DEPARTMENT OF ENVIRONMENTAL PROTECTION

BUREAU OF WATER QUALITY PROTECTION

DOCUMENT NUMBER: 362-2000-009

TITLE: Manual for Land Application of Treated Sewage and Industrial Wastewater:

AUTHORITY: The Clean Streams Law of Pennsylvania

POLICY: This document provides guidance regarding the land application of treated sewage and industrial wastewater

PURPOSE:
This document is a revision of the 1993 document of the same name. It provides general guidance on the existing methods and types of land application systems and their relative effectiveness and limitations. Factors are presented which must be considered when determining whether land application is a feasible and environmentally sound treatment alternative. This manual also contains information on the general design, installation, and maintenance of land application systems. In addition, it describes state and federal requirements and procedures regarding permit applications for installation of wastewater treatment systems, which are based in whole or in part on the use of land application.

APPLICABILITY:
The guidance document applies to consulting engineers, geologists, and soil scientists on site selection, system design, and planning and permitting requirements for the land application of treated sewage and industrial wastewater

DISCLAIMER:
The policies and procedures outlined in this guidance document are intended to supplement existing requirements. Nothing in the policies or procedures shall affect more stringent regulatory requirements.

The policies and procedures herein are not an adjudication or a regulation. There is no intent on the part of the Department to give these rules that weight or deference. This document establishes the framework, within which DEP will exercise its administrative discretion in the future. DEP reserves the discretion to deviate from this policy statement if circumstances warrant.

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MANUAL FOR LAND APPLICATION
OF
TREATED SEWAGE
AND
INDUSTRIAL WASTEWATER

A Guide To Site Selection, System Design,
And Planning And Permitting Requirements

COMMONWEALTH OF PENNSYLVANIA

DEPARTMENT OF ENVIRONMENTAL PROTECTION

BUREAU OF WATER QUALITY PROTECTION

This manual and related information is available electronically via Internet. Access the DEP Web Site at http://www.dep.state.pa.us (choose "Information by Environmental Subject"/ choose "Water Management/Water Quality Protection/Wastewater Management/")

10/15/97

The *Manual for Land Application of Treated Sewage and Industrial Wastewater* has been prepared as a guide for consulting engineers, geologists, and soil scientists on site selection, system design, and planning and permitting requirements. It is being sent to you because you might be interested or because you have requested a copy. The document is also available on DEP web site as indicated on the Cover Page of this Manual. At this time, all Appendices to the manual listed are only available in hard copy from the Department.

The manual may be revised from time to time as the need arises. If you have suggestions for improvement to this manual or desire that future revisions be sent to you, please return this letter to us with the following completed information.

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Send to: Ratilal B. Patel, P.E, Chief

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PREFACE

This document is intended to provide general guidance on the existing methods and types of land application systems and their relative effectiveness and limitations. It is not to be construed as an endorsement of any particular system. The information presented in this document will need to be supplemented with additional detailed research once a land treatment method has been selected. The Department will evaluate each land application proposal relative to its adherence to all applicable guidelines, policies, regulations, and laws. The manual replaces in entirety the Department's *Manual for Land Application of Treated Sewage and Industrial Wastewater* (DER#1588-9/93).

Questions or comments may be directed to the following:

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INTRODUCTION

The 1972 Clean Water Act stated that the goal of the Act was to eliminate the discharge of pollutants to the waters of the United States by 1985. Efforts to address the goal have taken various forms, but clearly land application of wastewater under proper circumstances of design and operation will eliminate the discharge of pollutants directly to our streams and lakes and can also eliminate discharge of pollutants to groundwater. As public demands and environmental impacts require literal enforcement of pollutant discharge elimination due to excessive costs of water supply treatment, demands for water recreation and increasing evidence of the significant destruction of various aquatic species, land application techniques require increased understanding.

The importance of providing acceptable methods of land treatment has intensified because of 1) the increasingly stringent requirements associated with the discharge of wastewater to surface water bodies and 2) the need for wastewater treatment where streams are not readily accessible. Methods of land treatment, known as land application, include slow rate infiltration, rapid infiltration, on-lot disposal systems, overland flow and constructed wetlands.

The primary purpose of this manual is to provide guidance to consulting engineers, geologists, and soil scientists on evaluating land application systems. Factors are presented which must be considered when determining whether land application is a feasible and environmentally sound treatment alternative. This manual also contains information on the general design, installation, and maintenance of land application systems. In addition, it describes state and federal requirements and procedures regarding permit applications for installation of wastewater treatment systems, which are based in whole or in part on the use of land application.

1.

LEGISLATIVE AND REGULATORY AUTHORITY

Land application is an acceptable method of treatment, recycling, and reuse of sewage and industrial wastewater in Pennsylvania. The Department's authority to regulate land application of wastes is contained in the Pennsylvania Clean Streams Law and the Pennsylvania Sewage Facilities Act (Act 537). Planning and permitting criteria differ slightly between the land application of sewage and industrial wastes. Although wastewaters may be treated by seasonal land application, any surface discharges of wastewaters are regulated through the National Pollutant Discharge Elimination System (NPDES) permit process.

1.1. SEWAGE

Act 537 requires that an applicant complete sewage facility planning modules before applying for a Clean Streams Law, Part II Water Quality Management permit (hereafter referred to as a "Part II permit") for land application of sewage. Planning module approval is a prerequisite to the submission of a Part II permit application. These planning modules can be obtained from the appropriate DEP regional office with an "Application for Sewage Facilities Planning Module" mailer (See Appendixes A and B). These mailers are available from local municipal governments, consulting firms, or DEP regional offices. Information indicated on the mailers determine which planning modules will be distributed. Completed modules must be submitted to the appropriate municipal government authority, county planning commission, and DEP regional office. Some projects may require an update to the Act 537 Sewage Facilities Plan. This will depend upon an analysis of each project.

1.2. INDUSTRIAL WASTEWATER

A Part II permit is required for land application of industrial wastewater as defined in 25 PA Code Chapter 97. The documents that are needed to support an application for industrial wastewater land application can be obtained from the appropriate DEP regional office. Land application of landfill leachate requires a Part II Permit for construction and operation of the preliminary treatment facilities. A Bureau of Land Recycling and Waste Management permit is required for landfill leachate storage and equalization facilities. Refer to the DEP Technical Guidance for NPDES Permitting of Landfill Leachate Discharges.

1.3. SEASONAL LAND APPLICATION

Seasonal discharges to surface waters are permissible when the conditions preclude land application. However, operators of sewage or industrial wastewater land application systems must obtain an NPDES ("Part I") discharge permit in addition to the requirements stated previously. The documents needed for NPDES permit application can be obtained from the appropriate DEP regional office.

1.4. HAZARDOUS WASTE

Land application of wastes or wastewater that are defined as hazardous under 25 PA Code Chapters 260 - 270 is not covered by this manual. As stated in Section 264.271(a), "Hazardous waste shall be placed in or on a land treatment facility only if the waste constituents are amenable to land treatment, the waste can be degraded, transformed, or immobilized within the treatment zone and the waste may not cause adverse environmental or human health problems" (See 25 PA Code Chapter 264, Subchapter M on Land Treatment). Any questions concerning land application of hazardous waste should be directed to the DEP Bureau of Land Recycling and Waste Management.

1.5. SPECIAL PROTECTION WATERSHEDS

Land application in watersheds that have been designated as "special protection" in 25 PA Code Chapter 93 will need to comply with all appropriate standards. The Department's *Special Protection Waters Implementation Handbook* (DEP # 391-0300-002) should be consulted for such proposals.

1.6. AGRICULTURAL WASTES

Land application of agricultural wastes for agricultural use does not require a Part II permit. The DEP Manure Management Manuals describe procedures for proper design, operation, and management of these activities. Additional sources of assistance include county agricultural extension agents and the local offices of the United States Department of Agriculture Soil Conservation Service.

Land application of most agricultural wastes for non-agricultural use will require a Part II permit. These sites follow the same procedures as proposals for land application of industrial waste. Questions regarding the classification of a site or waste should be directed to the appropriate DEP regional office.

2.

LAND APPLICATION SITE EVALUATION

The general intent of any land application system is to provide additional treatment of pretreated wastewaters by passage through the soil mantle. Pretreatment requirements and related performance criteria can only be determined on a site-by-site basis. Such requirements also may be affected by surface water quality standards where seasonal discharge to surface waters is proposed in place of "winter" storage.

Land application is an alternative for the treatment of both sewage and industrial wastewater effluents. The most important factors in evaluating and designing a site for land application include soil, geology, hydrogeology, hydrology, climate, vegetation, quality of wastewater to be applied, rate of application, and conditions under which application may occur. An accurate evaluation of these factors is critical to the assessment of any land application proposal.

2.1. PRELIMINARY CONSIDERATIONS

2.1.1. Soil Characteristics

Land application of wastewater should typically be considered only for undisturbed soils. However, some land application treatment options may require physical modifications to the soil profile (i.e. overland flow systems).

Soil is a natural filter that provides effluent renovation using physical, chemical, and biological processes. Physical characteristics influence the permeability of the soil. The permeability must be within a range that will provide adequate residence time for renovation and prevent rapid downward movement, but not so slow as to cause saturated conditions which result in excessive groundwater mounding. Chemical characteristics affect cation/anion attenuation, buffering, and viral deactivation. Biological considerations include the plant and "animal" communities residing within the profile that impact on such processes as nutrient and metal uptake, pathogen deactivation, and denitrification.

2.1.2. Geologic and Hydrogeologic Characteristics

The applicant should evaluate at a minimum the following geologic and hydrogeologic factors:

1. Location of rock outcrops and sinkholes
2. Depth to the water table
3. Depth to bedrock
4. Direction of groundwater flow
5. Location of groundwater discharge points

The location of rock outcrops and sinkholes, along with the depth to the water table and bedrock, are important factors for determining if the effluent has adequate residence time for renovation in the unsaturated zone. Depth to groundwater is a critical component in the groundwater mounding analysis, which is discussed in Section 2.3.3.

The applicant also must determine the groundwater flow direction to ensure that the dispersion plume does not adversely impact existing or potential downgradient water uses. This information, along with groundwater discharge points, is necessary to establish properly placed monitoring sites.

2.1.3. Hydrologic Characteristics

Hydrologic factors that should be considered include slope, topography, soil erosion characteristics, presence or absence of floodplains and springs, and stream flow patterns.

2.1.4. Climatic Characteristics

Although climate is the least site-specific consideration of a land application proposal, it may ultimately be the major operational concern. Climatic characteristics may require the most costly additions to a site, such as storage and surface/subsurface drainage structures. Climatic considerations include the duration and volume of storage needed due to cold, wet, or windy weather, alternate system management procedures during precipitation events, and any other concerns that may arise.

2.1.5. Vegetation Characteristics

The selection of cover vegetation is important in most land application systems. The vegetation must be able to survive extremely wet conditions, reduce erosion potentials, tolerate the various chemical parameters in the effluent, assure the desired level of nitrogen uptake, and provide additional treatment capacity if possible. Some land application systems require specific types of vegetation that will generate certain surface flow patterns. Management of the vegetative cover also should be considered (i.e. harvesting, usability, re-establishment).

2.2. SOILS

2.2.1. Land Surface and Soil Characterization

The applicant must characterize all soil series and phases present on the site. The initial stages of this evaluation must include soil test probes. These test probes should be of sufficient number and location to either:

1. Confirm the Soil Conservation Service mapping or
2. Recharacterize the soils if the mapping is inconsistent with the field determination.

2.2.2. Topography

The applicant must determine the average and maximum slopes within a proposed site to prevent potential difficulties during construction. United States Geological Survey (USGS) 7·1/2 minute topographic quadrangle maps may be used for the initial characterization. However, these slopes must be field verified and presented on a large scale map.

2.2.3. Soil Profile Description

All soil test probes must be described to a depth of at least seven feet or backhoe refusal. The recorded description of soil profiles should contain information regarding the soil's morphological features including, but not limited to:

1. Soil Depth - Depth to bedrock or unconsolidated coarse fragments with no fine earth materials.
2. Soil Drainage - Depth within the soil profile to a mottled or gleyed color pattern due to the seasonal high water table, or depth to seepage or standing water within the profile.
3. Horizonation - Each separate horizon within the soil profile should be further described with respect to its:
    a. Color
    b. Texture
    c. Consistence - workability or plasticity
    d. Structure
    e. Abundance of coarse fragments
    f. Abundance of roots
    g. Any other non-typical, but potentially significant feature within the horizon

A site plan, which is required as part of the approval process, must show all soil test probe locations.

2.2.4. Initial Soils Suitability Determination

Physical characteristics determined from the soil test probes will provide a good initial evaluation of a site's general suitability for land application. If soils prove to be shallow, or somewhat poorly to poorly drained, the site may be described as unsuitable for most of the land application alternatives. At this point, there would be very little reason to conduct additional soil evaluations. However, if the initial evaluation of soil test probes reveals adequate soil characteristics, a more in-depth evaluation of other chemical and physical soil characteristics will be required.

2.2.5. Physical Characteristics

Physical characteristics are important in determining a potential hydraulic acceptance rate for the site. The applicant must evaluate the texture, consistence, structure, and porosity/density data from the initial soil descriptions to determine which, if any, soil horizons within the profile will limit the downward passage of effluent. The permeability of the limiting horizon at this depth must be evaluated in the field. This will require additional excavation of test probes to determine the precise depth of the limiting horizon. On occasion, it may be determined that the most hydraulically limiting strata is the groundwater surface. In this case, the transmissivity of the aquifer must be evaluated.

2.2.6. Chemical/Biological Characteristics

Chemical and biological characteristics of the soil are important factors controlling the level of effluent treatment. However, some effluents may contain one or more chemical parameters that are significantly elevated in concentration relative to the other parameters. The effect of this potential chemical imbalance will need to be evaluated with respect to the selected pretreatment options, the chemical affinities of the proposed vegetation (discussed in Section 2.6), the total land area available, and the ability of the soil to renovate or remove the parameters of concern. The soil chemical characteristics that are important in making these judgments include:

- Soil pH/buffering capacity
- Cation Exchange Capacity (CEC)
- Sodium Absorption Ratio (SAR)/exchangeable sodium percentage
- Presence or absence of organic matter, and the soil carbon to nitrogen ratio
- Base saturation
- Background metal concentrations in the soil

Using these factors, the applicant can assess whether a proposed land treatment system will function properly.

For example, if an acidic industrial waste is applied to the land at a rate that exceeds the soil's buffering capacity, the soil pH may decrease significantly. This may cause the CEC to shift and any metals being stored in the soil to be released into the plant/soil system. The concentrations of metals could be toxic to the vegetation, causing "die-off." The resulting lack of nutrient and water uptake would cause the system to be ineffective in treating the effluent.

2.2.7. Interrelationships/Conclusion

The input of a soil scientist to the design of a land application system is critical because of 1) the complex interrelationships of the various soil characteristics, 2) the land limiting constituent analysis, and 3) the different pretreatment options. A precise evaluation of these subjects and other pertinent site-specific information will yield a conservative design that will provide for a long-term functioning land application system.

2.3. GEOLOGY AND HYDROGEOLOGY

The applicant must evaluate the geology and hydrogeology of the proposed land application areas to determine or complete the following:

- Limiting geologic conditions
- Most restrictive horizons
- Groundwater mounding
- Dispersion plume analysis

2.3.1. Limiting Geologic Conditions

Limiting geologic conditions are those that will prevent the effluent from maintaining enough residence time in the soil for renovation. For the proposed land treatment area, the applicant must evaluate the following potential problems:

1. Rock Outcrops - These are indicators of potentially shallow soil conditions that may result in untreated or partially treated effluent reaching and contaminating groundwater. Bedrock does

not renovate effluent since fractures provide direct conduits to the groundwater. Also, soils may not be thick enough to provide complete renovation. The soil/rock interface can provide a zone of increased permeability allowing partially treated effluent to reach groundwater.

2. Sinkholes and Solution Channels - These features are important components of groundwater flow systems in carbonate regions. Sinkholes and solution channels provide direct conduits to the groundwater for untreated or partially treated effluent. In areas of carbonate geology, the applicant must evaluate the potential for sinkhole activation or solution channel formation resulting from the operation of the proposed system. This is especially critical for proposals that will concentrate effluent in a localized area such as large volume community on-lot sewage disposal systems. At no time will land application be allowed over a sinkhole or closed depression.

3. Depth to Water Table - A high groundwater table may indicate that the unsaturated soil zone is too thin to adequately treat the effluent. Because land application systems in general, and community on-lot systems in particular, tend to cause a local rise in the groundwater table, an initially high water table becomes especially critical. If the unsaturated soil thickness is not already too thin for effluent renovation, system operation may render the unsaturated soil thickness inadequate at some later date. Seasonal fluctuations in the water table should be evaluated to assure an adequate treatment system design.

2.3.2. Most Restrictive Horizon

The applicant must determine the most restrictive (least permeable) horizon between the land surface and the regional groundwater table. All horizons above the water table must transmit the effluent at least as fast as it receives the effluent. This prevents the possibility of effluent becoming confined in the unsaturated zone resulting in incomplete renovation or groundwater mounding. A general cross-section identifying the different horizons under the proposed land treatment area must be provided at the planning stage. This information may be generated from borehole logs, split-spoon sampling, and soil probes.

Land application systems should be sized based on either the shallow or surface permeability test results, or generally four to ten percent of the vertical hydraulic conductivity rate, whichever is most restrictive (based on *EPA Process Design Manual for Land Treatment of Municipal Wastewater*, hereafter referred to as *EPA Design Manual 625*). However, the following conditions may warrant deviation from using four to ten percent of the vertical hydraulic conductivity:

1. <u>Design flow of the system</u> - Generally, as the design flow increases, the percentage of the vertical hydraulic conductivity to use as sizing criteria also increases. And as design flows increase, the more likely it will be that the system will achieve average flow rather than peak flow. This is due to the statistical probability associated with the number of users above or below the average at any given time. For example, the probability of four units on a system achieving peak flow at any one time is greater than the probability of a system with 40 units simultaneously achieving peak flow. As a result, the renovative capacity of the most restrictive horizon is not likely to be threatened. This is especially true of systems designed to 25 PA

Code Chapter 73 standards (i.e. flows derived as defined in Chapter 73.17(a)(b)). In such cases, flows over 10,000 gallons per day can increase system sizing based on a rate of up to 20 percent of the vertical hydraulic conductivity. Systems over 50,000 gallons per day may warrant using up to 30 percent of the vertical hydraulic conductivity. Flows derived from sources other than Chapter 73 will need to be considered differently since the safety factors built into Chapter 73 may not be included.

2. Depth to most restrictive horizon - The ultimate design factor cannot be determined by system flow alone. The depth to the most restrictive horizon is important when determining the percentage of vertical hydraulic conductivity to be used for system design. For example, on-lot system effluent is considered adequately renovated (except nitrate-nitrogen: see Section 2.3.4) after percolating through four feet of unsaturated soil. In theory, a restrictive horizon at or greater than four feet below the bottom of the system could allow 100 percent of the vertical hydraulic conductivity as sizing criteria. In reality, this would likely cause the effluent to mound above the restrictive horizon because the vertical hydraulic conductivity was determined under saturated conditions rather than unsaturated conditions that would be present under a properly operating absorption field. A saturated medium will transmit effluent faster than an unsaturated medium. A design with too high of a percentage of the vertical hydraulic conductivity may result in incomplete renovation, effluent mounding into the absorption bed itself, or a breakout to the land surface. For this reason, the following increases in the percentage of vertical hydraulic conductivity are recommended for sizing considerations.

Depth to Restrictive Horizon	Increase in Percentage of Hydraulic Conductivity
4-10 ft	0%
10-15 ft	+5%
15-20 ft	+10%
20-25 ft	+15%
25-30 ft	+20%
>30 ft	+25%

These potential increases should be considered as only one factor in the overall determination of system sizing. Site-specific conditions may require deviation from these numbers.

The goal of any evaluation dealing with the most restrictive horizon should be to take full advantage of the hydraulic capacity of the soil without compromising the soil's renovative capacity or the proper operation of the system. If doubt exists, the system may be enlarged or further pretreatment provided to overcome site-specific limitations. A maximum of 55 percent of the hydraulic conductivity may be allowed in sizing criteria under the preceding guidance. This will not be possible or desirable for each site. Further, since sizing is based on the most restrictive factor, the shallow permeability tests may be more restrictive and therefore become the basis for system design without any consideration of the vertical hydraulic conductivity.

2.3.3. Groundwater Mounding

A groundwater mound is a mound-shaped elevation in a water table or other potentiometric surface that is formed by the downward percolation of water through the soil mantle. It is commonly associated with land application systems because of recharge from the wastewater. The extent of the mound must be determined to ensure that it does not result in insufficient vertical isolation between the system and the water table. Groundwater mounding could result in inadequately treated effluent reaching the groundwater or breaking out onto the surface.

Aquifer characteristics that need to be evaluated in the groundwater mounding analysis include depth to water table, aquifer transmissivity, and aquifer specific yield. The mounding analysis should be completed for a recharge period of at least ten years.

The aquifer characteristics should be determined by methods that stress the entire aquifer such as long term (at least eight hours) pumping tests. Methods that give localized results (e.g. slug tests) with little penetration of the aquifer can be used to confirm the results of pumping tests and reduce the number of pumping tests to as few as one. Localized test methods used as a sole source of aquifer data will require a greater number of data points and an accurate determination of aquifer thickness.

The applicant also should address the interference of groundwater mounds from any multiple absorption fields and the issue of land surface elevations versus the water table gradient. These problems are most acute where the absorption field is large or the topography is variable. The applicant will need to address these issues in the hydrogeologic report submitted to support the system design. This is best accomplished using a site plan that provides topography, current groundwater elevations, and predicted groundwater elevations after full mound development. The groundwater mound must not rise to within four feet of the bottom of the absorption field to ensure adequate effluent renovation and proper system operation.

2.3.4. Dispersion Plume Analysis

The applicant must conduct a dispersion plume analysis for any parameters that are not adequately removed by the soil for industrial waste or sewage effluent land application systems. For example, because the nitrate-nitrogen of domestic sewage is not removed by the soil, the applicant must estimate its concentration at the property line. Also, the applicant must estimate the extent and shape of the dispersion plume, including the mixing and buffer zones. This must be estimated for normal precipitation and drought years.

The following information is needed to complete the dispersion plume analysis:

1. Direction of groundwater flow
2. Location of potential groundwater divides
3. Site-specific background groundwater quality for parameters of concern
4. Area of project site
5. Locations of existing or potential water supplies on the project site, surrounding properties, and within the projected dispersion plume

6. Infiltrating recharge, which should reflect precipitation losses to surface runoff, evapotranspiration, and groundwater withdrawal

During the preliminary analysis, only the project site area should be used to estimate recharge. Vertical mixing within the aquifer cannot be considered in the initial dispersion plume analysis for parameters that float. Constituents of industrial waste may need to be modeled differently depending upon waste characteristics and interaction within the aquifer.

To obtain approval for a land application system, applicants must be able to demonstrate that the contaminant plume will not exit the site or adversely impact existing or potential water supplies. Where a hydrogeologic study has shown that a contaminant plume will exit the site or adversely impact existing or potential groundwater supplies, the applicant must provide for mitigation. Proposals may include the following components for mitigation but are not limited to them.

1. Provide additional treatment to lower concentrations of the parameters of concern to acceptable levels
2. Gain control of the offsite groundwater by precluding its use as a water supply

2.4. HYDROLOGY

Whereas land treatment considers groundwater as the final receiving water, degraded groundwater from an improperly operated land treatment system may discharge to and thus adversely impact upon a surface water body. Lake studies linking eutrophication to an excessively dense use of on-lot septic systems illustrate the need to consider the interaction between groundwater and surface water.

Because of the potential impacts of wastewater upon surface water bodies, the applicant should describe and delineate, on a large scale plan, <u>all surface water bodies that may be affected</u>. Surface water bodies defined by the Clean Streams Law include, but are not limited to, perennial and intermittent free-flowing water bodies, lakes, ponds, impoundments, wetlands, springs, seeps, drainage swales, surface relief channels, and other natural conveyances. Floodplains and floodways that are associated with any of these waterbodies also require delineation on the plan.

2.4.1. Perennial Streams

A perennial stream generally has some surface water flow throughout the year. Perennial streams are defined in 25 PA Code Chapter 87, as follows:

<u>Perennial Stream</u> - A body of water flowing in a channel or bed composed primarily of substrates associated with flowing waters and is capable, in the absence of pollution or other man-made stream disturbances, of supporting a benthic macroinvertebrate community which is composed of two or more recognizable taxonomic groups of organisms which are large enough to be seen by the unaided eye and can be retained by a United States Standard No. 30 sieve (28 meshes per inch, 0.595 mm openings) and live at least part of their life cycles within or upon available substrates in a body of water or water transport system.

2.4.2. Intermittent Streams

An intermittent stream may lack surface water flow during some portion of the year. It is defined in 25 PA Code Chapter 87, as follows:

Intermittent Stream - A body of water flowing in a channel or bed composed primarily of substrates associated with flowing water, which during periods of the year, is below the local water table and obtains its flow from both surface runoff and groundwater discharges.

2.4.3. Lakes and Impoundments

Because of their long retention time of effluent products, lakes and impoundments may be adversely affected by a land application system. Extensive eutrophication or other problems may occur in a lake or impoundment when a properly designed land application system is improperly sited. Alternatively, the construction of an impoundment may impair the effectiveness of a properly designed and operational treatment system by artificially raising the groundwater table.

2.4.4. Floodplains and Floodways

Floodplains and floodways border all surface water bodies. Due to a lack of treatment during periods of floods, land treatment in a floodway is not permitted. Suitable documentation and design considerations may permit land treatment within the general floodplain outside of the 100-year floodplain. 25 PA Code Chapter 105 defines flood, floodplain, and floodway, as follows:

Flood - A general but temporary condition of partial or complete inundation of normally dry land areas from the overflow of streams, rivers, or other waters of this Commonwealth.

Floodplain - The lands adjoining a river or stream that have been or may be expected to be inundated by flood waters in a 100-year frequency flood.

Floodway - The channel of the watercourse and those portions of the adjoining floodplains which are reasonably required to carry and discharge the 100-year frequency flood. Unless otherwise specified, the boundary of the floodway is as indicated on the maps and flood insurance studies provided by FEMA. In an area where no FEMA maps or studies have defined the boundary of the 100-year frequency floodway, it is assumed (absent evidence to the contrary) that the floodway extends from the stream to 50 feet from the top of the bank of the stream.

2.4.5. Wetlands

Wetlands interrelate with many of the hydrologic systems discussed in the preceding sections, and also require delineation on a large scale plan. 25 PA Code Chapter 105 defines wetlands as follows:

Wetlands - Those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions, including swamps, marshes, bogs, and similar areas. The term includes but is not limited to wetland areas listed in the State Water

Plan, the United States Forest Service Wetlands Inventory of Pennsylvania, the Pennsylvania Coastal Zone Management Plan, and any wetland area designated by a river basin commission.

2.4.6. Springs and Seeps

Springs often provide information as groundwater discharge points and potential monitoring locations. Establishing locations of springs and seeps may require intensive field work. USGS topographic maps are not sufficient to locate all springs.

2.5. CLIMATE

The applicant must evaluate the effects of temperature, precipitation, and wind on the land application system. These factors may result in the cessation of land application, and subsequent utilization of effluent storage facilities.

2.5.1. Temperature

Temperature is an important factor in evaluating land treatment efficiencies and capacities. Low temperatures are the most critical and must be addressed if the proposed operation will occur during cold weather. Short-term periods of cold weather may cause problems in the physical operation of the distribution system. Pipes may become blocked with ice and damaged if the distribution piping is not properly designed to promote drainage after each application. Spray irrigation facilities may have problems when the spray nozzles become affected by ice build-up. More serious problems occur when the land application is proposed during long-term periods of cold weather. Frozen or ice covered ground can cause a “die-off” of vegetation, resulting in direct runoff of wastes. This condition requires the cessation of effluent application and subsequent storage of the treated effluent.

2.5.2. Wet Weather Considerations

Compared to cold weather occurrences, wet weather is typically a short-term event. It does, however, have major implications for land application systems. Pre-application design options will need to address the day-to-day management and operations of the land application system. Some design factors that should be evaluated based on wet weather conditions include:

1. <u>Hydraulic Budget</u> - A hydraulic budget accounting for applied wastewater, precipitation, evapotranspiration, and runoff must be addressed on no less than a monthly basis. In general, effluent should not be applied on a long-term basis if it will cause significant groundwater mounding and interfere with proper system function. Applied wastewater plus average infiltrating precipitation should not exceed the actual evapotranspiration rate of the site plus the hydraulic conductivity of the most restrictive horizon (See Section 2.3.2). This relationship will typically be of greatest concern before and after the height of the growing season.

2. <u>Hydraulic Acceptance Rate</u> - Hydraulic acceptance rate is that rate at which effluent can be applied to a soil without promoting runoff. Under field capacity moisture conditions, a soil will be able to accept effluent at a certain rate. However, the same soil will exhibit a significantly

reduced rate of acceptance under increased moisture conditions or saturation. The level of precipitation that will "trigger" runoff of the effluent or precipitation must be determined. When this "trigger" is reached, it will require a cessation of the land application and require storage of the effluent until hydraulic conditions are acceptable. The method and schedule for applying the stored effluent during appropriate weather conditions also must be addressed.

3. Periods of Excess Soil Moisture - After significant precipitation or during snowmelt events, the topsoil and upper portions of subsoil may remain saturated or excessively wet for long periods of time. This may interfere with proper function of the land application system. Therefore, the applicant must quantify the duration and intensity of a precipitation event that would cause interference with proper treatment. Further, an adequate "waiting period" following these precipitation events must be proposed to allow time for the soil to drain sufficiently, before the next application of effluent. The applicant must consider at a minimum the relationship between the precipitation event and site characteristics including the natural soil moisture holding capacity, high water table conditions, and the vegetation.

4. Farm Management and Operation - A schedule of typical crop rotations and anticipated farm operations must be provided with the proposal (See Section 2.6.3 for further discussion). This schedule may need to be altered if there are wet soil conditions because significant soil damage (i.e. compaction) can occur under some farming operations. Therefore, the applicant should document provisions that will prevent problems associated with the farming operations. The following are examples:

    a. Additional storage may be required due to variations in farming practices (i.e. crop rotation, harvesting).
    b. Additional available land area should be permitted as a portion of the land application site, for potential emergency use.
    c. Harvesting or management of vegetation should be conducted when facilities are shut down and no effluent is being produced.

5. Storage - Provisions must be made for adequate storage of effluent during periods of adverse soil moisture conditions as discussed in the preceding sections. Factors to be evaluated in determining storage needs include soil type, historical weather data, and effluent volume.

2.5.3. Wind Conditions

Wind can also cause problems with the operation of a land application system. Wind problems are typically short in duration, consisting mainly of "wind drift" of effluent away from the site. These concerns can generally be overcome by specific design options. All land application proposals must document the direction of the prevailing wind in the area. The proposal also should address the following concerns and options to minimize potential wind problems:

1. Wind Break - Natural or man-made obstruction to wind should be placed upwind with respect to the prevailing wind direction to reduce the wind velocity across the proposed site.

2. Application Method - Small diameter and/or low trajectory sprinkler heads, “trickle” flow applicators, sheet flow applicators, etc. should be incorporated into the land application design to keep the effluent closer to the ground surface and away from areas typically impacted by the wind.
3. Buffer Zone - Buffer zones need to be considered in any surface land application site. In no case will a buffer zone of less than 50 feet be considered for property boundaries, roadways, parking lots, and rock outcrops. Longer “downwind” lateral distances to various features such as streams and lakes, wells, occupied dwellings, and sinkholes must be considered based on the wind drift. Effluent may be applied only to areas that have been permitted. The potential over-application of downwind portions of a site should also be addressed.

If the site-specific design modifications or other methods cannot be used to overcome wind drift limitations, wind velocity and direction criteria should be proposed that will cause cessation of land application with subsequent effluent storage. For instance, spraying would have to cease when the effect of the wind drift would cause effluent to be carried off the permitted site or within the buffer zone.

2.5.4. Storage Requirements

The applicant must calculate the minimum storage requirement for all land application systems that distribute wastewater effluent onto the ground surface. Local climatic records, as well as nationally available climatic data, such as the National Oceanic and Atmospheric Administration’s *Use of Climatic Data in Estimating Storage Days for Soil Treatment Systems*, should be evaluated to determine minimum storage time. Several computer programs are available that provide a measure of intensity and duration of cold periods. The most commonly used is EPA-3, as discussed in the *EPA Design Manual 625*. To receive a copy, contact the Director, National Climatic Center, Federal Building, Asheville, NC 28801. EPA-3 possesses certain default information that helps to determine storage requirements. This default information considers the climatic characteristics of Pennsylvania. The Department supports the default values used by the program in determining a site’s storage requirements. More conservative values are welcome.

The default values are a mean daily temperature of 32°F with a minimum low of 26°F and a minimum high of 40°F. The maximum amount of snow on which effluent may be applied is one inch. Effluent may not be applied if more than 0.5 inches of rain falls during the previous 24-hour period.

The storage requirement will vary for seasonal and year-round operations. Seasonal operations that will not generate waste materials or effluents during the cold season must calculate the minimum storage volume to allow for wet weather and maintenance time. Year-round operations will require storage based on cold, wetness, and wind. The length of this storage period may vary widely across the state from a low of 60 days in the southeast to a high of 120 days in the northwest.

2.6. VEGETATION

There are many factors to consider in the selection of appropriate vegetative covers for a land application site. The primary consideration is how the vegetation will work with the land treatment system. Another consideration is the final use of the vegetation. Every effort should be made to grow a viable economic crop. Otherwise, it may require disposal once it is harvested. Before choosing the appropriate vegetative cover, the applicant must determine the assimilative capacity of the vegetation, and must consider management, economic, and other site issues, as discussed in the following sections. A good reference is *EPA Design Manual 625* or an agronomic textbook.

2.6.1. Assimilative Capacity

The vegetation selected must be able to assimilate the specific type of effluent being applied to the land surface. Typical sewage effluent varies from industrial waste effluent, which in itself is widely variable depending on the process and pretreatment methods involved. The applicant must address the following conditions or characteristics in order to select the vegetative cover most capable of assimilating the effluent.

2.6.1.1. Hydraulic Load

When a significant hydraulic load is to be placed on the land treatment system, the vegetation must be able to tolerate the wetness and still provide assimilative capacity to remove the chemical parameters of concern. Under certain conditions, vegetation should be selected that will uptake and transpire significant quantities of water, thereby lessening the hydraulic loading to the groundwater and decreasing the potential for groundwater mounding.

2.6.1.2. Anions

Anions, particularly NO_3, are generally not afforded significant renovation by the soil profile. Therefore, the major assimilative/renovative pathway for anions is vegetative uptake. The fraction of all anionic species not removed by vegetation moves largely unchanged into the groundwater where dilution takes place. A crop that can remove significant quantities of anions (mostly NO_3) from the soil water/effluent will lessen the impact of those parameters on groundwater. This is an especially important consideration if background groundwater quality concentrations are elevated.

2.6.1.3. Cations/Metals

Cationic species include heavy metals and phosphorous. Cations are typically complexed and tightly held within the soil system. However, certain events or circumstances that may occur within the land application system cause them to become mobile. Some plants have a natural affinity for uptake and storage or transport of certain metals, due to their inherent characteristics. Certain vegetation will show the effects of toxicity to certain metal species at much lower concentrations than others. Even essential cations like iron, chromium, potassium and phosphorous may be toxic if levels significantly exceed those required for growth.

While uptake of cations can be a major benefit of a vegetative species, the levels of metal concentrations and other soil/waste factors must be kept in equilibrium. Typical farm management operations such as liming and fertilizing may need to be limited as they may complicate the relationships within the system as time goes by and cationic concentrations build in the soil.

2.6.1.4. Oil/Grease Organics

The major mechanisms for breakdown of oil/grease organics occur by soil's microbial populations. However, the vegetation will assimilate certain organics and metabolites of organic compounds. The organics will typically be stored within the plant tissues and may become toxic to the plant itself or render the vegetation unsuitable for some uses after harvest. This consequence should be evaluated as well as the effect of applying oily or greasy wastewater on the vegetation. If the plants' transpiration is significantly reduced or halted due to "clogged" surfaces, the application may be self defeating.

2.6.2. Site-Specific Considerations

In general, the vegetation chosen must provide control against erosion and significant runoff, as well as furnish the desired treatment. Steeper slopes typically require a vegetation that can provide well-developed rooting that will aid in holding the soils in place. Irrigation must be limited to areas containing growing vegetation.

A year-round application proposal must consider use of forest vegetation on the winter-time site. The well-developed root system and organic blanket associated with forest vegetation deters significant frost effects. Turf-type, rather than clump-type vegetation, may be required in overland flow treatment systems. Conventional tillage and row crops may be used only on very gentle slopes.

Slopes of up to eight percent can typically be considered for most land application systems. However, with detailed substantiating data and specific design inclusions, proposals for spray irrigation may be considered on slopes up to 25 percent.

2.6.3. Management and Economic Considerations

A well-managed land application system will operate at design levels of treatment and will be aesthetically acceptable. It also can economically benefit the operator by providing return on the harvested vegetation, by reducing the cost of conventional treatment, and/or by eliminating the need for stream discharge of effluent. The proposal for a land application system should address the following management and operational considerations.

2.6.3.1. Crop Establishment

The type or species of vegetation may require different methods and durations for establishment. Forage crops may take as little as a few weeks to reach a stage of growth when application could commence. However, tree species may take several months to a year. A cover crop of some “rapid growth” vegetation should be considered to reduce erosional risks, if the proposed vegetation will take a significant period of time to reach full establishment. Also, the season of the year should be considered since very little vegetation can be established in late fall or winter.

2.6.3.2. Crop Rotation

Planting of perennial species or forest is typically a “one-time” or long time operation. Use of annual crops and intense crop rotations will require re-establishment on a much more frequent basis.

2.6.3.3. Harvesting

Vegetation must be harvested or removed from the site periodically. If this does not occur, all the parameters of concern that have been uptaken by the vegetation will simply return to the soil, causing an eventual overload of some parameter to the overall system.

Typically, forage crops should be harvested several times per year while in the vegetative (rather than productive) stage, when they are “taking up” nutrients at optimum rates. Row crops should be harvested at appropriate times based on applicable farming operations. Land application to sites where crops have been completely removed is not acceptable until other vegetation is established (i.e. harvesting of small grains with subsequent planting of annual rye or winter wheat).

2.6.3.4. Usage/Disposition

The ultimate disposition of vegetation must be addressed. Some crops have an inherent value and may be utilized or sold, whereas some vegetation is planted simply to provide uptake of certain parameters. Crops which are intended for human consumption will need to comply with the requirements of 25 PA Code Chapter 275 and Department Guidelines for the Agricultural Utilization of Sewage Sludge (May 1988). In addition, the Pennsylvania Department of Agriculture requires laboratory testing for heavy metals for any human consumption items grown on land where sewage or sludge has been applied. The proposal should indicate whether the crop is intended for human or animal consumption, industrial usage, horticultural usage, fertilization of “other” lands, land-filling, or other uses.

2.6.3.5. Natural Range

An obvious consideration in the selection of a plant species is whether it will survive in Pennsylvania’s climate or on the specific site. A plant species may possess the proper assimilative capacity, provide required tolerances and positive economic returns upon harvest; however, if the species cannot survive Pennsylvania’s climate or site-specific conditions, these attributes are all irrelevant.

2.7. QUALITY OF WATER TO BE APPLIED

The quality of the pretreated wastewater, prior to application to the land, should be addressed. While minimum treatment requirements exist for any land application system, pretreatment levels greater than the minimum can be proposed to overcome limiting site characteristics or system characteristics less desirable than those required for the "typical" system that just meets minimum requirements.

While the minimum typical pretreatment required prior to slow rate infiltration is defined as secondary (See Section 6.2), actual pretreatment needs are based on the type of application system proposed and the site-specific objectives of the system. The application of effluent pretreated to advanced levels can be used to overcome site characteristics that would render a site unsuitable for use under typical minimum pretreatment considerations.

2.7.1. Land Limiting Constituent Analysis

A land limiting constituent analysis establishes the interrelationships between 1) the proposed waste to be applied, 2) the rate at which it may be applied, and 3) the plant/soil/groundwater system. As effluent is applied, the eventual inability of the soil system to treat specific parameters will limit the application rate. This is especially true for industrial waste effluents, although sewage effluents may be limited by the hydraulic capacity of the soil or by nitrogen in areas of elevated background nitrate concentration. If the amount of land area available for renovation is limited, advanced pretreatment may be required for the parameters of concern. Sometimes pretreatment may be cheaper than the acquisition of additional land for proper renovation. If land availability is not a concern, the effluent applied per unit land area can be reduced to achieve an acceptable concentration of the limiting constituent.

Another component of the land limiting constituent analysis is the soil's biological communities. The applicant must characterize native vegetation and evaluate assimilative capacities. New vegetative cover may need to be established to ensure uptake or renovation of specific effluent parameters. Some waste material may require amendment of the soil's microbiological community to renovate constituents that are not typically renovated by naturally occurring processes.

2.8. RATE OF APPLICATION

A rate of application must be determined that will not cause inundation or over-application of the site which will promote runoff or inadequate renovation of the wastewater applied. Further, if the proposal includes a claim of additional nutrient removal by on-site vegetation, the rate of application must be such that rapid movement of this wastewater through the root zone and beyond does not occur. The chosen rate must insure that the on-site vegetation can make use of these nutrients (See Sections 2.7.1 and 6.5).

2.9. METHODS AND CONDITIONS OF APPLICATION

While there may be several methods of applying the effluent to the ground surface, it should become apparent based on review of site-specific characteristics and design considerations that may be applicable to the site in question.

The more favorable alternatives are those that will be more reliably managed and easily operated. Proposals that include a detailed management and operating plan combining site, seasonal, and weather related specifics with automated application and storage capabilities should receive primary consideration.

2.10. LAND OWNERSHIP AND MANAGEMENT

Although not necessary, it is generally desirable that the land on which the treatment occurs and storage facilities are located be in the ownership of the permittee. In these cases, there should be a covenant in the deed providing for land application in perpetuity. In those situations where the treatment area and storage cells are on property not owned by the permittee, the permittee must either secure a 20-year lease renewable for an additional 20 years or acquire development rights and perpetual rights for the amount of land required.

3.

LAND APPLICATION APPROVAL PROCESS

This chapter provides further detail on the procedures that must be followed to obtain all the Department approvals necessary for proposed land application systems, culminating in the final issuance of DEP permits. As noted in Chapter 1, land application systems may be permitted for both sewage and industrial wastewater. Permit application procedures for each are similar, except that for sewage cases, an Act 537 Official Sewage Plan Revision must be approved by the municipality in which the project is located, and then also be approved by the Department. This Act 537 approval must occur before any permit applications are submitted.

3.1. SEWAGE PROPOSALS

Sewage land application proposals must include the Act 537 plan approval. For smaller, nonmunicipal projects, this Act 537 plan revision may be accomplished by the completion of planning modules which may be obtained from the regional DEP office through the use of an "Application For Sewage Facilities Planning Module" mailer (See Appendix B). For larger municipal land application projects, a more comprehensive Act 537 update may be required by the Department. A comprehensive plan update requires a formal Act 537 study, which looks at the needs of larger service areas and which evaluates other alternatives from both an economic and environmental standpoint. Therefore, before starting the Act 537 planning step, project sponsors should contact the regional DEP office to determine appropriate planning requirements. After the local municipality and Department have approved the Act 537 plan revision, permit applications may be submitted.

Typically, both the sewage treatment plant facilities and the land application system may be permitted under the Part II permit. Part II permits are distinguished from NPDES ("Part I") permits which authorize discharges to surface receiving waters. Land application systems that do not propose seasonal discharge to surface waters only require the Part II permit. Projects which propose seasonal land application of treated wastewater with discharge to surface receiving waters during some portions of the year require both an NPDES and a Part II permit.

Procedures for applying for these two types of sewage permits are detailed in the DEP Domestic Wastewater Facilities Manual, which is available at the DEP regional offices. Appendix C includes pages 6 - 12 of the manual which describes the procedures for obtaining a Part II permit. Application forms and design modules are available at the regional DEP office.

In addition to the information that the DEP Domestic Wastewater Facilities Manual requires in Part II permit applications, the Design Engineer's Report for a land application system must contain considerable detail on the hydrogeology of the proposed site, the soils present, crop management procedures, nutrient loading information, and proposed groundwater monitoring systems. This part of the Design Engineer's Report must satisfy the design considerations that are given in subsequent chapters of this manual.

3.2. INDUSTRIAL WASTEWATER PROPOSALS

Procedures for applying for land application of treated industrial waste are similar to those applicable for sewage, except that no Act 537 planning approval is necessary. As with sewage proposals, all land application distribution and treatment systems may be covered under a single Part II permit. If a seasonal discharge to surface receiving waters is proposed, then an NPDES permit also will be necessary.

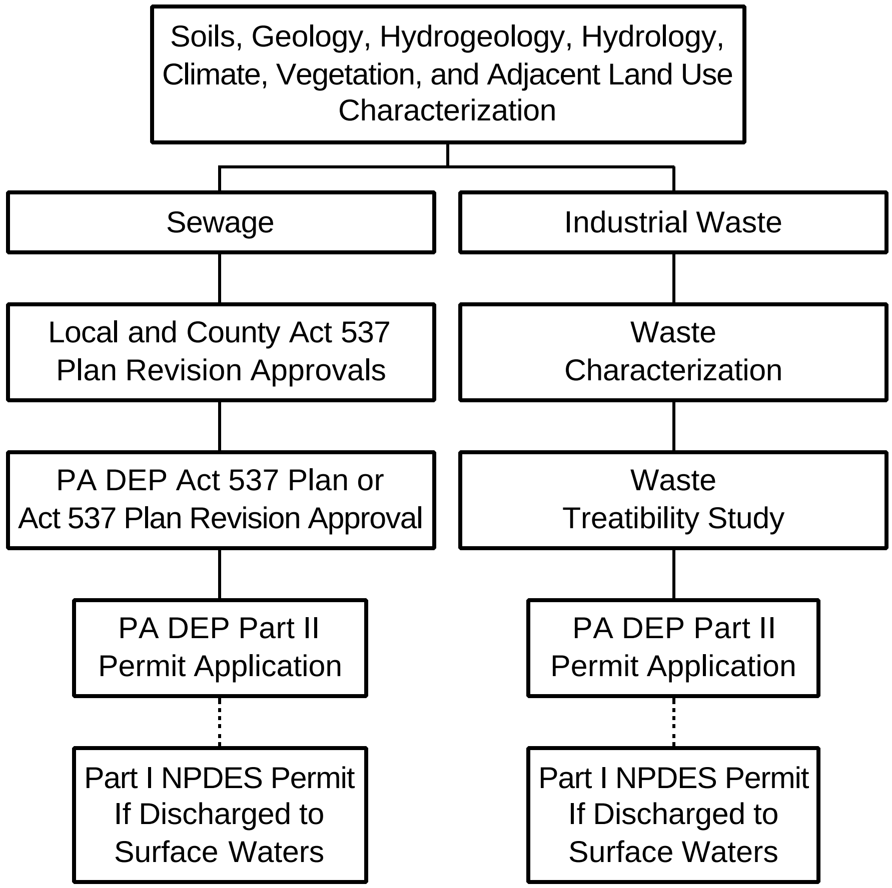
Procedures for applying for these two types of industrial waste permits are detailed in the DEP Industrial Waste Manual, available at the regional DEP office. Appendix D includes pages 9 - 30 of the Industrial Waste Manual which describes procedures for obtaining industrial waste permits.

Again, for industrial waste land application proposals, the Part II permit application also must contain detailed information on site hydrogeology, soils, crop management procedures, nutrient loading information, and groundwater monitoring. This portion of the design engineer's report must satisfy the design considerations which are given in the subsequent chapters of this manual. Figure 1 illustrates the planning and permitting procedure for sewage and industrial waste land application proposals.

PROPOSED FIVE-YEAR PERMIT RENEWAL PROCESS

The Bureau of Watershed Conservation is currently drafting a policy and procedure which would require that the Part II permit be renewed every five years. When this new guidance is finalized, it will be included as an addendum to this manual.

Figure 1. Planning and permitting procedure flow chart


Soils, Geology, Hydrogeology, Hydrology, Climate, Vegetation, and Adjacent Land Use Characterization
Sewage
Industrial Waste
Local and County Act 537 Plan Revision Approvals
Waste Characterization
PA DEP Act 537 Plan or Act 537 Plan Revision Approval
Waste Treatibility Study
PA DEP Part II Permit Application
PA DEP Part II Permit Application
Part I NPDES Permit If Discharged to Surface Waters
Part I NPDES Permit If Discharged to Surface Waters

4.

EFFLUENT QUALITY/STORAGE/DISTRIBUTION

4.1. PRE-APPLICATION TREATMENT

Prior to land application, all organic wastewaters must undergo pretreatment (See Sections 6.2, 7.2, 8.2, 9.2, and 10.2). Higher degrees of treatment or lower hydraulic loading may be considered for high strength wastes and/or to overcome site limitations. Wastes containing greases and emulsions that clog soils, plug nozzles, or coat vegetation must not be discharged to the land application field. In addition, wastes that are non-biodegradable, non-exchangeable with the soil materials, toxic to vegetative cover, or are persistently toxic in the environment must not be applied to the land surface.

Before applying any wastewater, the applicant should assess the following to determine pretreatment requirements and to prepare for implementation of the operational system:

1. Chemical, physical, and biological properties of the wastewater
2. Chemical and physical properties of the soil
3. Current groundwater quality
4. Water quality standards for adjacent waterways
5. Topographical and climatological features of the area
6. Long range land use
7. Cropping plans
8. Crop nutrient requirements and elemental sensitivities
9. Public comments to land application proposals (Refer to Planning Modules for New Land Development)

4.2. FINAL EFFLUENT QUALITY

The DEP *Principles of Ground Water Pollution Prevention and Remediation* states that the goal of groundwater quality protection is the prevention of groundwater contamination whenever possible. The Department intends to strive toward this goal because it provides the best protection of this valuable and vulnerable resource for future generations. The Department recognizes, however, that basic human activities have impacts on groundwater. In those cases where complete prevention of contamination is not possible due to demographics and the practicalities of technology and economics, the Department will consider the use and value of the resource in establishing protection measures. Theses principles define the framework for establishing program requirements which will provide for careful stewardship of the resource and advance the highest feasible level of groundwater protection through the use of control technologies, management practices, and pollution prevention measures at activities which may impact groundwater quality.

For the overland flow process, wetlands discharge, or certain rapid infiltration designs for which a surface discharge is expected, surface water quality criteria must be met in the surface water body. These criteria are set forth in 25 PA Code Chapter 16: Policy Statement Water Quality Toxics Management Strategy and 25 PA Code Chapter 93: Water Quality Standards. NPDES permits will be required for any surface water discharges.

4.3. STORAGE/EQUALIZATION TANKS

Storage is necessary in many land treatment systems because of the effect of climate on treatment or an imbalance between wastewater supply and application. For example, slow rate and overland flow applications may not be possible during adverse weather conditions. Storage requirements may be determined using daily, weekly or monthly water balance calculations. Seasonal discharge to surface waters is an alternative to storage. Any surface water discharges require an NPDES permit and must meet all applicable Pennsylvania surface water quality criteria and standards.

Slow rate or overland flow system operation may be adversely affected if severe cold weather persists for extended periods (i.e. 2 - 4 months). If annual crops are being irrigated, the growing season will determine storage requirements. If perennials are irrigated, application will normally be stopped only by frozen soil conditions. As noted in Section 2.5.4, there are several computer programs available that provide a measure of intensity and duration of cold periods. The most commonly used is EPA-3. To receive a copy, contact the Director, National Climatic Center, Federal Building, Asheville, NC 28801. These computer programs should be used in assessing cold climate storage needs. Any impoundment constructed to retain sewage effluent for future land application must comply with the pond construction details as described in Section 85.5 of the DEP Domestic Wastewater Facilities Manual.

For community on-lot and large volume on-lot systems, equalization tanks can be used to equalize the peak flows. This design is beneficial to facilities with regular, predictable, fluctuating flows in that it results in a smaller overall system size.

4.4. DISTRIBUTION

Once it is determined that the final effluent quality will meet all applicable Pennsylvania surface and groundwater quality standards and requirements, the wastewater can be distributed and applied to the land. Sprinkler systems are used for this purpose. A wide variety of sprinkler systems are available. A partial listing includes center pivot rigs, wheel rolls, solid set, and pop-up nozzles.

The two common methods for land application of wastewater are surface and sprinkler distribution. Selection of either of these methods depends on the objectives of the project and the limitations imposed by physical conditions such as topography, type of soil, crop requirements, and level of pre-application treatment. Surface distribution requires careful grading of surfaces and extensive systems of channels for distribution and ditches to collect effluent and surplus water. Sprinkler distribution is virtually independent of the shape and contour of the area.

4.4.1. Surface Distribution Systems

Surface distribution employs gravity flow from piping systems at open ditches to flood the application area with several inches of water. This method of distribution is more suited to soils with moderate to low intake rates. Graded land is essential to proper performance of surface systems. Surface distribution methods include: 1) ridge and furrow irrigation, 2) surface flooding irrigation, 3) rapid infiltration basins, and 4) overland flow.

<u>Surface Distribution System Design</u>

Canals or pipelines are normally used to convey wastewater to a surface distribution system. Design standards for these wastewater conveyance systems and for flow control and measurement techniques are published by the American Society of Agricultural Engineers. Methods of distribution to fields include turnouts, siphon pipes, valved risers, gated surface pipe, and bubbling orifices.

4.4.2. Sprinkler Distribution Systems

Sprinklers can be used for all types of land treatment systems. The most common types of sprinklers are 1) hand moved, 2) mechanically moved, and 3) permanent set. The more significant design considerations for sprinkler system selection include field conditions (shape, slope, vegetation, and soil type), climate, operating conditions, and economics.

4.4.2.1. Sprinkler Distribution System Design

The determination of a sprinkler system design involves the optimum rate of application, sprinkler selection, sprinkler spacing and performance characteristics, lateral design, and miscellaneous requirements. Detailed design requirements for specific systems may be obtained from equipment suppliers.

The optimum rate of application for a sprinkler system will provide uniform distribution under prevailing climatic conditions without exceeding the intake rate of the soil. Overland flow systems are an exception.

Sprinkler selection is dependent on the type of distribution system, pressure limitations, application rates, clogging potential, and effect of winds. Sprinklers used for application of wastewater are usually of the rotating head type with one or two nozzles. Manufacturers should be consulted for specific sprinkler specifications.

Sprinkler spacing and performance characteristics are jointly analyzed to determine the most uniform distribution pattern at the optimum rate of application. Since the amount of water applied by a sprinkler decreases with distance from the nozzle and the distribution pattern is circular, sprinklers and laterals are spaced to provide overlapping of the wetted diameter. Choice of spacing between sprinklers is closely associated with both the application rate and the amount of pressure at the nozzle. The primary factor that affects the choice of spacing is the vegetative cover (i.e. open field crops or forests). An 80 by 100 foot spacing is preferred for open fields and a 60 by 80 foot spacing is recommended for wooded areas. These appear to give the best relationship between good distribution and reasonable costs. Other spacing alternatives may be determined empirically or by using published guidelines.

Once the preliminary spacing has been determined, the nozzle discharge capacity to supply the optimum application rate is found by the following equation:

$$Q = (SL \times SM \times I) \div C$$

Q = flow rate from nozzle, gallons/minute (liter/second)
SL = sprinkler spacing along lateral, feet (meters)
SM = sprinkler spacing along main, feet (meters)

I = optimum application rate, inches/hour (centimeters/hour)
C = constant = 96.3 (360)

This establishes the basis for final sprinkler selection, which is a trial and adjustment procedure to match given conditions with performance characteristics of available sprinklers.

Lateral design consists of selecting sizes to deliver the total flow requirement of the lateral with friction losses limited to a predetermined amount. A general practice is to limit all hydraulic losses in a lateral to 20 percent of the operating pressure of the sprinklers. This will result in sprinkler discharge variations of approximately 10 percent along the lateral.

System automation selections should be based on a comparison of labor with the cost of controls at the desired level of operating flexibility. Common control devices include remote control valves energized electronically or pneumatically to start or stop flows in a lateral or main.

5.

SITE MONITORING

5.1. PURPOSE

Land application systems must be monitored to ensure that they are not causing groundwater or surface water pollution. Due to the variety of soils and geology in Pennsylvania, each monitoring system must be custom designed. This will require the expertise of hydrogeologists, soil scientists, and engineers.

The applicant must design and submit a monitoring plan as part of the permit application. The monitoring plan must characterize the wastewater, estimate the direction of groundwater flow, and describe the proposed monitoring methods in detail for groundwater, soil moisture, and the weather. The DEP *Groundwater Monitoring Guidance Manual* provides details on monitoring well construction and sampling.

5.2. WASTEWATER CHARACTERIZATION

To develop appropriate monitoring parameters, the applicant must describe the chemical and physical characteristics of the wastewater.

5.2.1. Chemical Characteristics

The chemical parameters typically associated with sewage are pH, phosphorous, nitrate, nitrite, ammonia, Kjeldahl nitrogen, chloride, sulfate, and sodium. Frequently, community sewage systems and municipal systems will also have metals or various organic chemicals. The specific parameters must be identified and quantified. These parameters must be monitored once the system begins operation.

Prior to land application, any industrial wastewater effluent must be monitored to ensure sufficient pretreatment. This includes monitoring for the chemical constituents designated for treatment along with any treatment byproducts.

5.2.2. Physical Characteristics

These characteristics include, but are not limited to:

1. Density - Because groundwater travels so slowly through most aquifers, the anticipated final effluent may float, sink, or dissociate evenly upon entry to the groundwater system.
2. Chemical Differentiation - Occasionally, the chemical constituents of some plumes can be expected to stratify within the aquifer. Certain parameters travel faster than others and should be listed in a theoretical order of appearance.
3. Adsorption/Absorption - The chemicals contained within the dispersion plume can adsorb or absorb to the soil or rock material permanently, temporarily, or variably.

5.3. DIRECTION OF GROUNDWATER FLOW

Because of the inherent difficulties in directly measuring treatment effectiveness, the permit application must describe the groundwater flow direction as accurately as possible. Knowledge of the direction of groundwater flow is critical for design of the monitoring network. If the monitoring network does not adequately cover groundwater flow beneath the site, additional monitoring points will be required.

Because gravity is the dominant force in the movement of groundwater, the regional water table often exists as a subdued image of topography. However, a detailed water table analysis may provide information to the contrary. Reliance on topography alone for the design of a groundwater monitoring system can cause monitoring wells to be improperly located.

The slope direction of the water table or potentiometric surface indicates the theoretical direction of groundwater movement. Therefore, the depth to groundwater must be determined to correctly map the hydraulic head gradients. This will generally require measurements from borings, piezometers, or wells to observe the groundwater levels. A minimum of three data points is required to describe the hydraulic gradient of the aquifer beneath the site. More data points may be necessary to adequately characterize groundwater flow, depending on the size and complexity of the proposal. Historical data from geological publications are an additional source of information. Various publications on groundwater resources can be obtained from the Department of General Services, the State Book Store, 1825 Stanley Drive, Harrisburg, PA 17103, (717) 787-5109.

Once reliable measurements of the water table or potentiometric surface are obtained, the interaction of the soil, geologic, hydrologic, and hydrogeologic characteristics should be assessed to determine potential irregularities in groundwater flow. Examples of factors with the potential to influence groundwater movement include lithology, bedding planes, folds, fracture traces and lineaments, faults, fractures, joints, cleavage planes, leaky aquitards, pumping wells, temporal variations in recharge, and solution channels. All permit applications must contain sufficient data to describe the actual groundwater flow.

Care should be taken to avoid errors in interpreting the groundwater level data. For example, water levels above long screens or open hole lengths in a well reflect a composite water level, which may differ from the water table. The same is true of wells or piezometers that monitor groundwater at depths below the water table.

5.4. MONITORING METHODS

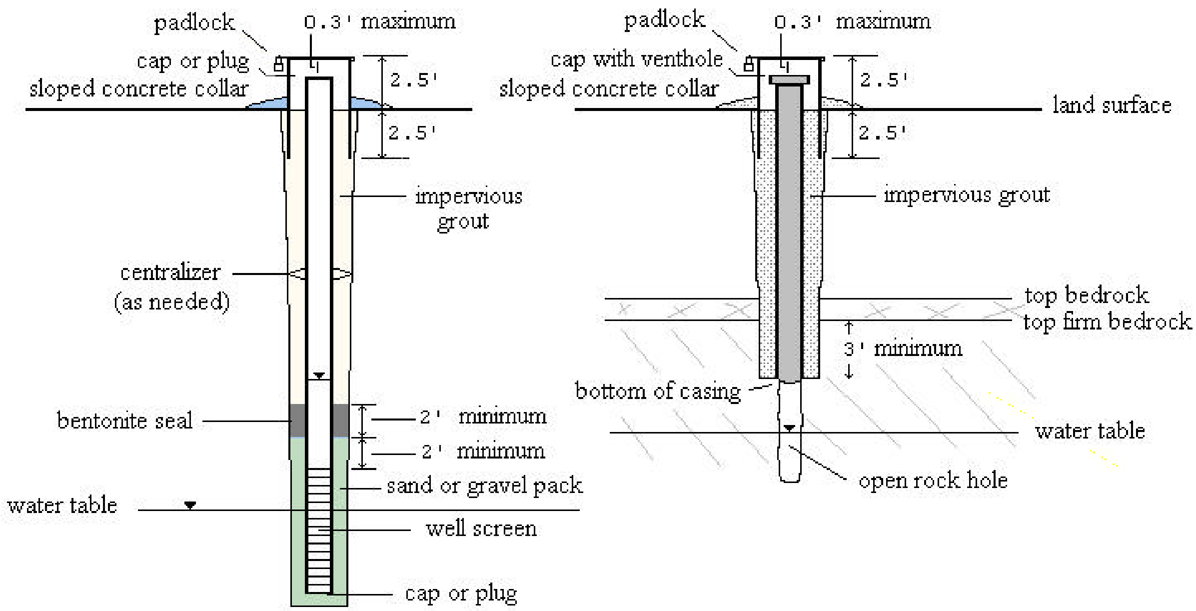
The applicant must submit a plan for monitoring the land application system. Common monitoring methods that may be required include water table monitoring wells, piezometers, lysimeters, facility monitoring ports, and spring sampling.

5.4.1. Monitoring Wells and Piezometers

Monitoring wells and piezometers are commonly used to assess groundwater in Pennsylvania. Water table wells, a type of monitoring well, are typically used for land application systems.

Water table wells are designed to contain the water table within the open or screened interval. Piezometers are small diameter wells, generally non-pumping, with a very short well screen or section of slotted pipe at the end that is used to measure the hydraulic head at a certain interval below the water table. Figure 2 shows recommended construction details for monitoring wells. Piezometers should be constructed similarly.

Figure 2. Typical overburden (left) and bedrock (right) water table monitoring wells.



Piezometers and water table wells may be placed in either unconsolidated or bedrock aquifers. Nests of piezometers with different depths may be used to determine vertical flow gradients from water level measurements.

A water table contour map can be drawn from measurements of the depth to water taken from these wells. Such wells lend themselves to monitoring floating parameters or those known to produce plumes that travel along the surface of an aquifer. Examples of chemicals that float or show marked decreases in concentration with depth are most petroleum products and nitrates.

In most cases, groundwater level data from piezometers that do not intercept the water table and wells that do intercept the water table may be horizontally incompatible due to differences of hydraulic head with depth. However, they may be compatible in assessing the vertical hydraulic gradient at the site.

5.4.1.1. Design Considerations

Monitoring well design will vary based upon the different hydrogeologic conditions encountered across Pennsylvania. Design also depends upon the chemical parameters to be monitored.

Construction: Because construction will require patience, intensive data collection, and monitoring well construction experience, the consulting hydrogeologist should understand the total project as well as the goals of the monitoring program. Complete records of the drilling procedures, strata descriptions, construction procedures, and materials used should be kept on file at the land application facility. Monitoring wells and piezometers both require the following construction features: 1) a locking well cap, 2) a protective, steel standpipe of larger diameter than the actual well casing, 3) a well casing, commonly constructed of standard steel, stainless steel, PVC plastic, or an inert substance such as teflon, as conditions or parameters warrant, and 4) grouting of the annular space between the casing and the drilled hole.

Installation of screened wells should include appropriately sized screen slots, sand or gravel, and lengths of screens. The sand or gravel pack should be 1-3 feet above the top of the screen. A bentonite seal approximately two feet thick should be placed on top of the sandpack. The bentonite seal is followed by cement-bentonite grout and well completion.

<u>Grouting</u>: A pressure grout seal provides monitoring wells with protection from surface water intrusion. A neat (no sand or stone), five percent bentonite clay, portland cement mix should be pumped into the casing annular space from the bottom up. The bentonite adds a certain pliability to the portland cement, making it expand and contract better while decreasing the cement's permeability. A cement seal should be placed around the top of the well bore and shaped so that surface water flows away from the casing.

Another method of grouting is to use a pure bentonite clay slurry. Bentonite clay is characterized by an extremely low permeability. A concrete or portland grout mix should be used to seal the top three feet of the annular space.

If pH is a parameter of concern, portland cement should only be used to grout that portion of the well above the highest level of the water table. The annular space between the bottom casing and the top of the water table can be grouted with a bentonite clay slurry or bentonite clay pellets. Bentonite clay pellets should be carefully introduced to the annular space to prevent bridging of the pellets prior to settling.

<u>Water Table Monitoring Well</u>: Water table wells should be constructed to penetrate the saturated zone and allow the water table to intersect the screened or open hole portion of the well throughout the year. However, it should not be so deep as to dilute the sample with water derived from deeper aquifers. Water table wells can have a well screen or an open hole, depending on whether the well is located in an unconsolidated or bedrock aquifer. If the well is open hole, the overburden must be cased off.

Wells must be constructed so that they provide quality data points. The wells also must be installed carefully to prevent them from being a conduit for untreated water to flow into groundwater.

After construction, the wells should be developed until the water is clear. Some development methods include overpumping, mechanical surging, jetting, and air-lift pumping.

A large quantity of literature is available on drilling techniques, and well construction practices and materials. Some suggested references are the *Groundwater and Wells* text (Driscoll, F. G., 1986) and the National Ground Water Association (601 Dempsey Road, Westerville, OH 43081. Telephone: (800) 551-7379).

5.4.1.2. Location

Only by using the groundwater flow data can effective monitoring well locations be chosen. At least one monitoring well must be located upgradient of the land application area to establish baseline groundwater quality. A minimum of two wells must be located downgradient of the application area. Additional wells may be required at large sites or in areas with complex geology. Wells must be placed in sufficient quantity to characterize the quality of the dispersion plume from the land application operation. If after time wells do not detect wastewater constituents for a given discharge, further exploration may be necessary to assure that the plume is not escaping detection, either horizontally or vertically.

Ideally, a monitoring well network would intercept a plume and encounter lower concentrations of contaminants farther from the land treatment facility. Such a monitoring system would demonstrate the plume diluting to concentrations approaching background.

5.4.2. Lysimeters

Lysimeters are used to determine the quality of the soil moisture in unsaturated soils. They consist of a ceramic cup that is placed in the soil. The pores in the cups become an extension of the soil pore-space so that the soil-water content in the soil and cup equilibrate at the existing soil-water pressure. Applying a slight vacuum to the interior of the cup causes the soil moisture to flow into the cup. The quality of the soil moisture can be determined by bringing the sample to the surface.

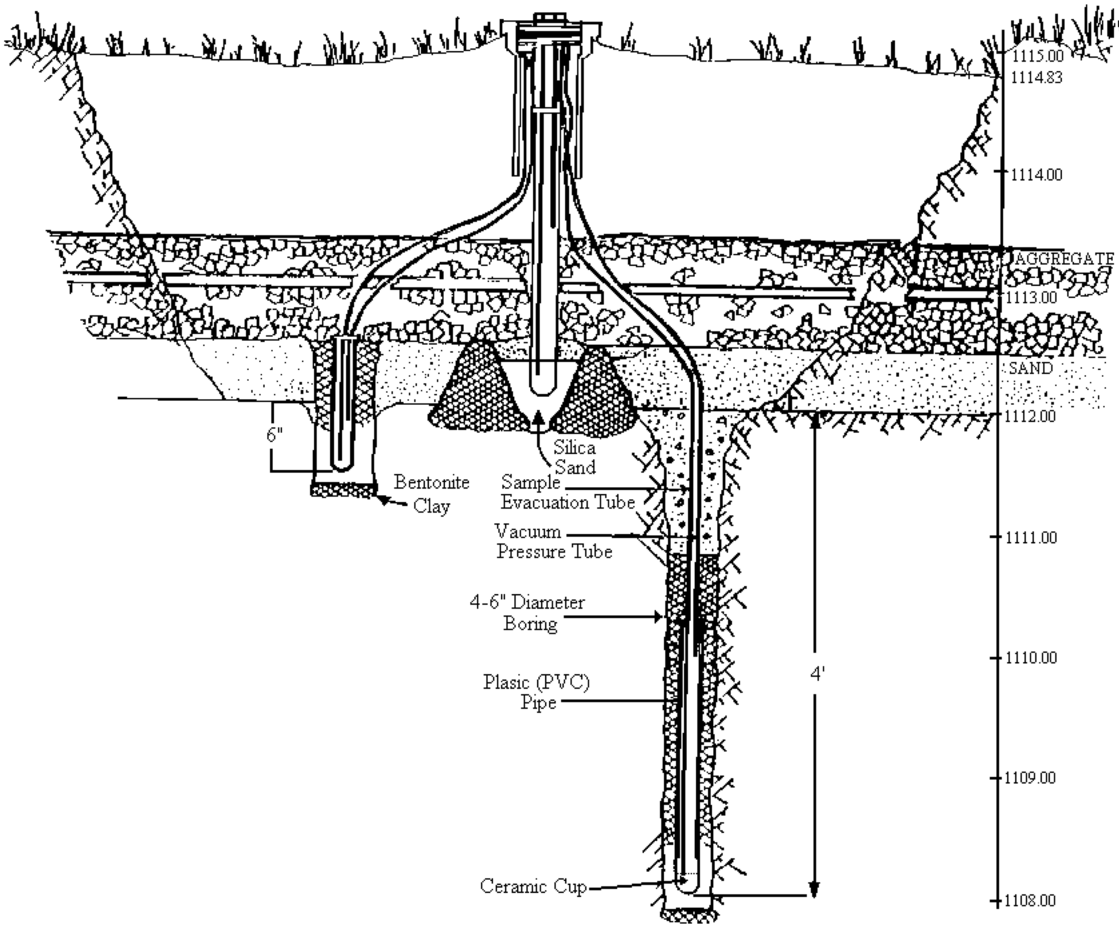
5.4.2.1. Location

The number and location of lysimeters must be proposed to monitor treatment performance within the field. Lysimeters should be placed within the application area to assure that the specified land treatment is occurring in addition to providing an observation of the final effluent entering the groundwater.

5.4.2.2. Construction

The basic design of the sampling unit includes a ceramic cup that is sealed onto a rigid-plastic body tube that is equal in length to the desired sampling depth. Small diameter tubing is inserted through a cap that seals the top of the body tube, down to the inside base of the cup. The other end of the tubing is attached to a collection flask during sampling. When a vacuum is applied to the lysimeter, the air pressure inside the lysimeter becomes less than the ambient pressure at the cup's location. This draws soil moisture into the lysimeter where it can be evacuated during sampling. Good contact must be obtained between the cup and the soil. Figure 3 illustrates a nest of lysimeters sampling an on-lot disposal system.

Figure 3. Nest of lysimeters sampling an on-lot system.



5.4.3. Facility Monitoring Port

A monitoring port is a valve or spigot from which a sample can be drawn. At least one should be located and designed to produce a representative sample of the partially treated effluent just prior to discharge to the final soil portion of the land treatment system.

5.4.4. Springs

Springs located around the land application site may provide an excellent supplemental location for monitoring; however, care must be taken to ensure that the groundwater emanating from the spring has originated from the site in question. Precipitation, temperature, and turbidity data must accompany proposals for use of springs as supplemental monitoring points.

Nearby small springs originating from the soil or bedrock may help to monitor the local impact of a site, and may be required monitoring points. Large springs flowing from carbonate bedrock (i.e.

limestone and dolomite) may drain entire watersheds or even adjacent watersheds. Subsequently, samples from such springs may not demonstrate the localized impact of the land application site.

5.5. SAMPLING PLAN

Each site proposal must outline a plan that describes the frequency and method of sampling for each chemical parameter designated for monitoring.

5.5.1. Monitoring Frequency

The applicant must propose a sampling schedule for each monitoring point. The monitoring schedule should present a sampling frequency for each parameter. Some parameters may require sampling more often than others depending upon site-specific conditions. Most applications will propose sampling with a combination of chemical parameters sampled quarterly and annually.

5.5.2. Sampling Procedure

All groundwater samples must be representative of the water in the aquifer and not that which has remained stagnant in the borehole. Therefore, the wells must be sufficiently purged. During the purging the well, frequently monitor the parameters of temperature, pH, and specific conductance. These parameters should be measured in-line if possible. When the measurements have stabilized, the groundwater that is being removed can be assumed to be formation water. In the absence of monitoring equipment, 3 to 5 borehole volumes can be used as an approximation of sufficient purging.

Samples should be collected in such a way that no significant changes in composition occur before the tests are made. Special procedures are necessary for samples containing organic compounds and trace metals. Constituents that may be present in small concentrations could be totally or partially lost if proper sampling and preservation procedures are not followed. The reference *Standard Methods For the Examination of Water and Wastewater* (Clescer, L.S., A.E. Greenberg And R.R. Trussel (eds.), 1989) should be consulted for general guidelines or more specific references. A description of the evacuation and sampling method should be included in the permit application.

5.6. WEATHER MONITORING

Since weather conditions largely determine when and how much effluent may be applied at a specific site, the proposal should contain provisions for monitoring the weather. The operator of the system should record the weather conditions during each day of aboveground effluent application. The records should contain a log of temperature, precipitation form and amount, wind direction, and wind speed.

6.

SLOW RATE INFILTRATION

6.1. SYSTEM/SITE OVERVIEW

The slow rate infiltration (SRI) system, often referred to as "spray irrigation," involves application of pretreated sewage or industrial waste effluent to the land surface for percolation and renovation within the soil mantle. Methods of application include spraying, ridge-and-furrow, and surface flooding.

Slopes in the range of 0 - 40 percent may be considered for different types of SRI systems (See Table 1). However, surface runoff of applied wastewater is not permitted. Vegetation is a critical component of any SRI system for managing nutrients, hydraulics, slope stability, and erosion potential.

Table 1: Potential for surface application.
(from *EPA Design Manual 625*)

Percent Slope	Cultivated Agriculture	Turf Agriculture	Forest Land
0 - 4	HIGH	HIGH	HIGH
4 - 12	LOW	MODERATE	HIGH
12 - 20	EXCLUDED	LOW	MODERATE
> 20	EXCLUDED	EXCLUDED	LOW

6.2. PRETREATMENT

The minimum pretreatment requirements prior to SRI application is Best Demonstrated Technology (BDT). For the purpose of this manual, unless deemed inadequate to ensure protection of groundwater quality, BDT for SRI will be as follows:

Secondary treatment for municipal wastewater must achieve 1) a minimum 85 percent removal of carbonaceous biochemical oxygen demand (C-BOD_5) and total suspended solids (TSS) and 2) the following effluent quality concentration levels based on a 30-day average:

C-BOD_5	25 milligrams/liter
TSS	30 milligrams/liter

Additionally, disinfection of the effluent is required to meet a fecal coliform level of 200/100 milliliters as a monthly geometric average, and the pH should be between 6.0 and 9.0.

Adjustments to these minimum treatment standards are allowable under federal (40 CFR 133) and state (25 PA Code Chapter 95) regulations, and on a case-by-case basis for certain specific treatment technologies (i.e. wastewater stabilization lagoons and trickling filters). Adjustments are also allowable for municipal systems that have dilute influent sewage or that accept a significant load of high strength industrial wastewater. The adjustment for industrial wastewater is established in federal regulation (40 CFR 133) which defines the allowable effluent quality as the mass-balanced average of sewage (at secondary treatment levels) and industrial waste (at best available treatment levels). These adjustments may be applied to the percent removal requirement, to the minimum concentration requirements for effluent quality, and/or when applicable, to redefining the secondary treatment standards for a specific facility. In general, treatment meeting these adjusted secondary standards will also be acceptable for producing an effluent that can be land applied. However, where such adjustments would result in significantly relaxed effluent limitations, the actual effluent limitations may be controlled by acceptable spray field loading rates, and the full degree of relaxation may not be allowable.

Best available treatment technology for industrial wastewater must meet the minimum technology-based requirements and effluent limit guidelines established in federal regulations for the relevant industrial category and subcategory. Alternatively, it is the treatment which, based on best professional judgment of the Department, will achieve a degree of treatment of conventional pollutants (C-BOD_5, TSS) and nonconventional and toxic pollutants. Such a treatment will be representative of a technology that has been demonstrated to be effective and economically achievable as the principal national means of controlling wastewater pollutants for that industry, or for an industry with similar wastewater characteristics.

Although the efficiencies achieved through best available treatment will vary from industry-to-industry, in general, at least 85 percent removal of conventional pollutants (C-BOD_5, TSS) should be achieved, with toxic substances generally removed to part-per-million levels. Best available treatment of industrial wastewaters will produce an effluent acceptable for SRI, if 1) the concentration of toxic pollutants is below the human health criteria or maximum contaminant levels for public water supply, or 2) their attenuation or degradation through the soil will result in acceptable concentrations in the groundwater.

Best available treatment also should include disinfection of the effluent, where necessary, to meet a fecal coliform level of 200/100 milliliters as a monthly geometric mean.

Prior to land application, industrial waste effluents must be amenable to final treatment within the soil. The pH of the effluent must be maintained between 6.0 and 9.0 unless special site or effluent characteristics dictate otherwise. These minimum requirements apply to all SRI systems. More stringent effluent limits may be required, depending on the site and waste characteristics.

6.3. BASIC SYSTEM DESIGN

The system components that are typical of any SRI system include pretreatment units, a disinfection unit, and some form of storage facility or lagoon. From the storage facility, the pretreated effluent is sent to the infiltration site where it is distributed by one of the following basic methods.

6.3.1. Fixed Sprinkler Systems

Application to large areas of gentle to steep slopes (0 - 25 percent), or to forested or variably covered sites are usually compatible with application by “fixed” sprinklers, which are part of a buried distribution network. Typically, fixed systems are arranged on several circuits that provide very specific design application patterns and rates. The sprinkler circuits generally distribute effluent to an area large enough to accept a single-day’s design flow with a predetermined rest period between applications. Alternative arrangements can be considered to manage other hydraulic or vegetative aspects of the SRI operations.

6.3.2. Moveable Sprinkler Systems

Sites that are low-flow, small, steep, seasonal, or heavily forested may require the use of temporary or moveable sprinklers and distribution lines, low-trajectory/low-pressure sprinklers, small diameter sprinkler heads, or "drip" emitters. The applicant should consider these methods, which may provide both cost effective and even distribution of effluent.

6.3.3. Flooding/Inundation Systems

For large areas of relatively flat, agricultural land, other methods of surface application include ridge and furrow, and surface flooding. These techniques allow for periodic inundation of portions of the system and rely on the soil's permeability to provide for the somewhat even distribution of wastewater. Although these systems are simpler in operation than other SRI systems, they are the most difficult to manage effectively. They also require more initial site preparation work (i.e. grading, leveling, ditching) prior to effluent application.

6.3.3.1. Ridge and Furrow Irrigation

The ridge and furrow method consists of installing irrigation streams along small channels (furrows) bordered by raised beds (ridges) upon which crops are grown. Furrows may be level or graded, straight or contoured. A variation of this is corrugation irrigation which consists of furrows excavated from the surface without creating raised beds.

For furrow irrigation, the water only partially covers a given field area and moves both downward and outward. Intake characteristics are best determined by inflow-outflow measurements in the field. Design application rates are then based on these results. Furrow intake rates are usually expressed as flow rate per unit length of furrow; application rates are usually expressed as flow rate per furrow, or furrow stream size. Factors that are critical for design of ridge and furrow are furrow stream size, length, slope, and spacing.

Distribution systems most commonly used for ridge and furrow consist of open ditches with siphon pipes or gated surface piping. Open ditch systems may be supplied by distribution ditches or canals with turnouts, or by buried pipelines with valved risers. Gated surface piping systems generally consist of aluminum pipe with multiple gated outlets, one per furrow. The pipe is connected to hydrants which are secured to valved risers from underground piping systems.

6.3.3.2. Surface Flooding Irrigation

Surface flooding irrigation is a method in which a sheet flow of water is directed along border strips, or cultivated strips of land bordered by small levees. It is suited to close-growing crops such as grasses that can tolerate periodic inundation. Border strips usually have slight, if any, cross slopes and may be level or graded in the direction of flow. They also may be straight or contoured. The application rate for border irrigation is dependent on the soil intake rate and physical features of the strip. Water is applied in the same manner as in ridge and furrow irrigation. However, the stream is normally shut off when it has advanced about 75 percent of the length of the border.

The objective is to have sufficient water remaining on the border after shut off to irrigate the remaining length of border to the proper depth with very little runoff. The widths of border strips are usually selected for compatibility with farm implements, but they also depend to a certain extent upon slope which affects uniformity of distribution.

Other design factors for border strip systems include soil intake characteristics, border strip lengths and slopes, and soil roughness, which is a measure of resistance to flow caused by soil and irrigation.

Distribution systems for surface flooding irrigation are similar to ridge and furrow irrigation distribution systems. Use of gated strips provides more uniform distribution at the head of border strips and allows the flexibility of easily changing to ridge and furrow irrigation if crop changes are desired.

6.4. SITE PREPARATION

Each SRI technology has specific site preparation requirements. Generally, the sprinkler distribution method requires the least amount of land surface modification. However, this method may require a significant amount of excavation to place the piping below the frost line if the lines are not designed to be drained during freezing conditions. The various "flooding" methods require a large amount of ground surface preparation including grading, leveling, and filling to provide a network of distribution ditches for uniform effluent loading. However, the need for deep excavations for buried piping is largely reduced.

The use of temporary or moveable piping networks, while requiring little if any initial surface preparation or excavation, will require a significant amount of daily maintenance. This includes management of the entire surface area so as not to interfere with placement or proper function of the system.

6.5. APPLICATION RATES

The ultimate application rate can be determined by a land limiting constituent analysis (See Section 2.7.1), analysis of the soil biological, chemical, and physical properties (See Section 2.2), hydrogeologic analysis (See Section 2.3 and 2.4), climatic conditions (See Section 2.5), and proposed vegetation (See Section 2.6), which is site and waste specific. The Department will generally not consider application rates greater than two inches/week/acre except in special circumstances with supporting documentation. General guidelines of maximum allowable application rates where the soils are to provide additional necessary treatment for renovation are shown in Table 2.

Table 2: Guidelines for maximum allowable application rates

Soil Type	Application Rate
Deep, well drained soils...	2.0 inches/week/acre
Moderately deep, well drained soils..	1.5 inches/week/acre
Deep, moderately well drained soils	1.0 inches/week/acre
Moderately deep, moderately well drained soils........................	0.5 inches/week/acre
Shallow, moderately well drained soils	Not typically acceptable
Deep, somewhat poorly drained soils ...	0.5 inches/week/acre (growing season only)

All other soil depth/drainage classes are generally unacceptable, unless detailed substantiating data has been provided that documents the feasibility of the system and alternate application rates.

6.6. PROCESS DESIGN

6.6.1. Hydraulic Loading Rates

Hydraulic loading rates for SRI are limiting where slow permeability soils are present or where there are not any other limiting parameters. Hydraulic loading rates must be within the measured or estimated soil capabilities. Loading is based on a water balance that includes precipitation, infiltration rate, evapotranspiration, soil storage capabilities, and subsoil permeability. Although the total monthly loading should be distributed uniformly, the applicant must address planting, harvesting, drying, and other periods of non-application.

The application rate must be balanced as shown in the following equation:

$$Lw + Pr = ET + Wp + R$$

Lw	=	wastewater hydraulic loading rate, inches per week (centimeters per week)
Pr	=	design precipitation, inches per week (centimeters per week)
ET	=	evapotranspiration (or crop consumptive use of water), inches per week (centimeters per week)
Wp	=	percolating water, inches per week (centimeters per week)
R	=	net runoff of precipitation, inches per week (centimeters per week)

The relationships in this equation can be used for weekly, monthly, or annual balance. Design precipitation is calculated from an analysis (using all available data) of the ten-year frequency of wetter-than-normal conditions. Evapotranspiration estimates and peak rates that affect maximum hydraulic loadings can be obtained from extension specialists, irrigation specialists or land grant universities. Values for percolating water can be estimated from soil characteristics and verified with field investigations. Wastewater is assumed to percolate, so net runoff can be assumed to be negligible.

6.6.2. Nitrogen Loading Rates

Nitrogen management for the SRI process is principally crop uptake with some denitrification. Aerobic nitrification involves the breakdown of organic nitrogen to ammonia and ammonium. Through the action of bacterial agents such as *Nitrosomonas*, the ammonium ion is broken down to nitrite-nitrogen. This is further broken down through the action of *Nitrobacter* bacterium to nitrate-nitrogen. Denitrification involves the biological reduction of nitrate to nitrite and finally nitrogen gas. Such biological denitrification requires bacteria (*Pseudomonas*, *Micrococcus*, *Bacillus*, and *Acomobacter*), anoxic conditions and a source of organic carbon.

The equation to determine the annual nitrogen is:

$$Ln = U + D + 2.7\ WpCp$$

Ln	=	wastewater nitrogen loading, pounds/acre.year (kilogram/hectare.year)
U	=	crop nitrogen uptake, pounds/acre.year (kilograms/hectare.year)
D	=	denitrification, pounds/acre.year (kilograms/hectare.year)
Wp	=	percolating water, feet/year (centimeter/year)
Cp	=	percolate nitrogen concentration, milligrams/liter

Design values for crop nitrogen uptake (U) will depend on actual crop yields. Local agricultural agents should be contacted for site-specific information. Denitrification is difficult to determine under field conditions, but losses generally range from 15 - 25 percent of the applied nitrogen. Conditions favorable to denitrification include soils that are fine textured and high in organic matter, frequent wetting, high temperatures, vegetative cover, high groundwater table, and neutral to slightly alkaline pH. Volatilization is known to occur, but is difficult to quantify.

6.6.3. BOD and Suspended Solids Removal

The expected BOD concentration of treated water after 1.5 meters of percolation is less than two milligrams/liter. Filtration and adsorption are the initial mechanisms in BOD removal, but biological oxidation is the ultimate treatment mechanism. Removal of suspended solids is not as well documented as BOD removal, but contributions of one milligram/liter or less can generally be expected in the renovated water. Filtration is the major removal mechanism for suspended solids. Volatile solids are biologically oxidized, and the fixed or mineral solids become part of the soil matrix.

6.6.4. Phosphorus Removal

Phosphorus is removed from solution by fixation processes in the soil, such as adsorption and chemical precipitation. Removal efficiencies are generally very high for slow rate systems and more dependent on the soil properties than on the concentration of phosphorus applied. Phosphorus retention can be enhanced by the use of crops such as grass with large phosphorus uptake. Field determination of levels of free oxides, calcium, aluminum, and soil pH will provide information on the type of chemical reaction that will occur. Determination of phosphorus sorption capacity of the soils requires laboratory testing of field samples. Systems with strict phosphorus controls for recovered water should include monitoring for nutrient soil phosphorus to verify retention in the soil and system performance.

6.6.5. Removal of Trace Elements and Other Parameters of Concern

The concentrations of trace elements and other parameters of concern vary significantly, depending on wastewater characteristics. Trace elements include metals and organic compounds such as pesticides, and volatile, acid extractable and base neutral organics. Trace element assessments are necessary to assure that levels will not be toxic to cover vegetation or impair groundwater quality. In some cases where applied concentrations of trace metals are excessive, it may be necessary to maintain soil pH at 6.5 or greater. Other constituents of concern include greases, emulsions, and salts. These may clog soils, plug nozzles, coat vegetation, be persistent or non-biodegradable, non-exchangeable with soil materials, or be toxic to vegetative cover. Effluent that exhibits these properties must not be applied to the land surface.

6.6.6. Microorganism Removal

The potential for public health risks from microorganism contamination from land application of wastewater varies greatly depending upon site-specific details. The factors include type of application, pre-application treatment, public access to the site, population density, adjacent land use, climate, type of on-site buffer zones, and type of vegetative cover.

The applicant should evaluate these variables to achieve the basic goal of minimizing public health risks from land application of wastewater. All wastes containing pathogens must be disinfected prior to application.

7. RAPID INFILTRATION

7.1. SYSTEM/SITE OVERVIEW

The use of the Rapid Infiltration (RI) method is limited in Pennsylvania because of the lack of the necessary conditions for operation. The following conditions should exist for RI treatment to be successful:

1. Soils are extremely permeable
2. Direct discharge to surface water is not possible due to effluent permit limitations
3. There is a direct connection from the groundwater to the surface water which provides sufficient renovation to meet surface water quality standards

RI systems are designed to handle large quantities of wastewater. The wastewater is applied to a confined basin built over a highly permeable infiltration surface, which overlies a highly permeable soil profile (i.e. sands and loamy sands). The applied wastewater is expected to percolate through the soil to some point where it will either be withdrawn to be used, recirculated, or discharged to combined flows to surface water, or become part of the groundwater.

Because of the nature of RI basin construction, the permissible slope range is limited to 0 - 20 percent. Slopes of less than 10 percent are preferred because they require less surface preparation and excavation to generate a level basin bottom, leaving adequate soil depths in place. Rolling or undulating topography is probably not conducive to RI. Depending on the ultimate disposal or use of the effluent, RI may be considered either a treatment or a treatment/discharge system.

RI differs from slow rate infiltration in the following ways:

1. Hydraulic applications are greater, so greater reliance on permeability measurements is required
2. Nitrogen removal mechanisms rely less on crop uptake and more on nitrification-denitrification
3. Solids application is greater
4. Systems can be adapted to severe climates

7.2. PRETREATMENT

Widely varying pretreatment levels may be used based on specific design objectives, ultimate disposal or use of the effluent, and the parameters of concern within the effluent. A minimum of primary treatment will usually be required to reduce the possibility of physical “plugging” of the infiltrative surface by solids and to control odor within the RI basin. Pretreatment levels also may need to be greater when limited land area is available or when an effluent quality of advanced secondary or tertiary treatment levels is required. If nitrogen removal is a primary treatment goal, a relatively high BOD:N ratio must be left in the pretreated wastewater to promote denitrification within the RI system. RI systems are capable of renovating wastewater parameters such as TSS, BOD, NH_3, and P.

7.3. BASIC SYSTEM DESIGN

The system components that are common to any RI system include pretreatment units and infiltration basins. The basins are contained by relatively impermeable dikes and overlie rapidly permeable native soil. The bottom of the basin forms the interface for infiltration of the wastewater.

The most important component of RI systems is the basin. The interface must remain rapidly permeable at all times and not become smeared or plugged with solids. The soil beneath the basin also must be evaluated and shown to sustain a rapid permeability. The underlying strata must be well enough defined to identify any layers or lenses of more restrictive permeability, both under and in the vicinity of the rapid infiltration basin. The groundwater flow direction should also be well defined to determine discharge zones.

Basins are usually formed by construction of earthen dikes or by excavation. Control of subsurface flow and recovery of renovated water are essential components of the system design. If discharge to groundwater is not a viable option, a recovery system is needed to withdraw and reuse the renovated water. Methods of recovery include underdrainage systems, pumped withdrawal, and natural discharge to surface water.

Where natural drainage to surface water is planned, the slope and elevation difference between the basin and surface water are important factors in determining discharge zones. Also, the groundwater table must be controlled to prevent mounding, which may alter the direction of groundwater flow. The aquifer should be able to readily transmit the renovated water away from the infiltration site toward the surface water body. Locations of probable discharge points to surface water must be identified and locations of effluent recovery wells must be plotted if reuse of the effluent/groundwater on-site is considered. All Pennsylvania surface water quality criteria and standards must be achieved in the receiving surface waters.

When designing the size of basins, the applicant should consider the amount of usable land, hydraulic loading rate, topography, and management flexibility. To operate a system on a continuous basis, at least two basins will normally be required, one for flooding and one for drying. Multiple basins will provide flexibility in the management of the system.

A distribution system for infiltration basins is often similar to that for surface irrigation. The purpose of this distribution system is to apply water at a rate that will constantly flood the basin at a nearly uniform depth. Sprinklers are sometimes used. Effluent weirs may be used to regulate the depth of applied water.

For the system design, the applicant also must evaluate the advantages of bare soil vs. vegetation for the basin surface. The RI basins need not be vegetated prior to application; however, vegetation will probably develop depending on the length of resting period between applications.

7.4. SITE PREPARATION

RI systems require extensive site preparation. This may include the clearing of all vegetation from the basin site(s), and construction of the dikes that will form the basins. The dikes should be made of impermeable materials that will hold the wastewater while it infiltrates into the basin bottom without leaking into the sides. If the system is intended for winter-time use, the basin bottom must be modified into a “ridge and furrow” form so that the inevitable “ice-sheet” will rest on the ridge tops and allow the effluent to completely percolate into the basin without interference. Similarly, routine maintenance must be accomplished prior to winter use to remove vegetation that may prevent the “ice-sheet” from floating to the top of the basin.

7.5. APPLICATION RATES

Rapid infiltration generally supports the greatest application rates on a continual or yearly basis. These application rates are usually determined by the degree of treatment necessary, amount of land area available, and a percentage of the soil’s hydraulic conductivity. Application is typically performed on a cycle that maximizes treatment capabilities by allowing a resting period between applications to promote reaeration of the subsurface. Typical annual application rates are in the range of 100 feet/year.

7.6. PROCESS DESIGN

7.6.1. Hydraulic Loading Rates

System design for the RI process includes the interrelated factors of hydraulic loading rate per application cycle, application and resting cycle, soil infiltration capacity, solids applied in the wastewater, and subsoil permeability. Although site investigations may show that the infiltration rate is greater than the soil permeability, the infiltration rate under design conditions with solids applications will usually decrease and control liquid applications. For final design values, soil infiltration tests should be conducted. The most limiting layer in the soil profile should be evaluated, and that permeability should be used in the design. For any specific RI site, the design must balance suspended solids application, land area requirements, and resting requirements. System design for maximum infiltration rates should consider adequate drying time based on local climate and solids loadings to restore infiltration rates. For soil surfaces that are maintained bare of vegetation, the surface should be periodically raked, harrowed or disked. The applicant should consider the effects of nitrogen removal by denitrification, including soil aeration and less opportunity for solids degradation.

7.6.2. Nitrogen Loading Rates

Ammonia sorption, denitrification, and nitrification in the RI process are generally of greater importance than crop uptake and can be exceeded by nitrogen loading rates. Retention of ammonia by cation exchange capacity can be excellent. Conversion of ammonia to nitrate occurs rapidly when short, frequent applications are used to promote aerobic conditions in the soil. Longer application cycles restrict soil aeration and favor nitrogen loss by denitrification. Available organic matter in the soil profile as a result of applied BOD also increases the amount of denitrification. Nitrification is favored by short application periods followed by relatively long resting periods. Nitrified effluents can be produced by rapid infiltration at nitrogen loadings up to 60 pounds/acre/day. Nitrification below 2°C and below pH 4.5 is minimal.

7.6.3. BOD and Suspended Solids Removal

The removal efficiency of BOD and suspended solids are site-specific and depend on soil type and travel distance in the soil. BOD removal is accomplished primarily by aerobic bacteria that require resting periods to reaerate the soil. The applicant must consider variables such as loading rates, temperature, and resting period which will affect BOD and suspended solids removal.

7.6.4. Phosphorus Removal

The basic mechanisms for phosphorus removal are similar to those described for slow rate infiltration systems in Section 6.6.4. Coarser textured soils used for RI may have less retention capacity for phosphorus. Soil capabilities should be estimated from site-specific tests.

7.6.5. Removal of Trace Elements and Other Parameters of Concern

The basic mechanisms and considerations for removal of trace elements and other parameters of concern are similar to those described for slow rate infiltration systems in Section 6.6.5. Additional considerations for heavy metals in RI systems are: 1) high rates of application and 2) potentially low adsorptive potential of the coarser soils.

7.6.6. Microorganism Removal

Mechanisms of microorganism removal include straining, sedimentation, percolation, disinfection or desiccation during pre-application treatment. Radiation, predation, desiccation, and other hostile environmental factors are effective mechanisms of removal during application.

8.

LARGE VOLUME AND COMMUNITY ON-LOT DISPOSAL SYSTEMS

8.1. SYSTEM/SITE OVERVIEW

Large volume and community on-lot systems are similar methods for treatment and disposal of sewage. A large volume on-lot system will handle sewage flows in excess of 10,000 gallons per day. A community on-lot system serves two or more Equivalent Dwelling Units (EDUs). Each system depends on soil for part of the sewage renovation.

Both on-lot systems consist of an aerobic or anaerobic treatment tank followed by a distribution system placed in aggregate over a soil absorption area. Sewage distribution occurs by a gravity or a pressure distribution system. Pressure distribution equipment is made up of a dosing tank followed by a system of pressurized laterals. The absorption areas can consist of a bed or trench configuration, either in-ground or elevated above the ground surface.

Additional pretreatment or post-treatment facilities may be required to overcome specific site restrictions (such as high concentrations of certain parameters). The addition of any pretreatment or post-treatment facilities with an on-lot system will require extensive documentation to show that the proposed system will consistently treat the chemical parameter of concern.

Community on-lot disposal systems are permitted by the sewage enforcement officer for the local agency when projected sewage flows are less than 10,000 gallons per day. However, when pretreatment exceeds the minimum required in 25 PA Code Chapter 73, a Clean Streams Law, Part II Water Quality Management permit must be obtained. When the projected sewage flows exceed 10,000 gallons per day (gpd), the on-lot disposal system is classified as a large volume on-lot system and is permitted by DEP under a Part II permit. Both classifications of systems must meet the requirements of Chapter 73, Standards for Sewage Disposal Facilities, as well as other site-specific requirements. The applicant should refer to these regulations for a more detailed description of system requirements.

The following site factors determine where these types of on-lot systems may be used:

1. Soils - The soil profile must be free of any "limiting zone" to a minimum depth of four feet below the actual absorption area. Limiting zones are soil horizons or conditions that limit either movement or renovation of the effluent. Examples include a seasonal high water table, rock with open joints, fractures or solution channels, insufficient fine soil between masses of loose rock fragments, and rock formations, stratum, or soil conditions that are so slowly permeable that they limit downward passage of effluent. The use of an in-ground absorption area at the three feet maximum depth on a lot with no slope would require seven feet of soil without any limiting zone.

   Sites with limiting zones between 20 and 60 inches may be considered for elevated sand mound systems if the site slope is less than 12 percent. The elevated sand mound system depends upon both the natural soils (minimum 20 inches) and a "sandy fill" to makeup the required minimum depth of four feet of suitable soil between the absorption area and the limiting zone that is needed to adequately renovate the effluent. Any fill material added to a site, other than the sand mound itself, must be pre-approved as suitable fill. Also, the fill must be in place four years to restore natural permeability prior to its evaluation by standard soil testing procedures. The fill material and the original soil must be free of limiting zones to a combined depth of 20 inches to be further considered for placement of an absorption area.

2. Hydrogeology - The proposed absorption area must be free of rock outcrops, shallow pinnacles, sinkholes, or closed depressions. Hydrogeologic evaluations are a prerequisite for site approval. Studies must document that the proposed system will not adversely impact groundwater, as described in 25 PA Code Section 71.62.

3. Slope - The maximum allowable slope is 25 percent for an in-ground trench system, 8 percent for an in-ground seepage bed, and 12 percent for an elevated sand mound. Large absorption areas are difficult to site on slopes because of the maximum and minimum absorption area depth requirements. Excavating or filling a site to achieve proper slopes will disqualify the site for an on-lot disposal system. When evaluating a site, the applicant must assess the relationship between the slope and the configuration of the system. The system must meet the maximum and minimum depth standards across the slope and must have sufficient downgradient area available for lateral liquid dispersion.

4. Isolation Distances - On-lot systems must meet a number of minimum isolation distances from features such as lakes, wells, etc. as described in 25 PA Code Section 73.13. Large volume on-lot disposal systems may be required to increase these isolation distances based upon hydrogeologic or design factors.

5. Floodplains - On-lot systems are prohibited in areas identified by Federal Flood Insurance mapping as a floodway. When this mapping is not available, on-lot systems will be prohibited on soils otherwise identified as floodplain soil, or in flood-prone areas.

6. Soil Permeability - For an on-lot system, the acceptable range of permeability, as measured by a standard percolation test, is 3 to 120 minutes per inch. The 25 PA Code Chapter 73 established the standard procedure for conducting a percolation test. The number of tests required is determined by a grid pattern established by the DEP regional soils scientist.

   Additional permeability (hydraulic conductivity) testing is required when 1) a large volume system is proposed, 2) where the total absorption area will exceed 5,000 square feet, and 3) soils or geologic evaluations reveal the presence of slow permeability conditions below the depth of the percolation test.

   Site suitability will be based on the permeability of the most restrictive strata under the absorption area. The permeability test results may also require that the system size be increased over the size determined from the percolation tests.

8.2. PRETREATMENT

Pretreatment is required for all community and large volume on-lot disposal systems. The most common pretreatment methods are septic tanks and aerobic tanks. These tanks are required to meet specific minimum design standards contained in 25 PA Code Chapter 73.

Additional treatment may be required to reduce specific components of the wastewater prior to discharge to the absorption area. Denitrification is a commonly required treatment where groundwater levels of nitrate-nitrogen are elevated. These systems should be designed in accordance with the DEP *Domestic Wastewater Facilities Manual*.

8.3. SITE PREPARATION

Site preparation varies with the proposed system configuration. However, the following are some site preparation and protection factors common to all on-lot systems:

1. The primary concern is the possibility of affecting the soil by heavy equipment needed to excavate or construct the system. When soil moisture levels are excessive or equipment is too heavy, soils may smear or compact, thereby losing their natural permeability. Clayey or loamy soils are especially susceptible. This can occur in the absorption area and around the fringe of the system. Since on-lot systems depend upon vertical and lateral movement of liquids through the soil mantle, any loss of permeability may impact system function. To avoid potential problems with compaction or smearing:

    a. Allow only light equipment on the site to conduct soil profile examinations and permeability testing.
    b. Rope off the proposed absorption area including a 10-foot buffer area and prohibit entry of any heavy equipment.
    c. Before allowing any equipment on the site to construct the system, conduct this soil moisture test: lightly squeeze the soil in your hand, then bounce it lightly in your hand or tap it with your finger. If the sample crumbles or breaks up immediately, the site can be worked.
    d. Use trench system designs where practical. Construction equipment should be kept out of the excavated area during trench construction.
    e. When large absorption areas are being constructed, use a trackhoe or other equipment that can operate from a position outside the bed area. Long and narrow system designs allow for less in-bed excavation and materials handling. Construct elevated sand mounds from the upslope side only.

2. Cut and remove all vegetation prior to excavation of the system. Avoid areas with large trees.

3. For elevated sand mounds, cut trees at the ground surface and leave stumps in place. Remove boulders or surface rocks. With light equipment, chisel plow the surface of the absorption area and berm. Rototilling is not permitted.

8.4. BASIC SYSTEM DESIGN

8.4.1. Distribution System Design

Effluent is transported through either a gravity or pressurized distribution system. Both systems distribute effluent to a bed or trench filled with an appropriate amount of aggregate over the entire absorption area. The lines and distribution system must be designed to provide for even application of the effluent across the entire absorption area (25 PA Code Section 73.42). Gravity distribution is accomplished by means of a distribution box or a header.

A pressurized distribution system consisting of a dosing tank, pump or siphon, and a distribution system of manifolds and laterals must be used when any of these conditions occurs (25 PA Code Section 73.43):

1. The absorption area exceeds 2,500 square feet
2. The percolation rate exceeds 60 minutes per inch
3. An elevated sand mound is proposed

8.4.2. Absorption Area Design

Three basic absorption systems used in on-lot systems include: 1) in-ground seepage bed and trench systems, 2) subsurface sand filters, and 3) elevated sand mounds. Each is dependent upon specific site conditions.

The in-ground seepage bed and trench systems are used where limiting zones are at a sufficient depth to allow the installation of absorption areas 1 - 3 feet below the surface (See Standards at 25 PA Code Sections 73.52 and 73.53).

Subsurface sand filters are used where the limiting zone is greater than 6 feet from the ground surface and the percolation rate within the upper three feet of the soil profile is greater than 90 minutes per inch. These systems replace unsuitable soils with sand (25 PA Code Section 73.54).

Elevated sand mounds combine a minimum of 20 inches of suitable native soil with a sand mixture to achieve the four feet of vertical separation above the limiting zone necessary for proper system function (25 PA Code Section 73.55).

Sand specifications for sand filters and sand mounds are defined in 25 PA Code Section 73.51.

8.4.3. Application Rates

The size of absorption areas is primarily based on anticipated sewage flows and the infiltrative capacity of the underlying strata. The infiltrative capacity is typically determined using results of the percolation tests, or a relatively small percentage (typically 4 - 10 percent) of the saturated vertical hydraulic conductivity.

Most test methods for hydraulic conductivity are under saturated conditions, while actual flow under the absorption areas will be in unsaturated strata. This must remain the case since saturated soils do not renovate effluent as effectively as unsaturated soils. Unsaturated hydraulic conductivity values can be determined using a few detailed test methods, but they typically are less than or equal to 10 percent of the saturated value for the same soil.

The applicant should base the actual design application rate on the most conservative value from the site test results. These results include the data from “shallow” percolation tests and the hydraulic conductivity tests of the most restrictive “deeper” subsurface horizon. To calculate the size of the absorption area, the applicant should include only the bottom aggregate area of the bed or trench.

Sidewalls, endwalls, and basal sand areas (in elevated sand mounds) are not considered in determining appropriate minimum absorption areas.

8.5. PROCESS DESIGN

8.5.1. Hydraulic Loading Rates

Hydraulic loading rates depend upon the capability of the soils and geology to accept the anticipated hydraulic load while maintaining unsaturated conditions for at least four feet below the absorption area. For systems limited only by this soil capacity, a percolation test is used to establish the loading rate. 25 PA Code Section 73.16 provides a table of aggregate requirements per gallon of hydraulic load for the range of percolation rates.

Additional permeability testing will be required to determine hydraulic loading rates when the following types of systems or site conditions are evaluated:

1. Large volume on-lot disposal systems
2. Systems with an anticipated absorption area of 5,000 square feet or more
3. Sites with slowly permeable conditions below the depth at which the percolation test was performed

Sufficient additional permeability testing must be conducted to:

1. Determine the permeability of the identified restrictive soil, geologic, or hydraulic layer,
2. Determine the vertical rate and the horizontal rate of flow in or above the restrictive layers in inches per hour
3. Determine the hydraulic loading rate based on hydraulic conductivity rather than percolation

Using the loading calculations, the applicant must document the potential for groundwater to mound into the required four foot zone of unsaturated suitable soil under the absorption area. Systems that use a pressurized distribution method must be designed to discharge the estimated daily hydraulic load to the absorption area in one or more doses (25 PA Code Sections 71.44 - 71.46).

8.5.2. Nitrogen Loading Rates

On-lot disposal systems convert organic nitrogen to nitratenitrogen. This occurs through the action of nitrifying bacteria in the aggregate, unsaturated soils, and sand making up the absorption area. The applicant must conduct hydrogeologic evaluations to consider the potential impact of nitrate-nitrogen on existing or potential downgradient groundwater uses. For the purpose of these evaluations, nitrate-nitrogen is considered to be loaded to the groundwater at 45 parts per million. Mass balance calculations of the dispersed and diluted nitrate-nitrogen must document that the waters of the Commonwealth will be protected. 25 PA Code Section 71.62 (c) (2) and (3), and Component 2 of the Sewage Facilities Planning Module describe why and when these studies are required, and how they should be conducted. Proposals for additional treatment of nitrogen to reduce the impact to groundwater must document consistent, reliable nitrogen reduction.

8.5.3. BOD and Suspended Solids Removal

The hydraulic loading rate and the soils suitability requirements contained in 25 PA Code Chapter 73 provide adequate minimum design criteria to meet necessary BOD and suspended solids removal. Design modifications to further reduce suspended solids include 1) the addition of septic solids retainers at the outlet tee of each septic tank or compartment and 2) the use of multi-chambered septic tanks.

8.5.4. Phosphorous Removal

Phosphorous is effectively removed from the wastewater entering an on-lot disposal system through soil adsorption. Use of community or large volume on-lot systems sited and designed in accordance with 25 PA Code Chapters 71 and 73 for treatment and disposal of normal household waste does not require evaluation of phosphorous removal.

8.5.5. Removal of Trace Elements and Other Parameters of Concern

Evaluation of trace elements is not required if normal household waste is proposed for treatment and disposal, and if the system is sited and designed in accordance with 25 PA Code Chapters 71 and 73.

Basic septic or aerobic tanks generally do not successfully treat modern industrial wastes. Many of these wastes possess substances such as metals, salts, and oils and greases in concentrations that either destroy the biota of a normal septic system or clog soil pores. Unless treatment occurs in the tank or in the soil, a septic system will only discharge contaminants to the subsurface. Claims of removal during the treatment stage or in the soils must be documented and proven.

8.5.6. Microorganism Removal

Evaluation of microorganism removal is not required for on-lot systems proposing treatment of normal household waste if the system is sited and designed in accordance with 25 PA Code Chapters 71 and 73.

8.6. DISPOSAL OF HIGHLY TREATED EFFLUENT USING ABSORPTION AREAS

Community and large volume on-lot systems commonly depend upon the soil as an integral part of effluent treatment. However, when the applicant proposes treatment processes where additional attenuation by the soil is not needed, the applicant must document that disposal of the hydraulic load will not cause nuisances such as runoff or other water related problems on the site or adjoining properties.

One method of disposal is to design an absorption area using criteria similar to the requirements for on-lot systems. Such proposed systems are not classified or reviewed as “on-lot” systems, but are reviewed as disposal systems under the Clean Streams Law permitting process. Although these systems do not depend upon the soil for treatment, the designer should consider factors such as soil permeability (hydraulic conductivity), depth to perched or seasonal high water table, hydrology, and hydrogeology. These factors will determine if the hydraulic load can be handled by the proposed system without causing significant groundwater mounding or a surface water breakout.

The Department will evaluate these proposals based on the supporting documentation for the treatment technology, and a system's capability to adequately treat sewage without the use of soils for renovation. Where such documentation is lacking, additional treatment using soils may be necessary. Compliance with the standards for on-lot systems must be met.

9.

OVERLAND FLOW

9.1. SYSTEM/SITE OVERVIEW

The overland flow (OLF) method appears similar to slow rate infiltration systems; however, the pretreatment requirements, treatment objectives, and final effluent disposal methods are significantly different. OLF is considered to be a type of treatment system, but not a method of disposal.

OLF is a land treatment method that is used mainly on impermeable soils. A thin sheet of wastewater passes across the land surface where biological and chemical processes occur. The land surface must be sloped so that the wastewater will flow at a rate sufficient to prevent puddling while allowing adequate travel times for treatment. Finished slopes (after surface preparation) in the range of 1 - 8 percent are preferred, although steeper slopes may be considered if data can substantiate the travel times. The resulting surface drainage must be collected for reuse or be given additional treatment, disinfected, and discharged.

The OLF process can provide significant reductions in BOD, TSS, and nitrogen so that screened, primary treated wastewater can reach secondary limits. One pass over the OLF site may make secondary treated effluents comparable to advanced or tertiary treated effluents.

The two major restrictions to OLF are 1) difficulty in maintaining consistent quality in the renovated water and 2) high site preparation costs. Also, since a surface-flow process is very dependent on weather conditions, year-round use is only practical in mild climates.

9.2. PRETREATMENT

The minimum pretreatment requirements prior to OLF application will be determined by the site-specific objectives of each system and the required effluent discharge limits.

9.3. BASIC SYSTEM DESIGN

The basic system components include the pretreatment unit(s), a distribution network of piping and sprinklers or emitters, the sloped surface, and a flow collection system.

The primary objective of the distribution system is to concentrate the applied water at the upper end of the slopes to produce runoff. The wastewater then flows over relatively impermeable and vegetated sloped surfaces. Methods of distribution include sprinkler, gated pipe, and bubbling orifices. Gravel is sometimes needed to dissipate energy and ensure uniform water distribution.

Sprinkler application for OLF systems consists of either permanently set systems or rotating booms. These systems are distinguished from those for slow rate infiltration by their layout arrangements (single row of sprinklers) and application rates designed for runoff. Design procedure typically selects a hydraulic loading rate based on required treatment performance for BOD in wastewater. Wastewater is applied by sprinkling to the upper one-third of terraces that are 100 - 150 feet in length and on grades up to eight percent. Renovation is achieved mainly by filtration and bacterial decomposition as the wastewater moves slowly through the grass cover.

The most important component of the OLF system is the suitability of the land application site. The soil must exhibit severely restricted permeability at a shallow depth within the soil profile. The uppermost layer of the soil must be able to support moisture tolerant plant growth with root systems that promote "turf forming," rather than "clumpy" characteristics. For optimum treatment, the site must exhibit uniform, gentle slopes over the entire area of application to promote sheet flow rather than concentrated flow in certain areas. Slopes must be steep enough to prevent ponding, yet gentle enough to prevent erosion and provide sufficient wastewater dilution time. Land preparation costs can be minimized by adapting a network of slopes and terraces to natural rolling terrain.

The runoff from the site must be collected and directed to a central location for disinfection, and discharged. Discharge from an OLF system could be to a leach field, constructed wetland, or surface water. Any runoff or discharge to surface waters from OLF systems must receive an NPDES ("Part I") permit. A Clean Streams Law, Part II Water Quality Management permit is required for these systems.

9.4. SITE PREPARATION

Of all the land application methods, OLF systems require the most intensive site preparation. The system installer should accomplish the following:

1. Completely clear any wooded site or site with highly variable vegetation
2. Provide uniform slopes to promote sheet flow
3. Cut/fill non-uniform slopes
4. Compact soils to obtain a lower permeability if necessary
5. Provide a steeper or gentler slope where necessary
6. Establish treatment slopes with uniform vegetation of turf-forming grasses
7. Provide a collection/conveyance structure at the site base to collect and carry treated effluent to the central location
8. Prevent stormwater runoff; possibly construct a storage facility

9.5. APPLICATION RATES

Unlike the land treatment systems which discharge to groundwater, the application rates for OLF systems are not typically constrained by a land limiting constituent analysis. This is because the main objective of OLF is sheet flow with little percolation. The groundwater under the site is rarely affected by the OLF systems. The application rate depends on the level of effluent treatment needed and site-specific considerations such as vegetation, length of available slope, and "residence" time on the treatment slope. Systems on record with application rates in the range of 2.5 to 16.0 inches per week have operated adequately using the waste/site criteria mentioned previously.

9.6. PROCESS DESIGN

9.6.1. Hydraulic Loading Rates

Loading rates and cycles are designed to maintain active microorganism growth on the soil surface. Loading rates can range from 2.5 to 16 inches per week (based on *EPA Design Manual 625*) depending on climate, required treatment performance, and detention time on the slope. Excellent results have been reported using wastewater at about four inches per week on 2 - 4 percent slopes that are approximately 120 feet long.

The resting period should be long enough to allow the soil surface to reaerate, yet short enough to keep microorganisms in an active state. Optimum cycles range from 6 - 8 hours on, and 16 - 18 hours off for 5 - 6 days per week, depending on the time of the year.

9.6.2. Nitrogen Removal

Nitrogen removal in OLF systems is excellent. Two important mechanisms responsible for these removals are biological nitrification/denitrification and crop uptake. The overlying water film and organic matter, and the underlying saturated soil forms an aerobic/anaerobic double layer necessary for nitrification followed by denitrification.

9.6.3. BOD and Suspended Solids Removal

Removal of BOD may improve with time. Suspended solids removal is generally less efficient than BOD removal.

9.6.4. Phosphorus Removal

Due to the minimal percolation of wastewater in OLF systems, the potential for phosphorus removal is very limited. Wastewater flowing over land does not have extensive contact with the components of the soil that normally fix large amounts of phosphorus. Phosphorus removal mechanisms include crop uptake and organic surface layers.

9.6.5. Trace Element Removal

Trace element removal by OLF is relatively good. Removal rates may exceed 90 percent. It appears that most of this removal occurs in the surface organic mat.

9.6.6. Microorganism Removal

Mechanisms for removal of bacteria are similar to those responsible for removal of metals. Microorganism removal efficiencies approach 90 to 95 percent.

10.

CONSTRUCTED WETLANDS

10.1. SYSTEM/SITE OVERVIEW

A constructed wetland is typically a lined basin containing some type of media (substrate) and wetland plants. They are also referred to as root zone systems, hydrobotanical systems, soil filter trenches, biological-macrophytic systems, marsh beds, vegetated submerged beds, and reed bed treatment systems. The configuration, media, and plants used in these systems are varied. Constructed wetlands are considered a type of treatment system, but not a method of disposal.

Constructed wetlands have been shown to effectively treat municipal wastes from small communities, mine drainage, and some industrial wastes. Additional applications for constructed wetlands are being evaluated across the nation. The Department is currently developing a set of Constructed Wetlands Manuals which will address the use of constructed wetland systems for specific types of wastewater.

10.2. PRETREATMENT

The minimum pretreatment requirements prior to discharge to a constructed wetland will be determined by the site-specific objectives of each wetland and the required effluent discharge limits.

10.3. BASIC SYSTEM DESIGN

Constructed wetlands are usually designed as several beds that can be operated and drained separately, with options for effluent recycling to improve efficiencies. The beds are lined to minimize infiltration and are surrounded by berms to minimize surface runoff.

In constructed wetlands systems, wastewater is typically introduced across one end of a bed by way of a concrete channel with v-notch weirs. The wastewater spills over the weirs and into an inlet zone which is a full-width trench filled with crushed rock. The distribution channel and inlet zone uniformly distribute wastewater across the bed of the wetland. Wastewater flows into the plant roots and media where it undergoes treatment by a variety of chemical, physical, and biological processes prior to collection in an outlet zone. The outlet zone resembles the inlet zone with the addition of a perforated pipe installed at the bottom to facilitate collection and discharge of the effluent.

Methods of disposal of the discharge from constructed wetlands could include subsurface absorption areas, land application, or direct discharge to surface waters. Any runoff or discharge to surface waters must receive an NPDES (“Part I”) permit. A Clean Streams Law, Part II Water Quality Management permit is also required for these systems.

System components influencing treatment in a constructed wetland include the media, wetland plants, and associated microorganisms.

A variety of media can be used in constructed wetlands. In general, larger fractions of clay and silt in the media result in more sorption and better filtration because of the increased surface area and smaller pore sizes. These materials, unfortunately, have low hydraulic conductivities which necessitate low hydraulic loadings. Sand and gravel media allow higher hydraulic loadings, but they are not as effective as clay and silt in sorption and filtration.

Wetland plants used in constructed wetlands are known as emergent hydrophytes and macrophytes. They have aerial leaves and flowers and submerged roots and rhizomes. Reeds, bulrushes, and cattails are commonly used in constructed wetlands.

Microbes are ubiquitous and the microbial community develops autogenically.

10.4. PROCESS DESIGN

10.4.1. Hydraulic Loading Rates

Hydraulic loadings are influenced by several factors. In selecting and designing a hydraulic loading rate, it is necessary to consider the following:

1. Detention time of applied wastewater
2. Rate of water loss from system by planned overflow or slow seepage
3. System trouble due to washouts by precipitation events or wastewater applications
4. Media composition (e.g., sand and gravel allow higher hydraulic loadings than clay and silt)

Hydraulic loading of a root zone bed can vary considerably from the wastewater design flow due to variable wastewater production and rainfall. The root zone bed must be able to handle these flow variations without significant deterioration in performance and without overland flow. Magnitude of peak flows should be considered when designing the length and width of the bed. Flow rate variation can be accommodated by using a safety factor in the design of bed width.

10.4.2. Nitrogen Removal

Nitrogen removal is attributed to the ability of wetland plants to translocate nitrogen to their roots. The combination of oxic and anoxic zones in the media/root zone stimulates sequential nitrification-denitrification. Nitrogen removal by volatilization, loss of particulate nitrogen, and plant nutrient uptake is believed to be insignificant. Ammonia removal efficiencies can range from 70 percent to 90 percent in cases where there is adequate residence time and adequate oxygen in the water and media. Total nitrogen removal efficiencies range from 75 percent to 95 percent. Total nitrogen removal decreases significantly at residence times of less than five days.

10.4.3. BOD and Suspended Solids Removal

Constructed wetlands are extremely efficient at assimilating BOD and suspended solids. Physical removal occurs through sedimentation; biological decomposition is provided by the microbial community supported on the media and on the roots and rhizomes of the plants. Removal efficiencies for BOD are generally between 45 percent and 95 percent, with average outflow concentrations as low as 3 - 5 milligrams/liter. Removal efficiencies increase with longer retention times (greater than five days), higher input concentrations, and higher hydraulic loading rates (greater than three inches/day). At high loadings, factors such as oxygen availability could limit BOD degradation and mass removal might level off.

Available data indicate that suspended solids removal can vary from 70 percent to 98 percent. In most systems, suspended solids effluent levels have been documented at less than 30 milligrams/liter.

10.4.4. Phosphorus Removal

Phosphorus removal efficiencies vary considerably with the range of wetland types. Removals ranging from 13 percent to 99 percent have been reported. The main phosphorus removal mechanisms are likely to be adsorption and sediment formation. In general, adsorption of phosphorus is enhanced by media such as silt or clay which have a high surface area and inhibited by media with lower surface area such as gravel. Removal capabilities are generally high during the growing season because the media has a high cation exchange capacity, and wetland plants account for luxury uptake of phosphorus. If significant phosphorous removal is a requirement, then very large land areas or alternative treatment methods will probably be required.

10.4.5. Removal of Trace Elements and other Parameters of Concern

Removal and long-term retention vary, depending upon retention times, the nature of the media, and the makeup of the wastewater. Heavy metals and other trace wastewater constituents may be immobilized by microbial action or retained in the media. Organic matter in the media may have high cation exchange capacities. The effect of pH on retention must also be considered. In addition, resolubilization may occur as biomass decays.

10.4.6. Microorganism Removal

The removal of pathogenic organisms depends on the pathway for water leaving the site. Systems that have no overflow and function by water seepage through a slightly permeable media will have excellent removal due to physical entrapment and die-off. Pathogenic organisms and viruses retained in root zone beds through sorption and filtration mechanisms may be destroyed by die-off and predation. Die-off in these systems must be assessed relative to detention time, climate, and other environmental variables.

Constructed wetlands have been shown to be capable of removing bacterial and viral indicators of pollution at efficiencies of 90 percent to 99 percent at retention times of 3 - 6 days. Viruses may be more resistant to inactivation than bacteria.

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LIST OF APPENDICES (*) TO THIS MANUAL

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DEP REGIONAL OFFICE LOCATIONS AND PHONE NUMBERS - (Also refer to Page 4 for counties covered by each DEP field office.)

APPENDIX B
APPLICATION FOR SEWAGE FACILITIES PLANNING MODULE MAILER

APPENDIX C
DEP DOMESTIC WASTEWATER FACILITIES MANUAL, PART II: PROCEDURE FOR OBTAINING A PERMIT TO DISCHARGE TO COMMONWEALTH WATERS AND/OR TO CONSTRUCT AND OPERATE DOMESTIC WASTEWATER TREATMENT FACILITIES (REFER TO DEP DOCUMENT # 364-0300-001)

APPENDIX D
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(*) All of the appendices are available from the Department in hard copy and can be obtained by contacting the Department contacts identified on Page 4 of this manual.