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MARYLAND DEPARTMENT OF THE ENVIRONMENT
GUIDELINES
FOR
LAND APPLICATION / REUSE
OF
TREATED MUNICIPAL WASTEWATERS

MDE-WMA-001-04/10

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1. PURPOSE

The purpose of these guidelines is to provide information regarding the State of Maryland's coordinated approach to the land application of municipal wastewater. Major emphasis is placed on site selection and evaluation, and the procedures followed in processing applications for land-treatment systems regulated by State Groundwater Discharge Permits. The criteria presented in the guidelines apply primarily to municipal wastewaters. However, these criteria may also be helpful to individuals involved in the development of land-treatment systems for the treatment and disposal of other organic wastewaters. All criteria reported in this manual are subject to exception, and changes will be considered on a case-by-case basis. Deviation from the criteria reported herein must be discussed with the Maryland Department of the Environment prior to the incorporation of the deviations into written documents such as Facilities Plans or design processes.

This document is not intended to function as a "cookbook" for design engineers, nor is it intended to suppress the state-of-the-art by enacting overly restrictive guidelines. It is, however, intended to function as a guide for private developers or municipalities and their consultants. In summary, it is hoped that the guidelines will expedite the implementation of land-treatment systems, where appropriate, while safeguarding the integrity of surface and groundwaters of the State.

2. INTRODUCTION

Ever since the first community was established, man has had to face the problem of regional waste disposal in one form or another. In the past, surface waters provided a means of disposal. The relatively large volume of surface water usually contained in rivers located adjacent to the communities diluted the discharged wastes and transported them away from the point (or points) of entry.

As the communities grew into towns and towns into cities, the volume of wastes requiring disposal grew accordingly. The increased waste load exerted an ever-increasing stress on the surface waters to assimilate this waste. In many waterways throughout the United States and other parts of the world, the assimilative capacity has been exceeded, producing in many cases, a state of accelerated eutrophication.

Along with man's increasing numbers has come both a more thorough understanding of his environment and significant technological advances. Sewage treatment plants are now capable of producing effluent of a much higher quality than ever before. Unfortunately, as the level of treatment increases, so does the cost. From a water-resources management standpoint, discharging treated municipal wastewater directly into surface waters has two major disadvantages. First, although treated and disinfected, most wastewaters contain relatively high levels of nitrogen, phosphorous, and organics in various forms. Unless advanced treatment is performed, these constituents contribute to the eutrophic progression of the receiving waters. Second, the waters collected in a particular basin are typically used by a municipality located within that basin and transported to a sewage treatment plant also located within that basin.

However, once the sewage is treated, it is discharged into a surface waterway and removed from the basin. Consequently, the water supply basin is never recharged by water collected within that basin and must rely entirely upon natural rainfall for recharge.

An alternative method of wastewater treatment and disposal has been used for at least a century, although only recently to any significant degree. This alternative is referred to as land application. The technique involves the application of treated wastewater to the land surface in any of several methods. The three most common methods of application are: 1) spray irrigation, 2) overland flow, and 3) rapid infiltration. Through the physical, chemical, and biological mechanisms operating in the soil, several important benefits can be obtained by using land [treatment] application. The three most important benefits are: 1) the concentrations of BOD, total suspended solids, bacterial and viral organisms, as well as the nutrients responsible for the acceleration of eutrophication are all greatly reduced as the wastewater infiltrates and percolates through the soil profile; 2) the nutrients removed by the soil can be available to support or increase the growth of vegetation occupying the site; and 3) the renovated wastewater percolates through the soil profile and recharges the groundwater system.

Based upon studies conducted by universities and government agencies, land application has proven to be both a feasible and an effective method of renovating and recycling wastewater. So wide has been its acceptance that the Environmental Protection Agency, through amendments PL 92-500 and PL 95-217 to the Federal Water Pollution Control Act, has required that land application be evaluated during the waste treatment Facilities Planning stage. On October 1, 2002, Section 9-303.1 of the Annotated Code of Maryland became effective. It stipulates that the Department shall encourage the use of reclaimed water as an alternative to discharging wastewater effluent into surface waters and authorizes the Department to establish buffer and setback requirements for the use of reclaimed water. These measures are not intended to force municipalities into using land application techniques, but are intended more to insure that techniques aimed at recycling and reuse of wastewater receive appropriate attention. To promote the reuse of reclaimed water, the Department amended the guidelines in 2009 to include the irrigation of highly treated Class III effluent in the non-restricted public access areas including parks, play grounds, school yards, cemeteries, highway landscapings and other green open spaces. Similar to Classes I and II effluent shown in Table 1, a State Groundwater Discharge Permit/ General Permit is required for irrigating Class III effluent.

In accordance with COMAR 26.08.04.02 entitled "Requirements for the Issuance and Reissuance of Discharge Permits," the Department may issue or reissue a discharge permit to a sewage treatment works if the treatment works and the sewerage systems, including the pumping stations, are in compliance with the approved county water and sewerage plan (Plan) adopted under Environment Article, Title 9, Subtitle 5, Annotated Code of Maryland. For a community or multi-use sewerage system using any class of effluent for land application of treated wastewater, the sewerage system will be considered in compliance with the Plan if that plan specifically identifies the wastewater treatment plant and its capacity, and identifies the area to be served by it as S-1 or S-2 (as defined in COMAR 26.03.01.04G(2)), and the project is otherwise in compliance with the Plan. This requirement shall not apply if a facility is not required by State and County law to be included in the county's water and sewerage plan.

3. REQUIREMENTS FOR LAND APPLICATION

Basically, there are two types of requirements for land application/reuse of municipal and agricultural wastewaters: pre-application treatment and site requirements.

Pre-application treatment requirements pertain to the quantity and quality of the effluent or treated wastewater that is to be applied to the land. The wastewater constituents of most importance to land application are BOD (biochemical oxygen demand), SS (suspended solids), pH, total and fecal coliforms, dissolved salts, and nitrogen compounds. Generally, these constituents, more than any others, determine how effective land application will be in renovating wastewater and what effect the wastewater will have on the soils and ultimately the groundwaters of the state.

Site requirements are expressed in terms of geologic, soil, and hydrologic characteristics that have a direct or indirect influence on the ability of a site to renovate and recycle wastewater. All three characteristics are interrelated and are at least as important as effluent requirements in affecting the success or failure of a land-treatment system. For each type of land application, there exists an optimum geology-soils-hydrology scheme or combination. A scheme that works well for one type of land application may not work at all for another type.

In the following sections, each of the major types of land application will be discussed along with the important effluent and site requirements that must be satisfied to ensure its effectiveness as a treatment process. These land application types are slow rate, overland flow and rapid infiltration. For protecting the public health and groundwater quality, wastewater must be pretreated to meet the effluent quality requirements prior to land application. The minimum pre-application treatment requirements for all land application systems are shown in Table 1. In areas where site characteristics are marginal for land application, the effluent requirements shown in Table 1 may be more stringent. The effluent sampling location is typically located after the pre-treatment process but prior to the land application system. For a land application system with a storage pond, effluent may be sampled prior to discharging to the storage pond. Table 2 is located at the end of the section and contains a summary of the site requirements for the major types of land application.

3.1, Slow Rate

The term "slow rate" applies to all systems that uniformly apply treated wastewater to the surface of the receiving site with the understanding that the wastewater will infiltrate into and percolate through the soil profile. Once the wastewater enters the soil, one of four consequences will be realized: (1) it will eventually return to the surface through capillarity and be lost to evaporation, (2) it will be taken up by plant roots and be lost to transpiration, (3) it will be stored within the soil and produce a change in soil moisture, or (4) it will percolate downward until the groundwater table is encountered. As the wastewater moves through the soil, most of the organic and inorganic constituents are removed, some of which will be decomposed and taken up by plants while others will be immobilized within the soil matrix.

3.1.1. Examples of slow-rate systems

1. piped irrigation
 - a. spray irrigation

- b. bubbling pipe irrigation
 - c. drip irrigation
2. open channel irrigation
- a. ridge and furrow
 - b. flooding

. For slow rate systems, the guidelines recognize three levels of pre-application treatment as shown in Table 1. there are three classes of effluent quality. Class I with a moderate effluent quality is likely achievable by a lagoon or secondary biological treatment systems. Irrigation with Class I effluent requires a larger buffer zone than Class II and Class III which have higher effluent qualities.

Table 1. Minimum Pre-Application Treatment Requirements for Various Land Application Systems^a

Parameter	Slow Rate			Overland Flow	Rapid Infiltration
	Class I	Class II	Class III		
5 day - Biochemical Oxygen Demand (monthly average)	70 mg/l	10 mg/l	10 mg/l	70 mg/l	Case by case
Suspended Solids (monthly average) or Turbidity (NTU) (continuous monitoring)	90 mg/l	10 mg/l	2 NTU (daily average) Not to exceed 5 NTU at any time	90 mg/l	Case by case
Fecal Coliform ^a (MPN per 100 mL; monthly geometric mean)	200 3 (golf courses)	3	2.2	200	Case by case
pH	6.5 - 8.5	6.5-8.5	6.5-8.5	6.5 - 8.5	6.5-8.5

a Higher levels of treatment and disinfection may be required under certain conditions such as a land application site located in a well head protection area with a significant amount of rock fragments in the soil.

3.1.2. Site requirements for slow-rate systems

3.1.2.1. Soils

1. minimum of four 4 feet depth to groundwater or bedrock, except on the Eastern Shore where a minimum of 2 feet should exist between the soil surface and the groundwater table.
2. moderately slow to moderately rapid permeability (0.2 to 6 inches per hour) in the most restrictive soil horizon.
3. U.S.D.A. textures ranging from clay loams to sandy loams.
4. moderately well to excessively well drained.

3.1.2.2. Slopes

Slopes not to exceed 15% on cultivated lands and 25% on uncultivated (forested) lands. For underground drip irrigation systems, higher sloped areas may be acceptable, if system installation is feasible and seepage at lower elevations can be eliminated.

3.1.2.3. Vegetation

A complete vegetational cover is required. It can be natural, as in the case of forest, or it can be planted, as in the case of cultivated fields.

3.1.2.4 Buffer

Class I Effluent

For irrigating Class I Effluent with water quality defined in Table 1, a minimum buffer zone of 200 feet shall be provided between the wetted perimeter of spray irrigation areas and property lines, waterways, roads, etc. For residential properties, parks, and other areas where people congregate, a 500-foot buffer between the wetted perimeter and structures on these properties shall be provided. A reduction of these buffer zone widths by up to 50% will be considered where it is demonstrated that an adequate windbreak will be provided to prevent spray from carrying beyond the irrigation area.

Class II Effluent

For irrigating Class II Effluent with water quality defined in Table 1, the buffer zone widths shall be 25 feet from property lines, housing structures, public roads and streams, 50 feet from schools and playgrounds, and 100 feet to potable wells and water intakes.

Class III Effluent

For irrigating Class III Effluent with water quality defined in Table 1, a minimum buffer zone of 100 feet shall be provided between the wetted perimeter of the irrigation areas and potable wells and water intakes. A minimum buffer zone of 100 feet shall be provided between the wetted perimeter of the irrigation areas and outdoor licensed public eating, drinking and bathing facilities.

Other Types of Slow Rate Systems

Slow rate systems not generating aerosols, such as a drip irrigation system and a ridge and furrow system, will have a minimum buffer zone of 50 feet from property lines, housing structures and public roads, and 100 feet to potable wells and streams.

3.1.2.5 Storage

A means for wastewater storage must be provided at each slow rate system to accommodate flows generated during those periods when the treated wastewater cannot be applied to the land. Since climatic influences vary geographically, storage capacity requirements will be dependent upon the location of the system. However, a minimum of 60 days storage should be provided for all spray irrigation systems receiving wastewater flows throughout the year. A minimum of 30 days storage should be provided for all underground drip irrigation systems receiving wastewater throughout the year. The Department will consider varying these presumptive storage requirements where Class III effluent is directly transmitted from a wastewater treatment plant for irrigation to meet vegetation water demand and an alternative means of discharge is available for periods when land application is not feasible.

3.1.2.6 Reserved Area

For a spray irrigation system, a reserved area of 25% of the total wetted field area shall be provided to maintain adequate capacity for wastewater disposal in the event that initial irrigation area is determined to be inadequate to meet the application needs.. For an underground drip irrigation system, a reserved area of 100% of the total wetted field area shall be provided. For Class III Effluent irrigation, no reserve area and no groundwater monitoring are required if the irrigation rate is equal to or less than the consumptive demand of the vegetation and adequate storage and/or alternative means of discharge is provided.

3.1.3. Application rates and loading cycles

The application rate or hydraulic-loading rate of a given system is dependent upon both the effluent and site characteristics. However, application rates for slow-rate systems generally range between 0 and 2 inches per week on an annual average basis. Slow-rate systems generally operate on a one-day load, six-day rest cycle. To determine the application rate suitable to the soil type at the proposed site, infiltration tests should be conducted. Infiltration tests should be conducted by using the Double-Ring Infiltrometer Method or the Basin Infiltration Method outlined in the Appendix A. The application rate shall not be greater than 4% of the steady infiltration rate measured from the Double- Ring Infiltrometer or shall not be greater than 10% of the steady infiltration rate measured from the Basin Infiltration test. Other infiltration test methods comparable to the above two methods may be acceptable upon approval by the Department.

3.1.4. Additional Class III Effluent Irrigation Requirements

1. Irrigation of Class III effluent on fruit and vegetables not commercially processed, including crops eaten raw, is prohibited.
2. Vegetation water demand varies with type of vegetation to be irrigated. The applicant shall submit vegetation water demand data with the discharge permit application to MDE. If irrigation of Class III effluent in the non-restricted public access areas is to meet the vegetation water demand only, no hydrogeological investigation of the proposed site is necessary.. If the irrigation rate of Class III effluent is greater than the vegetation water demand, the applicant shall conduct a

hydrogeological study or an irrigation pilot study to ensure that the irrigation rate will not cause persistent surface runoff, ponding, and contributions of nutrients or other health concerned chemicals to groundwater.

3. Irrigation of Class III effluent on bare soil is prohibited except for providing adequate moisture for seed germination in the seeding area. The irrigation area shall be planted with healthy vegetation cover. Irrigation on high water table or saturated soils which cause persistent surface runoff and ponding is prohibited.
4. "Reclaimed Water, Do Not Drink" signs shall be posted in the irrigation area to inform the public about irrigation of treated wastewater. A sign shall be posted at each entrance to the site and visible to the public with a size greater than 4 inches in height and 8 inches in width. Purple shall be the prominent color of the sign.

3.2 Overland Flow

The term "overland flow" applies to all systems that uniformly apply wastewater through the use of pipes or surface trenches to the sloped surface of the receiving site with the understanding that the wastewater will move laterally along the surface of the soil and be collected at the lowest point along the travel by drainage tile, surface trenches, or other collection structures. After collection, the renovated wastewater is recycled through the overland system a second time, or discharged directly into surface water, or land applied. The wastewater is renovated by physical, chemical, and biological processes present at the soil-vegetation interface as it flows in a thin film down the relatively impermeable slope.

Minimum pre-application treatment requirements for overland flow systems are given in Table 1.

3.2.1 Site requirements for overland-flow systems

3.2.1.1 Soils

1. minimum of 6 to 12 inches in depth.
2. very slow to moderately slow permeability (0.06 to 0.2 inches per hour).
3. U.S.D.A. textures ranging from clays to heavy clay loams.

3.2.1.2. Slope

Slopes should range from a minimum of 2% to a maximum of 8%.

3.2.1.3. Vegetation

A complete vegetational cover is required. It can be natural, as in the case of forest, or it can be planted, as in the case of cultivated fields.

3.2.1.4. Buffer

All types of overland flow systems should be surrounded by a minimum buffer zone of 50 feet.

3.2.1.5 Storage

A means of wastewater storage must be provided at each land-treatment system to accommodate flows generated during those periods when the treated wastewater cannot be applied to the land (e.g., frozen soil conditions, rain storms, etc.). Since climatic influences vary geographically, storage capacity requirements will be dependent upon the location of the system. However, a minimum of 60 days storage must be provided for all systems receiving wastewater flows throughout the year.

3.2.1.6 Reserved Area

Same as slow-rate system.

3.2.2. Application rates and loading cycles

The application rate or hydraulic loading rate of a given system is dependent upon both the effluent and site characteristics. Typical application rates for overland flow systems range from 2.5" to 8" per week for secondary effluent. Loading cycles for overland-flow systems generally range from 6 to 8 hours on and 16 to 18 hours off, for 5 to 6 days per week, depending upon the time of year.

3.3 Rapid Infiltration

The term "rapid infiltration" applies to all systems that apply wastewater through the use of excavated and/or bermed structures to subsurface soils under a positive hydraulic head with the understanding that the applied wastewater will move in a predominately vertical direction through the soil until the groundwater table or bedrock is encountered. The wastewater is renovated by physical, chemical, and biological processes present in the soils through which it moves. In rapid-infiltration systems, over 90 percent of the wastewater applied eventually reaches and recharges the groundwater. The remainder is lost to evaporation or is stored in the soils beneath the structure and above the underlying groundwater table.

As shown in Table 1, the pretreatment requirements for the rapid infiltration system are determined on a case- by -case basis depending on infiltration rate, water table depth and proximity to the drinking water source.

3.3.1 Site requirements for rapid-infiltration systems

3.3.1.1. Soils

1. a minimum of 10 feet of unsaturated soil between the bottom of the infiltration pond and the underlying groundwater or bedrock.
2. moderately rapid to very rapid permeability (2.0 to 20 inches per hour).
3. U.S.D.A. textures ranging from sandy loams to sands.

3.3.1.2. Buffer

All types of rapid infiltration systems should be surrounded by a minimum buffer zone of 50 feet.

3.3.1.3. Reserved Area

Same as slow-rate system.

3.3.2 Application rates and loading cycles

The application rate or hydraulic loading rate of a given system is dependent upon both the effluent and site characteristics. In general, application rates for standard rapid infiltration systems range from 5 to 100 inches per week. The systems are typically loaded for 1 to 2 days then allowed to rest for 1 to 14 days, depending upon the hydraulic conductivity of the soils and the depth to groundwater. Determination of application rate is the same as slow-rate system described in the previous section.

Table 2. Summary of Site Requirements for Various Types of Land Application Processes.

Site Requirements	Land-Application Processes		
	Slow Rate	Overland Flow	Rapid Infiltration
Soils			
Depth to Groundwater	4 ft. min.	Not Critical	10 ft. min. (standard)
	2 ft. min. (Eastern Shore)		
Permeability	mod. slow to mod. rapid	very slow to mod. slow	mod. rapid to very rapid
USDA Texture Class	clay loam to sand loam	clay to heavy clay loam	sandy loam to sand
Slopes	15% max. for cult.	2-8%	--
	25% max. for uncult.		
Buffer Requirements			
to property lines, roads, etc.	Class I effluent: 200 ft. for spray, 50 ft. for drip; Class II effluent: 25 ft; Class III effluent: no buffer required	50 ft.	50 ft.
to buildings	Class I effluent: 500 ft. for spray, 50 ft. for drip; Class II effluent: 25 ft; Class III effluent: 100 ft to licensed public eating, drinking and bathing facilities	50 ft.	50 ft.
to potable wells and water intakes	100 feet	100 feet	100 feet
Storage	60 days min. for spray irrigation and 30 days for drip irrigation, No storage is required for irrigating Class III effluent in meeting vegetation demand and alternative discharge is available during inclement weather	--	--
Annual Average	0-2 in./week	2.5-16 in./week	5-100 in./week

Site Requirements	Land-Application Processes		
	Slow Rate	Overland Flow	Rapid Infiltration
Application Rates			
Loading Cycles	1 day load, 6 days rest	6-8 hrs. load, 16-18 hrs. rest	1-2 days load, 1-14 days rest

4. STATE AND COUNTY COORDINATED APPROACH TO LAND APPLICATION

Systems involved in the land application/reuse of municipal wastewater fall within the administrative jurisdiction of the Maryland Department of the Environment. In addition, each county government has the responsibility of evaluating any new development with respect to incorporation of the new development into their Ten-Year Comprehensive Water and Sewerage Plan. State processing of a groundwater discharge permit application for a new development project will not be started until the development project is incorporated into the approved County Water and Sewerage Plan as indicated in the “Introduction” section of this document.

The Maryland Department of the Environment regulates the development and operation of land-application systems through the Groundwater Discharge Permit Program and regulates the design, funding, and installation of land-application systems through the MDE Wastewater Construction Permit Program.

A hypothetical situation has been developed to clarify the procedures involved in obtaining State and County authorization for the development, design, installation, and operation of land-application systems. The following example applies to both privately and publicly owned facilities.

A community has increased in size to such a point that their sewage treatment plant, which ultimately discharges into a nearby river, can no longer handle the increased flows. Consequently, the community is faced with an expansion and possible upgrading of their treatment facility. An engineering consultant is employed by the community to develop a Facilities Plan for the new sewage treatment plant. An important phase of the Facilities Plan is to investigate and evaluate the feasibility and cost effectiveness of land application as an alternative to surface discharge. The following is an outline of the major steps to be followed by the consultant and community planners:

<u>Step</u>	<u>Action</u>
1.	Contacts State (Maryland Department of the Environment) and local agencies for information regarding land-application systems.
2.	Acquires soils information from Soil Conservation Service and other pertinent information necessary to identify prospective land-application sites.
3.	Acquires necessary permission from appropriate landowners for site evaluations.
4.	Sends a letter to the Maryland Department of the Environment requesting a site evaluation. The letter includes the following: a. map(s) of proposed area(s) in scale of 1 inch equals 200 feet or larger scale; b. project flows; c. acreage of site(s); d. proposed application rate(s).
5.	Sets up preliminary site visit. The Project Manager request that a backhoe be available for preliminary site evaluation (at applicants expense). Based upon outcome of preliminary site evaluation, the Project Manager will make one of three recommendations: 1) that site is acceptable; 2) that site is conceptually acceptable, but a more detailed hydrogeologic study must be completed (at applicants expense); or 3) that site is not acceptable for land application. An

Step	Action
	outline for the comprehensive hydrogeologic study can be found in Appendix B . The detailed study is conducted by a qualified consultant chosen by the applicant.
6.	If conceptual approval is given for a particular site by the project manager, the applicant may proceed with a hydrogeologic study and addresses the items outlined in Appendix B in a hydrogeological report. At the same time, an application should be filed to appropriate County agencies for the inclusion of the project in the County Ten-Year Water and Sewerage Plan and any other appropriate planning and zoning programs.
7.	Upon completion of a hydrogeologic study, the applicant shall forward a copy of the hydrogeologic report to the Department for review and approval. The applicant may file a groundwater discharge permit application to the Department if the project is incorporated into the County Master Water and Sewerage Plan. If a public hearing is requested after publication of a tentative determination, the Department may schedule a hearing. At the public hearing, all pertinent testimony, both for and against the permit, will be taken by the hearing officer. If information is presented at the hearing which indicates that the land application system will result in adverse effects on the environment or public health, the permit may be modified or canceled. If no adverse information is presented, the permit will be finalized and issued, usually for a period of 5 years.
8.	After the applicant receives a State Groundwater Discharge Permit, appropriate applications should be made to the Maryland Department of the Environment for a State Construction Permit.

The preceding procedure will be followed whether it be in relation to a waste treatment Facilities Plan (as in the above hypothetical situation), an investigation resulting from an enforcement action taken against a violator unable to meet State Surface Water Discharge Permit requirements, a new privately owned development, or any other application for a permit to discharge wastewaters into the groundwater of the State via land application.

The comprehensive outline for the hydrogeologic study (given in Appendix B) is presented as a guide. The actual information that will be requested in the detailed study for any given project will depend upon the volume of wastewater, and the effluent and site characteristics of the project.

Two important parameters of any land-application system are the water and nutrient balances. The major components of a water balance are natural precipitation wastewater loading, and surface runoff. An example of the calculation of a water balance is given in Appendix C.

In some land-application systems, the nutrient input and not the hydraulic input is the deciding factor as to whether the system will have a detrimental effect on the environment. Nitrogen generally seems to be the most limiting nutrient with respect to groundwater quality. For this reason, an example of a nitrogen balance is given in Appendix D. To meet the drinking water standard of nitrate, a 10 mg/l nitrogen concentration in the percolate should be used for nitrogen balance calculations. However,

groundwater discharge that may impact impaired surface water body, the Department will determine the nitrogen input from the percolate on a case by a case basis.

There are many different methods used to calculate both water and nitrogen balances. Those described in the Appendices are two of the more common methods.

Besides water and nitrogen balances, where a land application system receives wastewater containing heavy metals from industrial discharges, a study to evaluate the potential impact of heavy metal discharge on groundwater quality must be conducted.

5. GROUNDWATER QUALITY MONITORING REQUIREMENTS

5.1 Monitoring Networks:

One of the basic or prime objectives of a monitoring program is to detect existing groundwater degradation caused by disposal of municipal wastewater. Where a potential for contamination exists, an assessment of the problem must be made to determine control strategies for a particular disposal site. Groundwater monitoring will play an important part in assessing and providing long-term verification of the integrity of the system.

5.2 Monitoring Design:

The following data should be carefully evaluated in designing a monitoring network: 1) groundwater flow direction; (2) location of nearby private wells; (3) subsurface geology including the hydraulic conductivity and porosity of each soil and rock formation; (4) present or future effects of domestic or commercial pumping on the flow system; and (5) existing groundwater quality. The existing groundwater quality would serve as a basis for later comparison. Analysis should include dissolved solids, nitrate, total phosphorus, and total nitrogen, depending on the chemical composition of waste.

5.3 Numbers of Monitoring Wells:

To detect groundwater contamination, a monitoring-well network should consist of the following:

- (1) At least two wells, adjacent to the Property line downgradient from the disposal site, which are screened from the seasonally high groundwater table downward 15 feet.
- (2) Monitoring wells (at least one) completed in an area upgradient from the disposal site so that it will not be affected by potential contaminants.

5.4 Specifications for Installation of Groundwater Monitoring Wells

Each monitoring well must be constructed utilizing 4" I.D., schedule 40, PVC pipe or casing satisfactory to the Department.

All related permits must be obtained before wells are installed by a well driller licensed by the State of Maryland in accordance with all laws and regulations.

The well shall be gravel packed to at least five feet above the top of the screen unless multiple aquifers are affected.

The screened interval must consist of at least 15 feet of schedule 40, 4" (103 mm), slotted PVC well screen.

Wells must penetrate a minimum of 15 feet below the groundwater table.

The well shall be continuously pressure grouted from top of gravel pack to ground surface. The well shall also be developed and disinfected prior to sampling according to Maryland well construction regulations, COMAR 26.04.04.

A copy of the well completion report must be submitted to the Maryland Department of the Environment.

5.5 Additional Monitoring:

Whenever the original monitoring network indicates groundwater degradation, steps must be taken to determine cause and if necessary the corrective measures taken. These measures may include construction of additional wells to determine lateral and vertical extent of contamination direction, rate of movement, dilution and attenuation, etc. Further quantitative studies can be performed to determine the exact nature of contamination. These studies will aid in determining the proper corrective measures needed to abate the problem.

5.6 Sampling Techniques:

The primary concern in sample withdrawal methods is to obtain a representative sample of groundwater. Stagnant water shall be removed so that the sample collected is fresh. Normally three volumes of stagnant water are pumped out prior to taking samples. Withdrawal methods may include pumps, compressor air, or boilers.

To protect against collection of non-representative, stagnant-water sample withdrawal, the guidelines and techniques outlined in EPA's Procedures Manual for GW Monitoring at S.W. Disposal Facilities pp. 220-237 "Sample Withdrawal, Storage and Preservation" is helpful. Other useful references for sample collection and preservation are also included in the references section.

5.7 Monitoring Frequency:

Monitoring frequency for a disposal site may be influenced by a number of factors and thus will be addressed on a case-by-case basis through individual State groundwater discharge permits.

6. REFERENCES

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4. Stone, J.E. (1976) "Land Application of Wastes: Nitrogen Considerations". Module 15. Educational Program. Cornell University, New York State College of Agriculture and Life Sciences, Ithaca, New York.
5. U.S. Environmental Protection Agency (1987), "Handbook, Ground Water", EPA 625/6-87/016.
6. U.S. Environmental Protection Agency (2006) "Process Design Manual, Land Treatment of Municipal Wastewater Effluents," EPA 625/R-06/016

APPENDICES

Appendix A

Methods for Soil Infiltration Test

(1). Double-Ring Infiltrometer Test

ASTM Standard D-3385 entitled "Standard Test Method for Infiltration Rate of Soils in Field Using Double-Ring Infiltrometer," ASTM International, www.astm.org.

(2). Basin Test - Excerpted from U. S. E. P. A. "Process Design Manual – Land Treatment of Municipal Wastewater Effluents" EPA/625/R-06/016 (September, 2006).

All infiltration tests should always be run at the actual locations and depths that will be used for the operational system. This is especially important for SAT systems. Pilot-scale basin tests are strongly recommended. These should be at least 9.3 m² (100 ft²) in area, located in the same soil zone that will be used in the full-scale system. Construction of the test basin should be done with the same techniques that will be employed full scale. The test basin should then be operated for several weeks using the same wet and dry cycles that are planned for full scale. A typical small-scale pilot test basin is illustrated in Figure 3-12.

The number of test basins required will depend on the system size and the uniformity of the soils and topography. One will serve for relatively small systems with uniform soils. In larger systems a separate basin should be used for every major soil type, which may require one basin for every 2-4 ha (5-10 acres) of total system area. When extremely variable conditions are encountered, the test basin should be full sized (0.4 to 1.2 ha or 1 to 3 acres) to insure reliability. If successful, it can then be incorporated into the operational system.

A smaller-scale basin type test has been developed by the U.S. Army Corps of Engineers (Abele et al., 1980). The purpose was to have a reproducible procedure with a larger surface area and zone of influence than existing infiltrometers and permeameters. The test facility prior to flooding (note the cylinder infiltrometer in the right foreground) is illustrated in Figure 3-13. The metal ring is aluminum flashing and is 3 m (10 ft) in diameter. Installation details are provided in Figure 3-14 and Figure 3-15.

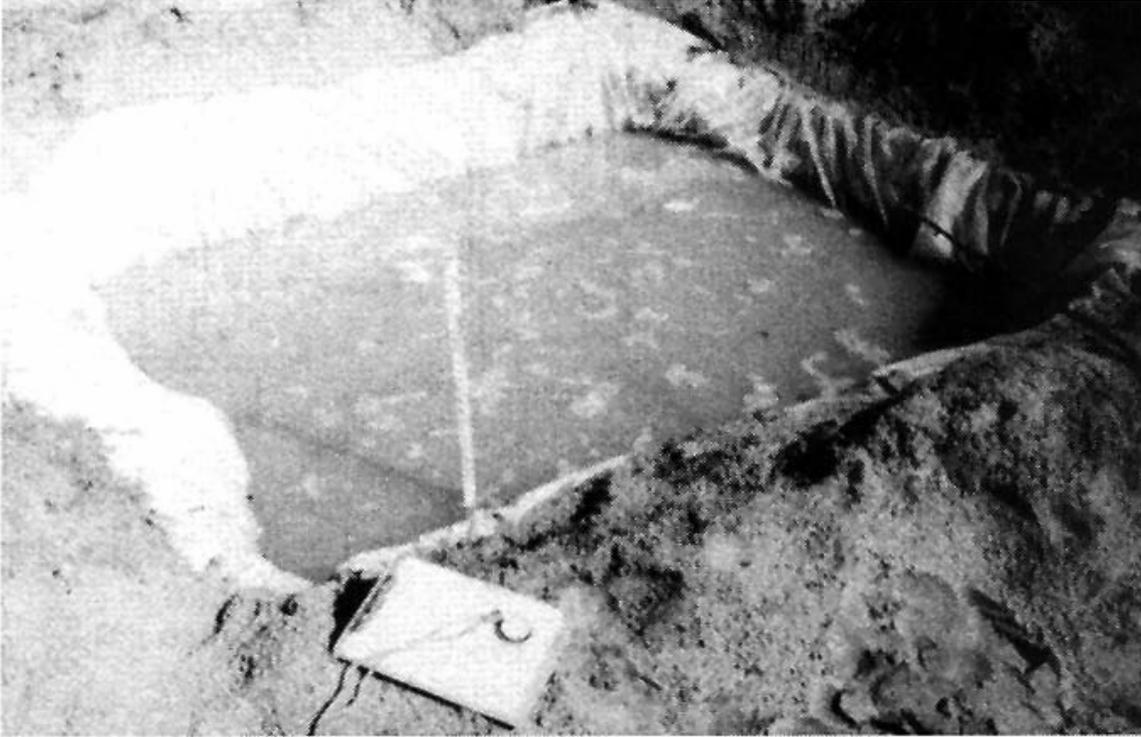


Figure 3-12. Small-scale Pilot Test Basin (Crites, et. al., 2000).

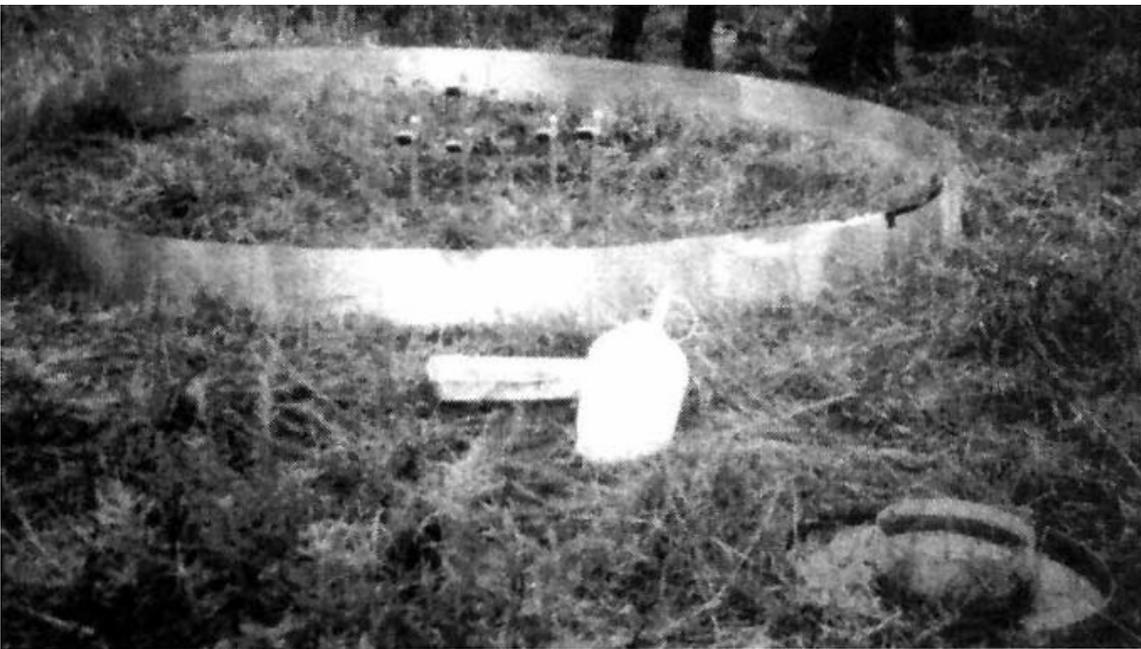


Figure 3-13. U.S. Army Corps of Engineers (USACE) Basin Test.

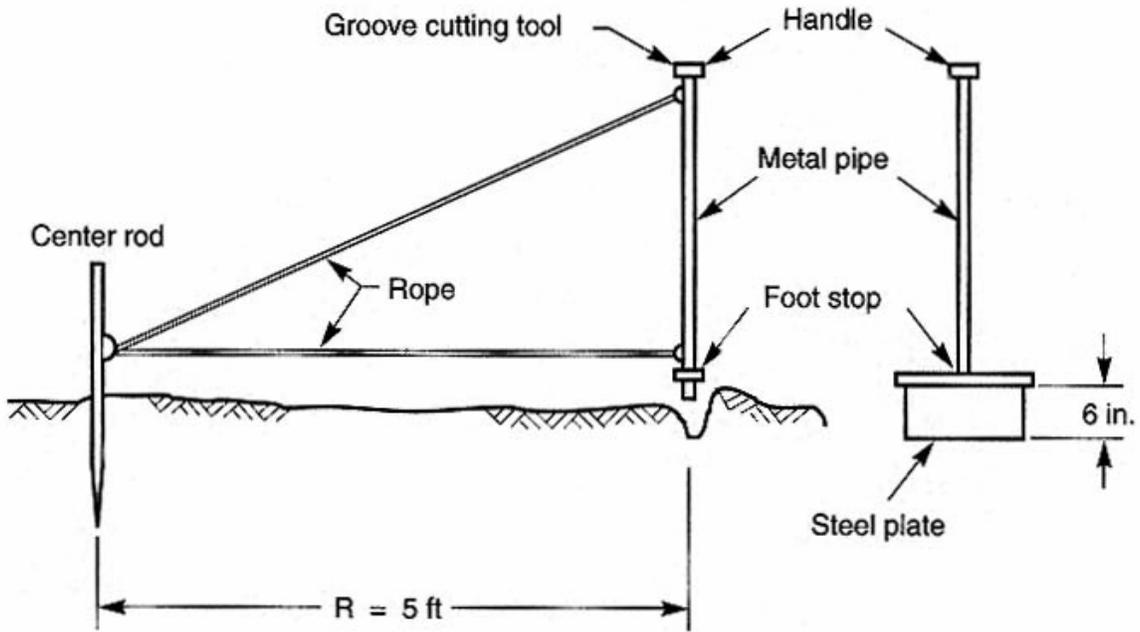


Figure 3-14. Groove Preparation for USACE Test.

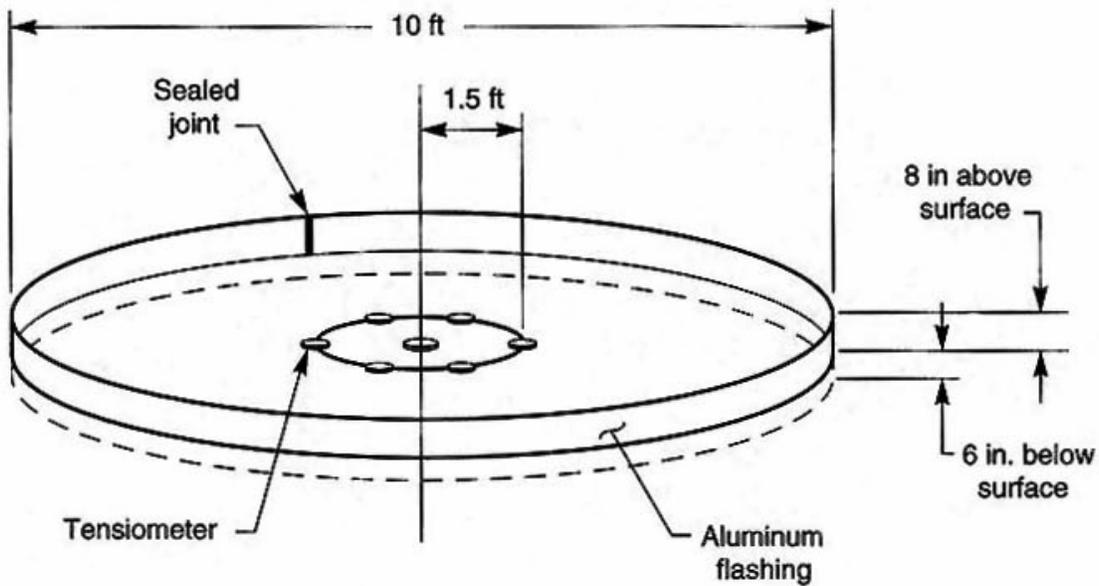


Figure 3-15. Groove Preparation for USACE Test.

Tensiometers are used in the central part of the test area to insure that saturated conditions prevail during the test period. One should be placed in each soil horizon. In soils lacking well-developed horizons, a uniform spacing down to about 0.6 m (2 ft) will be suitable. Following installation and calibration of the tensiometers, a few preliminary flooding events are executed to achieve saturation. Evidence of saturation is the reduction of tensiometer readings to near zero through the upper soil profile. Then a final flooding event is monitored to derive a cumulative intake versus time curve.

Typical test results are illustrated in Figure 3-16. The "limiting" value of 6.35 mm/h (0.25 in./h) was selected for design in this case.

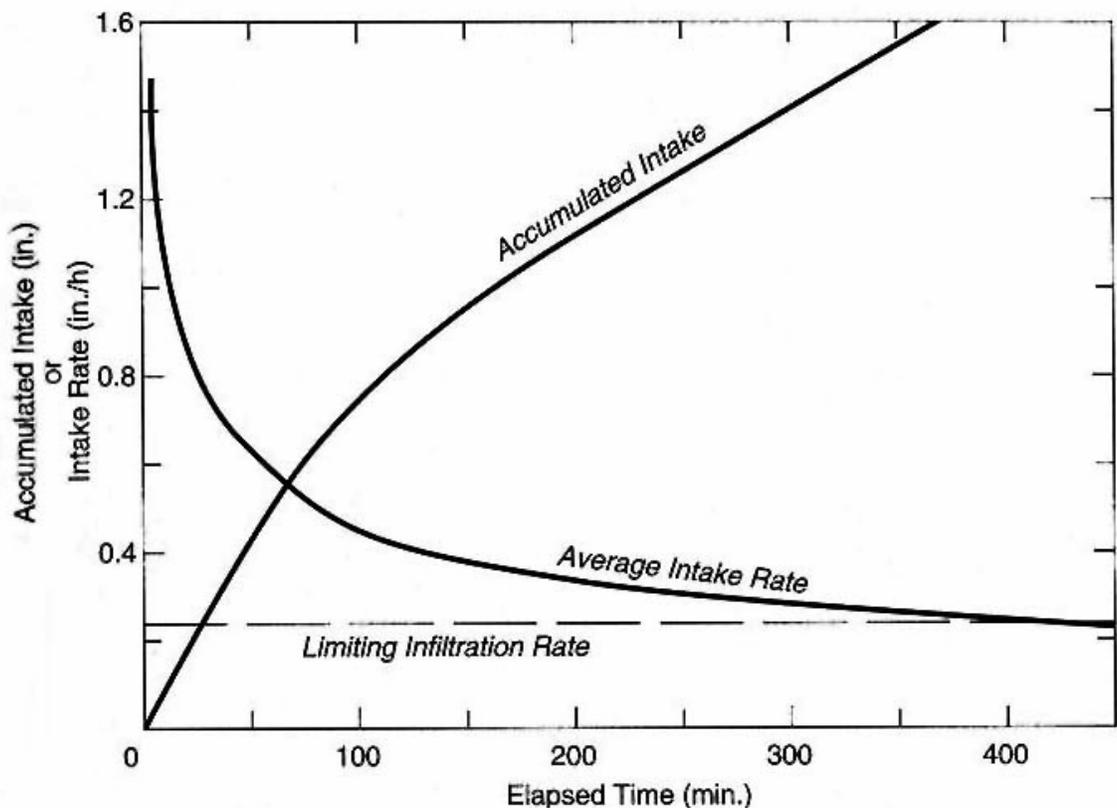


Figure 3-16. Typical Test Results, USACE Infiltration Test.

Appendix B

Outline for Hydrogeologic Report

- I. Site location and description
 - A. Site location (provide maps with minimum scale of 1 inch equals 200 feet and a contour interval of no more than 5 feet)
 - B. Areal extent of site (acres)
 - C. Present land use
 - D. Future land use
- II. Description of land-application techniques
 - A. Degree. of wastewater treatment to be employed prior to land application (i.e. primary, secondary, lagoons, etc.)
 - 1. Wastewater quality before treatment
 - 2. Wastewater quality after treatment
 - B. Volume of treated wastewater to be discharged (MGD)
 - C. Land-application techniques employed (i.e. spray irrigation, overland flow, rapid infiltration, well injection, etc.)
- III. Geology, soils, and hydrology
 - A. Geology of site and surrounding groundwater discharge area
 - 1. Rock or sediment types and formations
 - 2. Depths to bedrock and thickness of weathered or unconsolidated material
 - 3. Properties of bedrock and weathered or unconsolidated material
 - 4. Structural features
 - 5. Large-scale maps showing site characteristics
 - a. Surficial geology
 - b. Depth to bedrock and/or thickness of surficial material expressed in terms of contour lines
 - c. Geologic cross-sections
 - 6. Discussion of geologic materials and structural controls on the movement of infiltrating waters and groundwaters and the renovation of applied wastewaters.

B. Soils

1. Description of soil series present
2. List of soil mapping units and a copy of USDA Soil Survey maps
3. Discussion of available soil characterization and Soil Survey data regarding the movement and renovation of infiltrating wastewater.
4. Site-specific information from soil borings, test pits, etc.
 - a. Depths of soils
 - b. Textures of soils and substratum
 - c. Description of water-related soil characteristics
 - (1) Mottling
 - (2) Perched Water
5. Large-scale maps (1 inch equals 200 feet or larger scale) with locations of all auger borings, test pits, etc. with corresponding logs
6. Discussion of soil-materials control on the movement and renovation of applied wastewaters

C. Hydrology

1. Regional climate
 - a. Monthly precipitation
 - b. Monthly temperature
 - c. Monthly evapotranspiration
2. Surface phenomena
 - a. Slope
 - b. Vegetational cover type
 - c. Description and location on suitable map of surface waters (ponds, lakes, streams, springs, existing water wells, sinkholes, etc.)
 - d. Description of erosion present
 - e. Water-quality inventory of existing water wells within 1/4 mile of site
3. Permeability of soils
 - a. Infiltration capacity of surface soils
 - b. Vertical hydraulic conductivity of subsurface soils
4. Type of aquifer(s) present (refer to COMAR **26.08.02.09** Groundwater Quality Standards)
5. Develop hydrologic balance for proposed site considering ultimate fate and disposition of both natural precipitation and wastewater
6. Maps showing highest and lowest depth to water table using both sea-level datum and land-surface datum (include groundwater flow lines on sea-level datum map)
7. Discuss groundwater mounding potential
8. Develop nitrogen balance from discharge site to groundwater table

IV. Plan of operation for facility

A. Application rates (inches per week and inches per hour)

B. Loading rates

1. Wastewater
2. Nitrogen
3. Phosphorus
4. BOD
5. Suspended solids

C. Holding pond specifications

D. Maintenance of land application area

V. Monitoring-surveillance system

A. Observation wells

1. Number
2. Location
3. Method of installation

B. Surface water stations (ponds, lakes, streams)

1. Number
2. Location
3. Method of sampling

VI. General comments

A. Summation of sites advantages and points of concern

B. Overall summation of hydrogeologic report

1. Will it work?
2. For how long?

Appendix C

Calculation of Hydrologic Balance

All hydrologic balances contain parameters which fall into one of two categories, supply or demand. In order for an equation to express accurately a hydrogeologic balance, the sum of the water-supply parameters must equal the sum of the water-demand parameters. The following is an example of a simplified hydrologic balance applicable to a land-application system:

$$P + Lw = ET + GW + SM + RO$$

where:

P = natural precipitation occurring on-site. For design purposes, the wettest year in the last 10 years of record should be used.

Lw = amount of wastewater applied to site.

ET = evapotranspiration losses from site.

GW = amount of water entering groundwater system beneath site.

SM = amount of moisture contained in soil profile on site.

RO = amount of surface runoff flowing from site.

In most land-application systems, surface runoff from the site is not permitted. Consequently, the runoff term (RO) in the previous hydrologic balance is usually omitted. Soil moisture changes, gains and losses, on an annual basis are thought to balance each other out. Consequently, soil moisture (SM) from year to year is considered relatively constant and, therefore, usually omitted from the hydrology equation.

The precipitation and temperature data required for the hydrologic balance can be obtained from regional climatological stations owned and operated by the Weather Bureau, U.S. Department of Commerce. These climatic stations are established throughout the continental U.S., and the data published monthly. The precipitation data (P) is directly used in the equation. The temperature data, along with the precipitation data, is used to calculate the potential evapotranspiration term (ET) in the equation. There are several methods commonly used to calculate potential ET. Most of them can be found in basic hydrology texts.

Estimating the wastewater application rate (hydraulic loading rate) of any land application system is one of the most difficult steps in the design process. The application rate is a function of the physical properties of the soil, depth to groundwater, and the nutrient balance of the site. Traditionally, the application rate for slow-rate systems has been based upon annual precipitation information. In most places of the northeastern U.S., annual precipitation ranges between 35 and 45 inches. Assuming that land application is performed during 9 months of the year, applying wastewater at a rate of 1 inch per week would approximately double the amount of water received by the site under natural conditions; 2 inches per week would approximately triple the amount.

Some scientists and engineers use the permeability of the soils to determine the wastewater application rate. However, this technique can result in over-estimating the ability of the soil to transmit the wastewater. Research has shown that soil permeability decreases when wastewater is used in place of potable water. Soil permeability has also been found to decrease over time, regardless of the water used.

Just how much the permeability decreases over time is still open for discussion and depends upon a great many factors. Some of the more important factors affecting soil permeability are the physical and chemical properties of the soil, the amount and chemical composition of the wastewater, the climatology of the site, the vegetational cover type, and the management practices (e.g. crop harvesting) of the site. Activities affecting any one or more of these factors could result in a change in soil permeability, thus the sites ability to accommodate the applied wastewater.

In the past, the maximum application rate for the most commonly used technique, slow-rate, has been set at 2 inches per week. This rate was used in the research work conducted at Penn State University beginning in 1963 and continuing today. Little information has been collected elsewhere which suggests a relaxation of this maximum. In Maryland, an application rate of 2 inches per week is considered acceptable for soils ranging in texture from silt loams to sands. Application rates less than 2 inches per week are considered necessary for soil ranging in texture from silty clay loams to silty clays.

The actual application rate accepted by the Department of the Environment for any land-treatment system must consider not only the permeability of the soils but also the depth to groundwater and the nutrient balance of the site.

The groundwater term (GW) in the hydrologic balance is dependent upon the magnitudes of the precipitation, wastewater loading rate, and evapotranspiration terms. It is one of the more difficult terms of the balance to measure. Consequently, if it is not predetermined by a management plan, it is calculated using the hydrologic balance in a "check-book" type procedure.

The following example problem has been developed to demonstrate more fully the use of a hydrologic balance in a land-treatment system. The information that is given would be typical of that known about a system in the preliminary planning stages.

Example Problem

A small housing development located in Western Maryland has proposed a slow-rate land application system. The land-application system is to be responsible for handling only the municipal wastewater generated by the development. Several important hydrologic questions that need to be answered are: 1) what weekly application rate (loading rate) should be used, 2) how many acres of land will be required for the spray field, and 3) what is the total amount of water (wastewater plus precipitation) that will enter the underlying groundwater system?

The following information is known about the land-application system:

- a) The average daily wastewater flow is 100,000 gallons.
- b) The soils occupying the land application site are identified as Calvin channery loam. There are no impermeable layers or fragipans present in the profile, and the permeability of the horizons range from 0.6 to 2.0 inches per hour.
- c) The site is and will continue to be used as pastureland.

- d) Spray irrigation will begin each year in March and continue through the month of November for a total period of 275 days. Wastewater generated during the 90-day non-spray period will be held in a storage pond. The weekly loading cycle will consist of a one-day spray followed by a six-day rest period.

Question 1:

The soil present on the site is Calvin channery loam. There is neither an impermeable layer present in the soil profile nor any shallow groundwater present. Nutrient loading is not considered to be a problem. In light of these facts, the maximum application rate of 2 inches per week is considered acceptable for the site.

Question 2:

In order to determine the number of acres needed for the land-application system, the following equation was used:

$$A = \frac{Q \times 365 \times (E + F)}{27154 \times (365 - G) \times H}$$

where:

A = area in acres

Q = flow in gallons per day

E+F = loading cycle (loading plus rest periods) in days per week

E = loading period in days per week

F = rest period in days per week

G = storage requirement in days per year

H = application rate (loading rate) in inches per week

Conversion factors:

365 = days per year

27154 = gallons per acre-inch

Substituting the given information into the above equation yields:

$$A = \frac{100,000 \text{ gal/day} \times 365 \text{ days/year} \times (1 + 6) \text{ days/week}}{27154 \text{ gal/acre-inch} \times (365 - 90) \text{ days/year} \times 2 \text{ inches/week}}$$

A = 17.11 acres required for spray field (excluding buffers)

Question 3:

The hydrologic balance, previously given, was used to calculate the total amount of water (applied wastewater plus natural precipitation) that will enter the groundwater system beneath the spray field. The average monthly precipitation and temperature data were calculated using the most recent 10 years of data obtained at a nearby Weather Bureau climatic station. The Blaney-Criddle Method was used to estimate potential evapotranspiration for the site:

Calculation of potential evapotranspiration:

Blaney-Criddle Method

$$PET = KF$$

where:

PET = Potential ET in inches per unit area,

K = Crop-use coefficient,

F = Consumptive-use factor.

$$F = \frac{tp}{100}$$

where:

t = mean monthly temperature (°F),

p = percent of annual daytime hours occurring during each month of the year (Latitude for example site N 39", 30').

Month	Ave. Monthly Air Temp. (°F)	Percent Annual Daytime Hours	Veg. Consump. Use Coeff.	(Col 2 x Col 3)/100	Monthly PET (inches)
OCT	50.38	7.76	0.70	3.91	2.74
NOV	40.27	6.75	0.70	2.72	1.90
DEC	31.39	6.55	0.70	2.06	1.44
JAN	27.11	6.78	0.70	1.84	1.29
FEB	27.28	6.74	0.70	1.84	1.29
MAR	35.80	8.30	0.70	2.97	2.08
APR	47.33	8.94	0.70	4.23	2.96
MAY	57.62	9.99	0.70	5.76	4.03
JUN	65.19	10.03	0.70	6.54	4.58
JULY	69.18	10.17	0.70	7.04	4.93
AUG	68.21	8.52	0.70	5.81	4.07
SEPT	61.87	8.39	0.70	5.19	3.63

Calculation of water entering groundwater system:

The equation used to calculate the amount of water entering the groundwater system is as follows:

$$P + Lw = ET + GW$$

where:

P = natural precipitation, inches (conservatively, assuming 100% precipitation eventually recharging the groundwater flow)

Lw = wastewater loading, inches

ET = potential evapotranspiration, inches

GW = water entering groundwater, inches

Month	Natural Precip. (inches)	Wastewater loading (inches)	Potential ET (inches)	Entering Groundwater (inches)
OCT	2.63	8.67	2.74	3.61
NOV	2.29	8.67	1.90	9.06
DEC	3.04	--	1.44	1.6
JAN	2.57	--	1.29	1.28
FEB	2.10	--	1.29	0.81
MAR	3.08	8.67	2.08	9.67
APR	2.98	8.67	2.96	8.69
MAY	3.76	8.67	4.03	8.40
JUNE	3.01	8.67	4.58	7.10
JULY	3.45	8.67	4.93	7.39
AUG	3.25	8.67	4.07	7.85
SEPT	3.46	8.67	3.63	8.50
ANNUAL	35.87	78.03	34.94	78.96

The total amount of water entering the groundwater system beneath the spray field was calculated to be 78.96 inches per acre per year. To convert 78.96 inches per acre year to gallons per day, the following calculations are made:

$$\frac{(78.96 \text{ acre-inches/year}) \times (27154 \text{ gallons/acre-inch})}{365 \text{ days/year}} = 5874.2 \text{ gal/day}$$

APPENDIX D

Calculation of Nitrogen Balance

Nitrogen, especially in the nitrate (NO₃) form, is considered to be one of the most limiting constituents of municipal wastewater with respect to land application systems. The nitrate ion possesses a negative charge, as do soil particles. Since like charges repel, the nitrate ions tend to leach down through the soil profile. High nitrate concentrations in drinking water pose a health problem, especially in infants. For this reason the Environmental Protection Agency has imposed a maximum concentration of 10 milligrams per liter of nitrate-nitrogen in their Drinking Water Standards.

The nitrogen balance in any soil-water-plant scheme is dependent on several inputs (sources) and outputs (sinks). The major nitrogen inputs of land-application systems are the amount of nitrogen contained in the wastewater that is applied to the site and the amount of nitrogen contained in the natural precipitation that falls on the site. The major nitrogen outputs or sinks of a land-application system are removal by crops (plant uptake), leaching losses, denitrification, and ammonia volatilization. The nitrogen mass balance developed by J.E. Stone (1976) for the above situation can be expressed as follows:

$$\begin{array}{ccccccc} \text{Total N} & + & \text{N in} & = & \text{N Removal} & + & \text{Leaching} & + & \text{Denitri-} & + & \text{Ammonia} \\ \text{in Wastewater} & & \text{Precip.} & & \text{in crops} & & \text{Loss} & & \text{fication} & & \text{Volatilization} \end{array}$$

The above equation assumes: 1) that any short-term increase in nitrogen storage in the soil has already occurred, and 2) that there are no significant additions of nitrogen through nitrogen fixation by leguminous plants growing on-site.

When the nitrogen mass balance is combined with a simplified water balance (volume of water leaving site equaling precipitation plus wastewater loading minus evapotranspiration) and solved for the wastewater loading, the following equation is derived:

$$W = \frac{4.43C + a(P - ET) - cP}{y - a - y(d + n)}$$

where:

W = wastewater loading (acre-inch/acre-year)

C = removal of nitrogen in crop (lbs/acre-year)

a = allowable nitrogen concentration in percolation or runoff water (mg/L)

P = precipitation (acre-inch/acre-year)

ET = potential evapotranspiration (assumes that P + W will allow potential ET to be realized in all cases) (acre-inch/acre-year)

c = concentration of nitrogen in precipitation (mg/L)

y = concentration of nitrogen in wastewater (mg/L)

d = fraction of nitrogen which is denitrified (% x 10⁻²)

n = fraction of nitrogen which is volatilized as ammonia (% x 10⁻²)

For a more thorough explanation of the development and underlying assumption of the above equations, the reader is referred to Stone (1976).

Example Problem

A community located in the Piedmont region of the State is in the process of developing a spray-irrigation program for their treated municipal wastewater. The average annual precipitation and evapotranspiration values for the area are 40 and 28 inches, respectively. Determine how much wastewater, containing 25 mg/L total nitrogen, can be applied such that the soil leachate realized at the groundwater table will not exceed an average concentration of 10 mg/L total nitrogen (Public Drinking Water Standard). Assume that 275 lbs per acre per year of nitrogen will be taken up by a cover crop of reed canarygrass and removed from the site during harvesting. Natural precipitation contains an average concentration of 0.5 mg/L of nitrate-nitrogen. Since no site specific data are available, losses of nitrogen via denitrification and ammonia volatilization are assumed to be zero.

Substituting the appropriate values into the wastewater loading equation yields the following:

$$W = \frac{4.43(275) + 10(40 - 28) - 0.5(40)}{25 - 10}$$

$$W = 87.88 \text{ acre-inches/acre-year}$$

Assuming the annual irrigation season extends from March through November (a period of approximately 40 weeks), the average weekly wastewater loading rate would be:

$$\frac{87.88 \text{ acre-inches/acre-year}}{40 \text{ weeks/yr}} = 2.20 \text{ acre-inches/acre-week}$$

The above weekly loading rate should be compared with the weekly loading rate calculated from the soil permeability data. The smaller loading rate of the two should be the one at which the system is operated.

For discharging treated wastewater into a groundwater system nearby a surface water body, a more stringent nitrogen concentration in the percolate may be required. The term “a”, allowable nitrogen concentration in percolation may be 0 mg/l for an impaired surface water body. The wastewater loading rate (W) is reduced according to the following calculations.

$$W = \frac{4.43(275) + 0(40 - 28) - 0.5(40)}{25 - 0}$$

$$W = 47.93 \text{ acre-inches/acre-year}$$

Assuming the annual irrigation season extends from March through November (a period of approximately 40 weeks), the average weekly wastewater loading rate would be:

$$\frac{47.93 \text{ acre-inches/acre-year}}{40 \text{ weeks/yr}} = 1.20 \text{ acre-inches/acre-week}$$

The above weekly loading rate should be compared with the weekly loading rate calculated from the soil permeability data. The smaller loading rate of the two should be the one at which the system is operated.