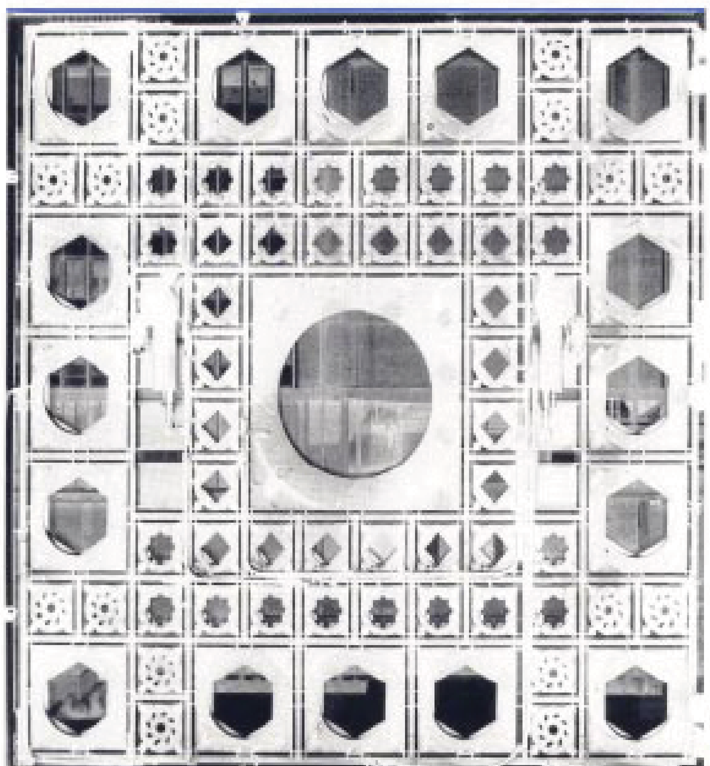
INSIDE Out

Second Edition



DESIGN PROCEDURES FOR PASSIVE ENVIRONMENTAL TECHNOLOGIES

A4–E4 Water

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INTRODUCTION A4.0

Goals

Use the aqueous resources on your site. Use rainwater when possible, conserve fresh (potable) water, and treat and recycle waste water.

Discussion

People once chose the sites for their settlements based, in part, on proximity to potable water. Until storage, plumbing, and water pumping systems were available, water was highly valued. Modern plumbing usually provides adequate quantities of high quality water with little apparent cost. The attitude of present-day water consumers in industrialized nations is much like their attitudes toward electricity and oil before the energy crisis. However, more and more people are realizing that water, too, is a limited resource. Water tables are lowering, urban land is subsiding into depleted aquifers, and regional droughts are affecting larger areas.

Even if water weren't a limited resource, the path it travels is often long, expensive, and environmentally damaging. Murray Milne (1976) describes the process. "Imagine how long it took to move through the stream, lake, river, reservoir, spillway, aqueduct, pump, main, lateral meter, pipe, valve, tube, and faucet before it finally flows out to fill your glass. Now think about the rest of the trip; down the drain, through the trap, out and down into a network of merging pipes and tunnels, and finally through a treatment plant and back into the watercourse."

A very small proportion of our direct consumption of water is actually used for drinking or cooking (approximately 5% of residential consumption). Most of the water we use transports waste. On the average during the course of a year, one person in the U.S. contaminates 13,000 gallons of fresh water to flush 165 gallons of human body waste (Stoner 1977). We also use tremendous amounts of water indirectly. For example, every time architects specify a ton of structural steel for a building they also specify the consumption of 37 tons of water (Vale and Vale 1975).

The costs of water and waste systems are more than the costs to transport the water from its source to your glass, cooking pot, or toilet. Even though most places in the U.S. have abundant water supplies, there is ample evidence to support the need for conservation. Merely reducing the amount used can have a limited effect on potable water's associated costs. More extravagant are those costs associated in support of water and waste systems.

A. The energy used for water pumping is the fastest growing line item in water system budgets. Some experts believe that within ten years, energy shortages will force the legislation of strict water conservation programs in most of the U.S.
B. It is likely that most homeowners spend more money and energy to heat water than they do to acquire the water. Because 4% of our national energy use is for domestic water heating, conserving hot water also means conserving energy.

INTRODUCTION (continued)

C. The monetary, material, land use, and energy costs of building additional waste treatment plants are directly related to the volume of contaminated water to be treated. Recycling water and reducing the amount used to transport waste can obviate the need for more and more waste treatment plants.

In this section you will:

1. Investigate the precedents of water supply and waste disposal in buildings.
2. Document your work through vignette sketches with short annotations.

WATER AND WASTE PRECEDENTS A4.1

Water and Waste Design Strategies

Site-Scale Strategy

- Minimize runoff to encourage recharging the water table.

Cluster-Scale Strategy

- Store water at an elevation higher than it is used; treat waste at lower elevations. Water moving downhill requires no pumping.

Building-Scale Strategies

- Use service spaces, which include toilet and mechanical rooms, to organize the building.
- Isolate toilet spaces acoustically; keep their ventilation patterns unshared by those of other spaces.

Component-Scale Strategy

- Group plumbing fixtures for cost savings and for convenience.
- Use water-efficient fixtures

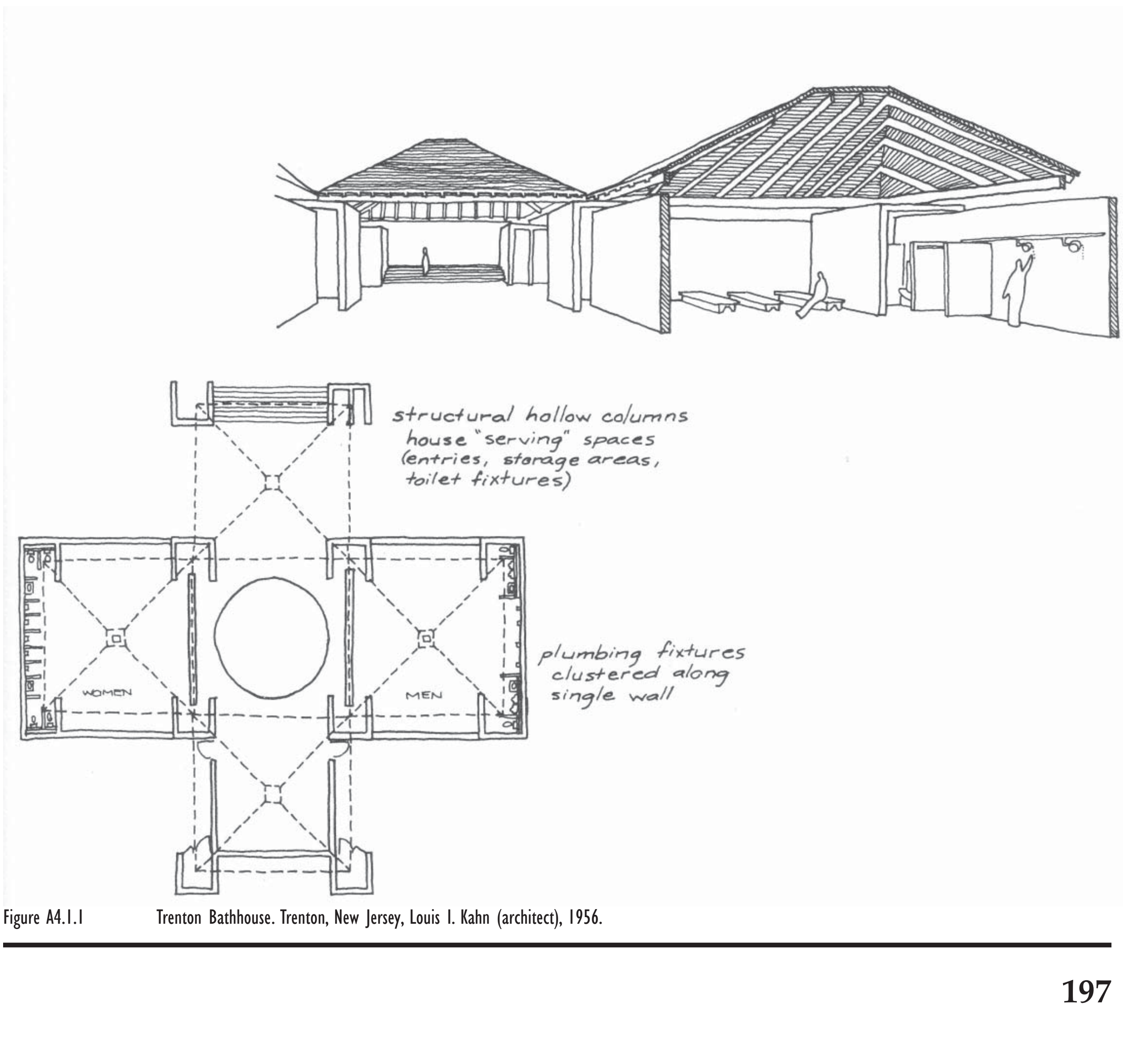

Figure A4.1.1 Trenton Bathhouse. Trenton, New Jersey, Louis I. Kahn (architect), 1956.

WATER AND WASTE PRECEDENTS (continued)

A4.1

Procedure

Choose an existing building or site that has: (1) a building program, aqueous environment, or both that is similar to your assigned building program or site and (2) a clear, conceptual approach that incorporates some of the design strategies above.

Document your choice as follows:

1. Identify the location, program, architect (if known), and source of your information.
2. Include photocopies or drawings (whichever is quick and easy for you) to illustrate the design.
3. Evaluate the building or site design with a building response diagram and short annotations that explain how this design is organized for water and waste.

INTRODUCTION

Goal

Determine your site's resources for water collection and waste treatment and what potential benefits or problems may arise from the climatic conditions on your site. Develop appropriate water-conserving strategies for your building.

Discussion

By determining the availability of water on your site and the drainage characteristics of your soil you can gauge the feasibility of design strategies for collecting water and treating wastes on-site. This information will also help determine the role of water conservation in your design. Sites having dry climates, dry seasons, or poor drainage capacity especially merit water-conserving designs.

Additionally, the site you have been assigned is typical of sites beyond city limits in that it has no city-provided water supply or sewer. For such sites, on-site water supply, water conservation, and on-site water treatment are particularly critical.

In this section you will:

1. Analyze your annual and monthly rainfall patterns.
2. Identify your soil's drainage characteristics.
3. Develop appropriate water collection, waste treatment, and water-conserving strategies.

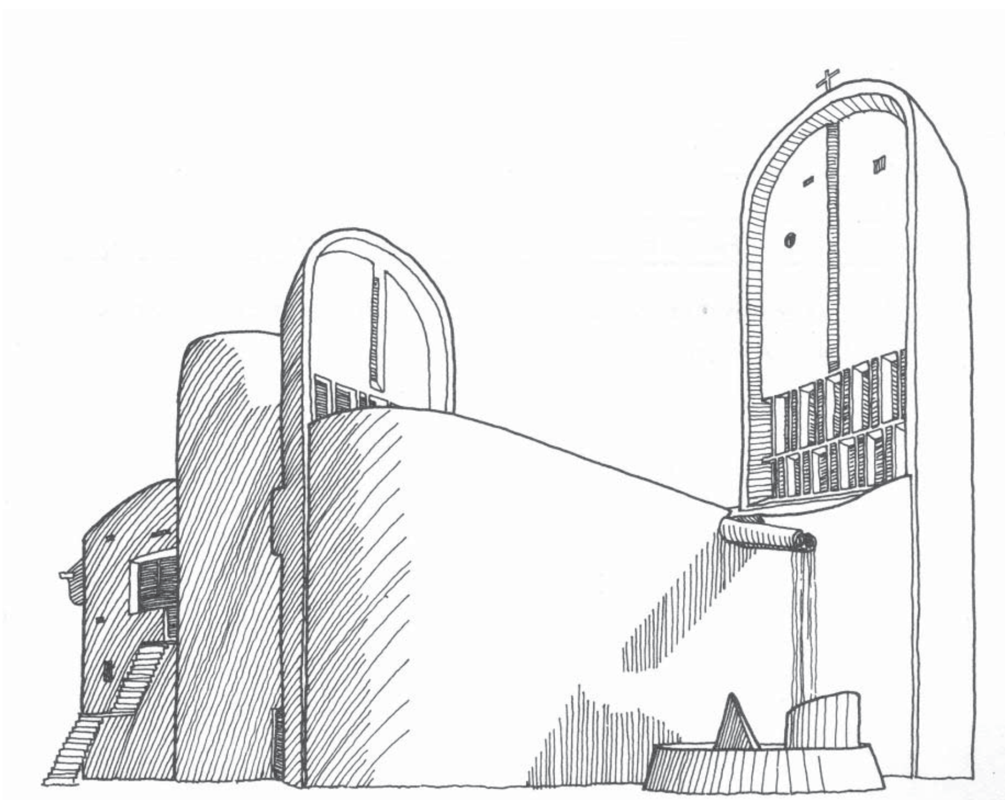

Figure B4.0.1 Scupper and Cistern. Notre Dame du Haut, Ronchamps, France, Le Corbusier (architect), 1950–55.

B4 WATER AND WASTE

CLIMATE AND SITE ANALYSIS — B4

ANNUAL RAINFALL COMPARISONS — B4.1

Discussion

The availability or scarcity of water on your site determines whether on-site, water collection can be effective and which water-conservation strategies are appropriate and applicable.

Procedure

1. Determine your location's annual rainfall [You can find the Palmer Drought Data for a specific year(s) for your climate on the NOAA website <http://www.ncdc.noaa.gov/onlineprod/drought/main.html>]. Determine whether the rainfall is unusually low, average, or unusually heavy [*MEEB*, Figure 20.7, p.878].

2. Print out the Palmer Drought Data or plot the monthly rainfall data on the bar graph below. Identify any wet or dry seasons.

Monthly Rainfall Bar Graph

Average Rainfall (in inches) per Month

10												
9												
8												
7												
6												
5												
4												
3												
2												
1												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec

3. Discuss the implications of your findings in terms of the importance and feasibility of water collection and conservation.

SOIL CHARACTERISTICS

Discussion

Your site's soil characteristics determine the feasibility of on-site, waste-water treatment since soil type determines the requisite size of the drainage field. The more porous the soil, the smaller the drainage field. In locations with poor drainage, water-conservation strategies are imperative.

For more information

MEEB, Section 22.6(a), pp.1029–1037 (discussion and examples of on-site, waste treatment for small buildings). *GSH* Waste and Water pp. 227–264.

Procedure

1. Identify your site's soil type.

Soil Characteristics

Location	Soil Type	Drainage
Minneapolis Denver	sandy loam or sandy clay	medium to good drainage
Phoenix	coarse sand or gravel	excellent drainage
New Orleans Eugene	clay with large amounts of sand or gravel	medium to poor drainage

2. Discuss the implications of the site's soil type and its ability to support on-site, waste-water treatment.

SITE CONCEPTS

Discussion

You have gained some insights about the water and waste environment of your site that will help you propose strategies appropriate to your site and program for conserving and collecting water and for treating wastes on-site. These concepts should be expressed in the form of very simple, annotated diagrams, which are the most appropriate level of detail for this stage of the design process. Show the approximate size and placement of buildings and the water and waste features on the site.

Procedure

1. Diagram each site design.
2. Annotate the drawings to explain the water and waste considerations.
3. Discuss the potential benefits and disadvantages of your water and waste proposal with respect to views, thermal control, and daylighting, and acoustics.

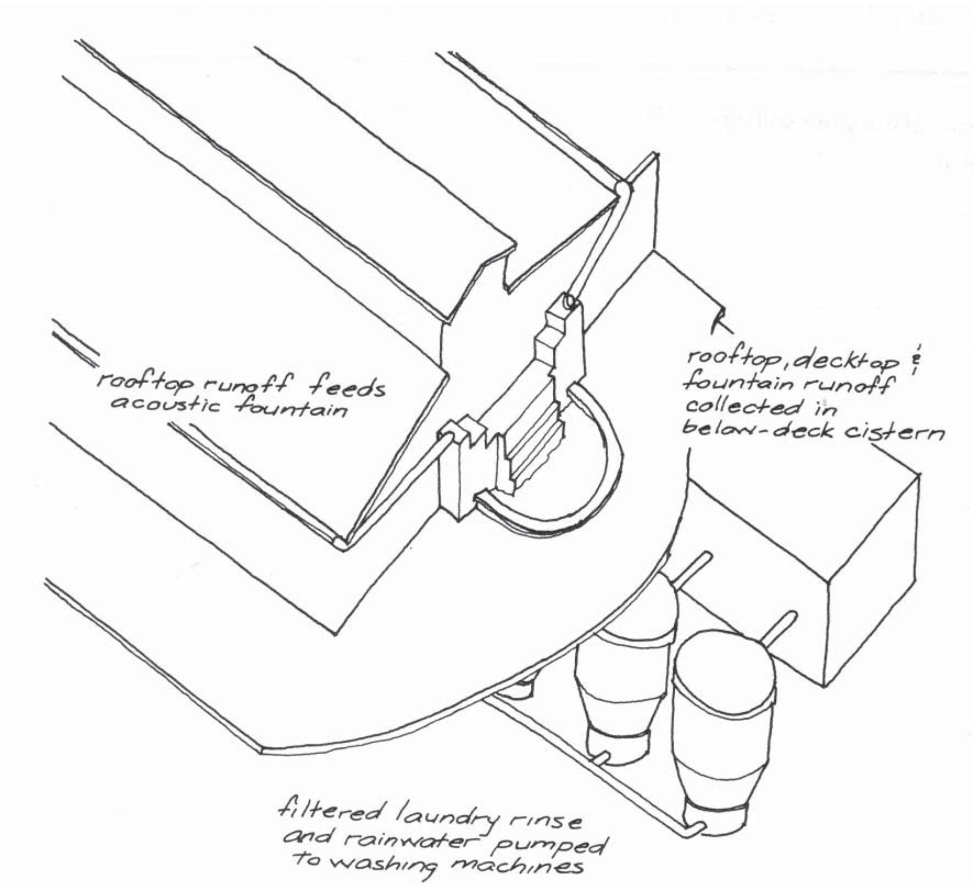

Figure B4.3.1 Water Conservation Measures. Linen supply, Charleston, South Carolina.

C4 WATER AND WASTE

PROGRAM ANALYSIS

INTRODUCTION

Goal

Determine the basic plumbing requirements for your building, estimate its conventional water use and waste production, and develop conserving design strategies.

Discussion

By determining conventional patterns of water use and waste production for your building type, you can determine how best to conserve water and recycle wastes. Since your water and waste schemes may seriously affect your building design and layout, it is best to consider them early in the design process. Additionally, the number and types of plumbing fixtures required by your building govern the size of certain building spaces, and the efficient layout of plumbing in the building affects the overall organization of building spaces.

In this section you will:

1. Determine the minimum required number and types of plumbing fixtures for your building.
2. Estimate the total water use of your building based on conventional design strategies.
3. Determine how much and what sorts of solid waste the occupants of your building will produce.
4. Generate a schematic water and waste design concept for your building and site.

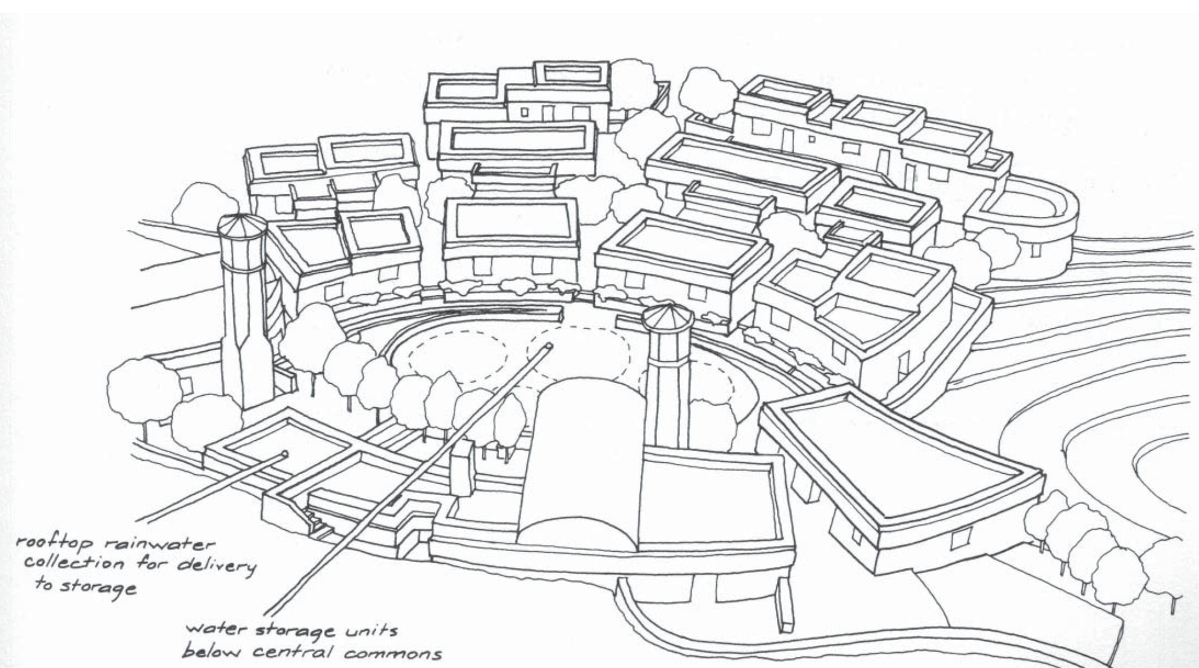

Figure C4.0.1 Foundation School (project). Ojai, California, Sim van der Ryn (architect), 1991.

C4 WATER AND WASTE

PROGRAM ANALYSIS

MINIMUM REQUIRED PLUMBING FIXTURES

C4

C4.1

Discussion

The function and population of your building determine the required number and types of plumbing fixtures you need. Plumbing codes specify required numbers of drinking fountains and toilet room facilities according to building occupancy, so your peak occupancy will be a determining factor. Since men and women are equally likely to use or occupy the building, two-thirds of the total population should be accommodated by either sex's toilet rooms. In addition, other plumbing fixtures may be needed to meet the requirements of your building program (e.g., vending machines, washing machines).

Procedure

1. Determine the minimum required number of drinking fountains and toilet room fixtures for your building type [*MEEB*, Table 20.3, pp.874].
   a. State the number of occupants during peak hours.
   b. If you decide to exceed the minimum number of fixtures or work with off-peak occupancy, explain your rationale.
2. Determine the number and types of any additional plumbing fixtures that your building program requires.
   a. State the number of users during peak hours.
   b. If you decide to exceed the minimum number of fixtures or work with off-peak occupancy, explain your rationale.
3. Determine whether the waste water from these fixtures is potentially recyclable for other uses in your building or on-site [*MEEB*, Table 22.12 or Figure 22.1, pp.1057 or 1000].

Required Plumbing Fixtures [suggested format]

Fixture Type	Men	Women	Either	Recyclable?
low-flush w/c	*5*	*5*	*-*	*no—black water*
drinking fountain	*-*	*-*	*2*	*yes—grey water*

C4
C4.2

PROGRAM ANALYSIS

CONVENTIONAL FIXTURE AND WATER USE ESTIMATE

Discussion

Based on your building type and occupancy, you can estimate the daily water use. The estimate is based on conventional water use practices and will serve as a basis for comparison as you develop water-conservation strategies.

Procedure

1. Determine the per capita daily water use for your building type [Table C4.2.1 (1997 data) or *MEEB*, Table 20.2, pp.872 (1975 data)]. Residential per capita use averages 69 gallons/day indoors (45 gpd for conserving households with 1.6gpf toilets) and 32 gallons/day outdoors. For building types not listed in the tables, make an educated guess based on similar building types and your program information. To more accurately determine your water use, divide your building into a few zones.

2. Multiply the per capita daily water use by the total building population to determine the total water use.

Water Use Estimate [suggested format]

Space	Per Capita Use (gallons/day)	# People	TOTAL (gallons/day)
executive washroom	*35*	*3*	*105*

CONVENTIONAL FIXTURE AND WATER USE ESTIMATE

Table C4.2.1

Water Use Benchmark Data for 1996

Estimates based on surveys of facilities

Facility	gpcd	ged
Airports (per passenger)	5	
Apparel and accessory stores		68
Auto dealers and service stations		49
Auto repair, services and parking		217
Amusement and recreation service		427
Bathhouses and swimming pools	10	
Camps	15-100	
Construction		21
Country clubs (per member)	25	
Dentist offices		259
Depository institutions		59
Factories (per employee per shift, excluding industrial waste water)	35	
Food stores		98
Health services		91
Highway rest area (per person)	5	
Hotels (two persons per room, private bath)	60	
Hotels (without private bath)	50	
Hotels and other lodging places		230
Hospitals (per bed)	300	
Laundromat (self-service, per customer)	50	
Manufacturing		133
Mobile home (per hook-up)	250	
Movie theatre (per patron)	5	
Museums, zoos, botanical gardens		208
Nondepository institutions		156
Nursing homes		197
Public administration		106
Restaurants (per patron)	2-10	
Retail stores (per restroom)	400	
Retail trade		93
Schools, boarding (per pupil)	100	
Schools, day (per pupil)	15-25	
Service stations (per vehicle)	10	
Shopping center (per 1,000 sqft of floor area)	300	
Social services		106
Wholesale durable goods		29
Wholesale non-durable goods		87
gpcd = gallons per capita per day; ged = gallons per employee per day		

Source: *Handbook of Water Use and Conservation*, Vickers, 2001

C4 WATER AND WASTE

PROGRAM ANALYSIS

SOLID-WASTE RESOURCE ESTIMATE

Discussion

You can estimate, based on your building type and size, how much and what types of solid waste your occupants produce. By establishing early in the design process what may be recycled, you can better generate a design that allows for convenient waste sorting, storage, and disposal.

Procedure

1. Estimate the amount of solid waste produced in your building [*MEEB*, Tables 23.1 & 23.2, pp.1066–1067].
2. Determine the potential for recycling the solid waste. List the types of waste resources produced, and propose a recycling method for each [*MEEB*, Figures 23.3–23.8, pp.1072–1077].

   NOTE: Certain plastics and paper products are also recyclable.

Solid-Waste Resource Recycling Potential [suggested format]

Waste Resource	Amount per Day	Recycling Method
newspapers	*2*	*recyling center*
aluminum	*50 cans*	*recyling center*
food scraps	*40 lb*	*composting*

WATER AND WASTE STRATEGIES

Discussion

Your investigations of where water is used and what wastes are produced should indicate the potential for water conservation and solid-waste recycling for your building. Keep in mind that clustering plumbing fixtures can simplify water use design. Moreover, water and solid-waste streams through the building represent circulation paths that affect the building's layout and position on the site.

Procedure

1. Diagram your concept, showing optimum plumbing and solid-waste management configurations. *MEEB*, Figures 23.6 and 23.7, pp.1075–1076, show examples of system schematic diagrams.
2. Annotate your diagram to indicate the water and waste strategies used and your rationale.
3. Discuss conflicts and harmonies in your design among water and waste, acoustic, lighting, and thermal needs.

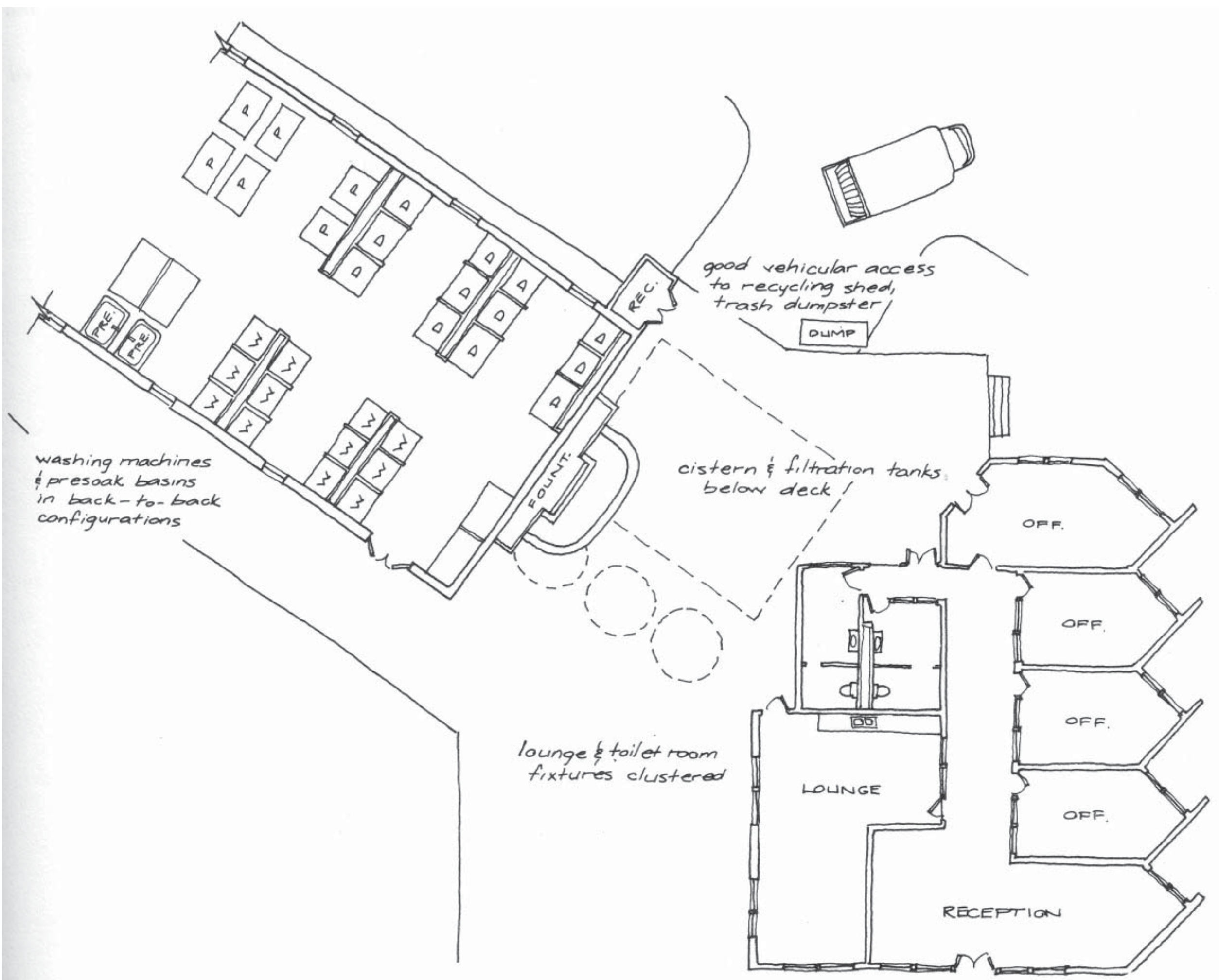

Figure C4.4.1 Schematic Water and Waste Design. Linen supply, Charleston, South Carolina.

D4 WATER AND WASTE

SCHEMATIC DESIGN

INTRODUCTION

Goals

Design a building that synthesizes the information you have acquired through the study of precedents; the analyses of your site, climate, and program requirements; and the application of water and waste design strategies. Use the site and building to the greatest degree possible to heat water, collect rainwater, and dispose of wastes.

Water and Waste Schematic Design Goals

A. Potable-water use and waste-water production are minimized through conservation and recycling.
B. At least 50% of the hot water is heated by solar collectors.
C. Adequate rainwater collection and storage are provided.
D. The septic tank and drainfield adequately treat the waste generated on-site.
E. Composting toilets meet the program requirements.
F. Facilities for solid-waste recycling are on-site.

Discussion

It is important to know if your site's climate is generally wet or dry or if it changes seasonally. Incorporate the effects of climate during the schematic design phase.

In this section you will:

1. Employ appropriate water and waste design strategies.
2. Compare a conventional water system for your building with a water-conserving system.
3. Size water and waste components (solar collectors, cistern, and septic field).
4. Evaluate whether composting toilets are appropriate for your building.
5. Layout a solid-waste recycling center.
6. Review and critique your design.

Water and Waste Schematic Design Strategies

Site-Scale Strategies

- Locate the septic tank and drainfield at an elevation lower than the building's.
- Use the naturally irrigated area over the drainfield as a flat, unpaved, open area for views or activities.
- Keep trees and shrubs away from drainfields. Roots may block the lines.
- Do not use the drainfield for parking.
- Provide adequate clearances from septic tank and drainfield to other site elements [*MEEB*, Table 22.9, p.1033].

Cluster-Scale Strategies

- Arrange roof slopes so rainwater converges at a single location above the cistern inlet.
- Celebrate the water flow from the collection area to the storage area.
- Group the water-using fixtures adjacent to, but at a lower elevation than, the storage area.

Building-Scale Strategies

- Use solar, hot-water collectors to shade the roof if they aren't integrated with the roof.
- Provide convenient access to the collection chamber below composting toilets for easy, regular compost removal.
- Provide adequate, solid-waste storage space with convenient access to the service entry.

Component-Scale Strategies

- Use water-conserving fixtures.
- Recycle water for other uses.
- Provide unshaded south-facing exposure for solar collectors; set them at an angle above the horizontal equal to or less than your site's latitude.

Procedure

Propose a schematic design for your building based on analyses of precedent [A4], site and climate [B4], and program [C4]. Use the appropriate water and waste design strategies for your design. Rely solely on the resources on-site for your water and waste systems—assume that on-site water collection and storage will meet your supply needs and that a septic tank, drainfield, and composting toilets will handle waste.

Document your design as follows:

1. Site plan or cluster plan, showing building, parking, drives, and, depending on your water and waste systems, cistern, rain collection areas, septic tank, drainfield, and solar collectors (scale: 1" = 100').
2. Floor plans, showing location of hot water storage, toilet rooms, plumbing lines, and solid-waste recycling space (scale: 1" = 20').
3. Building section, showing solar collectors, hot water storage, plumbing lines, cisterns, and composting toilets (scale: $^1/_8$" = 1'-0").

CONVENTIONAL WATER SYSTEM D4.2

Discussion

You have already determined your building's minimum required plumbing fixtures [C4.1] and estimated your conventional fixture water use [C4.2]. Now determine how your system would work as a conventional system, and identify ways to improve your design through conservation.

The supply fixture unit value determines the share of the total water use for each fixture. It is a unitless, weighted ratio based on the average comparative use of various plumbing fixtures. The number of gallons per day that one fixture unit represents varies from one plumbing system design to the next.

Procedure

Evaluate how well your building attains Water and Waste Schematic Design Goal A—**Potable-water use and waste-water production are minimized through conservation and recycling.**

1. List the number and types of fixtures in your building [C4.1], and assign each fixture a weight in conventional supply fixture units [*MEEB*, Table 21.15, p.991].

   > NOTE: For fixtures not listed in *MEEB*, Table 21.15, the number of fixture units may be estimated based on fixtures that use water in similar quantities at similar rates. Alternately, if a gallons-per-day figure for the fixture can be estimated, the weight in fixture units may be calculated from the equation in step 3. For these buildings you must determine fixture units now, and use those values in D4.3.

2. Determine how many gallons per day per supply fixture unit your building requires.

   GPFU = (WU) / (fu)

   where:

   GPFU = gallons/day/supply fixture unit

   WU = total conventional water use (gallons/day) [C4.2]

   fu = total number of conventional supply fixture units

SCHEMATIC DESIGN

CONVENTIONAL WATER SYSTEM (continued)

3. Determine how many gallons per day each supply fixture uses.

   GPF = (GPFU) (FU)

   where:

   GPF = gallons/day/fixture

   GPFU = gallons/day/supply fixture unit [step 2]

   FU = weight in supply fixture units

Conventional Supply Fixture Estimates [suggested format]

Fixture	Conventional Supply Fixture Units	gallons/day
3 tank-type, flush toilets	5	75

4. Draw a schematic diagram of how your system would operate as a conventional system based on Figure D4.2.1. You know input gallons per day, estimate output gallons per day (the two aren't necessarily equal).

5. Discuss whether your strategy is appropriate, and indicate any design changes you view as necessary to meet Goal A.

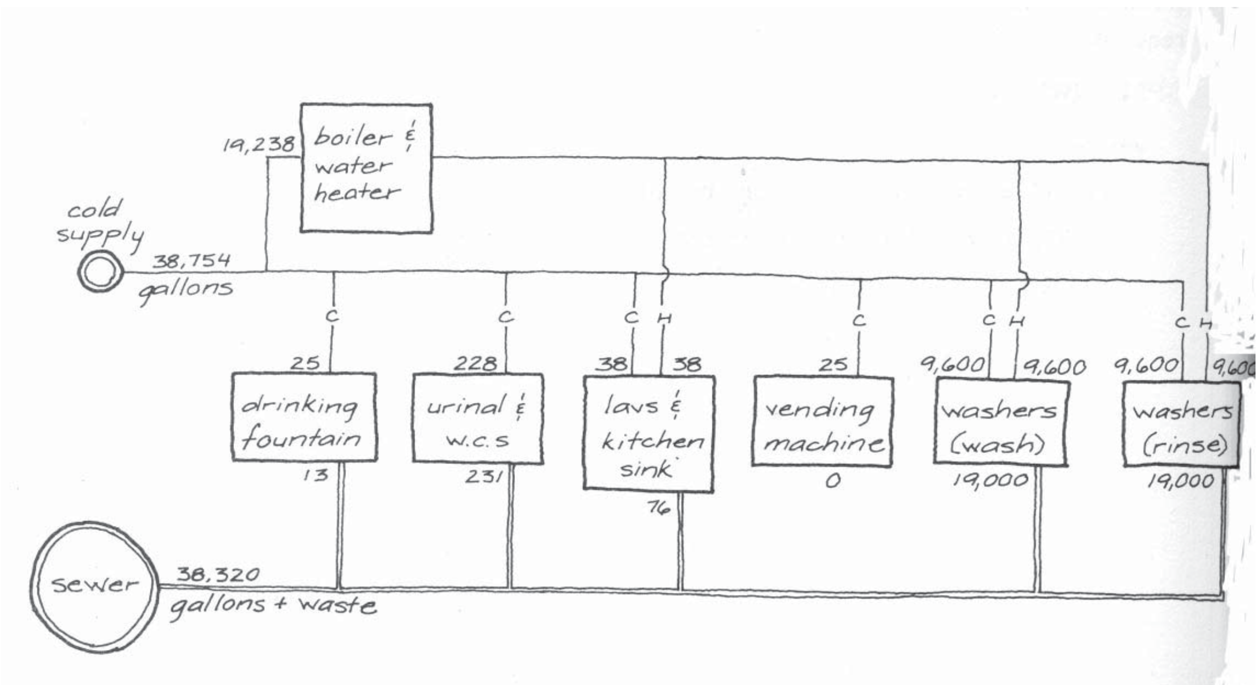

Figure D4.2.1 Conventional Water System Design Diagram

SCHEMATIC DESIGN

WATER-CONSERVING SYSTEM

Discussion

The conventional plumbing system you designed [D4.2] reveals the expected water use for each fixture and, more important, establishes the value in gallons per day for a single supply fixture unit. This value remains the same for the conserving plumbing system. To determine the water use of the individual conserving fixtures and of the entire conserving system, the supply fixture unit value for the conserving fixtures must be adjusted to compensate for reduced use.

Your conservation strategies should include conserving fixtures and recycling water [C4.1 and *MEEB*, Section 22.1, pp.999–1005]. For new buildings the government stands for fixtures are outlined in Table D4.3.1 on the next page. For remodeled buildings, the date of construction or plumbing upgrade gives a clue to water usage, especially for toilets as some jurisdictions enacted water use regulations before the Federal standards were enacted. See Table D4.3.2 for more information.

Toilet Water Use Based on Date of Manufacture or Installation

Year of Maufacture	Gallons/Flush
1994-Present	1.6
1980–1993	3.5
1950–1979	5.0
Pre-1950	7.0

Procedure

Evaluate how well your building attains Water and Waste Schematic Design Goal A—**Potable-water use and waste-water production are minimized through conservation and recycling.**

1. Outline a conservation strategy that includes conserving fixtures, flow restricters, and recycling.

2. Calculate conservation supply fixture units for each fixture.

$$FU_{cons} = (FU_{conv}) [(use_{cons}) / (use_{conv})]$$

where:

FU_{cons} = weight in conservation fixture units for the fixture

FU_{conv} = weight in conventional fixture units for the fixture

use_{cons} = water use by conserving fixture (gallons)

use_{conv} = water use by conventional fixture (gallons)

For example, a private 1.6 gpf tank toilet replaced by a dual flush 1.6/1.0 gpf (ave = 1.2 gpf) yeilds

$$FU_{cons} = (2.2) [(1.2) / (1.6)] = 1.65$$

Table D4.3.1

Federal Maximum Water-Use Requirements for Toilets, Urinals, Showerheads, and Faucets

Fixture	Maximum Water Use Allowed	Date Standard Became Effective*
Toilets (Water Closets)		
Gravity-tank	1.6 gpf	1/1/94
Gravity-tank, white, two-piece,	3.5 gpf	1/1/94 to 12/31/96
Labeled "Commercial Use Only"	1.6 gpf	1/1/97
Flushometer-tank	1.6 gpf	1/1/94
Flushometer-valve (except blowout-valve)	1.6 gpf	1/1/97
Blowout-valve	3.5 gpf	1/1/94
Electromechanical hydraulic	1.6 gpf	1/1/94
Urinals		
Any type	1.0 gpf	1/1/94
Showerheads		
Any type (except those used for safety reasons)	2.5 gpm (at 80 psi) or 2.2 gpm (at 60 psi)	1/1/94
Faucets and Replacement Aerators		
Lavatory faucets	2.5 gpm (at 80 psi) or 2.2 gpm (at 60 psi)	1/1/94
Lavatory replacement aerators		
Kitchen faucets		
Kitchen replacement aerators		
Metering Faucets	0.25 gpc (at 80 psi)	

* Some states required low-flush toilets at an earlier date. See Table D.3.4.2.
gpf = gallons per flush; gpm = gallons per minute; psi = pounds per square inch; gpc = gallons per cycle

Source: *Handbook of Water Use and Conservation*, Vickers, 2001

Table D4.3.2

Early adopters of low-flush (1.6 gpf) toilets	
State	**Effective year**
Massachusetts—New two-piece toilets All others	1989 1991
Rhode Island—New two-piece toilets All others	1990 1991
Delaware, New Jersey, Utah	1991
California, Connecticut, Georgia, Maryland, New York, Texas	1992
Arizona, Minnesota, Nevada, North Carolina, Oregon, Washington	1993
All states (per US EPA Policy Act of 1992)	1994

Source: *Handbook of Water Use and Conservation*, Vickers, 2001

WATER-CONSERVING SYSTEM (continued)

3. Determine how many gallons per day each supply fixture uses.

   $GPF = (GPFU)\ (FU_{cons})$

> NOTE: Alternately, the conservation fixture units may be determined according to how many gallons per day the fixture uses.

Conservation Fixture Estimates [suggested format]

Fixture	Conservation Supply Fixture Units	gallons/day
3 low-flush toilets	2.5	37.5

4. Draw a schematic diagram of your water-conserving system. Discuss why your strategy is appropriate, and indicate any design changes you view as necessary to meet Goal A.

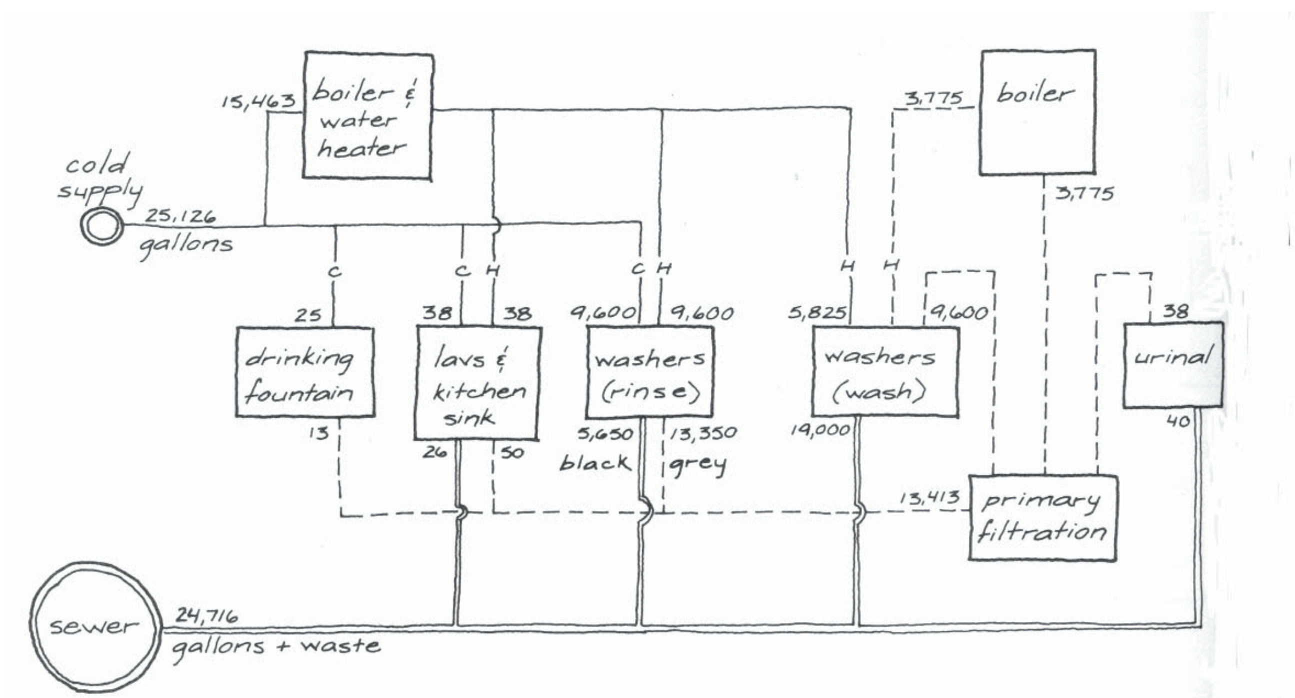

Figure D4.3.1 Water-Conserving System Design Diagram

SOLAR COLLECTOR SIZING ESTIMATE

Discussion

The type of solar, hot-water system you choose affects the sizing of your solar collectors and the placement of plumbing components. Systems are classified as either "passive" (reliant on gravity for circulation) or "active" (pumps used for circulation) and either "direct" (hot water used in the building is circulated through the collector) or "indirect" (heat is transferred from the collector to the stored hot water by means of another fluid). From the simplest, direct, passive or "batch" system to the more complex active, indirect systems, there is a broad range of available systems, each with advantages and disadvantages [*MEEB*, Section 21.6(i), pp.946–959].

System efficiency is also affected by the seasonal availability of insolation on your site, which will be accounted for in E4.6 and E4.7.

Procedure

Evaluate how well your design attains Water and Waste Schematic Design Goal B—**At least 50% of the hot water is heated by solar collectors.**

1. Choose an appropriate solar hot water system [*MEEB*, Table 21.11, p.950].
2. Estimate hot water storage tank size based on hot water needs [D4.3]. The storage tank must be large enough to meet the peak hourly hot water use.
3. Estimate solar collector size based on your hot water system type according to the following rules-of-thumb:
   - Batch Systems: .45–.65 ft^2 collector area/gallon of water stored
   - Other Systems: .65–1.0 ft^2 collector area/gallon of water stored

     (The lower figure applies to warmer climates.)
   - Swimming Pools: .5 ft^2 collector area/1.0 ft^2 of pool surface area
4. Discuss whether your solar water heating strategy is appropriate, and indicate any design changes you view as necessary to meet Goal B.

SCHEMATIC DESIGN

CISTERN SIZING ESTIMATE

Discussion

Rainwater is suitable anytime potable water is not required (e.g., toilet flushing, laundry, site irrigation). The catchment area, generally all or part of the roof, will deliver 75% of the rainfall it receives. The remainder is lost to evaporation, spillage, or contamination. A comparison of your monthly water needs and the monthly rainfall catchment can help you gauge the effectiveness of rainfall storage as a design strategy for your building.

Procedure I

Evaluate how well your design attains Water and Waste Schematic Design Goal C—**Adequate rainwater collection and storage are provided.**

1. Determine your average monthly water use based on your daily water use estimate [D4.3] for a 31-day month.
2. Determine your average annual rainfall catchment in gallons [*MEEB*, Figure 20.5, p.873].

   > NOTE: Assume the roof catchment area equals the corresponding ground floor area. Total precipitation equals two-thirds of the annual precipitation [Appendix C, Climatological Data]. These data give "dry year" or worst-case "design" precipitation.

   For very low levels of rainfall, use the formula

   $G = [(P)\ (A)] / (2.15)$,

   where:

   G = rainfall collected (gallons)

   P = total precipitation (inches)

   A = roof catchment area (ft^2).

3. Determine your average monthly rainfall catchment.
4. Discuss whether your design provides adequate catchment area, and indicate what design changes you deem necessary to meet Goal C.

PROCEDURE 2

1. Determine your cistern capacity in gallons based on the following rules-of-thumb:

   a. If the average monthly catchment exceeds the average monthly use,

   G = (U) (1.5),

   where:

   G = cistern capacity (gallons)
   U = average monthly use (gallons).

   b. If the average monthly use exceeds the average monthly catchment,

   G = 2C,

   where:

   C = average monthly catchment (gallons).

2. Determine your cistern volume.

   V = G / (7.48)

   where:

   V = cistern volume (ft^3)

3. Propose dimensions for your cistern (it should be at least 5 feet deep), and indicate schematically its placement in your design. Discuss any design changes necessary to accommodate your cistern and to meet Goal C.

D4 WATER AND WASTE

SCHEMATIC DESIGN

SEPTIC TANK AND DRAINFIELD SIZING I

Discussion

Waste-plumbing system design is based on drainage fixture units. Like supply fixture units, they are unitless ratios. The values are not equal to supply fixture unit values of comparable fixtures. In your water-conserving system, fixtures that recycle water or use no water will have drainage fixture unit values of zero because they produce no waste.

Procedure

Evaluate how well your design attains Water and Waste Schematic Design Goal D—**The septic tank and drainfield adequately treat the waste generated on-site.**

1. Determine the number of drainage fixture units in your conserving plumbing system [D4.3 or *MEEB*, Table 22.2, p.1017].

2. Determine the minimum septic tank capacity [*MEEB*, Table 22.7, p.1032].

> NOTE: If drainage fixture units are unknown, you may calculate septic tank capacity according to your daily sewage flow (in gallons per day):
>
> a. For flows up to 1,500 gallons per day,
>
> $C = 1.5F,$
>
> where:
>
> C = septic tank capacity (gallons)
>
> F = daily sewage flow (gallons).
>
> b. For flows over 1,500 gallons per day,
>
> $C = .75F + 1125.$

3. Repeat the procedure to determine the required septic tank capacity for your conventional water system design [D4.2]. Discuss the impact of your water-conserving system design on septic tank sizing and what design changes you deem necessary to meet Goal D.

Drainfield Sizing [suggested format]

Fixture	Conserving Drainage (fu)	Conventional Drainage (fu)
10 toilets	(10) (0) [Clivus Multrum] = 0	(10) (4) [tank-flush] = 40
5 lavatories	(5) (1) = 5	(5) (1) = 5
TOTALS	5	45
Septic Tank Capacity	720 gal	2,000 gal

SEPTIC TANK AND DRAINFIELD SIZING II

Discussion

Your soil type determines how rapidly water is absorbed by your site—soils with good absorption capacity will require a smaller drainfield area than soils with poor absorption characteristics. The maximum allowable septic tank size is also determined by soil type.

Procedure

Evaluate how well your design attains Water and Waste Schematic Design Goal D—**The septic tank and drainfield adequately treat the waste generated on-site.**

1. State what soil type you have at your site (U.S. Soil Conservation Service data or the table below).

Soil Characteristics

Location	Soil Type	Permeability*
Denver or Minneapolis	sandy loam or sandy clay	5 minutes
Phoenix	coarse sand or gravel	1 minute
Eugene or New Orleans	clay with considerable sand or gravel	10 minutes

* Time for water level to drop 1" in a test hole.

2. Determine whether your septic tank is sized within the allowable limits for your soil type [*MEEB*, Table 22.8, p.1032]. If not, indicate what design changes are necessary to stay within the limits.
3. Determine your required drainfield size based on your site's soil type and septic tank capacity [*MEEB*, Table 22.8, p.1032]. Discuss the ability of your design to supply adequate on-site wastewater treatment. Indicate any design changes you view as necessary to meet Goal D.
4. Determine the required drainfield size for your conventional water system design. Discuss the impact of your water-conserving system design on drainfield and septic tank sizing for your building and any changes necessary to meet Goal D.

COMPOSING TOILETS

D4.8

Discussion

The ultimate example of effective water conservation is the composting toilet. The Clivus Multrum system [*MEEB*, Figure 22.3, p.1002] requires organic kitchen waste as an agent for composting. The large composting chamber below the unit must be located to allow easy, periodic compost removal. The system uses neither water nor energy, yet produces compost suitable for landscape vegetation.

Procedure

Evaluate how well your design attains Water and Waste Schematic Design Goal E—**Composting toilets meet the program requirements.**

1. Schematically illustrate the composting toilets' place in your design, indicating how access to the composting chamber is achieved.
2. Discuss the impact of the composting system on your design, and indicate any design changes necessary to meet Goal E.

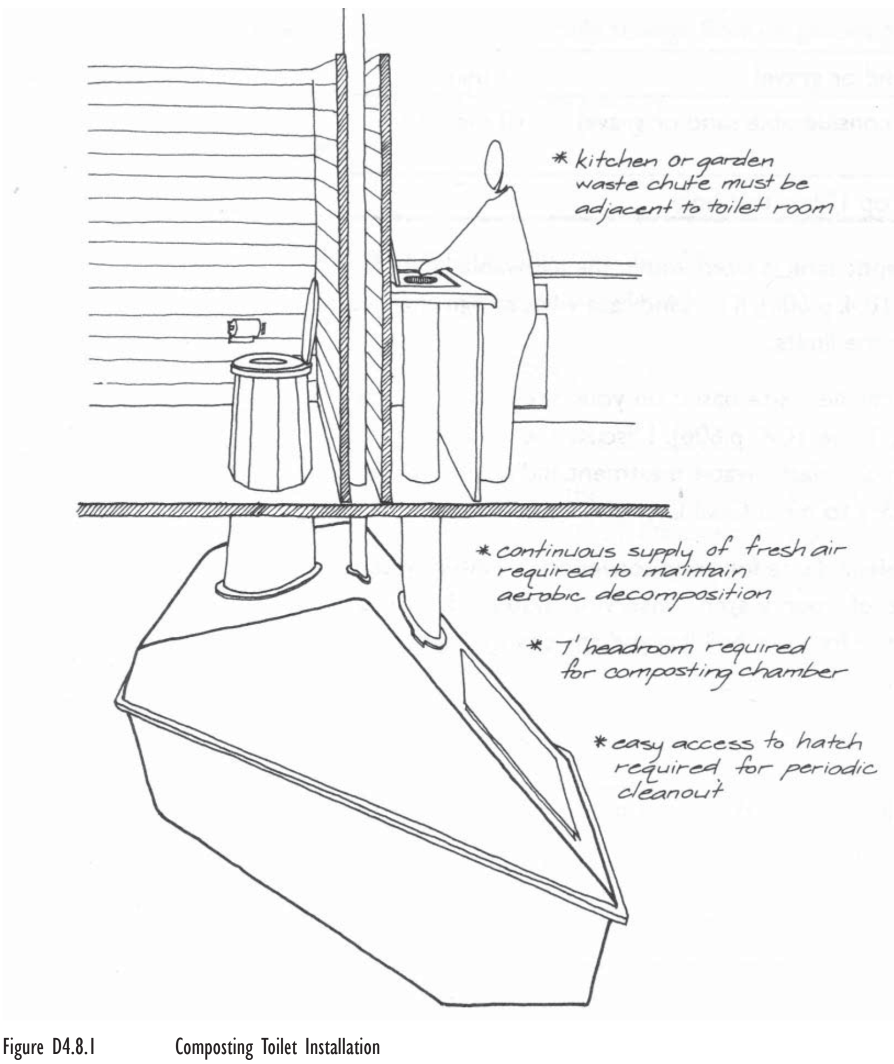

Figure D4.8.1 Composting Toilet Installation

SOLID-WASTE CENTER

Discussion

Recycling solid wastes from residential and commercial buildings can provide a source of low-cost, raw materials for industry (e.g., waste paper for pulp mills, aluminum cans for aluminum plants), fuel for utilities, and a source of income for the recycler. Recycling may occur either on-site or at a central collection point. The advantages of on-site recycling are that the recycling can be done manually rather than mechanically, and the recycler is the direct beneficiary of income derived from sales of recycled goods. Moreover, separation of wastes on-site reduces the amount of garbage sent to public landfills and can provide the safeguard of removing hazardous waste from the trash.

Procedure

Evaluate how well your design attains Water and Waste Schematic Design Goal F—**Facilities for solid-waste recycling are on-site.**

1. Design a solid-waste center to accommodate waste production [C4.3]. Indicate schematically its layout, position relative to waste-producing activities, and how wastes are removed. Designate storage areas for each class of recyclable materials, hazardous wastes, and garbage [*MEEB*, Sections 23.3 & 23.4, pp.1072–1077].
2. Discuss the impact of the solid-waste center on your overall design, and indicate any design changes necessary to meet Goal F.

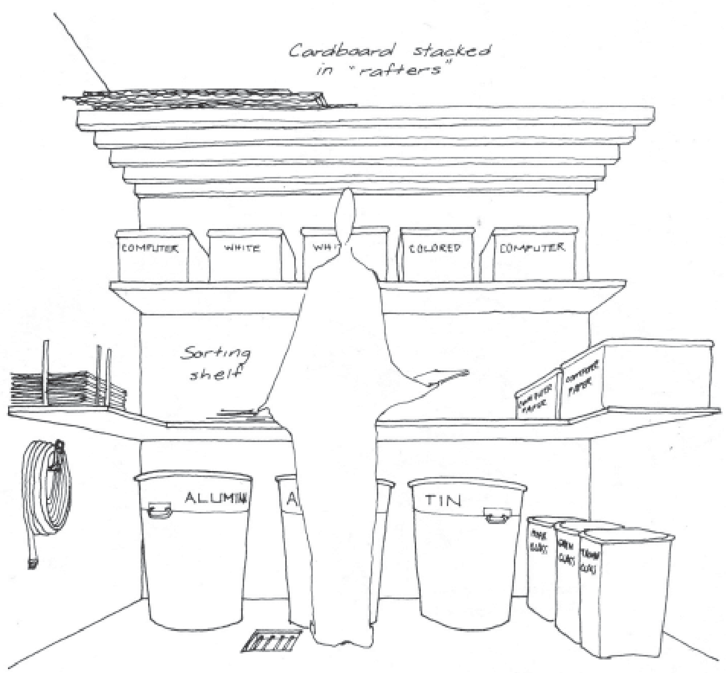

Figure D4.9.1 Recycling Center. Linen supply office, Charleston, South Carolina.

DESIGN REVIEW

D4.10

Discussion

You have studied the issues of water conservation, water supply, and solid-waste management and formulated a schematic design for your building and site. Each step has been accomplished independently and conflicting decisions may have been made. This design review affords you the opportunity to synthesize your cumulative design decisions.

Procedure

Review how well your design accomplishes Water and Waste Schematic Design Goals A–F.

1. Make schematic drawings that show how your design has evolved in response to meeting D4.0 goals.
2. Annotate your drawings to describe the systems used and the changes made.
3. Discuss the tradeoffs you have made among water and waste, acoustics, lighting, and thermal design considerations.
4. Discuss situations where your water and waste, acoustics, lighting, and thermal design strategies worked effectively together.

E4 WATER AND WASTE

DESIGN DEVELOPMENT

INTRODUCTION

Goals

Refine and develop the design to treat waste in an environmentally safe manner and to conserve water without sacrificing desirable views, thermal performance, lighting, or acoustics. Use your schematic design as the foundation for design development.

Water and Waste Design Development Goals

A. Toilet rooms are configured to ensure privacy and to allow access for all users.
B. The supply pipe system is designed and sized to carry the expected load.
C. The waste pipe system is designed and sized to carry the expected load.
D. The septic tank and drainfield are properly located on the site.
E. Solar collectors are sized to provide 100% of the hot water requirements in the month with the most solar radiation.
F. The cistern capacity is adequate to meet expected water needs year-round.

In this section you will:

1. Complete the water and waste design development.
2. Complete the design of toilet rooms.
3. Design both supply and waste pipe systems.
4. Select and design the appropriate domestic hot water system.
5. Complete the cistern and catchment system design.
6. Critique your building's water and waste design.

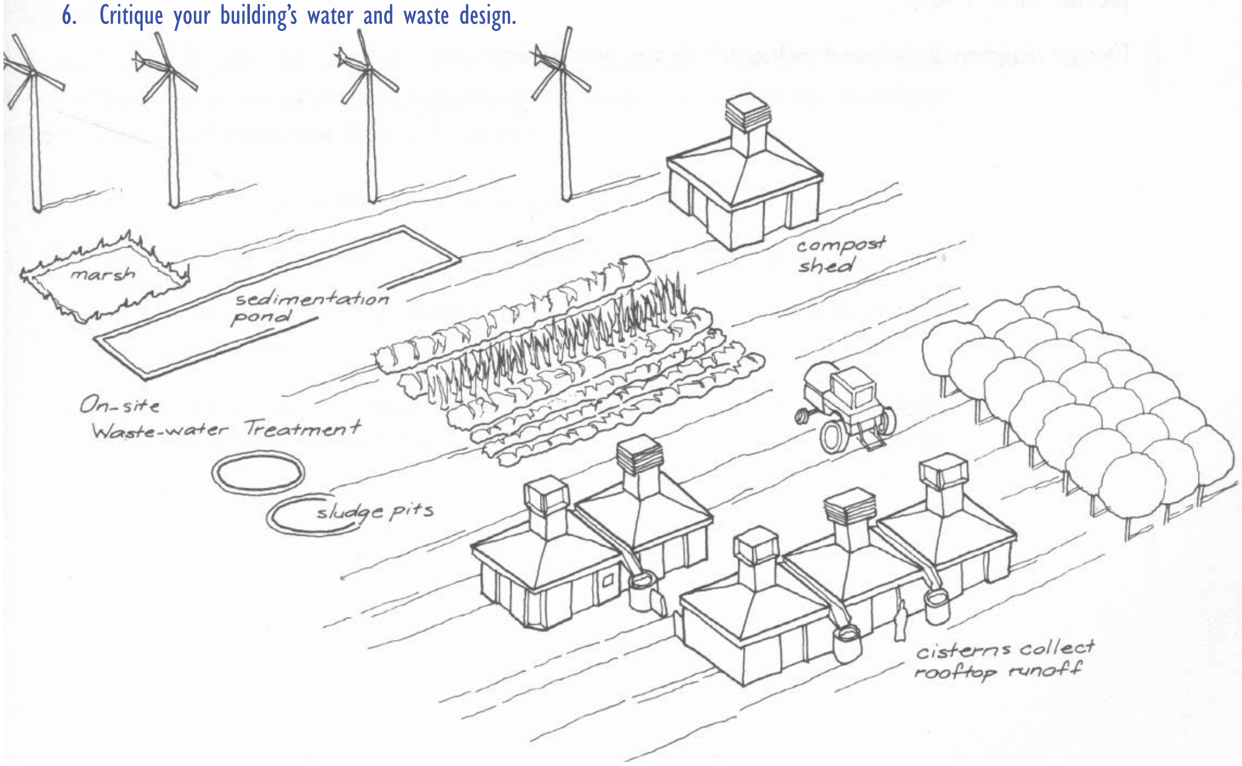

Figure E4.0.1 Blueprint Farm. Laredo, Texas, Pliny Fisk III (architect), 1991.

DESIGN

E4.1

Water and Waste Design Development Strategies

Component-Scale Strategies

- Ensure handicapped access to toilet rooms by designing in accordance with the *Uniform Building Code*.
- Block the line-of-sight into the toilet rooms.
- Locate fixtures on common walls to reduce piping and increase ease of installation.
- Minimize the distance from the water main or cistern to the farthest fixture.
- Set the solar collector tilt angle at approximately 10° less than your latitude to maximize performance.

Procedure

Refine your final schematic design [D4] to include component design considerations. Use the appropriate strategies to aid your design development. Modify your schematic design drawings to include the components you have developed.

Document your design as follows:

1. Site plan, including parking, access drives, solar collectors, septic tank, drainfield, and cistern locations (scale: 1" = 100').
2. Floor plans, including plumbing fixtures, hot water storage tank (scale: 1" = 20').
3. Sections, showing solar collectors and hot water storage tank (scale: $^1/_8$" = 1'-0").
4. Design diagram, annotated to identify design strategies.

TOILET ROOM

Discussion

The users of your toilet rooms should be able to use any fixture without being visible to anyone outside the rooms. A simple check of sight lines from beyond the entry way will ensure that vision into the rooms is properly obstructed.

To ensure handicapped access to your toilet rooms, certain design criteria must be achieved. The 1991 *Uniform Building Code*, Section 511(a), specifies:

- Doorways to toilet rooms:
  32" door width with 44" clearance beyond each side of the door.
- Clearance within toilet rooms:
  Sufficient to inscribe a circle of 5' diameter. Doors may encroach this circle by a maximum of 1' when open.
- WC stall:
  One for each gender must have 42" wide stall, with 48" clearance in front of stool within stall. (Stall door cannot encroach on this space so it usually swings outward.) The door width must be at least 32" if it is on the front of the stall or at least 34" if it is on the side of the stall.
- Lavatory:
  Under one lavatory, a space 30" wide, 29" high, and 17" deep for wheelchair access.

For more information

MEEB, Section 21.8, pp.970–974 (additional discussion and examples).

Procedure

Evaluate how well your design attains Water and Waste Design Development Goal A—**Toilet rooms are configured to ensure privacy and to allow ease of access for all users.**

1. Draw the floor plans of your toilet rooms (scale: ¼" = 1'-0").
2. Draw the sight lines from the entry to show that privacy is maintained.
3. Indicate schematically any changes necessary to ensure that vision into the rooms is blocked.
4. Check your toilet room designs against the *UBC* criteria. Indicate schematically any changes necessary to bring your designs up to code standards and to meet Goal A.

SUPPLY PIPE SYSTEM

Discussion

To maintain proper functioning, each fixture in your building requires a certain waterflow rate, which is achieved by providing adequate flow pressure at the fixture. Water leaves the main or cistern pump at a fairly high pressure. However, water pressure decreases along the line because of the height and distance that the water must travel and because of friction as it passes through the pipes and the water meter.

As a designer, you can decrease pressure loss by minimizing the distance water must travel to reach the farthest fixture. Then you can ensure proper pressure by choosing the proper supply pipe size. You must choose a pipe large enough to handle your maximum waterflow at a velocity of no greater than 10 feet per second (at faster speeds water can be heard within the pipes), yet small enough to maintain adequate water pressure. In most residential and small commercial buildings, the supply pipe is 2" in diameter or smaller. The sizing procedure requires a preliminary pipe size estimate, a series of calculations to determine whether this size is adequate, and possibly a check to determine whether a larger or smaller pipe size is more appropriate [*MEEB,* Section 21.11, pp.986–994].

Procedure

Evaluate how well your design attains Water and Waste Design Development Goal B—**The supply pipe system is designed and sized to carry the expected load.**

1. Determine flow pressure, FP, required at the fixture farthest from the water main or cistern pump [*MEEB*, Table 21.14, p.987].

2. Determine pressure loss due to height, PL_H. Assume the water main is at the street, 6' below grade. The pump is submerged within the cistern or is 6' below grade in the well.

   $PL_H = .433H$

   where:

   H = height difference from the pump to the highest fixture (ft)

3. Estimate your water supply flow in gallons per minute [*MEEB*, Figure 21.65, p.992] according to the number of your supply fixture units [D4.3] and whether toilets are primarily flush tank or flush valve fixtures [*MEEB*, Table 21.15, p.991].

4. Estimate your supply pipe size [*MEEB*, Figure 21.64, pp.989–990, may be helpful in narrowing the range of possibilities based on water flow].

5. Determine pressure loss due to water meters, PL_M [*MEEB*, Figure 21.63, p.988], based on your water supply flow and estimated supply pipe size. Even if city water isn't being used, water may be metered to keep an accurate record of water use.

SUPPLY PIPE SYSTEM (continued)

6. Calculate pressure loss due to friction in the pipes, PL_P.

   $PL_P = M - (FP + PL_H + PL_M)$

   where:

   M = cistern or well pump pressure (assume 40 psi)

7. Calculate desired friction loss, L, per 100' pipe length.

   $L = PL_P / TEL$

   where:

   TEL = total equivalent length of the piping or 1.5 times the distance from the main or pump to farthest fixture

8. Check your calculations [*MEEB*, Figure 21.63, pp.988]. Does the chart value for pipe diameter for your friction loss and flow in gallons per minute comply with your estimate? Is the velocity less than 10 feet per second? If not, revise your estimate and recalculate to meet Goal B.

DESIGN DEVELOPMENT

WASTE PIPE SYSTEM

Discussion

The design and sizing of the waste pipe system is relatively straightforward. First, the runout for each fixture is sized by its required trap size. The runouts from each cluster of fixtures feed into a fixture branch that is sized by the number of drainage fixture units it serves. These fixture branches feed into the building drainline via vertical soil stacks. Similarly, a system of vent pipes that penetrates the roof serves all of the fixtures.

For more information

MEEB, Sections 22.4 and 22.5, pp.1015–1029 (an extensive discussion with examples).

Procedure

Evaluate how well your design attains Water and Waste Design Development Goal C—**The waste pipe system is designed and sized to carry the expected load.**

1. Identify the locations of all plumbing fixtures. Use either a building section diagram [*MEEB*, Figures 22.24 and 22.30, pp.1022 & 1026] or an axonometric plumbing wall diagram [*MEEB*, Figure 22.17, p.1014].
2. Draw the waste pipe system serving the fixtures, minimizing pipe length wherever possible.
3. Size each fixture runout so runout size equals trap size [*MEEB*, Table 22.2A, p.1017]. Alternately, determine the drainage fixture unit value [*MEEB*, Table 22.2B, p.1017] and assign an appropriate runout pipe size [*MEEB*, Table 22.3, p.1018]. Label the plumbing diagram accordingly.
4. Size fixture branches and vertical stacks according to the number of drainage fixture units each serves [*MEEB*, Table 22.3, p.1018]. Label the plumbing diagram accordingly.
5. Determine the size and pitch of the building drain. What vertical drop is required for the drain to reach the septic tank at this pitch? Show how this is compatible with your site's topography.
6. Size the venting pipe system. For individual fixtures, vent size equals trap size. For collective vents, see *MEEB*, Table 22.4, p.1019. Label the plumbing diagram accordingly.
7. Discuss changes necessary to meet Goal C.

DRAINFIELD

E4.5

Discussion

You have already sized your septic tank and drainfield to accommodate your expected waste load and soil type. Now you must layout your drainfield lines with the proper length (100' maximum) and spacing (6' o.c. minimum). You must also evaluate its position on your site: Ideally the septic tank lies downhill from the building, and the drainfield has adequate clearances from structures, vegetation, and bodies of water. When the drainfield is above the septic tank, a pump must be used to serve the drainfield.

Procedure

Evaluate how well your design attains Water and Waste Design Development Goal D—**The septic tank and drainfield are properly located on the site.**

1. Draw required code clearances for features on your site plan [*MEEB*, Fig. 22.37, p.1034 & Table 22.9, p.1033]. Identify areas that are suitable for septic tank placement and drainfield location.
2. Draw the location and layout of the septic tank and drainfield lines on your site plan. Drainlines must meet code [*MEEB*, Table 22.10, p.1035].
3. Discuss whether or not your septic tank and drainfield meet code requirements. Indicate any design changes you deem necessary to meet Goal D.

DESIGN DEVELOPMENT

DOMESTIC HOT WATER (DHW) SYSTEM REQUIREMENTS

Discussion

The temperature of stored hot water is higher than the desired temperature at the point-of-use. An accurate, hot-water-use estimate will account for this temperature difference and for the amount of cold water (entering the building at groundwater temperature) that is mixed with the hot water load.

Procedure

1. Determine your site's groundwater temperature [Figure E4.6.1].

2. Determine the average point-of-use water temperature for your building [*MEEB*, Table 21.6, p.933]. Assume your water heater thermostat setting to be 20° higher than this average (and at least 10° higher than the highest point-of-use temperature).

3. Calculate the percentage of stored hot water that goes into producing the total amount of hot water used.

   $\% \text{ hot} = (T_{AV} - GWT) / (T_{therm} - GWT)$

   where:

   T_{AV} = average point-of-use temperature (°F)
   GWT = site's groundwater temperature (°F)
   T_{therm} = water heater thermostat setting (°F)

4. Calculate the daily total use of stored hot water.

   $S = (T)\ (\% \text{ hot})$

   where:

   S = total stored hot water (gallons/day)
   T = total hot water use in your building (gallons/day) [D4.4]

5. Determine the total heat required (Btu/day) to heat the stored water.

   $TH_R = (S)\ (8.33 \text{ lb/gal})\ (T_{therm} - GWT)$

DHW Requirements [suggested format]

GWT (°F)	T_{AV} (°F)	T_{therm} (°F)	Hot Water (%)	S (gal/day)	T (gal/day)	TH_R (Btu/day)
68	90	120	42	504	1,200	218,400

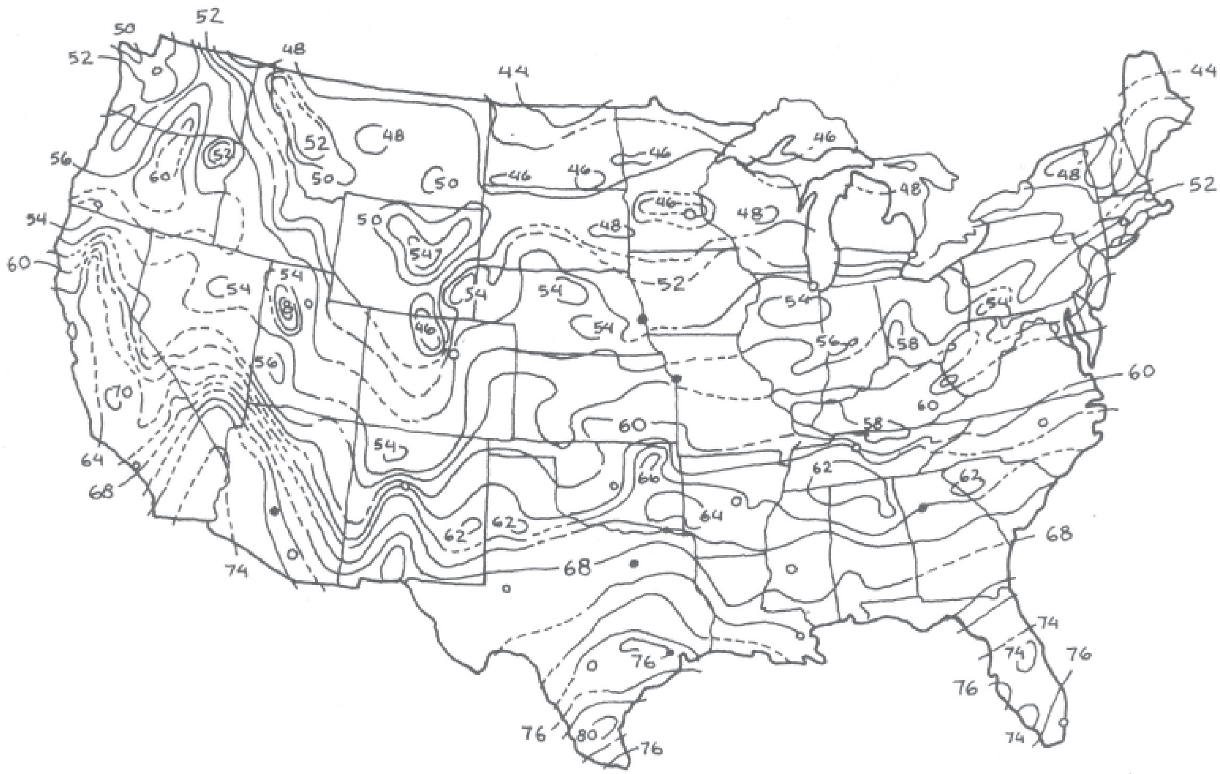

Figure E4.6.1 Groundwater Temperatures in the Continental United States. Reprinted, by permission, from the American Solar Energy Society, Passive Solar Journal 1 no.1, 5.

SOLAR DHW SYSTEM SIZING

Discussion

Your preliminary solar collector design should now be refined to optimize performance. By evaluating the average insolation data for your climate you can determine a collector tilt angle that maximizes received insolation during the best solar month and still performs fairly well during the worst month.

How efficiently the collector uses the insolation depends on a number of factors. Collector efficiency is determined by collector type, the input water temperature, and the outdoor daytime temperature. System efficiency calculations account for heat losses in the lines and for non-collection time—those periods when too little sun enters the collector to heat water above the input temperature (the temperature at the bottom of the water heater tank). Once these adjustments have been made, you can determine the appropriate collector area to deliver the desired number of Btus per day.

Procedure

Evaluate how well your design attains Water and Waste Design Development Goal E—**Solar collectors are sized to provide 100% of the hot water requirements in the month with the most solar radiation.**

Record the results of your calculations in a DHW Sizing Table.

1. Evaluate your climate's insolation data.

2. Choose a collector tilt angle that gives close-to-maximum best-month performance without suffering the worst-month performance.

Average Daily Solar Radiation Data (SOLMET) (Btu/ft^2)

	Worst Month				Best Month			
Tilt angle:	0°	30°	60°	90°	0°	30°	60°	90°
Madison	389	429	525	477	1,933	1,364	1,010	505
Dodge City	731	857	1,047	952	2,294	1,565	1,188	447
Phoenix	931	1,104	1,214	1,104	2,737	1,765	1,073	346
Charleston	744	732	789	665	1,859	1,251	876	416
Spokane	255	383	434	409	2,357	2,415	2,121	1,368

[If your climate isn't in the table above, solar radiation data is available on the NREL website: <http://rredc.nrel.gov/solar/old_data/nsrdb/redbook/>. Use the 30-Year Average of Monthly Solar Radiation chart for your climate.]

3. Determine hourly insolation, I_o, for the best and worst months. Assume the hourly total is 18% of the daily insolation.

SOLAR DHW SYSTEM SIZING (continued)

4. Determine input water temperature, T_i. For the best month, the sun heats the water heater above the thermostat setting, so:

   $T_i = T_{therm} + 5°$.

   For the worst month, the collector is fed colder water from the bottom of the tank, so:

   $T_i = T_{therm} - 15°$.

5. Find average daytime outdoor temperature, TA, for the best (hottest) and worst (coolest) months [Use the Climate Consultant software].

6. Calculate $(T_i - T_A) / I_o$ for "entry into" the nomograph in *MEEB*, Figure 21.36, p.957, to estimate collector efficiency for the best and worst months.

7. Calculate system efficiency, E, for the best and worst months.

   E = (0.8) (collector efficiency)

8. Determine the collector area that will deliver 100% of your hot water needs in the best month.

   area = TH_R / [(I) (E)]

   where:

   TH_R = total heat required (Btu/day) [E4.6]
   I = total daily insolation (Btu/dayft^2)
   E = best-month system efficiency

   NOTE: If your collector is made of modular units, round the area to the next larger modular size (e.g., 40 ft^2 means 3 @ 3' x 5' panels).

9. Determine how much heat will be collected during the worst month. What is the percentage of the total heat required?

   TH_C = (area) (I) (E)

   where:

   I = total daily worst-day insolation (Btu/dayft^2)
   E = worst-month system efficiency

Solar DHW Sizing [suggested format]

	I (Btu/dayft^2)	I_o (Btuh/ft^2)	T_i (°F)	T_A (°F)	$(T_i - T_A) / I_o$	Collector Efficiency	System Efficiency	Collector Area (ft^2)	TH_R (Btu/day)	TH_C (Btu/day)
Best Month	1,250	225	125	80	0.20	.70	.56	25	17,500	17,500
Worst Month	728	131	105	49	0.43	.50	.40	25	17,500	7,280

SOLAR DHW SYSTEM SIZING (continued)

10. Average your best- and worst-month performances to estimate yearly percentage of solar water heating.
11. How does the area of the solar collector compare with your previous estimate [D4.4]? How will this difference affect your design? Discuss whether or not your DHW system provides sufficient solar heated water. Indicate any design changes that are necessary to meet Goal E.

CISTERN SIZING

Discussion

Your cistern should be sized to supply enough water during your climate's dry season without falling below minimum capacity. Since the cistern outlet is located higher than the floor of the tank, the cistern can be as much as 10% full and still "run dry." A common sizing guideline is to accommodate at least minimum capacity plus the average rainy season rainfall. A month-by-month comparison of collected rainfall to actual water use will tell you if your cistern is adequate.

Procedure

Evaluate how well your design attains Water and Waste Design Development Goal F—**The cistern capacity is adequate to meet expected water needs year-round.**

1. Identify your climate's rainy season. Beginning with the first month after the rainy season, list the normal monthly rainfall [B4.1], in feet, for each month of the year.

   NOTE: B4.1 and NOAA data are listed in inches.

2. Determine how much rain is collected during each month.

   rain collected = (A) (R) (7.48 gal/ft^3)

   where:

   A = catchment area (three-fourths of roof area) (ft^2)

   R = monthly rainfall (ft) [B4.2]

3. Compare your cistern's capacity with the minimum sizing guideline. Does your cistern hold minimum capacity (10% total capacity) plus the average rainy season rainfall? If not, redesign or explain why you cannot meet this guideline.

4. Determine how much water your cistern holds at the end of each month. Begin with the holdings at 90% capacity after the rainy season ends, then for each month, add the rainfall collected and subtract the monthly water use. Does your cistern's capacity ever equal less than minimum capacity? If so, redesign and recalculate.

Cistern Design Scenario [suggested format]

Month	Monthly Rainfall (inches)	Rain Collected (gallons)	Monthly Use (gallons)	Cistern Holdings Before (gallons)	Cistern Holdings After (gallons)
#1 June	1.36	2,543	3,200	4,550	3,898
#2 July	0.40	748	3,200	3,898	1,446
carry forward to next month				1,446	

DESIGN REVIEW

E4.9

Discussion

You have just completed design development of the major components of your building's water and waste system. The methods you have used should give you some insight for successfully designing the remainder of the water and waste system. This design review affords you the opportunity to view your water and waste design holistically and to discuss the conflicts and tradeoffs with other design considerations for the entire program.

Procedure

1. Compare the developed design with the schematic design [D4]. Discuss how it has evolved and why.

2. You have explored the use of water and waste systems, acoustic, daylighting, and thermal strategies. Comment on what tradeoffs have been made and what strategies worked well together.

3. Illustrate your discussion of points (1) and (2) with annotated, schematic diagrams of your water and waste design for the entire building and site.