

Final Report

**Conversion Factors for
Individual Material Types**

Submitted to

California Integrated Waste Management Board

by

CalRecovery
INCORPORATED

Tellus Institute

ACT...now

December 1991

NOTE: Legislation (SB 63, Strickland, Chapter 21, Statutes of 2009) signed into law by Gov. Arnold Schwarzenegger eliminated the California Integrated Waste Management Board (CIWMB) and its six-member governing board effective Dec. 31, 2009.

CIWMB programs and oversight responsibilities were retained and reorganized effective Jan. 1, 2010, and merged with the beverage container recycling program previously managed by the California Department of Conservation.

The new entity is known as the Department of Resources Recycling and Recovery (CalRecycle) and is part of the California Natural Resources Agency. It is no longer part of the California Environmental Protection Agency (Cal/EPA).

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INDIVIDUAL MATERIAL TYPES**

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CONVERSION FACTORS FOR INDIVIDUAL MATERIAL TYPES

PREFACE

The California Code of Regulations [Title 14, Division 7, Chapter 9, Article 6.1, Section 18722(f) (1) (A)] requires the California Integrated Waste Management Board to complete a study and compile a list of acceptable conversion factors for each specific solid waste type listed in section 18722(j) by January 1, 1992. The list of acceptable conversion factors will be used by jurisdictions (cities and counties) to convert quantities of solid waste to the units required in Article 6.1 of the Regulations.

Both the legislation and the regulations implementing the legislation mandate that the quantification be based on weight. One method for calculating waste quantities consists of using volume estimations and appropriate bulk densities to estimate weights of materials. Error of estimation is introduced into the procedure in several forms, including those associated with measuring the volume of materials and those associated with accurately determining and using appropriate bulk densities. The present study addresses the important issue of defining bulk densities for a variety of material types and mixtures of materials encountered in solid waste management systems in the state. The bulk densities reported herein can be used to convert volumetric data to weight data or visa versa, (i.e., the bulk densities serve as the basis for conversion factors between volume and weight). Important applications of the bulk densities and conversion factors relevant to the State's recycling legislation include estimating volumes or weights of disposed and of diverted materials and mixtures of materials in a variety of physical forms.

This document reports the results of the study for individual material types. Later reports under the same contract will report the results of in-vehicle and in-place landfill density studies.

INTRODUCTION

The study identified those material types and their physical forms that are encountered in solid waste systems in California or are reasonably likely to be encountered in California over the next ten years. The material types that were identified and studied included recyclable components (e.g., tin cans) as well as mixed solid wastes (e.g., residential solid waste). The methods of identification of the material types and forms included:

- an outside literature search
- in-house information
- a mail and follow-up survey of collectors and processors of recyclables
- a selective survey of haulers and processors of mixed solid waste, covering both public and private operations
- visual observation of material types at selected processing facilities (materials recovery facilities (MRFs), as well as mixed waste processing facilities)

DETERMINATION OF MATERIAL TYPES

Before conversion factors were determined, CalRecovery identified the material types that are typically collected and processed at solid waste facilities. The list of material types was developed by evaluating waste generation studies, by identifying the types of waste materials accepted by collection systems and solid waste facilities in California, and through discussions with CIWMB staff. A copy of the list can be found in Appendix A.

FORM OF MATERIAL TYPE

A material type may be found in more than one processed or unprocessed form (i.e., physical state). Examples include: loose newspaper vs. baled newspaper and whole vs. crushed glass. Depending upon market specifications and other variables, materials may be processed into one or more forms. For example, plastic containers may be granulated (i.e., size reduced) or baled. Each processed form has its own material density.

In order to determine the types of forms that may be found within the processed and unprocessed waste streams, a comprehensive literature search and mail survey was conducted. The literature search examined data from a number of sources. The mail survey asked processors, recycling firms, and others to identify the physical forms that they accept or create as a result of processing a material type. In order to assist those completing the survey, a partial list of potential forms was developed and included in the survey. This partial list is presented in Appendix B.

CONVERSION FACTORS FOR INDIVIDUAL MATERIAL TYPES AND FORMS

Literature Search

An exhaustive literature search was conducted to determine densities for material types identified for study (see Appendix A), as well as for other material types that appear or may appear within the solid waste management system in California. Data were gathered from in-house sources, private communications with processors and generators, and periodicals and other available literature. A database was created from this information. The search of resources identified the material type, physical form(s), density or conversion factor, and the reference.

Table 1 presents the results of the literature search. The data represented in the table comes from a wide range of in-state and out-of-state sources. In some cases, data of an unknown state of origin or of out-of-state origin are reported and selected as representative density of material types currently encountered or likely to be encountered in California in the next ten years. CalRecovery applied its judgement in all such cases as to the adequacy and appropriateness of the data to conditions in or to be encountered in California.

Mail Recycling Program Survey

The purpose of the mail survey was to supplement information collected in the literature search and field studies. One mail survey was sent to over 200 recycling programs. The programs included drop-off centers and end users located in California. Those contacted were asked to identify the material types handled, and forms and density of any of the materials that they handled. Based on the poor response and lack of substantive information, it was decided to conduct a second mail survey.

The second mail survey targeted 47 specific California facilities. Facilities surveyed included MRFs, processors (such as glass manufacturers), and paper mills. Contacted firms were asked to indicate the average weight and dimensions of the form (e.g., bale of newspaper), and density if known. For those firms that did not indicate the density, CalRecovery calculated the density (based on the information provided).

Table 2 presents the result of the surveys. The table includes various material forms that are encountered during collection and as a result of processing and handling of materials. The forms include baled, granulated, shredded, and pelletized. Specific methodology, including the survey forms and other pertinent information, may be found in Appendix C.

Field Studies

Field studies were conducted to expand and to supplement the results of the mail survey and of the literature search. The field studies examined a variety of material types and forms.

Two studies were conducted in San Rafael, California, during the third week of September 1991, one at the Marin Recycling and Resource Recovery Facilities (MRRRF) and one at American Soil Products. These facilities were selected because of their proximity to one another and for the substantial variety of material types processed at the facilities. The densities of a wide variety of recyclables were collected at the MRRRF, both as a consequence

Table 1. CRWMB Bulk Density Study - Literature Search and Phone Search

Material Type	Form	lb/cu yd	Special Notes	References
METAL				
Lead Scrap	whole	1603.84		Advanced Recycling Concord, MA
Copper Scrap	whole	1083.52		Advanced Recycling Concord, MA
YARD WASTE				
Compost, sludge		808.00		NJ Ag. Exp. 1982
Compost, yard waste		682.00		Portland, 1989
Compost, MSW		1400.00*	40-50% moisture content	Sumpter County, FL
		1000.00	40% moisture content	Big Sandy, TX
OTHER ORGANICS				
FOOD WASTE				
Produce Waste, mixed	loose	1443.00	mixed produce	Harrisford Brothers, ME
MANURE				
Broiler		756.00	22% water incl. bedding	NC State 1990
Hen		1796.00	no bedding	NC State 1990
Ricca Hen, fresh		1376.00	65.4% water	NESFI
Ricca Hen, aged		1406.00	70.4% water	NESFI
Turkey*		734.00	21-43% water incl. bedding	NESFI
Cattle		1628.00		Cornell 1989
Horse		1225.00	68.7% water	NESFI
TEXTILES				
Used Clothing	compacted	540.00	in low grade compactor	Garment District Boston, MA
OTHER WASTES				
INERT SOLIDS				
Asphalt Tar Roofing		2918.82	mixed felt-paper, tar & gravel	High Tech Roofing Wakefield, MA
Brick		3024.00	face bricks, packed whole	PJ Cronin, Inc. 1991
Concrete		3780.00	asphaltic	MA DPW, 1991
		4050.00	gravel or conglomerate	MA DPW, 1991
		3998.00	limestone w/cement	MA DPW, 1991
		3000.00	unspecified as received at LF	Texaco
Gravel		2565.00	loose, dry	MA DPW, 1991
Stone, crushed		2700.00	crushed	MA DPW, 1991
Soil, sandy loam		2100.00	loam, dry, excavated	MA DPW, 1991
Soil		2430.00	moist, excavated	MA DPW, 1991
Soil		2700.00	wet, excavated	MA DPW, 1991
Soil		3375.00	dense earth	MA DPW, 1991
Soil		2016.00	soft, loose mud	MA DPW, 1991
Soil		2565.00	packed	MA DPW, 1991
Contaminated Soil		2600.00	oil contamination	Texaco/Ventura City
Fiberglass Insulation		16.60	R11 - residential insulation	Corning, NY
SPECIAL WASTES				
Ash				
wood		1100.00	50% water, dep. on boiler	RCS, NH
incinerator		1350.00	50% water, trucked	Vicon, Pittsfield, MA
		1958.00	15% water, in-place	Vicon, Pittsfield, MA
other ash		1110.00	unspecified 'ashes'	Mass DPW
baghouse		610.00		Vicon, Pittsfield, MA

*Ranges reported; lb/cu yd is the average of the range.

Table 1. CIWMB Bulk Density Study - Literature Search and Phone Search (Continued)

Material Type	Form	lb/cu yd	Special Notes	References
Sludge				
dewatered sludge		1552.50	14.7% solids	U.S. EPA 1989
		1199.00	28.4% solids	NJ Ag. Exp. 1982
		1801.00	24% solids	NC State 1990
		1789.00	17% solids	Vesilind 1986
		1890.00	38% solids	Manfield, MA - WTP
chem fx		2025.00	55% solids	MA - DEP
industrial, papermill*		1425.00	34-38% solids	RCS, NH
industrial, apple waste		1411.00	40.7% solids	NESFI
Asbestos	semi- compacted	378.50	bags of assorted sizes w/ assorted types of asbestos	Environmental Mgt Systems Walton Systems; Dec-Tarr;
Asbestos		4000.00	loose	Sawyer Environ., ME
		4600.00	in-place	Sawyer Environ., ME
Compacted Cars	baled	1215.00		Prolerized, MA
Compacted Cars*	flattened	579.20		Prolerized, MA
Compacted Cars	compacted	450.00		CADA, CA
				Prolerized, MA
Shredder Fluff		800.00	incl. glass, dirt, etc	Prolerized, MA
Concrete*		2529.00	dep. on compaction, etc.	Dewar, 1988
Broken Concrete Waste		3000.00		Jetway, Boston, MA
Cement Kiln Dust		1404.00	100% solids, loose	Blue Circle, NY
Slag		2970.00	broken	Mass DPW
Slag		3868.00	solid	Mass DPW
Slag, screenings		2495.00		Mass DPW
Slag	crushed	1998.00		Mass DPW
Slag, furnace	granulated	1620.00		Mass DPW
Dead Animals				
turkeys	bulk	600.00		Poss. Brinton Co., Wimar, MN
large	whole	1150.00	avg. weight of each animal	U.C. Davis School of Vet Medicine
small	whole	20.00	avg. weight of each animal	CalRecovery
Household Haz. Waste				
antifreeze	liquid	1653.00	poured into drum	Burlington, VT DPW
latex paint	liquid	1836.00	poured into drum	Burlington, VT DPW
flammable liquids	liquid	1653.00	poured into drum	Burlington, VT DPW
enamel paint	liquid	1653.00	poured into drum	Burlington, VT DPW
aerosol cans		918.00	packed w/vermiculite in drums	Burlington, VT DPW
flammable liquids		550.00	packed w/vermiculite in drums	
waste oil		1524.94	avg over range of water	B&L Oil Corp., Newark, NJ
oxidizers		92.00	packed w/vermiculite in drums	Burlington, VT DPW
poisons		550.00	packed w/vermiculite in drums	Burlington, VT DPW
Transformers			All transformer values below are for individual transformers	
15 KVA		1008.00	individual transformer	Jet Line Disposal, NH
25 KVA		1096.00	individual transformer	Jet Line Disposal, NH
37.5 KVA		1254.00	individual transformer	Jet Line Disposal, NH
50 KVA		1326.00	individual transformer	Jet Line Disposal, NH
75 KVA		1385.00	individual transformer	Jet Line Disposal, NH
100 KVA		1798.00	individual transformer	Jet Line Disposal, NH
167 KVA		1828.00	individual transformer	Jet Line Disposal, NH
Street Sweepings*		1667.00	dep. on season, water cont.	Cambridge, MA
Septic Tank Pumpings		1855.56		Septic Services Haverhill, MA

*Ranges reported: lb/cu yd is the average of the range.

Table 1. CIWMB Bulk Density Study - Literature Search and Phone Search (Continued)

Material Type	Form	lb/cu yd	Special Notes	References
Chem Toilet Wastes		1655.56		Septic Services Haverhill, MA
Grease Trap Pumpings		1594.90		Septic Services Haverhill, MA
Medical Wastes		166.15	assorted sizes of bags and	National Waste Mgt. Inc.
Drilling Mud		2222.00	25% moisture	Charter Evap. Resource Recovery, Colusa, CA
Beet Pulp	loose	350.00		North Carolina Ag. 1990
Spert Barley	loose	450.00		North Carolina Ag. 1990
Corn Silage	loose	480.00		North Carolina Ag. 1990
Dried Corn Stalks	loose	30.00		North Carolina Ag. 1990
Rice Hulls	loose	220.00		North Carolina Ag. 1990
Straw	loose	60.00		North Carolina Ag. 1990
Wood Furniture*	whole	166.00	composites of manufacturers & sizes	Sears Catalog, 1991
Dryers*	whole	224.00	composites of manufacturers & sizes	Sears Catalog, 1991
Refrigerators/Freezer*	whole	196.00	composites of manufacturers & sizes	Sears Catalog, 1991
Washers*	whole	321.00	composites of manufacturers & sizes	Sears Catalog, 1991
Stoves/Ovens*	whole	300.00	composites of manufacturers & sizes	Sears Catalog, 1991
Dishwashers*	whole	234.00	composites of manufacturers & sizes	Sears Catalog, 1991
Televisions*	whole	343.00	composites of manufacturers & sizes	Sears Catalog, 1991
Stereo Equipment*	whole	783.00	composites of manufacturers & sizes	Sears Catalog, 1991
Stuffed Furniture*	whole	60.00	composites of manufacturers & sizes	Sears Catalog, 1991
Asphalt/pavement	crushed	1380.00		NJ Office of Recycling, 1990
Tires/Heavy Equipment	whole	316.00	bias ply tires, avg. weight of tire only	Caterpillar Handbook, 1982
Fines		2700.00		Cal/Recovery

*Ranges reported: lb/cu yd is the average of the range.

Table 1. Supplemental Reference List

CIWMB BULK DENSITY STUDY - DATA SOURCES-TELLUS INSTITUTE

Personal Communication:

Advanced Recycling, Concord N.H., 603-225-2267
B&L Oil Corporation, Newark, NJ, (201) 824-9527
Big Sandy, TX: Compost facility, 903-845-2261
Blue Circle: Dr. Don Henley, New York State, 518-756-8610
Burlington, VT DPW: Aaron Frank, Environmental Depot Coordinator, (802) 862-6404
CADA: California Automobile Dismantlers Assoc., CA, Jean Duncan, (916)-969-7050.
Cambridge, MA : Dept. of Public Works, Bill Frazier, 617-349-4847
Coming: Owens Coming, Lee Burlingame, Toledo, OH, 800-447-3759
Dec-Tam, Peter Lachorite, (508) 470-2860
Earthlife: Pennsylvania, 215-348-9288
Environmental Management Systems, Robert Lee, (508) 222-8272
Garment District: Garment District, Bruce Cohen, Cambridge, MA, (617) 876-1122.
High Tech Roofing, Wakefield, MA, (617) 246-0220
HRSD: Hampton Roads Sanitation District compost facility, Newport News, VA, 804-877-2975
Jetaway: Jetaway Waste Technologies, Boston, MA, Pat Cody, 617-541-4013
Jetline Disposal, Dover, NH, 603-749-5735
MA DEP: Paul Emond, Boston, MA, 617-292-5974
Mansfield, MA - WTP: Jerry St. Hilaire, Composting Supervisor 508-295-6096
Mass DPW: Massachusetts Department of Public Works, Wellesley, MA, Neil Mackay, (617) 235-6100
Medical Waste Disposal, Randolph, MA, Debbie Bornstein, (617) 963-4231
Oil Recovery Corporation, West Springfield, MA, (413) 737-2949
National Waste Management, Shrewsbury, MA, Joe Roman, (800) 834-7828
PJ Cronin: PJ Cronin, Inc. Boston, MA.
Prolerized: Prolerized New Engineering Co., Everett, MA, John Cody, 617-389-8300
RCS: Resource Conservation Services, Shelagh Conolly, 603-536-5280
RCS: Resource Conservation Services, Yarmouth, ME, Jody Sapphire, 207- 846-3737
Sawyer Env.: Sawyer Environmental Landfill, Bill Shook, Maine, 207-862-4200
Septic Services, Haverhill MA:508-372-7471
Sumpter Cty: Sumpter County Compost Facility, Florida, 904-568-1100
Tetrapak, Ed Klein, Washington, D.C.
Texaco/Ventura: Texaco Exploration & Production, Inc., Ventura, CA, Frank Maccioli, (805) 648-8444.
Vicon: Vicon incinerator, Pittsfield, MA, Lew Clark, 413-443-7373
Walton Systems, Jim O'Connor, (617) 884-0350

Publications:

New England Small Farm Institute. Agricultural Composting in Massachusetts, January 1987
New Jersey Agricultural Experiment Station. Sludge Composting and Utilization, September 1982
U.S. EPA. In-vessel Composting of Municipal Wastewater Sludge, September 1989
Dewar, J.D., Manual of Ready Mixed Concrete, Blackie Press, Glasgow, GB, 1988.
Poss, Peter E. D.V.M. "Central Pick-up of Farm Dead Poultry"
Northeast Regional Ag Engineering Svc, Cornell Univ Proc from Dairy Manure Mgmt Symposium, Feb. 1989
Portland Metropolitan Service District. "A User's Guide to Yard Debris Compost," June 1989
Vesilind, P.A., Sludge Management and Disposal for Lewis Publishers, Inc. Chelsea, MI, 1986

Table 2. Mail Survey Results - Densities for Selected Materials and Forms

Material Types	Form	Special Notes	Survey: Reported lb/cu yd
Yard Waste			
Wood Chips	Shredded	2'	240
Prunings	Shredded	2'	527
Special Wastes			
Industrial Sludge-Dewatered (50% solids)	Landfill High Compaction		1500
Plastic			
PET	Granulated	1/2"	771
PET	Baled High Density	73"x42"x32"	571
PET	Baled High Density	3'x4'x5'	569
PET	Whole		45
HDPE (mixed color)	Baled High Density	73"x42"x32"	478
HDPE (mixed color)	Pelletized	3 to 4 cu in.	657
HDPE	Pelletized	3 to 4 cu in.	657
HDPE	Baled High Density	73"x42"x32"	571
HDPE	Whole		20
Paper			
Other Paper, trim (white fly)	Baled High Density	84"x32"x42"	498
Other Paper, trim (white fly)	Baled High Density	68"x45"x28"	408
Old Corrugated Cardboard	Whole		53
Old Corrugated Cardboard	Baled High Density	72"x48"x30"	675
Old Corrugated Cardboard	Baled High Density	68"x32"x34"	621
Old Corrugated Cardboard	Baled High Density	60"x45"x30"	348
Old Corrugated Cardboard	Baled High Density	60"x45"x28"	581
Old Corrugated Cardboard	Baled High Density	2'x3'x4'	590
Old Corrugated Cardboard	Baled Low Density	48"x42"x32"	378
Newspaper	Low Compaction Truck		422
Newspaper	Baled High Density	72"x68"x50"	359
Newspaper	Whole		1200
Newspaper	Baled High Density	84"x32"x42"	578
Newspaper	Baled Low Density	3'x4'x3'	1330
Newspaper	Low Compaction Truck		375
Newspaper	Whole		500
Mixed Paper	Baled High Density	58"x45"x36"	682
Mixed Paper	Baled High Density	72"x34"x32"	834
Mixed Paper	Baled High Density	62"x48"x30"	742
Mixed Paper	Baled High Density	6'x3'x3'	780
Mags. Glossy, in. coated	Baled High Density	3'x4'x5'	1083
Kraft (Brown) Bags, paper	Baled Low Density	68"x42"x40"	2222
High Grade Ledger, bond	Baled High Density	84"x32"x42"	579
High Grade Ledger	Baled High Density	3'x4'x5'	785
Computer Printout	Baled High Density	3'x4'x5'	635
Computer Printout	Baled High Density	62"x45"x30"	725
Computer Printout	Baled High Density	70"x32"x34"	768
Bleached Hardwood and Softwood Paper	Baled High Density	35"x30"x17"	1255

Table 2. Mail Survey Results -- Densities for Selected Materials and Forms (Continued)

Material Types	Form	Special Notes	Survey Reported lb/cu yd
Metals			
Ferrous Food & Beverage Cans	Whole		167
Copper Wire	Whole		338
Copper Pipe	Whole		211
Brass Scrap	Whole		633
Bi-Metal Cont.	Whole		84
Aluminum Scrap	Whole		175
Aluminum Cans	Baled High Density	42"x52"x54"	1108
Aluminum Cans	Whole		46
Aluminum Cans	Shredded	2"	363
Aluminum Cans	Baled Low Density	60"x30"x48"	432
Glass			
Cal Redemp. Value	Whole		475
Other Recy. Glass	Size Reduced	5/8"	2187
Cal Redemp. Value	Size Reduced	5/8"	2187

of processing source separated curbside recyclables and certain material types recovered from mixed wastes. At American Soil Products, bulk densities were determined for various types of soil amendments and mulches used in landscaping.

The field studies were designed to determine the density of: 1) processed recyclable materials in baled or cubed form, and 2) the loose form of processed and unprocessed materials. The test plan, which was approved by the CIWMB, and examples of the data recording forms, is included as Appendix D.

The list of waste types that are used in this report reflect the common practices of waste management and recycling industries in California and provide terms of common usage for waste types requiring special handling and/or disposal. The following subsections describe the methodology for each element of the sampling program.

Sample Methodology for Baled and Cubed Materials

Dimensions and weights of randomly chosen samples of material types were recorded to allow computation of material densities. Weights were recorded on a State-certified scale at the MRRRF with the assistance of a forklift operator from the MRRRF.

Table 3 presents the results and the number of samples analyzed for each material type. While the size of bales and cubes are not uniform in size or weight in the industry, cubes for this study averaged slightly less than half the length of bales.

Sample Methodology for Loose Processed and Unprocessed Materials

Appropriately sized containers were selected for sample analyses and, prior to the field study, all sampling containers were measured for volume and tare weight. All weighing was conducted on State-certified scales.

Loose processed materials at the MRRRF were either stockpiled in bins or on the facility floor. When necessary, CalRecovery crews hand-sorted commingled materials to accumulate sample quantities of a specific individual material type for measurement. All material samples were gathered similarly and all containers filled to a known volume. Table 3 presents the results and the number of samples selected for each material type.

Inert materials of large or heavy particle size required a different sampling technique than those procedures previously described. Large accumulations of concrete, brick, and demolition debris were manually sorted into more manageable sizes for measurement (e.g., broken brick less than 8 in. in size).

Weighings were conducted for randomly chosen samples from available materials. Weights were recorded on a State-certified scale. The material types and number of samples selected for weighing, are presented in Table 3.

A similar measurement protocol was used at the American Soil Products site. To account for the dependency of bulk density in the method of measurement, the ASTM "Standard Test Method for Determining the Bulk Density of Solid Waste Fractions" was utilized. The procedure was to fill the container to overflowing, then to tamp the container three times by lifting it,

Table 3. Densities for Selected Materials from CalRecovery Field Studies

Material Type	No. of Samples a)	Form	Average lb/cu yd	Percent Error b) c)
MARIN RECYCLING CENTER				
Aluminum (foil, pans)		loose	48.1	5.5
Aluminum Cans (crushed & uncrushed mixture)		loose	81.4	18.2
Brass (scrap < 12")		loose	906.4	12.2
Steel Food & Beverage Cans		loose	144.3	8.8
Glass (clear, CRV)		whole	485.5	3.0
Glass (clear, non-CRV)		whole	437.8	2.7
Glass (green)		whole	456.7	6.5
Glass (mix brown)		whole	439.6	3.0
Glass (mix clear)		whole	478.3	2.1
Glass (mix color-broken, < 2")		size reduced	1887.8	5.2
Books (hardback)		loose	529.3	6.7
Books (paperback)		loose	427.5	5.6
Computer Printout		loose	519.4	11.2
High Grade Ledger (w/o Computer Printout)		loose	363.5	21.5
Kraft Paper		loose	34.4	16.7
News w/o Inserts		loose	322.8	27.2
Glossy Inserts		loose	570.4	28.2
Old Corrugated Cardboard (flattened boxes)		loose	50.1	39.1
Old Corrugated Cardboard (whole boxes)		loose	16.6	24.6
Other Plastics (SPI Code #'s 3-7)		loose	49.8	6.4
PET (CRV)		whole	34.8	1.2
PET (mixed)		whole	43.3	5.5
HDPE (1 gal milk & H2O)		whole	22.1	8.0
HDPE (mix color)		whole	47.1	3.3
Film Plastic: mixed		loose	22.6	15.7
Polystyrene (blown formed foam)		loose	9.6	10.4
Styrofoam Kernels		loose	6.3	6.5
HHW Empty Containers (1 gal paint & spray)	3	whole	117.3	30.0
Auto Batteries (4 each/sample) d)			3027.2	17.2
Aluminum Cans		baled	398.8	8.4
Aluminum Foil	1	baled	188.4	NA
HDPE (colored) black nursery pots		baled	573.1	5.7
HDPE (mixed colored)		baled	511.0	7.7
HDPE (natural)		baled	575.7	4.5
Newspaper		baled	748.1	3.6
Old Corrugated Cardboard		baled	713.3	8.1
PET		baled	414.8	5.3
PET (clear), w/o REDEMP		baled	443.0	8.6
White Goods		cubed	1907.2	15.9
Scrap Metal (aluminum)	2	cubed	424.5	NA
Metal Food Cans		cubed	2082.6	6.5
MARIN RESOURCE RECOVERY FACILITY				
Asphalt Shingles (composite type)		loose	418.5	37.1
Carpet & Padding	2	loose	84.4	NA
Ceramic Tiles (6"x6")		loose	1213.9	12.7
Concrete (< 8" scrap)		loose	1855.2	6.5
Dry Leaves		loose	343.7	9.5
Dry Pine Needles		loose	74.4	4.8
Dry Prunings: < 4"	1	loose	36.9	NA
Garden Debris (flowers, plants)		loose	182.8	30.9
Grass Clipping (fresh)		loose	280.2	7.1
Green Prunings: < 4"		loose	46.7	32.7
Particle Board: < 6" scrap	1	loose	425.1	NA

a) Unless otherwise indicated, number of samples = 4.

b) At 90 percent confidence level.

c) NA = not applicable; percent error not reported for less than three samples.

d) Measurements were taken without containers. Volumes were measured at time of weighing.

e) Measurement was taken from an "as-delivered" container.

Table 3. Densities for Selected Materials from Cal/Recovery Field Studies (Continued)

Material Type	No. of Samples a)	Form	Average lb/cu yd	Percent Error b) c)
Red Brick (broken <8")		loose	1614.1	4.9
Sheetrock Scrap <2'		loose	393.6	36.2
Soil: via self-haul		loose	2385.5	4.1
Wood Scrap: < 2'		loose	329.5	26.9
Wooden Pallets (4 stacked/sample) d)		whole	201.0	8.7
Auto Oil Filters e)	1		834.4	NA
Computer Printout		baled	577.5	8.6
Mixed Paper (SuperMix)		baled	635.2	10.4
Old Corrugated Cardboard		baled	742.0	8.3
White Ledger		baled	644.3	12.0
AMERICAN SOIL PRODUCTS				
Fir Bark: 1/4"		size reduced	427.0	2.4
Fir Bark: 3/4"		size reduced	438.8	2.1
Fir Bark: 2"		size reduced	492.9	4.1
Mushroom Compost		loose	827.7	4.4
Red Lava Rock (5/16")		loose	1325.9	3.2
Redwood Mulch (coarse)		loose	187.5	17.7
Redwood Mulch (fine)		loose	277.5	8.9
Cedar Mulch		loose	392.0	10.2
Compost		loose	463.4	4.6
Sand		loose	2441.3	0.7
Sandy Loam Soil		loose	2392.0	2.7
Sawdust		loose	375.0	4.2
OTHER FIELD STUDIES				
Tomato Pomice		loose	827.1	1.2
Almond Hulls		loose	842.9	2.0
Street Sweepings		loose	1145.4	8.0
Sewage Sludge-dewatered 20.4% solid		loose	1293.8	9.5
Sewage Sludge-dewatered 94.5% solid		loose	1935.5	3.0
Grape Pomice-wet		loose	1240.2	2.8
Grape Pomice-semi dry		loose	781.6	6.2
Wood Waste				
Plywood	8	2'x4' sheet	778.3	2.4
Roofing/Shake Shingle	8	bundle	435.3	7.5
Aseptic Packaging (fruit juices, etc.)		whole	86.7	6.5
Paperboard/Boxboard		whole	21.5	6.8
Drinking Water/Wastewater				
(Diatomaceous Earth):55% moisture	1	loose	967.0	NA
(Diatomaceous Earth):air dry	1	loose	479.6	NA
Soiled Disposable Diapers	8	loose	540.0	72.3

a) Unless otherwise indicated, number of samples = 4.

b) At 90 percent confidence level.

c) NA = not applicable; percent error not reported for less than three samples.

d) Measurements were taken without containers. Volumes were measured at time of weighing.

e) Measurement was taken from an 'as-delivered' container.

approximately 2 to 3 in. above the ground, and to drop it squarely. After tamping, a straightedge was drawn across the top of the container to level the contents. The container and its contents were then weighed. Results from this facility can also be found in Table 3.

To supplement the above mentioned field studies, several smaller field studies were conducted in and outside of California to gather additional data. In all cases, the measurements were conducted in accordance with the methodology discussed above.

The California studies took place at: a tomato cannery, a winery, and a nut processing facility, in order to gather data for certain organic wastes; a local lumberyard for wood shakes and plywood; the City of Vacaville Wastewater Treatment Plant, for dewatered sludge; and B & J Sanitary Landfill in Vacaville, for street sweepings. The results of these studies are presented in Table 3.

The field studies conducted outside of California took place in the greater Boston area. Data was gathered from regional MRFs and private firms. These studies were used to determine densities for food waste, textiles and leather, plastic film, tires, certain glass, and miscellaneous plastics. These material types and forms are similar if not identical to those found in California, or likely to be encountered in the future in California. The results from these field studies are presented in Table 4.

RESULTS

Table 5 is the master table that presents conversion factors for weight-to-volume and volume-to-weight for individual material types and forms. The information in this table is derived from field studies, a literature search, and mail survey. Tables 1, 2, 3, and 4 present the results of various data collection efforts from which data for Table 5 were selected. Selection and incorporation of data from Tables 1, 2, 3, and 4 into the master table (i.e., Table 5) was based on the following hierarchy in descending order of reliability: field studies, literature search and telephone communication, and mail survey.

At the top of the hierarchy of selection is the use of field study data. Field studies were conducted under controlled conditions and where possible were replicated in order to provide statistically valid densities of materials. These studies also allowed, in some cases, the selection of sub-groups for measurements within a specific material type. For example, previously published densities for whole glass containers do not distinguish density of containers as a function of color. The field studies conducted for this project enabled this distinction to be studied.

In those cases where collection of field data for field data for certain material types or forms was not feasible, data was utilized from the literature survey and telephone communication where such data were available and judged to be reliable.

For this study the least reliable density data were judged to be supplied by the mail survey. Confirmation of measurement data and other uncertainties are reasons for relegating the density results of the mail survey to the lowest level of the hierarchy of data reliability. Lacking data from field measurements or from the literature search, data was used from the mail survey where the data were judged by CalRecovery to be reliable.

Table 4. Densities for Selected Materials Collected from Out-of-State Field Studies

Material Type	Number of Samples	Form	Average (lb/cu yd)	Reference
PAPER				
Mixed Paper	4	loose	484.00	Wellesley, MA Recycling Drop-off Facility
Telephone Directories	4	whole, stacked	944.91	Boston Public Library
PLASTIC				
PVC (fittings, pipe)	10	loose	341.12	Riverside Pipe & Supply Medford, MA E.J.P. Pipe Store North Andover, MA
LDPE Film Plastics	3	semi-compacted	72.32	Star Market Cambridge, MA
HDPE Film Plastics	3	semi-compacted	75.96	Star Market Cambridge, MA
Polystyrene, rigid	3	whole	21.76	Miller Service Company Wakefield, MA
Polypropylene, film	3	packed	9.26	Miller Service Company Wakefield, MA
Polypropylene, strap	3	packed, coiled	371.62	Miller Service Company Wakefield, MA
GLASS				
Other Non-Recyclable (plate glass, windows)	4	size-reduced <4"	1415.00	North Atlantic Recycling North Andover, MA
METAL				
Bi-Metal Containers	3	uncrushed	141.38	North Atlantic Recycling North Andover, MA
Copper Fittings	3	loose	1047.62	Riverside Pipe and Supply
YARD WASTE				
Compost, yard waste	4	loose	1739.75	Wellesley, MA Recycling Drop-off Fac.
OTHER ORGANICS				
FOOD WASTE				
Produce Waste (mixed fruit)	1	loose	1131.00	Star Market Cambridge, MA
Produce Waste (cantalopes)	1	loose	1000.0	Star Market Cambridge, MA
Produce Waste (mixed vegetable)	1	loose	909.0	Star Market Cambridge, MA
TIRES				
Tires, auto	4	whole, stack of 3 tires	221.57	Montvale Tire Co. Melrose, MA
Tires, truck (radial)	2	whole	476.06	North Atlantic Recycling North Andover, MA

Table 4. Densities for Selected Materials Collected from Out-of-State Field Studies (Continued)

Material Type	Number of Samples	Form	Average (lb/cu yd)	Reference
Tires, truck (bias)	2	whole	362.02	North Atlantic Recycling North Andover, MA
MANURE				
Horse Manure	3	loose	1252.00	Lazy S Ranch
TEXTILES				
Scrap Leather	1	semi-compacted 1/8" x 7" x 33" pieces	243.00	Columbia Tanning Brockton, MA
Scrap Leather	1	semi-compacted 1/8" x 6" x 18" pieces	303.00	Columbia Tanning Brockton, MA
Scrap Leather	1	semi-compacted 1/8" x 6" x 18" pieces packed flat	470.0	Columbia Tanning Brockton, MA
Leather Remnants	1	semi-compacted apron leather	383.6	Berman Leathercraft Boston, MA
Leather Remnants	1	semi-compacted shoe leather	363.4	Berman Leathercraft Boston, MA
Leather Remnants	2	semi-compacted hide scraps	514.9	Berman Leathercraft Boston, MA
Shoes (men's)	4		224.00	Walkover Shoe Factory
Used Clothes, winter coats	4	loose	241.00	Garment District Cambridge, MA
Used Clothes, jeans	4	loose	285.00	Garment District Cambridge, MA
Used Clothes, T-shirts	4	loose	260.00	Garment District Cambridge, MA
Used Clothes, mixed	4	loose	225.00	Garment District Cambridge, MA
OTHER WASTES				
INERT SOLIDS				
Rock (2-12")	4	loose	2570.96	Delourey Construction Co. Andover, MA

Table 5. Densities and Conversion Factors for Various Material Types

Material Type	Form a)	Special Notes b)	California Field Studies			Conversion Factors from Literature Review			Out of State Field Studies			California Mail Survey Results				
			Conversion Factors			Conversion Factors			Conversion Factors			Conversion Factors				
			lb/cu yd	Tons to cu yd	cu yd to Tons	lb/cu yd	cu yd	Tons	lb/cu yd	cu yd	Tons	lb/cu yd	cu yd	Tons		
PAPER																
Old Corrugated Cardboard/ flattened boxes	loose		60.06	39.63	0.03											
Old Corrugated Cardboard/ whole boxes	loose		16.64	120.19	0.01											
Old Corrugated Cardboard/ recycling center	baled	73"x42"x32"	713.00	2.61	0.36											
Old Corrugated Cardboard/ resource recovery facility	baled	87"x40"x29"	742.00	2.70	0.37											
Old Corrugated Cardboard	baled low density	48"x42"x32"											378.00	5.29	0.19	
Kraft (Brown) Bags/Paper	baled low density	69"x42"x40"											2221.71	0.90	1.11	
Brown Paper Bags	loose		34.43	58.09	0.02											
Mixed Paper	loose								484.00	4.13	0.24					
Mixed Paper/supermix	baled	76"x38"x34"	835.00	3.18	0.32											
Newspaper	baled	80"x42"x32"	748.00	2.67	0.37											
Newspaper: w/o inserts	loose		322.77	6.20	0.16											
Newspaper	low compaction truck															
Mags. Glossy/in. coated	baled high density	3"x4"x5"											421.88	4.74	0.21	
Glossy inserts	loose		670.37	3.51	0.29								1082.70	1.85	0.54	
High Grade White Ledger	baled	76"x34"x38"	844.00	3.11	0.32											
High Grade Ledger/w/o CPO	loose		363.51	5.50	0.18											
Books/hardback	loose		829.29	3.78	0.26											
Books/paperback	loose		427.50	4.68	0.21											
Telephone Directories/books	whole	stacked							644.81	2.12	0.47					
Computer Printout	loose		819.40	3.65	0.26											
Computer Printout	baled	76"x40"x30"	878.00	3.48	0.29											
Other Paper/trims (white fly)	baled high density	84"x32"x42"											498.82	4.03	0.25	
Other Paper/trims (white fly)	baled high density	66"x49"x26"											408.40	4.90	0.20	
Bleached HWD & SWD Paper	baled high density	35"x30"x17"											1294.62	1.99	0.63	
Paperboard/Boxboard/Chipboard	whole		21.80	83.02	0.01											
PLASTIC																
HDPE/colored (black nursery pots)	baled	81"x44"x31"	673.00	3.49	0.29											
HDPE/milk/water	whole		22.10	80.50	0.01											
HDPE/mix color	whole		47.03	42.50	0.02											
HDPE/natural	baled	91"x43"x32"	576.00	5.47	0.29											
HDPE (mixed colored)	baled	84"x44"x32"	811.00	3.91	0.26											
HDPE (mixed colored)	pelletized	3 to 4 cu ft.											657.14	2.33	0.43	

a) Refer to Appendix B for an explanation of processed and unprocessed forms
 b) < = less than

Handwritten calculations:
 $\frac{2000}{576} = 3.47$
 $\frac{576}{2000} = 0.29$
 29

Table 5. Densities and Conversion Factors for Various Material Types (Continued)

Material Type	Form a)	Special Notes b)	California Field Studies			Conversion Factors from Literature Review			Out of State Field Studies			California Mail Survey Results		
			Conversion Factors			Conversion Factors			Conversion Factors			Conversion Factors		
			Tons to lb/cu yd	cu yd to cu yd	Tons to Tons	Tons to lb/cu yd	cu yd to cu yd	Tons to Tons	Tons to lb/cu yd	cu yd to cu yd	Tons to Tons	Tons to lb/cu yd	cu yd to cu yd	Tons to Tons
PET	baled	92"x43"x32'	414.00	4.83	0.21									
PET/clear w/o redemp	baled	79"x43"x32'	443.00	4.51	0.22									
PET/CRV	whole		34.58	57.84	0.02									
PET/mixed	whole		43.30	46.19	0.02									
PET	granulated	1/2'									771.43	2.59	0.39	
PVC	loose								341.12	5.86	0.17			
Film Plastic/mixed	loose		22.55	88.69	0.01									
Other Plastic (SPI codes #3-7)	whole		49.76	40.19	0.02									
LDPE Film Plastic	semi-compacted	assorted bags							72.32	27.65	0.04			
HDPE Film Plastic	semi-compacted	assorted bags							75.98	26.33	0.04			
Polystyrene/rigid	whole	stacked sheets							21.76	91.91	0.01			
Polystyrene/blown formed foam	loose		9.62	207.87	0.00									
Styrofoam/burnable	loose		6.27	318.87	0.00									
Polypropylene/film	packed	can liners							9.26	215.96	0.01			
Polypropylene/strap	packed, coiled								371.62	5.38	0.19			
GLASS														
Other Non-Recyclable	size reduced	plate glass window, <4'							1415.00	1.41	0.71			
Glass/clear CRV	whole		466.49	4.29	0.23									
Glass/clear non-CRV	whole		437.77	4.57	0.22									
Glass/green	whole		458.71	4.38	0.23									
Glass/mix brown	whole		439.58	4.55	0.22									
Glass/mix clear	whole		476.26	4.20	0.24									
Glass/mix color	size reduced	< 2'	1867.75	1.07	0.93									
Cal Redemp. Value	size reduced	5/8'										2167.00	0.91	1.09
Other Recyclable	size reduced	5/8'										2167.00	0.91	1.09
METAL														
Aluminum Foil	loose		48.10	41.80	0.02									
Aluminum Foil	baled	65"x42"x29"	168.00	10.84	0.09									
Aluminum Cans	loose	uncrushed & crushed mix	91.40	21.88	0.05									
Aluminum Cans	baled	82"x41"x31"	399.00	6.01	0.20									
Aluminum Cans	uncrushed											49.00	40.82	0.02
Aluminum Cans	shredded	2"										383.00	5.51	0.16
Aluminum Scrap	cubed	34"x24"x20"	424.00	4.72	0.21									
Aluminum Scrap	whole											175.00	11.43	0.09

a) Refer to Appendix B for an explanation of processed and unprocessed forms

b) < = less than

Table 5. Densities and Conversion Factors for Various Material Types (Continued)

Material Type	Form a)	Special Notes b)	California Field Studies			Conversion Factors from Literature Review			Out of State Field Studies			California Mail Survey Results		
			lb/cu yd	cu yd	Tons	lb/cu yd	cu yd	Tons	lb/cu yd	cu yd	Tons	lb/cu yd	cu yd	Tons
Bi-Metal Containers	uncrushed								141.38	14.15	0.07			
Ferrous Food & Beverage Containers	loose		144.32	13.66	0.07									
Ferrous Food & Beverage Containers	cubed	29"x21"x24"	2093.00	0.96	1.05									
Brass/scrap	whole	<12"	908.43	2.21	0.45									
Lead Scrap	whole					1603.84	1.25	0.80						
Copper Scrap	whole					1093.52	1.83	0.55						
Copper Wire	whole											337.50	5.93	0.17
Copper Pipe	whole											210.94	9.48	0.11
Copper Fittings	loose								1047.62	1.91	0.52			
White Goods	cubed	30"x22"x23"	1807.00	1.05	0.95									
Dishwashers	whole					234.00	8.55	0.12						
Dryers	whole					224.00	8.93	0.11						
Refrigerators/freezers	whole					198.00	10.10	0.10						
Washers	whole					321.00	6.23	0.16						
Stoves/ovens	whole					300.00	6.67	0.16						
YARD WASTE														
Leaves/dry	loose		343.70	6.62	0.17									
Grass/clipping fresh	loose		260.22	7.14	0.14									
Prunings	shredded	2"										527.00	3.60	0.26
Prunings/dry	loose	<4"	36.90	54.20	0.02									
Prunings/green	loose	<4"	46.69	42.83	0.02									
Large Limbs & Stumps	loose	>4"				1080.00	1.85	0.64						
Garden Debris/flowers, plants	loose		182.81	10.94	0.09									
Pine Needles	loose	dry	74.42	26.88	0.04									
OTHER ORGANICS														
FOOD WASTE														
Produce Waste/cantalopes	loose								1000.00	2.00	0.50			
Produce Waste/mixed fruit	loose								1131.00	1.77	0.97			
Produce Waste/vegetable	loose								908.00	2.20	0.45			
Produce Waste/mixed	loose					1443.00	1.39	0.72						
MULCH/COMPOST														
Mulch/cedar	loose		361.98	6.24	0.19									
Mulch/redwood	loose	coarse	187.60	10.67	0.09									
Mulch/redwood	loose	fine	277.50	7.21	0.14									
Bark/br	size reduced	1/4"	426.86	4.66	0.21									

a) Refer to Appendix B for an explanation of processed and unprocessed forms
 b) < = less than

Table 5. Densities and Conversion Factors for Various Material Types (Continued)

Material Type	Form a)	Special Notes b)	California Field Studies			Conversion Factors from Literature Review			Out of State Field Studies			California Mail Survey Results		
			Conversion Factors			Conversion Factors			Conversion Factors			Conversion Factors		
			Tons to lb/cu yd	cu yd to cu yd	Tons to Tons	Tons to lb/cu yd c)	cu yd to cu yd	Tons to Tons	Tons to lb/cu yd	cu yd to cu yd	Tons to Tons	Tons to lb/cu yd	cu yd to cu yd	Tons to Tons
Bark/br	size reduced	3/4"	438.75	4.56	0.22									
Bark/br	size reduced	2"	492.86	4.06	0.25									
Wood Chips	shredded	2"												
Compost	loose		463.39	4.32	0.23									
Compost/MSW	loose	40-50% moisture				1400.00	1.43	0.70						
Compost/sludge	loose					474.00	4.20	0.24						
Compost/yard waste	loose	unscreened							1739.76	1.18	0.67			
Compost/mushroom	loose		627.66	2.42	0.41									
TIRES														
Tire/auto	whole	stack of 3 tires							221.57	9.03	0.11			
Tire/truck														
Radial	whole	individual tire							476.00	4.20	0.24			
Bias	whole	individual tire							362.00	6.52	0.16			
Tire/heavy equip.	whole	bias ply individual tire weight only				316.00	NA d)	NA						
Rubber Products	loose					1200.00	1.67	0.60						
WOOD WASTE														
Furniture	whole								166.00	12.05	0.06			
Pallets	whole	4/sample	200.96	9.95	0.10									
Saw dust	loose		375.00	5.33	0.19									
Wood scrap	loose	<2'	329.53	6.07	0.16									
Particle board	loose		425.14	4.70	0.21									
Shavings	loose					440.00	4.55	0.22						
Roofing/shake shingle	bundle		435.30	4.59	0.22									
Plywood	sheet	2'x4'	778.30	2.66	0.39									
AG CROP RESIDUE														
Field Residues														
Spent barley	loose					450.00	4.44	0.23						
Corn silage	loose					460.00	4.17	0.24						
Dried corn stalks	loose					30.00	66.67	0.02						
Almond shell/hulls	loose		642.66	3.11	0.32									

a) Refer to Appendix B for an explanation of processed and unprocessed forms
 b) < = less than
 c) Except for individual items (e.g., each) in which case the units are pounds (lb).
 d) NA means not applicable because data are reported on a unit basis.

Table 5. Densities and Conversion Factors for Various Material Types (Continued)

Material Type	Form a)	Special Notes b)	California Field Studies			Conversion Factors from Literature Review			Out of State Field Studies			California Mail Survey Results		
			Conversion Factors			Conversion Factors			Conversion Factors			Conversion Factors		
			lb/cu yd	cu yd	Tons	lb/cu yd	cu yd	Tons	lb/cu yd	cu yd	Tons	lb/cu yd	cu yd	Tons
Rice Hulls	loose					220.00	9.09	0.11						
Stew	loose					60.00	33.33	0.03						
Prunings	loose	<4"	46.69	42.83	0.02									
Cannery Waste														
Beet pulp	loose					350.00	5.71	0.18						
Tomato pomice	loose	wet	827.14	2.42	0.41									
Grape pomice	loose	wet	1240.18	1.61	0.62									
Grape pomice	loose	dry	781.61	2.58	0.39									
MANURE														
Poultry														
Ricca hen aged	loose	wet				1408.00	1.42	0.70						
Ricca hen fresh	loose	wet				1376.00	1.45	0.69						
Turkey	loose					734.00	2.72	0.37						
Broiler	loose	dry				758.00	2.65	0.38						
Hen	loose	wet				1798.00	1.11	0.90						
Livestock														
Horse Manure	loose	w/ wood chips							1252.00	1.61	0.63			
Cattle	loose					1628.00	1.23	0.81						
TEXTILES														
Carpet & Padding	loose		84.40	23.70	0.04									
Scrap Leather	semi-compacted	1/8"x7"x33" pieces							243.00	6.23	0.12			
Scrap Leather	semi-compacted	1/8"x8"x18" pieces							303.00	6.60	0.15			
Scrap Leather	semi-compacted	1/8"x8"x18" pieces-flat							470.00	4.26	0.24			
Leather Remnants	semi-compacted	apron leather							383.60	5.21	0.19			
Leather Remnants	semi-compacted	shoe leather							363.40	5.60	0.16			
Leather Remnants	semi-compacted	hide scraps							514.80	3.88	0.26			
Shoes/men's	loose								224.00	8.83	0.11			
Used Clothes/winter coats	loose								241.00	6.30	0.12			
Used Clothes/jens	loose								285.00	7.02	0.14			
Used Clothes/T-shirts	loose								260.00	7.69	0.13			
Used Clothes/mixed	loose								225.00	8.69	0.11			
Used Clothing	compacted					540.00	3.70	0.27						

a) Refer to Appendix B for an explanation of processed and unprocessed forms
 b) < = less than

Table 5. Densities and Conversion Factors for Various Material Types (Continued)

Material Type	Form a)	Special Notes b)	California Field Studies			Conversion Factors from Literature Review			Out of State Field Studies			California Mail Survey Results			
			Conversion Factors			Conversion Factors			Conversion Factors			Conversion Factors			
			Tons to lb/cu yd	cu yd to cu yd	cu yd to Tons	Tons to lb/cu yd	cu yd to cu yd	cu yd to Tons	Tons to lb/cu yd	cu yd to cu yd	cu yd to Tons	Tons to lb/cu yd	cu yd to cu yd	cu yd to Tons	
OTHER WASTES															
INERT SOLIDS															
Rock	loose	2-12'							2570.06	0.76	1.29				
Rock/red lava	loose	5/16"	1325.69	1.51	0.66										
Concrete Scrap	loose	<8"	1855.18	1.08	0.93										
Brick	whole					3024.00	0.66	1.51							
Brick/red (broken)	loose	<8"	1614.11	1.24	0.81										
Ceramic Tile	loose	6"x6"	1213.93	1.65	0.61										
Sand	loose		2441.25	0.82	1.22										
Contaminated Soil	loose					2600.00	0.77	1.30							
Soil/sandy loam	loose		2391.06	0.84	1.20										
Soil/via self haul	loose		2385.84	0.84	1.19										
Fines	loose					2700.00	0.74	1.35							
Asphalt/paving	crushed					1360.00	1.45	0.69							
Asphalt/roofing						2916.92	0.66	1.51							
Asphalt/shingles comp	loose		418.63	4.76	0.21										
Gravel	loose					2565.00	0.76	1.26							
Stone/crushed	size reduced					2700.00	0.74	1.35							
Sheetrock Scrap	loose	<2'	393.57	5.06	0.20										
Fiberglass insulation	loose					17.00	117.65	0.01							
Banded Disposable Diapers	loose		540.00	3.70	0.27										
Aseptic Packaging	whole		56.70	35.27	0.02										
Televisions	whole					343.00	6.83	0.17							
Stereo Equipment	whole					763.00	2.62	0.38							
Stuffed Furniture	whole					60.00	26.00	0.04							
Empty Discarded HHW Containers	whole		117.26	17.06	0.06										
Antifreeze	liquid					1653.00	1.21	0.83							
Auto Batteries	whole	4/sample	3027.16	0.66	1.51										
Auto Oil Filters	loose		634.40	2.40	0.42										
Enamel Paint	liquid					1653.00	1.21	0.83							
Latex Paint	liquid					1636.00	1.09	0.92							
Flammable Liquids						1653.00	1.21	0.83							
Flammable Liquids						850.00	3.64	0.28							
Aerosol Cans						918.00	2.18	0.46							
Oxidizers						92.00	21.74	0.05							

a) Refer to Appendix B for an explanation of processed and unprocessed forms

b) < = less than

Table 8. Densities and Conversion Factors for Various Material Types (Continued)

Material Type	Form a)	Special Notes b)	California Field Studies			Conversion Factors from Literature Review			Out of State Field Studies			California Mail Survey Results		
			Conversion Factors			Conversion Factors			Conversion Factors			Conversion Factors		
			Tons to lb/cu yd	cu yd to Tons	Tons	Tons to lb/cu yd c)	cu yd to Tons	Tons	Tons to lb/cu yd	cu yd to Tons	Tons	Tons to lb/cu yd	cu yd to Tons	Tons
Poisons						550.00	3.84	0.26						
Waste Oil						1524.94	1.31	0.76						
SPECIAL WASTES														
Ash/incinerator		50% solids				1350.00	1.48	0.68						
Ash/incinerator		15% water				1957.00	1.02	0.98						
Ash/wood		50% solids				1100.00	1.82	0.55						
Ash/other		dry				1110.00	1.80	0.56						
Boghouse						810.00	2.47	0.41						
Sewage Sludge/dewatered		20.4% solids	1293.75	1.55	0.65									
Sewage Sludge/dewatered		95.5% solids	1935.54	1.03	0.97									
Sludge/chem fix		55% solids				2025.00	0.99	1.01						
Industrial Sludge/apple waste		41% solids				1411.00	1.42	0.71						
Industrial Sludge/papermill		34-38% solids				1425.00	1.40	0.71						
Industrial Sludge/dewatered	landfill high compaction	50% solids									1500.00	1.33	0.75	
Asbestos Bags	semi-compacted					378.50	6.30	0.16						
Auto Shredder Fluff	loose					600.00	2.50	0.40						
Auto Bodies	baled					1215.00	1.65	0.61						
Auto Bodies	flattened					579.20	3.45	0.29						
Auto Bodies	compacted					450.00	4.44	0.23						
Cement Kiln Dust	loose					1404.00	1.42	0.70						
Slag	loose	broken				2970.00	0.67	1.48						
Slag	crushed					1998.00	1.00	1.00						
Slag/furnace	granulated					1620.00	1.23	0.81						
Slag/screenings	loose					2495.00	0.60	1.25						
Dead Animals/small	each	individual				20.00	NA d)	NA						
Dead Animals/large	each	individual				1150.00	NA	NA						
Dead Animals/turkey	bulk					600.00	3.33	0.30						
Transformer/100 kva	whole					1798.00	1.11	0.90						
Transformer/15 kva	whole					1008.00	1.98	0.50						
Transformer/187 kva	whole					1828.00	1.09	0.91						
Transformer/25 kva	whole					1098.00	1.82	0.55						
Transformer/37.5 kva	whole					1254.00	1.89	0.63						
Transformer/50 kva	whole					1328.00	1.51	0.66						
Transformer/75 kva	whole					1365.00	1.44	0.69						

a) Refer to Appendix B for an explanation of processed and unprocessed forms
 b) < = less than
 c) Except for individual items (e.g., each) in which case the units are pounds (lb).
 d) NA means not applicable because data are reported on a unit basis.

Table 5. Densities and Conversion Factors for Various Material Types (Continued)

Material Type	Form a)	Special Notes b)	California Field Studies			Conversion Factors from Literature Review			Out of State Field Studies			California Mail Survey Results		
			Conversion Factors			Conversion Factors			Conversion Factors			Conversion Factors		
			lb/cu yd	Tons to cu yd	cu yd to Tons	lb/cu yd	Tons to cu yd	cu yd to Tons	lb/cu yd	Tons to cu yd	cu yd to Tons	lb/cu yd	Tons to cu yd	cu yd to Tons
Street Sweepings	loose		1145.36	1.75	0.57									
Drilling Mud		25% moisture				2222.00	0.90	1.11						
Septic Tank Pumpings						1855.68	1.21	0.83						
Chemical Toilet Wastes						1655.56	1.21	0.83						
Grease Trap Pumpings						1594.90	1.25	0.80						
Intact Red Bags of Treated Medical Waste						168.15	12.04	0.08						
Drinking Water/wastewater treatment residue (Diatomaceous Earth)		85% moisture air dry	987.00	2.07	0.48									
			479.80	4.17	0.24									

a) Refer to Appendix B for an explanation of processed and unprocessed forms
 b) < = less than

Appendix A

Appendix A

MATERIAL TYPES APPROVED BY CIWMB

(1) WASTE CATEGORY

(A) WASTE TYPE

1.) PRIMARY SUB-TYPE

a.) SECONDARY SUB-TYPE

- * Conversion factor needed for individual type or sub-type.
- ** Conversion factor needed for combined types or sub-types, consisting of the minimum, maximum, and average.

(1) Paper:

(A) Corrugated containers and brown paper bags**

- 1.) Corrugated containers/boxboard*
- 2.) Kraft (Brown) bags/paper*

(B) Mixed paper*

(C) Newspaper*

(D) High grade ledger and bond*

(E) Other paper**

- 1.) Magazines, glossy inserts and coated paper*
- 2.) Telephone books and directories*
- 3.) Books*
- 4.) Paperboard/boxboard/chipboard*
- 5.) Computer printout*

(2) Plastics:

(A) High-density polyethylene (HDPE) containers*

(B) Polyethylene terephthalate (PET) containers*

(C) Film plastics**

- 1.) LDPE Film plastics*
- 2.) HDPE Film plastics*

(D) Other plastics**

- 1.) Polyvinyl Chloride (PVC)**
 - a.) PVC pipes & fittings*
 - b.) PVC containers*
- 2.) Polypropylene*
- 3.) Polystyrene (styrofoam)**
 - a.) expanded*
 - b.) rigid*

(3) Glass:

- (A) Refillable glass beverage containers*
- (B) California Redemption Value glass*
- (C) Other recyclable glass*
- (D) Other non-recyclable (including window & auto glass)*

(4) Metals:

- (A) Aluminum cans*
- (B) Bi-metal containers*
- (C) Ferrous metals and tin cans**
 - 1.) Ferrous food and beverage containers*
 - 2.) Ferrous metals other than containers*
- (D) Non-ferrous metals**
 - 1.) Copper scrap*
 - 2.) Brass scrap*
 - 3.) Aluminum scrap*
 - 4.) Lead scrap*
- (E) White goods*

(5) Yard Waste:

(A) Yard Waste**

- 1.) Grass*
- 2.) Leaves*
- 3.) Prunings < 4" diameter*
- 4.) Large limbs > 4" diameter*
- 5.) Stumps*
- 6.) Compost**
 - a.) composted sludge*
 - b.) composted yard waste*
 - c.) composted municipal solid waste*

(6) Other Organics:

(A) Food waste**

- 1.) Meat trimmings*
- 2.) Vegetable waste*
- 3.) Bones*
- 4.) Mixed food wastes*
- 5.) Cannery waste*

(B) Tires and rubber products**

- 1.) Tires**
 - a.) Auto, pickup, and motorcycle*
 - b.) Truck and tractor*
 - c.) Heavy equipment*
- 2.) Rubber products (straps, hoses, and belts)*

(C) Wood wastes (Not yard wastes)**

- 1.) Furniture*
- 2.) Pallets*
- 3.) Sawdust*
- 4.) Shavings*
- 5.) Woodchips*
- 6.) Lumber*
- 7.) Plywood*
- 8.) Shake/shingle roofing debris*

(D) Agricultural crop residues**

- 1.) Field residues * (CalRecovery will investigate)
- 2.) Rice hulls*
- 3.) Nut shell/hulls*
- 4.) Prunings* [see (5) (A) (3),]
- 5.) Fruit pumice*

(E) Manure**

- 1.) Poultry*
- 2.) Livestock*

(F) Textiles and Leather**

- 1.) Textiles/fabrics*
 - a.) Clothing
 - b.) Non-clothing (carpet, etc.)
- 2.) Leather**
 - a.) Shoes & boots*
 - b.) Remnants and garments*

(7) Other Wastes:

(A) Inert solids**

- 1.) Asphalt Pavement*
- 2.) Asphalt Roofing Materials**
 - a.) tar roofing*
 - b.) shingle roofing*
- 3.) Brick*
- 4.) Ceramics*

- 5.) Concrete*
- 6.) Drywall*
- 7.) Fines*
- 8.) Gravel (<2")*
- 9.) Rock (2"-12")*
- 10.) Sand*
- 11.) Soil*
- 12.) Fiberglass insulation*

(B) Household hazardous waste and discarded containers**

- 1.) Discarded HHW materials (under consideration)**
 - a.) Oil based Paint*
 - b.) Water based Paint*
 - c.) Dry cell batteries*
 - d.) Lead acid batteries*
 - e.) Used motor oil*
 - f.) Used oil filters*
 - g.) Anti-freeze*
 - h.) Solvents and Gasoline*
- 2.) Discarded HHW materials containers*

(C) Aseptic packaging*

(D) Soiled Disposable Diapers*

(E) Mattresses and stuffed furniture*

(F) Brown goods and electronics*

(8) Special Wastes:**

- (A) Ash**
 - 1.) Incinerator*
 - 2.) Wood*
- (B) Sewage sludge**
 - 1.) Sewage sludge*
 - 2.) Chemically fixed sewage sludge*
- (C) Industrial sludge*
- (D) Asbestos Bags*
- (E) Auto shredder waste**
 - 1.) Auto shredder waste*
 - 2.) Chemically fixed shredder waste*
- (F) Auto bodies - compacted*

(G) Other special wastes**

- 1.) Drilling mud*
- 2.) Dead animals**
 - a.) Small animals (dogs, chickens, etc.)*
 - b.) Large animals (cows, horses, etc.)*
- 3.) Septic tank pumpings*
- 4.) Chemical toilet wastes*
- 5.) Grease trap pumpings*
- 6.) Street Sweepings/Catch basin cleanings*
- 7.) Intact red bags of treated medical wastes*
- 8.) Drinking water and waste water treatment residue and filter cake solids*

Appendix B

Appendix B

Partial List of Processed and Unprocessed Forms a)

whole (i.e., unprocessed), loose (i.e., as-discarded)

low compaction truck b): i.e., <600 lb/cu yd compaction

medium compaction truck b): i.e., 601-900 lb/cu yd compaction

high compaction truck b): i.e., >900 lb/cu yd compaction

baled: high density and large bales, i.e., 40 to 80 cu ft

baled: low density and small bales, i.e., 2 to 39 cu ft

shredded (e.g., wood waste): 4" nominal

shredded: 2" nominal

granulated flake (e.g., PET, HDPE, styrene): 1/2"

granulated flake: 1/4"

pelletized (3 to 4 cu in.)

round wafers (12" to 18" diameter X 2" to 6" thickness)

briquette (10 to 20 cu in.)

size reduced particles (e.g., glass): 1 1/2" nominal

size reduced particles (e.g., glass): 5/8" nominal

size reduced particles (e.g., glass): 1/4" nominal

flattened (e.g., tin cans, PET)

wet (ash, sewage sludge)

dry (ash, sewage sludge)

a) Dimensions are approximate and are for the purposes of assisting in categorization of an appropriate physical form. Example material descriptions (e.g., PET) are given for the purposes of illustration only.

b) e.g., packer truck; roll-off compactor for mixed MSW

Appendix D

Draft

PROGRAM OUTLINE

Site: Marin Recycling & Resource Recovery Facilities
Approximate Duration: 5-7 days

A. DENSITY FIELD STUDY

Purpose of Study: Determine loose densities of selected material types.

Test Plan

- Collect materials in various quantities from recycling center and/or resource recovery center.
- If necessary, hand sort specified materials into transport containers.
- Bring materials to work area and fill container (specific for material), weigh, and record data. Volume of weighing container to be determined. Replicate 4 times for each material type. Selection of material will be based on random hand selection of certain materials and/or random gathering of materials from a hopper or collection vehicle.
- In some instances, certain materials (e.g., glass) may have to be crushed and screened by hand to create a specific material type.

Special Materials

There are a number of material types that will require special handling in order to determine loose densities. Examples are: yard waste, wood waste, tree stumps, concrete, auto bodies, and mattresses.

- Yard waste: A CalRecovery staff member will work with the scale house to identify incoming loads that contain homogeneous waste, such as brush or grass. These loads will be directed to a special area of the tipping floor to allow visual inspection and sampling of the load. In cases where only mixed loads are identified, CalRecovery staff will collect sufficient sub-samples to develop a representative sample. Bulky wastes (e.g., shrubs, small stumps, etc.), when necessary, will be weighed in either gaylords, a small drop-off box, or individually. If necessary, volumes of these materials will be determined by estimation with a measuring stick. Large tree stumps will be weighed during off-hours on the main scale by placing a number of stumps into a large drop-off box. CalRecovery will request Marin Sanitary to record weights and truck volume of outgoing loads of sawdust, fines, and wood chips. Tare weights will be determined.
- Wood waste: Because of their bulk, wooden pallets will be pulled off the tipping floor and weighed on the main scale. Field personnel will weigh and volume will be recorded

by stacking pallets on the main scale. Other loose lumber will be put into gaylords or small drop-off boxes for weighing on the main scale.

- Mattresses (see wood waste handling).
- Auto bodies: They are not compacted at the recycling center and therefore, Marin Sanitary will be asked to bring several auto bodies to the main scale so they can be weighed and overall dimensions recorded.
- White goods: Type, bale weight, and overall dimensions will be recorded.
- Concrete will be handled much like tree stumps. A metal bin or small front loader will be filled with concrete from outside storage and weighed on the main scale.

Location of Work Area

- Recycling center: outside in a parking bay where trucks are parked
- Resource recovery: area in back by baler, next to rest room
- American Soil Products: request permission to locate work area outside of office

B. PROCESSED MATERIAL FIELD STUDY

Purpose of Study: Determine weight and overall dimensions of baled processed recyclable materials.

Test Plan (Working with Marin Recycling Center Staff)

- Marin Recycling Center weighs 4 bales of each processed material
- CalRecovery staff records bale dimensions
- Work with Marin Sanitary to determine the dimensions of baled materials; record the pressure used to bale each material, if possible; type of baler and other information that may influence overall bale formation and density

CIWMB Density Study
 Marin Recycling & Resource Recovery Facilities
 Data Entry Form

Location: **BALER IN RECYCLING CENTER**

Manufacturer _____

Date: _____

Material Type	Weight (lbs)				Comments
	Sample 1	Sample 2	Sample 3	Sample 4	
Baled Computer Paper (CPO)					
bale dimension					
Baled White Ledger					
bale dimension					
Baled Mixed Paper (Super Mix)					
bale dimension					
Baled OCC (Recycling Center)					
bale dimension					
Baled OCC (RRC)					
bale dimension					

CIWMB Density Study
 Marin Recycling & Resource Recovery Facilities
 Data Entry Form

Location: **BALER IN RECYCLING CENTER** Manufacturer _____

Date: _____

Material Type	Weight (lbs)				Comments
	Sample 1	Sample 2	Sample 3	Sample 4	
Baled PET					
bale dimension					
Baled PET (no redemption)					
bale dimension					
Baled HDPE					
bale dimension					
Baled Black HDPE (nursery pots)					
bale dimension					
Baled Mix Plastic (3,5,7)					
bale dimension					

CIWMB Density Study
 Marin Recycling & Resource Recovery Facilities
 Data Entry Form

Location: **BALER IN RECYCLING CENTER**

Manufacturer _____

Date: _____

Material Type	Weight (lbs)				Comments
	Sample 1	Sample 2	Sample 3	Sample 4	
Baled Aluminum Foil					
bale dimension					
Baled Aluminum Cans					
bale dimension					
Cubed White Goods					
cube dimension					
Cubed Scrap Metal (Aluminum)					
cube dimension					
Cubed Scrap Metal (tin, etc.)					
cube dimension					

