Design Criteria for Sewage Works

Revised March 1, 2016

State of Tennessee
Department of Environment and Conservation
Division of Water Pollution Control
http://tn.gov/environment/wpc/

LEGEND
(YYMMDD) - Effective Date
TBA- To be added at a later date

DESIGN CRITERIA FOR SEWAGE WORKS
TABLE OF CONTENTS (160301)

Bibliography Chapter 19 (TBA)

Notes on latest Revision:

The latest revision as of March 01, 2016:

1. Converts all chapters to a common format without changing technical content;
2. Corrects and updates the Table of Contents and Guidance contents itself as follows:
    a. Adding version dates for each chapter;
    b. Correcting the titles of Chapters 10 & 15;
    c. Adding Appendices included with each chapter to Table of Contents;
    d. Added Current Review Fees as Appendix 1-D
    e. Removed Chapter 18 from active chapters in Table of Contents; and
    f. Added place holder for Chapter 19 on Re-Use Systems to be developed.

CHAPTER 1

General Engineering Requirements

GENERAL ENGINEERING REQUIREMENTS

1.1 General Information for projects reviewed by the Division of Water Resources

1.1.1 Application and Purpose of Criteria

These design criteria apply to the development, design, and submission of engineering documents for projects that convey or treat wastewater in the State of Tennessee as listed in Section 1.1.2. The Division of Water Resources (Division) staff will use the design criteria for the review and approval of those projects. However, these criteria are not laws, rules, or regulations.

"The Tennessee Board of Water Quality, Oil and Gas has broad rulemaking authority such that it may adopt regulations necessary to advance the legislative policy of preserving and protecting the waters of the State from conditions of pollution . . ." (Attorney General Opinion)

The Division does not recommend promulgation of these criteria as regulations. It has successfully applied an approach of using design criteria for establishing the requirements for review of wastewater conveyance and treatment projects without using a formal regulatory process. The intention of this approach is to provide flexibility during the design and review process for inclusion of technical advances, new products, and innovative approaches based on sound engineering judgment. By definition, these criteria represent "standards by which a judgment can be made; a model, test, or measure."

The Division has observed many instances in municipalities across the state where leakage of water into wastewater collection systems (I/I – infiltration and inflow) has been a direct or indirect cause of permit violations and pollution of the environment. Additionally, I/I reduce the capacity of wastewater collection and treatment systems.
In some cases, this loss of capacity has hindered growth and caused economic problems in those communities. Utility customers pay higher bills because I/I in wastewater collection systems increase the cost of conveyance and treatment.

Modern, proven technologies and materials are commonly available to stop or prevent leakage into wastewater collection systems. Therefore, these collection system design criteria promote new sewer designs that minimize the potential for infiltration and inflow. Examples would include methods that prevent trench water accumulation and stream capture, or new technologies such as HDPE heat fused pipe. Additionally, the design criteria include new design procedures to minimize solids deposition within sewers. The intention is to improve energy efficiency and system sustainability. Project reviews will ensure that life cycle analysis (including the cost of I/I over the life of the project) is part of design criteria and required for engineering report/plans submittal. Life-cycle cost analysis (LCCA) is an economic method of project evaluation in which considers all costs arising from building, operating and maintaining a project. LCCA is well suited to the economic evaluation of design alternatives that satisfy a required performance level but may have differing investment, operating, maintenance, or repair costs, and possibly different life spans. LCCA is particularly relevant to the evaluation of investments (high initial costs versus reduced future cost obligations). For example, one alternative may

have a significantly higher initial capital expenditure, but have much lower operation and maintenance costs compared to another alternative. Over the life of the project, the alternative with the higher initial cost may prove to be more cost-effective. The goal for newly constructed collection systems and rehabilitation of existing collection systems is zero I/I. Additionally, the life cycle cost of treating I/I compared to the cost of removing I/I completely is a valuable tool. This concept should apply to all wastewater system design projects, especially those that opt for plant expansions to treat excessive I/I rather than remove I/I in the collection system as a number one priority.

The Division will address the problem of inadvertent diversion of surface water when sewer pipelines cross or run close to surface streams (sometimes called "stream capture"). The disturbance of the ground and introduction of porous backfill affects the natural drainage and water quality of streams by providing new underground routes for drainage. When stream crossings are unavoidable, more controls that are stringent will be required in designs. The Division will require alternate routes (or greater offsets from surface streams) for pipelines when crossings are not necessary.

These criteria might not be sufficiently comprehensive to apply to all wastewater treatment and disposal problems in the State. However, the criteria will represent a minimum standard for design of projects for the public welfare and environmental protection. The design engineer should rely upon experience and judgment in supplementing these criteria. Additionally, these criteria may prove too comprehensive (for example, in the treatment of industrial wastes); in either case, the Division staff will consider variances to these criteria provided the engineer can justify the variances requested.

These design criteria use the words "should" and "shall" in various places. The intention is to indicate a difference in the degree of significance of the particular direction or design consideration. The word "shall" indicates a very high degree of concern or significance (compared to the word "should"). Since these criteria are not regulations, then use of the word "shall" does not indicate a legal obligation, unless that obligation is required in a law or regulation.

The Division has delegated authority to some municipal agencies to review plans and specifications for sewer line extensions and sewer rehabilitation projects. Agencies receiving this delegation shall certify that their review is based on the current design criteria used by the Division or standards of the municipality whichever is more stringent.

1.1.2 Types of Projects Affected

The purpose of this chapter is to describe the engineering and procedural steps required by the Division of Water Resources from beginning to completion of a sewerage project. These criteria apply to the development of the following facilities:

- Municipal sewerage systems, subdivisions, trailer parks, apartments, resorts, etc.
- Publicly or privately owned sewerage systems required to obtain a charter (certificate of need and convenience) from the Tennessee Public Service Commission.

- Public corporation sewerage systems organized under the General Corporation Act of Tennessee.
- Public sewerage systems organized under the Federal Housing Authority Title bond.
- All sewerage systems owned by the State of Tennessee.
- Industrial waste systems.
- Industrial sewerage systems.
- Federally owned systems.
- Sewerage systems for schools, service stations, shopping centers, truck stops, or motels.
- Sewerage and industrial waste systems for laundries and car wash facilities.

To be consistent, the Division requires the following procedures for wastewater treatment facilities and proposed discharges to the environment:

a. Upon receipt of a letter requesting planning limits of a proposed discharge, the Division will investigate the proposed point of discharge and may establish appropriate planning limits.
b. Divisional review of the final engineering report and preliminary plans will commence only after the issuance of the effluent planning limits and the site approval.

Detailed information is found in "Wastewater Discharge Checklist", Appendix 1-A.

1.1.3 Requirements

The Division requires the preparation of technical engineering information by an engineer whom has obtained professional licensure to practice within the State of Tennessee, representing the municipality, industry, or owner. The Division requires the submission of this information in two parts:

a. An engineering report and, if the design engineer feels it necessary, preliminary plans. The Division recommends preliminary project discussions, preliminary engineering reports and preliminary plans when there is a very complex project. This will help ensure that the owner, the design engineer and the reviewer are on the same page from the very beginning of the project. This is consistent with the requirements outlined in T.C.A. § 69-3-108 and the rules contained in Chapter 0400-40-02)

b. Final construction plans and specifications.

   In addition, a Preliminary Engineering Conference may be necessary on large or complex treatment plant projects. The Division during or prior to the site visit for planning limits will determine this.

Following these steps will reduce the time needed for approval of the project.

1.2 Engineering Report and Preliminary Plans

1.2.1 Goals

The goal of the Division is to promote the simplest treatment scheme available that will meet the requirements of the permit (or draft permit) while providing maximum ease of operation. New wastewater collection systems should be designed to and minimize the potential for infiltration and inflow, to avoid disrupting the flow of natural waters, and to minimize solids deposition in sewers to maintain capacity. While short-term construction cost comparisons are important, long-term operability and reliability should be an overriding influence in developing new sewerage collection and treatment works.

1.2.2 Purpose

Before plans and specifications are prepared for new wastewater facilities, for changes to existing facilities, for new sewer lines, or for sewer rehabilitation work which will decrease the cross-sectional area of an existing sewer by more than 15 percent: every owner or an authorized agent shall submit an engineering report to the Division. The purpose of the engineering report is to outline the goals and objectives of the project and to determine whether the proposed project follows the Division's treatment guidelines and satisfies the applicable minimum requirements set by these guidelines. The report should also serve as a comprehensive guide to the municipality in the decision to adopt a project.

1.2.3 Contents - General

The engineering report shall assemble the basic information, present design criteria and assumptions, evaluate alternative solutions, and offer conclusions and recommendations. The report must be sufficiently complete to facilitate further plans and specifications development. As a minimum, the engineering report for any project shall include the following information where appropriate.

1.2.3.1 Purpose and need for the proposed project.

1.2.3.2 Present and design population with the method of determination

1.2.3.3 Nature and extent of the service area (including immediate and probable future development).

1.2.3.4 Description of the existing collection and/or treatment system, including its condition and problems, renovation and rehabilitation or replacement requirements.

1.2.3.5 Present basis of design including reliable measurements or analysis of flow and wastewater constituents and hydraulic, organic and solids loadings attributed to residential, commercial, and industrial users. (See Chapter 2, Appendix 2-A)

1.2.3.6 The 100-year flood elevation.

1.2.3.7 All structures must comply with ASCE 7-10, *Minimum Design Loads for Building and Other Structures*, as identified in the current state building code, IBC-10. The link is found at: http://ascelibrary.org/doi/book/10.1061/asce7. This provision is very significant for protection in the 20 counties of West Tennessee where the greatest seismic risk exists in the New Madrid Seismic Zone.

1.2.3.8 An evaluation of alternative solutions and the rationale for recommending the chosen alternative, considering economics of operations and effectiveness and all costs over the life-cycle of the final project. The life-cycle cost considerations should include a calculation of savings and recaptured capacity that may result from sewer rehabilitation upstream of any new sewer interceptors, pump stations, treatment plants and other appurtenances in the submitted project.

1.2.4 Contents – Wastewater Collection Systems

1.2.4.1 Any new sewer alignments or existing sewers replaced in the same trench that cross a stream or are within 50 feet of the bank of the stream will trigger a "site characterization" conducted by the Division to determine the potential for stream capture. The Division uses *Guidance for Making Hydrologic Determinations*, Version 1.4, May 2011, TDEC, as a reference for making a site characterization. A "Stream" means surface water that is not a wet weather conveyance. [Rule 1200-4-3-.04(20)]

If the site characterization indicates there is no potential for stream capture, then the provisions of a general Aquatic Resource Alteration Permit (ARAP) and the criteria in Chapter 2 of these Design Criteria may apply.

If the site characterization determines that there is potential for stream capture, then the Engineering Report shall include a plan to prevent Stream Capture. The Division requires the process to obtain a site-specific ARAP be initiated at the planning stage. The characteristics of streams, hydrology, and subsurface conditions vary widely across the State. Therefore, the design engineer must exercise judgment for selecting appropriate site controls. For difficult site conditions, the Division may require the services of a professional Geologist and an underground (Geotechnical) survey. In some cases, it may be more economical to consider a different route for the sewer.

1.2.4.2 The Division excludes from the requirements of the design criteria sewer rehabilitation work that does not reduce the cross-sectional area of the sewer or that reduces the cross-sectional area of the sewer pipe by less than 15 percent. Submittal of an engineering report or construction plans and specifications is not required. The Division requires the submittal of an engineering report that includes calculations indicating the sewer capacity following rehabilitation relative to both existing and anticipated future flows for sewer rehabilitation projects that result in the decrease of the cross-sectional area of any sewer pipe by 15 percent or more. A reduction in capacity may be offset by work included in the project (or associated projects) to reduce I/I upstream of the rehabilitated pipe.

1.2.5 Contents – Wastewater Treatment Plants

1.2.5.1 Treatment process and schematic flow diagrams giving the plant unit design parameters.

1. 2. 5.2 Solids handling and disposal options and recommendations.

1.2.5.3 Soil and geologic conditions

Sufficient soils and geologic data shall be submitted with the engineering report (or, if the design engineer feels it to be more appropriate depending on the project scope, with the plans) to evaluate site conditions for all new or major upgrades to treatment plants. At a minimum, the following is required:

a) Soil tests performed - sufficient to provide moisture and compaction data for construction.
b) Borings for representative subsurface conditions. A depth below the bottom footing grade of major structures as recommended by a licensed Tennessee geotechnical engineer.
c) Boring logs or schematic drawings indicating changes of soil types and/or refusal depths.
d) Unsuitable soil conditions with correction or removal contingencies.
e) Karst features with an evaluation of surface water drainage and recommendations as appropriate from a hydrologist/geotechnical engineer licensed in the State of Tennessee.
f) Rock above the bottom footing grade of structures—the Division requires representative core data to a depth recommended by a licensed Tennessee geotechnical engineer. The Division requires an indication of weathered rock conditions along with mud seams or weathered bedding planes.

1.2.5.4 Domestic potable wells within 1000 feet of a plant should be located along with land use of the surrounding area (residential, agricultural, and industrial).

1.2.5.5 The Division requires the submittal of a mass balance for all plants.

The mass balances must include loadings to each unit process, operations, including all recycle, and side stream flows. Mass balances must include the following initial and design operating conditions: maximum, minimum, and average flow, BOD and suspended solids loadings; and maximum, minimum, and average nutrient loadings, especially nitrogen for plants with considerable industrial loadings and/or where nutrient removal.

The report should identify and be consistent with all applicable area wide projects, drainage basins, service areas, comprehensive master growth plans, and metropolitan area plans; e.g. 208, and 303(e) plans.

The design period should be for 20 years unless growth of the area dictated other design parameters.

Preliminary plans can be included with the engineering report. The Division will review preliminary plans for adequacy, but not for construction approval.

1.2.6 Submission of Engineering Report and Preliminary Plans

The Division will review and either approve or comment on the engineering report submittal within 30 days.

1.3 Plans and Specifications

1.3.1 General Content of Final Engineering Plans

All plans and specifications must be in accordance with the approved engineering report, unless modifications are justified based on newly discovered data or problems. All plans for sewerage systems or wastewater treatment works should bear a title showing the name of the municipality, sewer district, institution, or other owner and the seal and signature of the design engineer. The title should show the scale in feet, the north direction, and the date. The cover sheet and all other sheets should bear a general title and be logically numbered. Appropriate subtitles should be included on plan sheets.

The plans should be clear, legible, and drawn to a scale that shows clearly all necessary information. The size of the plans should be approximately 24 inches by 36 inches. All plans should include appropriate design data, including, but not limited to initial and design flow. A location map <u>must</u> be included with each set of plans. The cover letter or letter of transmittal should clearly indicate the system and design engineer with addresses.

Detail plans should include plan views, elevations, sections, profiles, and supplementary views. Plans should also specify dimensions and relative elevations of structures, the location and outline form of equipment, location and size of piping, water levels, ground elevations, and erosion control facilities.

1.3.2 Plans of Sewers

The plans should show the location, size, and direction of flow of all proposed and existing sewers draining to the concerned treatment facility. <u>Hydraulic calculations are required for all lines in the project.</u> The Division requires the clear showing of topography and elevations, both existing and any changes proposed, and all bodies of water (including direction of flow and high water elevations). The Division requires hydraulic calculations of pumping stations, taking into consideration existing loading plus projected loading from developments under construction as well as projected loading from the proposed extension.

Profiles for sewer detail should have a horizontal scale of not more than 100 feet to the inch and a vertical scale of not more than 10 feet to the inch. Plan views have a corresponding horizontal scale. All gravity conveyances are at one inch equal to 50 feet horizontal and one inch equal to 10 feet vertical. All pumped (force main) conveyances should be drawn at one inch equal to 100 feet horizontal and one inch equal to 10 feet vertical.

Plans and profiles should show:

1.3.2.1 Locations of streets and sewers.

1.3.2.2 Lines of ground surface, pipe type and size, manhole stationing, invert and surface elevation at each manhole, and grade of sewer between adjacent manholes. The Division requires manholes labeled on the plan and on the profile correspondingly. Ensure the sewer being sufficiently deep to serve any residence or other source, the elevation and location of the basement floor or other low point source on the profile of the sewer that is to serve the house or source in question.

1.3.2.3 Locations of all special features such as inverted siphons, concrete encasements, elevated sewers, and flow monitoring key manholes.

1.3.2.4 Location of all existing structures below and above ground that might interfere with the proposed construction; particularly water mains, gas mains, storm drains, etc.

1.3.2.5 Detail drawings of all stream crossings with elevations of the streambed and of normal and extreme high and low water levels to the 100-year flood plain, as established by FEMA. See Section 2.4.3.

1.3.2.6 Detail drawings of special sewer joints, cross sections, and appurtenances such as manholes, flush valves, inspection chambers, etc.

1.3.2.7 Location of adjacent streams and the extent of streamside vegetation.

1.3.2.8 An analysis of existing infiltration/inflow should be submitted (and may be required) where I/I is known to be a problem in the existing sewer, and extensions are proposed.

1.3.2.9 General topography including trees within 25 feet of centerline of the proposed sewer main.

1.3.3 Plans of Wastewater Pumping Stations

The Division requires plans be submitted on all wastewater pump stations that serve more than two residences. Any pump station of this size or larger is a "sewerage system" and, as such, must be designed and built in conformance with

these criteria. Large stations (serving more than 50 residences) must be owned by a utility or operate under the terms of a State Operation Permit.

1.3.3.1 The Division requires a general layout plan for projects involving construction or substantial modification of pumping stations. The plan should show:

a. The location and extent of the tributary area.

b. A contour map of the property.

c. Any municipal boundaries within the tributary area.

d. The location of the pumping station and force main and pertinent elevations.

e. A site plan showing the forms of land use (commercial, residential, and agricultural) existing or proposed for the near future within a 100-foot radius of the pumping station. Existing buildings and their types within 100 feet of the pumping station property lines should be included.

1.3.3.2 The Division requires detail plans showing:

a. The proposed pumping station, including provisions for installation of future pumps or ejectors.

b. Test boring locations and test boring information, including groundwater elevation, if encountered above the bottom of the proposed excavation for large (≥ 700 GPM) pumping station sites or a site with suspected unusual geological situations present, i.e., karst..

c. Plan and elevation views of the pump suction (from the wet well), and discharge piping showing all isolation valves and gates.

1.3.4 Plans of Wastewater Treatment Plants

1.3.4.1 General

The Division requires a plan to show the wastewater treatment plant in relation to the collection system. Sufficient topographic features should be included to indicate the plant's location in relation to existing buildings within 700 feet of the plant site, streams and the point of discharge of treated effluent.

1.3.4.2 The Division requires a submittal of layouts of the proposed wastewater treatment plant, showing:

a. Topography of the site.

b. Size and location of plant structures.

c. A schematic flow diagram including main and side stream or recycles with unit and pipe sizing through various plant units, in plain view.

d. A summary of design and initial waste loads, unit sizes, and design parameters for each unit process, from the engineering report, noting particularly, any changes in design assumptions.

e. Piping, the materials handled and the direction of flow through the pipes, and any arrangements for bypassing individual units.

f. Minimum, average, and maximum hydraulic profiles showing flow of wastewater, supernatant liquor, and sludge.

g. Test borings and groundwater elevations, if encountered.

h. Ultimate use or disposal of sludge or bio-solids.

1.3.4.3 Detail plans must show the following:

a. Location, dimensions, and elevations of all existing and proposed plant facilities.

b. Elevation of high-water level of the receiving body of water, at the 100- year flood, if known, as established by FEMA or some other generally recognized State/Federal agency.

c. Elevation of the low-water level of the receiving body of water.

Pertinent data concerning the rated capacity of all pumps, blowers, motors and other mechanical devices—include in the specifications and plans.

1.3.5 Specifications

The objective of the specifications is to supplement the plans by describing the intended project in sufficient detail for competitive bidding and construction.

The specifications should include, but not be limited to, all construction information which is not shown on the drawings and is necessary to inform the builder in detail of the design requirements as to: the quality of materials, workmanship and fabrication of the project, and the type, size, operating characteristics, and rating of equipment; allowable leakage; machinery; valves, piping, and jointing of pipe; electrical apparatus, wiring, and meters; laboratory fixtures and equipment; operating tools; construction materials; special materials such as stone, sand, gravel or slag; miscellaneous appurtenances; instructions for testing materials and equipment as necessary to meet design standards; and operating tests for the completed works and component units.

The specifications and/or plans should contain sufficient information to allow clear access to siphon structures with barrel isolation gates for cleaning.

A fence should surround all wastewater treatment plants. The Division requires a fence of fabric that is at least six feet high and of a type that is difficult to climb and topped with at least two strands of barbed wire. The exceptions to this type of fencing are lagoons and land application systems. Such treatment plants can use livestock fence, if a sufficient number of signs are attached which contain a warning against trespassing and indicate that the fenced area is used for treating wastewater. Generally, pumping stations should be fenced similarly to plants with the exception that the entrance tube to "canned" lift stations need not be fenced.

1.3.6 Review and Approval Procedure

Every owner or his authorized representative, before installing wastewater or industrial waste facilities, or for changes (rehabilitation, relocation or repair) in the existing system, should submit four sets of complete plans and specifications of the proposed facilities to the Division. Construction cannot start without approval from the Division.

If the owner of the project is not the ultimate recipient of the wastewater, the recipient must approve the plans and specifications and must agree to receive wastes and provide treatment, before construction begins.

All plans and specifications shall be prepared under the supervision of a professional engineer. All copies of plans and specifications submitted for review shall bear the seal and signature of the professional engineer, licensed to practice in the State of Tennessee, who supervised their preparation. Each sheet of the plans shall be hand dated with a copy of the seal and signature of the engineer. The original seal, signature and date are required only on the title sheet and front cover of the specifications.

The Division will review and either approve or comment on the final plans and specifications within 30 days. The Division will retain one copy of plans and specifications for the record, with the remaining returned to the owner.

The Division requires that one stamped copy of the approved plans and specifications be on the construction site and ready to show to the state inspector. Colorized photocopies or scanned plans approved by the Division are acceptable to be on site as an alternative but must be 24 inches by 36 inches in size. Failure to do so may result in a shutdown of construction until an approved copy of the plans is available on site.

1.3.7 Revisions to Approved Plans

Prior to any changes, the Division must approve any deviations from approved plans or specifications affecting capacity, flow, operation of units, or point of discharge in writing. The Division will permit minor structural revisions during construction with the concurrence of the design engineer.

1.3.8. Construction Supervision

The owners should ensure that competent and experienced personnel, preferably the design engineer or his representative, carefully monitor the progress of construction to see that all work conforms to the approved plans and specifications.

Any modifications to the plans or specifications during construction must have approval by the Division (Section 1.3.7).

1.3.9 Operation During Construction

The Division requires all construction to be in accordance with applicable permit requirements.

1.3.10 Final Review of Treatment Facilities

The Division must receive a written request for final review approval of the treatment facilities at least two weeks in advance of the requested date.

In cases of plant upgrades or modifications, the Division may allow individual units to operate prior to final review in order to facilitate construction. The Division requires prior approval to do this (see Section 1.3.9).

1.3.11 Reliability Classification

1.3.11.1General

Reliability standards establish minimum levels of reliability for three classes of sewerage works (see Section 1.1.2). Pump stations associated with, but physically removed from, the actual treatment works may have a

different classification than the treatment works itself. Specific requirements pertaining to treatment plant unit processes for each reliability class are described in EPA's technical bulletin, Design Criteria for Mechanical, Electric, and Fluid System and Component Reliability, EPA 430-99-74-001; available from Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

The Division of Water Resources will assign the reliability classification during the planning limits/site approval phase of the project.

1.3.11.2 Guidelines for classifying sewerage works as follows:

a. Reliability Class I
Examples of Reliability Class I works might be those discharging near drinking water reservoirs, into shellfish waters, or in close proximity to areas used for water contact sports.

b. Reliability Class II

Works which discharge into navigable waters that would not be permanently or unacceptably damaged by short-term effluent quality degradations, but could be damaged by continued (approximately several days) effluent quality degradation. An example of a Reliability Class II works might be one that discharges into recreational waters.

c. Reliability Class III

These are works not otherwise classified as Reliability Class I or Class II.

1.3.11.3 Component Backup Requirements

Below are requirements for Reliability Class I, II, and III works (backup components for the main wastewater treatment system).

The Division will not consider equalization basins or tanks as a substitute for component backup requirements.

a. Reliability Class I

For components included in the design of Reliability Class I works, the following backup requirements apply.

Mechanically-Cleaned Bar Screens or Equivalent Devices

A backup bar screen should be provided. It is permissible for the backup bar screen to be designed for manual cleaning only. Works with only two bar screens should have at least one bar screen designed to permit manual cleaning.

Pumps

For each set of pumps that perform the same function a backup pump is required. The capacity of the pumps should be such that, with any one pump out of service, the remaining pumps will have the capacity to handle the peak flow. It is permissible for one pump to serve as backup to more than one set of pumps.

Comminution Facility

An overflow bypass with an installed manually- or mechanically-cleaned bar screen is required if comminution of the total wastewater flow is provided. The hydraulic capacity of the comminutor overflow bypass should be sufficient to pass the peak flow with all comminution units out of service.

Primary Sedimentation Basins

There should be a sufficient number of units of a size such that, with the largest flow capacity unit out of service, the remaining units should have a design flow capacity of at least 50 percent of the total design flow to that unit operation.

Final and Chemical Sedimentation Basins, Trickling Filters, Filters and Activated Carbon Columns

There should be a sufficient number of units of a size such that, with the largest flow capacity unit out of service, the remaining units should have a design flow capacity of at least 75 percent of the total design flow to that unit operation.

Activated Sludge Process Components

Aeration Basin

At least two equal volume basins are required. (For the purpose of this criterion, the two zones of contact stabilization process equal only one basin.)

Aeration Blowers or Mechanical Aerators

A sufficient number of blowers or mechanical aerators are required to enable the design oxygen transfer with the largest capacity unit out of service. At least two units are required.

Air Diffusers

The requirement for the air diffusion system for each aeration basin is such that the largest section of diffusers can be isolated without measurably impairing the oxygen transfer capability of the system.

Disinfectant Contact Basins

There should be a sufficient number of units of a size such that, with the largest flow capacity unit out of service, the remaining units should have a design flow capacity of at least 50 percent of the total design flow to that unit operation.

b. Reliability Class II

The Reliability Class I requirements shall apply except as modified below.

Primary and Final Sedimentation Basins and Trickling Filters

There should be a sufficient number of units of a size such that, with the largest flow capacity unit out of service, the remaining units should have a design flow capacity of at least 50 percent of the design basis flow to that unit operation.

Components Not Requiring Backup

Requirements for backup components in the wastewater treatment system shall not be mandatory for components which are used to provide treatment in excess of typical biological (i.e., activated sludge or trickling filter), or equivalent physical/chemical treatment, and disinfection. This may include such components as:
Chemical Flash Mixer
Flocculation Basin
Chemical Sedimentation Basin
Filter
Activated Carbon Column

c. Reliability Class III

The Reliability Class I requirements should apply except as modified below.

Primary and Final Sedimentation Basins

There should be at least two sedimentation basins.

Activated Sludge Process Components

Aeration Basin

A single basin is permissible.

Aeration Blowers or Mechanical Aerators

There should be at least two blowers or mechanical aerators available for service.

Air Diffusers

The Reliability Class I requirements shall apply.

Components Not Requiring Backup

Requirements for backup components in the wastewater treatment system are not mandatory for components to provide treatment in excess of primary sedimentation, and disinfection, except as modified above.

This may include such components as:

- Trickling Filter
- Chemical Flash Mixer
- Flocculation Basin
- Chemical Sedimentation Basin
- Filter
- Activated Carbon Column

1.3.11.4 Component Design Features and Maintenance Requirements

Provisions for Isolating Components

Each component should have provisions to enable it to be isolated from the flow stream to permit maintenance and repair of the component without interruption of the works' operation.

Main Wastewater System Pump Isolation

Minimize the use of in-line valves to isolate the main wastewater pumps. It is permissible to place shutoff valves on the suction and discharge lines of each pump. However, in such a case, provide an alternate means for stopping flow through the pump suction or discharge lines to permit maintenance on the valve.

1.3.11.5 Electric Power System

The following criteria should apply to those portions of the system supplying power to vital components. A vital component is one whose operation or function is required to prevent a controlled diversion, is required to meet effluent parameters, or is required to protect other vital components from damage. Identify vital components in the permit/site approval phase, depending on the reliability class and treatment scheme employed. Find further information in Chapter 14, Instrumentation, Control and Electrical Systems.

Power Sources

Provide two separate and independent sources of electric power to the works either from two separate utility substations or from a single substation and a works (plant and/or main pump station) generator. If available from the electric utility, at least one of the works' power sources should be a preferred source (i.e., a utility source that is one of the last to lose power from the utility grid due to loss of power generating capacity). As a minimum, the capacity of the backup power source for each class of treatment works should be:

a. Reliability Class I

   Sufficient to operate all vital components, during peak wastewater flow conditions, together with critical lighting and ventilation.

b. Reliability Class II

   Same as Reliability Class I, except that vital components used to support the secondary processes (i.e., mechanical aerators or aeration basin air compressors) need not be included as long as the treatment provided is equivalent to sedimentation and disinfection.

c. Reliability Class III

   Sufficient to operate the screening or communication facilities, the main wastewater pumps, the primary sedimentation basins, and the disinfection facility during peak wastewater flow condition, together with critical lighting and ventilation.

Power Distribution External to the Works

Distribute the independent sources of power to the works' transformers in a way to minimize common mode failures from affecting both sources.

Example: The two sets of distribution lines should not be located in the same conduit or supported from the same utility pole. The two sets of overhead distribution lines, if used, should not cross or be located in an area where a single plausible occurrence (e.g., fallen tree) could disrupt both lines. Use devices to protect the system from lightning.

Transformers

Transform each utility source of power to the works to usable voltage with a separate transformer. Protect the transformers from common mode failure by physical separation or other means.

Power Distribution Within the Works

Service to Motor Control Centers

The internal power distribution system should be designed such that no single fault or loss of a power source will result in disruption (i.e., extended, not momentary) of electric service to more than one motor control center associated with the Reliability Class I, II, or III vital components requiring backup power.

Division of Loads at Motor Control Centers

Divide vital components of the same type and serving the same function as equally as possible between at least two motor control centers. Also, divide non-vital components in a similar manner, where practicable.

Power Transfer

Where power feeder or branch circuits can be transferred from one power source to another, a mechanical or electrical safety device should be provided to assure that the two power sources cannot be cross-connected, if unsynchronized. Provide automatic transfer in those cases when the time delay required to manually transfer power could result in a failure to meet effluent limitations, a failure to process peak influent flow, or cause damage to equipment. Also, where automatic pump control is used, similarly transfer the control panel power source and pump power source.

Example: The connection of the two power sources from utility substations to the motor control centers through circuit breakers. Provide a circuit breaker to cross-connect the two motor control centers in the event one of the two normally energized power feeders fails. Achievement of additional backup capability for the main pump by connecting one of the three pumps to the motor control center cross-connect. This assures that two out of three

pumps will be available in the event of a panel fire or panel bus short circuit.

Breaker Settings or Fuse Ratings

Breaker settings or fuse ratings should be coordinated to effect sequential tripping such that the breaker or fuse nearest the fault will clear the fault prior to activation of other breakers or fuses to the degree practicable.

Equipment Type and Location

Try to minimize failures resulting from plausible causes, such as fire or flooding through better equipment design and location. The following requirements apply:

Switchgear Location

Protect electric switchgear and motor control centers from sprays or moisture from liquid processing equipment and from breaks in liquid handling piping. Locate, where practicable, the electric equipment in a separate room from the liquid processing equipment. Do not run liquid handling piping through this room. Locate the electric switchgear and motor control centers above ground and at a minimum, two feet above the one hundred year flood (or wave action) elevation.

Conductor Insulation

Wires in underground conduits or in conduits that can be flooded should have moisture resistant insulation as identified in the National Electric Code.

Motor Protection from Moisture

Protect all outdoor motors adequately from the weather. Motors located indoors and near liquid handling, piping or equipment should be, at least, of splash-proof design. Consider providing heaters in motors located outdoors or in areas where condensation may occur.

The following criteria should apply to motors (and their local controls) associated with vital components. All outdoor motors, all large indoor motors (i.e., those not readily available as stock items from motor suppliers), and, where practicable, all other indoor motors, should be located at a minimum of two feet above the one hundred year flood (or wave action) elevation or from clogged floor drains. Indoor motors located at or below the one hundred year flood (or wave action) elevation should be housed in a room or building which is protected from flooding during the one hundred year flood (or wave action). The building protection should include measures such as no openings (e.g.,

submarine doors, windows, hatches) to the outside below the flood elevation and a drain sump pumped to an elevation above the flood elevation.

Explosion Proof Equipment

Use explosion proof motors, conduit systems, switches and other electrical equipment in areas where flammable liquid, gas or dust is likely to be present.

Routing of Cabling

To avoid a common mode failure, do not route conductors to components that perform the same function in parallel in the same conduit or cable tray. Conduits housing such cables should not be routed in the same underground conduit bank unless the conduits are protected from common mode failures (such as by encasing the conduit bank in a protective layer of concrete).

Motor Protection

Protect three-phase motors and their starters from electric overload and short circuits on all three phases.

Large motors should have a low-voltage protection device that, on the reduction or failure of voltage, will cause and maintain the interruption of power to that motor.

Consider the installation of temperature detectors in the stator and bearings of large motors in order to give an indication of overheating problems.

Provisions of Equipment Testing

Include provisions in the design of equipment requiring periodic testing, to accomplish the tests while maintaining electric power to all vital components. This requires being able to conduct tests, such as actuating and resetting automatic transfer switches, and starting and loading emergency generating equipment.

Maintainability

Design the electric distribution system and equipment to permit inspection and maintenance of individual items without causing a controlled diversion or causing violation of the effluent limitations.

Emergency Power Generator Starting

The means for starting a works-based emergency power generator should be completely independent of the normal electric power source. Air starting systems should have an accumulator tank(s) with a volume sufficient to furnish air for starting the generator engine a minimum of three (3) times without recharging. Batteries used for starting should have a sufficient charge to permit starting the generator engine a minimum of three (3) times without recharging.

The starting system should be appropriately alarmed and instrumented to indicate loss of readiness (e.g., loss of charge on batteries, loss of pressure in air accumulators, etc.).

1.3.12 New Technology

The definition of new technology is any method, process, or equipment used to treat or convey wastewater and not discussed in this manual. This does not refer to innovative technology as defined by EPA.

After review of treatability data and the complete engineering report, the Division may approve the plans if it is satisfied that the method, process or equipment will efficiently operate and meet the treatment requirements.

Appendix 1-B
Wastewater Discharge Checklist

1. Applicant contacts appropriate Environmental Field Office and Nashville Central Office, to discuss project submittals.

2. On all proposed discharges in the smaller flow ranges, the applicant must first investigate subsurface disposal (even at a remote site) and transference to a public sewer system.

3. Applicant submits required information and requests site inspection/planning limits. Field Office responds to applicant on results, including the assigned reliability classification.

4. Applicant submits NPDES application with associated information; i.e., owner/operator, financial information and preliminary engineering report to the Field Office.

5. Permit Section forwards draft permit to Field Office and applicant and issues public notice of intent to (not to) issue NPDES permit.

6. Permit Section evaluates responses to draft permit and public notice, makes decision on necessity for public hearing, issues public notice of hearing, if required, conducts public hearing, evaluates comments, makes and publicizes issuance decision.

7. Final engineering report submitted, reviewed and approved.

8. Final plans and specifications submitted, reviewed and approved for construction.

9. Construction proceeds and applicant requests final inspection by the Field Office.

Appendix 1-C
Guiding Principles, Goals, and Implementation Methods

Tennessee Collection Systems
Guiding Principles, Goals, and Implementation Methods

The Mission of the Department of Environment and Conservation (TDEC) is to enhance the quality of life for citizens of Tennessee and to be stewards of our natural environment by protecting and promoting human health and safety, and protecting and improving the quality of Tennessee's water through a responsible regulatory system.

In keeping with TDEC's mission, the purpose of this document is for the Division of Water Resources (DWR) to set guiding principles for the development and implementation of collection system policy for the State of Tennessee. Any policy, guidance and/or criteria established for the state must be consistent with these principles.

The Division staff has observed many instances in municipalities across the state where leakage of water into sewage collection systems (I/I – infiltration and inflow) has been a direct or indirect cause of permit violations and pollution of the environment. Additionally, I/I steals part of the capacity of sewage collection and treatment systems. In some cases, this loss of capacity has hindered growth and caused economic problems in those communities. I/I in sewage collection systems increases the cost of conveyance and treatment and this is reflected in higher bills paid by the customers.

The overarching goal is to ensure that Tennessee's wastewater infrastructure (primarily collection systems) is sustainable, energy efficient and protective of public health and water resources. Modern, proven technologies and materials are commonly available to stop or prevent leakage into sewage collection systems, Therefore, a major focus of this policy is to reduce I/I in Tennessee communities. This requires a two-pronged approach: 1) promote design and construction practices that do not allow leakage into new sewage collection systems, and 2) promote rehabilitation processes, practices and strategies that eliminate I/I in existing sewage collection systems. The following principles, goals and, implementation methods are focused on this two-pronged approach.

GUIDING PRINCIPLES

- Collection system policy, criteria and guidance should be developed in a transparent manner by TDEC with significant involvement of the key stakeholders (regulated and design communities).
- Collection system design criteria should promote new sewer design that minimizes the potential for infiltration and inflow. Examples would include methods that prevent trench water accumulation and stream capture or new technologies such as HDPE heat fused pipe. Additionally, the design criteria should include practices minimize solids deposition within sewers.
- Collection System operations and maintenance practices should optimize capacity utilization.
- The legal/enforcement framework for collection system policy should acknowledge that more time is often needed to build a more sustainable infrastructure than by

simply increasing capacity in terms of pipe size, pumping and treatment. The legal framework should also evaluate ways to address easement and ownership of private laterals and taps.

GOALS

- Tennessee's collection system policy should provide support for TDEC in setting requirements for system design, correction, operation and management.
- Tennessee's collection system policy should provide support for decision makers, tools for improved management (utility manager, boards, mayors & other elected officials), including improved request for proposal procedures.
- Tennessee's collection system policy should provide for better assurance of proper construction and promote slowing down the degradation of infrastructure.

IMPLEMENTATION METHODS

- Review and revise current design criteria for new construction and rehabilitation and establish set schedule for review.
- Train and educate utilities, consultants, contractors, and other stakeholders on successful sewer rehabilitation approaches.
- Establish procedures by which TDEC resources move towards construction inspection as opposed to plans review.
- Provide a collection system construction inspection class as well as other courses targeted for utility personnel training.
- Require that life cycle analysis (including the cost of I/I over the life of the project) is part of design criteria and required for engineering report/plans submittal.
- Require stricter adherence to design criteria and consistency with Tennessee Collection System Policy.

Sandra K. Dudley
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Director, Division of Water Resources

12/14/12
Date

CHAPTER 2

Sewers and Wastewater Pumping Stations

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2.1 General Requirements for Collection Systems

2.1.1 Construction Approval

In general, construction of new sewer systems or extensions of existing systems must ensure that the downstream conveyance system and the receiving wastewater treatment plant are either:

a. Capable of adequately conveying or processing the added hydraulic and organic load, or

b. Capable of providing adequate conveyance or treatment facilities on a time schedule acceptable to the Division

2.1.2 Ownership

Sewer systems including pumping stations integral to gravity sewer and low-pressure sewer designs require ownership by a responsible party, such as a public entity, for operation and maintenance.

2.1.3 Design

The design and construction of new sewer systems must achieve total containment of sanitary wastes and exclusion of infiltration and inflow (I/I). This includes installing pipe with watertight joints, watertight connections to manholes, and watertight connections to service laterals or service lateral stubs and trench design that minimizes the potential for migration of water along the trench. However, the new sewer system and appurtenances must be able to convey the wastewater load, including existing I/I, from upstream areas as appropriate.

2.1.4 Overflows

The Division of Water Resources (Division) will not permit overflows in separate sanitary sewers or new overflows in existing combined sewers. The Division will not permit overflows in new interceptor sewers intercepting existing combined sewers. An alarm system to signal existing overflow conditions and procedures for reporting overflows may be required.

2.1.5 Calculations

The Division requires the submittal of all computations and other data used for design of the sewer system.

2.2 Design Considerations

2.2.1 Design Period

2.2.1.1 Collection sewers (Laterals and Submains)

The Division requires collection sewers for the ultimate development of the tributary areas.

2.2.1.2 Main, Trunk, and Interceptor Sewers

The Division requires certain design factors for trunk sewers:

a. Possible solids deposition, odor, and pipe corrosion that might occur at initial flows
b. Population and economic growth projections and the accuracy of the projections
c. Comparative costs of staged construction alternatives
d. Effect of sewer sizing on land use and development

2.2.2 Basis of Design

The Division's design requirements for new sewer systems are on the basis of per capita flows or alternative methods.

2.2.2.1 Per Capita Flow

The Division requires the use of Appendix 2-A. Substitutions or additions to the information presented in this table are acceptable if better or more accurate data is available.

The Division requires the following:

a. Lateral and Submains: Minimum peak design flow should be not less than 400 percent of the average design flow.

   "Lateral" - a sewer that has no other common sewers discharging into it.

   "Submain" is defined as a sewer that receives flow from one or more lateral sewers.

b. Main, Trunk, and Interceptor sewers: Minimum peak design flow should be not less 250 percent of the average design flow.

   "Main" or "trunk" is defined as a sewer that receives flow from one or more submains.

   "Interceptor" - a sewer that receives flow from a number of main or trunk sewers, force mains, etc.

2.2.2.2 Alternative Methods

The Division allows alternative methods other than on the basis of per capita flow rates. Alternative methods may include the use of peaking factors of the contributing area, allowances for future commercial and industrial areas, separation of infiltration and inflow from the normal sanitary flow (for new sewers serving existing upstream sewers), and modification of per capita flow rates (based on specific data). There should be no allowance for infiltration or inflow into newly constructed or proposed sewers.

2.2.3 Design Factors

The Division requires consideration of the following factors:

a. Peak wastewater flows from residential, commercial, institutional, and industrial sources
b. Potential for groundwater infiltration from existing upstream sewers
c. Topography and depth of excavation
d. Treatment plant location
e. Soils conditions
f. Pumping requirements
g. Maintenance, including manpower and budget
h. Existing sewers
i. Existing and future surface improvements
j. Controlling service connection elevations
k. Proximity to surface streams, including minimizing the potential for draining or diversion of stream water into the pipe trench
l. Watertight and exclude groundwater and surface water.

2.3 Design and Construction Details

2.3.1 Gravity Sewers

The Division requires gravity sewers to be approximately one-half full when conveying the anticipated peak daily dry weather flow and does not surcharge when conveying the anticipated peak wet weather flow.

2.3.1.1 Minimum Size

The minimum size of new public sewers should be 8 inches (nominal) in diameter.

2.3.1.2 Depth

Generally, sewers should not be less than 2 ½ feet deep but should be sufficiently deep to prevent freezing and physical damage.

2.3.1.3 Roughness Coefficient

The Division requires that a roughness coefficient "n" value of 0.013 be used in Manning's formula for the design of all sewer facilities unless a roughness coefficient specific to the given pipe material is available. The roughness coefficient selected must consider the long-term condition of the sewer. However, the Division requires an "n" value equal to or greater than 0.011.

2.3.1.4 Slope

Sewers must be self-cleansing and capable of transporting most solids to the desired point, usually a treatment facility. Two methods are approved for design in the State of Tennessee: 1) Tractive Force and 2) Traditional (Ten-State Standards). For reasons of economical design and long-term maintenance, the Division prefers the Tractive Force Method.

Tractive Force Method:

ASCE and WEF (WEF Manual of Practice No. FD-5 *Gravity Sanitary Sewer Design and Construction*, 2007, Section 5.6) now advocates a transition to the tractive force approach for self-cleansing design. “Tractive Force (TF) design is a major improvement over traditional methods to achieve self-cleansing in gravity sewers. This approach results in a self-cleansing pipe slope value (S_{min}) for the design minimum flow rate (Q_{min}) in each sewer reach. Q_{min} is the predicted largest 1-hour flow rate in the reach during the lowest flow week over the sewer design life. Past design practices seldom included accurate estimation of Q_{min} values, but good estimates of Q_{min} are crucial for TF design. The engineer should show in the engineering report the calculations for Q_{min} for new sewer pipe projects. As compared to traditional minimum slopes, S_{min} slopes via the TF method are flatter for sewers carrying typical to larger Q_{min} values and steeper for sewers carrying smaller Q_{min} values.” (Merritt, LaVere B., *Tractive Force Design for Sanitary Sewer Self-Cleansing*, ASCE, May 2009)

Once a good estimate has been developed for Q_{min}, then Table 2-1 (WEF, 2007, Table 5.5, page 148) for calculating minimum slopes for a typical condition in sewers is provided to assist designers with applying TF principles.

Table 2-1 Tractive Force Equations for Minimum Slope

Sewer Size (inches)	When n is Variable* value of S_{min} = (Q in cfs)
8	$0.000848\ Q_{min}^{-0.5707}$
10	$0.000887\ Q_{min}^{-0.5721}$
12	$0.000921\ Q_{min}^{-0.5731}$
15	$0.000966\ Q_{min}^{-0.5744}$
18	$0.001004\ Q_{min}^{-0.5754}$
21	$0.001038\ Q_{min}^{-0.5761}$
24	$0.001069\ Q_{min}^{-0.5768}$
27	$0.001097\ Q_{min}^{-0.5774}$
30	$0.001123\ Q_{min}^{-0.5778}$
36	$0.001169\ Q_{min}^{-0.5787}$
42	$0.001212\ Q_{min}^{-0.5812}$

3Based on Darcy-Weisbach

Traditional Method:

The Traditional Method for conventional gravity sewers requires mean velocities, when flowing full, of not less than 2.0 feet per second. Table 2-2 provides minimum slopes when using the traditional method; however, slopes greater than these are desirable.

Table 2-2 Minimum Slope from Traditional Method

Sewer Size (inches)	Minimum Slope***** (feet per 100 feet)
8	0.40
10	0.28
12	0.22
15	0.15
18	0.12
21	0.10
24	0.08
27	0.067
30	0.058
36	0.05 **
42	0.042***

* Great Lakes Upper Mississippi River Board, 1997.
** Recommended steeper – to give velocity of 2.1 ft/sec (WEF, 2007)
*** Recommended steeper – to give velocity of 2.3 ft/sec (WEF, 2007)

Under special condition, the using the Traditional Method, the Division may allow slopes slightly less than those required for the 2.0 feet-per-second velocity when flowing full may be permitted. Such decreased slopes will only be considered where the depth of flow will be 0.3 of the diameter or greater for design average flow. Whenever such decreased slopes are proposed, the design engineer should furnish with his report his computations of the depths of flow in such pipes at minimum, average, and daily or hourly rates of flow. The maintaining wastewater agency must recognize and accept in writing the problems of additional maintenance caused by decreased slopes.

Uniform slope between manholes is required.

A minimum of 5 feet of horizontal separation between gas mains is required.

Anchors are required for sewers on 20 percent slope or greater. Secure anchors will have a minimum two-foot thick tightly compacted clay collar or equal. Suggested minimum anchorage spacing is as follows:

a. Not over 36 feet center to center on grades 20 percent and up to 35 percent.

b. Not over 24 feet center to center on grades 35 percent and up to 50 percent.

c. Not over 16 feet center to center on grades 50 percent and over.

2.3.1.5 Alignment

Straight alignment between manholes is required for gravity sewers. However, curved sewers may be approved where circumstances warrant but only in large (i.e., 24" and larger) diameter segments.

2.3.1.6 Increasing Size

When a smaller sewer joins a larger one, the Division requires the alignment to maintain the same energy gradient. An approximate method for securing these results is to match the crowns of the sewers entering/ exiting the manhole or junction structure.

2.3.1.7 High-Velocity Protection

Where velocities greater than 15 feet per second are expected, the Division requires protective measures against internal erosion or displacement by shock.

2.3.2 Materials

The Division will consider any generally accepted material for sewers. The material selected should be adapted to local conditions such as character of industrial wastes, possibility of septicity, soil characteristics, abrasion and similar problems. The Division requires careful consider of pipes and compression joint materials subjected to corrosive or solvent wastes. Chemical/stress failure and stability in the presence of common household chemicals such as cooking oils, detergents and drain cleaners are factors.

The specifications should stipulate need to keep clean the pipe interior, sealing surfaces, fittings and other accessories. Pipe bundles should be stored on flat surfaces with uniform support. The protection of stored pipe is required. Pipe with prolonged exposure (six months or more) to sunlight requires a suitable covering (canvas or other opaque material). The Division requires care be given to gaskets. Ensure that gasket not be exposed to oil, grease, ozone (produced by electric motors), excessive heat and direct sunlight. Consult with the manufacturers for specific storage and handling recommendations.

2.3.2.1 Rigid Pipe

Rigid pipe includes, but is not be limited to, concrete pipe. Any rigid pipe should have a minimum crushing strength of 2000 pounds per lineal foot. All pipes should meet the appropriate ASTM and/or ANSI specifications.

2.3.2.2 Semi-rigid Pipe

Semi-rigid pipe includes, but is not be limited to, ductile iron. All pipes should meet the appropriate ASTM and/or ANSI specifications.

2.3.2.3 Flexible Pipe

Flexible pipe includes, but is not be limited to, ABS solid wall pipe, polyvinyl chloride pipe (PVC), polyethylene pipe (PE), fiberglass composite pipe, reinforced plastic mortar pipe (RPM) and reinforced thermosetting resin pipe (RTR). PVC pipe should have a minimum Standard Dimension Ratio (SDR) of 35. The Division requires that all other flexible pipe have the same calculated minimum deflection under identical conditions as the SDR 35 PVC pipe.

To calculate the flexible pipe deflection under earth loading use the formula presented in the ASCE/WPCF publication, Design and Construction of Sanitary and Storm Sewers.

All pipes should meet appropriate ASTM and/or ANSI specifications. ASTM D-3033 and D-3034 PVC pipes differ in wall thickness and have non-interchangeable fittings.

2.3.3 Pipe Bedding and Backfilling

The Division requires that all sewers designs provide protection from damage from superimposed loads. The width and depth of the trench require allowances be made for loads on the sewer. Backfill material up to three feet above the top of the pipe should not exceed 6 inches in diameter at its greater dimension.

The Division requires ductile iron pipe in roadways where cover is less than 4 feet. In such cases, a minimum cover of six inches is required.

The Division requires ductile iron pipe or relocation when the top of the sewer is less than 18 inches below the bottom of a culvert or conduit.

2.3.3.1 Rigid Pipe

Bedding Classes A, B, or C as described in ASTM C-12 or WPCF MOP No. 9 (ASCE MOP No. 37) should be used for all rigid pipe, provided the proper strength pipe is used with the specified bedding to support the anticipated load. The Division requires the use of ASTM-C-12 (placement of bedding and backfill).

2.3.3.2 Semi-Rigid Pipe

The Division requires the use of Bedding Classes I, II, III, or IV (ML and CL only) as described in ASTM D-2321 for all semi-rigid pipe provided with the specified bedding to support the anticipated load.

The Division requires ASTM-A-746 be used to install ductile iron pipe.

2.3.3.3 Flexible Pipe

The Division requires the use of Bedding Classes I, II, or III as described in ASTM D-2321 for all flexible pipe. The Division requires the proper strength pipe with the specified bedding to support the anticipated load.

The Division requires ASTM-D-2321 for bedding, haunching, initial backfill, and backfill.

The Division requires Class I bedding material for bedding, haunching, and initial backfill as described in 2.3.3.4. (polyethylene pipe).

2.3.3.4 Alternate Bedding Option

The Division will allow all sewers bedded and backfilled with a minimum of 12 inches of Class I material over the top and below the invert of the pipe--an alternative to sub-sections 2.3.3.1, 2.3.3.2 and 2.3.3.3.

2.3.3.5 Deflection Testing

The Division requires deflection testing of all flexible pipes. The Division requires backfill testing after it has been in place at least 24 hours.

No pipe should exceed a deflection of 5%.

The test should be run with a rigid ball or an engineer approved 9-arm mandrel having a diameter equal to 95% of the inside diameter of the pipe. The test requires manually pulling the test device through the line.

2.3.4 Joints

The Division requires the specification to include the method of making joints and the materials used. The Division requires that sewer joints eliminate infiltration and prevent the entrance of roots.

Elastomeric gaskets, other types of pre-molded (factory made) joints, and ABS solvent-cement welded joints are required. The Division requires the use of ASTM-F2620 for butt fusion joining technique with polyethylene pipe. The Division requires the removal of internal beads for butt fusion joints on pipelines with slopes less than one percent. Cement mortar joints are not acceptable. Field solvent welds for PVC and PE pipe and fittings are not acceptable.

2.3.5 Leakage Testing

The Division requires the use of ASTM-C-828 for low-pressure air testing for all pipes. The time required for the pressure to drop from the stabilized 3.5 psig to 2.5 psig should be greater than or equal to the minimum calculated test time (the Division requires that air loss rate be part of the test criteria).
The testing method should take into consideration the range in groundwater elevations projected and the situation during the test. The height of the groundwater should be measured from the top of the invert (one foot of H_20 = 0.433 psi).

Table 2-3 provides the minimum test times and allowable air loss values for various pipe size per 100 ft.

Table 2-3 Leakage Test Parameters

Pipe Size (inches)	**Time**, T (sec/100 ft)	**Allowable Air Loss**, Q (ft^3/min)
6	42	2.0
8	72	2.0
10	90	2.5
12	108	3.0
15	126	4.0
18	144	5.0
21	180	5.5
24	216	6.0
27	252	6.5
30	288	7.0

2.3.6 Visual Inspection

The Division requires that new sewers be video inspected to confirm proper installation and to provide a visual record of the condition of the newly constructed sewer for future reference.

2.3.7 Low Pressure Systems

2.3.7.1 Application

The Division requires the consideration of low-pressure systems for situations in which gravity sewers are extremely costly or impractical, such as rock or high groundwater table.

2.3.7.2 Grinder Pumps

The Division requires all the collection and transport of raw wastewater from individual buildings/dwellings to the pressure system by appropriately sized grinder pumps.

Grinder pumps do not require a septic tank.

All pumps should have operating curves that do not allow backflow under maximum head conditions.

Pumps should be watertight and located above the seasonal groundwater table were possible where possible.

2.3.7.3 Septic Tank Effluent Pump (STEP) system

All STEP installations require careful attention to the following design details and construction techniques:

a. All STEPs preceded by a watertight septic tank. Retrofitting a STEP to an existing septic tank will require a visual inspection of the tank.

   Replacement of all defective septic tanks.

b. STEPs retrofitted to an existing septic tank and drain field must provide a positive means of preventing groundwater from backing up through the drain field to the STEP.

c. The STEP should be located as close as possible to the septic tank.

d. Electrical power supplied through the main circuit box. Electricity furnished to a separate circuit box installed on the exterior wall of the building, near the STEP.

2.3.7.4 Hydraulic

Hydraulic calculations are of extreme importance. Head losses within the low-pressure system will change with each pump activation.

2.3.7.5 Minimum Velocity

The recommended minimum operating velocity in a pressure system should be 2 feet per second (fps).

2.3.7.6 Flushing

There should be a means of cleaning the system, particularly to clear any settleable solids or grease accumulation.

2.3.7.7 Pressure Testing

There should be means for isolating and pressurizing sections of the system to detect and locate leaks.

2.3.7.8 Alarms

There should be an external visual warning system to indicate the malfunction of the pump. The high-level (in storage tank) warning system should be a dual audio / visual system.

2.3.7.9 Cleanouts

The Division requires cleanouts at a maximum of 400-foot intervals.

2.3.7.10 Ventilation

Ventilation of the pumping station should be provided via house vents where allowable or through a separate system.

2.3.8 Manholes

2.3.8.1 Location

The Division requires manholes at the end of each 8-inch diameter sewer or greater. The Division will waive this requirement if a stub-out is installed (assumes line will be extended in near future).

The Division requires manholes at all changes in grade, size, or alignment; at all intersections; and at distances not greater than 400 feet for sewers 15 inches or less. The Division requires manholes at 500 feet for sewer 18 inches to 30 inches. The Division may allow greater spacing in larger sewers and in those carrying a settled effluent.

2.3.8.2 Drop Connection

The Division requires a drop connection for a sewer entering a manhole at an elevation of 24 inches or more above the manhole invert. Where the difference in elevation between the incoming sewer and the manhole invert is less than 24 inches, a filleted invert will prevent solids deposition.

2.3.8.3 Diameter

The minimum diameter of manholes should be 48 inches; larger diameters are preferable. The minimum clear opening in the manhole frame shall meet current OSHA standards.

2.3.8.4 Flow Channels

Flow channels in manholes should be of such shape and slope to provide smooth transition between inlet and outlet sewers and to minimize turbulence. Channeling height should be to the crowns of the sewers. Benches should be sloped from the manhole wall toward the channel to prevent accumulation of solids.

2.3.8.5 Water tightness

The Division requires watertight manhole covers wherever the manhole tops may be flooded. Manholes of brick or segmented block are not appropriate materials for manhole construction where groundwater conditions are unfavorable. In pre-cast concrete manholes, the Division requires plastic gaskets, pre-molded rubber gaskets or flexible, plastic gaskets.

2.3.8.6 Connections

The Division requires special attention be paid to the connection between the manhole wall and the sewer pipe in order to minimize long-term infiltration into the system. The Division requires flexible joints for line connections directly to the manholes, or to short stubs integral with the manholes. Flexible joints are joints that permit the manholes to settle without destroying the watertight integrity of the line connections.

2.3.8.7 Ventilation

The Division requires consideration of ventilation of gravity sewer systems where continuous watertight sections are greater than 1,000 feet in length. Vent height and construction must consider flood conditions.

2.3.8.8 Frames, Covers, and Steps

Frames, covers, and steps, if utilized, should be of suitable material and designed to accommodate prevailing site conditions and to provide for a safe installation.
Materials used for manhole steps should be highly corrosion-resistant. The Division requires aluminum or plastic with reinforcing bar.

2.3.8.9 Vacuum Testing

New manholes should be vacuum tested after construction to verify they will not be new sources of infiltration or inflow. The Division requires the test to include the manhole frame. The Division considers the test acceptable if the vacuum remains at 10 inches of mercury or drops to no less than 9 inches of mercury within one minute. The Division may allow alternative testing methods--if demonstrated to be equal of better than vacuum testing.

2.4 Special Details

2.4.1 Protection of Water Supplies

2.4.1.1 Water Supply Interconnections

There shall be no physical connection between a public or private potable water supply system and a sewer or appurtenance thereto.

2.4.1.2 Relation to Water Mains

Horizontal Separation: Whenever possible, the Division requires at least 10 feet horizontal separation of the sewer from any existing or proposed water main. Should local conditions prevent a lateral separation of 10 feet, the Division may allow the sewer closer than 10 feet to a water main if in a separate trench and if the elevation of the top (crown) of the sewer is at least 18 inches below the bottom (invert) of the water main.

Vertical Separation: Whenever sewers must cross under water mains, the Division requires the sewer at such elevation that the top of the sewer is at least 18 inches below the bottom of the water main. The Division will consider other alternatives if the sewer evaluation cannot be varied.

When it is impossible to obtain proper horizontal and vertical separation as stipulated above, the sewer should be designed and constructed equal to the water main pipe and should be pressure-tested to assure water-tightness (see drinking water criteria) or the joints of the sewer pipe should be encased in concrete to inhibit infiltration/exfiltration. Details of the encasement should be clear and extend the necessary distance to achieve design goals. The designer should consider the temperature differential between the

pipe and the surrounding materials in their determination if reinforcement is necessary. Such arrangements are discouraged.
The Division requires the designer's evaluation, calculations, and conclusions in the project record and provided to all interested parties upon request.

2.4.2 Backflow Preventers

State approved reduced pressure backflow prevention devices are required on all potable water mains serving the wastewater treatment plant or pumping station. The Division can provide a list of approved backflow preventers.

2.4.3 Sewers in Relation to Streams

2.4.3.1 Site Characterizations for Sewers in Proximity to Streams

For new sewers or existing sewers replaced in the same trench that cross or have an alignment within 50 feet of the bank of a surface stream, upon notification of the potential route of the proposed sewer, the Division will perform a site characterization to determine the potential for stream capture. (See Section 1.2.4.1 of Chapter 1) If the Division determines there is potential for stream capture, a site-specific Aquatic Resource Alteration Permit (ARAP) is required, and obtaining this permit will require the design engineer to provide a plan to prevent stream capture. This may require additional study of the characteristics of the stream, including soil classification data, rock depth (if present), recommendations for controlling seepage, cut and fill recommendations, a trench dewatering plan, and other site specific data.

2.4.3.2 Location of Sewers in Streams

Open trench sewers located along streams should be located outside of the streambed and sufficiently removed there from to minimize disturbance or root damage to streamside trees and vegetation.

Sewer outfalls, headwalls, manholes, gate boxes or other structures should be located so they do not interfere with the free discharge of flood flows of the stream.

The Division requires open trench sewer crossings of streams to cross the stream as nearly perpendicular to the stream flow as possible and be free from change in grade.

2.4.3.3 Construction

Sewers entering or crossing streams should be ductile iron pipe from manhole to manhole, wrapped in plastic and encased in high strength flowable fill. (Note: This provision is subject to a case-by-case review. In this case, the Division requires an impermeable barrier that might be flowable fill, concrete, liners, casing pipe or a combination. The best practice may be different depending upon stream flow, local soils, topography and geology).

The sewer should be free of alignment or grade changes. The Division requires sewer systems designs to minimize the number of stream crossings. The Division requires the stream returned as nearly as possible to its original condition upon completion of construction. The Division requires the stream banks to be seeded or other erosion prevention methods employed to prevent erosion. Stream banks should be sodded, if necessary, to prevent erosion. The consulting engineer should specify the method or methods in the construction of the sewers in or near the stream to control siltation.

With regard to prohibitions on the contractor, the Division requires that the specifications contain the following clauses:

- unnecessarily disturbing or uprooting trees and vegetation along the stream bank and in the vicinity of the stream,
- dumping of soil and debris into streams and/or on banks of streams,
- changing course of the stream without encroachment permit,
- leaving cofferdams in streams,
- leaving temporary stream crossings for equipment,
- operating equipment in the stream, or
- pumping silt-laden water into the stream.

The Division requires provisions in the specifications to:

- retard the rate of runoff from the construction site,
- control disposal of runoff,
- liberal use of silt fencing to trap sediment resulting from construction in temporary or permanent silt-holding basins,
- pump discharges resulting from dewatering operations;
- deposit out of the flood plain area all material and debris removed from the streambed.

Specifications should require that cleanup, grading, seeding, planting or restoration of the work area should be carried out as early as practical as the construction proceeds. The Division requires the specifications mandate a trench-dewatering plan for new sewer alignments that cross a stream or are within 50 feet of the bank of the stream defined in Section 1.2.4.1.

2.4.3.4 Special Construction Requirements

The Division requires the employment of special design requirements to prevent stream drainage from sinking at the crossing and following along the sewer pipe bedding. The Division requires an in trench impounding structure of compacted clay or concrete check dams. The Division will consider other proposals.

2.4.3.5 Aerial Crossings

The Division may allow sewers that lay on piers across ravines or streams if no other practical alternative exists or, in the design engineer's judgment, other methods will not be as reliable.

The Division requires support for all joints. All supports designs must prevent frost heave, overturning or settlement. The Division requires precautions against freezing, such as insulation or increased slope and expansion joints between aboveground and belowground sewers. The Division requires deigns to consider the impact of floodwaters and debris. The design should consider maintenance of an adequate waterway for the 100-year flood flows. The design engineer should analyze the impact of the proposed aerial crossing(s) on flooding, including hydraulic modeling, such as Hydrologic Engineering Center-River Analysis System (HEC-RAS) modeling, as necessary.

2.4.3.6 Permits

It is the owner's responsibility to obtain all necessary permits along streams or rivers; i.e., Corps of Engineers, TVA, or the Natural Resources Section of the Division of Water Resources.

2.4.4 Inverted Siphons

Under normal conditions, the Division will not allow inverted siphons. However, if they are, the Division requires that the following:

- Minimum of two barrels,
- Minimum pipe size of six inches--provided with necessary appurtenances for convenient flushing and maintenance,
- Manholes with adequate clearances for rodding,
- Sufficient head and pipe sizes to secure velocities of at least 3.0 feet per second for average flows,
- Inlet and outlet details arranged so that the normal flow is diverted to one barrel, and so that either barrel may be cut out of service for cleaning,
- Design engineer furnishes hydraulic calculations with the plans,
- Proper access maintained.

2.5 General Requirements for Wastewater Pumping Stations

2.5.1 Location and Flood Protection

The Division requires wastewater pumping stations located as far as practicable from present or proposed built-up residential areas, with an all-weather road and noise control, odor control, and station architectural design taken into consideration. Sites for stations should be of sufficient size for future expansion or addition, if applicable. The Division requires security for the pumping station and controls.

The Division requires protection from the 100-year flood for the station's operational components.

Where the wet well is at a depth greater than the water table elevation, special provisions should be made to ensure watertight construction of the wet well. The Division requires connections to the pumping station at an elevation higher than the maximum water table elevation, where possible.

2.5.2 Pumping Rate and Number of Units

At least two pump units should be provided, each capable of handling the expected maximum flow. The Division requires the submittal of pump head and system head curves.

For three or more units the Division requires a design to fit actual flow conditions and must be of such capacity that, with any one unit out of services, the remaining units will have capacity to handle the maximum wastewater flow.

A station expected to operate at a flow rate less than one-half the average design flow for an extended period may create septic conditions due to long holding times in the wet well. The design should consider the need for additional measures to prevent the formation of odors.

The design should the use of variable-speed or multiple staged pumps, particularly when the pumping station delivers flow directly to a treatment plant. The design allows delivery of the wastewater at approximately the same rate as received at the pumping station.

2.5.3 Grit and Clogging Protection

Where it may be necessary to pump wastewater prior to grit removal, the design of the wet well should receive special attention, and the design of the discharge piping should be to prevent grit settling in pump discharge lines of pumps not operating.

Design of the pumping station should consider the protection of the pump from damage caused by grit and debris, where warranted. To accomplish this--maintain minimum pump operational speeds, through the installation of bar screens with a grinder or comminutor, or similar devices. For the larger or deeper stations, duplicate protection units, each sized at full capacity, are preferred.

2.5.4 Pumping Units

2.5.4.1 Pump Openings

The Division requires pumps be capable of passing a 3-inch compressible solid. The Division requires pump suction and discharge openings to be at least 4 inches in diameter unless it is a pump with chopping or grinding capabilities.

2.5.4.2 Priming

The Division requires the placement of pumps so that under normal operating conditions they will operate under a positive suction head (except for suction lift pumps).

2.5.4.3 Intake

Each pump should have an individual intake. Wet well design should be such as to avoid turbulence near the intake.

2.5.4.4 Controls

The location of controls should ensure that the flows entering the wet well to not affect them, by the suction of the pumps, or by proximity to wet well walls. Controls must be able to activate additional pumps if the water in the wet well continues to rise. Controls can be float switches, air-operated pneumatic, radar, ultrasonic or capacitance probe types. Provisions should be made to automatically alternate the pumps in use. Pumping stations with motors and/or controls below grade should be equipped with a secure external disconnect switch. The Division requires consideration of an "intrinsically safe" power source if float switches are used.

The Division requires consideration of redundant controls and/or remote monitoring to assist in preventing overflows.

2.5.5 Flow Measurement

At pumping stations with flow capacity greater than 0.5 million gallons per day (mgd), the Division recommends providing suitable devices for measuring flow.

2.5.6 Alarm System

The Division recommends an alarm system for all pumping stations such as, telemetry alarm to 24-hour monitoring stations or telephone alarms to duty personnel (when reliability classification or property damage warrants it). The Division requires an audiovisual device at the station for external observation when telemetry is not used.

The Division requires alarms for high wet well and power failure, as a minimum, for all pumping stations. For larger stations, the Division requires alarms signalizing pump and other component failures or malfunctions.

The Division requires a backup power supply, such as a battery pack with an automatic switchover feature, for the alarm system, such that a failure of the primary power source will not disable the alarm system. The alarm system must be tested and verified that it is in good working order.

2.5.7 Overflows and/or Bypasses

Pumping stations should be designed and built without any type of overflow or bypass structure.

2.6 Special Details

2.6.1 General

2.6.1.1 Materials

Materials must not contain hydrogen sulfide and other corrosive gases, greases, oils, and other constituents frequently present in wastewater. The Division recommends the use of concrete additives or protective coatings to prevent deterioration caused by corrosive gases.

2.6.1.2 Electrical Equipment

Electrical systems and components (e.g., motors, lights, cables, conduits, switchboxes, and control circuits) in enclosed or partially enclosed spaces where flammable mixtures occasionally may be present (including raw wastewater wet wells) should comply with the National Electrical Code requirements for Class I Division 1 locations.

2.6.1.3 Water Supply

There should be no physical connection between any potable water supply and a wastewater pumping station that under any conditions might cause contamination of the potable water supply. A potable water supply must comply with conditions stipulated in section 2.4.2.

2.6.1.4 Lighting

Adequate lighting is required for the entire pumping station.

2.6.1.5 Pump and Motor Removal

The Division requires the removal of pumps, motors, and other equipment, without interruption of system service.

2.6.1.6 Safety

The Division requires suitable and safe means of access to equipment requiring inspection or maintenance and that stairways and ladders satisfy all OSHA requirements.

2.6.1.7 Valves and Piping

The Division requires suitable shutoff valves on suction and discharge lines of each pump for normal pump isolation and a check valve on each discharge line between the shutoff valve and the pump. Pump suction and discharge piping should not be less than 4 inches in diameter except where design of special equipment allows. The velocity in the suction line should not exceed 6 feet per second and, in the discharge piping, 8 feet per second. A separate shutoff valve is desirable on the common line leaving the pumping station.

2.6.1.8 Ventilation

The Division requires ventilation for all pumping stations during all periods when the station is manned. Portable ventilation equipment is acceptable for small pumping stations. Mechanical ventilation is required if screens or mechanical equipment, which might require periodic maintenance and inspection, are located in the wet well. In pits over 15 feet deep, multiple inlets and outlets are desirable. The Division requires that dampers not be used on exhaust or fresh air ducts, and fine screens or other obstructions in air ducts should be avoided to prevent clogging.

2.6.2 Wet Well - Dry Well Stations

2.6.2.1 Separation

The Division requires complete separation of wet and dry wells, including their superstructures.

The Division recommends dividing the wet well into two sections, properly interconnected, to facilitate repairs and cleaning where continuity of pumping station operation is necessary.

2.6.2.2 Wet Well Size and Design

Provide an evaluation of the effective capacity of the wet well based on pumping requirements and reliability classifications.

Wet well design should consider approaches for minimizing solids deposition.

2.6.2.3 Dry Well Dewatering

The Division requires a separate sump pump in the dry wells to remove leakage or drainage with the discharge above the high water level of the wet well. The Division will not approve water ejectors connected to a potable water supply. All floor and walkway surfaces should have an adequate slope to a point of drainage.

2.6.3 Suction Lift Stations

2.6.3.1 Priming

Conventional suction-lift pumps should be of the self-priming type, as demonstrated by a reliable record of satisfactory operation. The maximum recommended lift for a suction lift pumping station is 15 feet, using pumps of 200 gallons per minute (gpm) capacity or less.

2.6.3.2 Capacity

The capacity of suction lift pumping stations should be limited by the net positive suction head and specific speed requirements, as stated on the manufacturer's pump curve, for the most severe operating conditions.

2.6.3.3 Air Relief

a. Air Relief Lines
   An air relief line on the pump discharge piping is required for all suction lift pumps. This line should be located at the maximum elevation between the pump discharge flange and the discharge check valve to ensure the maximum bleed-off of entrapped air. The air relief line should terminate in the wet well or suitable sump and be open to the atmosphere.

b. Air Relief Valves
   The Division requires air relief valves in air relief lines on pumps not discharging to gravity sewer collection systems. The air relief valve should be located as close as practical to the discharge side of the pump.

2.6.3.4 Pump Location

For standard designs, suction lift pumps are mounted on the wet well but not within the wet well.

2.6.3.5 Access to Wet Well

Access to the wet well should not be through the dry well, and the dry well should have a gastight seal when mounted directly above the wet well.

2.6.4 Submersible Pumps

2.6.4.1 Pump Removal

Submersible pumps should be readily removable and replaceable without dewatering the wet well or requiring personnel to enter the wet well.

The Division recommends a hoist or crane system for removing the pumps from the wet well either through a permanent installation at the site or a mobile system that could be utilized at multiple sites.

2.6.4.2 Controls

The control panel should be located outside the wet well and suitably protected from weather, humidity, vandalism, and gases migrating from the wet well.

2.6.4.3 Valves

The Division recommends all control valves on the discharge line for each pump in a convenient location outside the wet well in separate pits and protected from weather and vandalism.

2.6.4.4 Submergence

Positive provision, such as backup controls, is required to assure submergence of the pumping units.

2.6.5 Grinder and Effluent Pumps

The requirements for grinder pumps are included in Section 2.3.6.

2.7 Operability and Reliability

2.7.1 Objective

The objective of reliability is to prevent the discharge of raw or partially treated wastewater to any waters and to protect public health by preventing backup of wastewater and subsequent discharge to basements, streets, and other public and private property.

2.7.2 Backup Units

A minimum of two pumps or pneumatic ejectors are required in each station in accordance with section 2.5.2.

2.7.3 Power Outages

An emergency power source or auxiliary power is required for all pumping stations larger than 1 MGD to ensure continuous operability unless experience has shown the frequency and duration of outages to be low and the pumping station and/or sewers provide storage sufficient for expected interruptions in power service.

2.7.4 Emergency Power Supply (for Treatment Plants as well as Pumping stations)

2.7.4.1 General

The Division requires provision of an emergency power supply for pumping stations (and treatment plants) to at least two independent public utility sources, or by provision of portable or in-place internal combustion engine equipment that will generate electrical or mechanical energy, or by the provision of portable pumping equipment. Emergency power must be provided for all stations which are 1 MGD or larger, or as determined by the reliability classification.

Emergency power should be provided that, alone or combined with storage, will prevent overflows from occurring during any power outage that is equal to the maximum outage in the immediate area during the last 10 years. If available data were less than 10 years, an evaluation of a similar area served by the power utility for 10 years would be appropriate.

2.7.4.2 In -Place Equipment

The utilization of in-place internal combustion equipment requires the following guidelines:

a. Placement: bolted in place. Facilities for unit removal for purposes of major repair or routine maintenance.
b. Controls: automatic and manual startup and cut-in.
c. Size: adequate to provide power for lighting and ventilation systems and such further systems that affect capability and safety as well as the pumps.
d. Engine Location: located above grade, with suitable and adequate ventilation of exhaust gases.
e. Underground Fuel Storage Tank: design and construction must conform to the applicable requirements of Federal Regulations 40 CFR 280 and 281. Contact the Tennessee Division of Superfund, Underground Storage Tank Program, for guidance.

2.7.4.3 Portable Equipment

The utilization of portable equipment requires the following guidelines:

Pumping units have connections to operate between the wet well and the discharge side of station and the station provided with permanent fixtures that will facilitate rapid and easy connection of lines.

2.7.5 Storage

The Division requires wet well and tributary main capacity above the high-level alarm sufficient to hold the peak flow expected during the maximum power outage duration during the last 10 years.

2.8 Force Mains

2.8.1 Size

Minimum size force mains required to be not less than 4 inches in diameter, except for grinder pumps or septic tank effluent applications

2.8.2 Velocity

At pumping capacity, a minimum self-scouring velocity of 3 feet per second (fps) should be maintained unless flushing facilities are provided. Velocity should not exceed 8 fps.

2.8.3 Air/Vacuum Relief Valve

An air relief valve is required at the necessary high points in the force main to relieve air locking. Vacuum relief values may be necessary to relieve negative pressures on force mains to protect against pipe collapse.

2.8.4 Termination

The force main should enter the receiving manhole with its centerline horizontal and with an invert elevation that will ensure a smooth flow transition to the gravity flow section; but in no case should the force main enter the gravity sewer system at a point more than 1 foot above the flow line of the receiving manhole. The design should minimize turbulence at the point of discharge.

The Division requires the use of inert materials or protective coatings for the receiving manhole to prevent deterioration because of hydrogen sulfide or other chemicals where such chemicals are present or suspected to be present because of industrial discharges or long force mains.

2.8.5 Materials of Construction

The pipe material should be adapted to local conditions, such as character of industrial wastes, soil characteristics, exceptionally heavy external loadings, internal erosion, corrosion, and similar problems.

Installation specification should contain appropriate requirements based on the criteria, standards, and requirements established by the industry in its technical publications. Requirements should be set forth in the specifications for the pipe and methods of bedding and backfilling thereof so as not to damage the pipe or its joints, impede cleaning operations, not create excessive side fill pressures or ovality of the pipe, nor seriously impair flow capacity.

The Division requires that the design of all pipes prevent damage from superimposed loads. Proper design allowance for loads on the pipe because of the width and depth of trench is required.

2.8.6 Pressure Tests

The Division requires testing, before backfilling, of all force mains at a minimum pressure of at least 50 percent above the design operating pressure for at least 30 minutes. Leakage should not exceed the amount given by the following formula:

$$\mathbf{L} = \mathbf{ND}\ (\mathbf{P})^{.5}\ /7{,}400$$

Where **L** is allowable leakage in gallons per hour
N is the number of pipe joints
D is the pipe diameter in inches
P is the test pressure in psi

2.8.7 Anchorage

The Division requires sufficient anchorage of force mains within the pumping station and throughout the line length to include, thrust blocks, restrained joints, and/or tie rods.

2.8.8 Friction Losses

The Division requires the use of a C factor that will take into consideration the conditions of the force main at its design usage. For example, a grease-coated pipe after several years will not have the same C factor as a new pipe.

2.8.9 Water Hammer

The force main design should investigate the potential for the existence of water hammer.

2.8.10 Isolation and Valving

The Division recommends the installation of isolation valves at strategic locations along the force main to facilitate maintenance of the system.

APPENDIX 2-A

Design Basis for Wastewater Flow and Loadings

Table 2-A.1. Typical Wastewater Flow Rates from Commercial Sources
(Source: Crites and Tchobanoglous, 1998**)**

FACILITY	UNIT	Flow, gallons/unit/day	
		Range	Typical
Airport	Passenger	2 - 4	3
Apartment House	Person	40 - 80	50
Automobile Service Station	Vehicle served	8 - 15	12
	Employee	9 - 15	13
Bar	Customer	1 - 5	3
	Employee	10 - 16	13
Boarding House	Person	25 - 60	40
Department Store	Toilet Room	400 - 600	500
	Employee	8 - 15	10
Hotel	Guest	40 - 60	50
	Employee	8 - 13	10
Industrial Building (Sanitary waste only)	Employee	7 - 16	13
Laundry (self-service)	Machine	450 - 650	550
	Wash	45 - 55	50
Office	Employee	7 - 16	13
Public Lavatory	User	3 - 6	5
Restaurant (with toilet)	Meal	2 - 4	3
Conventional	Customer	8 - 10	9
Short order	Customer	3 - 8	6
Bar/cocktail lounge	Customer	2 - 4	3
Shopping Center	Employee	7 - 13	10
	Parking Space	1 - 3	2
Theater	Seat	2 - 4	3

Table 2-A.2. Typical Wastewater Flow Rates from Institutional Sources
(Source: Crites and Tchobanoglous, 1998**)**

FACILITY	UNIT	Flow, gallons/unit/day	
		Range	Typical
Assembly Hall	Seat	2 - 4	3
Hospital, Medical	Bed	125 -240	165
	Employee	5 - 15	10
Hospital, Mental	Bed	75 - 140	100
	Employee	5 - 15	10
Prison	Inmate	80 - 150	120
	Employee	5 - 15	10
Rest Home	Resident	50 - 120	90
	Employee	5 - 15	10
School, day-only:			
With cafeteria, gym, showers	Student	15 - 30	25
With cafeteria only	Student	10 - 20	15
Without cafeteria, gym, or showers	Student	5 - 17	11
School, boarding	Student	50 - 100	75

Table 2-A.3. Typical Wastewater Flow Rates from Commercial Sources
(Source: Crites and Tchobanoglous, 1998**)**

FACILITY	UNIT	Flow, gallons/unit/day	
		Range	Typical
Apartment, resort	Person	50 - 70	60
Bowling Alley	Alley	150 - 250	200
Cabin, resort	Person	8 - 50	40
Cafeteria	Customer	1 - 3	2
	Employee	8 - 12	10
Camps:			
Pioneer Type	Person	15 - 30	25
Children's, with central toilet/bath	Person	35 - 50	45
Day, with meals	Person	10 - 20	15
Day, without meals	Person	10 - 15	13
Luxury, private bath	Person	75 - 100	90
Trailer Camp	Person	75 - 125	125
Campground-developed	Person	20 - 40	30
Cocktail Lounge	Seat	12 - 25	20
Coffee Shop	Customer	4 - 8	6
	Employee	8 - 12	10
Country Club	Guests on-site	60 - 130	100
	Employee	10 -15	13
Dining Hall	Meal Served	4 - 10	7
Dormitory/bunkhouse	Person	20 - 50	40
Fairground	Visitor	1 - 2	2
Hotel, resort	Person	40 - 60	50
Picnic park, flush toilets	Visitor	5 - 10	8
Store, resort	Customer	1 - 4	3
	Employee	8 - 12	10
Swimming Pool	Customer	5 - 12	10
	Employee	8 - 12	10
Theater	Seat	2 - 4	3
Visitor Center	Visitor	4 - 8	5

CHAPTER 3

Laboratory, Personnel, Maintenance Facilities and Safety Design

LABORATORY, PERSONNEL, MAINTENANCE FACILITIES & SAFETY DESIGN

3.1 General

Suggested considerations are presented in this chapter for laboratory, personnel, maintenance facilities, and safety. If testing is contracted out (particularly for lagoon systems) minimal maintenance facilities will only be required.

3.2 Laboratory Facilities

3.2.1 General

A guide to provision of laboratory facilities is the EPA publication Estimating Laboratory Needs for Municipal Wastewater Treatment Facilities, EPA-430/9-74-002.

Lab work involves a significant portion of a small facility's work tasks. Each facility should estimate work tasks by obtaining the following documents:

a. "Minimum sampling schedule" should be obtained from the Permit Section of the Division of Water Pollution Control, containing compliance parameters from NPDES Permit as well as operation test.

b. List of Approved Analytical Procedures. See Code of Federal Regulations (CFR), June 30, 1986, pp. 23693-23700 for lab methods and preservation procedures for NPDES data.

c. Tennessee "Lab Manual" 1986. Contact the Julian Fleming Training Center in Murfreesboro.

d. Tennessee "Laboratory Equipment and Supplies for Wastewater Treatment Plants." Contact the Julian Fleming Training Center in Murfreesboro.

3.2.2 Space Requirements

Specific laboratory facilities should be based on the needs of the treatment plant. Minimum suggested space for one MGD facilities is:

- Floor space of 200 sq. ft.
- Percent of floor space required for bench area is 40%
- Cabinet volume of 200 cubic foot.

These figures apply to a typical treatment plant monitoring program. If laboratory testing will be performed for other sources, such as industrial discharges, receiving waters, and sewer overflows, appropriate space increases should be provided. If some of the plant monitoring tests are performed at other facilities, the space required could be significantly less.

3.2.3. Design

The following factors should be key considerations in design of plant laboratories:

- Flexibility, which provides for changes in use requirements
- Adaptability, for changes in occupancy requirements
- Expandability, for changes in space requirements

3.2.3.1 Location

The laboratory should be located at ground level and easily accessible to all sampling points. To assure sufficient environmental control, the laboratory should be located away from vibrating machinery, corrosive atmospheres, or equipment which might have adverse effects on the performance of laboratory instruments or the analyst.

3.2.3.2 Layout

New lab layouts should be modeled after proven exemplary layouts. Efficient laboratory operation depends largely on the physical layout of the laboratory. The physical layout includes items such as working area arrangement, the number and location of sinks and electrical outlets, the arrangement of laboratory equipment, materials of construction, and lighting. The details of the layout can affect the accuracy of the laboratory tests. For example, tests that include identification of a colorimetric end point, as in heavy metals determinations, can be drastically affected by the type of lighting and the finishes on laboratory facilities.

The following factors should be considered when laying out a laboratory:

a. A northern exposure is preferred for colorimetric analysis.

b. Adequate lighting should be provided. Color-corrected fluorescent lighting is suggested.

c. Wall and floor finishes should be nonglare-type and light in color. Flat-finish wall paint is suggested.

Floor finishes should be of a single color for ease of locating small items that have been dropped.

d. Floor covering, in addition to being nonglare, should be easy to clean and comfortable.

e. Doors shall have large glass windows for visibility into and out of the laboratory. There should be no obstructions near the doors.

f. Aisle width between work benches should be at least 4 feet. Adequate spacing should be provided around free-standing equipment, workbenches, and file cabinets to facilitate cleaning.

g. Storage space for reagent stock should be under workbenches. Reagent containers removed from storage areas under workbenches are less likely to be dropped than reagent containers removed from storage in the inconvenient and hard-to-reach areas above the workbenches. Only items that are infrequently used or chemicals of a nonhazardous nature should be stored above workbenches. Strong acids or bases should be stored within convenient reach of the laboratory personnel, preferably beneath or adjacent to the fume hood.

h. Sufficient cabinet and drawer space should be provided for the storage of equipment and supplies. Wall cabinets should be no more than 30 inches above the workbench top so that the contents of the top shelving can be reached. The base cabinets under the workbenches should contain a combination of drawers and storage spaces for large items. All cabinets and drawers should be acid resistant.

i. One sink with a large gooseneck faucet, large enough to wash laboratory equipment, should be provided for every 25 to 30 feet of bench length. One sink should be sufficient when total bench length is less than 25 feet. The sink should be made of chemical-resistant material.

Cup sinks, also of chemical-resistant material, should be provided at strategic locations on the bench surface to facilitate laboratory testing. The number of cup sinks depends largely on the type of tests that will be run;
the general rule is one cup sink for every 25 to 30 feet of bench length. Cup sinks should be alternated with the wash sinks at 12- to 15-foot intervals.

Where workbench assemblies are provided in the center of the laboratory, a trough-type sink down the center of the workbench may be provided in lieu of cup sinks. A hot and cold water tap should be placed at approximately every 5 to 10 feet along the trough.

The use of an automatic dishwasher should be considered. Where dishwashers are provided, some of the sinks can be replaced by cup sinks.

j. Electrical receptacles should be provided at strategic points for convenient and efficient operation of the laboratory. Duplex-type receptacles should be spaced at intervals along benches used for laboratory tests. Strip molding receptacles may be used. All receptacles must be elevated to prevent spills from entering the receptacles.

k. Gas and vacuum fixtures should be provided at convenient locations.

l. Bench tops should be suitable for heavy-duty work and resistant to chemical attack. Resin-impregnated natural stone and other manmade materials provide such a surface and should be used.

m. Bench surfaces should be approximately 36 inches high for work done from a standing position and 30 inches high for work done while sitting.

n. Bench surfaces should be approximately 30 inches wide.

o. Equipment arrangement should be given special consideration in laying out the laboratory facility in conjunction with the facility's owner and operators. Plumbing, and/or electrical connections should be provided for units such as the distillation apparatus, drying ovens or other wall-mounted equipment. Pieces of equipment used for making common tests should be in proximity.

For example, the drying oven used in making total, suspended, and dissolved solids tests should be close to the muffle furnace for use in determining total volatile solids and volatile suspended solids from the samples dried in the drying oven. The drying oven and the muffle furnace should be near the

balance table because the balance is used in the weight determinations for the various solids tests.

p. Safety is a prime consideration of a laboratory. The first aid kit, fire extinguisher, eye wash, and emergency shower should be near the main working area of the laboratory. If the safety shower is not provided in a separate shower stall, a floor drain should be nearby.

q. Sources of loud or startling noises, such as alarms or composite sampling equipment,should be located at sites remote or otherwise isolated from the laboratory.

r. The analytical balance should be on a separate table at least 30 inches long and 24 inches deep. The table should not transmit vibrations that would adversely affect the operation of the balance.

s. A separate table is desirable for microscopes. This table should be about 30 inches long, 24 inches deep, and 27 inches high.

t. Fume hoods, if provided, should be near the area where most laboratory tests are made.

u. All labs which run BOD_5 require air-conditioning to achieve a sufficiently high, stable D.O. in the dilution water.

   Laboratories should be separately air-conditioned, with external air supply for 100-percent makeup volume. Separate exhaust ventilation should be provided. Window air-conditioning should not blow directly on the analytical balance or furnaces.

v. Panic hardware should be provided for doors opening to the outside to allow for rapid exiting in an emergency.

3.3 Personnel Facilities

Personnel facilities are generally located in the administration building. This building serves the needs of the supervisory staff, the operation and maintenance personnel, and often the laboratory staff.

Sewer maintenance personnel may also share the administration building. However, facilities for the laboratory and operations and maintenance staff need not be provided in the administration building, even though this is customary.

A wastewater treatment plant staffed for 8 hours or more each day should contain support facilities for the staff. Toilets shall be provided in conformance with applicable building codes. The following should be provided:

a. **Wash-up and changing facilities:** Showers, lockers, sinks, and toilets sufficient for the entire staff at design conditions. A heated and ventilated mudroom is desirable for changing and storage of boots, jackets, gloves, and other outdoor garments worn on the job. Each staff member should have separate lockers for street clothes and plant clothes. Separate wash-up and changing facilities should be available for men and women, with the exception of the mudroom.

b. **Eating Facilities:** A clean, quiet area with facilities for storage and eating of light meals.

c. **Meeting facilities:** A place to assemble the plant staff and visitors. In many cases, meeting facilities and the eating facilities will be the same.

d. **Supervisors' facilities:** A place where discussion and writing can be carried out in private. A desk station should be provided for data entry.

Facilities should be provided for the storage of analytical methods and records, catalogs, as-built plans, operation and maintenance manual(s), etc.

Small mechanical treatment plants that are not manned 8 hours per day need not contain all of the personnel facilities required for larger plants, but shall contain a lavatory, and a storage area.

3.4 Maintenance Facilities

To assure adequate maintenance of equipment, convenient maintenance facilities should be available. Such facilities generally include a maintenance shop, a garage, storage space, and yard maintenance facilities.

Access to nearby municipal garages and other maintenance centers should be considered. Duplication of facilities should be avoided where possible.

3.4.1 Maintenance Shop

A separate maintenance shop should be designated where treatment plant equipment and vehicles can be repaired. The maintenance shop should be provided with the following facilities:

a. Work space with adequate area and lighting, including a workbench with vise.

b. Conveyances to move heavy items from the point of delivery to the appropriate work space.

c. Storage for small tools and commonly used spare parts.

d. Adequate power outlets and ratings for the equipment.

3.4.2 Storage Requirements

Storage space should be provided for paints, fuels, oils and lubricants, grounds maintenance equipment, spare parts, and collection system equipment.

In larger facilities, it may be desirable to have a separate storage building for things such as paints, fuel, oils and lubricants, spare parts, and yard supplies. For storage of flammable materials, the requirements of the uniform building code shall be met. In smaller facilities, it might be desirable to combine storage with the shop or garage so that the stored material can be protected against unauthorized use.

Where underground tanks are to be used to store controlled substances, the Division of Ground Water Protection shall be contacted regarding Underground Storage Tank (UST) requirements.

3.4.3 Yard Requirements

A landscaped yard helps to soften the visual impact of a treatment facility. Shrubs and treees judiciously located can screen unsightly areas from public view. Care must be taken that the plantings do not become a hindrance to operation. Deciduous leaves falling in clarifiers can hinder skimming and add unnecessarily to the digester loading. Roots from trees too close to pipes can cause clogging. Fencing should be adequate to prevent unauthorized or unattended entry.

3.5 Safety Design

The field of wastewater treatment has always been one of the most hazardous fields of employment.
This fact is accented by job-related deaths and accidents which happen each year. Safety designs are needed which should be supplemented by yearly inspections to gain awareness.

Adequate provisions shall be included in the design of all wastewater treatment facilities to minimize exposure of facility personnel and visitors to safety hazards.

Treatment facilities shall be designed in full compliance with the Occupational Safety and Health Standards of the State of Tennessee, Division of Occupational Safety and Health (TOSHA).

Pertinent safety design requirements as well as safety design practices are included in the attached on-site checklist for wastewater treatment plants (Appendix 3-A).

To gain awareness each operator should have other safety resources such as:

1.) Safety & Health in Wastewater Systems (MOP-1 by WPCF)
2.) Individual safety manual adopted by each plant's safety committee.
3.) Safety meetings with city.

Any unsafe practices or incidents should be reported to TOSHA and each facility's safety committee. As a last resort, complaints can be made anonymously by the operator or any other concerned citizen.

Appendix 3-A

On-Site Checklist

STANDARD SAFETY

1. Personnel Protective Clothing:

   a. Safety helmets (for operators and visitors)

   b. Ear protectors for high noise areas

   c. Goggles

   d. Gloves

   e. Rubber boots with steel toes

2. Safety Devices Available for Use:

   a. Non-sparking tools in areas where flammable or explosive gases may be present

   b. Fire extinguishers readily available

   c. Oxygen deficiency/explosive gas indicator

   d. Self-contained breathing apparatus near entrance to chlorine room, away from fan discharge

   e. Safety harness

   f. First aid kits readily available

   g. Ladders to enter manholes or wetwells (fiberglass or wooden for around electrical work)

   h. Traffic control cones

   i. Safety buoy at activated sludge plants

   j. Live preservers for around lagoons

   k. Portable crane/hoist

3. General Plant Safety:
   a. Railing around all tanks, with openings chained off
   b. No uncovered pits or wells
   c. Explosion-proof fixtures, where needed
   d. Equipment guards in place
   e. Emergency telephone numbers posted
   f. Proper flammable liquid storage
   g. Covered trash cans
   h. Ladders have safety cages or equiped with safety slide rail
   i. Portable hoists for equipment removal; e.g., pumps, aeration equipment

4. Are plant personnel immunized for typhoid and tetanus?

5. No cross connections exist between a potable water supply and a non-potable source:
   a. Pump and mixer seals
   b. Digester heating system make-up water
   c. Vacuum filter water sprays
   d. Chemical mixing tank
   e. Chlorinator water source
   f. Yard hydrants
   g. Properly installed backflow preventers

6. If anaerobic digesters are used, are the following present?:
   a. Pressure/vacuum relief valves
   b. "No smoking" signs
   c. Explosimeter
   d. Drip trap
   e. Flame traps within 25' of the flame source

7. Electrical Safety:

   a. All electrical circuitry enclosed and identified

   b. Electrical test equipment available, such as a voltmeter and amperage meter

   c. Rubber mats present for electrical work

   d. The personnel are familiar with the electrical work to be performed

   e. All personnel are trained in electrical safety, such as lockout procedures

   f. Warning and/or caution signs present

   g. Rubber gloves available

   h. Ground fault interrupter used

8. Chlorine Safety:

   a. NIOSH-approved self-contained 30 minute air pack

   b. All standing chlorine cylinders are chained in place

   c. All personnel are trained in the use of chlorine

   d. Chlorine repair kit is available

   e. Chlorine leak detector tied into the plant alarm system

   f. Ammonia for checking chlorine leaks is present

   g. Ventilator fan with an outside switch is present

   h. Safety precautions posted

   i. Doors open outward and are equipped with "panic" hardware

9. Process Chemical Safety:

   a. Respirator to protect the operator against dust inhalation, when needed

   b. All personnel are trained to handle the chemicals properly

   c. Proper safety clothing for the chemical to be handled, such as rubber aprons, boots and gloves for handling ferric chloride

   d. Has complied with the Tennessee Department of Labor, Hazardous Chemical Right To Know Law, T.C.A. 50-3-2001 thru 2019.

   e. Emergency Action Plan on file with local Fire Department and appropriate Emergency Agency

   f. Containment of chemical storage areas, including curbing and floor drains to appropriate areas

10. Laboratory Safety:

   a. Eye wash and shower station is present

   b. Fume hood is present

   c. All chemicals properly labeled and stored

   d. Laboratory safety devices such as pipette suction bulbs

INNOVATIVE SAFETY

1. Warning Signs:
    a. Non-potable water
    b. Chlorine hazard
    c. No smoking
    d. High Voltage
    e. "Watch your step" signs in certain areas
    f. Exit signs
    g. Piping signs
2. Safety programs
3. Operators provided with a shower and a locker for their work clothes
4. Are the operators trained in first aid and CPR?

CHAPTER 4

Preliminary and Pretreatment Facilities

PRELIMINARY AND PRETREATMENT FACILITIES

4.1 Screening and Grinding

4.1.1 General

Some type of screening and/or grinding device shall be provided at all mechanical wastewater plants. The effective removal of grit, rocks, debris, excessive oil or grease and the screening of solids shall be accomplished prior to any activated sludge process. Any grinding which does not dispose of the shredded material outside of the wastewater stream must be evaluated with regard to the influent characteristics (rags, combined sewers) of the waste prior to any activated sludge process.

4.1.2 Location

4.1.2.1 Indoors

Screening devices installed in a building where other equipment or offices are located shall be accessible only through an outside entrance. Adequate lighting, ventilation and access for maintenance or removal of equipment and screenings shall be provided.

4.1.2.2 Outdoors

The removal point for screenings should be as practical as possible for the plant personnel, preferably at ground level. Ladder access is not acceptable unless hoisting facilities for screenings are provided. Separate hoisting is not required for bar screens in manual bypass channels.

4.1.2.3 Deep Pit Installations

Stairway access, adequate lighting and ventilation with a convenient and adequate means for screenings removal shall be provided.

4.1.3 Bar Screens

4.1.3.1 Manually Cleaned

Clear openings between bars shall be from 1 to 2 inches. Slope of the bars shall be 30 to 60 degrees from the vertical. Bar size shall be from 1/4 to 5/8 inches with 1 to 3 inches of depth, depending on the length and material to maintain integrity. A perforated drain plate shall be installed at the top of the bar screen for temporary storage and drainage.

4.1.3.2 Mechanically Cleaned

Mechanically cleaned bar screens are recommended for all plants greater than 1 MGD. Both front cleaned or back cleaned models may be acceptable. Clear openings no less than 5/8 inch are acceptable. Protection from freezing conditions should be considered.

Other than the rakes, no moving parts shall be below the water line.

4.1.3.3 Velocities

Approach velocities no less than 1.25 fps nor a velocity greater than 3.0 fps through the bar screen is desired.

4.1.4 Fine Screens

4.1.4.1 General

Fine screens shall be preceeded by a trash rack or coarse bar screen. Comminution shall not be used ahead of fine screens. A minimum of two fine screens shall be provided, each capable of independent operation at peak design flow. The design engineer must fully evaluate a proposal where fine screens are to be used in lieu of primary sedimentation. Fine screens shall not be considered equivalent to primary sedimentation or grit removal, but will be reviewed on a case-by-case basis. Oil and grease removal must be considered.

4.1.4.2 Design

The operation should be designed to not splash operating personnel with wastewater or screenings. Fine screens will generally increase the dissolved oxygen content of the influent which may be beneficial in certain circumstances. The screens must be enclosed or otherwise protected from cold weather freezing conditions. Disposal of screenings must be addressed. To be landfilled, screenings must be dried to approximately 20% solids. Odors may be a problem in sensitive locations.

4.1.5 Comminution

4.1.5.1 General

In-line comminution may not be acceptable prior to an activated sludge process for facilities with a history of problems with rags. Out-of-stream comminution or disintegration is acceptable for activated sludge processes; however, screenings should not return to the wastewater stream.

4.1.5.2 Design

A coarse bar screen with an automatic bypass shall precede comminution for all mechanical plants. Gravel traps shall precede comminution which is not preceded by grit removal. Clear openings of 1/4 inch are prefered in the comminution device. An automatic unit bypass or other means of protection shall be provided to protect the comminutor motor from flooding. The design shall incorporate a method for removing the equipment from service and for repairs or sharpening of the teeth.

4.1.6 Operability

All screening devices shall have the capability of isolation from the wastewater stream. Sufficient wash water shall be available for cleanup of the area. All mechanical screening devices shall be provided with a manually cleaned bar screen bypass. Multiple bar screens should be considered for plants with rag problems instead of comminutors.

Adequate space must be provided for access to each screening or comminution device. This is critical in elevated, indoor or deep pit installations.

4.1.7 Disposal

All screenings shall be disposed of in an approved manner. Suitable containers shall be provided for holding the screenings. Run-off control must be provided around the containers, where applicable. If fine screens are proposed, consideration must be given to the wastewater overflow if the screens clog or blind. Overflows must be contained and bypassed around the screens by dikes or other means.

4.2 Grit Removal

4.2.1 General

Grit removal is recommended for all mechanical wastewater plants and is required in duplicate for plants receiving wastewater from combined sewers. Systems with a history of substantial grit accumulations may be required to provide for grit removal. Where a system is designed without grit removal facilities, the design shall allow for future installation by providing adequate head and area. Grit washing may be required.

4.2.2 Location

Wherever circumstances permit, grit removal shall be located prior to pumps and comminution when so equiped. Bar screens shall be prior to grit removal. Adequate lighting, ventilation and access for maintenance and removal of grit shall be provided. Stairway access is required if the chamber is above or below ground level. Adequate and convenient means of grit removal shall be provided.

4.2.3 Design

4.2.3.1 Channel Type

A controlled velocity of one foot per second is recommended. Control by either sutro or proportional weir should be used. If a Parshall flume is used for control, the grit chamber must be designed to approach a parabolic cross-section. The length of the channel depends on the size of grit to be removed. The design engineer shall provide this information. Inlet and outlet turbulence must be minimized.

4.2.3.2 Square Type

Square-type basins or similar arrangements should be sized for an overflow rate of 46,300 (WPCF) gallons per day per square foot at the peak flow based on 65-mesh grit at a specific gravity of 2.65. Other overflow rates may be used when the design incorporates particle travel distance and detention. Inlet and outlet turbulence must be minimized.

4.2.3.3 Aerated Type

Aerated grit chambers shall be designed on the basis of detention and/or particle travel distance. Detention time of 2-5 minutes at peak flow is acceptable. Control of the air shall be provided for flexibility. Skimming equipment must be provided in the aerated grit chamber if the outlet is below the water surface.

4.2.3.4 Other Types

Cyclone or swirl-type grit removal processes may be acceptable. The design engineer will be expected to provide a complete treatment analysis for approval.

4.2.4 Disposal

Temporary storage containers shall be provided to hold the grit. Run-off control shall be provided. Attention should be given to operations which may splash waste or grit on operating personnel. Grit washing is required before removal to drying beds. If not washed, the grit shall be disposed of in an approved landfill.

4.2.5 Operability

Adjustable control valves shall be included in each diffuser air line to control mixing and particle segregation. Variable speed arrangements should be provided in cyclone or mechanical type systems. Provisions shall be made for isolation and dewatering each unit or units.

4.3 Pre-Aeration

Pre-aeration is desirable in certain instances, such as to reduce septicity. Pre-aeration may be required where pressure or small diameter collection systems are used. Long detention times in pump stations or collection lines should also be considered. Units shall be designed so that removal from service will not interfere with normal plant operations.

4.4 Flow Equalization

4.4.1 General

Equalization may be used to minimize random or cyclic peaking of organic or hydraulic loadings when the total flow is ultimately processed through the plant. Either in-line or side-line equalization is acceptable. Equalization may be required where peak flows are greater than 2 times the average design flow.

4.4.2 Location

Tanks are generally located after screening and grit removal. Care should be taken in design to minimize solids deposition if located upstream of primary clarifiers. Equalization downstream of primary clarifiers should be investigated, as primary clarifier performance is less sensitive to flow peaking when compared to other processes. Other locations will be evaluated on a case-by-case basis.

4.4.3 Design and Operability

Generally, aeration will be required. Minimum requirements are to maintain 1.0 mg/l of dissolved oxygen. Odor consideration must be addressed when a plant is located in a sensitive area or large equalization basins are used. Large tanks must be divided into compartments to allow for operational flexibility, repair and cleaning. Each compartment shall be capable of dewatering and access. In plant upgrades, existing units which are otherwise to be abandoned may be used for equalization, where possible. Sizing the tankage and compartments will depend on the intended use; i.e., when equalization is for periodic high organic loadings, peak flow events, toxics, etc. A complete analysis shall accompany all engineering report (or plan) submission.

The tank must be capable of being drained and isolated. Controlling the flow rate from the equalization tank to the plant is desirable.

4.5 Swirls and Helical Bends

These units are not to be used in lieu of primary clarification unless special design considerations are used. They are primarily designed for 'coarse' floating and settleable solids removal and will be considered only on a case-by-case basis for in-plant processes. They will, however, be approved for replacing regulators in combined sewer systems, as an interim measure until separation of the sanitary and storm flows is completed. Treatability studies will be required as part of the design. A separate NPDES permit will be required for each of these units that will discharge to a surface water.

CHAPTER 5

Clarifiers

5.6 Operability, Flexibility, and Reliability

5.6.1 Scum Removal
5.6.2 Overflow Weirs
5.6.3 Unit Dewatering
5.6.4 Hydraulics
5.6.5 Sludge Removal
5.6.6 Other Design Considerations

CLARIFIERS

5.1 General Criteria

5.1.1 Purpose

Clarifiers (sedimentation basins, settling tanks) are designed to perform three (3) functions in a treatment scheme:

A. Remove solids from liquids by sedimentation
B. Remove scum from liquid by flotation
C. Thicken solids for removal and further treatment

Specific application of clarifier functions will be dependent upon the treatment process employed. This chapter does not attempt to set criteria for all types of clarifiers. If a unique clarifier is proposed, the design engineer shall submit operational and design data justifying its use.

5.1.2 Number of Units

Multiple units capable of independent operation shall be provided in all facilities where design flows exceed 250,000 gallons per day. Otherwise, the number of units required shall satisfy reliability requirements (see Section 1.3.11). Facilities not having multiple units shall include other methods to assure adequate operability and flexibility of treatment.

5.1.3 Arrangements

Clarifiers shall be arranged for greatest operating and maintenance convenience, flexibility, economy, continuity of maximum effluent quality, and ease of installation of future units.

5.1.4 Tank Configurations

Consideration should be given to the probable flow pattern in the selection of tank size and shape and inlet and outlet type and location.

5.1.5 Flow Distribution

Effective flow measuring devices and control appurtenances (i.e., valves, gates, splitter boxes, etc.) shall be provided to permit proper proportion of flow to each unit (see Section 13.2.1).

5.2 Design Loading

5.2.1 Primary Clarifiers

Primary clarifier designs are primarily based upon surface overflow rate. The following criteria are recommended for design:

Hydraulic Loading Rate	Surface Overflow Rate
Average Design Flow	800-1200 gpd/sq. ft.
Peak Design Flow	2000-3000 gpd/sq. ft.

If WAS is returned to the primary then

Hydraulic Loading Rate	Surface Overflow Rate
Average Design Flow	600-800 gpd/sq. ft.
Peak Design Flow	1200-1500 gpd/sq. ft.

Primary clarifier sizing shall be calculated for both flow conditions and the larger surface area derived shall be utilized. A properly designed primary clarifier should remove 30 to 35% of the influent BOD. However, anticipated BOD removal for wastewater containing high quantities of industrial wastewater should be determined by laboratory tests and considerations of the quantity and characteristics of the wastes.

5.2.2 Intermediate Clarifiers

Surface overflow rates for intermediate clarifiers should be based upon the following criteria:

Maximum Hydraulic Loading Rate	Surface Overflow Rate
Average Design Flow	1000 gpd/sq. ft.
Peak Design Flow	2500 gpd/sq. ft.

5.2.3 Final Clarifiers

Final clarifier designs shall be based upon the type of secondary treatment application used. Surface overflow and solids loading rates shall be the general basis for clarifier designs. Pilot studies of biological treatment is recommended when unusual wastewater characteristics are evident or when the proposed loading exceeds those noted in this section.

Table 5-1 depicts the criteria established for final clarifier surface overflow and solids loading rates. In activated sludge systems, the surface overflow rate for final clarifiers should be based on influent wastewater flows and not include return activated sludge flows (RAS). Solids loading rate criteria assume sludge recycle is 100% of the average design flow and the design mixed liquor suspended solids (MLSS) concentration.

TABLE 5-1
FINAL CLARIFIER DESIGN PARAMETERS

	Maximum Surface Overflow Rate gpd/sq.ft.		**Solids Loading Rate lbm/day-sq.ft.**	
Type of Process	**Average Design Flow**	**Peak Design Flow**	**Average Design Flow**	**Peak Design Flow**
Trickling Filter	600	1200	25	40
Activated Sludge	800 (600 for plants less than 1 MGD)	1200	30	50
Extended Aeration	400	1000	25	35
Nitrification	400	800	25	35
Pure Oxygen	700	1200	25	40

5.2.4 Weir Loading Rates

Weir loadings should not exceed 15,000 gallons per day per linear feet (gpd/li ft).

5.2.5 Depth/Detention Time

The sidewater depth (SWD) for clarifier designs associated with design surface overflow rates should dictate the hydraulic detention time of the clarifier. For design purposes, the following criteria in Table 5-2 are established specific to clarifier application:

TABLE 5-2		
CLARIFIER DEPTH		
Type of Process	**Diameter [ft]**	**Minimum Sidewater Depth [ft]**
*Primary	-	8
Trickling Filter	-	10
**Activated Sludge	Less than 40	11
	40-70	12
	71-100	13
	101-140	14
	Over 140	15

*The hydraulic detention time in primary clarifiers is not recommended to be greater than 2.5 hours as a function of the surface overflow rate and SWD, since septic conditions resulting in poor performance and odor conditions can occur.

**For rectangular-shaped clarifiers following activated sludge treatment,
the recommended SWD shall be no less than 12 feet at the shallow end.

5.3 Design Details

5.3.1 Inlets

Inlets should be designed to dissipate the influent velocity, to distribute the flow equally in both the horizontal and vertical vectors, and to prevent short-circuiting. Channels should be designed to maintain an inlet velocity of at least one (1) foot per second at one-half the design flow. Corner pockets and dead ends should be eliminated and corner fillets or channeling used where necessary. Provisions shall be made for elimination or removal of floating materials in inlet structures having submerged ports.

5.3.2 Submerged Surfaces

The tops of troughs, beams, and similar submerged construction elements shall have a minimum slope of 1.75 vertical to 1 horizontal. The underside of such structures should have a slope of 1 to 1 to prevent accumulation of scum and solids.

5.3.3 Weir Troughs

Weir troughs shall be designed to prevent submergence at
maximum design flow, and to maintain a velocity of at least one (1) foot per second at one-half design flow.

5.3.4 Freeboard

Walls of clarifiers shall extend at least six (6) inches above the surrounding ground surface and shall provide not less than twelve (12) inches of freeboard.

5.4 Sludge and Scum Removal

5.4.1 Scum Removal

Effective scum collection and removal facilities, including baffling ahead of the outlet weirs, shall be provided for all clarifiers. Provisions may be made for discharge of scum with sludge; however, other provisions may be necessary to dispose of floating materials which may adversely affect sludge handling and disposal. The unusual characteristics of scum which may adversely affect pumping, piping, sludge handling and disposal, should be recognized in the design. Scum piping should be glass lined or equivalent. Precautions should be taken to minimize water content in the scum.

5.4.2 Sludge Removal

Sludge collection and withdrawal facilities shall be designed to assure rapid removal of the sludge. Provisions shall be
made to permit continuous sludge removal from settling tanks. Final clarifiers in activated sludge plants shall be provided with positive scraping devices. Suction withdrawal should be provided for activated sludge plants designed for the reduction of nitrogenous oxygen demand.

5.4.3 Sludge Removal Piping

Each sludge hopper shall have an individually valved sludge withdrawal line at least six (6) inches in diameter if pumped and at least eight (8) inches in diameter if gravity flow is used. This does not apply to air lift methods of sludge removal, as this should be determined by the sludge removal rate. Static head available for sludge withdrawal shall be at least thirty (30) inches, as necessary, to maintain a three (3) feet per second velocity in the withdrawal pipe. Clearance between the end of the withdrawal line and the hopper walls shall be sufficient to prevent "bridging" of the sludge. Adequate provisions shall be made for rodding or back-flushing individual pipe runs.

***Air lift type sludge removal will not be approved for removal of primary sludges.

5.4.4 Sludge Removal Control

Sludge wells equipped with telescoping valves or other appropriate equipment shall be provided for viewing, sampling and controlling the rate of sludge withdrawal. A means for measuring the sludge removal rate and sludge return rate shall be provided. Sludge pump motor control systems shall include time clocks and valve activators for regulating the duration and sequencing of sludge removal. Gravity flow systems should have back-up pumping capabilities.

5.4.5 Sludge Hopper

The minimum slope of the side walls shall be 1.75 vertical to 1 horizontal. Hopper wall surfaces should be made smooth with rounded corners to aid in sludge removal. Hopper bottoms shall have a maximum dimension of two (2) feet. Extra-depth sludge hoppers for sludge thickening are not acceptable.

5.5 Protective and Service Facilities

5.5.1 Operator Protection

All clarifiers shall be equipped to enhance safety for operators. Such features shall appropriately include machinery cover lift lines, stairways, walkways, handrails and slip-resistant surfaces.

5.5.2 Mechanical Maintenance Access

The design shall provide for convenient and safe access to routine maintenance items such as gear boxes, scum removal mechanisms, baffles, weirs, inlet stilling baffle area, and effluent channels.

5.5.3 Electrical Fixtures and Controls

Electrical fixtures and controls in enclosed settling basins shall meet the requirement of the National Electrical Code. The fixtures and controls shall be located so as to provide convenient and safe access for operation and maintenance. Adequate area lighting shall be provided.

5.6 Operability, Flexibility, and Reliability

5.6.1 Scum Removal

5.6.1.1 A method of conveying scum across the water surface to a point of removal should be considered, such as water or air spray. Baffles should be designed to ensure capture of scum at minimum and maximum flow rates.

5.6.1.2 Facilities designed for flows of 0.1 MGD and greater should have mechanical scum removal equipment.

5.6.1.3.Scum holding tanks may be provided, with a method of removing excess water.

5.6.1.4 Large scum sumps should have a mixing device (pneumatic, hydraulic, or mechanical) to keep the scum mixed while being pumped.

5.6.1.5 Manual scum pump start-stop switches should be located adjacent to scum holding tanks.

5.6.2 Overflow Weirs

5.6.2.1 Since closely spaced multiple overflow weirs tend to increase hydraulic velocities, their spacing should be conservative.

5.6.2.2 Center-feed, peripheral draw-off clarifiers shall not have the overflow weir against the clarifier sidewall. Weir placement shall be 1/10 diameter or greater toward the center.

5.6.2.3 The up-flow rate shall not be greater than the surface overflow rate at any location within the solids separation zone of a clarifier.

5.6.2.4 Overflow weirs should be of the notched type; straight edged weirs will not be approved.

5.6.2.5 Overflow weirs shall be adjustable for leveling.

5.6.3 Unit Dewatering

5.6.3.1 The capacity of dewatering pumps should be such that the basin can be dewatered in 24 hours; eight hours is preferable.

5.6.3.2 The contents of the basin should be discharged to the closest process upstream from the unit being dewatered that can accept the flow.

5.6.3.3 Consideration shall be given to the need for hydrostatic pressure relief devices to prevent flotation of structures.

5.6.4 Hydraulics

5.6.4.1 Lift/pump stations located immediately upstream of secondary clarifiers shall have flow-paced controls to reduce shock loadings.

5.6.4.2 Square clarifiers with circular sludge withdrawal mechanisms shall be designed such that corner hydraulic velocities do not cause sludge carry-over.

5.6.5 Sludge Removal

5.6.5.1 When two or more clarifiers are used, provisions shall be made to control and measure the rate of sludge withdrawal from each clarifier.

5.6.5.2 Consideration should be given to removing activated sludge from the effluent end of rectangular clarifiers.

5.6.5.3 Consideration shall be given to chlorination of return activated sludge and digester supernate. Sufficient mixing and contact time should be provided.

5.6.6 Other Design Considerations

5.6.6.1 Designs should consider the possible need for future modifications to add chemicals such as flocculants.

5.6.6.2 A method of foam control should be considered for all inlet channels and feed wells in activated sludge systems.

CHAPTER 6

Fixed Film Reactors

FIXED FILM REACTORS

6.1 Trickling Filters

6.1.1 General

Trickling filters may be used for treatment of wastewater amenable to treatment by aerobic biological processes. This process is less complex and has a lower power requirement than some of the other processes.

6.1.2 Pretreatment

Trickling filters shall be preceded by effective clarifiers equipped with scum removal devices or other suitable pretreatment facilities. (See Chapters 4 & 5)

6.1.3 Types of Processes

Trickling filters are classified according to the applied hydraulic and organic loadings. The hydraulic loading is the total volume of liquid applied, including recirculation, per unit time per square unit of filter surface area. Organic loading is the total mass of BOD applied, including recirculation, per unit time per cubic unit of filter volume.

6.1.3.1 Low or Standard Rate

These are loaded at 1 to 4 million gallons per acre per day (mgad) and 5 to 25 pounds BOD per 1,000 cubic feet per day (lb BOD/1000 cu ft/day. Nitrification of the effluent often occurs.

6.1.3.2 Intermediate Rate

These are loaded at 4 to 10 mgad and 10 to 40 lb BOD/1000 cu ft/day. Nitrification is less likely to occur.

6.1.3.3 High Rate

These are loaded at 10 to 40 mgad and 25 to 300 lb BOD/1000 cu ft/day. Nitrification is not likely to occur.

6.1.3.4 Super Rate

These are loaded at 15 to 90 mgad (not including recirculation) and up to 300 lb BOD/1000 cu ft/day. Filters designed as super rate require a manufactured media. Nitrification is not likely to occur.

6.1.3.5 Roughing

These are loaded at 60 to 180 mgd (not including recirculation) and 100 lb BOD/1000 cu ft/day. Nitrification will not occur. Roughing filters shall be followed by additional treatment, and will be equipped with manufactured media.

6.1.4 Considerations for Design

The following factors should be considered when selecting the design hydraulic and organic loadings:

Characteristics of raw wastewater
Pretreatment
Type of media
Recirculation
Temperature of applied wastewater
Treatment efficiency required

The following table presents allowable ranges for the design of trickling filters. Modifications of these criteria will be considered on a case-by-case basis.

Design Loading Table					
Operating Characteristics	Low or Standard Rate	Intermediate Rate	High Rate	Super High Rate Manufactured Media	Roughing
Hydraulic Loading Mgd/acre gpd/ sq ft	1-4 25-90	4-10 90-230	10-40 230-900	15-90 350-2000*	60-180* 1400-4200*
Organic Loading lb BOD/acre-ft day lb BOD/1000ft3/day	200-1000 5-25	700-1400 10-40	1000-12,000 25-300	Up to 300	100+
Depth ft BOD Removal %	5-10 80-85	4-8 50-70	3-6 65-80	3-8 65-85	15-40 40-65
*does not include recirculation					

6.1.5. Estimation of Performance

A number of equations are available for use in estimating trickling filter performance.
Any design should evaluate several different formulas to compare the various parameters in different combinations with one another. Winter operating

conditions must be analyzed since winter operations normally result in lower efficiency than summer operations. The trickling filter design must evaluate the impacts of recirculation, air draft temperatures and medium.

6.1.5.1 Recirculation

Recirculation capability is required for all variations of the trickling filter process except roughing filters provided that minimum hydraulic loading rates are maintained at all times. The recirculation ratio should be in the range of 0.5 to 4.0. Recirculation should be provided for manufactured media to maintain 0.5 to 1.0 gallon per minute per square foot (gpm/sq ft) or the manufacturer's recommended minimum wetting rate at all times. Recirculation ratios greater than 4.0 should not be used to calculate effluent quality.

6.1.5.2 Staging

Staging of filters can be considered for high-strength wastes or for nitrification.

6.1.6 Special Details

6.1.6.1 Media

a.Rock, Slag, or Similar Media

Rock, slag, and similar media should not contain more than 5 percent by weight of pieces whose longest dimension is three times the least dimension. They should be free from thin, elongated and flat pieces, dust, clay, sand, or fine material and should conform to the following size and grading when mechanically graded over a vibrating screen with square openings:

Passing 4-1/2 inch screen: 100 percent by weight

Retained on 3-inch screen: 90-100 percent by weight

Passing 2-inch screen: 0-2 percent by weight

Passing 1-inch screen: 0 percent by weight

Hand-picked field stone should be as follows:

Maximum dimension of stone: 5 inches

Minimum dimension of stone: 3 inches

Material delivered to the filter site should be stored on wood-planked or

other approved clean hard-surfaced areas. All material should be rehandled at the filter site, and no material should be dumped directly into the filter. Crushed rock, slag, and similar media should be rescreened or forked at the filter site to remove all fines. Such material should be placed by hand to a depth of 12 inches above the tile underdrains, and all materials should be carefully placed so as not to damage the underdrains. The remainder of the material may be placed by means of belt conveyors or equally effective methods approved by the engineer. Trucks, tractors, or other heavy equipment should not be driven over the filter during or after construction.

b.Manufactured Media

Application of manufactured media should be evaluated on a case-by-case basis. Suitability should be evaluated on the basis of experience with installations handling similar wastes and loadings.

Media manufactured from plastic, wood, or other materials are available in many different designs. They should be durable, resistant to spalling or flaking, and relatively insoluble in wastewater. They are generally applied to super high rate and roughing filter designs.

6.1.6.2 Underdrainage System

a. Arrangement

Underdrains with semicircular inverts or equivalent should be provided and the underdrainage system should cover the entire floor of the filter. Inlet openings into the underdrains should have an unsubmerged gross combined area equal to at least 15 percent of the surface area of the filter.

b.Slope

The underdrains should have a minimum slope of 1 percent. Effluent channels should be designed to produce a minimum velocity of 2 feet per second at average daily rate of application to the filter.

c.Flushing

Provision should be made for flushing the underdrains and effluent channel.
In small filters, use of a peripheral head channel with vertical vents is acceptable for flushing purposes. Inspection facilities should be provided.

d.Ventilation

The underdrainage system, effluent channels, and effluent pipe shall be designed to permit free passage of air. The size of drains, channels, and pipe should be such that not more than 50 percent of their cross-sectional area will be submerged under the design hydraulic loading. Provision should be made in the design of the effluent channels to allow for the possibility of increased hydraulic loading.

6.1.6.3 Dosing Equipment

a.Distribution

The sewage shall be distributed over the filter by rotary distributors or other suitable devices which will permit reasonably uniform distribution to the surface area. At design average flow, the deviation from a calculated uniformly distributed volume per square foot of the filter surface should not exceed plus or minus 10 percent at any point. Provisions must be made to spray the side walls to avoid growth of filter flies.

b.Application

Sewage may be applied to the filters by siphons, pumps, or by gravity discharge from preceding treatment units when suitable flow characteristics have been developed. Application of sewage should be practically continuous. Intermittent dosing shall only be considered for low or standard rate filters. In the case of intermittent dosing, the dosing cycles should normally vary between 5 and 15 minutes, with distribution taking place approximately 50 percent of the time. The maximum rest should not exceed 5 minutes, based on the design average flow.

c. Hydraulics

All hydraulic factors involving proper distribution of sewage on the filters should be carefully calculated. For reaction-type distributors, a minimum head of 24 inches between the low-water level in the siphon chamber and center of the arms should be required. Surge relief to prevent damage to distributor seals, should be provided where sewage is pumped directly to the distributors.

d. Clearance

A minimum clearance of 6 inches between medium and distributor arms should be provided. Greater clearance is essential where icing occurs.

e. Seals

The use of mercury seals is prohibited in the distributors of newly constructed trickling filters. If an existing treatment facility is to be modified, any mercury seals in the trickling filters shall be replaced with oil or mechanical seals.

6.1.6.4 Recirculation Pumping

Low-head, high-capacity pumps are generally used. Submersible pumps are commonly used. A means to adjust the flow is recommended in order to maintain constant hydraulic operation.

6.1.6.5 Waste Sludge Equipment

Pumps for trickling filter sludge should be capable of pumping material up to 6-percent solids (or more if needed) when pumping directly to the digester. Time clock controlled on-off control is desirable. When secondary sludge is pumped to the primary clarifier, the sludge pumps should be designed to pump material with low solid concentrations and high flow rates.

6.1.6.6 Miscellaneous Features

a. Flooding

Consideration should be given to the design of filter structures so that they may be flooded.

b. Maintenance

All distribution devices, underdrains, channels, and pipes should be installed so that they may be properly maintained, flushed, or drained.

c. Flow Measurement

A means shall be provided to measure recirculated flow to the filter.

6.2 Rotating Biological Contactors

6.2.1 General

6.2.1.1 Description

This section presents the requirements for fixed-film reactors using either partially submerged vertical media rotated on a horizontal shaft or other designs with similar concepts.

6.2.1.2 Applicability

Rotating biological contactors (RBC) may be used for treatment of wastewater amenable to treatment by aerobic biological processes. The process is especially applicable to small communities. These requirements shall be considered when proposing this type of treatment.

6.2.1.3 Pretreatment

Primary clarifiers or fine screens should be placed ahead of the RBC process to minimize solids settling in the RBC tanks. (See Chapters 4 & 5)

6.2.2 Media

6.2.2.1 Description

Typical media consists of plastic sheets of various designs with appropriate spacings to maximize the surface area, allow for entrance of air and wastewater, the sloughing of excess biological solids and prevention of plugging. The medium is mounted on a horizontal steel shaft. Other similar systems will be considered on a case-by-case basis.

6.2.2.2 Types

Two types of medium are currently available.

a. Standard Density

Standard-density medium is available in sizes up to 100,000 square feet (sq ft) per shaft. It should be used for all secondary treatment applications.

b. High Density

High-density medium is available in sizes up to 150,000 sq ft per shaft.
It should be used only for nitrification or effluent polishing where the influent BOD is sufficiently low to ensure that plugging of the medium will not occur.

6.2.3 Design Loadings

6.2.3.1 RBC Media

Design loadings should be in terms of total organic loading expressed as pounds BOD_5 per day per 1000 square feet of media surface area (lb BOD_5/day/1000 sq. ft.). The development of design loadings should consider influent BOD, soluble BOD, effluent BOD, flows, temperature, and the number of treatment stages. The design loading should generally range between 2.5 and 3.5 lb BOD_5/day/1000 sq. ft.

6.2.3.2 Final Clarifiers

The following requirements are in addition to those set forth in Chapter 5, "Clarifiers."

The overflow rate should be less than or equal to 600 gpd/sq ft at the average daily design flow.

6.2.4 Special Details

6.2.4.1 Enclosures

Enclosures should be provided for the RBC medium to prevent algae growth on the medium and minimize the effect of cold weather. Enclosures may be either fabricated individual enclosures or buildings enclosing several shafts. Buildings may be considered for installations with several shafts or, where severe weather conditions are encountered, to promote better maintenance.

a. Fabricated Individual Enclosures

Enclosures should be made of fiberglass or other material resistant to damage from humidity or corrosion. The exterior of the enclosures should be resistant to deterioration from direct sunlight and ultraviolet radiation. Access points should be provided at each end of the enclosure to permit inspection of shafts and to perform operation and maintenance. Enclosures shall be removable to allow removal of the shaft assemblies. Access around enclosures shall be sufficient to permit suitable lifting equipment access to lift covers and shafts.

b. Buildings

Adequate space should be provided to allow access to and removal of shafts from enclosures. Buildings should be designed with provisions to remove shafts without damage to the structure. Buildings should be designed with adequate ventilation and humidity control to ensure adequate atmospheric oxygen is available for the RBC shafts, provide a safe environment for the operating staff to perform normal operation and maintenance, and minimize the damage to the structure and equipment from excess moisture.

6.2.4.2 Hydraulic Design

The RBC design should incorporate sufficient hydraulic controls, such as weirs, to ensure that the flow is distributed evenly to parallel process units. RBC tank design should provide a means for distributing the influent flow evenly across each RBC shaft. Intermediate baffles placed between treatment stages in the RBC system should be designed to minimize solids deposition. The RBC units should be designed with flexibility to permit series or parallel operation.

6.2.4.3 Dewatering

The design should provide for dewatering of RBC tanks.

6.2.4.4 Shaft Drives

The electric motor and gear reducer should be located to prevent contact with the wastewater at peak flow rates.

6.2.4.5 Recycle

Effluent recycle should be provided for small installations where minimum diurnal flows may be very small. Recycle should be considered in any size plant where minimum flows are less than 30% of the average design flow.

6.2.4.6 Access

Access shall be allowed for lifting equipment to provide maintenance in the event of a failure.

6.3 Activated Biofilter

6.3.1 General

6.3.1.1 Description

The activated biofilter (ABF) process is a combination of the trickling filter process using artificial media and the activated sludge process.

6.3.1.2 Applicability

The activated biofilter process may be used where wastewater is amendable to biological treatment. This process requires close attention and competent operating supervision, including routine laboratory control. These requirements should be considered when proposing this type of treatment. The process is more adaptable to handling large seasonal loading variations, such as those resulting from seasonal industries or changes in population, than are some of the other biological processes. Where significant quantities of industrial wastes are anticipated, pilot plant testing should be considered.

6.3.2 ABF Media

Artificial media are used in the trickling filter portion of the process to allow high BOD and hydraulic loadings and permit recycle of activated sludge through the trickling filter without plugging. Either wood or plastic artificial medium may be used. Medium depth typically ranges from 7 to 25 feet.

6.3.3 Design

6.3.3.1 General

Calculations shall be submitted to justify the basis of design of the ABF tower pump station, ABF tower, aeration basin, aeration equipment, secondary clarifiers, activated sludge return equipment, and waste sludge equipment.

6.3.3.2 ABF Tower Pump Station

The ABF tower pump station shall be designed to pump the peak influent flow plus the maximum design ABF tower recirculation and return activated sludge flows. Application of wastewater to the ABF tower should be continuous.

6.3.3.3 ABF Tower

The ABF tower shall be designed based on organic loading expressed as pounds of influent BOD per 1,000 cubic feet per day (lb BOD/1,000 cu ft/day). The organic loading should be established using data from similar installations or pilot plant testing. A minimum hydraulic wetting rate should be maintained and be expressed as gallons per minute per square foot (gpm/sq ft).

Typical values for organic loading range from 100 to 350 lb BOD/1,000 cu ft/day (4,300 to 15,000 pounds BOD per acre-foot per day), and hydraulic wetting rates range from 1.5 to 5.5 gpm/sq ft, including recirculations and return flows.

6.3.3.4 Aeration Basin

The aeration basin should be designed in accordance with Chapter 7, "Activated Sludge," based on the food-to-microorganism (F/M) ratio expressed as pounds of influent BOD per day per pound of mixed liquor volatile suspended solids (MLVSS). The F/M ratio should be based on the influent total BOD to the ABF tower or the estimated soluble BOD leaving the ABF tower. Designs using total BOD to the ABF tower should be based on data from similar installations or pilot plant testing. Designs using the estimated soluble BOD leaving the ABF tower should use typical F/M ratios (presented in Chapter 7, "Activated Sludge"). Estimate of BOD removal in the ABF tower should be based on similar installations or pilot plant testing. Calculations of mixed-liquor suspended solids should include the influent suspended solids and solids sloughing from the ABF tower in addition to growth of activated sludge due to removal of soluble BOD. Determination of aeration basin volume should include consideration of aeration basin power levels (using aeration equipment horsepower) expressed as horsepower per 1,000 cubic feet of basin volume. Aeration basin power levels should be limited to prevent excessive turbulence, which may cause shearing of the activated sludge floc. Aeration prior to the ABF tower may also be considered.

6.3.3.5 Aeration Equipment

Oxygen requirements should be estimated as outlined in Chapter 7, "Activated Sludge," for the ABF tower effluent plus the oxygen requirements of the sloughed solids from the ABF tower.

6.3.3.6 Secondary Clarifiers

Secondary clarifiers should be equipped with rapid sludge withdrawal mechanisms and be designed in accordance with Chapter 5, "Clarifiers," and Chapter 7, "Activated Sludge."

6.3.3.7 Return Sludge Equipment

Return sludge equipment should be designed in accordance with Chapter 5, "Clarifiers."

6.3.3.8 Waste Sludge Equipment

Waste sludge equipment should be designed in accordance with Chapter 12, "Sludge Processing and Disposal."

6.3.3.9 ABF Tower Recirculation

ABF tower recirculation should normally be provided. At a minimum, recirculation capacity should meet the requirements for the minimum hydraulic wetting rate.

6.3.4 Special Details

6.3.4.1 ABF Tower

The ABF tower dosing equipment and underdrainage system should be designed in accordance with Section 6.1.6.3 "Dosing Equipment." Fixed or rotating distributors may be used. In addition, the design of the ABF tower should incorporate a skirt around the top to prevent spray from falling to the ground around the tower.

6.3.4.2 Maintenance Provisions

All distribution devices, underdrains, channels, and pipes should be installed so that they may be properly maintained, flushed, and drained.

6.3.4.3 Flow Measurement

Devices should be provided to permit measurement of flow to the ABF towers, ABF tower recirculation, return activated sludge, and waste activated sludge flows.

CHAPTER 7

Activated Sludge

ACTIVATED SLUDGE

7.1 General

7.1.1 Applicability

The activated sludge process and its various modifications may be used where sewage is amenable to biological treatment. This process requires close attention and more competent operator supervision than some of the other biological processes. A treatability study may be required to show that the organics are amendable to the proposed treatment. For example, industrial wastewaters containing high levels of starches and sugars may cause interferences with the activated sludge process due to bulking.

Toxic loadings from industries and excessive hydraulic loadings must be avoided to prevent the loss or destruction of the activated sludge mass. If toxic influents are a possibility, a properly enforced industrial pretreatment program will prove extremely beneficial to the WWTP and will be required. It takes days and sometimes weeks for the plant to recover from a toxic overload and will likely result in permit violations. Flow equalization, as detailed in Chapter 4, may be required in some instances. These requirements shall be considered when proposing this type of treatment.

7.1.2 Process Selection

The activated sludge process and its several modifications may be employed to accomplish varied degrees of removal of suspended solids and reduction of BOD and ammonia. Choice of the process most applicable will be influenced by the proposed plant size, type of waste to the treated, and degree and consistency of treatment required. All designs should provide for flexibility to incorporate as many modes of operation as is reasonably possible.

Calculations and/or documentation shall be submitted to justify the basis of design for the following:

a. Process efficiency
b. Aeration tanks
c. Aeration equipment (including oxygen and mixing requirements)
d. Operational rationale (including maintenance)
e. Costs (capital and operating)

In addition, the design must comply with any requirements set forth in other chapters such as clarifiers, sludge processing, etc.

7.1.3 Pretreatment

Where primary settling tanks are not used, effective removal or exclusion of grit, debris, excessive oil or grease, and comminution or screening of solids shall be accomplished prior to the activated sludge process.

Where primary settling is used, provisions should be made for discharging raw sewage directly to the aeration tanks to facilitate plant start-up and operation during the initial stages of the plant's design life. Also, primary effluents are often low in D.O. This should be planned for in the design.

7.2 Types of Processes

Figure 7.1 shows the flow schematics of the major types of activated sludge processes, excluding pretreatment. The types that are simply modifications of these processes are not shown.

7.2.1 Conventional

Conventional activated sludge is characterized by introduction of influent wastewater and return activated sludge at one end of the aeration tank, a plug-flow aeration tank, and diffused aeration.

7.2.2 Complete Mix

Complete mix activated sludge is characterized by introduction of influent wastewater and return activated sludge throughout the aeration basin and the use of a completely mixed aeration tank. Complete mix aeration tanks may be arranged in series to approximate plug flow and conventional activated sludge.

7.2.3 Step Aeration

Step aeration activated sludge is characterized by introduction of the influent wastewater at two or more points in the aeration tank, use of a plug-flow aeration tank, and diffused aeration.

7.2.4 Tapered Aeration

Tapered aeration is similar to conventional activated sludge except that the air supply is tapered to meet the organic load within the tank. More air is added to the influent end of the tank where the organic loading and oxygen demand are the greatest.

7.2.5 Contact Stabilization

Contact stabilization activated sludge is characterized by the use of two aeration tanks for each process train, one to contact the influent wastewater and return activated sludge (contact tank) and the other to aerate the return activated sludge (stabilization tank) and promote the biodegradation of the organics absorbed to the bacterial flocs.

7.2.6 Extended Aeration

Extended aeration activated sludge is characterized by a low F/M ratio, long sludge age, and long aeration tank detention time (greater than 18 hours). For additional details on oxidation ditches see Section 7.7).

7.2.7 High-Rate Aeration

High-rate aeration activated sludge is characterized by high F/M ratio, low sludge age, short aeration tank detention time, and high mixed-liquor suspended solids. High-rate aeration should be followed by other BOD and suspended solids removal processes to provide secondary treatment.

7.2.8 High-Purity Oxygen

High-purity oxygen activated sludge is characterized by the use of high-purity oxygen instead of air for aeration.

7.2.9 Kraus Process

Kraus process activated sludge is characterized by use of an aeration tank to aerate a portion of the return activated sludge, digester supernatant, and digested sludge in order to provide nitrogen (ammonia) to a nitrogen-deficient wastewater.

7.2.10 Sequencing Batch Reactors (SBR)

The SBR process is a fill-and-draw, non-steady state activated sludge process in which one or more reactor basins are filled with wastewater during a discrete time period, and then operated in a batch treatment mode. SBR's accomplish equalization, aeration, and clarification in a timed sequence. For additional details see Section 7.6.

7.3 Aeration Tanks

7.3.1 Required Volume

The size of the aeration tank for any particular adaptation of the process shall be based on the food-to-microorganism (F/M) ratio, using the influent BOD (load per day) divided by the mixed-liquor volatile suspended solids. Alternatively, aeration tanks may be sized using sludge age. The calculations using the F/M ratio or sludge age shall be based on the kinetic relationships.

APPENDIX 7A shows the permissible range of F/M ratio, sludge age, mixed-liquor suspended solids, aeration tank detention time, aerator loading, and activated sludge return ratio for design of the various modifications of the activated sludge process. All design parameters shall be checked to determine if they fall within the permissible range for the selected F/M ratio or sludge area and the aeration tank size. Diurnal load variations and peak loadings must be considered when checking critical parameters.

7.3.2 Shape and Mixing

The dimensions of each independent mixed-liquor aeration tank or return sludge reaeration tank should be such as to maintain effective mixing and utilization of air when diffused air is used. Liquid depths should not be less than 10 feet or more than 30 feet except in special design cases. For plug-flow conditions using very small tanks or tanks with special configuration, the shape of the tank and/or the installation of aeration equipment should provide for elimination of short-circuiting through the tank.

Aerator loadings should be considered and the horsepower per 1,000 cubic feet of basin volume required for oxygen transfer should be limited to prevent excessive turbulence in the aeration basins, which might reduce activated sludge settleability.

7.3.3 Number of Units

Multiple tanks capable of independent operation may be required for operability and maintenance reasons, depending on the activated sludge process, size of the plant, and the reliability classification of the sewerage works (refer to Section 1.3.11).

7.3.4 Inlets and Outlets

7.3.4.1 Controls

Inlets and outlets for each aeration tank unit in multiple tank systems should be suitably equipped with valves, gates, stop plates, weirs, or other devices to permit control of the flow and to maintain reasonably constant liquid level. The hydraulic properties of the system should permit the maximum instantaneous hydraulic load to be carried with any single aeration tank unit out of service.

7.3.4.2 Conduits

Channels and pipes carrying liquids with solids in suspension should be designed to maintain self-cleaning velocities or should be agitated to keep such solids in suspension at all rates of flow within the design limits.

7.3.4.3 Hydraulics

Where multiple aeration tanks and secondary clarifiers are used, provisions should be made to divide the flow evenly to all aeration tanks in service and then recombine the flows, and to divide the flow evenly to all secondary clarifiers in service and then recombine the flows. Treatments plants using more than four aeration tanks and secondary clarifiers may divide the activated sludge systems into two or more process trains consisting of not less than two aeration tanks and secondary clarifiers per process train.

7.3.4.4 Bypass

When a primary settling tank is used, provisions shall also be made for discharging raw wastewater directly to the aeration tanks following pretreatment for start-ups.

7.3.5 Measuring Devices

For plants designed for less than 250,000 gallons per day, devices shall be installed for indicating flow rates of influent sewage, return sludge, and air to each aeration tank. For plants designed for greater than 250,000 gallons per day, devices shall be installed for totalizing, indicating, and recording influent sewage and returned sludge to each aeration tank. Where the design provides for all returned sludge to be mixed with the raw sewage (or primary effluent) at one location, the mixed-liquor flow rate to each aeration tank shall be measured, and the flow split in such a manner to provide even loading to each tank, or as desired by operations.

7.3.6 Freeboard and Foam Control

Aeration tanks shall have a freeboard of at least 18 inches. Freeboards of 24 inches are desirable with mechanical aerators.

Consideration shall be given for foam control devices on aeration tanks. Suitable spray systems or other appropriate means will be acceptable. If potable water is used, approved backflow prevention shall be provided on the water lines. The spray lines shall have provisions for draining to prevent damage by freezing.

7.3.7 Drain and Bypass

Provisions shall be made for dewatering each aeration tank for cleaning and maintenance. The dewatering system shall be sized to permit removal of the tank contents within 24 hours. If a drain is used, it shall be valved. The dewatering discharge shall be upstream of the activated sludge process.

Provisions shall be made to isolate each aeration tank without disrupting flow to other aeration tanks.

Proper precautions shall be taken to ensure the tank will not "float" when dewatered.

7.3.8 Other Considerations

Other factors that might influence the efficiency of the activated sludge process should be examined. Septic and/or low pH influent conditions are detrimental, particularly where primary clarifiers precede the activated sludge process or when the collection system allows the sewage to go septic. Often, the pH is buffered by the biological mass, but wide variations in the influent should be avoided and, if present, chemical addition may be necessary.

Aerobic organisms require minimum quantities of nitrogen and phosphorus. Domestic wastewater usually has an excess of nitrogen and phosphorus; however, many industrial wastewaters are deficient in these elements. A mass balance should be performed to see if the combined industrial and domestic influent contains sufficient nitrogen and phosphorus or if nutrient levels will have to be supplemented.

7.4 Aeration Equipment

7.4.1 General

Oxygen requirements generally depend on BOD loading, degree of treatment, and level of suspended solids concentration to be maintained in the aeration tank mixed liquor. Aeration equipment shall be designed to supply sufficient oxygen to maintain a minimum dissolved oxygen concentration of 2 milligrams per liter (mg/l) at average design load and 1.0 mg/l at peak design loads throughout the mixed liquor. In the absence of experimentally determined values, the design oxygen requirements for all activated sludge processes shall be 1.1 lbs oxygen per lb peak BOD_5 applied to the aeration tanks, with the exception of the extended aeration process, for which the value shall be 2.35. Aeration equipment shall be of sufficient size and arrangement to maintain velocities greater than 0.5 foot per second at all points in the aeration tank.

The oxygen requirements for an activated sludge system can be estimated using the following relationship:

O_2 = (a) (BOD) + b (MLVSS)

O_2 = pounds of oxygen required per day

BOD = pounds of BOD removed per day (5-day BOD)*

MLVSS = pounds of mixed liquor volatile suspended solids contained in the aeration basin

a= amount of oxygen required for BOD synthesis. "a" will range from 0.5 to 0.75 pound of oxygen per pound of BOD removed

b= amount of oxygen required for endogenous respiration or decay. "b" will range from 0.05 to 0.20 pound of oxygen per pound of MLVSS

*BOD removal shall be calculated as influent BOD_5 minus soluble effluent BOD_5.

For preliminary planning before process design is initiated, a rough estimate can be obtained by using 1.0 to 1.2 pounds of oxygen per pound of BOD removed (assuming no nitrification).

7.4.2 Diffused Air Systems

7.4.2.1 Design Air Requirements

The aeration equipment shall be designed to provide the oxygen requirements set forth above. Minimum requirements for carbonaceous removal are shown below. (Oxygen requirements for nitrification are in addition to that required for carbonaceous removal where applicable; i.e., low F/M.)

Process	Cubic Feet of Air Available per Pound of BOD Load Applied **to Aeration Tank**
Conventional	1,500
Step Aeration	1,500
Contact Stabilization	1,500
Modified or "High Rate" (depending upon BOD removal expected)	400 to 1,500
Extended Aeration	2,100

Air required for channels, pumps, or other air-use demand shall be added to the air volume requirements.

Manufacturers' specifications must be corrected to account for actual operation conditions (use a worst case scenario). Corrections shall be made for temperatures other than 20^{o}C and elevations greater than 2,000 feet.

7.4.2.2 Special Details

The specified capacity of blowers or air compressors, particularly centrifugal blowers, shall take into account that the air intake temperature might reach extremes and that pressure might be less than normal. Motor horsepower shall be sufficient to handle the minimum and maximum ambient temperatures on record.

The blower filters shall be easily accessible. Spare filters should be provided.

The blowers shall be provided in multiple units, arranged and in capacities to meet the maximum air demand with the single largest unit out of service. The design shall also provide for varying the volume of air delivered in proportion to the load demand of the plant.

The spacing of diffusers shall be in accordance with the oxygen and mixing requirements in the basin. If only one aeration tank is proposed, arrangement of

diffusers should permit their removal for inspection, maintenance, and replacement without de-watering the tank and without shutting off the air supply to other diffusers in the tank.

Individual units of diffusers shall be equipped with control valves, preferably with indicator markings, for throttling or for complete shutoff. Diffusers in each assembly shall have substantially uniform pressure loss. The adjustment of one diffuser should have minimal influence on the air supply rate to any other diffusers.

Flow meters and throttling valves shall be placed in each header. Air filters shall be provided as part of the blower assembly to prevent clogging of the diffuser system. Means shall be provided to easily check the air filter so that it will be replaced when needed.

7.4.3 Mechanical Aeration Equipment

Power input from mechanical aerators should range from 0.5 to 1.3 horsepower per 1,000 cubic feet of aeration tank.

The mechanism and drive unit shall be designed for the expected conditions of the aeration tank in terms of the proven performance of the equipment.

Due to the high heat loss, consideration shall be given to protecting subsequent treatment units from freezing where it is deemed necessary. Multiple mechanical aeration unit installations shall be designed to meet the maximum oxygen demand with the largest unit out of service. The design shall normally also provide for varying the amount of oxygen transferred in proportion to the load demand on the plant.

A spare aeration mechanism shall be furnished for single-unit installations. Access to the aerators shall be provided for routine maintenance.

7.4.4 Flexibility and Energy Conservation

The design of aeration systems shall provide adequate flexibility to vary the oxygen transfer capability and power consumption in relation to oxygen demands. Particular attention should be given to initial operation when oxygen demands may be significantly less that the design oxygen demand. The design shall always maintain the minimum mixing levels; mixing may control power requirements at low oxygen demands.

Dissolved oxygen probes and recording should be considered for all activated sludge designs. Consideration will be given to automatic control of aeration system oxygen transfer, based on aeration basin dissolved oxygen concentrations, provided manual back-up operation is available. A dissolved oxygen field probe and meter is to be provided for all activated sludge installations.

Watt-hour meters shall be provided for all aeration system drives to record power usage.

Energy conservation measures shall be considered in design of aeration systems. For diffused aeration systems, the following shall be considered:

a. Use of small compressors and more units

b. Variable-speed drives on positive-displacement compressors

c. Intake throttling on centrifugal compressors

d. Use of timers while maintaining minimum mixing and D.O. levels (consult with manufacturer's recommendations for proper cycling)

e. Use of high-efficiency diffusers

f. Use of separate and independent mixers and aerators

For mechanical aeration systems, the following shall be considered:

a. Use of smaller aerators

b. Variable aeration tank weirs

c. Multiple-speed motors

d. Use of timers

7.5 Additional Details

7.5.1 Lifting Equipment and Access

Provisions shall be made to lift all mechanical equipment and provide sufficient access to permit its removal without modifying existing or proposed structures.

7.5.2 Noise and Safety

Special consideration shall be given to the noise produced by air compressors used with diffused aeration systems and mechanical aerators. Ear protection may be required. Silencers for blowers may be required in sensitive areas.

Handrails shall be provided on all walkways around aeration tanks and clarifiers.

The following safety equipment shall be provided near aeration tanks and clarifiers:

Safety vests
Lifelines and rings
Safety poles

Walkways near aeration tanks shall have a roughened surface or grating to provide safe footing and be built to shed water.

Guards shall be provided on all moving machinery in conformance with OSHA requirements.

Sufficient lighting shall be provided to permit safe working conditions near aerations tanks and clarifiers at night.

7.6 Sequencing Batch Reactors (SBRs)

SBRs shall be designed to meet all the requirements set forth in preceding sections on activated sludge. Special consideration shall be given to the following:

7.6.1 A pre-aeration, flow-equalization basin is to be provided for when the SBR is in the settle and/or draw phases. If multiple SBR basins are provided, a pre-aeration basin will not be needed if each SBR basin is capable of handling all the influent peak flow while another basin is in the settle and/or draw phase.

7.6.2 When discharging from the SBR, means need to be provided to avoid surges to the succeeding treatment units. The chlorine contact tank shall not be hydraulically overloaded by the discharge.

7.6.3 The effluent from the SBRs shall be removed from just below the water surface (below the scum level) or a device which excludes scum shall be used. All decanters shall be balanced so that the effluent will be withdrawn equally from the effluent end of the reactor.

7.6.4 Prevailing winds must be considered in scum control.

7.7 Oxidation Ditch

7.7.1 General

The oxidation ditch is a complete-mixed, extended aeration, activated sludge process which is operated with a long detention time. Brush-rotor (or disk type) aerators are normally used for mixing and oxygen transfer. All requirements set forth in previous sections and/or chapters must be met, with the exception of those items addressed below.

7.7.2 Special Details

7.7.2.1 Design Parameters

The design parameters shall be in the permissible range as set forth in Table 7.1 for F/M, sludge age, MLSS, detention time, aerator loading, and activated sludge return ratio.

7.7.2.2 Aeration Equipment

Aeration equipment shall be designed to transfer 2.35 pounds of oxygen per pound of BOD at standard conditions. The oxygen requirement takes into account nitrification in a typical wastewater. Also, a minimum average velocity of one foot per second shall be maintained, based on the pumping rate of the aeration equipment and the aeration basin cross-sectional area.

A minimum of two aerators per basin is required.

7.7.2.3 Aeration Tank Details

a. Influent Feed Location

Influent and return activated sludge feed to the aeration tank should be located just upstream of an aerator to afford immediate mixing with mixed liquor in the channel.

b. Effluent Removal Location

Effluent from the aeration channel shall be upstream of an aerator and far enough upstream from the injection of the influent and return activated sludge to prevent short-circuiting.

c. Effluent Adjustable Weir

Water level in the aeration channel shall be controlled by an adjustable weir or other means. In calculating weir length, use peak design flow plus maximum recirculated flow to prevent excessive aerator immersion.

d. Walkways and Splash Control

Walkways must be provided across the aeration channel to provide access to the aerators for maintenance. The normal location is above the aerator. Splash guards shall be provided to prevent spray from the aerator on the walkway. Bridges should not be subject to splash from the rotors.

e. Baffles

Horizontal baffles, placed across the channel, may be used on all basins with over 6 feet liquid depth, and may be used where the manufacturer recommends them to provide proper mixing of the entire depth of the basin.

Baffles should be provided around corners to ensure uniform velocities.

7.7.3 45-Degree Sloping Sidewall Tanks

7.7.3.1 Liquid Depth

Liquid depth shall be 7 to 10 feet, depending on aerator capability, as stated by the manufacturer.

7.7.3.2 Channel Width at Water Level

The higher ratios (channel width at water level divided by aerator length) are to be used with smaller aerator lengths.

3- to 15-foot-long rotors, ratio 3.0 to 1.8.

16- to 30-foot-long rotors, ratio 2.0 to 1.3

Above 30-foot-long rotors, ratio below 1.5

7.7.3.3 Center Island

When used, the minimum width of center island at liquid level, based on aerator length, should be as follows (with center islands below minimum width, use return flow baffles at both ends):

3- to 5-foot-long rotor, 14 feet

6- to 15-foot-long rotor, 16 feet

16- to 30-foot-long rotor, 20 feet

Above 30-foot-long rotors, 24 feet

7.7.3.4 Center Dividing Walls

Center dividing walls can be used but return flow baffles at both ends are required. The channel width, W, is calculated as flat bottom plus 1/2 of sloping sidewall. Baffle radius is W/2. Baffles should be offset by W/8, with the larger opening accepting the flow and the smaller opening downstream compressing the flow.

7.7.3.5 Length of Straight Section

Length of straight section of ditch shall be a minimum of 40 feet or at least two times the width of the ditch at liquid level.

7.7.3.6 Preferred Location of Aerators

Aerators shall be placed just downstream of the bend, normally 15 feet, with the long straight section of the ditch downstream of the aerator.

7.7.4 Straight Sidewall Tanks

7.7.4.1 Liquid Depth

Liquid depth shall be 7 to 12 feet, depending on aerators.

7.7.4.2 Aerator Length

Individual rotor length shall span the full width of the channel, with necessary allowance required for drive assembly and outboard bearing.

7.7.4.3 Center Island

Where center islands are used, the width should be the same as with 45-degree sloping sidewalls, or manufacturer's recommendation.

7.7.4.4 Center Dividing Walls

When a center dividing wall is used, return flow baffles are required at both ends. Return flow baffle radius is width of channel, W, divided by 2, W/2. Baffles should be offset by W/8, with the larger opening accepting the flow and the smaller opening downstream compressing the flow.

7.7.4.5 Length of Straight Section

Length of straight section downstream of aerator shall be near 40 feet or close to two times the aerator length. In deep tanks with four aerators, aerators should be placed to provide location for horizontal baffles.

7.7.4.6 Preferred Location of Aerators

Aerators should be placed just downstream of the bend with the long straight section of the tank downstream of the aerator. Optimal placement of rotors will consider maintaining ditch center line distance between rotors close to equal.

APPENDIX 7-A

CHAPTER 8

Nitrification

NITRIFICATION

8.1 General

8.1.1 Applications

Nitrogen exists in treated wastewater primarily in the form of ammonia which is oxidized to nitrate by bacteria. This process requires oxygen and can exert a significant oxygen demand on the receiving water.

Nitrification shall be considered when ammonia concentrations in the effluent would cause the receiving water to exceed the limitations established to prevent ammonia toxicity to aquatic life, or when the effluent ammonia quantity would cause the dissolved oxygen level of the receiving stream to deplete below allowable limits. The degree of treatment required will be determined by the NPDES permit limit.

8.1.2 Process Selection

Calculations shall be submitted to support the basis of design. The following factors should be considered in the evaluations of alternative nitrification processes:

a. Ability to meet effluent requirements under all environmental conditions to be encountered, with special emphasis on temperature, pH, alkalinity, and dissolved oxygen.

b. Cost (total present worth)

c. Operational considerations, including process stability, flexibility, operator skill required, and compatibility with other plant processes.

d. Land requirements.

8.2 Suspended Growth Systems

8.2.1 Single - Stage Activated Sludge

This section details the requirements for activated sludge systems designed to both remove carbonaceous matter and oxidize ammonia.

8.2.1.1 Process Design

Design must provide adequate solids retention time in the activated sludge system for sufficient growth of nitrifying bacteria. A safety factor of 2.5 or greater should be used to calculate the design mean cell residence time or sludge age. This safety factor must be large enough to provide enough operational flexibility to handle diurnal, peak, and transient loadings. The calculation of the solids retention time shall consider influent BOD, TSS, BOD_5/TKN (Total Kjeldahl Nitrogen) ratio and kinetic parameters. The kinetic parameters can be taken from the literature, similar installations, or pilot plant studies. The effect of temperature on the kinetics must be considered since nitrification will not proceed as rapidly during winter months.

8.2.1.2 Special Details

The following requirements are in addition to those included in Chapter 5, "Clarifiers", and Chapter 7, "Activated Sludge":

a. Sufficient oxygen must be provided for both carbonaceous BOD oxidation and ammonia oxidation. Use 4.6 pounds O_2 per pound total Kjeldahl nitrogen to calculate the oxygen requirements for nitrification, in addition to the oxygen needed for BOD removal.

b. Aeration basin design dissolved oxygen shall be greater than or equal to 2.0 mg/l.

c. Diurnal peak mass flow rates of BOD and total Kjeldahl nitrogen must be considered in the aeration system design.

d. The pH levels must be controlled within the range of 6.5 to 8.4. Nitrification is optimized in the upper portion of this range (7.9 to 8.4) but pH levels in the range of 7.6 to 7.8 are recommended since CO_2 produced will be released from the wastewater.

e. Nitrification requires alkalinity, 7.1 pounds as $CaCO_3$ per pound NH_3-N oxidized. The wastewater must be shown to have sufficient alkalinity or chemical treatment must be considered to provide adequate alkalinity.

f. Clarifier and return sludge pumping must be designed with the capability to allow operation over a range of solids retention times. Flexibility should be provided to prevent denitrification in the clarifier from low D.O.
levels in the sludge blanket. This could cause violations of other effluent limits (i.e., suspended solids).

8.2.2 Two-Stage with Activated Sludge Nitrification

This section details the requirements for systems in which carbonaceous BOD is removed in the first stage and ammonia is oxidized by activated sludge in the second stage. BOD removal in the first stage could be by activated sludge, trickling filters, or physical - chemical treatment.

8.2.2.1 Process Design

The first stage shall be designed using the requirements of the appropriate chapters, such as activated sludge, trickling filters, and clarifiers. To promote a sludge with good settling characteristics in the second stage clarifier, some carbonaceous BOD shall enter the second stage aeration basin. This allows a less conservative design of the first stage as long as total BOD removal is sufficient. The requirements for the process design of the second stage are the same as those presented previously for the single-stage nitrification system.

8.2.2.2 Special Details

The following details are in addition to those in Chapter 5, "Clarifiers," Chapter 6, "Fixed Film Reactors," and Chapter 7, "Activated Sludge."

a. Sufficient oxygen must be provided for both carbonaceous BOD oxidation and ammonia oxidation. Use 4.6 pounds O_2 per pound total Kjeldahl nitrogen to calculate the oxygen requirements for nitrification, in addition to the oxygen needed nitrogen to calculate the oxygen requirements for nitrification, in addition to the oxygen needed for BOD removal.

b. Aeration basin design dissolved oxygen shall be greater than or equal to 2.0 mg/l.

c. Diurnal peak mass flow rates of BOD and total Kjeldahl nitrogen must be considered in the aeration system design.

d. The pH levels must be controlled within the range of 6.5 to 8.4. Nitrification is optimized in the upper portion of this range (7.9 to 8.4) but pH levels in the range of 7.6 to 7.8 are recommended since CO_2 produced will be released from the wastewater.

e. Nitrification requires alkalinity, 7.1 pounds as $CaCO_3$ per pound NH_3-N oxidized. The wastewater must be shown to have sufficient alkalinity or chemical treatment must be considered to provide adequate alkalinity.

f. Clarifier and return sludge pumping must be designed with the capability to allow operation over a range of solids retention times.
Flexibility should be provided to prevent denitrification in the clarifier from low D.O. levels in the sludge blanket. This could cause violations of other effluent limits (i.e., suspended solids).

8.3 Fixed - Film Systems

8.3.1 Trickling Filters

8.3.1.1 Process Design

Recirculation is required to provide a constant hydraulic loading on the medium.

a. Single - Stage

This section details the requirements for a trickling filter that is designed for both carbonaceous BOD removal and ammonia oxidation. Design shall be based on the organic loading expressed as pounds BOD per 1,000 cubic feet. The design loading rate shall by justified from literature, similar installations, or pilot plant data for a particular depth and type of filter medium. Design shall consider temperature effects on ammonia removal and organic loading rates, and any proposal to attain nitrification in a single-stage rock media trickling filter will be more closely scrutinized than with other types of media.

b. Two - Stage

This section details the requirements of using a trickling filter for nitrification which is preceded by a trickling filter, activated sludge system, or physical - chemical treatment for carbonaceous BOD removal. Design must be based on either a surface area loading expressed as square feet per pound NH_4-N oxidized per day or a volumetric loading expressed as pounds NH_4-N per 1,000 cubic feet per day. Loading rates must be justified from literature, similar plants, or pilot plant data. The effects of temperature on loading rates and ammonia oxidation must be considered in the design.

8.3.1.2 Special Details

The following requirements are in addition to those in Chapter 5, "Clarifiers," and Chapter 6, "Fixed Film Reactors."

a. Clarifiers will be required for second-stage trickling filters for nitrification.

b. Higher specific surface area and lower void ratio media may be used for second-stage trickling filters providing nitrification.

8.3.2 Activated Biofilter (ABF) Process

8.3.2.1 Process Design

Process design shall be based on the literature, similar installations, or pilot plant data. The design shall consider the effects of temperature, pH, and aeration basins.

8.3.2.2 Special Details

a. Sufficient oxygen must be provided for both carbonaceous BOD oxidation and ammonia oxidation. Use 4.6 pounds O_2 per pound total Kjeldahl nitrogen to calculate the oxygen requirement for nitrification, in addition to the oxygen needed for BOD removal.

b. Aeration basin design dissolved oxygen shall be greater than or equal to 2.0 mg/l.

c. Diurnal peak mass flow rates of BOD and total Kjeldahl nitrogen must be considered in the aeration system design.

d. The pH levels must be controlled within the range of 6.5 to 8.4. Nitrification is optimized in the upper portion of this range (7.9 to 8.4) but pH levels in the range of 7.6 to 7.8 are recommended since CO_2 produced will be released from the wastewater.

e. Nitrification requires alkalinity, 7.1 pounds as $CaCO_3$ per pound NH_3-N oxidized. The wastewater must be shown to have sufficient alkalinity or chemical treatment must be considered to provide adequate alkalinity.

f. Clarifier and return sludge pumping must be designed with the capability to allow operation over a range of solids retention times. Flexibility should be provided to prevent denitrification in the clarifier from low D.O. in the sludge blanket. This could cause violations of other effluent limits (i.e., suspended solids).

8.3.3 Submerged Media

8.3.3.1 General

This section includes all designs for fixed-film reactors using stones, gravel, sand, anthracite coal, or plastic media or combinations thereof in which the medium is submerged and air or oxygen is used to maintain aerobic conditions.
Pilot plant testing or a similar full-scale installation with a minimum of 1 year of operation is required before consideration will be given to a submerged design. No design will be considered unless the following can be demonstrated:

a. Reliable operation

b. Ability to transfer sufficient oxygen

c. Ability to handle peak flows without washout of medium

d. Methods of separating suspended solids from effluent, removing waste sludge, and stabilization and dewatering of waste sludge

e. Media resistance to plugging

8.3.3.2 Process Design

Data for design and calculations shall be submitted upon request to justify the basis of design.

8.3.4 Rotating Biological Contactors

8.3.4.1 Process Design

Process design shall be based on the surface area loading expressed as gallons per day per square foot. Design surface area loading shall consider the number of stages, temperature, BOD concentration entering and leaving each stage, and ammonia concentration entering and leaving each stage. Calculations shall be submitted upon request to justify the basis of design.

8.3.4.2 Special Details

The following requirements are in addition to those set forth in Chapter 5, "Clarifiers," and Chapter 6, "Fixed Film Reactors."

a. Standard media (100,000 square feet per shaft or less) shall be used until influent BOD concentration is less than manufacturer's recommendation for high-density media (150,000 square feet per shaft or more). High-density media may be used for influent BOD concentrations less than manufacturer's recommendation for high-density media.

b. Clarifiers will be required following rotating biological contactors that follow a secondary process.

CHAPTER 9

Ponds and Aerated Lagoons

PONDS AND AERATED LAGOONS

9.1 General

This chapter describes the requirements for the following biological treatment processes:

a. Stabilization ponds

b. Aerated lagoons

Additionally, this chapter describes the requirements for use of hydraulic control release lagoons for effluent disposal.

A guide to provisions for lagoon design is the EPA publication Design Manual - Municipal Wastewater Stabilization Ponds, EPA-625/1-83-015.

9.1.1 Applicability

In general, ponds and aerated lagoons are most applicable to small and/or rural communities where land is available at low cost and minimum secondary treatment requirements are acceptable. Advantages include potentially lower capital costs, simple operation, and low O&M costs.

9.1.2 Supplement to Engineering Report

The engineering report shall contain pertinent information on location, geology, soil conditions, area for expansion, and any other factors that will affect the feasibility and acceptability of the proposed treatment system.

The following information should be submitted in addition to that required in the Chapter 1 section titled "Engineering Report and Preliminary Plans":

a. The location and direction of all residences, commercial development, and water supplies within 1/2 mile of the proposed pond

b. Results of the geotechnical investigation performed at the site

c. Data demonstrating anticipated seepage rates of the proposed pond bottom at the maximum water surface elevation

d. A description, including maps showing elevations and contours, of the site and adjacent area suitable for expansion

e. The ability to disinfect the discharge is required.

9.1.3 Effluent Requirements

See Chapter 1, Section 1.1.

9.2 Design Loadings

9.2.1 Stabilization Ponds

Stabilization ponds are facultative and are not artificially mixed or aerated. Mixing and aeration are provided by natural processes. Oxygen is supplied mainly by algae.

Design loading shall not exceed 30 pounds BOD per acre per day on a total pond area basis and 50 pounds BOD per acre per day to any single pond (from Middlebrooks).

9.2.2 Aerated Lagoons

An aerated lagoon may be a complete-mix lagoon or a partial-mix aerated lagoon. Complete-mix lagoons provide enough aeration or mixing to maintain solids in suspension. Power levels are normally between 20 and 40 horsepower per million gallons. The partial-mix aerated lagoon is designed to permit accumulation of settleable solids on the lagoon bottom, where they decompose anaerobically. The power level is normally 4 to 10 horsepower per million gallons of volume.

BOD removal efficiencies normally vary from 80 to 90 percent, depending on detention time and provisions for suspended solids removal.

The aerated lagoon system design for minimum detention time may be estimated by using the following formula; however, for the development of final parameters, it is recommended that actual experimental data be developed.

$$\frac{Se}{So} = \frac{1}{1 + 2.3K_1 t}$$

where:
t = detention time, days
K_1 = reaction coefficient, complete system per day, base 10

For complete treatment of normal domestic sewage, the K_1 value will be assumed to be:

$K_1 = 1.087$ @20°C for complete mix
$K_1 = 0.12$ @20°C for partial mix
Se = effluent BOD_5, mg/l
So = influent BOD_5, mg/l

The reaction rate coefficient for domestic sewage that includes significant quantities of industrial wastes, other wastes, and partially treated sewage should be determined experimentally for various conditions that might be encountered in the aerated ponds. Conversion of the reaction rate coefficient to temperatures other than 20 degrees C should be according to the following formula:

$$K_1 = K_{20}\ 1.036^{(T-20)} \qquad \text{(T = temperature in degrees C)}$$

The minimum equilibrium temperature of the lagoon should be used for design of the aerated lagoon. The minimum equilibrium temperature should be estimated by using heat balance equations, which should include factors for influent wastewater temperature, ambient air temperature, lagoon surface area, and heat transfer effects of aeration, wind, and humidity. The minimum 30-day average ambient air temperature obtained from climatological data should be used for design.

Additional storage volume shall be considered for sludge storage and partial mix in aerated lagoons.

Sludge processing and disposal should be considered.

9.3 Special Details

9.3.1 General

9.3.1.1 Location

a. Distance from Habitation

A pond site should be located as far as practicable from habitation or any area that may be built up within a reasonable future period, taking into consideration site specifics such as topography, prevailing winds, and forests. Buffer zones between the lagoon and residences or similar land use should be at least 300 feet to residential property lines, and 1000 feet to existing residence structures.

b. Prevailing Winds

If practical, ponds should be located so that local prevailing winds will be in the direction of uninhabited areas. Preference should be given to sites that will permit an unobstructed wind sweep across the length of the ponds in the direction of the local prevailing winds.

c. Surface Runoff

Location of ponds in watersheds receiving significant amounts of runoff water is discouraged unless adequate provisions are made to divert storm water around the ponds and protect pond embankments from erosion.

d. Water Table

The effect of the ground water location on pond performance and construction must be considered.

e. Ground Water Protection

Ground Water Protection's main emphasis should be on site selection and liner construction, utilizing mainly compacted clay. Proximity of ponds to water supplies and other facilities subject to contamination and location in areas of porous soils and fissured rock formations should be critically evaluated to avoid creation of health hazards or other undesirable conditions. The possibility of chemical pollution may merit appropriate consideration. Test wells to monitor potential ground water pollution may be required and should be designed with proper consideration to water movement through the soil as appropriate.

An approved system of ground water monitoring wells or lysimeters may be required around the perimeter of the pond site to facilitate ground water monitoring. The use of wells and/or lysimeters will be determined on a case-by-case basis depending on proximity of water supply and maximum ground water levels. This determination will be at the site approval phase (see Section 1.1).

A routine ground water sampling program shall be initiated prior to and during the pond operation, if required.

f. Floodwaters

Pond sites shall not be constructed in areas subject to 25-year flooding, or the ponds and other facilities shall be protected by dikes from the 25-year flood.

9.3.1.2 Pond Shape

The shape of all cells should be such that there are no narrow or elongated portions. Round, square, or rectangular ponds should have a length to width ratio near 1:1 for complete mix ponds. Rectangular ponds with a length not exceeding three times the width are considered most desirable for complete mix aerated lagoons. However, stabilization ponds should be rectangular with a length exceeding three times the width, or be baffled to ensure full utilization of the basin. No islands, peninsulas, or coves are permitted. Dikes should be rounded at corners to minimize accumulations of floating materials. Common dike construction should be considered whenever possible to minimize the length of exterior dikes.

9.3.1.3 Recirculation

Recirculation of lagoon effluent may be considered. Recirculation systems should be designed for 0.5 to 2.0 times the average influent wastewater flow and include flow measurement and control.

9.3.1.4 Flow Measurement

The design shall include provisions to measure, total, and record the wastewater flows.

9.3.1.5 Level Gauges

Pond level gauges should be located on outfall structures or be attached to stationary structures for each pond.

9.3.1.6 Pond Dewatering

All ponds shall have emergency drawdown piping to allow complete draining for maintenance.

Sufficient pumps and appurtenances should be available to facilitate draining of individual ponds in cases where multiple pond systems are constructed at the same elevation or for use if recirculation is desired.

9.3.1.7 Control Building

A control building for laboratory and maintenance equipment should be provided.

9.3.1.8 General Site Requirements

The pond area shall be enclosed with an adequate fence to keep out livestock and discourage trespassing, and be located so that travel along the top of the dike by maintenance vehicles is not obstructed. A vehicle access gate of width sufficient to accommodate mowing equipment and maintenance vehicles should be provided. All access gates shall be provided with locks. Cyclone-type fences, 5 to 6 feet high with 3 strands of barbed wire, are desirable, with appropriate warning signs required.

9.3.1.9 Provision for Sludge Accumulation

Influent solids, bacteria, and algae that settle out in the lagoons will not completely decompose and a sludge blanket will form. This can be a problem if the design does not include provisions for removal and disposal of accumulated sludge, particularly in the cases of anaerobic stabilization ponds and aerated lagoons. The design should include an estimate of the rate of sludge accumulation, frequency of sludge removal, methods of sludge removal, and ultimate sludge handling and disposal. Abandoning and capping of the lagoon is an acceptable solution (Re: The Division of Solid Waste Management guidelines for abandonment of a lagoon). However, the design life shall be stated in the report.

9.3.2 Stabilization Ponds

9.3.2.1 Depth

The primary (first in a series) pond depth should not exceed 6 feet. Greater depths will be considered for polishing ponds and the last ponds in a series of 4 or more.

9.3.2.2 Influent Structures and Pipelines

a. Manholes

A manhole should be installed at the terminus of the interceptor line or the force main and should be located as close to the dike as topography permits; its invert should be at least 6 inches above the maximum operating level of the pond to provide sufficient hydraulic head without surcharging the manhole.

b. Influent Pipelines

The influent pipeline can be placed at zero grade. The use of an exposed dike to carry the influent pipeline to the discharge points is prohibited, as such a structure will impede circulation.

c. Inlets

Influent and effluent piping should be located to minimize short-circuiting and stagnation within the pond and maximize use of the entire pond area.

Multiple inlet discharge points shall be used for primary cells larger than 10 acres.

All gravity lines should discharge horizontally onto discharge aprons. Force mains should discharge vertically up and shall be submerged at least 2 feet when operating at the 3-foot depth.

d. Discharge Apron

Provision should be made to prevent erosion at the point of discharge to the pond.

9.3.2.3 Interconnecting Piping and Outlet Structures

Interconnecting piping for pond installations shall be valved or provided with other arrangements to regulate flow between structures and permit variable depth control.

The outlet structure can be placed on the horizontal pond floor adjacent to the inner toe of the dike embankment. A permanent walkway from the top of the dike to the top of the outlet structure is required for access.

The outlet structure should consist of a well or box equipped with multiple-valved pond drawoff lines. An adjustable drawoff device is also acceptable. The outlet structure should be designed so that the liquid level of the pond can be varied from a 3.0- 5.0 foot depth in increments of 0.5 foot or less. Withdrawal points shall be spaced so that effluent can be withdrawn from depths of 0.75 foot to 2.0 feet below pond water surface, irrespective of the pond depth.

The lowest drawoff lines should be 12 inches off the bottom to control eroding velocities and avoid pickup of bottom deposits. The overflow from the pond shall be taken near but below the water surface. A two-foot deep baffle may be helpful to keep algae from the effluent. The structure should also have provisions for draining the pond.

A locking device should be provided to prevent unauthorized access to level control facilities. An unvalved overflow placed 6 inches above the maximum water level shall be provided.

Outlets should be located nearest the prevailing winds to allow floating solids to be blown away from effluent weirs.

The pond overflow pipes shall be sized for the peak design flow to prevent overtopping of the dikes.

9.3.2.4 Minimum and Maximum Pond Size

No pond should be constructed with less than 1/2 acre or more than 40 acres of surface area.

9.3.2.5 Number of Ponds

A minimum of three ponds, and preferably four ponds, in series should be provided (or baffling provided for a single cell lagoon design configuration) to insure good hydraulic design. The objective in the design is to eliminate short circuiting.

9.3.2.6 Parallel/Series Operation

Designs, other than single ponds with baffling, should provide for operation of ponds in parallel or series. Hydraulic design should allow for equal distribution of flows to all ponds in either mode of operation.

9.3.3 Aerated Lagoons

9.3.3.1 Depth

Depth should be based on the type of aeration equipment used, heat loss considerations, and cost, but should be no less than 7 feet. In choosing a depth, aerator erosion protection and allowances for ice cover and solids accumulation should be considered.

9.3.3.2 Influent Structures and Pipelines

The same requirements apply as described for facultative systems, except that the discharge locations should be coordinated with the aeration equipment design.

9.3.3.3 Interconnecting Piping and Outlet Structures

a. Interconnecting Piping

The same requirements apply as described for facultative systems.

b. Outlet Structure

The same requirements apply as described for facultative systems, except for variable depth requirements and arrangement of the outlet to withdraw effluent from a point at or near the surface. The outlet shall be preceded by an underflow baffle.

9.3.3.4 Number of Ponds

Not less than three basins should be used to provide the detention time and volume required. The basins should be arranged for both parallel and series operation. A settling pond with a hydraulic detention time of 2 days at average design flow must follow the aerated cells, or an equivalent of the final aerated cell must be free of turbulence to allow settling of suspended solids.

9.3.3.5 Aeration Equipment

A minimum of two mechanical aerators or blowers shall be used to provide the horsepower required. At least three anchor points should be provided for each aerator. Access to aerators should be provided for routine maintenance which does not affect mixing in the lagoon. Timers will be required.

9.4 Pond Construction Details

9.4.1 Liners

9.4.1.1 Requirement for Lining

The seepage rate through the lagoon bottom and dikes shall not be greater than a water surface drop of 1/4 inch per day. (Note: The seepage rate of 1/4 inch per day is 7.3×10^{-6} cm/sec coefficient of permeability seepage rate under pond conditions.) If the native soil cannot be compacted or modified to meet this requirement, a pond liner system will be required.

If a lagoon is proposed to be upgraded, it must be shown that it currently meets the 1/4-inch per day seepage rate before approval will be given.

9.4.1.2 General

Pond liner systems that should be evaluated and considered include (1) earth liners, including native soil or local soils mixed with commercially prepared bentonite or comparable chemical sealing compound, and (2) synthetic membrane liners.
The liner should not be subject to deterioration in the presence of the wastewater. The geotechnical recommendations should be carefully considered during pond liner design.
Consideration should also be given to construct test wells when required by the Department in any future regulations, or when industrial waste is involved.

9.4.1.3 Soil Liners

The thickness and the permeability of the soil liners shall be sufficient to limit the leakage to the maximum allowable rate of 1/4 inch per day. The evaluation of earth for use as a soil liner should include laboratory permeability tests of the material and laboratory compaction tests. The analysis should take into consideration the expected permeability of the soil when compacted in the field. All of the soil liner material shall have essentially the same properties.

The analysis of an earth liner should also include evaluation of the earth liner material with regard to filter design criteria. This is required so that the fine-grained liner material does not infiltrate into a coarser subgrade material and thus reduce the effective thickness of the liner.

If the ponds are going to remain empty for any period of time, consideration should be given to the possible effects on the soil liners from freezing and thawing during cold weather or cracking from hot, dry weather. Freezing and thawing will generally loosen the soil for some depth. This depth is dependent on the depth of frost penetration.

The compaction requirements for the liner should produce a density equal to or greater than the density at which the permeability tests were made. The minimum liner thickness should be 12 inches, to ensure proper mixing of bentonite with the native soil. The soil should be placed in lifts no more than 6 inches in compacted thickness. The moisture content at which the soil is placed should be at or slightly above the optimum moisture content.

Construction and placement of the soil liner should be inspected by a qualified inspector. The inspector should keep records on the uniformity of the earth liner material, moisture contents, and the densities obtained.

Bentonite and other similar liners should be considered as a form of earth liner. Their seepage characteristics should be analyzed as previously

mentioned, and laboratory testing should be performed using the mixture of the native or local soil and bentonite or similar compound.

In general, the requirements for bentonite or similar compounds should include the following: (1) The bentonite or similar compound should be high swelling and free flowing and have a particle size distribution favorable for uniform application and minimizing of wind drift; (2) the application rate should be least 125 percent of the minimum rate found to be adequate in laboratory tests; (3) application rates recommended by a supplier should be confirmed by an independent laboratory; and (4) the mixtures of soil and bentonite or similar compound should be compacted at a water content greater than the optimum moisture content.

9.4.1.4 Synthetic Membrane Liners

Requirements for the thickness of synthetic liners may vary due to the liner material, but it is generally recommended that the liner thickness be no less than 20 mils; that is, 0.020 inch. There may be special conditions when reinforced membranes should be considered. These are usually considered where extra tensile strength is required. The membrane liner material should be compatible with the wastewater in the ponds such that no damage results to the liner. PVC liners should not be used where they will be exposed directly to sunlight. The preparation of the subgrade for a membrane liner is important. The subgrade should be graded and compacted so that there are no holes or exposed angular rocks or pieces of wood or debris. If the subgrade is very gravelly and contains angular rocks that could possibly damage the liner, a minimum bedding of 3 inches of sand should be provided directly beneath the liner. The liner should be covered with 12 inches of soil. This includes the side slope as well. No equipment should be allowed to operate directly on the liner. Consideration should be given to specifying that the manufacturer's representative be on the job supervising the installation during all aspects of the liner placement. An inspector should be on the job to monitor and inspect the installation.

Leakage must not exceed 1/4-inch per day.

9.4.1.5 Other Liners

Other liners that have been successfully used are soil cement, gunite, and asphalt concrete.

The performance of these liners is highly dependent on the experience and skill of the designer. Close review of the design of these types of liners is recommended.

9.4.2 Pond Construction

9.4.2.1 General

Ponds are often constructed of either a built-up dike or embankment section constructed on the existing grade, or they are constructed using a cut and fill technique. Dikes and embankments shall be designed using the generally accepted procedures for the design of small earth dams. The design should attempt to make use of locally available materials for the construction of dikes. Consideration should also be given to slope stability and seepage through and beneath the embankment and along pipes.

9.4.2.2 Top Width

The minimum recommended dike top width should be 12 feet on tangents and 15 feet on curves to permit access of maintenance vehicles. The minimum inside radius of curves of the corners of the pond should be 35 feet.

9.4.2.3 Side Slopes

Normally, inside slopes of either dikes or cut sections should not be steeper than 3 horizontal to 1 vertical. Outer slopes should not be steeper than 2 horizontal to 1 vertical. However, in many instances, the types of material used, maintenance considerations, and seepage conditions can indicate that other slopes should be used.

9.4.2.4 Freeboard

There should be sufficient freeboard to prevent overtopping of the dike from wave action and strong winds. A minimum of one foot is required.

9.4.2.5 Erosion Control

Erosion control should be considered for the inside slopes of the dike to prevent the formation of wavecut beaches in the dike slope. In the event that earth liners or membrane liners with earth cover are used, consideration should be given to erosion protection directly beneath aeration units. If the currents are strong enough, considering the type of material used for the earth cover, erosion pads may be necessary beneath the aeration units. Erosion control should also be considered wherever influent pipes empty into the pond.

If a grass cover for the outer slopes is desired, they should be fertilized and seeded to establish a good growth of vegetative cover. This vegetative cover will help control erosion from runoff. Consideration should also be given to protection of the outer slopes in the event that flooding occurs. The erosion protection should be able to withstand the currents from a flood.

9.4.3 Prefilling

The need to prefill ponds in order to determine the leakage rate shall be determined by the Department and incorporated into the plans and specifications. The strongest consideration for prefilling ponds will be given to ponds with earth liners. Ponds in areas where the surrounding homes are on wells will also be given strong consideration for prefilling.

9.4.4 Utilities and Structures Within Dike Sections

Pipes that extend through an embankment should be bedded up to the springline with concrete. Backfill should be with relatively impermeable material. No granular bedding material should be used. Cutoff collars should be used as required. No gravel or granular base should be used under or around any structures placed in the embankment within the pond. Embankments should be constructed at least 2 feet above the top of the pipe before excavating the pipe trench.

9.5 Hydrograph Controlled Release (HCR) Lagoons

All lagoons requirements apply to HCR lagoons with the following additional concerns:

HCR lagoons control the discharge of treated wastewater in accordance with the stream's assimilative capacity. Detention times vary widely and must be determined on a case-by-case basis.

HCR sites require much receiving stream flow pattern characterization. For this purpose, EPA Region IV has developed a computer design program. The Division of Water Pollution Control can assist in sizing the HCR basin using this program. HCR sites may be more economical if the design is combined with summertime land application. Their design is more economical if summer/winter or monthly standards are available.

The design and construction of the in-stream flow measurement equipment are critical components of an HCR system. The United States Geological Survey (USGS) should be contacted during the design phase. The USGS also has considerable construction experience concerning in-stream monitoring stations, although construction need not necessarily be done or supervised by the USGS.

9.6 Polishing Lagoons

Polishing lagoons following activated sludge are not permissible in Tennessee due to the one-cell algae interference.

9.7 Operability

Once a pond is designed, little operation should be required. However, to avoid NPDES permit violations, pond flexibility is needed. Operation flexibility is best facilitated by the addition of piping and valves to each pond which allows isolation of its volume during an algal bloom.

9.8 Upgrading Existing Systems

There are approximately sixty existing lagoons in Tennessee which were built utilizing standards and criteria from the 1960 period. Most are single- or double-cell units which need upgrading. Many are required to meet tertiary standards. The upgrade case should, in general, utilize the guidance in this chapter or proven configurations. It is noted, however, that there are many lagoon combinations available, such as complete-mix pond, partial-mix pond, stabilization pond, HCR pond and marsh-pond (wetlands)concepts. The combination of these alternatives should be based upon the effluent permit design standards as well as site economics.

CHAPTER 10

Disinfection

DISINFECTION

10.1 General

10.1.1 Requirement for Disinfection

Proper disinfection of treated wastewater before disposal is required for all plants (with the exception of some land application systems) to protect the public health.

Disinfection as a minimum shall:

a. Protect public water supplies

b. Protect fisheries and shellfish waters

c. Protect irrigation and agricultural waters

d. Protect water where human contact is likely

10.1.2 Methods of Disinfection

10.1.2.1 Chlorination

Chlorination using dry chlorine (see definition in following section) is the most commonly applied method of disinfection and should be used unless other factors, including chlorine availability, costs, or environmental concerns, justify an alternative method.

10.1.2.2 Ozonation

Ozonation may be considered as an alternative to chlorination for the reasons described above. Ozonation is considered as Developmental Technology, and should only be considered for very large installations.

10.1.2.3 Other

Other potential methods of disinfection, such as by ultraviolet light, are available and their application will be considered on a case-by-case basis.

10.1.3 Dechlorination

Capability to add dechlorination should be considered in all new treatment plants. Dechlorination of chlorinated effluents shall be provided when permit conditions dictate the need.

10.2 Chlorination

10.2.1 General

10.2.1.1 Forms of Chlorine

a. Dry Chlorine

Dry chlorine is defined as elemental chlorine existing in the liquid or gaseous phase, containing less than 150 mg/l water. Unless otherwise stated, the word "chlorine" wherever used in this section refers to dry chlorine.

b. Sodium Hypochlorite

Sodium hypochlorite may be used as an alternative to chlorine whenever dry chlorine availability, cost, or public safety justifies its use. The requirements for sodium hypochlorite generation and feeding will be determined on a case-by-case basis.

c. Other

Other chlorine compounds such as chlorine dioxide or bromine chloride may be used as alternatives to chlorine whenever cost or environmental concerns justify their use. The acceptability of other chlorine compounds will be determined on a case-by-case basis.

10.2.1.2 Chlorine Feed Equipment

Solution-feed vacuum-type chlorinators are generally preferred for large installations. The use of hypochlorite feeders of the positive displacement type may be considered. Dry chlorine tablet type feeders may also be considered for small flows, into large streams.

Liquid chlorine evaporators should be considered where more than four 1-ton containers will be connected to a supply manifold.

10.2.1.3 Chlorine Supply

a. Cylinders

Cylinders should be considered where the average daily chlorine use is 150 pounds or less. Cylinders are available in 100-pound or 150-pound sizes.

b. Containers

The use of 1-ton containers should be considered where the average daily chlorine consumption is over 150 pounds.

c. Large-Volume Shipments

At large installations, consideration should be given to the use of truck or railroad tank cars, or possibly barge tank loads, generally accompanied by gas evaporators.

10.2.1.4 Chlorine Gas Withdrawal Rates

The maximum withdrawal rate for 100- and 150- pound cylinders should be limited to 40 pounds per day per cylinder.

When gas is withdrawn from 2,000-pound containers, the withdrawal rate should be limited to 400 pounds per day per container.

10.2.2 Design Considerations

10.2.2.1 General

Chlorination system designs should consider the following design factors:

Flow

Contact time

Concentration and type of chlorine residual

Mixing

pH

Suspended solids

Industrial wastes

Temperature

Concentration of organisms

Ammonia concentration

10.2.2.2 Capacity

Required chlorinator capacities will vary, depending on the use and point of application of the chlorine. Chlorine dosage should be established for each individual situation, with those variables affecting the chlorine reaction taken into consideration. For normal wastewater, the following dosing capacity may be used as a guideline.

Type of Treatment	**Dosage Capacity* (mg/l)**
Prechlorination for Odor Control	20-25
Activated Sludge Return	5-10
Trickling Filter Plant Effluent (non-nitrified)	3-15
Activated Sludge Plant Effluent (non-nitrified)	2-8
Tertiary Filtration Effluent	1-6
Nitrified Effluent	2-6
Stabilization Pond Effluent	Up to 35

*** Based on Average Design Flow.**

The design should provide adequate flexibility in the chlorination equipment and control system to allow controlled chlorination at minimum and peak flows over the entire life of the treatment plant. Special consideration should be given to the chlorination requirements during the first years of operation to ensure the chlorination system is readily operable at less than design flows without overchlorination. Chlorination equipment should operate between 25% and 75% of total operating range, to allow for adjusting flexibility at design average flow.

10.2.2.3 Mixing

The mixing of chlorine and wastewater can be accomplished by hydraulic or mechanical mixing.

Hydraulic mixing is preferred in smaller plants over mechanical mixing and should be done according to the following criteria.

a. Pipe Flow:

A Reynolds Number of greater than or equal to 1.9×10^4 is required.

Pipes up to 30 inches in diameter: chlorine injected into center of pipe.

Pipes greater than 30 inches in diameter: chlorine injected with a grid-type diffuser.

Chlorine applied at least 10 pipe diameters upstream from inlet to contact tank.

b. Open channel flow:

A hydraulic jump with a minimum Froude Number of 4.5 is necessary to provide adequate hydraulic mixing. Point of chlorine injection must be variable because jump location will change with changes in flow.

When mechanical mixing must be used, the following criteria apply:

Use where Reynolds Number for pipe flow is less than 1.9×10^4 or for open channel flow without a hydraulic jump.

A mixer-reactor unit is necessary that provides 6 to 18 seconds contact.

Inject chlorine just upstream from mixer.

Mixer speed a minimum of 50 revolutions per minute (rpm).

Jet Chlorinators may be used in a separate chamber from the contact chamber.

The contact chamber shall conform to Section 10.2.2.4 with an average design flow minimum detention time reduced to 15 minutes and a peak detention time of 7.5 minutes.

10.2.2.4 Contact Period

Contact chambers shall be sized to provide a minimum of 30 minutes detention at average design flow and 15 minutes detention at daily peak design flow, whichever is greater. Contact chambers should be designed so detention times are less than 2 hours for initial flows.

10.2.2.5 Contact Chambers

The contact chambers should be baffled to minimize short-circuiting and backmixing of the chlorinated wastewater to such an extent that plug flow is approached. It is recommended that baffles be constructed parallel to the longitudinal axis of the chamber with a minimum length-to-width ratio of 30:1 (the total length of the channel created by the baffles should be 30 times the distance between the baffles). Shallow unidirectional contact chambers should also have cross-baffles to reduce short-circuiting caused by wind currents.

Provision shall be made for removal of floating and settleable solids from chlorine contact tanks or basins without discharging inadequately disinfected effluent. To accomplish continuous disinfection, the chlorine contact tank should be designed with duplicate compartments to permit draining and cleaning of individual compartments. A sump or drain within each compartment, with the drainage flowing to a raw sewage inlet, shall be provided for dewatering, sludge accumulation, and maintenance. Unit drains shall not discharge into the outfall pipeline. Baffles shall be provided to prevent the discharge of floating material.

A readily accessible sampling point shall be provided at the outlet end of the contact chamber.

In some instances, the effluent line may be used as chlorine contact chambers provided that the conditions set forth above are met.

10.2.2.6 Dechlorination

a. Sulfur Dioxide

Sulfur dioxide can be purchased, handled, and applied to wastewater in the same way as chlorine. Sulfur dioxide gas forms sulfurous acid, a strong reducing agent, when combined with water. When mixed with free and combined chlorine residuals, sulfurous acid will neutralize these active chlorine compounds to the nontoxic chloride ion.
Sulfur dioxide dosage required for dechlorination is 1 mg/l of SO_2 for 1 mg/l of chlorine residual expressed as Cl_2. Reaction time is essentially

instantaneous. Detention time requirements are based on the time necessary to assure complete mixing of the sulfur dioxide.

b. Other Methods

For very small treatment systems, detention ponds should be considered for dechlorination.

Design rationale and calculations shall be submitted upon request to justify the basis of design for all major components of other dechlorination processes.

10.2.2.7 Sampling, Instrumentation, and Control

For treatment facility designs of 0.5 mgd and greater, continuously modulated dosage control systems should be used. The control system should adjust the chlorine dosage rate to accommodate fluctuations in effluent chlorine demand and residual caused by changes in waste flow and waste characteristics with a maximum lag time of five minutes. These facilities should also utilize continuous chlorine residual monitoring.

Flow proportional control is preferred over manual control for smaller facilities and may be required on a case-by-case basis. The design shall shut off the chlorination for small systems where the flow is zero, such as late at night.

In all cases where dechlorination is required, a compound loop control system or equivalent should be provided.

All sample lines should be designed so that they can be easily purged of slimes and other debris and drain or be protected from freezing.

Alarms and monitoring equipment that adequately alert the operators in the event of deficiencies, malfunctions, or hazardous situations related to chlorine supply metering equipment, leaks, and residuals may be required on a case-by-case basis.

Design of instrumentation and control equipment should allow operation at initial and design flows.

10.2.2.8 Residual Chlorine Testing

Equipment should be provided for measuring chlorine residual. There are five EPA accepted methods for analysis of total residual chlorine and they are:

1) Ion Selective Electrode,
2) Amperometric End Point Titration Method,
3) Iodometric Titration Methods I & II,
4) DPD Colormetric Method and,
5) DPD Ferrous Titrimetric Method.

Where the discharge occurs in critical areas, the installation of facilities for continuous automatic chlorine residual analysis and recording systems may be required.

10.2.3 Design Details

10.2.3.1 Housing

a. General

An enclosed structure shall be provided for the chlorination equipment.

Chlorine cylinder or container storage area shall be shaded from direct sunlight.

Chlorination systems should be protected from fire hazards, and water should be available for cooling cylinders or containers in case of fire.

Any building which will house chlorine equipment or containers should be designed and constructed to protect all elements of the chlorine system from fire hazards. If flammable materials are stored or processed in the same building with chlorination equipment (other than that utilizing hypochlorite solutions), a firewall should be erected to separate the two areas.

If gas chlorination equipment and chlorine cylinders or containers are to be in a building used for other purposes, a gastight partition shall separate this room from any other portion of the building. Doors to this room shall open only to the outside of the building and shall be equipped with panic hardware. Such rooms should be at or above ground level and should permit easy access to all equipment.

A reinforced glass, gastight window shall be installed in an exterior door or interior wall of the chlorinator room to permit the chlorinator to be viewed without entering the room.

Adequate room must be provided for easy access to all equipment for maintenance and repair. The minimum acceptable clearance around and in back of equipment is 2 feet, except for units designed for wall or cylinder mounting.

b. Heat

Chlorinator rooms should have a means of heating and controlling the room air temperature above a minimum of 55° F. A temperature of 65° F is recommended.

The room housing chlorine cylinders or containers in use should be maintained at a temperature less than the chlorinator room, but in no case less than 55° F unless evaporators are used and liquid chlorine is withdrawn.

All rooms containing chlorine should also be protected from excess heat.

The room containing ozone generation units shall be maintained above 35°F at all times.

c. Ventilation

All chlorine feed rooms and rooms where chlorine is stored should be force-ventilated, providing one air change per minute, except "package" buildings with less than 16 square feet of floor space, where an entire side opens as a door and sufficient cross-ventilation is provided by a window. For ozonation systems, continuous ventilation to provide at least 6 complete air changes per hour should be installed. The entrance to the air exhaust duct from the room should be near the floor and the point of discharge should be so located as not to contaminate the air inlet to any building or inhabited areas. The air inlet should be located to provide cross-ventilation by air at a temperature that will not adversely affect the chlorination equipment.

Chlorinators and some accessories require individual vents to a safe outside area. The vent should terminate not more than 25 feet above the chlorinator or accessory and have a slight downward slope from the highest point. The outside end of the vent should bend down to preclude water entering the vent and be covered with a screen to exclude insects.

d. Electrical

Electrical controls for lights and the ventilation system should operate automatically when the entrance doors are opened. Manually controlled override switches should be located adjacent to and outside of all entrance doors, with an indicator light at each entrance. Electrical controls should be excluded, insofar as possible, from rooms containing chlorine cylinders, chlorine piping, or chlorination equipment.

e. Dechlorination equipment (SO2) shall not be placed in the same room as the Cl2 equipment. SO2 equipment is to be located such that the safety requirements of handling Cl2 are not violated in any form or manner.

10.2.3.2 Piping and Connections

a. Dry Chlorine

Piping systems should be as simple as possible, with a minimum number of joints; piping should be well supported, adequately sloped to allow drainage, protected from mechanical damage, and protected against temperature extremes.

The piping system to handle gas under pressure should be constructed of Schedule 80 black seamless steel pipe with 2,000-pound forged steel fittings. Unions should be ammonia type with lead gaskets. All valves should be Chlorine Institute-approved. Gauges should be equipped with a silver protector diaphragm.

Piping can be assembled by either welded or threaded connections. All threaded pipe must be cleaned with solvent, preferably trichlorethylene, and dried with nitrogen gas or dry air. Teflon tape should be used for thread lubricant in lieu of pipe dope.

b. Injector Vacuum Line

The injector vacuum line between the chlorinator and the injector should be Schedule 80 PVC or fiber cast pipe approved for moist chlorine use.

c. Chlorine Solution

The chlorine solution lines can be Schedule 40 or 80 PVC, rubber-lined steel, saran-lined steel, or fiber cast pipe approved for moist chlorine use. Valves should be PVC, PVC-lined, or rubber- lined.

10.2.3.3 Water Supply

An ample supply of water shall be available for operating the chlorinator. Where a booster pump is required, duplicate equipment shall be provided, and, when necessary, standby power as well. When connection is made from domestic water supplies, equipment for backflow prevention shall be provided. Where treated effluent is used, a wye strainer shall be required. Pressure gauges should be provided on chlorinator water supply lines.

10.2.3.4 Standby Equipment and Spare Parts

Standby chlorination capabilities should be provided which will ensure adequate disinfection with any unit out of operation for maintenance or repairs. An adequate inventory of parts subject to wear and breakage should be maintained at all times.

10.2.3.5 Scales

Scales shall be provided at all plants using chlorine gas. At large plants, scales of the indicating and recording type are recommended. Scales shall be provided for each cylinder or container in service; one scale is adequate for a group of cylinders or containers connected to a common manifold. Scales should be constructed of or coated with corrosion-resistant material. Scales shall be recommended for day tanks when using HTH.

10.2.3.6 Handling Equipment

Handling equipment should be provided as follows for 100- and 150-pound cylinders:

A hand truck specifically designed for cylinders

A method of securing cylinders to prevent them from falling over

Handling equipment should be provided as follows for 2,000-pound containers:

Two-ton-capacity hoist

Cylinder lifting bar

Monorail or hoist with sufficient lifting height to pass one cylinder over another cylinder trunnions to allow rotating the cylinders for proper connection.

10.2.3.7 Container Space

Sufficient space should be provided in the supply area for at least one spare cylinder or container for each one in service.

10.2.3.8 Automatic Switchover of Cylinders and Containers

Automatic switchover of chlorine cylinders and containers at facilities having less than continuous operator attendance is desirable and will be required on a case-by-case basis.

10.2.4 Safety

10.2.4.1 Leak Detection and Controls

A bottle of 56% ammonium hydroxide solution shall be available for detecting chlorine leaks.

All installations utilizing 2,000-pound containers and having less than continuous operator attendance shall have suitable continuous chlorine leak detectors. Continuous chlorine leak detectors would be desirable at all installations. Whenever chlorine leak detectors are installed, they should be connected to a centrally located alarm system and shall automatically start exhaust fans.

10.2.4.2 Breathing Apparatus

At least one gas mask in good operating condition and of a type approved by the National Institute for Occupational Safety and Health (NIOSH) as suitable for high concentrations of chlorine gas shall be available at all installations where chlorine gas is handled and shall be stored outside of any room where chlorine is used or stored. Instructions for using, testing, and replacing mask parts, including canisters, shall be posted. At large installations, where 1-ton containers are used, self- contained air breathing apparatus of the positive pressure type shall be provided.

10.2.4.3 Container Repair Kits

All installations utilizing 1-ton containers should have Chlorine Institute Emergency Container Kits. Other installations using cylinders should have access to kits stored at a central location.

10.2.4.4 Piping Color Codes

It is desirable to color code all piping related to chlorine systems.

10.3 Alternate Methods

10.3.1 Ozonation

10.3.1.1 Application

Ozonation may be substituted for chlorination whenever chlorine availability, cost, or environmental benefits justify its application.

Ozone is generated on-site from either air or high-purity oxygen. Ozonation should be considered if high-purity oxygen is available at the plant for other processes.

10.3.1.2 Design Basis

The design requirements for ozonation systems should be based on pilot testing or similar full-scale installations.

As a minimum, the following design factors should be considered:

a. Ozone dosage

b. Dispersion and mixing of ozone in wastewater

c. Contactor design

All design criteria shall be submitted upon request to justify the basis of design of the ozonation system. The detailed design requirements will be determined on a case-by-case basis.

10.3.2 Ultraviolet Disinfection

10.3.2.1 Application

UV disinfection may be substituted for chlorination, particularly whenever chlorine availability, cost, or environmental benefits justify its application. For tertiary treatment plants where dechlorination is required or chlorine toxicity is suspected, UV disinfection is a viable alternative.

10.3.2.2 Design Basis

In the design of UV disinfection units there are three basic areas that should be considered:

a. Reactor hydraulics

b. Factors affecting transmission of UV light to the microorganisms

c. Properties of the wastewater being disinfected.

UV disinfection is considered as Developmental Technology and all design criteria shall be submitted upon request to justify the basis of the UV disinfection system. The detailed design requirements will be determined on a case-by-case basis.

CHAPTER 11

Tertiary Treatment/Advanced Wastewater Treatment

TERTIARY TREATMENT/ADVANCED WASTEWATER TREATMENT

11.1 Filtration

11.1.1 General

Supplementary solids separation, following secondary clarification of wastewater, may be needed either as a final treatment step or prior to discharging to an ion exchange bed, carbon bed, reverse osmosis or other system. Filtration should be accomplished through a filter consisting of sand; sand and anthracite; anthracite; or anthracite, sand and garnet (or ilmenite).

11.1.2 High Rate Gravity Filters

11.1.2.1 Design

A minimum wastewater depth of 3 feet, measured from the normal operating wastewater surface to the surface of the filter medium, shall be provided. Even distribution of the wastewater over the filter area shall be provided. The top filter material shall not be displaced by the influent wastewater. The bottom washwater trough elevation shall be above the maximum level of expanded medium during backwashing. A top washwater trough elevation shall be no more than 30 inches above the filter surface. Spacing of the troughs shall be such that horizontal partical travel distance is not greater than 3 feet, and equal spacing between troughs is provided so that the same number of square feet of filter area is served by each trough.

For High Rate Filtration, dual or multi-media only shall be used. The maximum filter rate shall be 4 gpm/ft^2 immediately after backwash with a nominal rate of less than 4 gpm/ft^2 at the peak daily flow. A minimum of two filters shall be provided. Filtration shall be designed so that, with one filter out of service, each of the remaining filter(s) shall filter no greater than 4 gpm/ft^2 at the design peak daily flow. Equipment for the application of filter aids to the filter influent should be provided.

11.1.2.2 Medium

a. Sand - The medium shall be clean silica sand having

1. a depth of 30 inches;
2. an effective size of from 0.35 mm to 0.55 mm, depending upon the loading of the wastewater, and;
3. a uniformity coefficient not greater than 1.70.

b. Anthracite - a combination of sand and clean crushed anthracite may be used. The anthracite shall have:

1. an effective size of 0.8 mm - 1.2 mm, and;

2. a uniformity coefficient not greater than 1.85;

3. anthracite layer shall not exceed 20 inches in a 30-inch bed.

c. A 3-inch layer of torpedo sand may be used as a supporting medium for the filter sand; such torpedo sand shall have:

1. an effective size of 0.8 mm to 2.0 mm, and,

2. a uniformity coefficient not greater than 1.70.

d. Gravel - Gravel, when used as the supporting medium, shall consist of hard, rounded silicious particles.

1. The minimum gravel size of the bottom layer should be 3/4 inch or larger.

2. For proper grading of intermediate layers:

   (i) the minimum particle size of any layer should be as large as the maximum particle size in the layer next above and;

   (ii) within any layer the maximum particle size should not be more than twice the minimum particle size.

3. The depth of any gravel layer should not be less than 2 inches or less than twice the largest gravel size for that layer, whichever is greater. The bottom layer should be thick enough to cover underdrain laterals, strainers, or other irregularities in the filter bottom.

4. The total depth of gravel above the underdrains should not be less than 10 inches.

(Reduction of gravel depths may be considered upon justification when proprietary filter bottoms are installed.)

e. Multi-media - To be approved on a case-by-case basis.

The medium should consist of anthracite, silica sand, and/or other suitable sand. Since filters presently utilizing dual media and mixed media are proprietary in nature, no attempt will be made to set standards for minimum filter media depth, effective size and uniformity coefficient of filter media, or the specific gravity of that medium.

11.1.2.3 Underdrains.

Porous-plate bottoms shall not be used. Perforated pipe underdrains should be used, consisting of a manifold and laterals. Underdrain systems allowable in water plants such as Leopold or Wheeler bottoms are acceptable. The orifice loss in backwashing must exceed the sum of the minor hydraulic losses in the underdrain system to secure good distribution of flow over the entire area of the filter bottom. In order to insure adequate design of perforated pipe underdrain systems the following ratios must fall within the ranges shown:

$$\frac{\textbf{orifice area}}{\textbf{bed area}} = \frac{0.0015}{1} \text{ to } \frac{0.005}{1}$$

$$\frac{\textbf{lateral area}}{\textbf{area of orifices served}} = \frac{2}{1} \text{ to } \frac{4}{1}$$

$$\frac{\textbf{manifold area}}{\textbf{area of laterals served}} = \frac{1.5}{1} \text{ to } \frac{3}{1}$$

Orifices should have 3 to 12 inch spacing, and laterals the same. Underdrains should be made of corrosion and scale resistant materials, or properly protected against corrosion.

Orifices through false filter bottoms or underdrain design are preferred. The glazed tile filter block used in some filter bottoms and the stainless steel modulars used in other filter bottom designs are recommended to provide even and uniform distribution of backwash water. Hydraulic distribution data on each standard filter size should be submitted.

11.1.2.4 Backwash

Provisions shall be made for washing filters as follows:

a. a rate to provide for a 50 percent expansion of the medium is recommended, consistent with water temperatures and specific gravity of the filter medium; a minimum rate of 15 gpm/ft^2 is recommended, however 20 gpm/ft^2 may be required for adequate expansion of the filter medium.

b. filtered wastewater provided at the required backwash rate by washwater tanks, a washwater pump(s) or a combination of these is required,

c. washwater pumps in duplicate unless an alternate means of obtaining washwater is available; air release must be provided;

d. washwater supply to backwash two filters for at least 5 minutes at the design rate of wash; plus surface wash requirements;

e. A washwater regulator or valve on the main washwater line to obtain the desired rate of filter wash with the washwater valves on the individual filters completely open is required.

f. Air scouring at 3-5 cu ft/min/ft^2 of filter area for at least 3 minutes preceding water backwash is acceptable.

g. Rate of flow indicators on the main washwater line shall be provided and should be located so that it can be easily read by the operator during backwash.

h. Backwash wastewater treatment and disposal must be accomplished within the rated design capacities of the treatment system. Backwash wastewater cannot be discharged to a stream without first receiving adequate treatment. If it is desired to recycle the backwash wastewater through a secondary system, then the hydraulic design of the entire system (including the clarifier and filter) must be based on the anticipated rate of raw influent flow plus the flow rate at which the backwash water enters the system. In most systems a backwash water holding tank and controlled discharge system will be required. This holding system must be capable of storing the wastes from two backwashes and discharging the wastes to the treatment system within 24 hours at a rate which, in combination with the raw influent, does not exceed the hydraulic design of any system component when the loading period for the plant is 24 hours. For plants with loading periods less than 24 hours, additional backwash holding capacity may

be required. For example, a school's sewage treatment plant with an 8-hour loading period and a backwash holding system which pumps from its holding tank to the head of the treatment process only during low loading periods may require a holding tank with a capacity for three or more backwash volumes.

i. Backwash may be initiated either automatically or manually; the length of the backwash period must be automatically controlled by a timing device adjustable in one minute increments up to a possible 15 minute backwash duration.

11.1.2.5 Surface Wash

Surface wash facilities are required. Disinfected filtered wastewater effluent should be used for surface wash. Revolving-type surface washers should be provided; however, other types may be considered. All rotary surface wash devices should be designed with:

a. Provisions for minimum washwater pressures of 40 psi and;

b. Provisions for adequate surface washwater to provide 0.5 to 1 gallon per minute per square foot of filter area.

11.1.3 Pressure and Vacuum High Rate Filters

11.1.3.1 General

Pressure sand filters are those operating under pressure in a closed container. Generally, a pump discharge line delivers the influent to the pressure filter. Vacuum sand filters are those operating under partial vacuum within the underdrain system; they can have open beds. Generally, a pump suction line is connected to the underdrain of a vacuum sand filter.

11.1.3.2 Design

Design requirements for pressure or vacuum filters include all of those listed for High Rate Gravity Filters in paragraphs 11.1.2.1 through 11.1.2.5, plus the following; Pressure filter containers must meet all applicable safety codes and requirements. Containers must be large enough to permit a man to work inside for medium removal and underdrain maintenance. A minimum diameter of 3 feet is suggested. An access port must be provided for inspection and maintenance purposes.

11.1.4 Standard Rate Gravity Filters

11.1.4.1 General

A minimum of two complete units is required. Each unit must be designed to treat 100 percent of plant flow except where design flow is 100,000 gpd or greater (see Design Section 11.1.4.2). The sand surface must be submerged at all times. Generally, standard rate filters are monomedium sand filters (see Media Section 11.1.4.3).

11.1.4.2 Design

The hydraulic design loading for each filter must be within the range of 1.0 to 2.0 gpm/ft^2. For installation less than 100,000 gpd the nominal filter rate shall be 1.0 gpm/ft^2 with one cell loaded no more than 2.0 gpm/ft^2 during backwash of the other cell. For installations greater than 100,000 gpd it is expected that each filter cell will be loaded at 2 gpm/ft^2 and during periods of backwash; no other cell may be loaded higher than 4 gpm/ft^2. Even distribution of the wastewater over the filter shall be provided. The filter sand shall not be displaced by the influent wastewater. The bottom washwater trough elevation shall be above the maximum level of expanded medium during backwash. A top washwater trough elevation shall be no more than 30 inches above the filter surface. Spacing of the troughs shall be such that horizontal partical travel distance is not greater than 3 feet, and equal spacing between troughs is provided so that the same number of square feet of filter area is served by each trough.

11.1.4.3 Medium

The filter medium should have the following properties:

a. Sand

A sieve analysis should be provided by the design engineer. The medium should be clean silica sand having (1) a depth of not less than 27 inches and generally not more than 30 inches after cleaning and scraping and (2) an effective size of 0.35 mm to 0.5 mm, depending upon the quality of the applied wastewater, and a uniformity coefficient not greater than 1.6.

Clean crushed anthracite or a combination of sand and anthracite may be used. Such media should have (1) an effective size from 0.45 mm to 0.8 mm and (2) a uniformity coefficient not greater than 1.7.

b. Supporting medium for the filter sand

A sieve analysis should be provided by the design engineer. A 3-inch layer of torpedo sand should be used as the supporting medium for the filter sand. Such torpedo sand should have (1) an effective size of 0.8 mm to 2.0 mm and (2) a uniformity coefficient not greater than 1.7.

c. Gravel

Gravel when used as a supporting medium should consist of hard, rounded particles and should not include flat or elongated particles. The coarsest gravel should be 2 1/2 inches in diameter when the gravel rests directly on the strainer system and should extend above the top of the perforated laterals or strainer nozzles. Not less than four layers of gravel should be used.

11.1.4.4 Underdrains

All requirements of Section 11.1.2.3 apply.

11.1.4.5 Backwash

All requirements of Section 11.1.2.4 apply with the additional consideration:

There shall be the capability to backwash at a rate of 20 gpm/ft^2 for adequate expansion of the filter medium.

11.1.4.6 Surface Wash

All requirements of Section 11.1.2.5 apply.

11.1.5 Shallow Bed Filters (Slow Sand Filters)

These filters are normally used at small treatment facilities and will be reviewed on a case-by-case basis.

11.1.6 Operability

11.1.6.1 The clear well must be protected to keep unfiltered effluent from entering the clear well in the event that some accident or malfunction causes a filter to overflow.

11.1.6.2 It is suggested that a supplementary clean water source, such as a high volume hydrant (protected by a back-flow prevention device) be available for filling the clear well.

11.1.6.3 Any wastewater treatment facility that has a flow peaking factor equal to or greater than 1.5 shall have an equalization/surge tank to control filtration rate. The size of the equalization/surge tank must be determined on the basis of rate and duration of peak flows including the recirculated backwash water. For systems with a flow peaking factor less than 1.5, the rate of filtration may be accomplished by valves in such a way that will not cause water to surge through the filter at rates higher than design. Position indicators must be provided for automatic valves. Pressure or head loss gages must be provided on the influent and effluent side of each filter. Micro switches will also be acceptable. On larger installations (75,000 gpd or greater) a rate of flow indicator will be required. Rapid variations of filtration rate are undesirable as they may cause dislodging of deposited matter and subsequent deterioration of effluent quality.

11.1.6.4 A by-pass around the filters must be provided and controlled by an easily accessible valve with markings for open or closed positions.

11.1.6.5 The capability to disinfect both prior to and after the filters shall be provided.

11.1.6.6 Vertical walls within the filter are required unless otherwise approved.

11.1.6.7 There shall be no protrusion of the filter walls into the filter medium.

11.1.6.8 Sufficient head room shall be provided when filters are indoors to permit normal inspection and operation.

11.1.6.9 The minimum depth of filter shall be 8 feet.

11.1.6.10 Trapped effluent to prevent backflow of air to the bottom of the filters is required.

11.1.6.11 Washwater drain capacity shall be designed to carry maximum flow.

11.1.6.12 Walkways around filters, not less than 24 inches wide, shall be provided where the installation is above ground level.

11.1.6.13 When backwash is automatically controlled, the backwash rate shall increase gradually or "step up" in a manner so to not displace the media or "blow" the filter bottom with a sudden surge.

11.2 Post Aeration

11.2.1 General

Post aeration is used to maintain a required minimum dissolved oxygen residual in treated wastewater effluent. Post aeration is often needed following a dechlorination process where an oxygen depleting chemical such as sulfur dioxide is used.

11.2.2 Aeration Tank Systems

Design consists of determining the oxygen requirements and providing sufficient oxygen transfer capability to satisfy these requirements. The design should consider the quantity of oxygen to satisfy the oxygen deficit required to meet the receiving water standards plus the oxygen-utilization rate of the effluent wastewater. Design of the oxygen transfer equipment in an aeration tank stage should be based on the final dissolved oxygen leaving that aeration tank stage. Design of aeration tanks and equipment should conform to the pertinent requirements of Chapter 7, "Activated Sludge."

Calculations shall be submitted to justify the basis of design.

Aeration equipment may be any of the following:

1. Fine-bubble diffused air
2. High or Low speed surface aerators
3. Submerged turbine
4. High-purity oxygen

Other types will be considered based on performance and design data submitted with the request.

11.2.3 Cascade Systems

Cascade aeration consists of a series of steps or weirs over which the wastewater is passed in thin layers to maximize turbulence and promote transfer of atmospheric oxygen.
The engineer shall demonstrate that the design will meet the receiving water standards either by use of data from the literature or pilot testing. Calculations shall be submitted to justify the basis of design.

11.2.4 Operability

11.2.4.1 The design should incorporate provisions for the control of foam.

11.2.4.2 A series of basins may improve transfer efficiency and also reduce total horsepower required as opposed to one large basin.

11.2.4.3 Baffles should be used with mechanical aerators to prevent vortexing.

11.3 Nutrient Removal

Nutrient removal, either supplementary or incorporated within standard secondary treatment facilities may be required in areas where receiving waters are greatly used and re-used or where highly restrictive use classifications have been established. For organization purposes, a very broad definition of "nutrients" shall be adopted herein to include refractory organics, nitrogen, phosphorus and inorganic salts. Sufficient operating data and information are not available to permit the establishment of detailed criteria outlining the proper application of the various available processes and operations to a specific treatment situation. Until sufficient operating data are obtained, the development and design of nutrient removal processes must be based upon the best obtainable pilot plant data (developed by the application of standard processes and operations to the specific waste treatment problem on a small scale basis). In order for approval of any type of supplementary nutrient removal system, sufficient pilot plant operating data must be made available to allow an evaluation of the adequacy and efficacy of the proposed process. No process will be approved unless adequate provisions are made for the ultimate disposal of concentrated pollutants "created" by the process (such as spent ion exchange regenerants, concentrated brines from reverse osmosis and electrodialysis systems, contaminated sorption media, chemical sludges and so forth).

CHAPTER 12

Sludge Processing and Disposal

SLUDGE PROCESSING AND DISPOSAL

12.1 General

12.1.1 Definition

Sludge is a broad term used to describe the various aqueous suspensions of solids encountered during treatment of sewage. The nature and concentration of the solids control the processing characteristics of the sludge. Grit screenings and scum are not normally considered as sludge and therefore are not discussed in this section.

12.1.2 Total Systems Approach to Design

The most frequently encountered problem in wastewater treatment plant design is the tendancy to optimize a given subsystem, such as sludge dewatering, without considering the side effects of this optimization on the overall plant operation and treatment costs.

Sludge handling processes can be classified as thickening, conditioning, stabilization, dewatering, and disposal. Numerous process alternatives exist within each of these categories. Each unit process should be evaluated as part of the total system, keeping in mind that the objective is to use that group of processes that provides the most cost-effective method of sludge disposal.

The analysis should include a materials balance to identify the amounts of material which enter, leave, accumulate, or are depleted in the given process and the system as a whole. Energy requirements should also be provided to aid in determining capital and operating costs of the total system.

12.1.3 Recycle Streams

Recycle streams from the process alternatives, including thickener overflow, centrate, filtrate, and supernatant, should be returned to the sewage treatment process at appropriate points to maintain effluent quality within the limits established. Volume and strength of each recycle stream should be considered in the plant design. Sidestream treatment should be provided if the load is not included in the plant design or if the side stream will upset the treatment process. Equalization of side streams should be considered to reduce instantaneous loading on the treatment process.

12.1.4 Multiple Units

Multiple units and/or storage facilities should be provided so that individual units may be taken out of service without unduly interrupting plant operation.

12.1.5 Sludge Pumps

12.1.5.1 Capacity

Pump capacities should be adequate to maintain pipeline velocities of 3 feet per second. Provisions for varying pump capacity are desirable.

12.1.5.2 Duplicate Units

Duplicate units shall be provided where failure of one unit would seriously hamper plant operation.

12.1.5.3 Type

Plunger pumps, progressing cavity pumps, or other types of pumps with demonstrated solids handling capability should be provided for handling raw sludge.

12.1.5.4 Minimum Head

A minimum positive head of 24 inches (or the manufacturer's recommendation) should be provided at the suction side of centrifugal-type pumps and is desirable for all types of sludge pumps. Maximum suction lifts should not exceed 10 feet (or the manufacturer's recommendation) for plunger pumps.

12.1.5.5 Sampling Facilities

Unless sludge sampling facilities are otherwise provided, quick-closing sampling valves should be installed at the sludge pumps. The size of valve and piping should be at least 1-1/2 inches.

12.1.6 Sludge Piping

12.1.6.1 Size and Head

Sludge withdrawal piping shall have a minimum diameter of 8 inches for gravity withdrawal and 6 inches for pump suction and discharge lines. Where withdrawal is by gravity, the available head on the discharge pipe should be at least 2 feet and preferably more, with provisions to backflush the line.

12.1.6.2 Slope

Gravity piping shall be laid on uniform grade and alignment. Slope on gravity discharge piping should not be less than 3 percent.

12.1.6.3 Cleaning

Provision should be made for draining and flushing suction and discharge lines. Where sludge pumps are available, piping should be such that suction lines can be backflushed with pump discharge or rodded. Glass-lined or equivalent pipe should be considered for raw sludge piping and scum lines.

12.1.6.4 Corrosion Resistance

Special consideration shall be given to the corrosion resistance and continuing stability of pipes and supports located inside digestion tanks.

12.2 Sludge Production

The sludge production rates listed in the literature have often been shown to be underestimated. The sludge production rates (SPR) listed below in Table 12-1 have been determined from various studies and provide a more realistic basis for designing solids handling facilities. These values shall be used for design unless other acceptable data is submitted.

Table 12-1
Sludge Production Rates

Type of Treatment	**SPR (lb sludge) / (lb BOD removed)**
Conventional Activated Sludge	**0.85**
Extended Aeration	**0.75**
Contact Stabilization	**1.00**
Other Activated Sludge	**0.85**
Trickling Filter	**0.75**
Roughing Filters	**1.00**

12.3 Thickening

12.3.1 General

The cost-effectiveness of sludge thickening should be considered prior to treatment and/or disposal.

12.3.1.1 Capacity

Thickener design should provide adequate capacity to meet peak demands.

12.3.1.2 Septicity

Thickener design should provide means to prevent septicity during the thickening process. Odor consideration should be considered.

12.3.1.3 Continuous Return

Thickeners should be provided with a means of continuous return of supernatant for treatment. Provisions for side-stream treatment of supernatant may be required.

12.3.1.4 Chemical Addition

Consideration should be given to the use of chemicals or polymer to improve solids capture in the thickening process. This will not normally increase the solids level of the thickened sludge.

12.3.2 Gravity Thickeners

12.3.2.1 Stirring and skimming

Mechanical thickeners should employ pickets on rake arms for continuous gentle stirring of the sludge. Skimmers should be considered for use with biological sludges.

12.3.2.2 Depth and Freeboard

Tank depth shall be sufficient so that solids will be retained for a period of time needed to thicken the sludge to the required concentration and to provide storage for fluctuations in solids loading rates.
The thickener should be operated to avoid denitrification. At least two feet of freeboard shall be provided above the maximum water level.

12.3.2.3 Continuous Thickening

Variable-speed sludge draw-off pumps may be provided so that thickening can be continuous, or an adjustable on-off time clock control for pulse withdrawal may be used with constant-speed pumps to improve control over the thickening.

12.3.2.4 Solids and Surface Loading Rates

The engineer shall provide the design basis and calculations for the solids and surface loading rates and the support calculations upon request. Thickener solids loading rates vary with the type of sludge. Some typical solids loading rates are given below in Table 12-2. These values shall be used for design unless other acceptable data are submitted. For loading rates of other type sludges, refer to Table 5.2 of the EPA Process Design Manual-Sludge Treatment and Disposal.

Table 12-2
Solids Loading Rate

Type of Sludge	**(lb/day/sq ft)**
Primary	20-30
Activated sludge	5-6
Trickling filter	8-10
Primary and activated combined	6-10
Primary and trickling filter combined	10-12

Surface loading rates of 400 gallons per day per square foot (gpd/sq ft) or less will normally result in septic conditions. To prevent septic conditions, surface overflow rates should be maintained between 500 and 800 gpd/sq ft. For very thin mixtures or WAS only, hydraulic loading rates of 100-200 gpd/sq ft are appropriate. An oxygen-rich water source, such as secondary effluent, shall be available as a supplemental flow to the thickener to achieve the necessary overflow rates.

The diameter of a gravity thickener should not exceed 80 feet.

12.3.2.5 Bottom Slope

Bottom slopes shall be sufficient to keep the sludge moving toward the center well with the aid of a rake. Generally, the slope should be greater than conventional clarifiers. A floor slope of 2-3 inches per foot is recommended.

12.3.3 Flotation Thickeners

Flotation thickeners are normally used to concentrate waste activated sludge.

12.3.3.1 Air-Charged Water

The thickener underflow is generally used as a source of water for the air-charging units, although primary tank effluent or plant effluent may also be used.

12.3.3.2 Design Sizing

The engineer shall provide the design basis for sizing the units and for the support calculation. Design sizing should be based on rational calculations, including: total pounds of waste sludge anticipated, design solids and hydraulic loading of the unit, operating cycle in hours per day per week, removal efficiency, and quantity and type of chemical aids required. Flotation thickeners are normally sized by solids surface loadings.

Typical design loadings range from 1.0 to 2.5 pounds per hour per square foot. (See Table 12-3, for typical solids loading rates to produce a minimum 4% solids concentration.)

12.3.3.3 Hydraulic Loading Rates

If polymers are used, hydraulic loading rates of 2.5 gpm/sq ft or less should be used. The hydraulic loading rates shall be lower if polymers are not used. Hydraulic loading rates shall be based on the total flow (influent plus recycle). The design of any thickened sludge pump from DAF units should be conservative. Frequently, polymer conditioned sludge will result in a solids concentration greater than 4%. Pumps shall be capable of handling a sludge of at least 5% thickness.

TABLE 12-3

TYPICAL DAF THICKENER SOLIDS LOADING RATES NECESSARY TO PRODUCE A MINIMUM 4 PERCENT SOLIDS CONCENTRATION

	Solids loading rate, lb/sq ft/hr	
Type of sludge	No chemical addition	Optimum chemical addition
Primary only	0.83 - 1.25	up to 2.5
Waste activated		
sludge (WAS)		
Air	0.42	up to 2.0
Oxygen	0.6 - 0.8	up to 2.2
Trickling filter	0.6 - 0.8	up to 2.0
Primary + WAS (air)	0.6 - 1.25	up to 2.0
Primary + trickling		
filter	0.83 - 1.25	up to 2.5

12.3.4 Centrifugal Thickeners

12.3.4.1 Pretreatment

Any pretreatment required is in addition of that required for the main wastewater stream. For example, separate and independent grit removal may be needed for the centrifuge feed stream.

Disc nozzle centrifuges require pretreatment of the feed stream. Both screening and grit removal are required to reduce operation and maintenance requirements. Approximately 11% of the feed stream will be rejected in pretreatment, consideration should be given to the treatment of this flow. It is usually routed to the primary clarifier.

Basket centrifuges do not require pretreatment and are recommended in small plants (1.0-2.0 MGD) without primary clarification and grit removal.

Solid bowl decanter centrifuges require grit removal in the feed stream and are a potentially high maintenance item.

12.3.4.2 Chemical Coagulants

Provisions for the addition of coagulants to the sludge should be considered for improving dewatering and solids capture.

12.3.4.3 Design Data

The engineer shall provide the design basis for loading rates and support calculations. Both hydraulic and solids loading rate limitations should be addressed.

12.3.5 Other Thickeners

Other thickner designs will be evaluated on a case-by-case basis. Pilot plant data shall be provided by the design engineer upon request.

12.4 Conditioning

12.4.1 General

Pretreatment of the sludge by chemical or thermal conditioning should be investigated to improve the thickening, dewatering, and/or stabilization characteristics of the sludge.

The effects of conditioning on downstream processes and subsequent side-stream treatment should be evaluated. Thermal conditioning will concentrate the BOD level of the side stream. Its treatment must be considered in calculating organic loadings of other units.

12.4.2 Chemical

Type of chemical, location of injection, and method of mixing should be carefully considered to ensure obtaining anticipated results. Pilot testing is often necessary to determine the best conditioning system for a given sludge.

12.5 Digestion

12.5.1 Anaerobic Digestion

12.5.1.1 General

a. Operability

Anaerobic digestion is a feasible stabilizing method for wastewater sludges that have low concentrations of toxins and a volatile solids content above 50%. It should not be used where wide variations in sludge quantity and quality are common. Anaerobic digestion is a complex process requiring close operator control. The process is very susceptible to upsets as the microorganisms involved are extremely sensitive to changes of their environment. Frequent monitoring of the following parameters is required:

(i) pH (6.4 - 7.5 recommended)

(ii) volatile acids/alkalinity ratio (always 0.5 or greater)

(iii) toxics (volatile acids, heavy metals, light metal cations, oxygen, sulfides, and ammonia)

(iv) temperature (within 1° F of design temperature)

(v) recycle streams (BOD, SS, NH_3, phenols)

The importance of avoiding digester upsets cannot be overlooked. The methane-producer bacteria have a very slow growth rate and it will take two weeks or more to resume normal digester performance.

b. Multiple Units

Multiple units should be provided. Staged digestion design may be used, provided the units can be used in parallel as well as in series. Where multiple units are not provided, a lagoon or storage tanks should be provided for emergency use so that digestion tanks may be taken out of service without unduly interrupting plant operation. Means of returning sludge from the secondary digester unit to the primary digester should be provided. In large treatment plants where digesters are provided, separate digestion of primary sludges should be considered.

c. Depth

The proportion of depth to diameter should provide for the formation of a supernatant liquor with a minimum depth of 6 feet. Sidewall depth is generally about one-half the diameter of the digester for diameters up to 60 feet, and decreases to about one-third the diameter for diameters approaching 100 feet.

d. Maintenance Provisions

To facilitate emptying, cleaning, and maintenance, the following features are required:

(i) Slope

The tank bottom shall slope to drain toward the withdrawal pipe. A slope of between 1 inch per foot and 3 inches per foot is recommended.

(ii) Access Manholes

At least two access manholes should be provided in the top of the tank, in addition to the gas dome. One opening should be large enough to permit the insertion of mechanical equipment to remove scum, grit, and sand. A separate side wall manhole should be provided at ground level.

(iii) Safety

Nonsparking tools, rubber-soled shoes, safety harness, gas detectors for flammable and toxic gasses and the hose type or self-contained type breathing apparatus shall be provided.

e. Pre-thickening of sludge may be advantageous, but the solids content shall be less than 8% to ease mixing problems.

12.5.1.2 Sludge Inlets and Outlets

Multiple sludge inlets and draw-offs and multiple recirculation suction and discharge points should be provided to facilitate flexible operation and effective mixing of the digester contents, unless adequate mixing facilities are provided within the digester. One inlet should discharge above the liquid level and be located at approximately the center of the tank to assist in scum breakup. Raw sludge inlet points should be located to minimize short-circuiting to the supernatant drawoff.

12.5.1.3 Tank Capacity

a. General

Two cultures of bacteria are primarily involved in anaerobic digestion: acid formers and methane formers. Capacity of the digester tank shall be based on the growth rate of the methane-formers, as they have extremely slow growth rates.

b. Solids Basis

Where the composition of the sewage has been established, tank capacity should be computed from the volume and character of sludge to be digested. The total digestion tank capacity should be determined by rational calculations based upon factors such as volume of sludge added, its percent solids and character, volatile solids loading, temperature to be maintained in the digesters, and the degree or extent of mixing to be obtained. These detailed calculations shall be submitted to justify the basis of design.

Where composition of the sewage has not been established, the minimum combined digestion tank capacity outlined below shall be provided. Such requirements assume that the raw sludge is derived from ordinary domestic wastewater, a digestion temperature is maintained in the range of 85° to 100° F, there is 40 to 50 percent volatile matter in the digested sludge, and that the digested sludge will be removed frequently from the process.

(i) Completely Mixed Systems

For heated digestion systems providing for intimate and effective mixing of the digester designed for a constant feed loading rate of 150 to 400 pounds 1,000 cubic feet of volume per day in the active digesting unit. The design average detention time in completely mixed systems shall have sufficient mixing capacity to provide for complete digester turnover every 30 minutes.

(ii) Moderately Mixed Systems

For digestion systems where mixing is accomplished only by circulating external
heat exchanger, the system may be loaded up to 40 pounds of volatile solids per 1,000 cubic feet of volume per day in the active digestion units. This loading may be modified upward or downward, depending upon the degree of mixing provided. Where mixing is accomplished by other methods, loading rates will be determined on the basis of information furnished by the design engineer.

c. Population Basis

Where solids data are not available, the following unit capacities shown in Table 12-4 for conventional, heated tanks shall be used for plants treating domestic sewage.
The capacities should be increased by allowing for the suspended solids population equivalent of any industrial wastes in the sewage. The capacities stated apply where digested sludge is dewatered on sand drying beds and may be reduced if the sludge is dewatered mechanically or otherwise frequently withdrawn.

Table 12-4
Cubic Feet Per Capita

Type of Plant	Moderately Mixed Systems	Completely Mixed Systems
Primary	2 to 3	1.3
Primary and Trickling Filter	4 to 5	2.7 to 3.3
Primary and Activated Sludge	4 to 6	2.7 to 4

For small installations (population 5,000 or less) the larger values should be used.

12.5.1.4 Gas Collection System

a. General

All portions of the gas system, including the space above the tank liquor, storage facilities, and piping shall be so designed that under all normal operating conditions, including sludge withdrawal, the gas will be maintained under positive pressure. All enclosed areas where any gas leakage might occur shall be adequately ventilated.

b. Safety Equipment

All necessary safety facilities shall be included where gas is produced. Pressure and vacuum relief valves and flame traps, together with automatic safety shutoff valves, are essential. Water-seal equipment shall not be installed on gas piping.

c. Gas Piping and Condensate

Gas piping shall be of adequate diameter and shall slope to condensation traps at low points.
The use of float-controlled condensate traps is not permitted. Condensation traps shall be placed in accessible locations for daily servicing and draining. Cast iron, ductile iron, and/or stainless steel piping should be used.

d. Electrical Fixtures and Equipment

Electrical fixtures and equipment in enclosed places where gas may accumulate shall comply with the National Board of Fire Underwriters' specifications for hazardous conditions. Explosion-proof electrical equipment shall be provided in sludge-digestion tank galleries containing digested sludge piping or gas piping and shall be provided in any other hazardous location where gas or digested sludge leakage is possible.

e. Waste Gas

Waste gas burners shall be readily accessible and should be located at least 50 feet away from any plant structure, if placed near ground level, or may be located on the roof of the control building if sufficiently removed from the tank. Waste gas burners shall not be located on top of the digester. The waste gas burner should be sized and designed to ensure complete combustion to eliminate odors.

f. Ventilation and Cover

Any underground enclosures connecting with digestion tanks or containing sludge or gas piping or equipment shall be provided with forced ventilation. Tightly fitting, self-closing doors shall be provided at connecting passageways and tunnels to minimize the spread of gas. A floating cover should be provided instead of a fixed cover for increased operational flexibility and safety.

g. Metering

Gas meters with bypasses should be provided to meter total gas production and utilization.

h. Pressure Indication

Gas piping lines for anaerobic digesters should be equipped with closed-type pressure indicating gauges. These gauges should read directly in inches of water. Normally, three gauges should be provided, one to measure the main line pressure, a second to measure the pressure upstream of gas-utilization equipment, and the third to measure pressure to wasteburners.
Gas-tight shutoff and vent cocks shall be provided. The vent piping shall be extended outside the building, and the opening shall be screened to prevent entrance by insects and turned downward to prevent entrance of rainwater. All piping shall be protected with safety equipment.

i. Gas Utilization Equipment

Gas-burning boilers, engines, and other gas utilization equipment should be located at or above ground level in well-ventilated rooms. Gas lines to these units shall be provided with suitable flame traps.

12.5.1.5 Heating

a. Insulation

Digestion tanks should be constructed above the water table and should be suitably insulated to minimize heat loss.

b. Heating Facilities

Sludge may be heated by circulating the sludge through external heaters or by units located inside the digestion tank.

(i) External Heating

Piping should be designed to provide for the preheating of feed sludge before introduction to the digesters. Provisions should be made in the layout of the piping and valving to facilitate cleaning of these lines.

Heat exchanger sludge piping should be sized for heat transfer requirements.

(ii) Internal Coils

Hot water coils for heating digestion tanks should be at least 2 inches in diameter and the coils, support brackets, and all fastenings should be of corrosion-resistant material. The use of dissimilar metals should be avoided to minimize galvanic action. The high point in the coils should be vented to avoid air lock.

(iii) Other Methods

Other types of heating facilities will be considered on their own merits.

c. Heating Capacity

Sufficient heating capacity shall be provided to consistently maintain the digesting sludge temperature to within 1°F (0.6°C) of the design temperature. An alternate source of fuel should be available and the boiler or other heat source should be capable of using the alternate fuel if digester gas is the primary fuel. Thermal shocks shall be avoided. Sludge storage may be required to accomplish this.

d. Hot Water Internal Heating Controls

(i) Mixing Valves

A suitable automatic mixing valve should be provided to temper the boiler water with return water so that the inlet water to the heat jacket or coils can be held to below a temperature (130° to 150°F) at which sludge caking will be accentuated. Manual control should also be provided by suitable bypass valves.

(ii) Boiler Controls

The boiler should be provided with suitable automatic controls to maintain the boiler temperature at approximately 180°F to minimize corrosion and to shut off the main fuel supply in the event of pilot burner or electrical failure, low boiler water level, or excessive temperature.

(iii) Thermometers

Thermometers shall be provided to show temperatures of the sludge, hot water feed, hot water return, and boiler water.

12.5.1.6 Mixing

Facilities for mixing the digester contents shall be provided where required for proper digestion by reason of loading rates, or other features of the system.

12.5.1.7 Supernatant Withdrawal

a. Piping Size

Supernatant piping should not be less than 6 inches in diameter, although 4-inch lines will be considered in special cases.

b. Withdrawal Arrangements

(i) Withdrawal Levels

Piping should be arranged so that withdrawal can be made from three or more levels in the tank. A positive unvalved vented overflow shall be provided.

(ii) Withdrawal Selection

On fixed-cover tanks the supernatant withdrawal level should preferably be selected by means of interchangeable extensions at the discharge end of the piping.

(iii) Supernatant Selector

If a moveable supernatant selector is provided, provision should be made for at least one other draw-off level located in the supernatant zone of the tank in addition to the unvalved emergency supernatant draw-off pipe. High-pressure backwash facilities should be provided.

(iv) Sampling

Provisions shall be made for sampling at each supernatant draw-off level. Sampling pipes should be at least 1-1/2 inches in diameter.

(v) Supernatant Handling

Problems such as shock organic loads, pH, and high ammonia levels associated with digester supernatant shall be addressed in the plant design. Recycle streams should be bled continuously back to the treatment process.

12.5.2 Aerobic Sludge Digestion

12.5.2.1 Mixing and Aeration

Aerobic sludge digestion tanks shall be designed for effective mixing and aeration. Minimum mixing requirements of 20 cubic feet per minute per 1,000 cubic feet for air systems and 0.5 horsepower per 1,000 cubic feet for mechanical systems are recommended. Aeration requirements may be more or less than the mixing requirements, depending on system design and actual solids loading. Approximately 2.0 pounds of oxygen per pound volatile solids are needed for aeration.

If diffusers are used, types should be provided to minimize clogging and designed to permit removal for inspection, maintenance, and replacement without dewatering the tanks, if only one digester is proposed.

12.5.2.2 Size and Number of Tanks

The size and number of aerobic sludge digestion tank or tanks should be determined by rational calculations based upon such factors as volume of sludge added, its percent solids and character, the degree of volatile solids reduction required and the size of installation with appropriate allowance for sludge and supernatant storage.

Generally, 40 to 50 percent volatile solids destruction is obtained during aerobic digestion. To ensure a stabilized sludge which will not emit odors, the volatile solids content should be less than 60 percent in the digested sludge. Calculations shall be submitted upon request to justify the basis of design. The following design parameter ranges should be considered the minimum in designing aerobic digestion facilities.

a. Hydraulic Detention Time

Hydraulic detention time at 20°C should be in the range of 15 to 25 days, depending upon the type of sludge being digested. Activated sludge alone requires the lower detention time and a combination of primary plus activated or trickling filter sludges requires the high detention time. Detention times should be adjusted for operating temperatures other than 20°C.

b. Volatile Solids

The volatile solids loading shall be in the range of 0.1 to 0.2 pound of volatile solids per cubic foot per day.

c. Dissolved Oxygen

Design dissolved oxygen concentration should be in the range of 1 to 2 mg/l. A minumum of 1.0 mg/l shall be maintained at all times.

d. Mixing Energy

Energy input requirements for mixing should be in the range of 0.5 to 1.5 horsepower per 1,000 cubic feet where mechanical aerators are used; 20 to 35 standard cubic feet of air per minute per 1,000 cubic feet of aeration tank where diffused air mixing is used on activated sludge alone; and greater than 60 cubic feet per minute per 1,000 cubic feet for primary sludge alone and primary plus activated sludge.

e. Storage

Detention time should be increased for temperatures below 20°C. If sludge cannot be withdrawn during certain periods, additional storage capacity should be provided. Plants smaller than 75,000 gpd should have storage capacity of 2 cubic foot per population equivalent served.

12.5.2.3 Supernatant Separation

Facilities should be provided for separation or decantation of supernatant. Provisions for sidestream treatment of supernatant should be considered.

12.6 Composting

Composting operations will be considered on a case-by-case basis, provided that the basis for design and a cost-effective analysis are submitted by the engineer.

12.7 Sludge Dewatering

12.7.1 General

Drainage from drying beds and centrate or filtrate from dewatering units should be returned to the sewage treatment process at appropriate points preceding the secondary process. The return flows shall be returned downstream of the influent sample and/or flow measuring point and a means shall be provided to sample return flows. These organic loads must be considered in plant design.

12.7.2 Sludge Drying Beds

12.7.2.1 Area

It is recommended that wastewater systems have a hybrid sludge disposal method because of the seasonal downtime associated with drying beds. The amount of rainfall
normal for our state makes the use of sludge drying beds insufficient at times.

Consideration shall be given to the location of drying beds to avoid areas where moisture in the air is higher than normal (i.e., adjacent to rivers where morning fog is common).

In determining the area for sludge drying beds, consideration shall be given to climatic conditions, the character and volume of the sludge to be dewatered, type of bed used, and methods of ultimate sludge disposal. Design calculations shall be submitted upon request to substantiate the area used.

Drying bed design should be based on square feet per capita or pounds of sludge solids per square foot per year.
Table 12-5 presents the range of values that should be used, these values are for drying anaerobically digested sludges. Additional area is required for wetter sludges such as those resulting from aerobic digestion; therefore, use the higher number of the required range.

Table 12-5 DRYING BED DESIGN CRITERIA*

	Open Beds		Covered Beds
Type of Sludge	Per Capita (sq ft/capita)	Solids (lb/sq ft/yr)	Per Capita (sq ft/capita)
Primary	1.0 to 1.5	27.5	0.75 to 1.0
Attached Growth	1.25 to 1.75	22.0	1.0 to 1.25
Suspended Growth	2.50	15.0	2.00

*The design engineer should rely on his experience and the plant location.

These criteria are a minimum.

12.7.2.2. Percolation Type

a. Gravel

The lower course of gravel around the underdrains should be properly graded to range in size from 1/4-inch to 1-inch and should be 12 inches in depth, extending at least 6 inches above the top of the underdrains. It is desirable to place this in 2 or more layers. The top layer of at least 3 inches should consist of gravel 1/8 inch to 1/4 inch in size. The gravel shall be laid on an inpervious surface so that the filtrate will not escape to the soil.

b. Sand

The top course shall consist of at least nine inches of sand with a uniformity coefficient of less than 3.5. For trickling filter sludge, the effective size of the sand shall be between 0.8 to 3.0 millimeter. For waste activated sludge, the effective size of the sand shall be between 0.5 to 0.8 millimeter. For combinations, use the lower size range.

c. Underdrains

Underdrains should be clay pipe, concrete drain tile, or other underdrain acceptable material and shall be at least 4 inches in diameter and sloped not less than 1 percent to drain. Underdrains shall be spaced between 8 and 20 feet apart. The bottom of the bed shall slope towards the underdrains. Consideration should be given to placing the underdrain in a trench.

12.7.2.3 Impervious Types

Paved surface beds may be used if supporting data to justify such usage are acceptable to the Department. The use of paved beds for aerobically digested sludge is generally not recommended.

12.7.2.4 Walls

Walls should be watertight and extend 15 to 18 inches above the ground surface. Outer walls should be curbed to prevent soil from washing onto the beds.

12.7.2.5 Sludge Removal

Not less than two beds should be provided and they should be arranged to facilitate sludge removal. Concrete truck tracks should be provided for all

percolation-type sludge beds with pairs of tracks for the beds on appropriate centers. If truck access is by way of an opening in the drying bed wall, the opening shall be designed so that no sludge will leak out during the filling process.

12.7.2.6 Sludge Influent

The sludge pipe to the beds should terminate at least 12 inches above the surface and be arranged so that it will drain. Concrete splash plates shall be provided at sludge discharge points.

12.7.3 Mechanical Dewatering

12.7.3.1 Methods and Applicability

The methods used to dewater sludge may include use of one or more of the following devices:

a. Rotary vacuum filters

b. Centrifuges, either solid bowl or basket type

c. Filter presses

d. Horizontal belt filters

e. Rotating gravity concentrators

f. Vacuum drying beds

g. Other "media type" drying beds

The technology and design of sludge dewatering devices are constantly under development; therefore, each type should be given careful consideration.
The applicability of a given method should be determined on a case-by-case basis, with the specifics of any given situation being carefully evaluated, preferably in pilot tests. The engineer shall justify the method selected using pilot plant data or experience at a similar treatment plant.

12.7.3.2 Considerations

Considerations in selection should include:

a. Type and amount of sludge

b. Variations in flow rate and solids concentration

c. Capacity of the equipment

d. Chemicals required for conditioning

e. Degree of dewatering required for disposal

f. Experience and qualifications of plant staff

g. Reliability

h. Operation and maintenance cost

i. Space requirements

12.7.3.3 Storage

Adequate storage shall be provided for all systems.

12.8 Sludge Storage Lagoons

Refer to Chapter 9, Ponds and Aerated Lagoons, for the requirements of sludge storage lagoons.

12.9 Sludge Disposal

The ultimate disposal of sludge through various methods (i.e., landfilling, land application) is subject to the regulations and/or guidelines of the Tennessee Division of Water Pollution Control (DWPC). Approval by DWPC is required prior to initiation of the selected disposal alternative.

CHAPTER 13

Plant Flow Measurement and Sampling

PLANT FLOW MEASUREMENT AND SAMPLING

13.1 Purpose

Complete and accurate flow measuring and sampling are essential in the proper treatment of wastewater. Compliance with discharge limits requires proper flow measurement and sampling. They provide the operator with the information to optimize process control and operational costs, as well as providing an accurate data base of flows and process performance which can be used to analyze changes in operational strategy or assist future plant design.

13.2 Flow Measurement

13.2.1 General Considerations

13.2.1.1 Facilities for measuring the volume of sewage flows should be provided at all treatment works.

13.2.1.2 Plants with a capacity equal to or less than 100,000 gallons per day (gpd) shall be equipped, as a minimum, with a primary metering device such as: a Parshall flume having a separate float well and staff gauge, a weir box having plate and staff gauge, or other approved devices. Continuous recording devices may be required where circumstances warrant.

13.2.1.3 Plants having a capacity of greater than 100,000 gpd shall be provided with indicating, recording, and totalizing equipment using strip or circular charts and with flow charts for periods of 1 or 7 days. The chart size shall be sufficient to accurately record and depict the flow measured.

13.2.1.4 Flows passed through the plant and flows bypassed shall be measured in a manner which will allow them to be distinguished and separately reported.

13.2.1.5 Measuring equipment shall be provided which is accurate under all expected flow conditions (minimum initial flow and maximum design peak flow). The accuracy of the total flow monitoring system (primary device, transmitter, and indicator) must be acceptable. The effect of such factors as ambient temperature, power source voltage, electronic interference, and humidity should be considered. Surges must be eliminated to provide accurate measurement.
Two primary devices and flow charts may be required in some cases.

13.2.1.6 Metering devices within a sewage works shall be located so that recycle flow streams do not inadvertently affect the flow measurement. In some cases, measurement of the total flow (influent plus recycle) may be desirable.

13.2.1.7 All clarifiers must be provided with a means for accurate flow measurement of sludge wasting and sludge return lines so that solids handling can be controlled. Sludge digesters, thickeners, and holding tanks should be provided with some way to determine the volume of sludge added or removed. This can be accomplished by a sidewall depth scale or graduation in batch operations.

13.2.1.8 Flow meter and indicator selection should be justified considering factors such as probable flow range, acceptable headloss, required accuracy, and fouling ability of the water to be measured. For more detailed information the consultant is encouraged to read the EPA Design Information Report "Flow Measurement Instrumentation"; Journal WPCF, Volume 58, Number 10, pp. 1005-1009. This report offers many installation details and considerations for different types of flow monitoring equipment.

13.2.1.9 Flow splitter boxes shall be constructed so that they are reliable, easily controllable, and accessible for maintenance purposes.

13.2.1.10 Where influent and effluent flow-proportional composite sampling is required, separate influent and effluent flow measuring equipment is required.

13.2.1.11 Consideration should be given to providing some types of flow meters with bypass piping and valving for cleaning and maintenance purposes.

13.2.2 Parshall Flumes

Parshall Flumes are ideal for measuring flows of raw sewage and primary effluents because clogging problems are usually minimal.

The properly sized flume should be selected for the flow range to be encountered. All Parshall Flumes must be designed to the specified dimensions of an acceptable reference.

The following requirements must be met when designing a Parshall Flume.

13.2.2.1 Flow should be evenly distributed across the width of the channel.

13.2.2.2 The crest must have a smooth, definite edge. If a liner is used, all screws and bolts should be countersunk.

13.2.2.3 Longitudinal and lateral axes of the crest floor must be level.

13.2.2.4 The location of the head measuring points (stilling well) must be two-thirds the length of the converging sidewall upstream from the crest. Sonar-type devices are only acceptable when foaming or turbulance is not a problem.

13.2.2.5 The pressure tap to the stilling well must be at right angles to the wall of the converging section.

13.2.2.6 The invert (i.e., inside bottom) of the pressure tap must be at the same elevation as the crest.

13.2.2.7 The tap should be flush with the flume side wall and have square, sharp corners free from burrs or other projections.

13.2.2.8 The tap pipe should be 2 inches in size and be horizontal or slope downward to the stilling well.

13.2.2.9 Free-flow conditions shall be maintained under all flow rates to be encountered by providing low enough elevations downstream of the flume. No constrictions (i.e., sharp bends or decrease in pipe size) should be placed after the flume as this might cause submergence under high flow conditions.

13.2.2.10 The volume of the stilling well should be determined by the conditions of flow. For flows that vary rapidly, the volume should be small so that the instrument float can respond quickly to the changes in rate. For relatively steady flows, a large-volume stilling well is acceptable. Consideration should be given to protecting the stilling well from freezing.

13.2.2.11 Drain and shut-off valves shall be provided to empty and clean the stilling well.

13.2.2.12 Means shall be provided for accurately maintaining a level in the stilling well at the same elevation as the crest in the flume, to permit adjusting the instrument to zero flow conditions.

13.2.2.13 The flume must be located where a uniform channel width is maintained ahead of the flume for a distance equal to or greater than fifteen (15) channel widths.
The approach channel must be straight and the approaching flow must not be turbulent, surging, or unbalanced. Flow -lines should be essentially parallel to the centerline of the flume.

13.2.3 Sharp Crested Weirs

The following criteria are for V-notch weirs, rectangular weirs with and without end contractions, and Cipolletti weirs. The following details must be met when designing a sharp crested weir:

13.2.3.1 The weir must be installed so that it is perpendicular to the axis of flow. The upstream face of the bulkhead must be smooth.

13.2.3.2 The thickness of the weir crest should be less than 0.1 inch or the downstream edge of the crest must be relieved by chamfering at a 45° angle so that the horizontal (unchamfered) thickness of the weir is less than 0.1 inch.

13.2.3.3 The sides of rectangular contracted weirs must be truly vertical. Angles of V-notch weirs must be cut precisely. All corners must be machined or filed perpendicular to the upstream face so that the weir will be free of burrs or scratches.

13.2.3.4 The distance from the weir crest to the bottom of the approach channel must be greater than twice the maximum weir head and is never to be less than one foot.

13.2.3.5 The distance from the sides of the weir to the side of the approach channel must be greater than twice the maximum weir head and is never to be less than one foot (except for rectangular weirs without end contractions.

13.2.3.6 The nappe (overflow sheet) must touch only the upstream edges of the weir crest or notch. If properly designed, air should circulate freely under and on both sides of the nappe. For suppressed rectangular weirs (i.e., no contractions), the enclosed space under the nappe must be adequately ventilated to maintain accurate head and discharge relationships.

13.2.3.7 The measurement of head on the weir must be taken at a point at least four (4) times the maximum head on the crest upstream from the weir.

13.2.3.8 The cross - sectional area of the approach channel must be at least eight (8) times that of the nappe at the crest for a distance upstream of 15-20 times the maximum head on the crest in order to minimize the approach velocity.

The approach channel must be straight and uniform upstream of the weir for the same distance, with the exception of weirs with end contractions where a uniform cross section is not needed.

13.2.3.9 The head on the weir must have at least three (3) inches of free fall at the maximum downstream water surface to ensure free fall and aeration of the nappe.

13.2.3.10 All of the flow must pass over the weir and no leakage at the weir plate edges or bottom is permissable.

13.2.3.11 The weir plate is to be constructed of a material equal to or more resistant than 304 Stainless Steel.

13.2.4 Venturi and Modified Flow Tube Meters

The following requirements should be observed for application of venturi meters:

13.2.4.1 The range of flows, hydraulic gradient, and space available for installation must be suitable for a venturi meter and are very important in selecting the mode of transmission to the indicator, recorder, or totalizer.

13.2.4.2 Venturi meters shall not be used where the range of flows is too great or where the liquid may not be under a positive head at all times.

13.2.4.3 Cleanouts or handholes are desirable, particularly on units handling raw sewage or sludge.

13.2.4.4 Units used to measure air delivered by positive - displacement blowers should be located as far as possible from the blowers, or means should be provided to dampen blower pulsations.

13.2.4.5 The velocity and direction of the flow in the pipe ahead of the meter can have a detrimental effect on accuracy. There should be no bends or other fittings for 6 pipe diameters upstream of the venturi meter, unless treated effluent is being measured when straightening vanes are provided.

13.2.4.6 Other design guidelines as provided by manufacturers of venturi meters should also be considered.

13.2.5 Other Flow Metering Devices

Flow meters, such as propeller meters, magnetic flow meters, orifice meters, pitot tubes, and other devices, should only be used in applications in accordance with the manufacturer's recommendations and design guidelines.

13.2.6 Hydrograph Controlled Release (HCR) Systems

For plants utilizing HCR systems, accurate stream flow measurements are required. Detailed plans must be submitted outlining the construction of the primary stream flow measuring device and the associated instrumentation. The following factors should be emphasized in the design.

13.2.6.1 Accuracy over the flow range required for effluent discharge limiting purposes.

13.2.6.2 Operational factors such as cleaning and maintenance requirements.

13.2.6.3 Cost

The use of sharp crested weirs as described in Section 13.2.3 will not be allowed due to the installation requirements such as approach channel details and upstream pool depth and since entrapment and accumulation of silt and debris may cause the device to measure inaccurately. Parshall Flumes may be used due to their self-cleaning ability but field calibration will be required. Self-cleaning V-notch weirs are recommended due to their accuracy in low flow ranges. The weir can be made self-cleaning by sloping both sides of the weir away from the crest. The top portion of the crest shall be covered with angle-iron to prevent its breakdown. The angle of the V-notch should be determined by the stream characteristics; however, a smaller angle will increase accuracy in the low flow range. The primary device shall be built with sufficient depth into the stream bed to prevent undercutting and sufficient height to cover the required flow range.

It is recommended that the wastewater system director, engineer, or other city official contact the U.S. Geological Survey (USGS), Water Resources Division, in Nashville, Tennessee, for assistance with the design and installation of the flow measuring device. They offer a program which shares much of the costs for designing and maintaining the device. After visiting the site, they can assist with the design of a self-cleaning weir for the stream. They provide the consultant with a field design that shows the proper location and installation of the weir. From this field design, the consultant must provide detailed plans to the State.
The wastewater system is responsible for constructing the weir at their own cost. The flow measuring station is installed, maintained, and calibrated by USGS personnel so that accurate results are insured.

The primary device will record continuous flow of the stream and can be designed to send a feedback signal to the WWTP for other purposes such as controlling plant discharge rates.

This program benefits both the local wastewater system, the State of Tennessee, and the USGS, as it adds to stream flow data bases archived for public use. Cost sharing allows the flow measuring station to be built and operated at a lower cost for all parties concerned.

13.3 Sampling

13.3.1 Automatic Sampling Equipment

The following general guidelines should be adhered to in the use of automatic samplers:

13.3.1.1 Automatic samplers shall be used where composite sampling is necessary.

13.3.1.2 The sampling device shall be located near the source being sampled, to prevent sample degradation in the line.

13.3.1.3 Long sampling transmission lines should be avoided.

13.3.1.4 If sampling transmission lines are used, they shall be large enough to prevent plugging, yet have velocities sufficient to prevent sedimentation. Provisions shall be included to make sample lines cleanable. Minimum velocities in sample lines shall be 3 feet per second under all operating conditions.

13.3.1.5 Samples shall be refrigerated unless the samples will not be effected by biological degradation.

13.3.1.6 Sampler inlet lines shall be located where the flow stream is well mixed and representative of the total flow.

13.3.1.7 Influent automatic samplers should draw a sample downstream of bar screens or comminutors. They should be located before any return sludge lines or scum lines.

13.3.1.8 Effluent sampling should draw a sample immediately upstream of the chlorination point. This will eliminate the need to dechlorinate and then re-seed the sample.

13.3.2 Manual Sampling

Because grab samples are manually obtained, safe access to sampling sites should be considered in the design of treatment facilities.

13.3.3 Long Outfall Lines

Many wastewater systems are constructing long outfall lines to take advantage of secondary or equivalent permit limits.

Due to possible changes in effluent quality between the treatment facility and the outfall, a remote sampling station will be required at or near the confluence of the outfall line and the receiving stream on all outfall lines greater than one mile in length.

Dissolved oxygen, fecal coliform, and chlorine residual may have to be measured at the remote sampling station for permit compliance purposes.

13.3.4 Sampling Schedules

Samples must be taken and analyzed for two purposes: permit compliance and process control. Any time a new permit is issued, a sampling schedule for permit compliance will be determined by the Division of Water Pollution Control. An additional sampling program needs to be set up for process control purposes. This would include all testing required for completing the monthly operational report, as well as any other tests that might aid the operation of the plant. This schedule can be determined by the Division of Water Pollution Control, Wastewater Treatment Section or the appropriate field office once final plans are approved. The designer shall provide safe access points to collect representative influent and effluent samples of all treatment units and to collect samples of all sludge transmission lines. This makes it possible to determine the efficiency of each treatment process. Additional information about methods of analyses can be obtained from the Federal Register 40 CFR Part 136. Information about sampling locations and techniques can be obtained from the EPA Aerobic Biological Wastewater Treatment Facilities Process Control Manual and EPA's NPDES Compliance Inspection Manual.

CHAPTER 14

Instrumentation, Control and Electrical Systems

INSTRUMENTATION, CONTROL AND ELECTRICAL SYSTEMS

14.1 General Requirements

14.1.1 Codes and Regulations

Sewage treatment systems are classified by reliability as noted in publication number EPA-430-99-74-001. Plant instrumentation, control and electrical systems shall be designed to comply with the applicable requirements of this standard. See Chapter 1, Section 1.3.11.

The design of the treatment facilities instrumentation, control and electrical systems shall conform to applicable codes and regulations including:

National Electric Code (NEC)
Occupational Safety and Health Act (OSHA)
State and Local Building Codes
National Electrical Safety Code (NESC)
Instrument Society of America (ISA)

14.1.2 Plan Requirements

The instrument and control plans shall include, as a minimum, the following drawings:

Instrumentation, control and systems legend and general notes

Process and instrumentation diagram (P&ID)

Process flow diagram (may be combined in P&ID)

Site plan

Plant power distribution plan (can be included in site plan)

Switching logic or schematic drawings

Complete electrical one-line diagram

Building lighting plans

Building power plans

Motor control diagram
Equipment and installations details as required

Instrument loop diagram

14.2 Instrumentation and Control Systems Requirements

14.2.1 General

An instrumentation and control system must be designed with both operational reliability (accurate and repeatable results) and maintainability if it is to properly serve its purpose.

14.2.2 Backup Equipment

Instrumentation whose failure could result in wastewater bypassing or a violation of the effluent limitations shall be provided with an installed backup sensor and readout. The backup equipment may be of a different type and located at a different point, provided that the same function is performed. No single failure shall result in disabling both sets of parallel instrumentation.

14.2.3 Automatic Control

Where system automation is employed, a manual intervention/override or backup shall be provided.

14.2.4 Calibration

Vital instrumentation and control equipment shall be designed to permit alignment and calibration without requiring bypassing of wastewater or a violation of the effluent limitations. Automated systems shall have provisions for operator verification of performance and all necessary systems calibration devices.

14.2.5 Test Circuits

Test circuits shall be provided to enable the alarms and annunciators to be tested and verified to be in working order.

14.2.6 Alarms and Annunciators

Alarms and annunciators shall be provided to monitor the condition of equipment whose failure could result in wastewater bypassing or a violation of the effluent limitations. Alarms and annunciators shall also be provided to monitor conditions which could result in damage to vital equipment or hazards to personnel.

The alarms shall sound in areas normally manned and also in areas near the equipment. The combination of alarms and annunciators shall be such that each announced condition is uniquely identified.

14.3 Electrical System Requirements

14.3.1 Electric Power Sources

14.3.1.1 Primary Power Source

Generally, the local electric utility will be the primary source of electrical power. Second source of electrical power may be on-site generation or a second connection to the electric utility. If the second source is a connection to the electric utility, it must be arranged that a failure of one source does not directly effect the other. See Chapter 1, Reliability Class.

14.3.1.2 Standby Power Source

All treatment facilities greater than 100,000 gpd (average design flow) shall be equipped with an emergency generator to provide an alternate power source <u>when a second power source is not available</u>. The capacity of the backup emergency generator system shall conform to the Reliability Classification together with critical lighting and ventilation. If a main pump station is on site (or near) and would result in zero flow reaching the plant during power outages, it shall have a second power feed or standby power.

14.3.2 Power Distribution Within the Plant

The electrical power distribution system within the plant should be planned and designed on the following basis:

Plant electrical loads (peak and average demand)

Maximum fault currents available

Proper protective device coordination and device fault current withstand and interrupt ratings

Plant physical size and distribution of electrical loads

Plant power factor correction requirements

Location of other plant utility systems and facilities

Reliability requirements

Voltage drop limitations

Planned future plant expansions

Feasibility and possible economic justification for electrical demand control system

Life-cycle cost of major electrical equipment

All codes and regulations, and good engineering practice

14.4 Miscellaneous Requirements

14.4.1 Fire and Flooding

Failure of electrical equipment from such causes as fire and flooding shall be minimized by provision of suitable equipment housing and location, as well as by proper equipment design.

14.4.2 Housing of Electrical Equipment

Where practicable, electrical equipment shall be located in a separate room having an adequately controlled environment.

14.4.3 Ventilation

Mechanical ventilation shall be provided as necessary to protect electrical equipment from excessive temperatures.

14.4.4 Spare Components

An adequate number of spare components shall be specified by the design engineer to permit in-plant repairs or modifications and adjustment. These components include starters, low voltage contactors, and buried conduit. Spare electrical components which are subject to wear, such as motor brushes and switches, should also be specified by the design engineer as appropriate to minimize downtime.

14.4.5 Lighting

Adequate lighting throughout the wastewater treatment facility shall be provided, particularly in areas of operation and maintenance activities. Adequate emergency lighting shall be provided in the event of power failure.

CHAPTER 15

Small Alternative Wastewater Systems

15.1 Preface

This chapter presents the method to determine the proper design for decentralized wastewater treatment systems (DWWTS). DWWTS are systems that are not the traditional, centralized/regionalized wastewater treatment systems. DWWTS treat domestic, commercial and industrial wastewater using water tight collection, biological treatment, filtration and disinfection. These systems typically will utilize land application with either surface or subsurface effluent dispersal.

15.2 General Considerations

15.2.1 Ownership

Plans for sewer systems including domestic wastewater treatment systems will not be approved unless ownership and responsibility for operation are by a municipality, publicly owned utility, or a privately owned public utility regulated by the Tennessee Regulatory Authority (TRA). The owner is defined as the entity responsible for the operation of the system. The property being served is defined as the user.

Legal title to tanks, pumps, or other components should be vested with the owner. The objective of having title invested to the owner rather than the user is to avoid potential for cost disputes over equipment selection and repair methods. Regardless of where title is vested, the owner should completely control all tanks, pumps, service lines and other components of the system on private property. This requirement is essential to assure operable hydraulics and overall system reliability.

The owner shall possess a recorded general easement or deed restriction to enter the private property being served, and to access the system and its components. Access must be guaranteed to operate, maintain, repair, restore service and remove sludge.

Owners should operate and maintain facilities without interruption, sewage spills on the grounds, sewage backup into buildings, or other unhealthy conditions.

15.2.2 Planning

The applicant should contact the Division of Water Pollution Control as early as possible in the planning process. If a discharge to surface waters is proposed, the treatment works will be designated an appropriate Reliability Classification as detailed in Chapter 1 of this design criteria. Also for proposed surface water discharges, the designer should refer to the Wastewater Discharge Checklist, Appendix 15-A.

15.3 Design Basis

Small systems are more sensitive to influent problems due to a reduction in hydraulic or organic buffering capacity. Small systems are much more susceptible to flow variations due to daily, weekend or seasonal fluctuations. An accurate characterization of the waste and flow conditions should be projected for the site and should include flow, BOD_5, TSS, ammonia and, oil and grease.

15.3.1 Hydraulic Loading

For residential developments, the flows given below are generally considered appropriate for design purposes. For developments that include a preponderance of larger homes, higher flows should be considered. For non-residential flows, the engineer should use the tables given in Appendix 15-A. If the engineer determines that it is necessary to deviate from those values, then he/she must submit the basis for design flow, both average and peak. The type of collection system should be given serious consideration when determining total flow to the wastewater treatment plant.

For systems using water tight collection, the recommended design flow should be 300 gallons per day per unit. For projects dealing with commercial or very large residential developments, design flows should reflect expected variations from conventional systems and be evaluated and approved by the Division of Water Pollution Control based upon site-specific evaluation.

15.3.2 Engineering Report

An engineering report is required for all wastewater treatment projects. Small treatment plants require different design considerations than larger plants. During the design of a small treatment facility, the design engineer should evaluate the feasibility of various process alternatives. Except for systems proposed to serve single residential units, all other small flow systems or systems proposing to use land application for effluent dispersal should also submit an application for an NPDES permit or a State Operation Permit (SOP) to the Division of Water Pollution Control (Note: Exceptions may be contained in Memorandum of Agreement between the Divisions of Water Pollution Control and Ground Water Protection). The SOP application should include an engineering report, Water Pollution Control soils map, soil profile descriptions derived from soil borings and pit evaluations to determine soil type, texture and structure for all areas proposed for drip dispersal or spray irrigation as described in Chapters 17 and 16 of this criteria.

15.3.3 Pollutant Loading

While best engineering judgments for waste characterizations are sometimes necessary, an attempt should be made to project this character from similar facilities, instead of the absolute use of flow tables. For example, excess ammonia should be considered during design of a treatment system for a rest stop, truck stop or recreational vehicle park.

These types of facilities can have a significantly higher influent ammonia concentration than typical domestic systems

15.4 Preliminary Treatment

Preliminary treatment involves the removal of large solids that could damage pumps and equipment in the downstream treatment process. Such treatment may include properly designed and water tight septic tanks, or filters.

15.4.1 Septic Tank Effluent Pumping (**STEP**) and Septic Tank Effluent Gravity (**STEG**) Systems

An effluent sewer is a wastewater collection and treatment system shared by multiple users, consisting of multiple watertight septic tanks (to capture and remove gross solids, oil and grease), and small diameter watertight piping to convey wastewater from the tanks to a treatment facility and common dispersal area. Treated "clear" effluent from the mid-depth of the septic tank is filtered (through an effluent filter or screened pump vault) and transported under pressure via the pressurized collection system. An effluent sewer may include septic tank effluent pumping (STEP) systems, or septic tank effluent gravity (STEG) systems, or both. In a STEP system, the effluent is pumped from the septic tank under pressure while in a STEG system, pressurization is achieved using hydrostatic pressure (gravity).

Septic tanks should be sized to accommodate a minimum of two and one-half (2.5) times the design daily sewage flow anticipated to flow through the tank. Additionally, septic tanks may be either compartmentalized or not, since un-baffled tanks allow the tank to be pumped from either end. **All tanks regardless of size must be water-tight as evidenced by post installation testing and structurally sound by design as certified by a Licensed Professional Engineer stamp on tank plans and structural analysis**. Tanks may be made of concrete or other structurally sound materials such as fiberglass Water testing is preferred with the water level being a minimum of 3-inches above the top of the cover for the tank. If vacuum testing, it is preferred that the tank be capable of maintaining 4-inches of mercury (HG) without loss for five (5) minutes. However, at minimum the tank must meet the water pressure testing and vacuum testing in accordance with ASTM C1227. Structural soundness will usually require reinforcing bars incorporated into the tank walls, sides, top, and bottom. Acceptable burial depths and loading conditions should be explicitly noted on the drawings and made available to installers.

All tanks should be equipped with rubber inlet and outlet boots installed through the tank wall and sealed to the piping with stainless steel band clamps. All tanks should be equipped with water-tight risers over the inlet and outlet of the tank. The riser should have a water tight seal to the top of the tank. Access risers should extend to grade and be equipped with a water-tight lid bolted or locked to the riser.

15.4.1.1 STEP Tanks

In a typical septic tank system, household sewage is pretreated in a watertight septic tank where gross solids and grease are held back. A “clear” effluent from the mid-depth of the tank is transported to a common or lateral sewer. In a septic tank effluent pump (STEP) system, the effluent is pumped from the septic tank under pressure to a small-diameter, pressurized collector sewer.

In most cases, a single phase, ½ HP effluent pump is adequate for septic tank effluent. However, if a working head over 150 feet is expected, a higher horsepower pump may be required.

The effluent pump should be located within a screened pump vault. The vault, at a minimum, should be fitted with 1/8-inch mesh polyethylene screen and a 4-inch diameter PVC (or equivalent) flow inducer for a high head pump.

The pump chamber should also include float switches that turn the pump on and off and activate high and low level alarms.

15.4.1.2 STEG Tanks

Effluent may also flow by gravity, where available hydraulic gradient allows, to small-diameter gravity collector lines. Gravity system tanks should be equipped with an effluent filter that at a minimum consists of a 1/8-inch mesh polyethylene screen housed within a PVC (or equivalent) vault. The lateral from the tank to the collection line should be laid at a uniform grade with no high points.

15.4.2 Grinder Pumps

For systems served by grinder pumps, all raw wastewater should be collected from individual buildings/dwellings and transported to the pressure or gravity system by appropriately sized pumps. For restaurants or facilities with commercial-grade kitchen facilities, grease and oil interceptors (as described in 15.4.4) should be installed prior to the grinder pump.

All pumps must have adequate operating curves that allow for pumping into the pressurized common line under maximum head conditions. Additionally, each pump must be equipped with properly installed and approved backflow prevention assembly. Furthermore, tanks must be watertight and located above the seasonal groundwater table where possible. Where it is not possible to locate tanks above the seasonal groundwater table, the design engineer must provide anti-buoyancy calculations and specify appropriate anti-flotation devices. Installations should ensure that odors are minimized.

15.4.3 Grease and Oil

Facilities with commercial-grade kitchen facilities should be equipped with an effective grease and oil interceptor. Other potential sites of grease/oil production should be investigated by the design engineer.

One or more interceptors in series are required where grease or oil waste is produced that could hinder sewage disposal or treatment, and/or create line stoppages.
Interceptors must be located so as to provide easy access for inspection, cleaning and maintenance. In commercial-grade kitchen facilities, the dishwasher(s) must not be connected to the primary grease trap and/or separator. A separate device may be required to allow for cooling of the dishwasher discharge prior to primary treatment.

As vegetable oil usage has become more common, it should be understood that oils will not solidify until approximately 70^{o} F. or less. Therefore, the minimum interceptor design should be a baffled, three-compartment, elongated chamber to allow for cooling with a capacity of at least 1,500 gallons. The design should be in accordance with accepted engineering practice. Tanks must also be sized in accordance with local requirements. The tank should be buried, with manhole accesses to all compartments. Tanks should be manufactured and furnished with access openings having a minimum diameter of twenty-one (21) inches. The tank top should be able to support a minimum of 2500 lb. wheel load. Inlet plumbing should be designed to penetrate 18 inches or more below the discharge invert elevation. In order to demonstrate water-tightness, tanks (including all risers and lids) must be tested prior to acceptance by filling with either air or water in accordance with ASTM standard C1227-05.

15.5 Secondary Treatment Design

The following secondary systems should be evaluated for small flow designs.

15.5.1 Fixed Media Biological Reactors

A fixed media biological reactor (FMBR) is an aerobic, fixed film process that uses sand, gravel or other media to provide secondary treatment of septic tank effluent. The FMBR typically consists of a septic tank and recirculating tank, media bed with a special distribution system installed within a structure or excavation lined with impervious synthetic liner and a flow splitter device.

Design considerations include the media size, type and surface area, the required bed area and depth, dose volumes and dosing frequency.

All sites for fixed media reactors should be properly prepared before installation. For reactors that are installed directly on soil with a synthetic liner (as opposed to package units with rigid bottoms), the liner may lie directly on the graded soil if it is free from material that might puncture the liner. Otherwise, a layer of sand or other suitable material should be placed below the liner to protect it from puncturing.

15.5.1.1 Granular Media Reactor

The media bed should be sized by comparing the organic and hydraulic loads and then using the more restrictive of the two. Table 15-1 gives suggested design parameters for the reactor, support bedding and underdrain media. All media should be washed and screened to limit fines to less than 1% by weight passing a 100 screen (0.15 mm).

Table 15-1 Suggested Design Parameters for Granular Media Reactors

Design Parameter	**Effective Size (D_{10})**	**Depth**	**Design Value**
Reactor Media:			
Sand or other, similar granular media	1.5-2.5 mm (Uniformity Coefficient = 1-3)	24 to 30 inches	3-5 gpd/ft^2 (hydraulic loading – forward flow) ≤ 6.2 lb BOD_5 /1000 ft^2/day (organic loading)
Gravel or other, similar granular media	0.6 - 1 cm diameter	24 – 30 inches	10 - 15 gpd/ft^2 (hydraulic loading – forward flow) ≤ 10 lb BOD_5 /1000 ft^2/day (organic loading)
Underdrain Media	#57 inch stone	12-18 inches	

A synthetic media may also be used as long as it meets the above criteria.

A minimum of 30 mil impermeable synthetic liner is required for the bottom and sides of the filter.

15.5.1.2 Other Fixed Media Reactors

These systems will be approved on a case-by-case basis. The design engineer must provide adequate rationale that such systems are preferable to more traditional granular media reactors.

15.5.1.3 Distribution and Underdrain System

15.5.1.3.1 Spacing

Distribution mechanisms should ensure uniform application of the applied flow to the surface of the media. These mechanisms may involve spray nozzles in synthetic media reactors or drilled or perforated pipe in sand filter or other fixed media reactors.

For sand filters, the distribution pipes should be spaced on 18-inch centers or less. Underdrain lines, where used, should be spaced no farther than 8-feet on center.

15.5.1.3.2 Sizing of Lines

Distribution pipes should be no smaller than 1-inch. Clean-out caps should be provided on the ends of the distribution pipes. In the underdrain system, pipes should have a minimum inside diameter of 4 inches. As an alternative, collection vaults may also be employed.

15.5.1.4 Recirculation Tank and Pump System

Where a separate recirculation tank is used, the tank may serve as a wet well for the septic tank effluent and treated, recirculated effluent to be pumped to the media bed. The minimum tank volume should equal the design daily flow.

The tank should be equivalent in strength and materials to the septic tank as described in 15.4.1. No internal baffles are necessary. An access manhole is necessary for replacement of submersible dosing pumps if such are used.

A minimum of two alternating recirculation pumps are required for commercial multiuser FMBRs. Recirculating pump operation should be time-controlled. Float switches are required and should be wired in parallel with the timer to control the pumps during periods of either low or high wastewater flows, and as a back-up in case of timer malfunction.

A quick disconnect coupler and hanger pipe are recommended for pump removal and convenience. Additionally, panels for operation of FMBRs should also feature programmable digital timers and multiple settings for optimizing dosing during normal and peak flow conditions.

15.5.1.5 Flow Splitter

The system should be equipped with a device or computerized process control that allows for reactor effluent to be split between the recycle stream and discharge to either the disinfection system and/or drip disposal area. It is recommended that the designer choose a device that provides flexibility in setting the recycle ratio.

15.5.1.6 Dosing Chamber

Where the treated effluent is intended to be distributed through a drain field, drip dispersal system or other land application mechanisms, a dosing chamber should be employed, sized and equipped to provide timed-dosing of the daily wastewater flow with adequate reserve storage capacity for system malfunctions.

The dosing chamber should be equipped with an audible visual or other approved high-water alarm set to provide notification to the owner/operator of a malfunction when the design high water level is exceeded and the emergency reserve capacity is being used. A low-water cutoff device must be provided to prevent damage to the pump during low-water conditions.

A programmable timer and control panel should be employed to regulate the dosing frequency and volume, and to record wastewater flow, the number of doses and other pertinent dosing data.

Time dosing should be utilized to dose the absorption field or zones. The frequency of dosing must be based upon the soil's hydraulic loading rate and the design flow. Fields or zones should be time dosed to ensure the total twenty-four (24) hour wastewater effluent flow is applied in a 24-hour period.

15.6 Disinfection and Fencing

Disinfection of effluent is required prior to spray irrigation. Disinfection of effluent will be required for drip dispersal of unfenced drip irrigation if the drip field access is classified as either "Open Access" (where drip areas are used for ball fields, playgrounds, picnic areas, golf courses, etc.) or "Attractive Access" (where open spaces are maintained similar to residential lawns with easy access and with grass maintained at short heights, but with the area undeveloped for recreational purposes). In these cases, if the entire drip dispersal area is properly fenced, disinfection of the effluent is not required.

Disinfection of effluent may not be required for drip dispersal of unfenced drip irrigation if the drip field access is classified as either "Inhibited Access" (where drip areas are allowed to return to natural vegetation and are used for wildlife food plots or other similar uses and where routine access by humans is discouraged by growth of vegetation) or "Difficult Access" (where drip areas are located on generally steep, greater than 10% slopes, on heavily wooded slopes, and access by humans will be rare due to terrain, location, or vegetation).

In the design of UV disinfection units there are three basic areas that should be considered:

a. Reactor hydraulics – adequate residence time.

b. Factors affecting transmission of UV light to the microorganisms.

c. Properties of the wastewater being disinfected.

In addition, an automatic self-cleaning mechanism is recommended to ensure proper performance of the UV system.

As an alternative to disinfection, the drip field may be fenced with a 4-foot chain link, woven wire fence, wooden, four-strand barbed wire, or other as approved by the Department of Environment and Conservation.

15.7 Oxidation Ponds and Artificial Wetlands

15.7.1 Oxidation Ponds

1. The maximum design loading on the primary cell(s) should be 30 lbs BOD_5 per acre per day.
2. The design average flow rate should be used to determine the volume required to provide a minimum combined storage capacity of 90 days in the stabilization ponds. The minimum recommended operating depth is 3 feet for facultative ponds and 10 feet for aerated ponds.
3. The minimum number of cells should be three when the system is designed to discharge to surface waters.
4. The shape of the cells should be such that there are no narrow, L-shaped or elongated portions. Round or rectangular ponds are most desirable. Rectangular ponds should generally have a length not exceeding three times the width. Dikes should be rounded at the corners to minimize accumulation of floating material.

15.7.2 Basis of Wetland Design

The artificial wetland treatment system has been around since the 1980's. Like other land application systems, artificial wetlands are site specific. Consequently, all proposals will be reviewed on a site-by-site basis. This section is limited to subsurface flow wetlands utilizing gravel or other granular media. Free-water surface wetlands can also be used, but their design follows different parameters and approval will be on case-by-case basis.

1. Design

a. Artificial wetlands designed to discharge to surface waters will have to meet NPDES permit limits at all times and must be designed accordingly.
b. Artificial wetlands are designed on the basis of a BOD removal rate which is assumed to follow the classic first order removal equation corrected for temperature.
c. The minimum recommended detention time for treatment of normal domestic waste in the artificial wetland system is 4 to 7 days.
d. The recommended depth of flow in the wetland system should be between 18 and 24 inches, with twenty-four (24) inches as the recommended optimum depth.
e. The aspect ratio of the wetland is determined by the design flow and substrate cross sectional area perpendicular to the flow. The aspect ratio should be such that one-third (⅓) of the available flow rate, as determined by Darcy' Law, is preserved and all flow remains subsurface. This will generally result in a rectangular configuration with a length to width ratio of between 1:1 and 1:3.
f. Seepage rates in the artificial wetland areas will be addressed on a site-by-site basis based upon in-situ material, groundwater depth and the groundwater use. Generally, no compaction will be required on wetland pond bottoms. The berms should be compacted to at least 90 percent of Standard Proctor Density.

g. The bottom of the artificial wetland treatment units should not have a slope greater than 0.2%.
h. Due consideration should be given to multiple wetland cells and to possible future expansion on suitable land when the original land acquisition is made for flexibility and for maximum operational capability.

2. Construction

a. The project site should be protected from surface inflow waters. The site should also be protected such that the top of the wetland surface is at least one foot above the 100 year flood elevation.
b. In order to prevent erosion and channelization at the inlet of the wetland, a discharge header should be utilized. The header should be equipped with removable end-plugs so the line may be drained to prevent freeze-up. Uniform distribution of wastewater to prevent short-circuiting through the wetland should be assured. It is recommended that the header outlet elevation be at or above the maximum design depth.
c. It is recommended that pipes and flumes located in or near inlet and discharge structures will not be in a completely submerged condition to maintain the integrity of the system and reduce freeze-up problems.
d. A suitable discharge structure from the wetland should be utilized. The structure should be adjustable so that the depth in the wetland may be modified as needed.
e. Care should be taken to establish the vegetation as soon as possible after construction. However, it is difficult to establish the vegetation in winter or mid to late summer. The emergent vegetation, once established, should prevent the erosion of the berms of the system. Riprap may be required around the inlet and outlet structures of the wetland. A cover crop may be planted on the interior slopes to prevent erosion prior to the establishment of the emergent vegetation. Consideration may be given to the use of excelsior blanket over seeding.
f. The exterior and interior slopes of the wetland berms surrounding the wetland basins should not be steeper than 3H:1V.
g. The top width of the berms should be a minimum of eight feet.
h. Following the final grade, the substrate should consist of a minimum of two feet of clean ¾-inch to 11/2-inch stone (#57).
i. The dike elevation should be a minimum of two feet above the high water level in the wetland.
j. If groundwater contamination is a potential problem, the bottom of the wetland may be sealed with a suitable material. However, generally no liner will be necessary in the artificial wetland.
k. Aluminum, concrete, or PVC pipe or other material generally accepted for sewers should be specified for the piping requirements in the wetland. Provisions may be required to prevent the settling of the piping structures under load. It is recommended where structures are partially or completely submerged in ice conditions that a flexible piece of pipe be installed to allow for some movement of structure.
l. The effluent discharge structure should be equipped with a suitable flow monitoring device, such as a flume or V-Notch weir, to monitor flows leaving the treatment site. Staff gages for measuring depths in structures should be provided where flow monitoring is required.

m. In order to accurately monitor influent flows to the artificial wetland system, an influent measurement structure should be included.
n. The entire wetland area must be enclosed with a suitable fence to provide public safety, exclude livestock and to discourage trespassing.
o. Warning signs must be provided along the fence around the treatment facility. There must be at least one sign on each side of the facility, with a minimum spacing of 500 feet.
p. Removable screens should be provided on pipe ends to prevent entrance of trash and wildlife.

3. Vegetation Establishment

a. Specifications for the seeding of the artificial wetland should as a minimum include:

1. Plant species
2. Plant distribution (vegetative zone)
3. Planting (including time restraints)
4. Fertilization
5. Water level control and site maintenance.

b. Placing top soil in the graded wetland area is generally not required. Substrate properties generally do not limit the establishment of a wetland.

c. Only indigenous plant species should be used; preferably collected within a 100 mile radius. Preferred species include, but are not limited to:

1. Typha Latifolia - Common cattail,
2. Typha Angustifolia - Narrow leaf cattail,
3. Scirpus spp. - Bullrush, and/or
4. Phragmites communis - Reed.

d. Transplanting of live or dormant plant stock will achieve greater success than seed. However, the plants have to be set into the gravel with their roots near the water level in the wetland. Transplanting of reeds is by placing a section of rhizome containing the "eye" in the shallow surface of the gravel.

e. Seeding should generally be accomplished in the spring. Also, at least one fertilization should be required, preferably shortly after seed germination or at one month. The recommended fertilizer is the standard 10- 10-10 or 20-10-10 mixture at a rate of 600 lbs/ac or 300 lbs/ac, respectively. Where wastewater stabilization ponds exist, fertilization may not be necessary, as the nutrients in wastewater may suffice.

f. For seeding, the following is recommended:

The seed should be broadcast uniformly over the substrate at a rate of 10 viable seeds per square foot. The seeds should be cultivated to subsurface depths of 0 to 1 inch followed by lightly packing, rolling or dragging the tilled surface. Flood the site with 1-2 inches of water until the seeds germinate and become several inches tall. At this time, the area should be fertilized.

g. For transplanting (the recommended method of vegetation establishment) the propagule should be transplanted, as a minimum, on a two foot grid. The number of transplants required may be calculated from Equation 15-1:

$$N = (L/D + 1) \times (W/D + 1)$$ (**Equation 15-1**)

Where:

N = Number of transplants

D= Distance between transplants

L = Length of site (ft.)

W = Width of site (ft.)

Transplanting on a two foot grid should provide a uniform vegetative cover in one growing season. Transplants should be kept moist, but not flooded to submerged conditions. The transplants should also be fertilized, preferably with controlled release fertilizer such as Osmocote 18-5-11 for fall and winter planting, Osmocote 18-6-12 for spring planting, and Osmocote 19-6-12 for summer planting. Refer to suppliers instructions when transplanting.

15.8 Lagoons (Note: This chapter does not replace Chapter 9)

- The maximum allowable seepage is 0.0625 inches per day.
- A lagoon must be artificially lined with clay, bentonite, plastic, rubber, concrete, or other materials to prevent groundwater pollution.
- Lagoons can be round, square, or rectangular with rounded corners. Their length should not exceed three times their width, and their banks should have outside slopes of about three units horizontal to one unit vertical.
- A lagoon must be surrounded by a 4-foot high fence with a locking gate and sign.
- There should be a 2 x 2 ft concrete pad in the center of the lagoon directly below the opening of the outlet pipe to protect the integrity of the liner.
- There should be a minimum of 2 feet between the bottom of the lagoon and groundwater. The liquid depth of a lagoon should be maintained between 2 to 5 feet.
- There should be a depth marker near the center of the lagoon.
- A minimum of 1 foot of freeboard should be maintained.

15.9 Package Activated Sludge Plants

For any activated sludge or fixed film process, the criteria presented in Chapters 4, 5, 6, 7, 8, 10, 11, and 12 of these design criteria must be utilized for each unit process.

The design should include aerobic digestion or sludge holding for sludge wasting. A sludge wasting schedule should be included in the engineering report to better define operator time requirements. The disposal site or landfill should be given. Where tertiary filters are employed, the use of an equalization tank is mandatory. Also, based on the Reliability Classification as determined by the appropriate WPC field office, multiple units and standby power (or a generator) may be required. These costs should be included in the cost effective/reliability analysis.

APPENDIX 15

Recirculation Tank/Pump System Example Calculation

Given: 20,000 gpd (14 gpm) system a desired 4:1 recycle rate and numerous small doses.

1. Pumping volume = (1440 min/day / (On + Off time)) x On time x # of pumps x Pump Capacity
2. 80,000 gpd = (1440 min/day / (On Off Time) x On Time x 4 x 45 gpm
3. 80,000 gpd/(1440 min/day x 4 x 45 gpm) = On time/(On + Off time)
4. On time/(On + Off time) = 0.31
5. On time = 0.31 On + 0.31 Off
6. 0.69 On = 0.31 Off
7. Off = 2.22 On
8. Choose 2 minutes On: Off = 4.44 minutes
9. Total dosing cycle = 6.44 minutes.
10. Adjust dose cycle if calculated pumping volume is less than minimum recommended for selected recycle rate
11. Note: The above is an iterative process. The quickest solution is to pick a cycle time, divide it into 1440 min/day, multiply by the On time, multiply by the number of pumps, and multiply by the pump capacity. Compare this number to the desired total pumping volume including recycle. If too little increase On time. If too much decrease on time. .

CHAPTER 16

Design Guidelines for Wastewater Treatment Systems Using Spray Irrigation

16.9 Land Area Requirements

16.9.1 General
16.9.2 Field Area Requirements
16.9.3 Buffer Zone Requirements

16.10 Storage Requirements

16.10.1 General
16.10.2 Estimation of Storage Requirements Using Water Balance Calculations

16.11 Distribution System

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16.12 Spray Irrigation of Wastewater from Gray Water Facilities

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16.13 Plan of Operation and Management

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SPRAY IRRIGATION
LAND TREATMENT SYSTEMS

16.1 General

16.1.1 General

This chapter provides guidelines and criteria for the design of surface spray irrigation land treatment systems.

The wastewater loading rate is limited by the maximum amount of a particular wastewater constituent that can be applied to a specific site. For wastewater from municipalities, the limiting design factor is usually either the hydraulic capacity of the soil or the nitrogen content of the wastewater. For industrial wastewater, the limiting design factor may be the hydraulic capacity of the soil, nitrogen or any other wastewater constituent such as metals, organics, etc.

16.1.2 Applicability

Spray irrigation wastewater treatment systems must be designed and operated so that there is no direct discharge to surface waters. Treatment consists of evaporation directly to the atmosphere, by transpiration to the atmosphere via vegetation uptake and by percolation to groundwater. A State of Tennessee Operation Permit (SOP) is required for operation of spray irrigation land treatment systems.

16.1.3 Location

The spray irrigation treatment site should be relatively isolated, easily accessible and not susceptible to flooding. The site can be developed on agricultural land and/or forests or can include parks, golf courses, etc. Site location shall take into account dwellings, roads, streams, etc. A site evaluation by the Division of Water Pollution will be required before review of the Engineering Report and/or application for an SOP.

16.1.4 Topography

Maximum grades for wastewater spray fields should be limited to 8% for row crops, 15% for forage crops and 30% for forests. The greater the slope the greater potential for lateral subsurface drainage, ponding and extended saturation of the soil. Depressions, sink holes, etc., are to be avoided.

16.1.5 Soils

The infiltrative capacity of soil is a critical factor to be considered when designing any type of spray irrigation system. If the profile of a particular soil considered for spray irrigation extended to a significant depth without a restrictive horizon (most limiting layer), the ability to load that soil per unit area would be relatively high.

On the other extreme, if a soil being considered for spray irrigation has a shallow restrictive horizon, the ability to load that soil would be lower relative to the deeper soil. Depth to restrictive horizon, soil permeability and slope of the restrictive horizon are factors that control the amount and rate at which ground water can exit an area. If the amount of treated effluent applied to an area, in combination with rainfall over the area and groundwater moving into the area, exceed the soil profile's ability to transmit the water away from the application area, surface runoff of wastewater effluent will likely occur.

Evaluation of a soil area's suitability for spray irrigation should take into consideration limiting aspects of the soil profile. Sites with shallow restrictive horizons overlain by low permeability soils represent one of the more limited scenarios for spray irrigation and the application rate and/or application area should be suitably modified.

Also critical when designing systems in soils with shallow restrictive horizons are the presence and location of hydrologic boundaries such as drainage ways and waterways. These hydrologic boundaries provide an outlet for ground water discharge. Not only is it critical to identify these features in consideration of appropriate setbacks/buffers, it is also critical to factor in their role in the overall hydrologic cycle of the landscape.

Horizons along which lateral flow would be expected include, but are not necessarily limited to: bedrock, fragipans, and zones with high clay percentage overlain by more permeable soil.

Spray irrigation design submittals should take into consideration all factors influencing the infiltrative capacity of the soil and the ability of the soil and site to transport ground water away from the application area. Spray pattern designs must properly utilize the site soil and topography. It should be noted that the use of historical information from existing systems installed and operated in similar soils, with documented loading rates, landscape positions and design conditions similar to the proposed system may be applicable. Therefore, soils that have been highly compacted and/or disturbed, such as old road beds, foundations, etc., must be excluded when evaluating suitable areas for surface spray irrigation systems.

16.2 Soil Investigations

16.2.1 General

Preliminary soil investigations should be done to identify areas best suited for surface spray irrigation. The proposed surface spray area must be mapped at sufficient accuracy to identify each soils series (or lowest possible level of soil classification) present and the boundary location between series. Once those areas are identified, the more detailed procedures outlined below will be employed.

It is required that all soil investigations be performed by a soil scientist currently on the Ground Water Protection list of approved soil scientists/soil consultants.

For spray irrigation wastewater treatment systems, moderately permeable and well-drained soils are desirable. However, the use of any soil is acceptable if it meets the following four (4) criteria:

1. The applied effluent loading rate does not exceed the applicable hydraulic loading rate in **Table 16-1**. The applicable hydraulic loading rate is determined by a detailed site evaluation in which the site is mapped utilizing soil borings and pits to determine the physical properties of soil horizons and soil map units.
2. The applied effluent maximum loading rate does not exceed 10% of the minimum NRCS saturated vertical hydraulic conductivity (K_{SAT}) for the soil series or 0.25 GPD/SF whichever is least. Note: this may have to be lowered based upon the results of the nutrient loading rate calculation per Equation 16-1.
3. The soil does not have a restrictive horizon within its top twenty (20) inches.
4. The soil is well drained, or capable of being drained.

   It is desirable to have a minimum depth of twenty (20) inches of undisturbed soil above a restrictive horizon (eg., rock, fragipan, high water table, etc.)

TABLE 16-1

Hydraulic Loading Rates (GPD/SF) – For Spray Irrigation Systems

(Reference: EPA/R-00/08, February 2002, "*Onsite Wastewater Treatment Systems Manual*")

TEXTURE	STRUCTURE		HYDRAULIC LOADING RATE*	
	SHAPE	GRADE	GPD / SF BOD ≤ 150 mg/L	GPD / SF BOD ≤ 30 mg/L
Coarse Sand, Loamy Coarse Sand	NA	NA	0.80	NA
Sand	NA	NA		NA
Loamy Sand, Fine Sand, Loamy Fine Sand, Very Fine Sand, Loamy Very Fine Sand	Single Grain	Structureless	0.40	1.00
Coarse Sandy Loam, Sandy Loam	Massive	Structureless	0.20	0.60
	Platy	Weak	0.20	0.50
		Moderate, Strong		
	Blocky, Granular	Weak	0.20	0.70
		Moderate, Strong	0.40	1.00
Loam	Massive	Structureless	0.20	0.50
	Platy	Weak, Moderate, Strong		
	Angular, Blocky	Weak	0.40	0.60
	Granular, Subangular	Moderate, Strong	0.60	0.80
Silt Loam	Massive	Structureless		0.20
	Platy	Weak, Moderate, Strong		
	Angular, Blocky, Granular, Subangular	Weak	0.40	0.60
		Moderate, Strong	0.60	0.80
Sandy Clay Loam,	Massive	Structureless		

Clay Loam, Silty Clay Loam	**Platy**	**Weak, Moderate, Strong**		
	Angular, Blocky Granular, Subangular	**Weak**		**0.30**
		Moderate, Strong		**0.60**
Sandy Clay Clay, Silty Clay	**Massive**	**Structureless**		
	Platy	**Weak, Moderate, Strong**		
	Angular, Blocky Granular, Subangular	**Weak**		
		Moderate, Strong	**0.20**	**0.30**

*** Maximum allowable is 0.25 GPD/SF; however all hydraulic loading rates may be adjusted based upon special site specific evaluations approved by TDEC.**

These soils are considered unacceptable for spray irrigation.

16.2.2 Soil Mapping

The mapping procedure will usually begin with the property/land being generally evaluated to delineate or separate areas with suitable characteristics. This procedure will save time and money since some areas will be too shallow, too wet, too steep, etc. Adequate ground control is mandatory for all sites. The ground control is necessary to reproduce the map if needed. All located coordinates (soil map boundaries and pit locations) must be shown on the final Water Pollution Control (WPC) Soil Map.

Soil data collection shall be based upon one, or combination of the following:

1. Grid staking at intervals sufficient to allow the soils scientist to attest to the accuracy of the map for the intended purpose;
2. Mapping of pits and critical auger locations using dual frequency survey grade Global Positioning System (GPS) units.
3. Other controls adequate to map the location of pits, physical features, and separations.
4. Grid stakes and GPS data points must be locatable to within two (2) feet of distance shown.
5. The ground control has to correlate to the exterior boundaries of the property so as to show the location of the soils areas within the bounds of the project and must be certified by a Registered Land Surveyor per TCA 62-18-102(3).

The soil scientists are responsible for conducting a sufficient number of borings that, in their professional opinion, will allow them to certify the soils series (or lowest possible level of soil classification) present, identify boundaries between series, and describe each soil horizon as to color, depth to restrictive horizon, and depth to rock. Any redoximorphic features observed are to be described. This delineation should be based upon the texture and structure of the soils to a depth of forty-eight (48) inches or restrictive horizon whichever is shallower.

After the mapped soils area is established and marked, soil borings to a minimum depth of forty-eight (48) inches or restrictive horizon, whichever is shallowest, shall be taken at sufficient intervals to identify and map the boundaries of the soils series (or lowest possible level of soil classification) present on the site. The exact number and location of borings will be determined by the soils scientist in consultation with the design engineer. Sufficient borings should be made to identify any dissimilar soils accounting for more than 10 percent of the total proposed surface spray irrigation area.

The soil scientist shall excavate an adequate number of pits to determine the typical profiles and soils characteristics that are expected for all soils mapped. It is recommended that a minimum of two (2) pits per acre in polygons of qualifying soils be excavated; however, the actual number and location of pits will be left to the best professional judgment of the soil scientist. If less than two (2) pits per acre are utilized, the soil scientist must include the rationale in notes on the WPC Soil Map.

The pit description must be entered onto a pedon sheet and submitted with the soils map and engineering report. The "Soil Description" should include all of the information contained on form NRCS-Soils-232G (5-86), U.S. Department of Agriculture, Natural Resources Conservation Service (as shown in Chapter 17, Appendix D).

In their description of the pit profiles, the soil scientists must describe the soil's structure, texture, color, and any redoximorphic features present. They should also describe root depth and presence of macropores, etc. The series name or lowest possible level of soil classification will be recorded. The depth to hard rock using an auger or a tile probe must be specified if the depth is less than forty-eight (48) inches and estimated if greater than forty-eight (48) inches. The auger borings and soil backhoe pits should be located, numbered and shown on the WPC Soil Map. The soil scientist will be required to prepare and sign a detailed certification statement for each site evaluated as follows:

Water Pollution Control Soil Map Completed by:

Signature Date

John/Jane Doe, Soils Consultant

The following statement should appear on the map:

"I, (Soils Consultant's Name) affirm that this Water Pollution Control Soil Map has been prepared in accordance with accepted standards of soil science practice and the standards and methodologies established in the NRCS Soil Survey Manual and USDA Soil Taxonomy. No other warranties are made or implied."

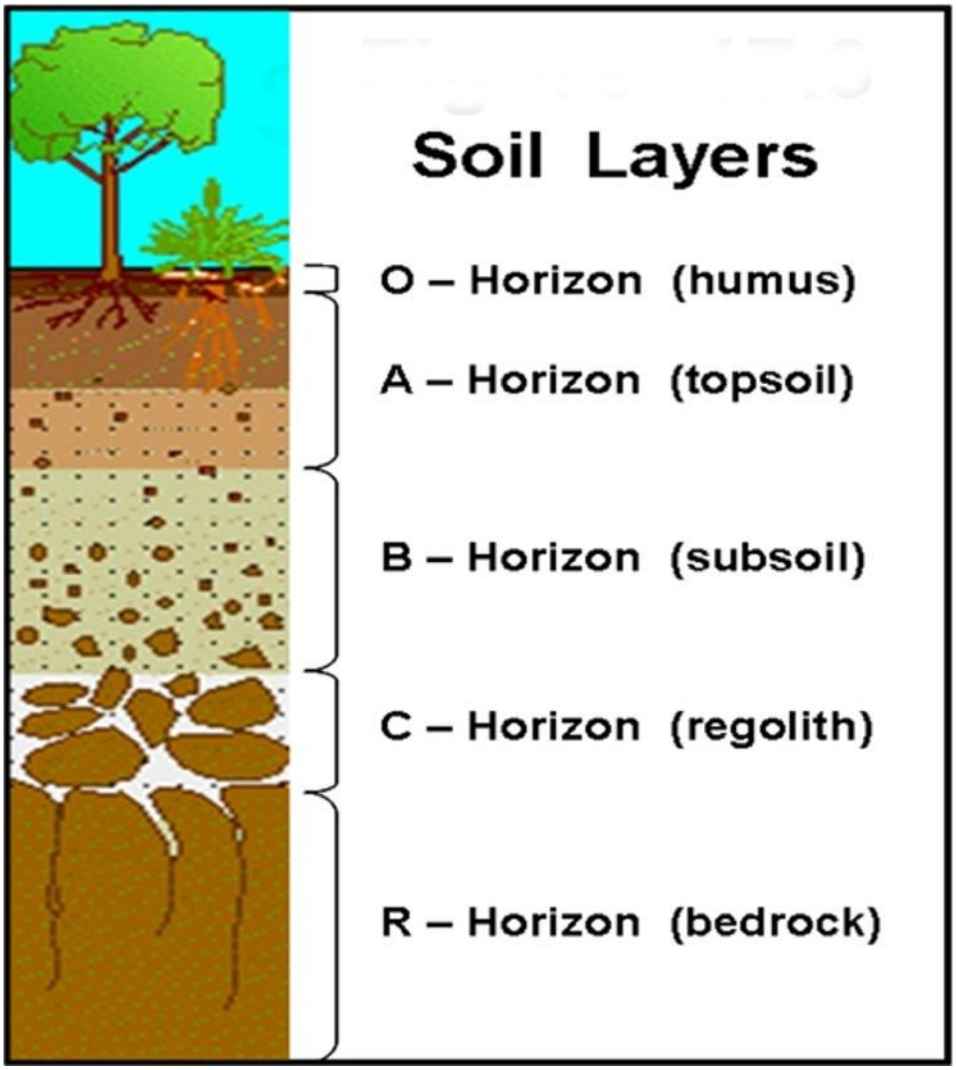
Soil profile information and pit excavation, as described in these design criteria, are additional requirements deemed necessary to properly assess an area's suitability for surface spray irrigation.

16.2.3 Soil Definitions

Soil Horizons (layers): Soil is made up of distinct horizontal layers; these layers are called horizons and display vertical zones. They range from rich, organic upper layers (humus and topsoil) to underlying rocky layers (subsoil, regolith and bedrock).

Soil horizons develop due to the nature of soil formation. Soil is the product of the weathering of parent material (i.e. bedrock), accompanied by the addition of organic matter. The method for naming the soil horizons is quite simple as the **Figure 16.1** shows. In the simplest naming system, soils horizons are designated **O** (organic), **A** (topsoil), **B** (mineral soil), **C** (weathered parent material), and **R** is the unweathered rock (bedrock) layer that is beneath all the other layers. The horizons of most importance to plant growth and forest health are the **O** and **A horizons**. The **litter layer** found covering the soil is also of interest because it provides most of the organic matter found in the O and A horizons.

FIGURE 16.1



The **Litter Layer** is the topmost layer on the forest floor. It consists of leaves, needles and other non-decomposed material on the forest floor. While this is not considered part of the soil, it is interesting to measure the depth of the litter layer when sampling the soil. The depth of the litter layer can vary greatly even within a particular site. Because of this, several measurements are required to attempt to characterize litter layer depth. The litter layer can be considered part of the overall soils depth.

The **O-Horizon** primarily consists of decomposed organic matter and has a dark rich color, increased porosity, and increased aggregate structure (larger soil "clumps"). The depth of the O horizon is measured from the surface of the soil (after the litter layer has been cleared away) to the point where the darker organic color changes to a slightly lighter colored soil that contains increased mineral particles in addition to organic matter.

The transition from the O to the A horizon can also be recognized by a significant increase in the mineral soil particles. In many urban soils, the O horizon may very thin if it exists at all. The O horizon can also be considered part of the overall soils depth.

The **A-Horizon** is the **mineral** “topsoil” and consists of highly weathered **parent material** (rocks), which is somewhat lighter in color than the O horizon due to a decrease in **organic matter**. The particles in the A horizon are more granular and “crumb-like”. Seeds germinate and plant roots grow in this layer. It is made up of humus (decomposed organic matter) mixed with mineral particles. The depth of the A horizon is measured from the region of color changes from the dark O horizon to the transition to the B horizon. The transition to the B horizon can be identified by increased clay content (see below) and the absence of organic material: no root hairs, small pieces of needle, etc.

The most thorough soil study involves analysis on separate O and A horizon samples. This requires separating and storing O and A horizon samples. It also involves completing the entire soil analysis on both the O and A samples. If this is not possible, the O and A samples can be combined (or composited) and the analysis can be completed on the O and A sample together.

The **B-Horizon** is also called the **subsoil** - this layer is beneath the A horizon and above the C horizon. It contains clay and mineral deposits (like iron, aluminum oxides, and calcium carbonate) that it receives when soil solution containing dissolved minerals drips from the soil above.

The B horizon is identified by increased clay content which makes the soil hold together when moist. A simple test for clay content is to moisten a small handful of soil and attempt to smear a small portion up the forefinger. Soils high in clay will hold together and form a “ribbon”, soils with more sand and silt will be granular and fall apart. It is lighter in color and often may be reddish due to the iron content.

The **C Horizon** (layer beneath the B Horizon) consists of porous rock (broken-up bedrock, bedrock with holes). It is also called regolith or **saprolyte** which means "rotten rock." Plant roots do not penetrate into this layer; very little organic material is found in this layer.

The **R-Horizon** is the unweathered rock (bedrock) layer that is beneath all the other layers. For the purposes of drip dispersal designs, the R horizon is considered an impermeable layer.

Water Pollution Control (WPC) Soils Map. A first order survey as defined in the Soil Survey Manual, United States Department of Agriculture, October 1993.

These surveys are made for various land use that requires detailed soils information.

Map scale should be one (1) inch equals one hundred (100) feet or a scale that will allow the map to fill a 24” x 36” plan sheet. These maps should have adequate cartographic detail to satisfy the requirements of project. The WPC Soils Map is essentially a special map that shows a very high degree of soil and landscape detail. Baseline mapping standards for these WPC Soil Maps prepared in support of surface spray irrigation should be a first order survey in accordance with the current edition of the Soil Survey Manual, United States Department of Agricultural, October 1993. Soil profile information and pit excavation, as described in these design criteria are additional requirements deemed necessary to properly assess an area’s suitability for surface spray irrigation. These maps should be clearly marked or labeled as “Water Pollution Control Soil Map”.

Soil map unit. A unique collection of areas that have common soil characteristics and/or miscellaneous physical and chemical features.

Soil scientist. A person having the experience and education necessary to measure soil properties and classify soils per *Soil Taxonomy*, synonymous with the term “soil consultant”.

Soil series. A group of soils having similar properties; the lowest level of soil classification.

Most limiting horizon. A horizon in the soil (bedrock or fragipan) that either provides the greatest impediment to or completely stops, the downward movement of liquids through the soil.

16.3 Preapplication Treatment Requirements

16.3.1 General

Wastewater spray irrigation systems have a demonstrated ability to treat high strength organic wastes to low levels. However, such systems require a high degree of management with particular attention paid to organic loading rates and aeration of the soil profile between wastewater applications.

The Division of Water Pollution requires that all domestic and municipal wastewaters receive biological treatment prior to irrigation.

This is necessary to:

a. Protect the health of persons contacting the irrigated wastewater.

b. Reduce the potential for odors in storage and irrigation.

Some industrial wastewaters may be suitable for direct land treatment by irrigation under intensive management schemes. The Division of Water Pollution Control will evaluate such systems on a case-by-case basis.

16.3.2 BOD and TSS Reduction, and Disinfection

Preapplication treatment standards for domestic and municipal wastewaters prior to storage and/or irrigation are as follows:

a. Sites Closed to Public Access

All wastewater must be treated to a level afforded by lagoons which are designed in accordance with Chapter 9.

Disinfection is generally not required for restricted and fenced access land treatment sites. The Division of Water Pollution Control may, however, require disinfection when deemed necessary.

b. Sites Open to Public Access

Sites open to public access include golf courses, cemeteries, green areas, parks, and other public or private land where public use occurs or is expected to occur. Wastewater that is spray irrigated on public access sites must not exceed a 5-day Biochemical Oxygen Demand and Total Suspended Solids of 30 mg/L, as a monthly average. Disinfection to reduce E. coli bacteria to 23 colonies/100 mL is required.

The preapplication treatment standards for wastewater that is to be applied to public access areas will be reviewed by the Division of Water Pollution Control on a case-by-case basis. More stringent preapplication treatment standards may be required as the Division of Water Pollution Control deems necessary. The Division of Water Pollution Control recommends that the engineer give preference to pretreatment systems that will provide the greatest degree of reliability.

16.3.3 Treatment and Storage Ponds

The storage pond and irrigation pump station must be hydraulically separate from the treatment cells (i.e., pumping must not affect hydraulic detention time in these cells). The Division of Water Pollution Control recommends the use of Chapter 9 of the Design Criteria for Sewage Works, as well as the United States Environmental Protection Agency's October 1983 Design Manual: Municipal Wastewater Stabilization Ponds as a reference for design of preapplication treatment ponds.

16.4 Inorganic Constituents of Treated Wastewater

Inorganic constituents of effluent from preapplication treatment should be compared with Table 16-2 to insure compatibility with land treatment site soils and cover crops.

Table 16-2

Recommended Values for Inorganic Constituents in Wastewater Surfaced Applied to Land

Potential Problem and Constituent	No Problem	Increasing Problem	Severe Problem
pH (Standard Units)	6.5 – 8.4		<5.0 or >9.0
Permeability			
Electrical Conductivity (mho/cm)	>0.50	<0.50	<2.0
Sodium Adsorption Ratio (a)	<5.0	5.0 – 9.0	>9.0
Salinity			
Electrical Conductivity (mho/cm)	<0.75	0.75 – 3.0	>3.0
Anions:			
Bicarbonate (meq/L)	<1.5	1.5 – 8.5	>8.5
(mg/L as $CaCO_3$)	<150	150 – 850	>850
Chloride (meq/L)	<3.0	3.0 – 10	>10
(mg/L)	<100	100 – 300	>300
Fluoride (mg/L)	<1.8		
Cations:			
Ammonia (mg/L as N)	<5.0	5.0 – 30	>30
Sodium (meq/L)	<3.0	3.0 – 9.0	>9.0
(mg/L)	<70	70 or greater	
Trace Metals (mg/L)			
Aluminum	<10		
Arsenic	<0.2		
Beryllium	<0.2		
Boron	<0.5	0.5 – 2.0	>2.0
Cadmium	<0.02		
Chromium	<0.2		
Cobalt	<0.1		
Copper	<0.4		
Iron	<10		
Lead	<10		
Lithium	<2.5		
Manganese	<0.4		
Molybdenum	<0.02		
Nickel	<0.4		
Selenium	<0.04		
Zinc	<4.0		

(a) Sodium Adsorption Ratio (SAR) = $$\frac{Na^{+1}}{SQR\ (Ca^{+2} + Mg^{+2}) / 2}$$

Where, Na+1, Ca+2, and Mg+2 in wastewater are expressed in milliequivalents per liter(meq/L).

SQR represents “Square Root of”

16.5 Protection of Irrigation Equipment

Prior to pumping to the spray field distribution system, the wastewater must be screened to remove fibers, coarse solids, oil and grease which might clog distribution pipes or spray nozzles. As a minimum, screens with a nominal diameter smaller than the smallest flow opening in the distribution system should be provided. Screening to remove solids greater than one-half (½) the diameter of the smallest sprinkler nozzle is recommended by some sprinkler manufacturers. The planned method for disposal of the screenings must be provided.

Pressurized, clean water for backwashing screens should be provided. This backwash may be manual or automated. Backwashed screenings should be captured and removed for disposal. These screenings should not be returned to the storage pond(s) or preapplication treatment system.

16.6 Determination of Design Application Rates

16.6.1 General

One of the key steps in the design of a spray irrigation system is to develop a "design application rate" in gallons per day per square foot (GPD/SF). This value is derived from either the hydraulic (water) loading rate (Lwh) based upon the most restrictive of (1) the NRCS hydraulic conductivity data and the texture and structure (per Table 16-1), or (2) the nutrient (nitrogen) loading rate (Lwn) calculations to determine design wastewater loading(s) and, thus, spray irrigation field area requirements.

16.6.2 Design Values

The most limiting horizon, of each soil series shall be identified. Any surface condition which limits the vertical or lateral drainage of the soil profile shall also be identified. Examples of such conditions are shallow bedrock, a high water table, aquitards, and extremely anisotropic soil permeability. Design considerations relative to the soils per Section 16.1.5 must be used.

Sites with seasonal high groundwater less than twenty-four (24) inches deep may require drainage improvements before they can be utilized for spray irrigation land treatment. The design hydraulic conductivity at such sites is a function of the design of the drainage system.

16.7 Determination of Design Wastewater Loading

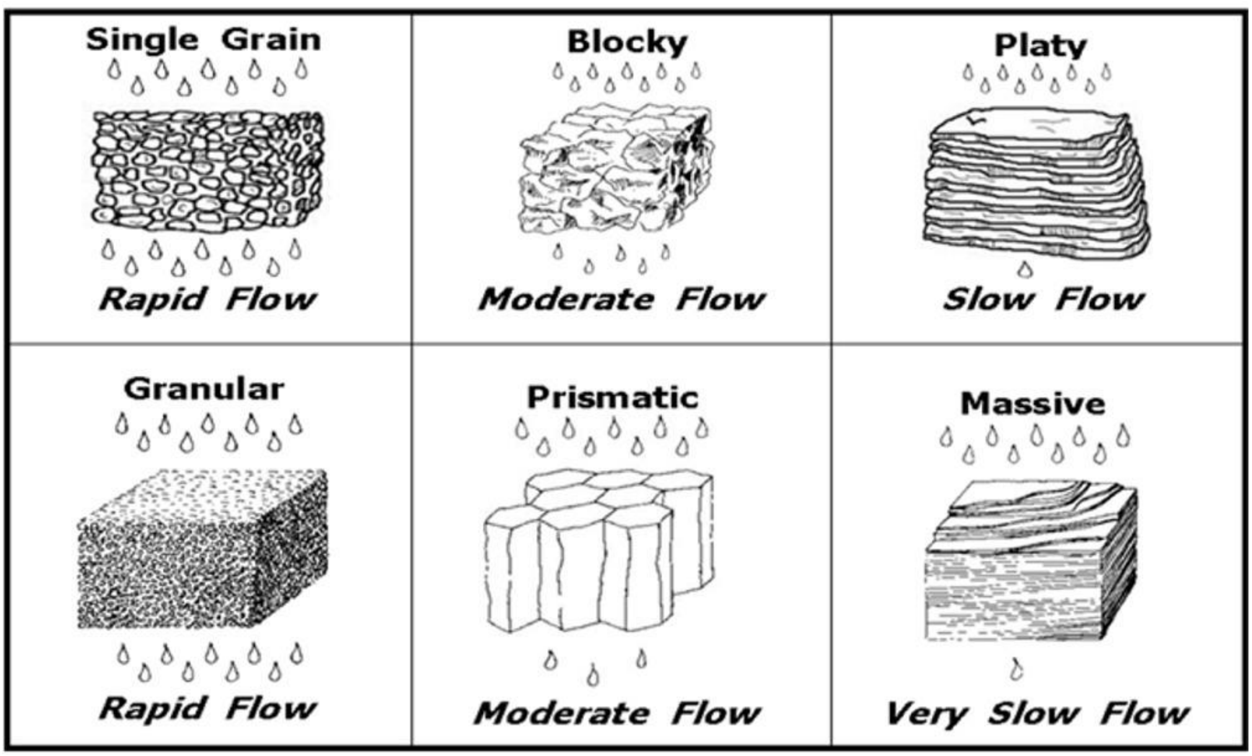
16.7.1 General

The design wastewater loading is a function of:

a. Precipitation.
b. Evapotranspiration.
c. Design hydraulic conductivity rate.
d. Nitrogen loading limitations.
e. Other constituent (i.e., organic/BOD) loading limitations.
f. Groundwater and drainage conditions.
g. Average and peak design wastewater flows.
h. Soil denitrification rates
i. Rate of nitrogen uptake in site vegetation

Therefore, developing the design wastewater loading is an interative process. The Lwh value is determined by a detailed site evaluation and will be dependent upon the soil characteristics as shown in Table 16-1 and pictorially represented in **Figure 16.2**. This loading is then compared to the Lwn loading limitations (reference Section 16.8). If the initial Lwh value exceeds the Lwn value, the design wastewater loading resulting from the nitrogen reduction evaluation described in Section 16.8 becomes the design loading rate.

FIGURE 16.2



16.8 Nitrogen Loading and Crop Selection and Management

16.8.1 General

Nitrate concentration in percolate from wastewater spray irrigation systems will be limited via a State Operation Permit (SOP) to not exceed 10 mg/L nitrate-nitrogen at the site property line. Percolate nitrate concentration is a function of nitrogen loading, cover crop, and management of vegetation and hydraulic loading. The design wastewater loading determined from using the criteria stipulated in 16.1.5 for hydraulic loading rates must be checked against nitrogen loading limitations.

16.8.2 Nitrogen Loading

In some instances, the amount of wastewater that can be applied to a site may be limited by the amount of nitrogen in the wastewater. A particular site may be limited by the nitrogen content of the wastewater during certain months of the year and limited by the infiltration rate during the remainder of the year.

16.8.3 Organic / BOD Loading

When wastewater is high strength (above 150 mg/L BOD), the organic loading rate should be limited as follows based upon the soil:

10,000 pounds of BOD per acre per year for Clays.

15, 000 pounds of BOD per acre per year for Loams.

20,000 pounds of BOD per acre per year for Sandy.

(Reference: Dr. Robert Rubin, NC State University, who cited work by Phillips and Carlile)

Equation 16-1 is used to calculate, on a monthly basis, the allowable hydraulic loading rate based on nitrogen limits:

(**Equation 16-1)**

$$\mathbf{Lwn} = \frac{Cp\,(Pr - PET) + U(4.413)}{(1 - f)(Cn) - Cp}$$

Where:

Lwn = allowable monthly hydraulic loading rate based on nitrogen limits, inches/month

Cp = nitrogen concentration in the percolating wastewater, mg/L.

This will usually be 10mg/L Nitrate-Nitrogen

Pr = Five-year return monthly precipitation, inches/month

PET = potential evapotranspiration, inches/month

U = nitrogen uptake by cover, lbs/acre/year pounds/acre/year

(value should not exceed 100 lbs/acre/year)

Cn = Nitrate-Nitrogen concentration in applied wastewater, mg/L

(after losses in preapplication treatment)

F = fraction of applied nitrogen removed by denitrification and volatilization.

The values of ***Lwh*** and ***Lwn*** are compared for each month.

The lesser of the two values will be used to determine the amount of acreage needed.

NOTES:

- A "**Cn**" value of less than 23 mg/L will become a permit condition.
- The allowable vegetative uptake "**U**" of nitrogen on the drip area will be limited to an uptake rate of 100 pounds per acre per year unless trees are the vegetation.
- The "**f**" values for denitrification have been estimated based upon data supplied by the University of Tennessee and Oak Ridge National Laboratory. Denitrification rates (f) ranging from 25% in January and February to 35% in July and August are very conservative, but are defendable based upon the literature. Denitrification rates are assumed to vary linearly with the temperature and the actual rates are likely to be higher than the default values shown in Table 16-1.
- Conversion Factor - **4.413** mg-acre-inch/liter-lb. The equation and factor are from the TDHE Design Criteria for Sewage Works (April 1989).

The factor comes from assuming that one pound of contaminant of concern is diluted within a volume of water equal to one acre-inch. For Example calculation see Chapter 17, Appendix 17-A. For the derivation of this factor see Chapter 17, Appendix 17-C.

Table 16-2 shows the default values for Lwn calculations. Other values may be used provided adequate rationale and documentation is presented to, and approved by the Division of Water Pollution Control.

TABLE 16-2

MONTH	Pr(1) Inches / Month	PET(2) Inches / Month	N Uptake(3) Percent / Month	f Denitrification(4) Percent / Month
JAN	7.62	0.10	1%	25%
FEB	6.72	0.27	2%	25%
MAR	8.85	0.97	4%	27%
APR	6.59	2.30	8%	29%
MAY	6.13	3.59	12%	31%
JUN	5.52	4.90	15%	33%
JUL	6.85	5.44	17%	35%
AUG	4.73	5.00	15%	35%
SEP	5.54	3.79	12%	34%
OCT	4.47	1.98	8%	32%
NOV	6.11	0.82	4%	29%
DEC	7.55	0.27	2%	26%

(1) Based upon Table A-3 – 5-year return monthly precipitation

(2) Based upon Table A-2 – Potential Evapotranspiration

(3) Based upon Table A-5 – Monthly Nitrogen Uptake by Vegetation

(4) Applied Nitrogen Fraction Removed by Denitrification / Volatilization

Note: Appendix 16-B shows Equation 16-1, using the default values.

16.8.4 Cover Crop Selection and Management

Row crops may be irrigated with wastewater via spray irrigation only when not intended for direct human consumption. Livestock must not be allowed on wet fields so that severe soil compaction and reduced soil infiltration rates can be avoided. Further, wet grazing conditions can also lead to animal hoof diseases. Pasture rotation should be practiced so that wastewater spray application can be commenced immediately after livestock have been removed. In general, a pasture area should not be grazed longer than 7 days. Typical regrowth periods between grazings range from 14 to 35 days. Depending on the period of regrowth provided, one to three spray applications can be made during the regrowth period. At least 3 to 4 days drying time following an application should be allowed before livestock are returned to the pasture. Unmanaged, volunteer vegetation (i.e., weeds) is not an acceptable spray irrigation field cover. Disturbed areas in forest systems must be initially grassed and replanted for succession to forest.

Spray irrigation field cover crops require management and periodic harvesting to maintain optimum growth conditions assumed in design. Forage crops should be harvested and removed several times annually. Pine forest systems should be harvested at 20 to 25 year intervals. Hardwood forest systems should be harvested at 40 to 60 years. It is recommended that whole tree harvesting be considered to maximize nutrient removal. However, wastewater spray irrigation loadings following the harvesting of forest systems must be reduced until the hydraulic capacity of the site is restored. Spray field area to allow for harvesting and the regeneration cycle should be considered by the design engineer.

While high in nitrogen and phosphorus, domestic and municipal wastewaters are usually deficient in potassium and trace elements needed for vigorous agronomic cover crop growth. High growth rate forage crops such as Alfalfa and Coastal Bermuda will require supplemental nutrient addition to maintain nitrogen uptake rates assumed in design. Industrial wastewaters considered for irrigation should be carefully evaluated for their plant nutrient value.

16.9 Land Area Requirements

16.9.1 General

The land area to which wastewater is spray irrigated is termed a "field". The total land requirement includes not only the field area, but also land for any preapplication treatment facilities, storage reservoir(s), buffer zone, administration/maintenance structures and access roads. Field and buffer zone requirements are addressed in this Section. Land area for storage reservoirs is discussed in Section 16.10. All other land requirements will be dictated by standard engineering practices and will not be addressed in this document.

16.9.2 Field Area Requirements

The area required for the field is determined by using the following equation:

$$A = \frac{(Q_y + V)C}{Lwd} \qquad \textbf{(Eq. 16-2)}$$

Where:

A = Field area, acres

Q_y = Flow, MG per year

V = Net loss or gain in stored wastewater due to precipitation, evaporation and/or seepage at the storage reservoir, gallons per day

Lwd = Design hydraulic loading rate, in/year

$$C = \frac{1{,}000{,}000 \text{ gal}}{\text{MG}} \times \frac{\text{ft}^3}{7.48 \text{ gal}} \times \frac{12 \text{ in}}{\text{ft}} \times \frac{\text{acre}}{43{,}560 \text{ ft}^2} = 36.83$$

The first calculation of the field area must be made without considering the net gain or loss from the storage reservoir. After the storage reservoir area has been calculated, the value of V can be completed. The final field area is then recalculated to account for V. The Appendix includes the use of Equation 16-2.

16.9.3 Buffer Zone Requirements

The objectives of buffer zones around land treatment sites are to control public access, improve project aesthetics and, in case of spray irrigation, to minimize the transport of aerosols. Since development of off-site property adjacent to the treatment site may be uncontrolable, the buffer zone must be the primary means of separating the field area from off-site property. Table 16-3 gives minimum widths of buffer zones for varying site conditions:

Table 16-3

On-Site Buffer Zone Requirements

	SURFACE SPREAD	SPRINKLER SYSTEMS (Edge of Impact Zone)	
		Open Fields	Forested
Site Boundaries	100 Feet	300 Feet	150 Feet
On-Site streams, ponds and roads	50 Feet	150 Feet	75 Feet

16.10 Storage Requirements

16.10.1 General

The design of a wastewater spray irrigation land application system must take into account that wastewater application will be neither continuous nor constant. Provisions must be made for containing wastewater when conditions exist such that either wastewater cannot be applied or when the volume of wastewater to be applied exceeds the maximum application rate. The minimum storage requirement should be sixty (60) days at design flow unless engineering rationale can be presented and approved by the Division of Water Pollution Control that justifies less storage capacity.

The storage requirement may be determined and/or evlauted by either of two methods. The first method involves the use of water balance calculations and is illustrated in Appendix A. The second method involves the use of a computer program that was developed based upon an extensive NOAA study of climatic variations throughout the United States. The program entitled EPA-2 would probably be the most appropriate of the three programs available. For information on the use of the computer program, contact the National Climatic Center of NOAA at (704) 259-0448.

16.10.2 Estimation of Storage Requirements Using Water Balance Calculations

The actual wastewater that is available is compared to the actual amount that can be applied. Any excess wastewater must be stored. The actual wastewater volume must be converted to units of depth for that comparison. Equation 16-3 will be used:

$$Wp = \frac{Qm \times C}{Ap} \qquad (\textbf{Eq. 16-3})$$

Where:

Wp = depth of wastewater, in inches

Qm = volume of wastewater for each month of the year, in million gallons

$$C = \frac{1{,}000{,}000\ gd}{MG} \times \frac{ft^3}{7.48\ gal} \times \frac{acre}{43{,}560\ ft^2} \times \frac{12\ in}{ft} = 36.83$$

Ap = field area, in acres

The months in which storage is required are cumulated to determine the maximum amount of total storage needed. The use of the method is illustrated in Appendix A.

The maximum storage amount in inches, over the field area, is converted to a volume, in cubic feet. A suitable depth is chosen and a storage basin surface area is calculated.

This storage basin will be affected by three factors: precipitation, evaporation and seepage. These three factors are determined and the result is V, which is then introduced back into equation 16-2. A new, final field area is calculated and a corresponding new storage volume is determined.

In Tennessee, the maximum seepage is 1/4 inch per day. This amount can be used unless the storage basin will be constructed so that a lesser seepage rate will result. In some cases, where an impervious liner will be constructed, the seepage rate will be zero.

16.11 Distribution System

16.11.1 General

The design of the distribution system is a critical aspect of the land application. The field area and the storage volume were derived with the assumption that wastewater would be evenly distributed. For high strength wastes or wastes with high suspended/settleable solids, sprinkler applications are preformed. Sprinklers will distribute these wastes more evenly over the treatment area whereas surface application may result in accumulation of solids and odors near the application point.

16.11.2 Surface Spreading

With surface spreading, wastewater is applied to the ground surface, usually by perforated pipe or by an irrigation-type ditch, and flows uniformly over the field by gravity. The uniform flow is critically dependent upon a constant slope of the field, both horizontal and perpendicular to the direction of flow. Several other factors are of importance:

a. Uniform distribution cannot be achieved on highly permeable soils. The wastewater will tend to percolate into the soil that is nearest to the point of application.

b. A relatively large amount of wastewater must be applied each time so that wastewater will reach all portions of the field.
The dosing must account for the fact that the field area nearest the point of application will be wetted for a longer period of time and, thus, will percolate more wastewater.

c. Erosion and/or runoff may be a problem. Since a surface discharge will not be allowed to occur, a return system may be necessary.

16.11.3 Sprinkler Spreading

Sprinkler systems can be classified into one of three general categories:
(1) solid set, (2) portable and (3) continuously moving.

The following factors should be considered during design:

a. The hydraulic conditions within the distribution system must be given a thorough review. Head losses through pipes, bends, nozzles, etc., must be balanced so that the wastewater is uniformly applied to the field.

b. Design must consider the effects of cold weather. Nozzles, risers, supply pipes, etc., must be designed to prevent wastewater from freezing in the various parts.

c. Wind can distort the spray pattern. Also, aerosols may be carried off the field area. A properly designed buffer zone should alleviate most of the aerosol problems. Also, the O&M manual can include a provision which would prevent spraying when the wind velocity is high enough to carry wastewater off the field area.

d. Crop selection is important. The higher humidity level may lead to an increase in crop disease.

e. Higher slopes can be used than in surface spreading. Also, slopes do not need to be constant. Further, the type of crop is nearly unlimited. Forests can be irrigated

with solid set sprinklers. Forage crops can be irrigated with any of the three basic types of systems.

f. The system layout must take into consideration the method that will be used for harvesting the crop.

16.12 Spray Irrigation of Wastewater from Gray Water Facilities

16.12.1 General

This Section provides criteria for facilities that produce a "gray water" wastewater. These facilities include coin-operated laundries, car washes and swimming pool backwash filters.

Wastewater disposal requirements are not as complex as are those for domestic wastewater. An engineering report which provides information on the design of the facilities must be submitted to the Division of Water Pollution Control.

16.12.2 Site Location

16.12.2.1 The Division of Water Pollution Control must inspect and approve the proposed site prior to <u>any</u> construction being undertaken.

16.12.2.2 The site must be chosen such that the operation of the system will not affect surrounding property owners. No surface runoff or stream discharge will be allowed.

16.12.3 Design Flow

Since these are service enterprises, the amount of wastewater that is generated is directly related to the desire of people to use the facilities. Thus, an estimate of the number of potential users (and frequency) is extremely important.

Various factors must be taken into consideration:

a. A rural setting would tend to have a shorter daily usage period than would an urban location.

b. An area that is predominately single-family houses would tend to have a lesser usage rate for laundries and car washes than would an area with apartment complexes.

c. The amount of water that washing machines use will vary among manufacturers and models. The Division recommends the use of water-saving machines.

The design engineer should use 250 gpd/washer for laundries and 700 gpd/bay for car washes unless more reliable data is available.

16.12.4 Pretreatment

16.12.4.1 General

Facilities that produce gray water have different pretreatment requirements, designed not only to the type of facility but also to the specific establishment.

16.12.4.2 Laundries

a. All laundry wastewater (does not include sanitary wastes) shall pass through a series of lint screens.
   A series will consist of five screens, starting with a screen with 1-inch mesh and ending with a screen that is basically equivalent to a window screen.

b. Since some detergents produce a wastewater with a pH in the range of 11.0 to 11.5, some type of pH adjustment may be necessary. This may occur as a retrofit if the vegetation in the spray plots is being stressed by the high pH.

c. Disinfection will generally not be required unless the operation of the facilities will result in a potential hazard to the public. The need for disinfection will be determined by the Division of Water Pollution Control on a case-by-case basis.

16.12.4.3 Car Washes

a. All car wash wastewater shall pass through a grit removal unit. The flow-through velocity shall be less than 0.5 feet per second. The grit removal unit shall be constructed to facilitate the removal of grit.

b. The use of detergents with a neutral (or nearly neutral) pH is recommended. The use of high-pH detergents may require neutralization if the vegetation is being stressed by the high pH.

16.12.4.4 Swimming Pools

a. A holding tank/pond shall be provided to receive the backwash water from the swimming pool filters. The solids shall be allowed to settle to the bottom before the supernatant is removed for disposition on the spray plots.

b. Dechlorination may be required if the vegetation on the plots is being stressed by the chlorine in the water.

c. If the entire pool volume is to be emptied, by using the spray plots, the rate shall be controlled so as to not exceed the application rate that is specified in Section 16.7.

16.12.5 Field Requirements

16.12.5.1 The maximum wastewater that can be sprayed on a site is based either on the nitrogen content of the wastewater or an amount equal to 10% of the infiltration rate of the most restrictive layer of soil which shall be determined by the design engineer with input from a qualified soil scientist.

16.12.5.2 The application of wastewater shall alternate between at least two separate plots. Each plot shall not receive wastewater for more than three consecutive days and must have at least three days rest between applications. Reserve land area of equivalent capacity must be available for all gray water systems.

16.12.5.3 Ground slopes shall not exceed 30%. Extra precautions must be taken on steep slopes (15-30%) to prevent runoff and erosion.

16.12.5.4 The field shall be covered with a good lawn or pasture grass unless an existing forested area is chosen. The ground cover should be a sturdy perennial that will resist erosion and washout. Forested areas should be chosen so that installation of sprinkler equipment will not damage the root systems of the trees and will not produce runoff due to the usual lack of grass in forested areas.

16.12.6 Application Equipment

16.12.6.1 Sprinklers shall be of a type and number such that the wastewater will be evenly distributed over the entirety of a plot. Information on sprinklers shall be included in the engineering report. In forest plots, sprinklers shall be on risers which shall be tall enough to allow the wastewater to be sprayed above the undergrowth. Sprinklers shall be of the type that are not susceptible to clogging.

16.12.6.2 All piping (excluding risers) shall be buried to a depth that will prevent freezing in the lines. An exception to this burial requirement can be made in the case where piping will be laid in forested areas. Burial in this case may be difficult, expensive and may kill some trees. All risers shall be designed such that wastewater will drain from them when wastewater is not being pumped. This can be accomplished by either draining all lines back into the pump sump or by placing a gravel drain pit at the base of each riser. Each riser would necessarily be equipped with a weep hole. Particular attention

must be given during the design so that the entire subsurface piping does not drain into these pits.

16.12.6.3 The engineering report must contain hydraulic calculations that show that each nozzle distributes an equivalent amount of wastewater. Differences in elevation and decreasing pipe sizes will be factors which need to be addressed.

16.12.6.4 The piping must be of a type that will withstand a pressure equal to or greater than 1-1/2 times the highest pressure point in the system. The risers should be of a type of material such that they can remain erect without support. The pipe joints should comply with the appropriate ASTM requirements. Adequate thrust blocks shall be installed as necessary.

16.12.6.5 A sump shall be provided into which the wastewater will flow for pumping to the spray plots. The pump can be either a submersible type, located in the sump, or a dry-well type, located immediately adjacent to the sump in a dry-well. The pump shall be capable of pumping the maximum flow that can be expected to enter the sump in any 10-minute period. The pump shall be operated by some type of float mechanism. The float mechanism shall activate the pump when the water level reaches 2/3 of the depth of the sump and should de-activate the pump before the water level drops to the point to where air can enter the intake.

If the distribution system is designed to drain back into the sump, the sump shall be enlarged to account for that volume.

If desired, the sump for laundries can also contain the lint screens. The screens shall, in any case, be constructed so that they cannot be bypassed. They shall be built so that they can be easily cleaned. A container shall be provided for disposal of the lint which is removed from the screens.

16.12.6.6 The pipe from the facility to the sump shall be large enough to handle the peak instantaneous flow that could be realistically generated by the facility. Flow quantities, head loss calculations, etc., shall be included in the engineering report.

16.12.7 Operation of System

16.12.7.1 The operator shall insure that wastewater is applied to alternate plots on a regular basis.

16.12.7.2 Monthly operating reports shall be submitted to the appropriate field office of the Division of Water Pollution Control. The parameters to be reported shall be delineated by field office personnel but should include, as a minimum, dates of spray plot alternation.

16.12.7.3 The owner of the system shall apply for and receive an operating permit from the Division of Water Pollution Control prior to initiation of operation of the system.

16.12.7.4 The system operator shall inspect and maintain the pump and sprinklers in accordance with manufacturer's recommendations. An operations manual shall be located at the facility for ready reference.

16.12.7.5 The operator shall inspect the wastewater facilities on a regular basis. The inspection shall include the spray plots to determine whether or not runoff and/or erosion are or have occurred, the spray patterns of the sprinklers, the physical condition of the system (looking for damage due to adverse pH conditions, etc.)

16.12.7.6 The spray plots shall be mowed on a regular basis to enhance evapotranspiration. Grass height shall not exceed 6-inches.

16.12.7.7 The lint screen at laundries shall be cleaned on a schedule that is frequent enough to prevent upstream problems due to head loss through the screens. Disposition of the lint shall be in accordance with applicable requirements.

16.12.7.8 The grit traps at car washes shall be cleaned at a frequency that is sufficient to keep the trap in its designed operating condition.

16.12.7.9 If the car wash is equipped with an automatic wax cycle, the operator shall be especially attentive to the possibility of wax build-up on the sump, pump and all downstream piping.

16.12.7.10 The operator shall insure that the car wash facility is not used as a sanitary dumping station for motor homes or for washing trucks/trailers that are used for hauling livestock. If necessary, the facility shall be posted with signs which clearly indicate this prohibition.

16.12.7.11 The sludge holding tank/pond at a swimming pool facility shall be cleaned at a frequency that is sufficient to prevent solids from being carried over into the pump sump. Cleaning shall be performed in a manner that will minimize re-suspending the solids and allowing them to enter the pump sump.

16.13 Plan of Operation and Management

A Plan of Operation and Management (POM) is required before an Operation Permit (SOP) can be issued. The Plan is written by the owner or the owner's engineer during construction of the slow rate land treatment system. Once accepted by the Division, the Plan becomes the operating and monitoring manual for the facility and is incorporated by reference into the Permit.

This manual must be kept at the facility site and must be available for inspection by personnel from the Tennessee Department of Health and Environment.

This POM should include, but not be limited to, the following information:

16.13.1 Introduction

a. System Description:

1. A narrative description and process design summary for the land treatment facility including the design wastewater flow, design wastewater characteristics, preapplication treatment system and spray fields.

2. A map of the land treatment facility showing the preapplication treatment system, storage pond(s), spray fields, buffer zones, roads, streams, drainage system discharges, monitoring wells, etc.

3. A map of force mains and pump stations tributary to the land treatment facility. Indicate their size and capacity.

4. A schematic and plan of the preapplication treatment sytem and storage pond(s) identifying all pumps, valves and process control points.
5. A schematic and plan of the irrigation distribution system identifying all pumps, valves, gauges, sprinklers, etc.

b. Discuss the design life of the facility and factors that may shorten its useful life. Include procedures or precautions which will compensate for these limitations.

c. A copy of facility's State Operation Permit.

16.13.2 Management and Staffing

a. Discuss management's responsibilities and duties.

b. Discuss staffing requirements and duties:

1. Describe the various job titles, number of positions, qualifications, experience, training, etc.

2. Define the work hours, duties and responsibilities of each staff member.

16.13.3 Facility Operation and Management

a. Preapplication Treatment System:

1. Describe how the sytem is to be operated.

2. Discuss process control.

3. Discuss maintenance schedules and procedures

b. Irrigation System Management:

1. Wastewater Application.

Discuss how the following will be monitored and controlled.
Include rate and loading limits:

(a) Wastewater loading rate (inches/week)

(b) Wastewater application rate (inches/hour)

(c) Spray field application cycles

(d) Organic, nitrogen and phosphorus loadings (lbs/acre per month, etc)

2. Discuss how the system is to be operated and maintained.

(a) Storage pond(s)

(b) Irrigation pump station(s)

(c) Spray field force main(s) and laterals

3. Discuss start-up and shut-down procedures.

4. Discuss system maintenance.

(a) Equipment inspection schedules

(b) Equipment maintenance schedules

5. Discuss operating procedures for adverse conditions.

(a) Wet weather

(b) Freezing weather

(c) Saturated Soil

(d) Excessive winds

(e) Electrical and mechanical malfunctions

6. Provide troubleshooting procedures for common or expected problems.

7. Discuss the operation and maintenance of back-up, stand-by and support equipment.

c. Vegetation Management:

1. Discuss how the selected cover crop is to be established, monitored and maintained.

2. Discuss cover crop cultivation procedures, harvesting schedules and uses.

3. Discuss buffer zone vegetative cover and its maintenance.

d. Drainage System (if applicable):

1. Discuss operation and maintenance of surface drainage and runoff control structures.

2. Discuss operation and maintenance of subsurface drainage systems.

16.13.4 Monitoring Program

a. Discuss sampling procedures, frequency, location and parameters for:

1. Preapplication treatment system.

2. Irrigation System:

(a) Storage pond(s)

(b) Groundwater monitoring wells

(c) Drainage system discharges (if applicable)

(d) Surface water (if applicable)

b. Discuss soil sampling and testing:

c. Discuss ambient conditions monitoring:

1. Rainfall
2. Wind speed
3. Soil moisture

d. Discuss the interpretation of monitoring results and facility operation:

1. Preapplication treatment system.
2. Spray fields.
3. Soils.

16.13.5 Records and Reports

a. Discuss maintenance records:

1. Preventive.
2. Corrective.

b. Monitoring reports and/or records should include:

1. Preapplication treatment system and storage pond(s).
   (a) Influent flow
   (b) Influent and effluent wastewater characteristics
2. Irrigation System.
   (a) Wastewater volume applied to spray fields.
   (b) Spray field scheduling.
   (c) Loading rates.
3. Groundwater Depth.
4. Drainage system discharge parameters (if applicable).

5. Surface water parameters (if applicable).

6. Soils data.

7. Rainfall and climatic data.

CHAPTER 17

Design Guidelines for Wastewater Dispersal Using Drip Irrigation

DRIP DISPERSAL TREATMENT

17.1 General

17.1.1 General

This chapter provides guidelines and criteria for the design of drip dispersal systems for domestic wastewater effluent treated to a level of secondary treatment. It is not applicable to spray irrigation, overland flow or rapid infiltration. The design engineer should use best professional judgment (BPJ) to produce a system that will be robust and sustainable for many years.

17.1.2 Applicability

Drip dispersal systems are designed and operated to allow the soil to provide final treatment of the wastewater prior to its introduction to groundwater. Dispersal and treatment occurs via physical, chemical and biological processes within the soil and through evapotranspiration and nutrient uptake by plant matter.

The ultimate goal is to create a treatment and dispersal system that will return the treated water to the environment while protecting ground water and surface waters from excessive pollution. Water does not disappear in the soil column, it evaporates into the atmosphere, is used by plants and/or organisms, or moves through the soils to ground water or into water courses. There are many factors to be considered when designing drip dispersal systems, such as the quality of treated effluent being applied, depth of soils, and retention time in the soils before water returns to either ground water or surface water. The development of these guidelines utilized general assumptions, best professional judgment (BPJ) and empirical data.

The infiltrative capacity of soil is a critical factor to be considered when designing any type of subsurface sewage disposal system. However, equal consideration should be given to other factors that control the overall lateral movement of groundwater within the soil profile.

If the profile of a particular soil considered for drip dispersal extended to a significant depth without a restrictive horizon (most limiting layer), the ability to load that soil per unit area would be relatively high. On the other extreme, if a soil being considered for drip dispersal had a shallow restrictive horizon, the ability to load that soil would be lower relative to the deeper soil. Depth to restrictive horizon, soil permeability and slope of the restrictive horizon are factors that control the amount and rate at which ground water can exit an area. If the amount of treated effluent applied to an area, in combination with rainfall over the area and groundwater moving into the area, exceed the soil profile’s ability to transmit the water away from the application area, mounding and runoff will occur.

Evaluation of a soil area’s suitability for drip dispersal should take into consideration limiting aspects of the soil profile. Level sites with shallow restrictive horizons overlain by low permeability soils represent one of the more limited scenarios for drip dispersal and the application rate and/or application area should be suitably modified.

Also critical when designing systems in soils with shallow restrictive horizons are the presence and location of hydrologic boundaries such as drainage ways and waterways.

These hydrologic boundaries provide an outlet for ground water discharge. Not only is it critical to identify these features in consideration of appropriate setbacks/buffers, it is also critical to factor in their role in the overall hydrologic cycle of the landscape.

Horizons along which lateral flow would be expected include, but are not necessarily limited to: bedrock, fragipans, and zones with high clay percentage overlain by more permeable soil.

Drip dispersal design submittals should take into consideration all factors influencing the infiltrative capacity of the soil and the ability of the soil and site to transport ground water away from the application area. It should be noted that the use of historical information from existing systems installed and operated in similar soils, with documented loading rates, landscape positions and design conditions similar to the proposed system may be applicable. Therefore, soils that have been highly compacted and/or disturbed, such as old road beds, foundations, etc., must be excluded when evaluating suitable areas for drip dispersal systems.

17.1.3 Slopes and Buffers

Slopes - Slopes up to and including 50% slope with suitable soils may be considered for drip dispersal. Depending upon the overall shape of the slope (concave, convex or linear on the planar and profile view) the design engineer may have to make adjustments in the aspect ratio of the drip lines on the slope, the loading rate, or both to ensure that all applied effluent will move down gradient and/or into the underlying formations without surfacing. It is important to note that when the proposed drip field area slopes are greater than 30%, the design engineer may need to a obtain a geologic investigation conducted by a geologist or geotechnical engineer evaluating the slip potential of the slope under operating conditions. When slopes increase above 10 percent, wastewater flow down the slope (parallel to the slope) may control the hydraulic design of the system.

For land application areas with slopes between 10 percent and 50 percent and with a restrictive horizon less than 48 inches, the design engineer should calculate the percentage saturation of the soil column at the narrowest portion of the cross-sectional area of the dispersal area perpendicular to the direction of flow. This landscape loading rate analysis will determine the saturation depth at design load and flow of the most restrictive cross-section in the down gradient flow path within and beyond the drip field. The aspect of ratio of the drip field should be adjusted or the loading rate reduced as necessary to ensure that surfacing does not occur.

Buffers - Treatment and dispersal system components should be located so as to protect potable water supplies and distribution systems and surface waters. The design engineer is responsible to identify setbacks on construction drawings. Setbacks from water bodies, water courses, and sink holes will be a function of local subsurface geology and quality of the applied effluent. It is important to note that varying site conditions may require different distances of separation. The distances may increase or decrease as soil conditions so warrant as determined by a qualified professional (engineer, soil scientist, geologist, etc.).

If site buffers are different from Table 17-1, then the design engineer must provide rationale used for the recommended site buffers which must be approved by the Tennessee Department of Environment and Conservation.

TABLE 17-1

	Buffer Distance	
Site Feature	**Septic Tank and /or Dosing Chamber (Feet)**	**Dispersal Field (Feet)**
Wells and Springs	**50**	**50**
Dwellings and Buildings	**5**	**10**
Property Lines	**10**	**10**
Underground Utilities	**10**	**10**
Septic Tank	**NA**	**5**
Gullies, Ravines, Blue Line Streams, Drains Drainways, Cutbanks, and Sinkholes	**25**	**25**
Closed Depressions	*	*
Soil Improvement Practice	**25**	**25**

*To be determined by the design engineer and approved by the Division of Water Pollution Control.

17.1.4 Soils

In general, moderately permeable and well-drained soils are desirable. However, the use of any soil is acceptable if it meets the following four (4) criteria:

1. The applied effluent loading rate does not exceed the applicable hydraulic loading rate in **Table 17-2**. The applicable hydraulic loading rate is determined by a detailed site evaluation in which the site is mapped utilizing soil borings and pits to determine the physical properties of soil horizons and soil map units.
2. The applied effluent maximum loading rate does not exceed 10% of the minimum NRCS saturated vertical hydraulic conductivity (K_{SAT}) for the soil series or 0.25 GPD/SF whichever is least. Note: this may have to be lowered based upon the results of the nutrient loading rate calculation per Section 17.5.2.
3. The soil does not have a restrictive horizon within its top twenty (20) inches.
4. The soil is well drained, or capable of being drained.

TABLE 17-2

Hydraulic Loading Rates (GPD/SF) – For Drip Dispersal Systems

TEXTURE	STRUCTURE		HYDRAULIC LOADING RATE* GPD / SF BOD ≤ 30 mg/L
	SHAPE	GRADE	
Coarse Sand, Loamy Coarse Sand	NA	NA	NA
Sand	NA	NA	NA
Loamy Sand, Fine Sand, Loamy Fine Sand, Very Fine Sand, Loamy Very Fine Sand	Single Grain	Structure less	1.00
Coarse Sandy Loam, Sandy Loam	Massive	Structure less	0.60
	Platy	Weak	0.50
		Moderate, Strong	
	Blocky, Granular	Weak	0.70
		Moderate, Strong	1.00
Loam	Massive	Structure less	0.50
	Platy	Weak, Moderate, Strong	
	Angular, Blocky	Weak	0.60
	Granular, Sub angular	Moderate, Strong	0.80
Silt Loam	Massive	Structure less	0.20
	Platy	Weak, Moderate, Strong	
	Angular, Blocky, Granular, Sub angular	Weak	0.60
		Moderate, Strong	0.80
Sandy Clay Loam, Clay Loam, Silty Clay Loam	Massive	Structure less	
	Platy	Weak, Moderate, Strong	
	Angular, Blocky	Weak	0.30
	Granular, Sub angular	Moderate, Strong	0.60
Sandy Clay, Clay, Silty Clay	Massive	Structure less	
	Platy	Weak, Moderate, Strong	
	Angular, Blocky	Weak	
	Granular, Sub angular	Moderate, Strong	0.30

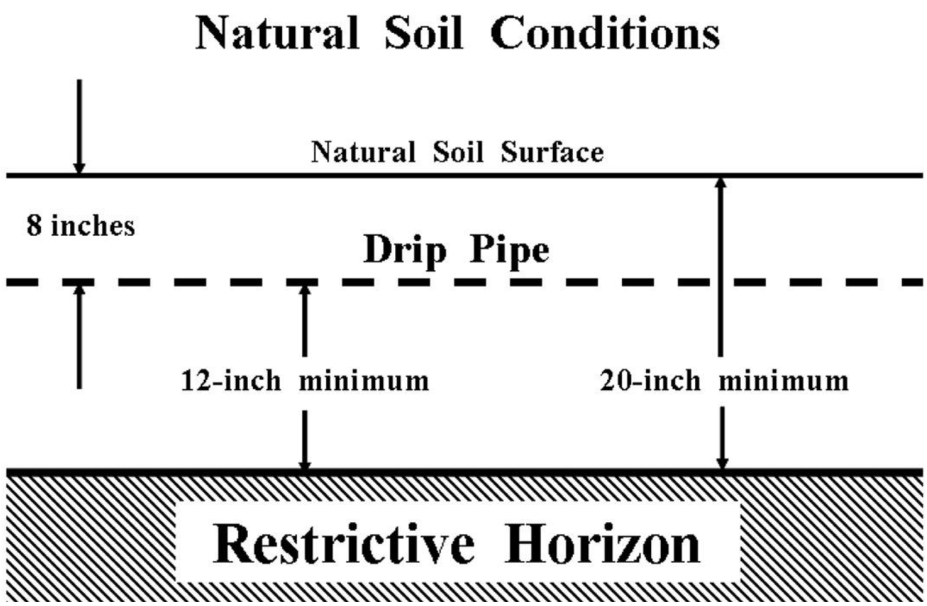
***Maximum allowable hydraulic loading rate is 0.25 GPD/SF; however, all hydraulic loading rates may be adjusted based upon special site specific evaluations approved by TDEC.**

These soils are considered unacceptable for drip dispersal.

Reference: EPA/R-00/08, February 2002, "*Onsite Wastewater Treatment Systems Manual*"

It is desirable to have a minimum depth of twenty (20) inches of undisturbed soil above a restrictive horizon which may need to be increased as slope increases. This is necessary to provide adequate installation depth and buffer below the drip line. (For example, see **Figure 17.1**).

FIGURE 17.1



Even if a soil meets the depth requirements it may not be suitable due to the texture and/or structure. If a soil shows signs of wetness within a depth of 20 inches of the soil surface, it will most likely require a soil improvement practice such as an interceptor or drawdown drain. The location and size of the drains and buffers must be factored into the total area required for the drip dispersal system.

17.1.5 Line Spacing

In an attempt to achieve even distribution of the wastewater and maximum utilization of the soil, it is recommended that the emitter line spacing and emitter spacing be at 2-foot spacing. Depending upon site conditions (soil type, slope and reserve area) the Department of Environment and Conservation may allow spacing to increase to ensure that each emitter supplies a minimum wetted area of not more than ten (10) square feet (i.e., 5-foot line spacing with 2-foot emitter spacing or 10-foot line spacing with 1-foot emitter spacing).

17.1.6 Line Depth

Drip dispersal lines should be placed at depths of six (6) to ten (10) inches below the surface. The drip lines should be laid level and should run with the contour.

17.2 Soil Investigations

17.2.1 General

Preliminary soil investigations should be done to identify areas best suited for subsurface wastewater drip dispersal. The proposed drip dispersal area must be mapped at sufficient accuracy to identify each soils series (or lowest possible level of soil classification) present and the boundary location between series. Once those areas are identified, the more detailed procedures outlined below will be employed. It is required that all soil investigations be performed by a soil scientist currently on the Ground Water Protection list of approved soil scientists/soil consultants.

17.2.2 Soil Mapping

The mapping procedure will usually begin with the property/land being generally evaluated to delineate or separate areas with suitable characteristics. This procedure will save time and money since some areas will be too shallow, too wet, too steep, etc.

Adequate ground control is mandatory for all sites. The ground control is necessary to reproduce the map if needed. All located coordinates (soil map boundaries and pit locations) must be shown on the final Water Pollution Control (WPC) Soils Map.

Soil data collection shall be based upon one, or combination of the following:

1. Grid staking at intervals sufficient to allow the soils scientist to attest to the accuracy of the map for the intended purpose;
2. Mapping of pits and critical auger locations using dual frequency survey grade Global Positioning System (GPS) units.
3. Other controls adequate to map the location of pits, physical features, and separations.
4. Grid stakes and GPS data points must be locatable to within two (2) feet of distance shown.
5. The ground control has to correlate to the exterior boundaries of the property so as to show the location of the soils areas within the bounds of the project and must be certified by a Registered Land Surveyor per TCA 62-18-102(3).

The soil scientists are responsible for conducting a sufficient number of borings that, in their professional opinion, will allow them to certify the soils series (or lowest possible level of soil classification) present, identify boundaries between series, and describe each soil horizon as to color, depth to restrictive horizon, and depth to rock. Any redoximorphic features observed are to be described. This delineation should be based upon the texture and structure of the soils to a depth of forty-eight (48) inches or restrictive horizon whichever is shallower.

After the mapped soils area is established and marked, soil borings to a minimum depth of forty-eight (48) inches or restrictive horizon, whichever is shallowest, shall be taken at sufficient intervals to identify and map the boundaries of the soils series (or lowest possible level of soil classification) present on the site. The exact number and location of borings will be determined by the soils scientist in consultation with the design engineer. Sufficient borings should be made to identify any dissimilar soils accounting for more than 10 percent of the total proposed drip dispersal area.

The soil scientist shall excavate an adequate number of pits to determine the typical profiles and soils characteristics that are expected for all soils mapped. It is recommended that a minimum of two (2) pits per acre in polygons of qualifying soils be excavated; however, the actual number and location of pits will be left to the best professional judgment of the soil scientist. If less than two (2) pits per acre are utilized, the soil scientist must include the rationale in notes on the WPC Soil Map. The pit description must be entered onto a pedon sheet and submitted with the soils map and engineering report. The "Soil Description" should include all of the information contained on form NRCS-Soils-232G (5-86), U.S. Department of Agriculture, Natural Resources Conservation Service (as shown in Appendix D).

In their description of the pit profiles, the soil scientists must describe the soil's structure, texture, color, and any redoximorphic features present. They should also describe root depth and presence of macropores, etc. The series name or lowest possible level of soil classification will be recorded. The depth to hard rock using an auger or a tile probe must be specified if the depth is less than forty-eight (48) inches and estimated if greater than forty-eight (48) inches. The auger borings and soil backhoe pits should be located, numbered and shown on the WPC Soils Map. The soil scientist will be required to prepare and sign a detailed certification statement for each site evaluated as follows:

Water Pollution Control Soils Map Completed by:

Signature Date

John/Jane Doe, Soils Consultant

The following statement should appear on the map:

"I, (Soils Consultant's Name) affirm that this Water Pollution Control Soils Map has been prepared in accordance with accepted standards of soil science practice and the standards and methodologies established in the NRCS Soil Survey Manual and USDA Soil Taxonomy. No other warranties are made or implied."

Soil profile information and pit excavation, as described in these design criteria, are additional requirements deemed necessary to properly assess an area's suitability for drip dispersal.

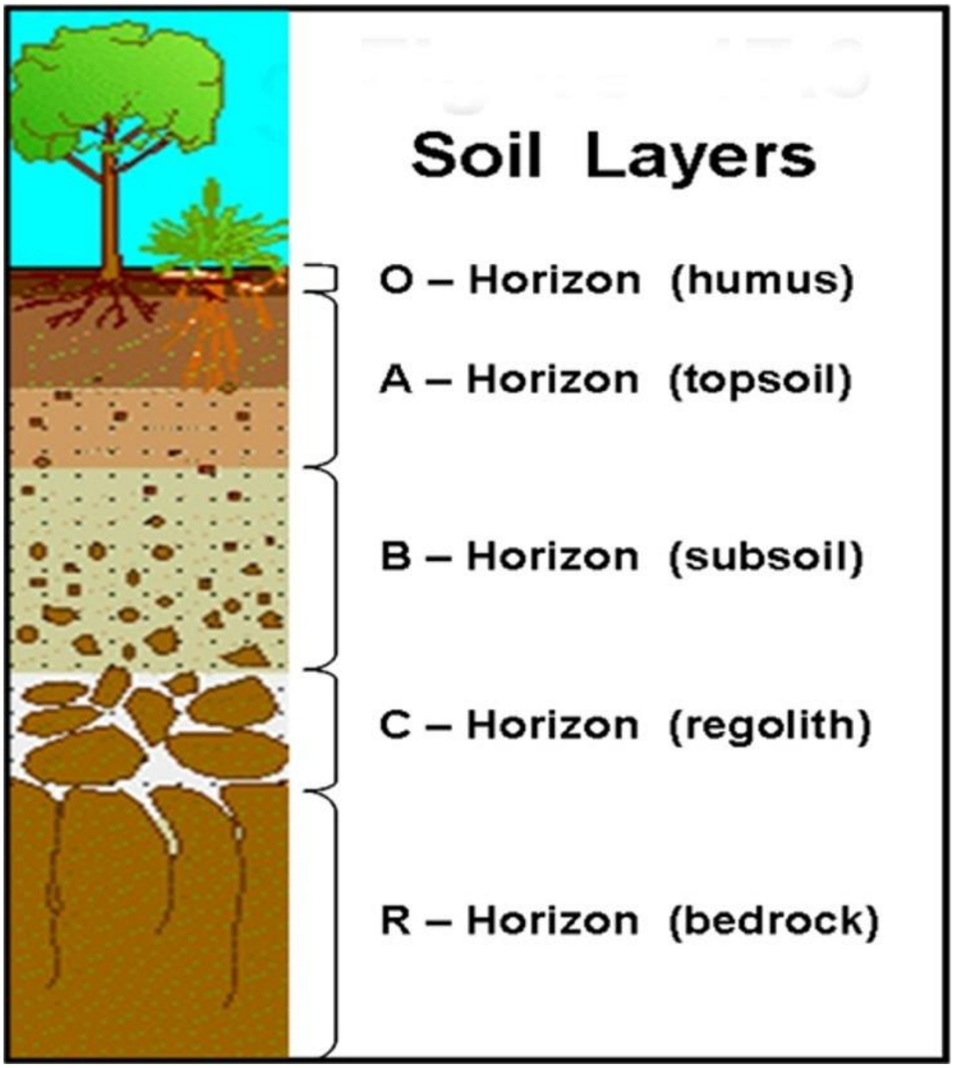
17.2.3 Definitions:

Soil Horizons (layers): Soil is made up of distinct horizontal layers; these layers are called horizons and display vertical zones. They range from rich, organic upper layers (humus and topsoil) to underlying rocky layers (subsoil, regolith and bedrock).

Soil horizons develop due to the nature of soil formation. Soil is the product of the weathering of parent material (i.e. bedrock), accompanied by the addition of organic matter. The method for naming the soil horizons is quite simple as the **Figure 17.2** shows.

In the simplest naming system, soils horizons are designated **O** (organic), **A** (topsoil), **B** (mineral soil), **C** (weathered parent material), and **R** is the un-weathered rock (bedrock) layer that is beneath all the other layers. The horizons of most importance to plant growth and forest health are the **O** and **A horizons**. The **litter layer** found covering the soil is also of interest because it provides most of the organic matter found in the O and A horizons.

FIGURE 17.2



The **Litter Layer** is the topmost layer on the forest floor. It consists of leaves, needles and other non-decomposed material on the forest floor. While this is not considered part of the soil, it is interesting to measure the depth of the litter layer when sampling the soil. The depth of the litter layer can vary greatly even within a particular site. Because of this, several measurements are required to attempt to characterize litter layer depth. The litter layer can be considered part of the overall soils depth.

The **O-Horizon** primarily consists of decomposed organic matter and has a dark rich color, increased porosity, and increased aggregate structure (larger soil "clumps"). The depth of the O horizon is measured from the surface of the soil (after the litter layer has been cleared away) to the point where the darker organic color changes to a slightly lighter colored soil that contains increased mineral particles in addition to organic matter. The transition from the O to the A horizon can also be recognized by a significant increase in the mineral soil particles. In many urban soils, the O horizon may very thin if it exists at all. The O horizon can also be considered part of the overall soils depth.

The **A-Horizon** is the **mineral** "topsoil" and consists of highly weathered **parent material** (rocks), which is somewhat lighter in color than the O horizon due to a decrease in **organic matter**. The particles in the A horizon are more granular and "crumb-like". Seeds germinate and plant roots grow in this layer. It is made up of humus (decomposed organic matter) mixed with mineral particles. The depth of the A horizon is measured from the region of color changes from the dark O horizon to the transition to the B horizon. The transition to the B horizon can be identified by increased clay content (see below) and the absence of organic material: no root hairs, small pieces of needle, etc.

The most thorough soil study involves analysis on separate O and A horizon samples. This requires separating and storing O and A horizon samples. It also involves completing the entire soil analysis on both the O and A samples. If this is not possible, the O and A samples can be combined (or composited) and the analysis can be completed on the O and A sample together.

The **B-Horizon** is also called the **subsoil** - this layer is beneath the A horizon and above the C horizon. It contains clay and mineral deposits (like iron, aluminum oxides, and calcium carbonate) that it receives when soil solution containing dissolved minerals drips from the soil above.

The B horizon is identified by increased clay content that makes the soil hold together when moist. A simple test for clay content is to moisten a small handful of soil and attempt to smear a small portion up the forefinger. Soils high in clay will hold together and form a "ribbon", soils with more sand and silt will be granular and fall apart. It is lighter in color and often may be reddish due to the iron content.

The **C Horizon** (layer beneath the B Horizon) consists of porous rock (broken-up bedrock, bedrock with holes). It is also called regolith or **saprolyte** which means "rotten rock." Plant roots do not penetrate into this layer; very little organic material is found in this layer.

The **R-Horizon** is the un-weathered rock (bedrock) layer that is beneath all the other layers. For the purposes of drip dispersal designs, the R horizon is considered an impermeable layer.

Water Pollution Control (WPC) Soils Map. A first order survey as defined in the Soil Survey Manual, United States Department of Agriculture, October 1993. These surveys are made for various land use that requires detailed soils information. Map scale should be one (1) inch equals one hundred (100) feet or a scale that will allow the map to fill a 24" x 36" plan sheet. These maps should have adequate cartographic detail to satisfy the requirements of project. The WPC Soils Map is essentially a special map that shows a very high degree of soil and landscape detail. Baseline mapping standards for these WPC Soils Maps prepared in support of drip dispersal should be a first order survey in accordance with the current edition of the Soil Survey Manual, United States Department of Agricultural; October 1993. Soil profile information and pit excavation, as described in these design criteria are additional requirements deemed necessary to properly assess an area's suitability for drip dispersal. These maps should be clearly marked or labeled as "Water Pollution Control Soils Map".

Soil map unit. A unique collection of areas that have common soil characteristics and/or miscellaneous physical and chemical features.

Soil scientist. A person having the experience and education necessary to measure soil properties and classify soils per *Soil Taxonomy*, synonymous with the term “soil consultant”.

Soil series. A group of soils that have similar properties; the lowest level of soil classification.

Most limiting horizon. A horizon in the soil (bedrock or fragipan) that either provides the greatest impediment to or completely stops the downward movement of liquids through the soil.

17.2.4 Special Soil/Geologic Considerations

For sites with slopes between 30% and 50%, TDEC may request, a special investigation (performed by a qualified professional, such as a geologist, geo-tech engineer, engineering geologist, etc.) to be conducted to evaluate those sites. To adequately complete these determinations the following information should be provided.

- Strike and dip angle of underlying bedrock
- Depth to either hard rock and partly weathered rock
- Type of rock (limestone, shale, etc.)
- Soil particle-size class designation to a depth of six (6) feet or to hard rock whichever is less
- Slippage potential of slope
- Certification statement signed by a qualified professional that addresses all of the above characteristics.

For sites with slopes between 30% and 50%, in addition to meeting all other soil suitability requirements, the site should also meet the following requirements:

- Have a vertical depth of at least twenty (20) inches of soil above the rock layer.
- Not have a predominant particle size class of fragmental or sandy-skeletal.

17.3 Determination of Design Application Rates

17.3.1 General

One of the key steps in the design of a drip dispersal system is to develop a "design application rate" in gallons per day per square foot (GPD/SF). This value is derived from either the hydraulic (water) loading rate (Lwh) based upon the most restrictive of (1) the NRCS hydraulic conductivity data and the texture and structure (per Table 17-2), or (2) the nutrient (nitrogen) loading rate (Lwn) calculations to determine design wastewater loading(s) and, thus, drip field area requirements.

17.3.2 Design Values

The most limiting horizon, of each soil series (or lowest possible level of soil classification) shall be identified. Any surface condition that limits the vertical or lateral drainage of the soil profile shall also be identified. Examples of such conditions are shallow bedrock, a high water table, aquitards, and extremely anisotropic soil permeability. Design considerations relative to the soils per Section 17.1.4 must be used.

Sites with seasonal high groundwater less than twenty-four (24) inches deep may require drainage improvements before they can be utilized for slow rate land treatment. The design hydraulic conductivity at such sites is a function of the design of the drainage system.

17.4 Determination of Design Wastewater Loading

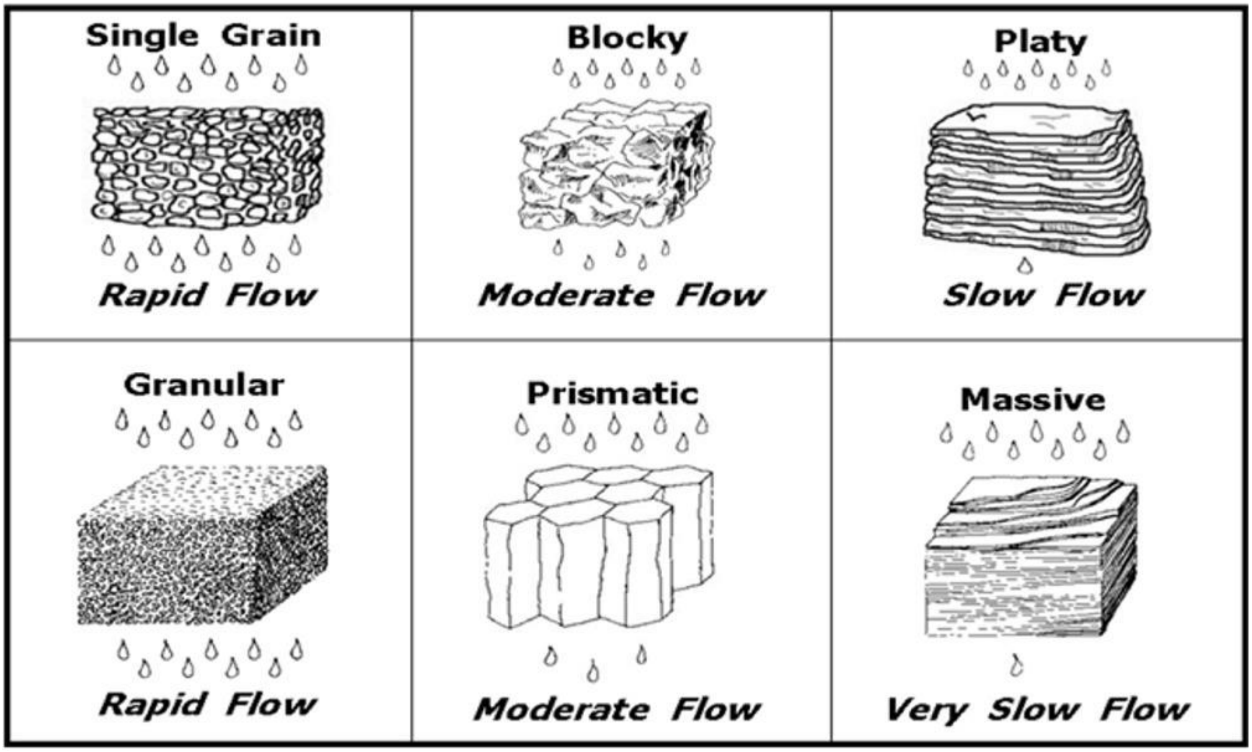
17.4.1 General

The design wastewater loading is a function of:

a. Precipitation.
b. Evapotranspiration.
c. Design hydraulic conductivity rate.
d. Nitrogen loading limitations.
e. Other constituent loading limitations.
f. Groundwater and drainage conditions.
g. Average and peak design wastewater flows.
h. Soil denitrification rates
i. Rate of nitrogen uptake in site vegetation

Therefore, developing the design wastewater loading is an iterative process. The Lwh value is determined by a detailed site evaluation and will be dependent upon the soil characteristics as shown in Table 17-2 and pictorially represented in **Figure 17.3**. This loading is then compared to the Lwn loading limitations (reference Section 17.5). If the initial Lwh value exceeds the Lwn value, the design wastewater loading resulting from the nitrogen reduction evaluation described in Section 17.5 becomes the design loading rate.

FIGURE 17.3



17.5 Nitrogen Loading and Crop Selection and Management

17.5.1 General

Nitrate concentration in percolate from wastewater irrigation systems will be limited via a State Operation Permit (SOP) to not exceed 10 mg/L nitrate-nitrogen at the site property line. Percolate nitrate concentration is a function of nitrogen loading, cover crop, and management of vegetation and hydraulic loading. The design wastewater loading determined from using the criteria stipulated in 17.1.4 for hydraulic conductivity must be checked against nitrogen loading limitations.

17.5.2 Nitrogen Loading

In some instances, the amount of wastewater that can be applied to a site may be limited by the amount of nitrogen in the wastewater. A particular site may be limited by the nitrogen content of the wastewater during certain months of the year and limited by the infiltration rate during the remainder of the year.

Equation **17-2** is used to calculate, on a monthly basis, the allowable hydraulic loading rate based on nitrogen limits:

$$\mathbf{Lwn} = \frac{Cp\,(Pr - PET) + N(4.413)}{(1 - f)(Cn) - Cp} \qquad \textbf{(Equation 17-2)}$$

Where:

Lwn = allowable monthly hydraulic loading rate based on nitrogen limits, inches/month

Cp = nitrogen concentration in the percolating wastewater, mg/L. This will usually be 10mg/L Nitrate-Nitrogen

Pr = Five-year return monthly precipitation, inches/month

PET = potential evapotranspiration, inches/month

U = nitrogen uptake by cover, lbs./acre/year

N = nitrogen uptake by cover, lbs./acre/month

Cn = Nitrate-Nitrogen concentration in applied wastewater, mg/L (after losses in pre-application treatment)

f = fraction of applied nitrogen removed by denitrification and volatilization.

The values of Lwh and Lwn are compared for each month.

The lesser of the two values will be used to determine the amount of acreage needed.

NOTES:

- A "**Cn**" value of less than 23 mg/L will become a permit condition.
- The allowable (default value) vegetative uptake "**U**" of nitrogen on the drip area will be an uptake rate of 100 pounds per acre per year unless trees or other vegetation are acceptable to, and permitted by WPC.
- The "**f**" values for denitrification have been estimated based upon data supplied by the University of Tennessee and Oak Ridge National Laboratory. Denitrification rates (f) ranging from 25% in January and February to 35% in July and August are very conservative, but are defendable based upon the literature. Denitrification rates are assumed to vary linearly with the temperature and the actual rates are likely to be higher than the default values shown in Table 17-2.
- Conversion Factor - **4.413**mg-acre-inch/liter-lb. The equation and factor are from the TDHE Design Criteria for Sewage Works (April 1989). The factor comes from assuming that one pound of contaminant of concern is diluted within a volume of water equal to one acre-inch. For the derivation of this factor see Appendix 17-C.

Table **17-3** shows the default values for Lwn calculations. Other values may be used provided adequate rationale and documentation is presented to, and approved by the Department of Environment and Conservation.

TABLE 17-3

MONTH	$Pr^{(1)}$ Inches / Month	$PET^{(2)}$ Inches / Month	N Uptake[(3)] Percent / Month	f Denitrification[(4)] Percent / Month
JAN	7.62	0.10	1%	25%
FEB	6.72	0.27	2%	25%
MAR	8.85	0.97	4%	27%
APR	6.59	2.30	8%	29%
MAY	6.13	3.59	12%	31%
JUN	5.52	4.90	15%	33%
JUL	6.85	5.44	17%	35%
AUG	4.73	5.00	15%	35%
SEP	5.54	3.79	12%	34%
OCT	4.47	1.98	8%	32%
NOV	6.11	0.82	4%	29%
DEC	7.55	0.27	2%	26%

(1) Based upon Table A-3 of Chapter 16 – 5-year return monthly precipitation

(2) Based upon Table A-2 of Chapter 16 – Potential Evapotranspiration

(3) Based upon Table A-5 of Chapter 16 – Monthly Nitrogen Uptake by Vegetation

(4) Applied Nitrogen Fraction Removed by Denitrification / Volatilization

Note: Appendix 17-B shows Equation 17-2, using the default values.

17.6 Plan of Operation and Management

Each decentralized wastewater treatment system utilizing drip effluent dispersal should be covered by a Plan of Operation and Management (POM). For public utility systems, a General POM applicable to all of the utility's facilities and covering the items discussed below will suffice. The POM is written by the owner or the owner's engineer and once accepted by the Division of Water Pollution Control, the POM becomes the operating and monitoring manual for the facility. This manual should be kept on file by the facility owner and should be available for inspection by personnel from the Tennessee Department of Environment and Conservation.

This Plan should include, but not be limited to, the following information unless previously submitted via the permit application process:

17.6.1 Introduction

a. System Description:

1. A narrative description and process design summary for the land treatment facility including the design wastewater flow, design wastewater characteristics, pre-application treatment system and drip fields.

2. A map of the land treatment facility showing the pre-application treatment system, drip fields, buffer zones, roads, streams, drainage system discharges, monitoring wells, etc.

3. A map of the collection system including gravity lines, force mains and pump stations tributary to the land treatment facility. Indicate their size and capacity.

4. A schematic and plan of the pre-application treatment system identifying all pumps, valves and process control points.

5. A schematic and plan of the irrigation distribution system identifying all pumps, valves, gauges, etc.

b. Discuss the design life of the facility and factors that may shorten its useful life.

Include procedures or precautions that will compensate for these limitations.

17.6.2 Management and Staffing

a. Discuss management's responsibilities and duties.

b. Discuss staffing requirements and duties:

1. Describe the various job titles, number of positions, qualifications, experience, training, etc.

2. Define the work hours, duties and responsibilities of each staff member.

3. Describe the location of operational and maintenance personnel relative to the location of the treatment system.

17.6.3 Facility Operation and Management

a. Pre-application Treatment System:

1. Describe how the system is to be operated.

2. Discuss process control.

3. Discuss maintenance schedules and procedures.

4. Discuss the use of telemetry

b. Drip Dispersal System Management:

1. Wastewater Application. Discuss how the following will be monitored and controlled. Include rate and loading limits.

(a) Wastewater loading rate

(gallons per day per square foot or inches/week)

(b) Drip dispersal field application cycles

2. Discuss how the system is to be operated and maintained.

(a) Storage pond(s), where utilized.

(b) Irrigation pump station(s)

(c) Drip dispersal field force main(s) and laterals

3. Discuss start-up and shut-down procedures.

4. Discuss system maintenance.

(a) Equipment inspection schedules

(b) Equipment maintenance schedules

5. Discuss operating procedures for adverse conditions.

(a) Electrical and mechanical malfunctions

6. Provide troubleshooting procedures for common or expected problems.

7. Discuss the operation and maintenance of back-up, stand-by and support equipment.

c. Drainage System (if applicable):

1. Discuss operation and maintenance of surface drainage and run off control structures.

2. Discuss operation and maintenance of subsurface drainage systems.

17.6.4 Monitoring Program

a. Discuss sampling procedures, frequency, location and parameters for:

1. Pre-application treatment system.

2. Drip Dispersal System:

(a) Storage pond(s), where utilized

(b) Groundwater monitoring wells

(c) Drainage system discharges (if applicable)

(d) Surface water (if applicable)

b. Discuss soil sampling and testing:

c. Discuss ambient conditions monitoring:

1. Rainfall
2. Soil moisture

d. Discuss the interpretation of monitoring results and facility operation:

1. Pre-application treatment system.
2. Drip dispersal fields.
3. Soils.

17.6.5 Records and Reports

a. Discuss maintenance records:

1. Preventive.
2. Corrective.

b. Monitoring reports and/or records should include:

1. Pre-application treatment system and storage pond(s).
   (a) Influent flow
   (b) Influent and effluent wastewater characteristics
2. Drip Dispersal System.
   (a) Wastewater volume applied to drip dispersal fields.
   (b) Loading rates.
3. Groundwater Depth.
4. Drainage system discharge parameters (if applicable).
5. Soils data.
6. Rainfall and climatic data.

APPENDIX 17 – A

APPENDIX 17-B

Hydraulic Values and Conversion Factors

0.2 gallons per day per square foot (GPD/SF) = 2.25 inches per week (in/wk.)

0.18 GPD/SF = 2.00 in/wk.

0.13 GPD/SF = 1.5 in/wk.

0.11 GPD/SF = 1.25 in/wk.

0.10 GPD/SF = 1.12 in/wk.

Moderately Slowly Permeable @ 0.2 in/hr. x 10% = 3.4 in/wk.

Slowly Permeable @ 0.06 in/hr. x 10% = 1 in/wk.

0.25 GPD/SF = 2.81 in/wk. = 0.4 in/day = 10,899 gallons per acre per day (gal/ac/day)

1 in/wk. = 0.089 GPD/SF = 3,880 gal/ac/day

0.1 GPD/SF = 4.7 x 10^{-6} cm/sec

APPENDIX 17 – C

EXAMPLE (Hydraulic & Nutrient Loading Calculations)

Lwn = [Cp (Pr - PET) + N(4.413)] / [(1 - f)(Cn) – Cp]

Lwn =			Calculated Allowable Nitrate Loading Rate
Pr =			Table A-3 of Chapter 16 - 5-year return monthly precipitation (in/month)
PET =			Table A-2 of Chapter 16 - Potential Evapotranspiration (in/month)
N	**=**	**Uptake**	Table A-5 of Chapter 16 - Monthly Nitrogen Uptake Rate by Vegetation (lbs./acre/month)
F	**=**		Applied Nitrogen Fraction Removed by Denitrification / Volatilization (%)
Cp	**=**	10	Maximum Nitrate Concentration in Leachate (mg/L)
Cn	**=**	23	Nitrogen Concentration in Applied Wastewater (mg/L)
		4.413	Conversion Factor
U	**=**	100	Annual Nitrogen Uptake Rate for Crop, Variable (lbs./acre/yr.)

MONTH	**Pr in/mo**	**PET in/mo**	**N Uptake %/mo**	**N Uptake lb/ac/mo**	**f (Denitrif) %/mo**	**Lwn in/mo**	**Lwn in/wk**	**Lwn in/day**	**Lwn GPD/SF**	**Lwh GPD/SF**
JAN	7.62	0.10	1%	1	25%	10.98	2.48	0.35	0.221	
FEB	6.72	0.27	2%	2	25%	10.12	2.53	0.36	0.225	
MAR	8.85	0.97	4%	4	27%	14.21	3.21	0.46	0.286	
APR	6.59	2.30	8%	8	29%	12.37	2.89	0.41	0.257	
MAY	6.13	3.59	12%	12	31%	13.37	3.02	0.43	0.269	
JUN	5.52	4.90	15%	15	33%	13.41	3.13	0.45	0.279	
JUL	6.85	5.44	17%	17	35%	18.04	4.07	0.58	0.363	
AUG	4.73	5.00	15%	15	35%	12.86	2.90	0.41	0.258	
SEP	5.54	3.79	12%	12	34%	13.63	3.18	0.45	0.283	
OCT	4.47	1.98	8%	8	32%	10.69	2.41	0.34	0.215	
NOV	6.11	0.82	4%	4	29%	11.15	2.60	0.37	0.232	
DEC	7.55	0.27	2%	2	26%	11.63	2.63	0.38	0.234	
TOTALS	**76.68**	**29.43**	**100%**	**100**		**152.47**				

APPENDIX 17 – D

Derivation of Conversion Factor for Equation 17-2.

(Provided by Harry J. Alexander, P.E.)

1 acre-inch: (1 acre) (1 inch) (43,560 SF/acre) (1 foot/12 inches) = 3,630 CF

(3,630 CF) (7.481 gal/CF) (3.785 liters/gal) = 102,785 liter, or 102,790 to the correct number of significant figures which is 5 in this case since the resultant product began with a "1" but none of the other figures (which each were taken to have 4 significant figures) began with a "1"

1 lb. = 453, 590 mg (here again we have 5 significant figures)

(453,590 mg/lb.) (102,790 liters/acre-inch) = 4.41278mg-acre-inch/liter-lb.

or 4.4128 mg-acre-inch/liter-lb. to the correct number of significant figures. But it would probably be best to state it to only four significant figures.

or 4.413 mg-acre-inch/liter-lb. This would be preferred given that it is likely nothing else in Equation **16-5** would be known to be more than four significant figures.

The foregoing explains where the conversation factor and its units (mg-acre-inch/liter-lb.) come from.

The number **4.413** is a better number than the previously used number of 4.424.

APPENDIX 17 – E

U.S. DEPARTMENT OF AGRICULTURE
NATURAL RESOURCES CONSERVATION SERVICE

NRCS-Soils-232G
5-86

SOIL DESCRIPTION

Soil type | File No.

Area | Date | Stop No.

Classification

Location

N. veg. (or crop) | Climate

Parent material

Physiography

Relief | Drainage | Salt or alkali

Elevation | Gr. water | Stoniness

Slope | Moisture

Aspect | Root distrib. | % Clay *

Erosion | % Coarse fragments * | % Coarser than V.F.S. *

Permeability

Additional notes

* Control section average

Hori-zon	Depth	Color		Texture	Structure	Consistence			Reac-tion	Bound-ary				
		Dry	Moist			Dry	Moist	Wet						