Design Period

The design period establishes the target date when the design capacity of the facilities will be reached. Design periods may vary for individual components, depending upon the ease or difficulty of expansion. Typical design periods for various types of facilities are given in Table 5-13. Longer periods are preferred for structures and hydraulic conduit systems, that cannot be easily expanded. The selection of the design period depends upon growth characteristics, environmental considerations, and the availabilty and source of construction funds.

Treatment Process Flow Diagrams

Treatment process flow diagrams are graphical representations of particular combinations of unit operations and processes. Depending on the constituents that must be removed, an almost limitless number of different flow diagrams can be developed by combining the unit operations and processes reported in Tables 4-2 and 4-3. Apart from the analysis of the suitability of the types of individual treatment units, the exact configuration of process units selected will also depend on factors such as (1) the designer's past experience, (2) design and regulatory agency policies on the application of specific treatment methods, (3) the availability of suppliers of equipment for specific treatment methods, (4) the maximum use that can be made of existing facilities, (5) initial construction costs, and (6) future operation and maintenance costs. A typical process flow diagram for the treatment of wastewater to meet secondary treatment standards, as defined by the U.S. Environmental Protection Agency (see Table 4-1), is shown in Fig. 5-10.

Process Design Criteria

After one or more preliminary process flow diagrams have been developed, the next step is to establish the process design criteria so that the size of the physical facilities

TABLE 5-13
Typical design periods for wastewater facilities

Facility	Planning period range, yrs
Collection systems	20–40
Pumping stations	
Structures	20–40
Pumping equipment	10–25
Treatment plants	
Process structures	20–40
Process equipment	10–20
Hydraulic conduits	20–40

can be determined. For example, if the hydraulic detention time in the aerated grit chamber shown in Fig. 5-10 is to be 3.5 min at a peak flowrate, the corresponding grit chamber volume required would be calculated. The hydraulic detention time would be an example of the process design criteria for the grit chamber. Similar procedures are followed for each unit operation and process.

When the computations have been completed, all the key design criteria should be listed in a summary table. Some of the design parameters commonly used in developing a summary table are listed in Appendix A-3. Because most treatment plants are designed to be effective for some time in the future (up to 20 years), design criteria are given for the time when the facilities will first be put into operation, and for the end of the design period. The latter will be influenced by projections of the population to be served and the economic studies of cost effectiveness for various design periods.

Preliminary Sizing

After the design criteria have been established, the next step is to determine the number and size of the physical facilities needed. In considering sizing, physical site

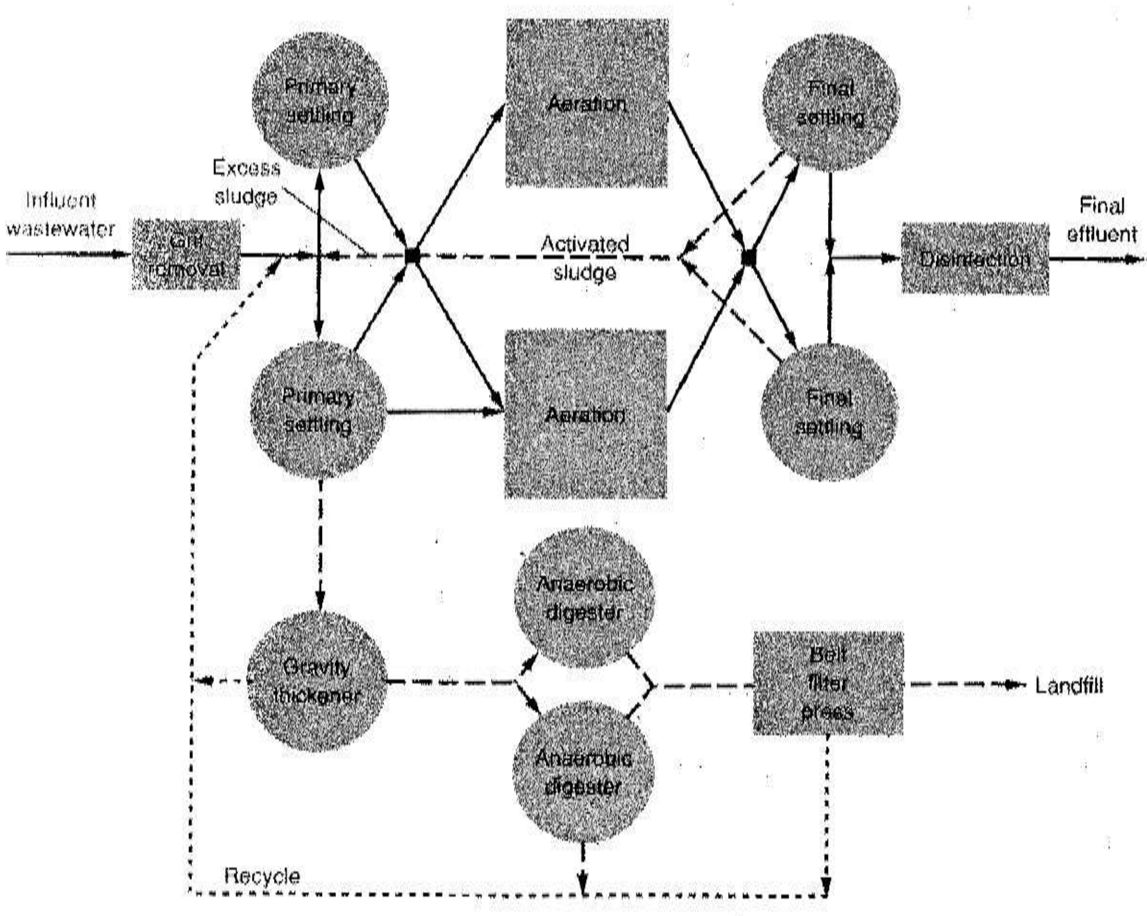


FIGURE 5-10
Process flow diagram for treatment plant designed to meet secondary treatment standards of the U.S. EPA.

constraints need to be considered: for example, will the site accommodate the use of round tanks or will rectangular tanks have to be used? Operational considerations, such as flow splitting and load balancing, will have to be evaluated, particularly in process trains that combine different numbers of unit operations or processes (e.g., two primary clarifiers and three aeration tanks). Maintenance factors have to be considered in selecting the number of units so that provisions are included for taking a unit out of service for maintenance and repair. In small plants where a single unit is being considered, maintenance of that unit may be a particular problem, unless special provisions, such as temporary storage, are included.

Solids Balance

After the design criteria are established and the preliminary sizing is completed, solids balances should be prepared for each process flow diagram. They should be prepared for the average load with appropriate peaking factors applied for maximum loads. Such information must be available to size (1) sludge-thickening and storage facilities, (2) sludge digestors, (3) sludge-dewatering facilities, (4) thermal reduction systems, (5) composting facilities, and (6) sludge-piping and -pumping equipment and other appurtenant facilities. The preparation of a solids balance is illustrated in Chap. 12.

Plant Layout

Plant layout refers to the spatial arrangement of the physical facilities required to achieve a given treatment objective. The overall plant layout includes the location of the control and administrative buildings and any other necessary structures. Several different layouts, using scaled cardboard cutouts of the various treatment facilities or computer-generated overlays, are normally evaluated before a final selection is made. Among the factors that must be considered when laying out a treatment plant are the following: (1) geometry of the available treatment plant sites, (2) topography, (3) soil and foundation conditions, (4) location of the influent sewer, (5) location of the point of discharge, (6) plant hydraulics, preferably with straight-flow paths between units to minimize head loss and provide symmetry for flow splits, (7) types of processes involved, (8) process performance and efficiency, (9) transportation access, (10) accessibility to operating personnel, (11) reliability and economy of operation, (12) aesthetics, (13) environmental control, and (14) provisions for future plant expansion, including additional area. The physical layouts of a variety of plants, both small and large, are shown in Figs. 5-11 through 5-13.

Plant Hydraulics

After the process flow diagram has been selected and the size of the corresponding physical facilities is determined, hydraulic computations and profiles are prepared for both average and peak flowrates. Hydraulic computations are made to size the interconnecting conduits and channels and to compute the headlosses through the plant. Typical ranges of headlosses through treatment units are given in Table

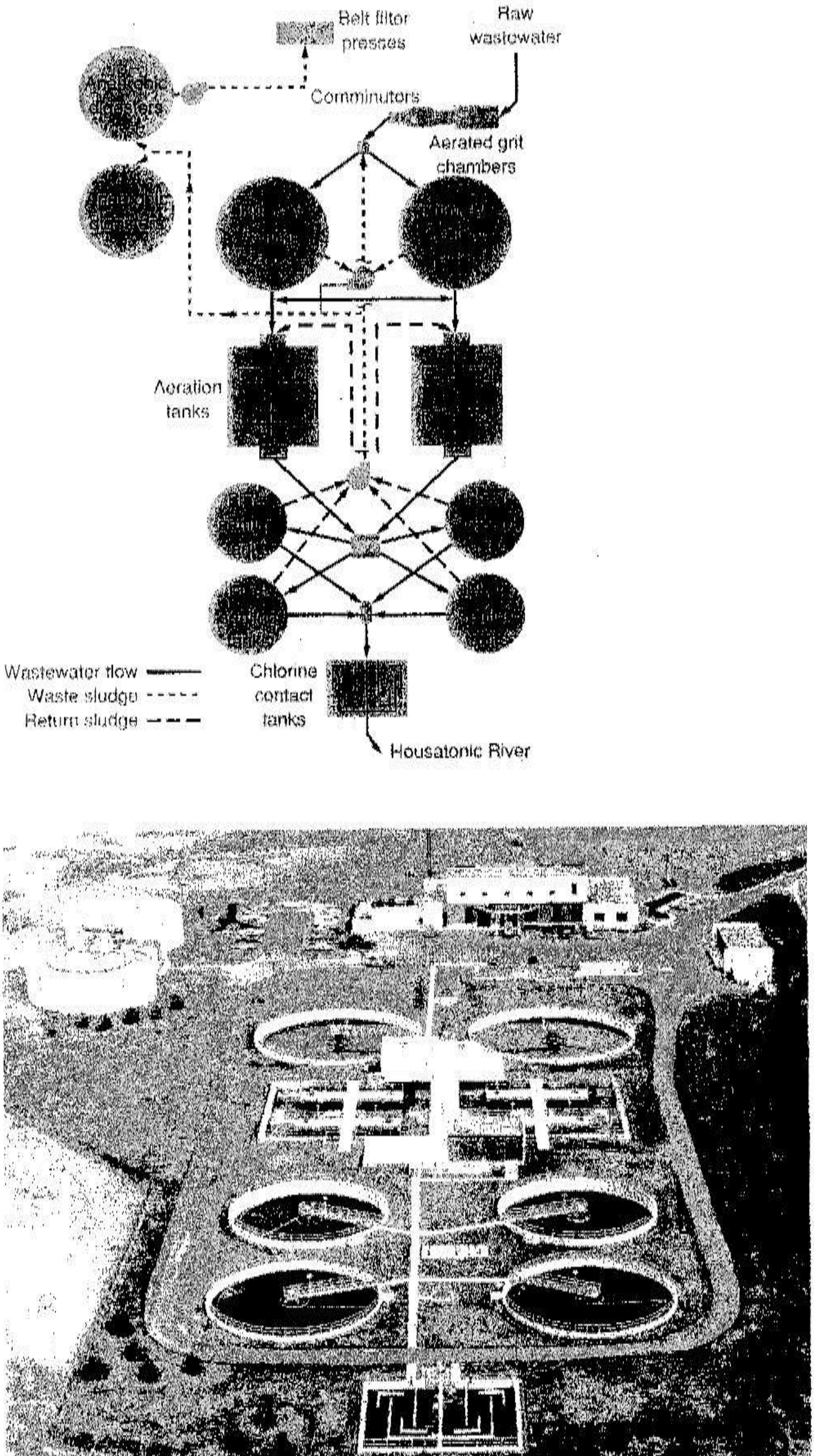


FIGURE 5-11
Layout and aerial view of Housatonic Wastewater Plant, Milford, CT. (Design average flowrate = 8 Mgal/d)

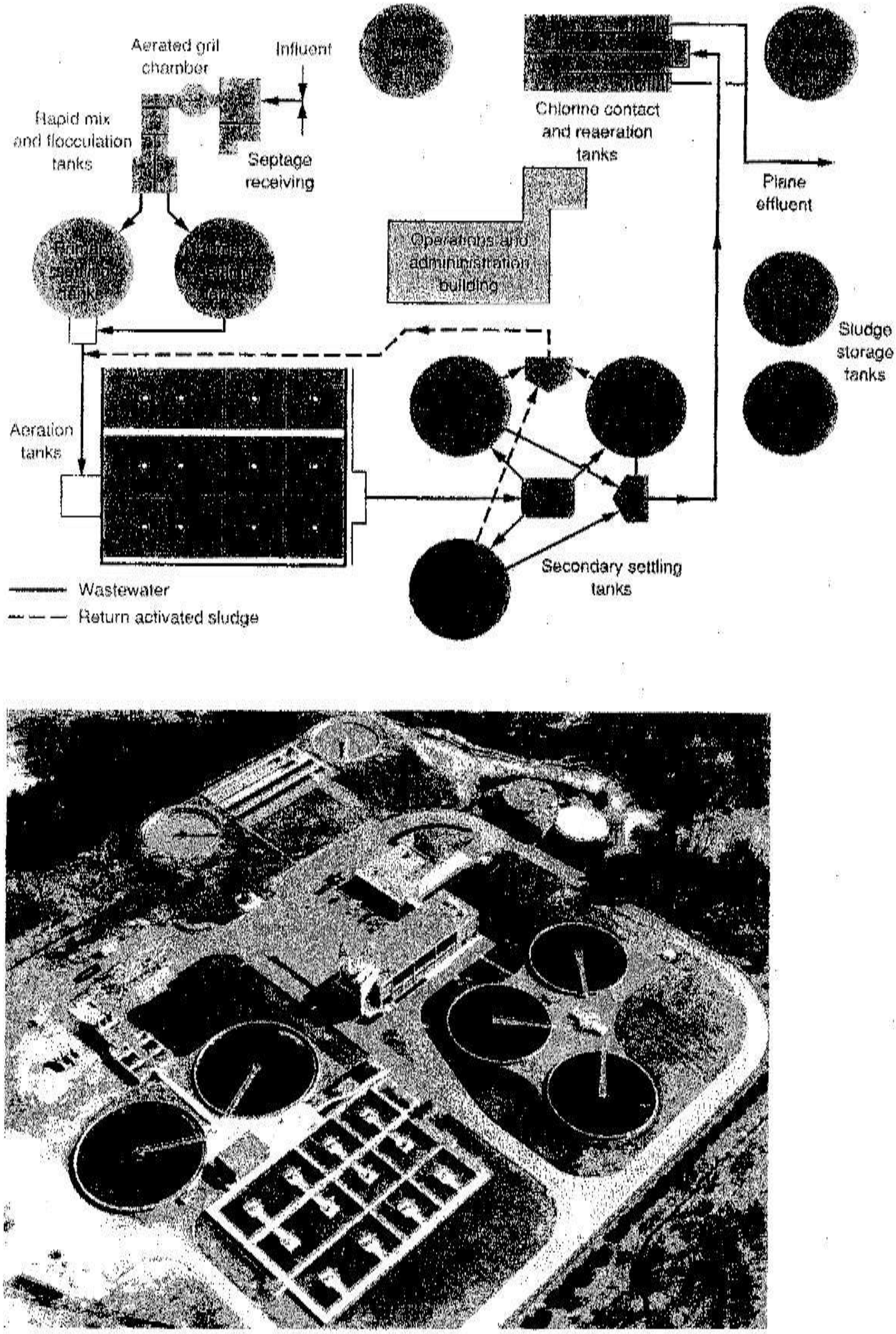
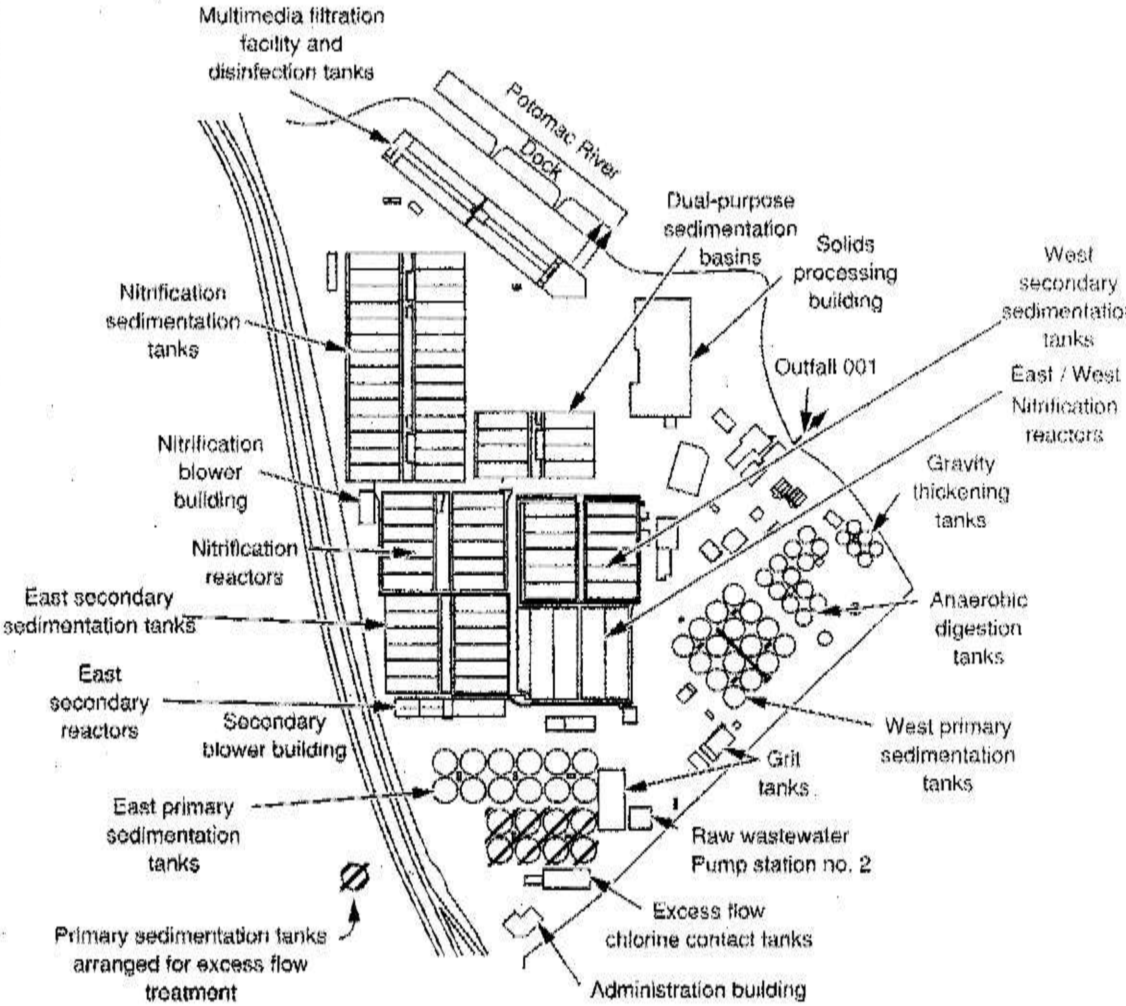


FIGURE 5-12
Layout and aerial view of Leominster Wastewater Treatment Plant, Leominster, MA. (Design average flowrate = 9.3 Mgal/d)



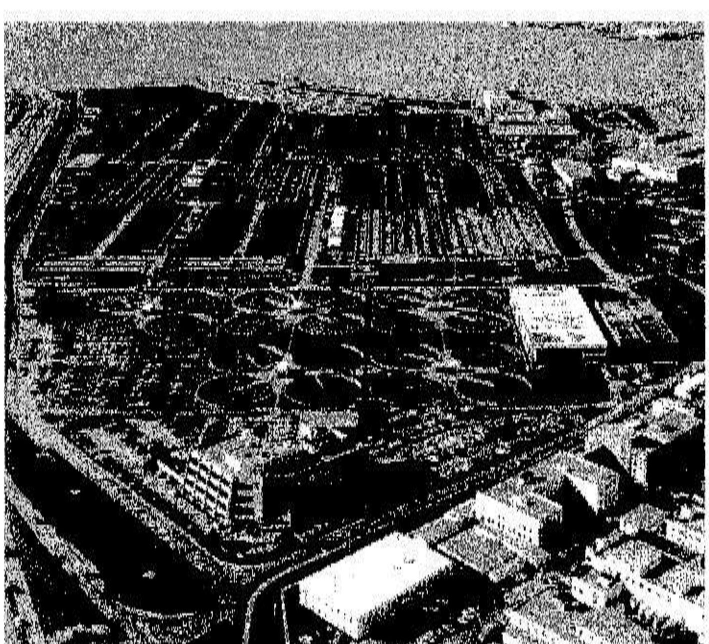


FIGURE 5-13
Layout and aerial view of Blue Plains Wastewater Treatment Plant, Washington, DC. (Design average flowrate = 309 Mgal/d)

5-14. In designing the plant hydraulic system, consideration needs to be given to (1) equalizing the flow splitting between the treatment units, (2) making provisions for bypassing secondary treatment units at extreme peak flows to prevent loss of biomass, and (3) minimizing the number of changes in direction of wastewater flow in conduits and channels.

Hydraulic profiles are prepared for three reasons: (1) to ensure that the hydraulic gradient is adequate for the wastewater to flow through the treatment facilities by gravity, (2) to establish the head requirement for the pumps where pumping will be needed, and (3) to ensure that the plant facilities will not be flooded or backed up during periods of peak flow. Profiles for the flow diagram given in Fig. 5-10 are shown in Fig. 5-14. In preparing a hydraulic profile, distorted vertical and horizontal scales are commonly used to depict the physical facilities.

Hydraulic profile computations involve the determination of the headloss as the wastewater flows through each of the physical facilities in the process flow diagram. Specific computational procedures may vary depending on local conditions. For example, if a downstream discharge condition is the control point, some designers prepare the hydraulic profile by working backward from the control point. Other designers prefer to work from the head end of the plant. Still others work from the center in each direction, adjusting the elevations at the end of the computations. The use of

TABLE 5-14
Typical headlosses across various treatment units[a]

Treatment unit	Headloss range, ft
Bar screen	0.5–1.0
Grit chambers	
Aerated	1.5–4.0
Velocity controlled	1.5–3.0
Primary sedimentation	1.5–3.0
Aeration tank	0.7–2.0
Trickling filter	
Low-rate	10.0–20.0
High-rate, rock media	6.0–16.0
High-rate, plastic media	16.0–40.0
Secondary sedimentation	1.5–3.0
Filtration	10.0–16.0
Carbon adsorption	10.0–20.0
Chlorine-contact tank	0.7–6.0

[a] Adapted in part from Refs. 10 and 17.

Note: ft × 0.3048 = m

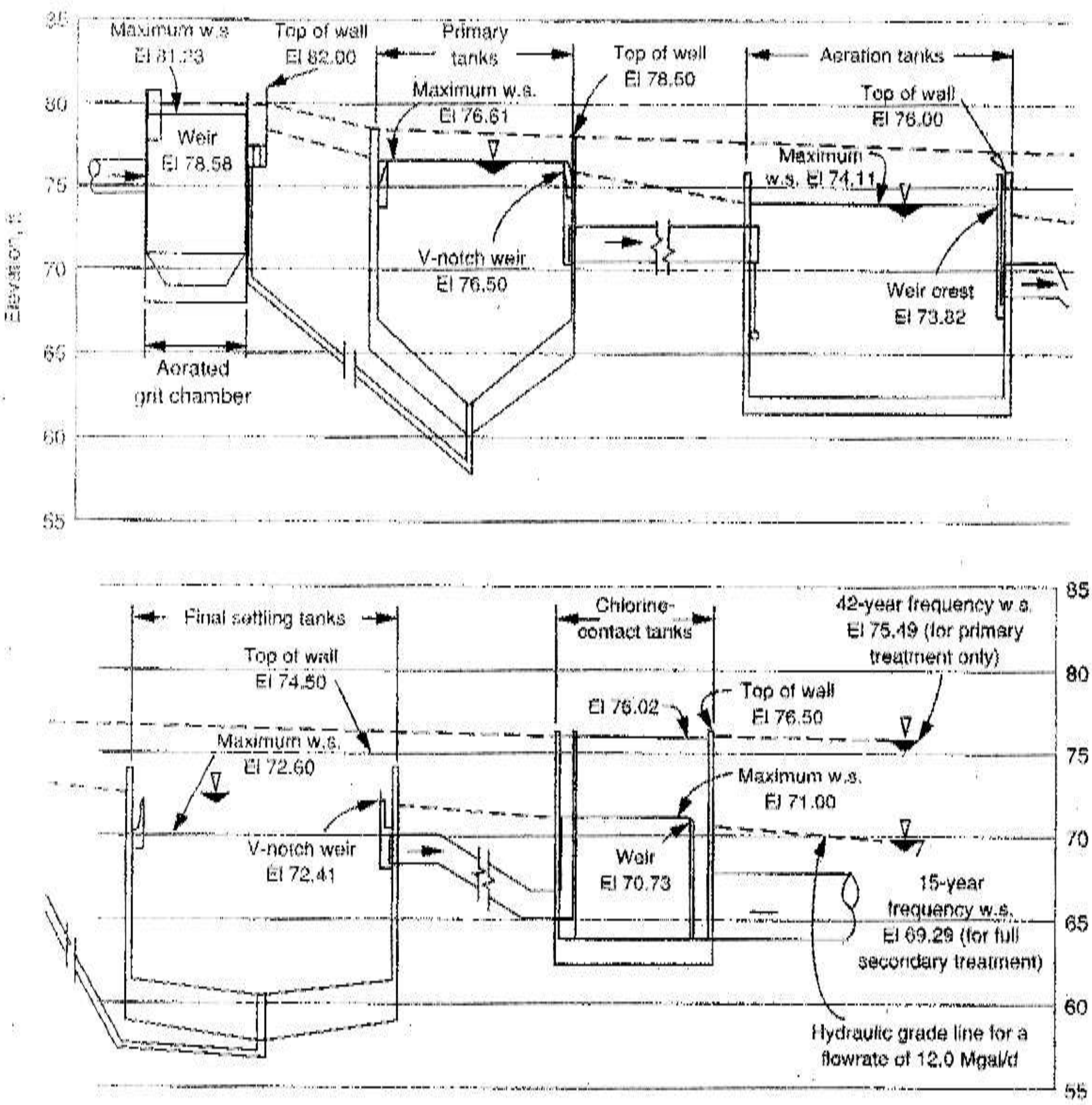


FIGURE 5-14
Hydraulic profile for treatment plant shown in Fig. 6-8. *Note:* ft × 0.3048 = m; Mgal/d × 0.043813 = m^3/s; w.s. = water surface.

mathematical models and digital computers allows many possible hydraulic conditions to be analyzed. For information on head loss calculations through a treatment plant, Ref. 10 may be consulted.

DISCUSSION TOPICS AND PROBLEMS

5-1. With the data given in Fig. 5-2, compute the hourly BOD mass loadings and plot a mass-loading curve. At what time is the mass loading at its maximum? At its minimum? What are the ratios of the maximum and minimum mass loadings to the average?

5-2. The variations of influent flowrate and BOD with time are given in the following figure. Compute both the average and the flow-weighted BOD.