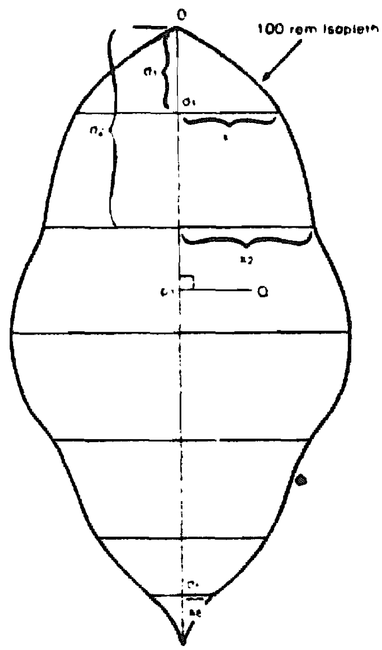

FIGURE E.1 Using GRID with a Site Map

GRID can also compute the doses or dose commitments at (almost) any downwind location off the plume centerline. Say, for example, that we wish to determine the dose commitment at point Q, shown in Figure E.1. GRID will request the downwind distance OP_1 and the (orthogonal) distance P_1Q. Once these values are supplied, GRID will return the dose commitment at Q. GRID functions as follows: CRAC2 is run to produce a file of ground concentrations along the plume centerline at each of several downwind distances. At all distance intervals, the plume is assumed to have a Gaussian distribution taken orthogonally to the centerline. The mean of the distribution is, of course, on the centerline, and the standard deviation is denoted by σ_y. DOSES transforms this information on ground concentrations into corresponding information on doses or dose commitments. Using trigonometric relationships, GRID can estimate the dose or dose commitment at almost any downwind point based on the Gaussian distribution value, σ_y, and the dose or dose commitment at the corresponding point on the centerline.

Because the dispersion model used by GRID does not give an accurate dose estimate close to the release point, other dose estimates derived from these estimates will also be imprecise. Points for which dose estimates will be imprecise are those that lie in proximity to the line through the release point and orthogonal to the centerline. Doses at these points have been rendered "inestimable" within the GRID program.

To facilitate the use of GRID with maps of different scale, GRID will accept map distances measured in inches or centimeters. To make the necessary conversions, GRID requires that the map scale be specified.

E.3 SITE DATA PROGRAMS

There are two programs that can be used for preparing the site data base. One is called **IR-GRID** and the other **SD-INPUT**. Both of these models transform the areas for each land use type into corresponding areas by surface type. In addition, SD-INPUT has the ability to take information based on political subdivisions and to reapportion this information to each grid element. Both programs then compile the site data into a single file that is used directly by DECON. These functions are described below.

E.3.1 Imputing Data Values to Grid Elements

DECON requires that for each grid element a complete set of population, property and contamination data be specified. If the grid element boundaries correspond to the boundaries of political subdivisions, then data reported at the political subdivision level can be used directly. However, if the grid element boundaries are not coterminous with the boundaries of political subdivisions and the analyst wants to make use of data reported at the political subdivision level, then IR-GRID can be used to transform the data accordingly. The calculational models in this section describe how IR-GRID takes data that are for the most part commonly available from published sources and transforms these into data for each grid element. The variables that are used in making these transformations are defined below.

$AV_{k,c}$ - total assessed value in land use k in county c

$RAVS_{k,c}$ - ratio of assessed value to sales in land use k in county c

$MV_{k,c}$ - market value of all property in land use k in county c

$MV_{k,t}$ - market value of all property of land use k in township t

$MVA_{k,c}$ - market value per acre of property in land use k in county c

$FAV_{k,c}$ - fraction of assessed value comprised of land use k in county c

$A_{k,c}$ - acres in land use k in county c

$A_{k,t}$ - acres in land use k in township t

NTP_c - value of nontaxable property in county c

$NTPA_c$ - value per acre of nontaxable property in county c

OH_c - number of occupied housing units in county c

OH_t - number of occupied housing units in township t

VH_t - number of vacant housing units in township t

MPH_t - median number of persons per occupied housing unit in township t

MHV_c - median house value in county c

MHV_t - median house value in township t

P_t - population in township t

f - adjustment factor to correct for using median housing value rather than the mean market value

p - factor to adjust nonresidential property values in township

The subscript k is an index spanning the following land uses: s (total for all land uses), r (residential), a (agricultural), ci (commercial/industrial) and nt (nontaxable property). It is noted that the acreage in Multi-family Residential is counted with residential for computing property values, but with commercial for decontamination purposes.

The first step is to compute the market value of each of the land use types within each county. This is done as follows:

$$MV_{s,c} = AV_{s,c} / RAVS_{s,c} \qquad \text{all c} \qquad (8)$$

$$MV_{r,c} = (AV_{s,c} \bullet FAV_{r,c}) / RAVS_{r,c} \qquad \text{all c} \qquad (9)$$

$$MV_{a,c} = MVA_{a,c} \bullet A_{a,c} \qquad \text{all c} \qquad (10)$$

$$MV_{ci,c} = MV_{s,c} - (MV_{r,c} + MV_{a,c}) \qquad \text{all c} \qquad (11)$$

$$MV_{nt,c} = 0.95 \bullet MV_{s,c} \qquad \text{all c} \qquad (12)$$

The factor 0.95 in equation 12 is from the Census of Governments (1977).

The next three equations compute the per acre value of each land use type for each county, except for agriculture which is known directly.

$$MVA_{r,c} = MV_{r,c} / A_{r,c} \qquad \text{all c} \qquad (13)$$

$$MVA_{ci,c} = MV_{ci,c} / A_{ci,c} \qquad \text{all c} \qquad (14)$$

$$MVA_{nt,c} = MV_{nt,c} / A_{nt,c} \qquad \text{all c} \qquad (15)$$

In equation 16 we estimate the population, based on the median number of occupants per household. Since the median rather than the arithmetic mean is used here, the population could be slightly underestimated.

$$P_t = MPH_t \bullet OH_t \qquad \text{all } t \qquad (16)$$

The next two equations provide an estimate of the market value of residential property within each township. An adjustment factor is used to correct for the fact that the median value rather than the (arithmetic) mean value of housing units is used in the calculation. **c(t)** in equation 18 and in subsequent equations represents the county **c** in which township **t** lies.

$$f_c = \frac{MV_{r,c}}{MHV_c \bullet (OH_c + VH_c)} \qquad (17)$$

$$MV_{r,t} = k_{c(t)} \bullet (MHV_t \bullet (OH_t + VH_t)) \qquad \text{all } t \qquad (18)$$

Equations 19 through 22 are used to estimate the market value of the other land uses within each township. The market value of nonresidential property within each township is adjusted under the following assumption: if residential property within the township is more (less) valuable on average than residential property within the county, then nonresidential property within the township is more (less) valuable than nonresidential property within the county by the same proportion.

$$P_t = MHV_t \, / \, MHV_{c(t)} \qquad \text{all } t \qquad (19)$$

$$MV_{a,t} = MVA_{a,c} \bullet A_{a,t} \bullet P_t \qquad \text{all } t \qquad (20)$$

$$MV_{ci,t} = MVA_{ci,c} \bullet A_{nt,t} \bullet P_t \qquad \text{all } t \qquad (21)$$

$$MV_{nt,t} = MVA_{nt,c} \bullet A_{nt,t} \bullet P_t \qquad \text{all } t \qquad (22)$$

This concludes the calculation of property values for each township. To compute relocation costs for businesses, it is necessary to estimate the number of employees within each major sector in each township economy. The procedures are described below. It is assumed that employment data are available at the county level, but not at the township level.

Employment in the commercial sector is defined as employment in: Services; Wholesale and Retail Trade; Finance, Insurance and Real Estate; and half the employment in Local and State Government. The assumption here is that only half of state and local government offices would be relocated; the others would be shut down. In addition, Construction businesses are assumed not to relocate.

Employment in the industrial sector is defined as employment in: Manufacturing of Durables, Manufacturing of Nondurables, and half of the employment in Transportation and in Communications and Utilities.

Let $E_{n,c}$ = employment in sector n in county c

$E_{n,t}$ = employment in sector n in township t

EI_c = employment in industrial sectors in county c

EC_c = employment in commercial sectors in county c

EI_t = employment in industrial sectors in township t

EC_t = employment in commercial sectors in township t

and m_t = the fraction of the area of township t within the criteria boundary

The subscript **n** is an index spanning the following employment sectors: **sv** (services); **wt** (wholesale trade); **rt** (retail trade); **fi** (finance, insurance and real estate); **g** (local and state government); **md** (manufacturing of durables); **mn** (manufacturing of nondurables); **tu** (transportation, communications and utilities).

Then $$EI_c = E_{md,c} + E_{mn,c} + 0.5 \bullet E_{tu,c} \qquad \text{all } c \qquad (23)$$

$$EC_c = E_{sv,ct} + E_{wt,c} + E_{rt,c} + E_{fi,c} + 0.5 \bullet E_{g,c} \qquad \text{all } c \qquad (24)$$

$$EI_t = (A_{ci,t} / A_{ci,c}) \bullet m_t \bullet EI_c \qquad t=1, \ldots, T_c \qquad (25)$$

$$EC_t = (A_{ci,t} / A_{ci,c}) \bullet m_t \bullet EC_c \qquad t=1, \ldots, T_c \qquad (26)$$

E.3.2 Transformation of Land Uses into Surface Types

It is obviously more appropriate that decontamination methods be applied to specific surfaces rather than land uses. This is particularly true of residential, commercial and industrial property, which are comprised of a large variety of surfaces. Since information on the types and quantities of different surfaces are unavailable for most geographical areas, a major function of both SD-INPUT and IR-GRID is to transform land use information, which is usually available, into corresponding information on surfaces. In this section we describe the basis for transforming land use data into data relating to surfaces. Our approach is to decompose the land use areas to be decontaminated into a number of surface types. When this information is supplied to DECON, DECON selects an appropriate decontamination method for each surface type.

E.3.2.1 Land Use Categories Currently Implemented

Currently, 12 different land use categories are implemented by DECON; they are reported in Table E.3.1. In addition to these 12 land uses, automobiles are also addressed. Unfortunately, there is no single scheme in general use for classifying land uses. Thus, depending upon the location of the radiological accident, land use information may be available, but it may be for a classification of land uses different from the one shown in Table E.3.1. It may therefore be necessary to restructure the land uses so that they are conformable with the categories in this table. Both IR-GRID and SD-INPUT allow the analyst to accomplish this by expressing other land uses as a linear combination of those land uses appearing in Table E.3.1. For example, recreational land does not appear in Table E.3.1. However, one could define this land use in terms of vacant land, lawn areas, wooded areas and commercial property. With the exception of bodies of water that cannot be processed as reservoirs, this feature should allow all major land uses to be addressed.

E.3.2.2 Relationship of Land Use to Surface Type

As already indicated, the approach is to use land use information to characterize the areas that need to be decontaminated. Land use information is 1) site-specific; 2) readily available from state and local government agencies and/or from Unites States Geological Survey (USGS) maps in most areas; and, most importantly, 3) adaptable to a decontamination analysis framework.

When conceptualizing the process of decontaminating property, it is more precise to consider the treatment of specific physical surfaces rather than of land uses. The decontamination of plaster walls, linoleum floors and asphalt roofs lends an accuracy to the analysis that is lost in the more general concept of decontaminating residential property. To implement such an approach, it is necessary to provide the linkage between land use types and surface types. The surface types currently implemented by DECON are presented in Table E.3.2.

TABLE E.3.1. Land Uses Currently Implemented

1. Single-Family Residential	7. Vacant Land
2. Multi-Family Residential	8. Lawns
3. Commercial	9. Parking Areas
4. Industrial	10. Agricultural Fields
5. Streets and Roads	11. Orchards
6. Wooded Areas	12. Reservoirs

The following discussion documents our development of the relationship between land use types and surfaces. The estimates that have been developed are based on land use and surface relationships that are believed to be widely representative. The relationships have been incorporated within a

TABLE E.3.2. Surface Types Currently Implemented by DECON

1.	Agricultural Fields	16.	Interior Wood/Plaster Walls
2.	Orchards	17.	Interior Concrete Walls
3.	Vacant Land	18.	Interior Glass
4.	Wooded Land	19.	Carpeted Floors
5.	Reservoirs	20.	Linoleum Floors
6.	Streets/Roads/Parking, Asphalt	21.	Wood Floors
7.	Other Paved Asphalt	22.	Concrete Floors
8.	Streets/Roads/Parking, Concrete	23.	Hard-Surface Furnishings
9.	Other Paved Concrete	24.	Soft-Surface Furnishings
10.	Lawns	25.	Electronic Equipment
11.	Roofs	26.	Paper Products
12.	Exterior Wood Walls	27.	Auto Exteriors
13.	Exterior Brick Walls	28.	Auto Interiors
14.	Exterior Concrete Walls	29.	Auto Tires
15.	Exterior Glass	30.	Auto Engines/Drive Trains

subroutine used by both SD-INPUT and IR-GRID, and which prepares the site database used in DECON. This subroutine, called XFORM, has been structured so that it is a relatively simple matter to alter these relationships either because better general information has become available, or because the analyst wishes to exploit available information relating to a specific study area.

E.3.2.2.1 Methodology. A comparison of Table E.3.1 with Table E.3.2 reveals that for several of the land use types there is a one-to-one correspondence to surface type. For example, the orchard land use type is entirely equivalent to the orchard surface type. This equivalence also exists for agricultural fields, vacant land, wooded land and reservoirs. The land use types consisting of paved surfaces are further subdivided into just two surfaces: asphalt and concrete. However, for some land use types, there are several different constituent surfaces. This is especially true of land use types containing structures. These are residential, commercial and industrial areas. The presence of buildings means that not only are there more surface types, but because of vertical walls and multiple floors, total surface area is greater than the area of the corresponding land use type.

A similar methodology is applied to residential, commercial and industrial areas. Conceptually, there are four basic steps in this methodology, although these are often combined in the actual calculation. The first step is to disaggregate the total land area into its horizontal components. For residential, commercial and industrial property these components generally include roofs, lawns, asphalt and concrete pavement and vacant land. Because roofs may overhang the structure, or because multi-layered open-air parking garages may be present, the total horizontal exterior surface area may somewhat exceed the corresponding land area. After obtaining estimates for the horizontal exterior surfaces, the second step involves specifying the basic dimensions for a representative structure for that land use type. The most important of these dimensions is projected roof area, which is defined as the vertical projection of the roof surface,

excluding roof overhangs, onto a horizontal plane. The other dimensions of the structure are then specified as a proportion of the projected roof area. In this way, the surface area of interior walls, exterior walls, floors and basements are all derived.

In the third step, the percentage of wall and floor areas covered by different materials is specified. Thus, total floor area is apportioned among the various floor surface materials: carpet, linoleum, wood and concrete. Due to resource constraints, not all types of surfaces could be considered. For example, ceramic tile floors and exterior walls of aluminum siding are surfaces that have not been addressed.

Finally, the fourth step is to determine the building contents falling into each of the following categories: hard-surface furnishings, soft-surface furnishings, electronic equipment and paper products. These surface types are expressed as a function of floor area. Obviously, these building contents categories do not encompass all of the contents likely to be found within a building, but they do include a major subset of them.

The foregoing methodology and the factors to be estimated are described explicitly by the equations in Table E.3.3. The term **LUA** denotes land use area and represents the land area within the grid element. **HH** denotes the number of households; as explained below, the number of residential structures is set equal to the number of households. **PRA** stands for the projected roof area, also explained below. The S's represent the different surface types being estimated, with the subscripts referring to the surface type number given in Table E.3.2. The lower case letters refer to factors that are to be estimated.

These equations serve to define the relationships between surface areas and land use types. The definitions of the factors are given in Table E.3.4, and the estimated values developed for these factors appear in Table E.3.5. The discussion of how these estimates are developed is presented in Section E.3.2.2.2. The following discussion is devoted to explaining the meaning of the equations in Table E.3.3.

Equations 1.1 through 1.7d in Table E.3.3 deal with horizontal, exterior surfaces. They utilize factors that represent simple fractions of the total land use area; these are factors **b** through **g** and **b'**. Note that these factors need not sum to unity since such things as multi-storied, open-air parking garages may make the total area of horizontal, exterior surfaces greater than the corresponding land area.

Equation 1.7a computes the actual roof area for residential units, while equation 1.7c computes the projected roof area. As explained in the next section, the actual roof area is derived from the exterior wall dimensions of a representative single-family detached housing unit and the assumed characteristics of the roof.

TABLE E.3.3. Land Use Transformation Equations

Surface	Equation	
Vacant land	$S_3 = g \bullet LUA$	1.1
Asphalt streets/roads/parking	$S_6 = b \bullet LUA$	1.2
Other paved asphalt	$S_7 = d \bullet LUA$	1.3
Concrete streets/roads/parking	$S_8 = c \bullet LUA$	1.4
Other paved concrete	$S_9 = e \bullet LUA$	1.5
Lawns		
Residential, All	$S_{10} = [(d + e) / f] \bullet LUA$	1.6a
Commercial/Industrial	$S_{10} = f \bullet LUA$	1.6b
Roofs, actual area		
Residential, All	$S_{11} = b' \bullet HH$	1.7a
Commercial/Industrial	$S_{11} = a / b' \bullet LUA$	1.7b
Roofs, projected area		
Residential, All	$PRA = a \bullet HH$	1.7c
Commercial/Industrial	$PRA = a \bullet LUA$	1.7d
Exterior glass	$S_{15} = h \bullet c' \bullet PRA$	1.8
Exterior wood walls	$S_{12} = [(h \bullet PRA) - S_{15}] \bullet j$	1.9
Exterior brick walls	$S_{13} = [(h \bullet PRA) - S_{15}] \bullet i$	1.10
Exterior concrete walls	$S_{14} = [(h \bullet PRA) - S_{15}] \bullet d'$	1.11
Interior glass	$S_{18} = S_{15}$	1.12
Interior painted wood/plaster walls	$S_{16} = (x \bullet v + z \bullet w \bullet 1) \bullet PRA - x \bullet S_{18}$	1.13
Interior concrete walls	$S_{17} = (y \bullet v + a' \bullet w \bullet 1) \bullet PRA - y \bullet S_{18}$	1.14
Carpeted floor	$S_{19} = (p \bullet k + t \bullet m \bullet 1) \bullet PRA$	1.15
Linoleum floors	$S_{20} = (n \bullet k + r \bullet m \bullet 1) \bullet PRA$	1.16
Wood floor	$S_{21} = (o \bullet k + s \bullet m \bullet 1) \bullet PRA$	1.17
Concrete floor	$S_{22} = (q \bullet k + u \bullet m \bullet 1) \bullet PRA$	1.18
Hard-surface furnishings	$S_{23} = e' \bullet k \bullet PRA / 1000$	1.19
Soft-surface furnishings	$S_{24} = f' \bullet k \bullet PRA / 1000$	1.20
Electronic equipment	$S_{25} = g' \bullet k \bullet PRA / 1000$	1.21
Commercial paper	$S_{26} = h' \bullet k \bullet PRA / 1000$	1.22

NOTE: LUA = land use area; HH = number of households; and PRA = projected roof area.

In one important respect, residential areas are treated differently from industrial and commercial areas. For the latter, the various exterior, horizontal surface areas--both land and structures--are in fixed proportion. On the other hand, the number of residential structures is assumed to depend on the number of households; surfaces that are not a part of the structure--namely, lawns and paved surfaces--are computed as a residual.

Certain conventions are applied in handling paved surfaces. The residential land use does not include roads, which are a separate land use type. However, commercial and industrial properties may contain large paved areas such as loading dock areas and parking areas. These large paved areas are treated in the same way as either concrete or asphalt roads. Parking lots are treated somewhat differently from streets, roads and parking areas.

TABLE E.3.4. Factors and Definitions for Subroutine XFORM

Factor	Definition
a	**commercial/industrial:** ratio of projected roof area to land use area (excluding overhangs) **residential:** projected roof area per housing unit, excluding overhangs (meters)
b	ratio of asphalt road area to land use area
c	ratio of concrete road area to land use area
d	ratio of other asphalt area to land use area
e	ratio of other concrete area to land use area
f	**commercial/industrial:** ratio of lawn area to land use area **residential:** ratio of other asphalt and concrete areas to lawn area
g	ratio of vacant area to land use area
h	ratio of exterior wall area (including glass surfaces) to projected roof area
i	fraction of exterior walls that are brick
j	fraction of exterior walls that are painted wood
k	ratio of floor area to projected roof area
l	fraction of buildings with basements
m	ratio of basement floor area to projected roof area
n	fraction of floor area that is linoleum
o	fraction of floor area that is wood
p	fraction of floor area that is carpeted
q	fraction of floor area that is concrete
r	fraction of basement floor area that is linoleum
s	fraction of basement floor area that is wood
t	fraction of basement floor area that is carpeted
u	fraction of basement floor area that is concrete
v	ratio of interior wall area (including glass surfaces) to projected roof area
w	ratio of basement wall area to projected roof area
x	fraction of interior wall area that is painted wood or plaster
y	fraction of interior wall area that is concrete
z	fraction of basement wall area that is painted wood or plaster
a'	fraction of basement wall area that is concrete
b'	**commercial/industrial:** ratio of projected roof area to actual roof area **residential:** actual roof area (sq meters)
c'	ratio of window area to external wall area
d'	fraction of exterior walls that are concrete
e'	hard-surface furnishings units per 1000 sq meters of floor area
f'	soft-surface furnishings units per 1000 sq meters of floor area
g'	electronic equipment units per 1000 sq meters of floor area
h'	paper products units per 1000 sq meters of floor area

The allocation of the latter is assumed to consist of half asphalt and half concrete by area, whereas parking lots are assumed to consist of 35% asphalt and 65% concrete. The categories "other paved asphalt" and "other paved concrete" refer to smaller exterior paved areas, such as patios, driveways

TABLE E.3.5. Factor Estimates by Land Use Type

Factor	Single-Family Residential	Multi-Family Residential	Commercial	Industrial
a	136.80	101.20	0.70	0.27
b	0.00	0.20	0.20	0.25
c	0.00	0.13	0.13	0.13
d	0.01	0.01	0.00	0.00
e	0.04	0.04	0.00	0.00
f	0.14	0.50	0.00	0.02
g	0.00	0.00	0.00	0.33
h	1.46	1.99	1.20	1.14
i	0.15	0.45	0.00	0.00
j	0.85	0.45	0.00	0.00
k	1.40	1.00	1.80	1.60
l	0.48	0.70	0.40	0.00
m	0.73	0.90	0.90	0.00
n	0.20	0.20	0.54	0.15
o	0.25	0.25	0.00	0.00
p	0.55	0.55	0.24	0.05
q	0.00	0.00	0.22	0.80
r	0.00	0.20	0.20	0.00
s	0.00	0.00	0.00	0.00
t	0.00	0.00	0.00	0.00
u	1.00	0.80	0.80	0.00
v	2.18	2.54	2.22	1.15
w	0.70	0.77	1.30	0.00
x	1.00	1.00	1.00	0.45
y	0.00	0.00	0.00	0.55
z	0.00	0.20	0.20	0.00
a'	1.00	0.80	0.80	0.00
b'	205.58	62.11	1.00	1.00
c'	0.09	0.07	0.06	0.02
d'	0.00	0.10	1.00	1.00
e'	6.34	6.34	19.02	15.85
f'	6.34	6.34	19.02	0.00
g'	6.34	6.34	25.36	12.68
h'	6.34	6.34	31.70	1.27

and carport floors; these are not generally amenable to the decontamination techniques that can be applied at high production rates to roadways.

As we have already noted, the estimation of projected roof area is especially important because it is used in essentially all of the remaining equations. Equations 1.9, 1.10 and 1.11 are an example. They define exterior wall surfaces of painted wood, brick and concrete. Factor h represents the ratio of total exterior wall area to projected roof area, and factors j, i and d' further break down exterior wall areas into painted wood, brick, and concrete surfaces, respectively. Note that in these equations,

the wall area is reduced by the area of the wall that consists of glass--viz., windows and sliding glass doors--as estimated by Equation 1.8.

Equations 1.13 and 1.14 estimate the area of painted wood/plaster and concrete interior wall surfaces. The structure of these equations is analogous to the exterior wall equations. Factor **v** is the ratio of interior wall area to projected roof area, and factor **w** is the ratio of basement wall area to projected roof area. Factors **x**, **y**, **z**, and **a'** indicate the proportions of wall area constructed of painted wood/plaster and concrete.

Equations 1.15 through 1.18 deal with floor surfaces. These equations are not quite as simple as the exterior wall equations. The primary reason is that two types of floors are explicitly estimated: nonbasement floors and basement floors. Factor **k** represents the ratio of nonbasement floor area to projected roof area. In other words, **k** is approximately the average number of floors per housing unit or structure. The factor preceding **k** in the equations is the proportion of nonbasement floor that is comprised of carpet (**p**), linoleum (**n**), wood (**o**), or concrete (**q**). The basement floor surfaces are added to the nonbasement floor surfaces, as indicated by the addition within the parentheses. The three terms on the right side of the plus sign refer to basement floor surfaces. The factor **l** represents the proportion of homes that have basements. Factor **m** is the ratio of basement floor area to projected roof area. Factors **t**, **r**, **s**, and **u** are the fractions of basement floors that are covered with the four materials listed.

The last four equations, 1.19 through 1.22, generate the number of units of building contents (hard-surface furnishings, soft-surface furnishings, electronic equipment, and paper products) per 1000 sq meters of floor area in residential, commercial, and industrial structures. An important characteristic of the four categories making up the building contents group is that they are not themselves homogeneous. This means that some care must be taken to define appropriate units of measurement. For example, hard-surface furnishings in a single-family home typically include such varied objects as a stove, cabinets, tables and so forth.

A useful unit of measurement for building contents is not immediately apparent. Measuring in terms of surface area is not appropriate since the varying shape, weight, and accessibility of the objects suggest that the decontamination effort may not be closely related to surface area. Further complicating the issue is the variation in the types of items in the different land use categories. For example, residential property has relatively more appliances, commercial property has relatively more file cabinets, and industrial property has relatively more machinery.

The approach taken here is to consider the contents of a representative residential unit. An inventory of items is determined for each contents category (hard-surface furnishings, soft-surface furnishings, electronic equipment and paper products). This inventory is then defined as equal to one unit of that contents category. Finally, for each contents category, the relative number of units--measured in terms of <u>decontamination effort</u> per 1000 sq meters of floor area--is estimated for commercial and industrial buildings.

Taking hard-surface furnishings as an example, we first consider the representative collection of such furnishings found in a representative or "average" household. If this representative household is, in fact, representative of the average household within a grid element, then the total number of residential, hard-surface furnishings units within a grid element will be equal to the number of households. Factor **e'** is defined as the number of hard-surface furnishing units per 1000 sq meters of floor area in representative housing units. Thus, **e'** is computed as 1000 sq meters divided by the sq meters of floor area in the representative household. Because units of soft-surface furnishings, electronic equipment and paper products are defined in the same way, the estimated value for **e'** can be used for factors **f'**, **g'** and **h'** as well.

The next step is to estimate the relative number of hard-surface furnishings in terms of decontamination effort per 1000 sq meters of floor area in commercial and industrial buildings. If applying a decontamination operation to the hard-surface furnishings in a representative household takes, say, ten hours, and the same procedure over the same floor area of representative commercial building floor space takes 15 hours, then the commercial property is assumed to have 1.5 times the hard-surface furnishings per sq meter of floor area as do households. If there are 1005 sq meters in the typical commercial structure and 158 sq meters in the representative household, then there would be

$$1.5 \bullet 1005 / 158 = 9.54$$

hard-surface furnishings units in the commercial structure. From these relationships it can be seen that in this example factor **e'**, representing the number of hard-surface furnishing units per 1000 sq meters of commercial property floor area, is

$$9.54 / 1.005 = 9.49$$

Three important assumptions are implicit in this methodology. The first is that the mix of inputs for a decontamination operation does not change from property type to property type. The second assumption is that, as with other operations, the ones considered here are characterized by constant returns to scale; that is, if the quantity of property to be decontaminated increases by some factor θ, then the inputs needed to decontaminate the property also must be increased by the factor θ. Finally, it is assumed that the ratio of effort between any two land use categories is invariant with respect to the decontamination method used. For example, if dusting hard-surface furnishings in 1000 sq meters of commercial space takes 10% more effort than dusting the hard-surface furnishings in 1000 sq meters of residential space, then washing these furnishings in the commercial space is also assumed to take a 10% greater effort.

The methodology embodied in the 22 equations in Table E.3.3 is intended to be flexible and general. Factors can be easily re-estimated to reflect local conditions, and additional surface types can be readily incorporated within the present framework.

E.3.2.2.2 Estimation of Factors. In this section the derivation of the factor estimates is described, and principle information sources are provided. The discussion of the factor estimates generally follows the methodology for estimating surface areas. That is, the first step is to determine the exterior, horizontal surface factors. Then, based on the dimensions of a representative structure for that land use type, the projected roof area is estimated and then the exterior wall area, interior wall area, and floor areas are estimated as proportions of this. Wall and floor surfaces are then subdivided into the specific materials with which they are constructed or covered. For example, once the floor area factor is estimated it is necessary to estimate the proportion which is linoleum, wood, concrete, or carpeted. The factors for surfaces associated with basements are also estimated. Finally, the factors associated with the building contents categories are estimated.

Two important facts regarding the factor estimates should be noted. First, data for estimating the factors are extremely limited, and much of the data that are available provide only indirect information about the factors. Second, the intent of these estimates is to characterize the surface makeup of representative single-family residential, multi-family residential, commercial and industrial areas. For each of these land use categories there is a wide variance in design, construction techniques, land cover, materials, and so forth. Therefore, true factor values for any particular area could differ significantly from the estimates developed here. This suggests that where such differences are large it may be desirable to specify alternate values for these factors.

Both of these difficulties could be addressed, at least to the extent of identifying horizontal exterior surfaces for any particular area, by the use of high quality aerial photographs combined with standard manual or automated aerial reconnaissance techniques. By determining building dimensions and density, it may also be possible to refine estimates of factors for interior surfaces. Such photographs are sometimes available from the United States Geological Survey or from local municipalities, where they are used for zoning, planning, and mapping purposes. In fact, the NRC already has a set of high-quality aerial photographs (transparencies and prints) covering the vicinity around approximately 60 reactor sites. There is one photograph per site, and each covers a square area about 18 km on a side. With good equipment, the transparencies can be used to identify features less than one sq meter in size. Also, they could be scanned and digitized for computer storage and analysis. A major reactor accident, however, could affect areas significantly further away than the area covered by these photographs.

Single-Family Residential Areas. Single-family residential land use areas in this work refer to areas comprised of single-family detached homes and excluding public roads, vacant land and wooded areas. Multi-family units

are considered separately in the next section. Other residential types, such as single-family attached and mobile homes, are not separately addressed.

To be considered first are the factors defining the structural surface areas (roofs, interior and exterior walls, glass surfaces, and floors). The number of roofs is set equal to the number of households within the study area. Next, the dimensions of a typical single-family housing unit are determined. One of these dimensions is the roof area. The dimensions of the structural surfaces are estimated in terms of the projected roof area. Then, the factors associated with wall materials, floor coverings, and building contents are estimated. The remainder of the residential land use area within the study area is then allocated to the other exterior, horizontal surfaces; namely, lawns and other paved asphalt and concrete surfaces.

First, we develop the dimensions of a hypothetical representative house. The two basic measures needed are the average floor space and the average number of floors per home. The number of floors is particularly important for determining the height and, therefore, the area of the exterior walls. The Residential Energy Consumption Survey: Housing Characteristics, 1982 (1984) (cited in Statistical Abstract of the United States 1986) reports that the average floor area of a single-family detached household is 191.5 sq meters (2061 sq ft).

According to the National Association of Home Builders, of the homes completed in 1982, 61% are single story, 33% are two or more stories, and 6% are split level. Assuming that these 1982 figures are not greatly different from those for the housing stock, a weighted average number of floors per house is calculated as follows: Split-level homes are considered to be one story, and homes designated as two or more stories are assumed to be 2.2 stories on average. The relationships for computing the weighted average number of floors are presented in Table E.3.6.

From this table, it is clear that the

$$\text{Average number of floors} = 139.6 / 100 = 1.4$$

Given a total floor area of 191.5 sq meters over 1.4 floors, the area of the projection of the roof, excluding overhangs, on a plane is:

$$\text{Projected roof area} = 191.5 / 1.4 = 136.8 \text{ sq meters}$$

If we assume that the dimensions of the projection are 10 x 13.7 meters, that the ridge of the roof runs over the 10 meter dimension, and that the roof has a slope of 30° with overhangs of one meter on the long side and .67 meter on the short side, then the area of the roof itself is:

$$\text{Roof area} = [2 \bullet ((6.85 + 1) / \cos 30^{\circ}] \bullet [2 \bullet (5 + 0.67)] = 205.6 \text{ meters}$$

TABLE E.3.6. Computation of Number of Floors per Average Single-Family Residence

	Percentage Weight	x	Number of Floors	=	Product
	61		1		61
	33		2.2		72.6
	6		1		6
Total	100				139.6

Factor k, the ratio of nonbasement floor area to projected roof area, is

$$k = 191.5 / 136.8 = 1.40$$

which, by definition, is equal to the average number of floors per housing unit.

Given the exterior building dimensions of 10 x 13.7 meters, the building perimeter is 47.4 meters. Assuming a wall height of 3 meters per story, the average exterior wall height is 3 x 1.4 = 4.2 meters. The total exterior wall area is, therefore, 4.2 x 47.4 = 199.1 sq meters. Factor **h**, the ratio of exterior wall area to roof area, becomes

$$h = 199.1 / 136.8 = 1.46$$

To estimate v, the ratio of interior wall area to projected roof area, we note first that according to the Census Bureau the average number of rooms per home is 5.1. A simple floor plan for a 5-room house is used to develop the interior wall area. This floor plan is shown in Figure E.2. If each room has four walls 2.4 meters (8 ft) high, then total interior wall area is 92.8 x 2.4 = 298.1 sq meters. This estimate will be low to the extent that closets, utility rooms and other small or unheated areas add to wall area. On the other hand, the estimate could be too high if there are open passageways, if the hall area is smaller, and/or if there are half walls. Factor v in terms of projected roof area is

$$v = 222.7 / 136.8 = 2.18$$

All interior walls are assumed to be painted wood or plaster, so factor x is 1.00.

Next we consider basements, focusing first on factor 1, the fraction of homes that have basements. The National Association of Home Builders, in the September 1983 Housing Backgrounder, lists the percentage of new single-family homes built with basements by year. This information is presented in Table E.3.7 and was developed by the U.S. Census Bureau. Reference to the 1970 Census of Housing, Vol. 1, Part 1, Table 22, gives additional information about numbers of housing units with basements by

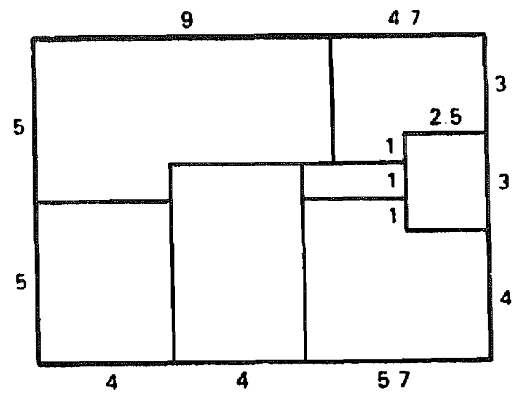

FIGURE E.2. Floor Plan for a Single-Family Residential Structure

region. This is presented in Table E.3.8. The information in these two tables suggests that 0.48 is an acceptable estimate for l. However, the regional figures in Table E.3.8 might serve as a guide for adjusting factor l to address regional conditions.

Factor m represents the size of the basement in relation to projected roof area. Here we have no reliable data; a reasonable estimate is that the average basement floor is an area 10 x 10 meters; this makes it 0.73 times the projected roof area. If the basement consists of a single room with walls 2.4 meters high, then factor w, the ratio of basement wall area to projected roof area, is 96 / 136.8 = 0.70. All basement walls and floors are assumed to be exposed concrete. Therefore, factors u and a' are 1.00.

This completes our estimates of the structural surface areas; these must now be further disaggregated by type of material. For this task there appears to be little or no government-collected data. What data do exist are primarily commercial marketing data. There are two difficulties with this information. First, since it is proprietary, many sources are reluctant to release it. Second, companies are most often concerned with current sales figures rather than data on the existing stock. For example, businesses dealing with floor covering materials are less interested in the percentage

TABLE E.3.7. Percentage of New, Single-Family Houses with Basements, by Year

	1972	1977	1978	1979	1980	1981	1982
Houses with full or or partial basements	37%	44%	42%	42%	36%	33%	31%

Source: National Association of Home Builders, Housing Backgrounder

of total floor area that is carpeted than in the percentage of current sales of floor covering materials accounted for by carpeting.

Roofs of single-family homes are assumed to be of asphalt shingles. This is based on casual observation and on a listing of building materials for a typical 158 sq meter (1700 sq foot) home in the National Association of Home Builders' September 1983 Housing Backgrounder.

In this report we assume that exterior walls of single-family residences are either brick or painted wood. There is apparently no direct quantitative information on the relative usage of brick versus wood siding. The Brick Institute of America reports that 8 to 9 billion bricks per year are sold and, of those, 65% are used in single- and multi-family home construction. It is not clear, however, how much of this goes to exterior wall construction. Of the total brick sales, only about 600 million bricks--less than one-tenth of the total--are used west of the Rocky Mountains, where the hazard of earthquake is considerably larger. We estimate that 15% of exterior walls are brick (factor **i**); the remainder are assumed to be painted wood (factor **j**).

Nonbasement floors are assumed to consist of either wood, linoleum (all resilient floor coverings), or carpet. The floor covering industry seems to be particularly protective of marketing information. However, the Retail Fl r Covering Institute did provide its 1983 Management Report. The sales profile data in this report provide percentage of sales by type of customer (e.g., contractor, residential, industrial/commercial). Also listed is the percentage of sales by product type. Soft-surface products (carpet) comprise 74.9% of sales. Sheet vinyl and resilient tile together account for 13.1% of sales. Hardwood flooring makes up 1.2% of sales. Also listed in this publication is the average price per sq meter of soft-surface products sold on a retail basis ($13.09) and the average price per sq meter for hard-surface products sold on a retail basis ($16.72).

To obtain an idea of the relative areas for different kinds of surfaces, we compare the ratio of percentage of sales to the average cost per sq meter for both hard and soft surfaces. The area of carpet sold was roughly six times the total area of hard surface floor coverings sold. Hard surface coverings include wood, ceramic tile, and resilient floor coverings. Total sales in this group are dominated by sheet vinyl. This material accounts for

TABLE E.3.8. Number of Houses with Basements, by Region

		Region			
	U.S.	North East	North Central	South	West
Basement	36,112,009	14,398,977	14,141,653	4,407,897	3,163,482
Concrete slab	14,358,800	1,040,632	1,971,873	6,668,107	4,678,188
Other	17,228,275	758,253	2,561,706	9,807,562	4,100,754

Source: 1970 Census of Housing, Vol. 1, Part 1, Table 22.

about two-thirds of sales. Hardwood flooring, considering that its price is much greater than sheet vinyl, accounts for less than one-tenth of the area of vinyl.

Additional information comes from a representative of the Wood and Synthetic Flooring Institute. He estimated that in existing homes wood floors are the second most common after carpeted floors. Vinyl surfaces are third. However, he had no quantitative data to indicate the relative shares of these materials. He also provided information about regional differences. In the South, especially in Florida, homes are often constructed on a concrete slab. These homes have no basements and very seldom have wood floors. In other areas, wood joist construction techniques are used. These homes more often have wood floors and basements. This suggests that the regional basement data provided in Table E.3.8 might also be useful for adjusting the floor covering factors.

From the foregoing discussion, the fraction of floor surfaces that is linoleum (n) is estimated to be 0.20. The wood factor (o) is estimated at 0.25, and 0.55 is the estimate for the carpet factor (p).

All nonbasement interior walls are assumed to be painted wood or plaster, so factor **x** has a value of 1.00. Similarly, basement floors and walls are assumed to be concrete, giving factors **u** and **a'** a value of 1.00 also. Finally, 9% of exterior wall area is assumed to be glass, so factor **c'** is 0.09.

Next we turn to building contents including hard-surface furnishings, soft-surface furnishings, electronic equipment, and paper products. For each of these surface types, we consider the relevant contents in a representative household. According to the Residential Energy Consumption Survey: Housing Characteristics, 1982, (U.S. Energy Information Administration 1984; cited in Statistical Abstract of the United States 1986, Table 1318) the average number of square feet per household for all households in the U.S. in 1982 was 1698, or 157.8 sq meters. In what follows, we assume that the number of building contents units per unit of floor area is constant irrespective of the size or type of housing unit. As explained in Section E.3.2.2.1, one unit of a building contents category is defined as the contents in the representative residential unit. Thus, factor **e'**, the number of units of soft-surface furnishings per 1000 sq meters of floor area, is computed as

$$e' = 1000 / 157.8 = 6.34$$

The units of soft-surface furnishings, electronic equipment and paper products are defined similarly. Thus, factors **f'**, **g'**, and **h'** are also equal to 6.34

Specifying the physical inventories of these building contents categories is necessary for two reasons. The first is to estimate the decontamination costs and rates, as discussed in Appendix A. The second reason is to facilitate estimating the relative number of units of each

contents category per sq meter of floor area in commercial and industrial structures.

Hard-surface furnishings in residential structures consist primarily of appliances, nonfabric furniture, and plumbing fixtures. Information on the representative appliance contents of a home is reported by the Residential Energy Consumption Survey: Housing Characteristics, 1982 and presented in Table E.3.9. This table shows the percentage of households with selected energy-using appliances.

We interpret this table to mean that the representative household has 0.309 room air conditioners, 0.271 central air conditioners, etc. Included in the original source, but not shown here, are the percentage of households

TABLE E.3.9. Percent of Households Using Selected Appliances, 1982

Appliance	Percent of Households
Room air conditioner	30.9
Central air conditioner	27.1
Clothes washer	71.4
Clothes drier	59.8
Dehumidifier	9.0
Dishwasher	36.1
Evaporative cooler	4.2
Freezer	37.0
Humidifier	13.5
Microwave oven	20.7
Outdoor gas grill	11.2
Outdoor gas light	1.7
Oven, electric	51.9
Oven, gas	41.7
Portable heater, electric	9.2
Portable heater, kerosene	3.3
Range, electric	53.3
Range, gas	46.6
Refrigerator, frost-free	63.5
Refrigerator, non frost-free	43.2
Water heater, gas	51.1
Water heater, electric	30.4
Water heater, other	4.2
Whole house cooling fan	7.8
Window or ceiling fan	28.0

Source: Residential Energy Consumption Survey: Housing Characteristics, 1982, U.S. Energy Information Administration 1984; cited in Statistical Abstract of the United States 1986, page 734.

with color and black and white television sets. These items are included in the electronic equipment category. Another aspect of this list is that it is not complete in that heating equipment is not included. These are discussed below.

Small appliances such as toasters and blenders also are included neither in this list nor within the definition of hard-surface furnishings used in this report.

Table E.3.10 presents a summary of the types of heating equipment in occupied housing units. For convenience, each heating equipment unit is designated as large or small. Large units include warm air furnace, heat pump, steam or hot water, and fireplaces, stoves or portable heaters. The other items on the list are classified as small. Summing the percentage of housing units with the respective types of heating equipment yields 77.4% having large heating equipment and 22.0% having small heating equipment. As with appliances, this is interpreted to mean that the representative household has 0.774 large heating equipment units and 0.220 small heating equipment units.

Next to be considered is hard-surface furniture in the representative home. Information for this comes from Aaron Rents and Grantree Furniture

TABLE E.3.10. Percent of Occupied Housing Units with Selected Heating Equipment, 1983

Heating Equipment	Percent of Housing Units
Warm air furnace	52.4
Heat pump	2.6
Steam or hot water	16.3
Floor, wall, or pipeless furnace	7.1
Built-in electric units	7.3
Room heaters with flue	4.1
Room heaters without flue	3.5
Fireplaces, stoves, or portable heaters	6.1
None	0.8

Source: U.S. Department of Commerce, Statistical Abstract of the United States 1986, Table 1315, p. 733. Information from the U.S. Bureau of the Census, Census of Housing, 1980, vol. 1; Current Housing Reports, series H150-83, Annual Housing Survey: 1983, part A.