CHAPTER 4

WASTEWATER CHARACTERISTICS

4.1 Introduction

The effective management of any wastewater flow requires a reasonably accurate knowledge of its characteristics. This is particularly true for wastewater flows from rural residential dwellings, commercial establishments and other facilities where individual water-using activities create an intermittent flow of wastewater that can vary widely in volume and degree of pollution. Detailed characterization data regarding these flows are necessary not only to facilitate the effective design of wastewater treatment and disposal systems, but also to enable the development and application of water conservation and waste load reduction strategies.

For existing developments, characterization of the actual wastewaters to be encountered may often times be accomplished. However, for many existing developments, and for almost any new development, wastewater characteristics must be predicted. The purpose of this chapter is to provide a basis for characterizing the wastewater from rural developments. A detailed discussion of the characteristics of residential wastewaters is presented first, followed by a limited discussion of the characteristics of the wastewaters generated by nonresidential establishments, including those of a commercial, institutional and recreational nature. Finally, a general procedure for predicting wastewater characteristics for a given residential dwelling or nonresidential establishment is given.

4.2 Residential Wastewater Characteristics

Residential dwellings exist in a variety of forms, including single- and multi-family households, condominium homes, apartment houses and cottages or resort residences. In all cases, occupancy can occur on a seasonal or year-round basis. The wastewater discharged from these dwellings is comprised of a number of individual wastewaters, generated through water-using activities employing a variety of plumbing fixtures and appliances. The characteristics of the wastewater can be influenced by several factors. Primary influences are the characteristics of the plumbing fixtures and appliances present as well as their frequency of use. Additionally, the characteristics of the residing family in terms of number of family members, age levels, and mobility are important as

is the overall socioeconomic status of the family. The characteristics of the dwelling itself, including seasonal or yearly occupancy, geographic location, and method of water supply and wastewater disposal, appear as additional, but lesser, influences.

4.2.1 Wastewater Flow

4.2.1.1 Average Daily Flow

The average daily wastewater flow from a typical residential dwelling is approximately 45 gal/capita/day (gpcd) (170 liters/capita/day [lpcd]) (Table 4-1). While the average daily flow experienced at one residence compared to that of another can vary considerably, it is typically no greater than 60 gpcd (227 lpcd) and seldom exceeds 75 gpcd (284 lpcd) (Figure 4-1).

4.2.1.2 Individual Activity Flows

The individual wastewater generating activities within a residence are the building blocks that serve to produce the total residential wastewater discharge. The average characteristics of several major residential water-using activities are presented in Table 4-2. A water-using activity that falls under the category of miscellaneous in this table, but deserves additional comment, is water-softener backwash/regeneration flows. Water softener regeneration typically occurs once or twice a week, discharging about 30-88 gal (114 to 333 l) per regeneration cycle (11). On a daily per capita basis, water softener flows have been shown to average about 5 gpcd (19 lpcd), ranging from 2.3 to 15.7 gpcd (8.7 to 59.4 lpcd) (7).

4.2.1.3 Wastewater Flow Variations

The intermittent occurrence of individual wastewater-generating activities creates large variations in the wastewater flow rate from a residence.

a. Minimum and Maximum Daily Flows

The daily wastewater flow from a specific residential dwelling is typically within 10% and 300% of the average daily flow at that dwelling, with the vast majority within 50 and 150% of the average day. At the

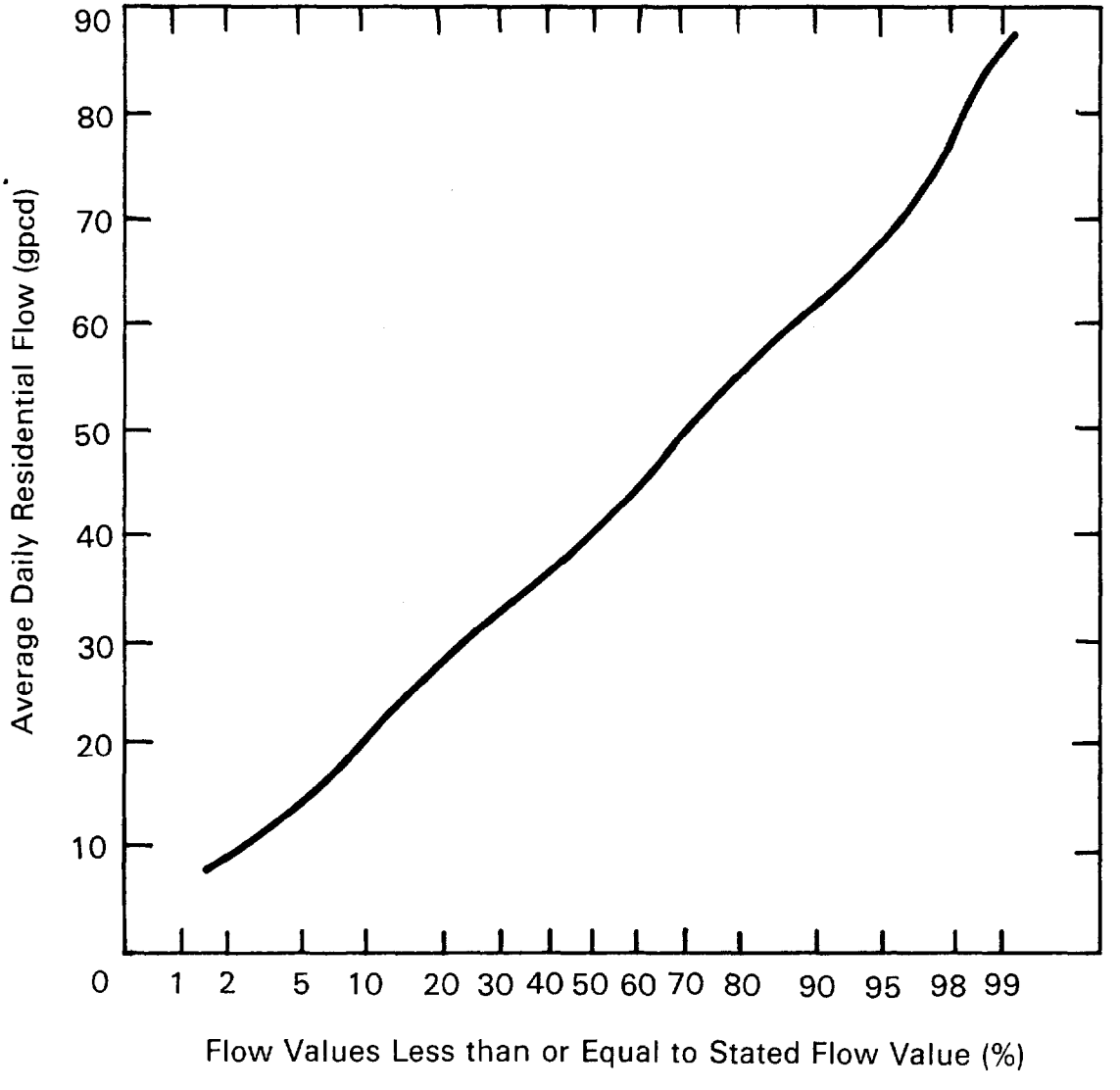
TABLE 4-1

SUMMARY OF AVERAGE DAILY RESIDENTIAL WASTEWATER FLOWS

Study	No. of Residences	Duration of Study months	Wastewater Flow	
			Study Average gpcd	Range of Individual Residence Averages gpcd
Linaweaver, et al. (1)	22	-	49	36 - 66
Anderson and Watson (2)	18	4	44	18 - 69
Watson, et al. (3)	3	2-12	53	25 - 65
Cohen and Wallman (4)	8	6	52	37.8 - 101.6
Laak (5)	5	24	41.4	26.3 - 65.4
Bennett and Linstedt (6)	5	0.5	44.5	31.8 - 82.5
Siegrist, et al. (7)	11	1	42.6	25.4 - 56.9
Otis (8)	21	12	36	8 - 71
Duffy, et al. (9)	16	12	42.3	-
		Weighted Average	44	

FIGURE 4-1

FREQUENCY DISTRIBUTION FOR AVERAGE DAILY
RESIDENTIAL WATER USE/WASTE FLOWS



Note: Based on the average daily flow measured for each of the 71 residences studied in (2) (3) (4) (5) (6) (7) (8).

TABLE 4-2

RESIDENTIAL WATER USE BY ACTIVITY[a]

Activity	Gal/use	Uses/cap/day	gpcd[b]
Toilet Flush	4.3 4.0 - 5.0	3.5 2.3 - 4.1	16.2 9.2 - 20.0
Bathing	24.5 21.4 - 27.2	0.43 0.32 - 0.50	9.2 6.3 - 12.5
Clotheswashing	37.4 33.5 - 40.0	0.29 0.25 - 0.31	10.0 7.4 - 11.6
Dishwashing	8.8 7.0 - 12.5	0.35 0.15 - 0.50	3.2 1.1 - 4.9
Garbage Grinding	2.0 2.0 - 2.1	0.58 0.4 - 0.75	1.2 0.8 - 1.5
Miscellaneous	-	-	6.6 5.7 - 8.0
Total	-	-	45.6 41.4 - 52.0

[a] Mean and ranges of results reported in (4)(5)(6)(7)(10).

[b] gpcd may not equal gal/use multiplied by uses/cap/day due to difference in the number of study averages used to compute the mean and ranges shown.

extreme, however, minimum and maximum daily flows of 0% and 900% of the average daily flow may be encountered (2)(3)(12).

b. Minimum and Maximum Hourly Flows

Minimum hourly flows of zero are typical. Maximum hourly flows are more difficult to quantify accurately. Based on typical fixture and appliance usage characteristics, as well as an analysis of residential water usage demands, maximum hourly flows of 100 gal/hr (380 l/hr) can occur (2)(13). Hourly flows in excess of this can occur due to plumbing fixture and appliance misuse or malfunction (e.g., faucet left on or worn toilet tank flapper).

c. Instantaneous Peak Flows

The peak flow rate from a residential dwelling is a function of the characteristics of the fixtures and appliances present and their position in the overall plumbing system layout. The peak discharge rate from a given fixture/appliance is typically around 5 gal/minute (gpm) (0.3 liters/sec), with the exception of the tank-type water closet which discharges at a peak flow of up to 25 gpm (1.6 l/sec). The use of several fixtures/appliances simultaneously can increase the total flow rate from the isolated fixtures/appliances. However, attenuation occurring in the residential drainage network tends to decrease the peak flow rates in the sewer exiting the residence.

Although field data are limited, peak discharge rates from a single-family dwelling of 5 to 10 gpm (0.3 to 0.6 l/sec) can be expected. For multi-family units, peak rates in excess of these values commonly occur. A crude estimate of the peak flow in these cases can be obtained using the fixture-unit method described in Section 4.3.1.2.

4.2.2 Wastewater Quality

4.2.2.1 Average Daily Flow

The characteristics of typical residential wastewater are outlined in Table 4-3, including daily mass loadings and pollutant concentrations. The wastewater characterized is typical of residential dwellings equipped with standard water-using fixtures and appliances (excluding garbage disposals) that collectively generate approximately 45 gpcd (170 lpcd).

TABLE 4-3

CHARACTERISTICS OF TYPICAL RESIDENTIAL WASTEWATER[a]

Parameter	Mass Loading gm/cap/day	Concentration mg/l
Total Solids	115 - 170	680 - 1000
Volatile Solids	65 - 85	380 - 500
Suspended Solids	35 - 50	200 - 290
Volatile Suspended Solids	25 - 40	150 - 240
BOD_5	35 - 50	200 - 290
Chemical Oxygen Demand	115 - 125	680 - 730
Total Nitrogen	6 - 17	35 - 100
Ammonia	1 - 3	6 - 18
Nitrites and Nitrates	<1	<1
Total Phosphorus	3 - 5	18 - 29
Phosphate	1 - 4	6 - 24
Total Coliforms[b]	-	10^{10} - 10^{12}
Fecal Coliforms[b]	-	10^{8} - 10^{10}

[a] For typical residential dwellings equipped with standard water-using fixtures and appliances (excluding garbage disposals) generating approximately 45 gpcd (170 lpcd). Based on the results presented in (5)(6)(7)(10)(13).

[b] Concentrations presented in organisms per liter.

4.2.2.2 Individual Activity Contributions

Residential water-using activities contribute varying amounts of pollutants to the total wastewater flow. The individual activities may be grouped into three major wastewater fractions: (1) garbage disposal wastes, (2) toilet wastes, and (3) sink, basin, and appliance wastewaters. A summary of the average contribution of several key pollutants in each of these three fractions is presented in Tables 4-4 and 4-5.

With regard to the microbiological characteristics of the individual waste fractions, studies have demonstrated that the wastewater from sinks, basins, and appliances can contain significant concentrations of indicator organisms as total and fecal coliforms (14)(15)(16)(17). Traditionally, high concentrations of these organisms have been used to assess the contamination of a water or wastewater by pathogenic organisms. One assumes, therefore, that these wastewaters possess some potential for harboring pathogens.

4.2.2.3 Wastewater Quality Variations

Since individual water-using activities occur intermittently and contribute varying quantities of pollutants, the strength of the wastewater generated from a residence fluctuates with time. Accurate quantification of these fluctuations is impossible. An estimate of the type of fluctuations possible can be derived from the pollutant concentration information presented in Table 4-5 considering that the activities included occur intermittently.

4.3 Nonresidential Wastewater Characteristics

The rural population, as well as the transient population moving through the rural areas, is served by a wide variety of isolated commercial establishments and facilities. For many establishments, the wastewater-generating sources are sufficiently similar to those in a residential dwelling that residential wastewater characteristics can be applied. For other establishments, however, the wastewater characteristics can be considerably different from those of a typical residence.

Providing characteristic wastewater loadings for "typical" non-residential establishments is a very complex task due to several factors. First, there is a relatively large number of diverse establishment categories (e.g., bars, restaurants, drive-in theaters, etc.). The inclusion of potentially diverse establishments within the same category produces a potential for large variations in waste-generating sources

TABLE 4-4

POLLUTANT CONTRIBUTIONS OF MAJOR RESIDENTIAL WASTEWATER FRACTIONS[a] (gm/cap/day)

Parameter	Garbage Disposal	Toilet	Basins, Sinks, Appliances	Approximate Total
BOD_5	18.0 10.9 - 30.9	16.7 6.9 - 23.6	28.5 24.5 - 38.8	63.2
Suspended Solids	26.5 15.8 - 43.6	27.0 12.5 - 36.5	17.2 10.8 - 22.6	70.7
Nitrogen	0.6 0.2 - 0.9	8.7 4.1 - 16.8	1.9 1.1 - 2.0	11.2
Phosphorus	0.1 0.1 - 0.1	1.2 0.6 - 1.6	2.8 2.2 - 3.4	4.0

[a] Means and ranges of results reported in (5)(6)(7)(10)(14)

TABLE 4-5

POLLUTANT CONCENTRATIONS OF MAJOR RESIDENTIAL WASTEWATER FRACTIONS[a] (mg/l)

Parameter	Garbage Disposal	Toilet	Basins, Sinks, Appliances	Combined Wastewater
BOD_5	2380	280	260	360
Suspended Solids	3500	450	160	400
Nitrogen	79	140	17	63
Phosphorus	13	20	26	23

[a] Based on the average results presented in Table 4-4 and the following wastewater flows: Garbage disposal - 2 gpcd (8 lpcd); toilet - 16 gpcd (61 lpcd); basins, sinks and appliances - 29 gpcd (110 lpcd); total - 47 gpcd (178 lpcd).

and the resultant wastewater characteristics. Further, many intangible influences such as location, popularity, and price may produce substantial wastewater variations between otherwise similar establishments. Finally, there is considerable difficulty in presenting characterization data in units of measurement that are easy to apply, yet predictively accurate. (For example, at a restaurant, wastewater flow in gal/seat is easy to apply to estimate total flow, but is less accurate than if gal/meal served were used.)

In this section, limited characterization data for nonresidential establishments, including commercial establishments, institutional facilities, and recreational areas, are presented. These data are meant to serve only as a guide, and as such should be applied cautiously. Wherever possible, characterization data for the particular establishment in question, or a similar one in the vicinity, should be obtained.

4.3.1 Wastewater Flow

4.3.1.1 Average Daily Flow

Typical daily flows from a variety of commercial, institutional, and recreational establishments are presented in Tables 4-6 to 4-8.

4.3.1.2 Wastewater Flow Variation

The wastewater flows from nonresidential establishments are subject to wide fluctuations with time. While difficult to quantify accurately, an estimate of the magnitude of the fluctuations, including minimum and maximum flows on an hourly and daily basis, can be made if consideration is given to the characteristics of the water-using fixtures and appliances, and to the operational characteristics of the establishment (hours of operation, patronage fluctuations, etc.).

Peak wastewater flows can be estimated utilizing the fixture-unit method (19)(20). As originally developed, this method was based on the premise that under normal usage, a given type of fixture had an average flow rate and duration of use (21)(22). One fixture unit was arbitrarily set equal to a flow rate of 7.5 gpm (0.5 l/sec), and various fixtures were assigned a certain number of fixture units based upon their particular characteristics (Table 4-9). Based on probability studies, relationships were developed between peak water use and the total number of fixture units present (Figure 4-2).

TABLE 4-6

TYPICAL WASTEWATER FLOWS FROM COMMERCIAL SOURCES (18)

Source	Unit	Wastewater Flow gpd/unit Range	Typical
Airport	Passenger	2.1 - 4.0	2.6
Automobile Service Station	Vehicle Served	7.9 - 13.2	10.6
	Employee	9.2 - 15.8	13.2
Bar	Customer	1.3 - 5.3	2.1
	Employee	10.6 - 15.8	13.2
Hotel	Guest	39.6 - 58.0	50.1
	Employee	7.9 - 13.2	10.6
Industrial Building (excluding industry and cafeteria)	Employee	7.9 - 17.2	14.5
Laundry (self-service)	Machine	475 - 686	580
	Wash	47.5 - 52.8	50.1
Motel	Person	23.8 - 39.6	31.7
Motel with Kitchen	Person	50.2 - 58.1	52.8
Office	Employee	7.9 - 17.2	14.5
Restaurant	Meal	2.1 - 4.0	2.6
Rooming House	Resident	23.8 - 50.1	39.6
Store, Department	Toilet room	423 - 634	528
	Employee	7.9 - 13.2	10.6
Shopping Center	Parking Space	0.5 - 2.1	1.1
	Employee	7.9 - 13.2	10.6

TABLE 4-7

TYPICAL WASTEWATER FLOWS FROM INSTITUTIONAL SOURCES (18)

Source	Unit	Wastewater Flow Range	Wastewater Flow Typical
		gpd/unit	
Hospital, Medical	Bed	132 - 251	172
	Employee	5.3 - 15.9	10.6
Hospital, Mental	Bed	79.3 - 172	106
	Employee	5.3 - 15.9	10.6
Prison	Inmate	79.3 - 159	119
	Employee	5.3 - 15.9	10.6
Rest Home	Resident	52.8 - 119	92.5
	Employee	5.3 - 15.9	10.6
School, Day:			
With Cafeteria, Gym, Showers	Student	15.9 - 30.4	21.1
With Cafeteria Only	Student	10.6 - 21.1	15.9
Without Cafeteria, Gym, Showers	Student	5.3 - 17.2	10.6
School, Boarding	Student	52.8 - 106	74.0

TABLE 4-8

TYPICAL WASTEWATER FLOWS FROM RECREATIONAL SOURCES (18)

Source	Unit	Wastewater Flow gpd/unit Range	Typical
Apartment, Resort	Person	52.8 - 74	58.1
Cabin, Resort	Person	34.3 - 50.2	42.3
Cafeteria	Customer	1.1 - 2.6	1.6
	Employee	7.9 - 13.2	10.6
Campground (developed)	Person	21.1 - 39.6	31.7
Cocktail Lounge	Seat	13.2 - 26.4	19.8
Coffee Shop	Customer	4.0 - 7.9	5.3
	Employee	7.9 - 13.2	10.6
Country Club	Member Present	66.0 - 132	106
	Employee	10.6 - 15.9	13.2
Day Camp (no meals)	Person	10.6 - 15.9	13.2
Dining Hall	Meal Served	4.0 - 13.2	7.9
Dormitory, Bunkhouse	Person	19.8 - 46.2	39.6
Hotel, resort	Person	39.6 - 63.4	52.8
Laundromat	Machine	476 - 687	581
Store Resort	Customer	1.3 - 5.3	2.6
	Employee	7.9 - 13.2	10.6
Swimming Pool	Customer	5.3 - 13.2	10.6
	Employee	7.9 - 13.2	10.6
Theater	Seat	2.6 - 4.0	2.6
Visitor Center	Visitor	4.0 - 7.9	5.3

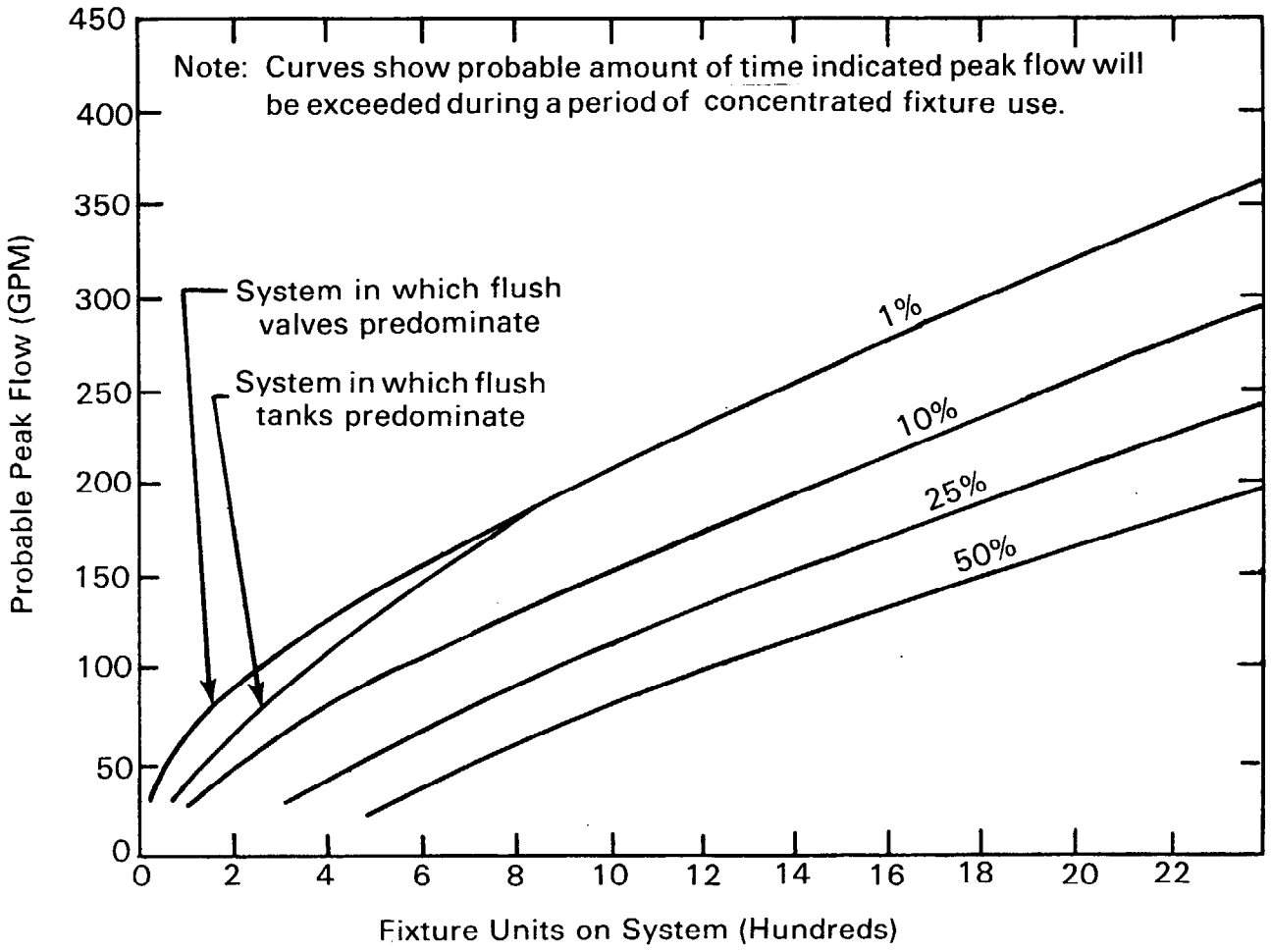
TABLE 4-9

FIXTURE-UNITS PER FIXTURE (19)

Fixture Type	Fixture-Units
One bathroom group consisting of tank-operated water closet, lavatory, and bathtub or shower stall	6
Bathtub (with or without overhead shower)	2
Bidet	3
Combination sink-and-tray	3
Combination sink-and-tray with food-disposal unit	4
Dental unit or cuspidor	1
Dental lavatory	1
Drinking fountain	1/2
Dishwasher, domestic	2
Floor drains	1
Kitchen sink, domestic	2
Kitchen sink, domestic, with food waste grinder	3
Lavatory	1
Lavatory	2
Lavatory, barber, beauty parlor	2
Lavatory, surgeon's	2
Laundry tray (1 or 2 compartments)	2
Shower stall, domestic	2
Showers (group) per head	3
Sinks	
Surgeon's	3
Flushing rim (with valve)	8
Service (trap standard)	3
Service (P trap)	2
Pot, scullery, etc.	4
Urinal, pedestal, syphon jet, blowout	8
Urinal, wall lip	4
Urinal stall, washout	4
Urinal trough (each 2-ft section)	2
Wash sink (circular or multiple) each set of faucets	2
Water closet, tank-operated	4
Water closet, valve-operated	8

FIGURE 4-2

PEAK DISCHARGE VERSUS FIXTURE UNITS PRESENT (22)



4.3.2 Wastewater Quality

The qualitative characteristics of the wastewaters generated by nonresidential establishments can vary significantly between different types of establishments due to the extreme variation which can exist in the waste generating sources present. Consideration of the waste-generating sources present at a particular establishment can give a general idea of the character of the wastewater, and serve to indicate if the wastewater will contain any problem constituents, such as high grease levels from a restaurant or lint fibers in a laundromat wastewater.

If the waste-generating sources present at a particular establishment are similar to those typical of a residential dwelling, an approximation of the pollutant mass loadings and concentrations of the wastewater produced may be derived using the residential wastewater quality data presented in Tables 4-3 to 4-5. For establishments where the waste-generating sources appear significantly different from those in a residential dwelling, or where more refined characterization data are desired, a detailed review of the pertinent literature, as well as actual wastewater sampling at the particular or a similar establishment, should be conducted.

4.4 Predicting Wastewater Characteristics

4.4.1 General Considerations

4.4.1.1 Parameter Design Units

In characterizing wastewaters, quantitative and qualitative characteristics are often expressed in terms of other parameters. These parameter design units, as they may be called, vary considerably depending on the type of establishment considered. For residential dwellings, daily flow values and pollutant contributions are expressed on a per person (capita) basis. Applying per capita data to predict total residential wastewater characteristics requires that a second parameter be considered, namely, the number of persons residing in the residence. Residential occupancy typically ranges from 1.0 to 1.5 persons per bedroom. Although it provides for a conservative estimate, the current practice is to assume that maximum occupancy is two persons per bedroom.

For nonresidential establishments, wastewater characteristics are expressed in terms of a variety of units. Although per capita units are employed, a physical characteristic of the establishment, such as per seat, per car stall, or per square foot, is more commonly used.

4.4.1.2 Factors of Safety

To account for the potential variability in the wastewater characteristics at a particular dwelling or establishment, versus that of the average, conservative predictions or factors of safety are typically utilized. These factors of safety can be applied indirectly, through choice of the design wastewater characteristics and the occupancy patterns, as well as directly through an overall factor. For example, if an average daily flow of 75 gpcd (284 lpcd) and an occupancy of two persons per bedroom were selected, the flow prediction for a three-bedroom home would include a factor of safety of approximately 3 when compared to average conditions (i.e., 45 gpcd [170 lpcd] and 1 person per bedroom). If a direct factor of safety were also applied (e.g., 1.25), the total factor of safety would increase to approximately 3.75.

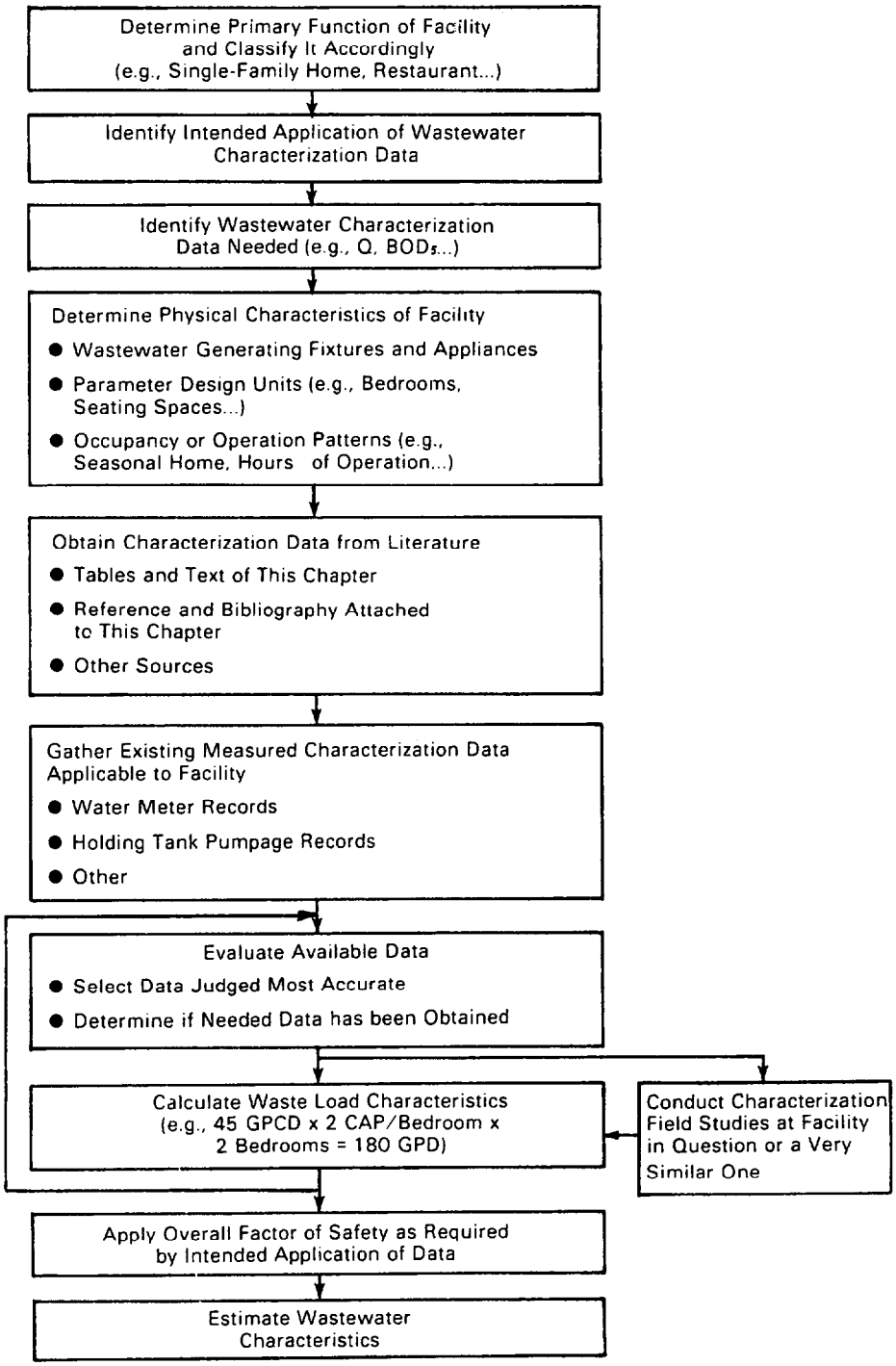
Great care must be exercised in predicting wastewater characteristics so as not to accumulate multiple factors of safety which would yield an extremely overconservative estimate.

4.4.2 Strategy for Predicting Wastewater Characteristics

Predicting wastewater characteristics from rural developments can be a complex task. Following a logical step-by-step procedure can help simplify the characterization process and render the estimated wastewater characteristics more accurate. A flow chart detailing a procedure for predicting wastewater characteristics is presented in Figure 4-3.

FIGURE 4-3

STRATEGY FOR PREDICTING WASTEWATER CHARACTERISTICS



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