast-in-place concrete and may be bearing walls. The steel frame is designed for vertical loads only. Diaphragms of almost any material transfer lateral loads to the shear walls. The steel frame may provide a secondary lateralforce- resisting system depending on the stiffness of the frame and the moment capacity of the beam-column connections. In modern "dual" systems, the steel moment frames are designed to work together with the concrete shear walls.

B.7 Steel Frame with Unreinforced Masonry Infill Walls (S5)

This is one of the older types of buildings. The infill walls usually are offset from the exterior frame members, wrap around them, and present a smooth masonry exterior with no indication of the frame. Solidly infilled masonry panels, when they fully engage the surrounding frame members (i.e. lie in the same plane), may provide stiffness and lateral load resistance to the structure.

B.8 Reinforced Concrete Moment Resisting Frames (C1)

These buildings are similar to steel moment frame buildings except that the frames are reinforced concrete. There are a large variety of frame systems. Some older concrete frames may be proportioned and detailed such that brittle failure of the frame members can occur in earthquakes leading to partial or full collapse of the buildings. Modern frames in zones of high seismicity are proportioned and detailed for ductile behavior and are likely to undergo large deformations during an earthquake without brittle failure of frame members and collapse.

B.9 Concrete Shear Walls (C2)

The vertical components of the lateral-force-resisting system in these buildings are concrete shear walls that are usually bearing walls. In older buildings, the walls often are quite extensive and the wall stresses are low but reinforcing is light. In newer buildings, the shear walls often are limited in extent, generating concerns about boundary members and overturning forces.

B.10 Concrete Frame Buildings with Unreinforced Masonry Infill Walls (C3)

These buildings are similar to steel frame buildings with unreinforced masonry infill walls except that the frame is of reinforced concrete. In these buildings, the shear strength of the columns, after cracking of the infill, may limit the semi-ductile behavior of the system.

B.11 Precast Concrete Tilt-Up Walls (PC1)

These buildings have a wood or metal deck roof diaphragm, which often is very large, that distributes lateral forces to precast concrete shear walls. The walls are thin but relatively heavy while the roofs are relatively light. Older or non-seismic-code buildings often have inadequate connections for anchorage of the walls to the roof for out-of-plane forces, and the panel connections often are brittle. Tilt-up buildings usually are one or two stories in height. Walls can have numerous openings for doors and windows of such size that the wall looks more like a frame than a shear wall.

B.12 Precast Concrete Frames with Concrete Shear Walls (PC2)

These buildings contain floor and roof diaphragms typically composed of precast concrete elements with or without cast-in-place concrete topping slabs. Precast concrete girders and columns support the diaphragms. The girders often bear on column corbels. Closure strips between precast floor elements and beam-column joints usually are castin- place concrete. Welded steel inserts often are used to interconnect precast elements. Precast or cast-in-place concrete shear walls resist lateral loads. For buildings with precast frames and concrete shear walls to perform well, the details used to connect the structural elements must have sufficient strength and displacement capacity; however; in some cases, the connection details between the precast elements have negligible ductility.

B.13 Reinforced Masonry Bearing Walls with Wood or Metal Deck Diaphragms (RM1)

These buildings have perimeter bearing walls of reinforced brick or concrete-block masonry. These walls are the vertical elements in the lateral-force-resisting system. The floors and roofs are framed with wood joists and beams either with plywood or braced sheathing, the latter either straight or diagonally sheathed, or with steel beams with metal deck with or without concrete fill. Interior wood posts or steel columns support wood floor framing; steel columns support steel beams.

B.14 Reinforced Masonry Bearing Walls with Precast Concrete Diaphragms (RM2)

These buildings have bearing walls similar to those of reinforced masonry bearing wall structures with wood or metal deck diaphragms, but the roof and floors are composed of precast concrete elements such as planks or tee-beams and the precast roof and floor elements are supported on interior beams and columns of steel or concrete (cast-in-place or precast). The precast horizontal elements often have a cast-in-place topping.

B.15 Unreinforced Masonry Bearing Walls (URM)

These buildings include structural elements that vary depending on the building's age and, to a lesser extent, its geographic location. In buildings built before 1900, the majority of floor and roof construction consists of wood sheathing supported by wood framing. In large multistory buildings, the floors are cast-in-place concrete supported by the unreinforced masonry walls and/or steel or concrete interior framing. In unreinforced masonry constructed after 1950 (outside California) wood floors usually have plywood rather than board sheathing. In regions of lower seismicity, buildings of this type constructed more recently can include floor and roof framing that consists of metal deck and concrete fill supported by steel framing elements. The perimeter walls, and possibly some interior walls, are unreinforced masonry. The walls may or may not be anchored to the diaphragms. Ties between the walls and diaphragms are more common for the bearing walls than for walls that are parallel to the floor framing. Roof ties usually are less common and more erratically spaced than those at the floor levels. Interior partitions that interconnect the floors and roof can reduce diaphragm displacements.

B.16 Mobile Homes (MH)

These are prefabricated housing units that are trucked to the site and then placed on isolated piers, jack stands, or masonry block foundations (usually without any positive anchorage). Floors and roofs of mobile homes usually are constructed with plywood and outside surfaces are covered with sheet metal.

Appendix C
WME Numerical Results Display, Rounding, and Significant Figures

C.1 General Significant Figure (SigFig) Function Information

A legacy function originally developed for EPA wastewater regulation development was modified for use in the WME. Some adjustments were made to force very large numbers in scientific notation. The SigFig routine applies standard mathematical rules to values to return a specified number of significant figures appropriate for the analysis.

C.2 Steps for Significant Figure Formatting

This function is passed the number to be formatted and the number of significant figures requested and returns a formatted number with the appropriate number of significant figures.

Example: SigFigIt(1412.34, 3) returns 1,410

- If the input value is not numeric, the function returns an error (exits function).
- If the input value is less than 1 but greater than 0, the function formats the number in scientific notation, if applicable.

Example: myNumber = FormatNumber((myNumber *1000)/1000, 20)

- If the input value is in scientific notation, the numeric portion to the left of E is sent through sig fig routine, E etc. is added back on, and the number is returned (exits function).

Example: 5.92700000000001E+15 becomes 5.93E+15

- If the input value is not in scientific notation, the function checks to see if it is very large (>999999999). If so, the function formats the number in scientific notation and returns (exit function).
- If the input value is not very large (not > 999999999), the function captures the digits on the left of the decimal place, and the digits on the right of the decimal place (if any). The function notes the location of the decimal place and removes.
- If the total number of digits in the input value is less than the number of significant digits requested, the function returns the number as is (exits function).
- If the total number of digits to the left of the decimal place of the input value is greater than the number of significant figures requested, the function adds zeros after the last required significant figure.

Example: 1412.34 (to 3 significant figures) returns 1,410.

- Otherwise, if the total number of digits (including those to the right of the decimal place) of the input value is greater than the number of significant digits requested, the function rounds the last significant figure up using the next digit only.

Example: 1.2345 (to 3 significant figures) returns 1.23 (rather than 1.24).

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