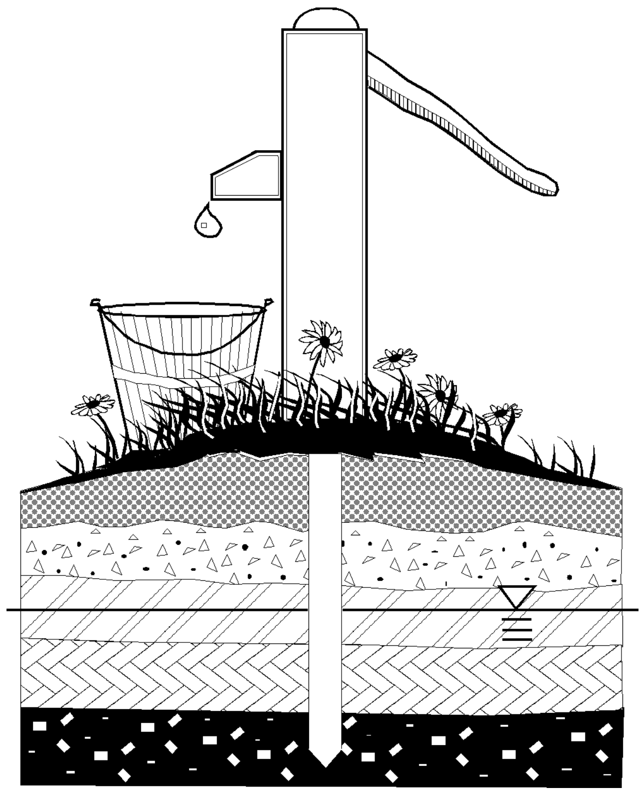
Technical Guidance For Sizing and Positioning of:
Spray Irrigation Systems
Overland Flow Systems
Infiltration/Percolation Lagoon Systems, and
Surface Impoundments



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Forward

For each of the citizens of New Jersey, protecting ground water should be an important goal. We all rely on the ground water to some extent for potable use, and it is a source of stream and river recharge. Clearly, it is one of our most important resources.

In an industrial state like ours, with nearly 8 million people, and with both old and new industrial sites, our ground water resources are always at risk. Pollution from sewage and industrial wastes needs to be carefully controlled if we are to maintain a high quality of ground water for human uses and as an ecological resource. Fortunately for all of us, New Jersey has a strong record of controlling and eliminating pollution, through implementation of the New Jersey Pollutant Elimination System (NJPDES). Over the past 20 plus years, the NJPDES program has been instrumental in helping to preserve and protect our ground water resources.

When discharges of pollutants are intended to go to ground water, the treatment and control of the discharge is enhanced by several different types of engineered devices. A few of the most common devices employed are surface impoundments, spray irrigation systems, overland flow treatment systems, and infiltration/percolation lagoon systems. The design and management of some of these devices and systems is rather complicated, and requires an understanding of engineering, agriculture, geology, and microbiology. Usually, people who must discharge pollutants hire consultants who understand these issues, and this guidance is primarily intended for their use.

This manual provides guidance regarding technical considerations a person would need to construct and operate wastewater treatment systems for discharges to ground water. The regulations relevant to these devices are found in N.J.A.C. 7:14A-7.10, 7.11, 7.12 and 7.13 respectively. This manual presents explanations of the current technology underlying the regulatory requirements, and provides explanation of NJDEP policies and procedures.

This manual has been produced by the New Jersey Department of Environmental Protection (NJDEP) to make the NJPDES permit process less complicated and time-consuming for you. It is one of a series of guidance documents produced by the DEP to make the permit application process more consistent and predictable.

NJDEP welcomes suggestions for improving its technical guidance products. Please direct your comments to the Bureau of Nonpoint Pollution Control at the address below.

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Section 1. SPRAY IRRIGATION

A. INTRODUCTION

Spray irrigation is frequently a wastewater treatment alternative when large volumes of water are generated, and when the water can be effectively used to irrigate vegetation or an agronomic crop for some beneficial use. Using spray irrigation methods, nutrients can be incorporated into the plants, thereby removing them from the water that ultimately enters the ground water. In addition, the volume of water that ultimately enters the ground is significantly reduced by evaporation and transpiration when spray irrigation is used.

B. GENERAL CONSIDERATIONS

In order for spray irrigation systems to perform properly, several conditions must exist.

1. Soils must be sufficiently permeable to allow applied wastewater to infiltrate into the water table at a rate that will prevent saturation of the soil and that will achieve the desired level of treatment.
2. A minimum of four (4) feet of suitable soil should be maintained throughout the area for spray irrigation. Where advanced disinfection is provided prior to spray irrigation, this thickness can often be reduced while still maintaining the desired degree of treatment.
3. Fill material should not typically be used to meet the requirements of B.2 above but may be used if no adverse impacts will result. Grading may be employed to modify drainage or improve topography.
4. In areas of irregular bedrock topography or deep weathering, site suitability may need to be more carefully considered based upon soils data, test pits, borings or geophysical data.
5. A minimum of four (4) feet of unsaturated soil must be maintained during all periods of spray irrigation between the highest elevation of the mounded ground water table (calculated according to guidelines in the NJDEP Technical Manual for NJPDES-DGW Permits) and the ground surface throughout the area of spray irrigation. Where advanced wastewater treatment is provided prior to spray irrigation, the distance may be reduced.
6. The use of under drains to lower the ground water table to meet the requirements of B.5 above is possible but is discouraged by the Department. The designer should be able to demonstrate that the regional hydrogeology is not adversely impacted and the discharge from under drains does not violate ground water or surface water quality standards.

C. PREAPPLICATION TREATMENT AND STORAGE

1. Prior to land application by spray irrigation, good management practices involve wastewater treatment to remove pathogens and odors. Treatment also addresses public health as it relates to consumption of crops or direct exposure to applied wastewater, to prevent nuisance conditions during storage, to prevent operating problems in wastewater distribution systems, and to protect vegetation from toxic effects of land application of wastewater. The degree of pretreatment is also dependent upon the capability of the land treatment system to renovate the applied wastewater.

2. Adequate storage capacity must be provided to account for the total number of days where spray irrigation is not feasible†. In New Jersey, days when irrigation is not feasible are considered to be:

   - The total number of days per year where the mean daily air temperature is less than 32 degrees F based upon the yearly average over the 10 year period preceding the date of land application. Climatic data is acquired from the National Weather Service (NWS) weather station located nearest to the land application site. Information concerning NWS weather stations can be obtained from either the National Climatic Data Center in Asheville, N.C., or Rutgers University - Cook College, Department of Meteorology in New Brunswick, N.J.
   - The total number of days devoted to maintenance of spray irrigation area (i.e. crop harvesting, tilling, resowing).

   † Additional capacity should be factored into yearly storage volume to account for periods of snow covered, frozen and water-logged ground conditions.

D. BUFFERS AND SLOPES

1. Spray irrigation of row crops (corn, soybean, etc.) in cultivated fields is most reasonably controlled when confined to slopes no greater than five (5) percent.

2. Spray irrigation of open fields planted with grasses or forage crops is confined to slopes no greater than fifteen (15) percent.

3. Spray irrigation of wooded tracts is possible on slopes steeper than fifteen (15) percent provided when understory growth and application schedules limit runoff and erosion.

4. The slopes specified in D.1, 2 and 3 above may be increased the nature of the vegetative cover, soil type, proximity to surface water bodies or any other characteristics of the spray irrigation site will limit the persistence and impact of runoff and erosion.

5. Good practices involve maintenance of buffer zones between the spray irrigation site and other land uses. The recommended buffer zones from the wetted perimeter of the spray irrigation area are:

   - four-hundred (400) feet from an occupied building or dwelling,
   - two-hundred (100) feet from a surface water body or wetlands, and
   - one-hundred (100) feet from a property line.

   Buffer zones are determined in consideration of spray type and radius, and the level of wastewater treatment prior to spray irrigation.

6. Where spray irrigation occurs on wooded tracts which are managed as multi-storied forests, a minimum buffer zone of fifty (50) feet will be sufficient to meet all of the objectives of D.5 above. Where natural existing forests are used as a buffer, a minimum width of fifty (50) feet may be sufficient to meet all the objectives of D.5 above, provided that there is adequate vegetative density.

7. Buffers and separation distances from spray irrigation areas may need To Whom It May Concern: be increased when in the opinion of the Department site specific factors increase the risk of aerosol transmission.

E. DESIGN CRITERIA

1. The minimum required area for land application of wastewater by spray irrigation is based upon the maximum daily volume of wastewater generated and the design hydraulic loading rate. The design hydraulic loading rate is be based upon the more restrictive of two limiting conditions:

   - The capacity of the soil to transmit water (HL_W); or
   - The anticipated nutrient concentration of the applied wastewater beyond the root zone (HL_n).

   The design hydraulic loading may be further reduced for the purposes of meeting the requirements of B.5 above.

2. The hydraulic loading rate based upon the capacity of the soil to transmit water (HL_W) can be calculated for an annual period based upon the sum of monthly HL_W values. Monthly HL_W values are calculated using the general water balance equation below:

$$HL_w = ET - PR + IR$$

   Where:

   HL_W = Wastewater hydraulic loading rate (in/mo);
   ET = Evapotranspiration rate (in/mo) based upon the yearly average over the 10 year period preceding the date of land application for the selected

crop(s). ET data can be acquired from Cook College - Rutgers University in New Brunswick, N.J.; or county branches of the Soil Conservation Service; or appropriate studies that may be recommended by the Department;

PR = Precipitation rate (in/mo) based upon the yearly average over the 10 year period preceding the date of land application. Climatic data is acquired in the same manner as prescribed in C.2 above; and

IR = Infiltration rate (in/mo) is be calculated by first establishing a daily design infiltration rate which does not exceed 5 percent of the minimum saturated hydraulic conductivity in the soil profile. The design daily infiltration rate is to then be multiplied by the maximum number of operating days per month, using the data collected in C.2 above.

3. The hydraulic loading rate based upon the nutrient concentration of the percolate water beyond the root zone (HL_n) can be calculated for an annual period using the equation below:

$$HL_n = \frac{CP(PR - ET) + U(4.4)}{CN - CP}$$

Where:

HL_n = Annual wastewater hydraulic loading rate based on nutrient limitation (in/yr);

CP = Design nutrient concentration in percolation water below root zone (mg/l);

ET = Evapotranspiration rate (in/mo) based upon the yearly average over the 10 year period preceding the date of land application for the selected crop(s). ET data can be acquired from Cook College - Rutgers University in New Brunswick, N.J.; or county branches of the Soil Conservation Service; or appropriate studies to be approved by the Department;

PR = Precipitation rate (in/mo) based upon the yearly average over the 10 year period preceding the date of land application. Climatic data is acquired in the same manner as prescribed in C.2 above;

U = Annual nutrient uptake per crop (lbs/acre∗yr). Nutrient uptake information for individual crops throughout the state can be obtained from Cook College - Rutgers University Cooperative Extension Service in New Brunswick, N.J.; crop extension specialists; or any appropriate data or studies to be approved by the Department; and

CN = Nutrient concentration of wastewater at the point of land application (mg/l).

NOTE: When nutrient uptake is not a mitigating design factor, hydraulic loading (*HL*) is determined according to E.2 above.

4. The minimum required area for land application of wastewater by spray irrigation can be calculated using the equation below:

$$A = \frac{Q(365\ d/yr)}{C(HL)}$$

Where:

A = Minimum required field area (acre);
Q = Maximum daily volume of wastewater generated (ft^3/d);
C = Constant (3630); and
HL = Design hydraulic loading rate (in/yr). When both HL_w and HL_n are calculated, the lower value is used.

5. Wastewater loading may not exceed the irrigation need of the crop(s) provided the crop is tolerant of saturated or oxygen deficient conditions.

6. Wastewater loading may not exceed twice the annual nutrient requirements of the crop. Crop nutrient requirements can be obtained from Cook College - Rutgers University Cooperative Extension Service in New Brunswick, N.J.; crop extension specialists; or any appropriate data or studies to be approved by the Department.

7. Initial Biochemical Oxygen Demand (BOD) loading should not exceed 7,000 lbs BOD/acre∗yr unless it can be demonstrated that odor problems will not occur. This loading may be increased after one (1) year provided it can be demonstrated that earlier BOD loading rates did not result in odor or nuisance conditions.

F. OPERATION, MONITORING AND MAINTENANCE

1. No wastewater is land applied to bare ground by spray irrigation. Land application by spray irrigation may only occur on land surfaces covered by an adequate vegetative cover.

2. Wastewater can not be safely land applied by overland flow when the ambient air temperature is at or below 32°F, when snow or ice is on the ground, or when the ground is frozen or water-logged.

3. Rest periods incorporated into the design of all spray irrigation schedules. Spray and rest periods is determined on the basis of soils, vegetation, hydrogeology, wastewater characteristics and loading rates, with a maximum application period of four (4) hours per section of spray field followed by at least four (4) hours of rest.

4. Design operating pressure of sprinkler heads must be compatible with maintenance of vegetation and intrinsic soil structural properties. Protection of tree bark in coniferous, immature and multi-storied wooded tracts must be considered in spray irrigation designs. Suggested design operating pressure should never exceed 55 lbs/in^2. Where

spray irrigation occurs within mature tracts of hardwoods, NJDEP will consider approving a higher design operating pressure provided vegetation and intrinsic soil structural properties can be maintained.

5. In addition to the ground water monitoring required in N.J.A.C. 7:14A-7, soil conditions within the root zone will need to be monitored. At a minimum, soil pH, exchangeable sodium percentage (ESP), electrical conductivity and nutrient status will be monitored on an annual basis. The level of trace elements in the soil will be monitored on a less frequent basis in order to observe the rate of accumulation within the soil for the purposes of preventing trace elements from reaching levels which are toxic to plants.

6. The ESP of the soil should not exceed fifteen (15) percent. ESP of the soil may be lowered when necessary through addition of calcium sulfate (gypsum) as approved by NJDEP.

7. The vegetation of the spray field is harvested at such a frequency as to ensure the optimal nutrient uptake capacity of the crop(s). The time period required for tilling and resowing the spray field is incorporated into satisfying the requirements for determining storage volume in C.2 above.

Section 2. OVERLAND FLOW

A. GENERAL CONSIDERATIONS

1. Land treatment of wastewater by overland flow is most suitable to sites having surface soils, or soils with fragipans no deeper than 2 feet below grade, which exhibit a hydraulic conductivity less rapid than 0.2 inches per hour. Where soils exhibit a hydraulic conductivity more rapid than 0.2 inches per hour, the NJDEP will require that additional ground water quality considerations be addressed in the application.

2. Soils should be of sufficient depth to form slopes which are uniform and which can maintain a healthy vegetative cover.

3. Placement of fill to meet the requirements of B.1 above is discouraged but may be allowed by the NJDEP if it can be demonstrated that no adverse impacts will result. Grading to modify or improve topography for terrace construction and drainage is acceptable.

4. The operator must always avoid an un-permitted direct or indirect discharge to surface water, because will usually violate a ground water discharge permit.

B. PREAPPLICATION TREATMENT AND STORAGE

1. Prior to land application of wastewater by overland flow, wastewater treatment is provided in order to prevent nuisance conditions during storage, prevent operating problems in the distribution system, and to protect the vegetation from the toxic effects of land application of some wastewater.

2. Storage volume is provided to account for the total number of days where overland flow is infeasible†. The total number of infeasible days are:

    - Total number of days per year where the mean daily air temperature is less than 32 degrees F based upon the yearly average over the 10 year period preceding the date of land application. Climatic data is acquired from the National Weather Service (NWS) weather station located nearest to the land application site. Information concerning NWS weather stations can be obtained from either the National Climatic Data Center in Ashville, N.C., or Rutgers University - Cook College, Department of Meteorology in New Brunswick, N.J.
    - Total number of days devoted to maintenance of overland flow terrace area (i.e. crop harvesting, terrace maintenance, regrading).

    † Additional capacity should be factored into yearly storage volume to account for periods of snow covered, frozen and water-logged ground conditions.

C. DESIGN CONSIDERATIONS

1. Where wastewater is to be land applied by overland flow, NJDEP recommends the range of hydraulic loading rates listed below . Generally, the median and upper end of each range specified below applies to normal operating conditions (spring, summer and fall), while the lower end applies to winter operation where reduced hydraulic loading may be required to overcome cooler soil temperatures and reduced treatment efficiency.

Recommended Hydraulic Loading Rates	
Degree of Pretreatment	Hydraulic Loading (in/yr)
Screening/comminution	0.8-2.8
1° sedimentation	1.0-3.6
2° biological	1.2-3.9

2. The period of application of wastewater by overland flow should be from 8-12 hours per day.

3. The frequency of application of wastewater by overland flow should be from 5-7 days per week

4. The minimum terrace length for land application of wastewater by overland flow should be 150 feet from the top of the terrace to the runoff collection channel. Where wastewater is distributed using full circle impact sprinklers, the minimum terrace length is the sprinkler diameter plus 65 feet.

5. The application rate of wastewater by overland flow can be determined as follows:

$$Ra = \frac{(Lw)(S)}{P(12in/ft)}$$

Where:

Ra = Application rate ($ft^3/hr*ft$)
Lw = Hydraulic loading rate (in/d)
P = Application period (h/d)
S = Terrace length (ft)

6. The area of terraces to which wastewater will be land applied by overland flow can be calculated as follows:

$$As = \frac{Q(365\, d/yr) + \Delta Vs}{(Da)(Lw)(4.36 \times 10^{4}\ ft^{2}/ac)(.08\ ft/in)}$$

Where:

As = Terrace area (ac)
Q = Average daily volume of wastewater (ft^3/d)
ΔVs = Net storage (ft^3/yr)
Da = Total operating days (d/yr)
Lw = Hydraulic loading (in/d)

D. DISTRIBUTION SYSTEMS

1. Land application of wastewater by overland flow can be accomplished by any of the following methods:

- Surface distribution methods
  - Gated aluminum pipe
  - Slotted or perforated PVC pipe
- Low pressure sprays or bubbling orifices
- High pressure sprays
  - Impact sprinklers mounted on fixed risers or rotating booms

2. Distribution systems are located along the uppermost edge of the overland flow terrace. Distribution systems are selected and designed to achieve the design application rate of the system while minimizing erosion to the overland flow terrace.

3. Spacing between gates, slots or perforations for surface distribution should not exceed 2 feet. In-line valves need to be provided where distribution mains exceed 300 feet in length.

4. Sprays heads or orifices for low pressure sprays or bubbling orifices (design operating pressure $\approx$ 20 lbs/in^2) are spaced so that wastewater can be uniformly applied along the top of the overland flow terrace. Splash blocks or gravel layers are located beneath each orifice or spray head in order to prevent erosion.

5. The spacing between sprinklers for high pressure sprinklers (design operating pressure $\approx$ 50 lbs/in^2) should at a minimum be 80% of the individual sprinkler area diameter (either full circle or half circle).

D. TERRACE LOCATION, DESIGN AND CONSTRUCTION

1. Land application of wastewater by overland flow are restricted to terraces with slopes between 2 and 8 percent. Any cutting and filling during land forming processes to achieve the above, must take into consideration the mechanical properties of the soil.

2. Buffer zones are maintained from the perimeter of the spray irrigation area. The recommended buffer zones from the perimeter of the spray irrigation area are:

   - four-hundred (400) feet from an occupied building or dwelling,
   - two-hundred (100) feet from a surface water body or a wetland, and
   - one-hundred (100) feet from a property line.

   Buffer zones are determined in consideration of spray type and radius, and the level of wastewater pretreatment prior to spray irrigation.

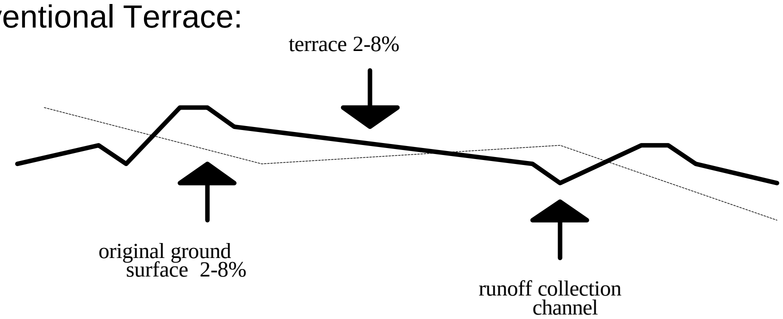
3. Where overland flow areas are bounded by wooded tracts which are managed as multi-storied forests, a minimum buffer zone of fifty (50) feet will be sufficient to meet all the objectives of E.3 above, provided there is adequate vegetative density.

4. Buffers and separation distances from overland flow areas may be increased, when in the opinion of the NJDEP site specific factors increase the risk of aerosol transmission when high pressure sprinklers are used for distribution.

5. The general arrangement of individual terraces should be such that wastewater can flow by gravity from each terrace runoff collection channel, to main drainage channel(s), to the final discharge location. It is preferable to have a grading plan which results in a single, final discharge location.

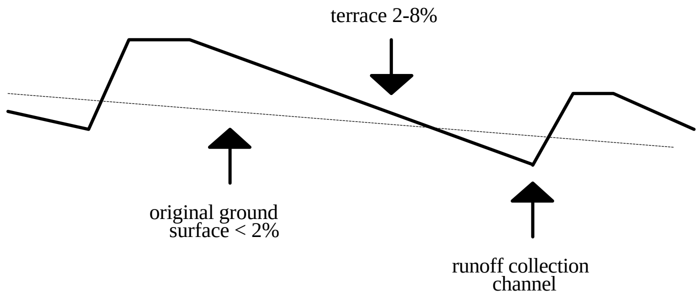
6. Any of the four basic types of terrace configurations listed below are recommended for land application of wastewater by overland flow:

   (a) Conventional Terrace:



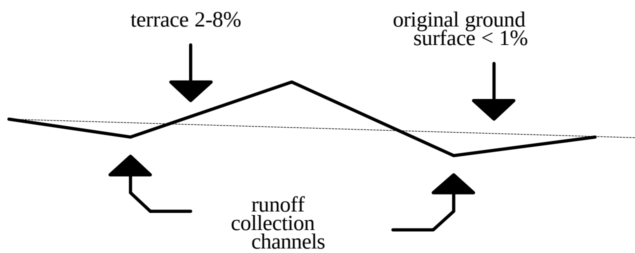
   Used when existing field grade generally meets the criteria of 2-8 % slope. Localized cutting and filling is accomplished as necessary to fully meet grade criteria.

(b) Step-Up Terrace:



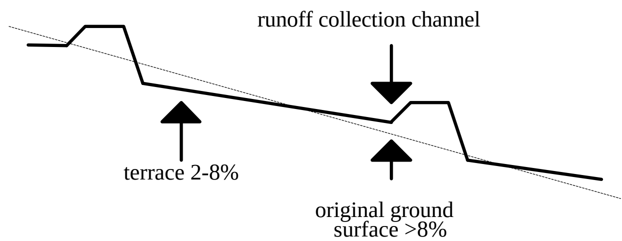
Used where the existing grade is less than desired (< 2%) and it is necessary to increase existing field grades. The front slope of the adjacent terrace provides one side of the runoff collection channel, while the lower portion of the terrace itself provides the other side.

(c) Back-to-Back Terrace:



Used where the existing field grade is virtually flat. Construction of individual drainage channels is not necessary because the point where the bottom of adjacent slopes intersect acts as a broad channel.

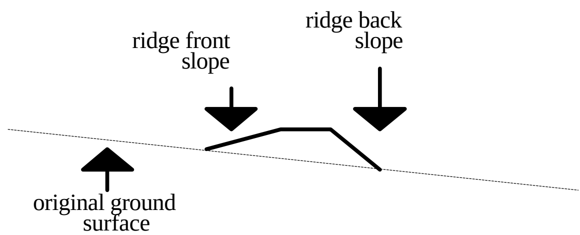
(d) Step-Down Terrace:



Used where existing field grades are greater than desired (> 8%). Drainage channels are constructed along the lower edge of the higher terrace, adjacent to the step-down to the lower terrace.

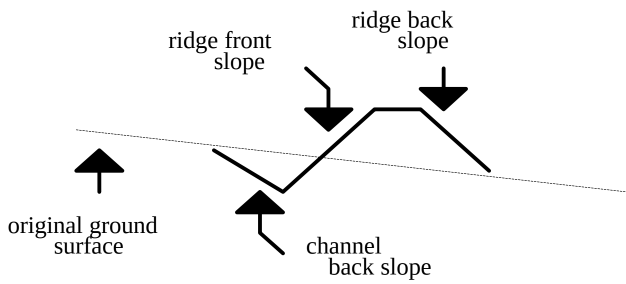
7. Runoff collection channels and main drainage channels are designed to handle the peak rate of runoff from a 25-year/24 hour storm frequency, while maintaining between 4-8 inches of freeboard. Drainage channels consist of three basic types:

(a) Ridge Channel:



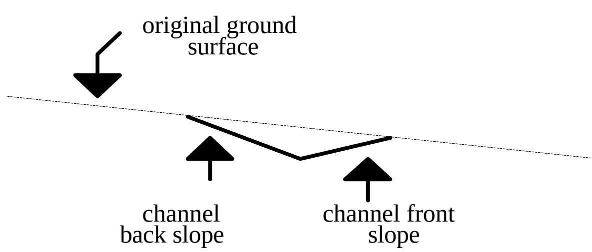
The ridge front slope provides one side of the V-channel while the bottom of the terrace provides the other.

(b) Ridge and Trough Channel:



The ridge and trough channel is constructed by excavating the trough and using the excavated soil to form the ridge.

(c) Trough Channel:



The trough channel is usually constructed by excavating the channel and disposing or stockpiling the soil at another location.

E. VEGETATION

1. Good practices predicate that vegetation on terraces to which wastewater will be land applied by overland flow consist of perennial grasses with long growing seasons which have high moisture tolerance, extensive root formation, and are able to form into a sod. Grasses with annual growing seasons or those which grow in bunches can only be used as nurse crops or in combination with other grasses which meet the above criteria.

2. Planting by seeding needs to be accomplished in a manner which distributes the seed evenly, covers the seed with a small amount of soil, without leaving wheel tracks on terrace surfaces.

3. Seeding operations along terrace surfaces should be carried out parallel to the steepest terrace slopes.

4. Seeding density should take into consideration the type(s) of grass to be planted, climatic factors, expected germination time, water availability and time available for crop development. Where seeding is necessary to accomplish temporary terrace stabilization or if water for cover crop development is in short supply, seeding should be at a density of 135-250 seeds/ft^2. A seeding density of 400-800 seeds/ft^2 should be used when planting occurs at the optimum time for development by natural rainfall. Where rapid development of a dense cover crop is prescribed, and adequate irrigation water is available, a seeding density of up to 1900 seeds/ft^2 may be used.

5. Sprigging can be accomplished through broadcast planting at a density of 40-50 bushels/acre. Sprigging can only be used where there is an adequate source of irrigation water.

F. OPERATION, MONITORING AND MANAGEMENT

1. No wastewater is land applied to bare ground. Land application by overland flow may only occur on terrace surfaces covered by a dense sod of grass(es).

2. Wastewater cannot be safely land applied by overland flow when the ambient air temperature is at or below 32°F, snow or ice is on the ground and the ground is frozen or water-logged.

3. Harvesting usually occurs at least twice per year with the cutting of the first harvesting left on the terraces. Where wastewater is distributed through sprinkler systems with rotating booms, the frequency of harvesting may need to be increased to facilitate operation of the distribution system. The time period required for harvesting overland flow terraces is incorporated into satisfying the requirements for determining storage volume in C.2 above.

4. Ponding or channeling conditions are unacceptable on overland flow terraces. If ponding or channeling occurs, the overland flow terrace is taken off line, regraded as necessary to prevent the condition from continuing, and replanted.

5. In addition to the monitoring required in N.J.A.C. 7:14A-7, soil conditions within the root zone will need to be monitored. At a minimum, soil pH, exchangeable sodium percentage (ESP), electrical conductivity and nutrient status will be monitored on an annual basis. The level of trace elements in the soil will be monitored on a less frequent basis in order to observe the rate of accumulation within the soil for the purposes of preventing trace elements from reaching levels which are toxic to plants.

6. The ESP of the soil should not exceed fifteen (15) percent. ESP of the soil may be lowered when necessary through addition of calcium sulfate (gypsum) as approved by the Department.

Section 3. INFILTRATION/PERCOLATION LAGOONS

A. INTRODUCTION

Infiltration/Percolation Lagoons are frequently a wastewater treatment alternative when a facility has a large area of land, and when loading rates need to be high. An infiltration basin can provide extra storage, enhanced evapotranspiration, or higher loading rates than can be available by direct discharge to the ground or to the underground.

B. GENERAL CONSIDERATIONS

1. Infiltration/percolation lagoons are designed so that wastewater may infiltrate into the ground water table at a rate that will prevent saturation of the soil.

2. A minimum of four (4) feet of unsaturated soil is maintained between the highest elevation of the mounded ground water table (calculated according to the guidelines in the NJDEP Technical Manual for NJPDES-DGW permits) and the bottom of any infiltration/percolation lagoon. Where advanced wastewater treatment is provided prior to rapid infiltration, the distance may be reduced by NJDEP

3. In areas of irregular bedrock topography or deep weathering, NJDEP will determine site suitability based upon soils data, test pits, borings or geophysical data provided by the applicant.

C. PREAPPLICATION TREATMENT

1. Prior to land application of wastewater by infiltration/percolation lagoons, a minimum of primary wastewater treatment is provided in order to prevent nuisance conditions during periods of application, and to protect the infiltrative capacity of the lagoon system. Additional pretreatment may be required dependent upon the characteristics of the wastewater and the capability of the land treatment system to renovate and discharge the applied wastewater. The level of pretreatment will also be dependent upon the method selected by the applicant for complying with ground water quality standards as offered in NJDEP Technical Manual for NJPDES-DGW Permits.

D. DESIGN CONSIDERATIONS

1. Hydraulic loading is based on the minimum vertical saturated hydraulic conductivity or infiltrative capacity within the soil profile in the proposed area of rapid infiltration. If the site investigation reveals a specific layer of soil that will restrict flow, the design should be based on the hydraulic conductivity of the layer, regardless of its thickness. It may be possible to remove this restricting layer and locate the infiltrative surface in the underlying soils.

2. Annual hydraulic loading rates are determined based upon the minimum vertical saturated hydraulic conductivity or infiltrative capacity within the soil profile in the proposed area of rapid infiltration. Hydraulic loading may need to be further reduced to

meet the conditions of B.2 above. Field measurements should be adjusted as follows to determine annual hydraulic loading:

Recommended Annual Hydraulic Loading Rate†	
Field Measurement	Annual Hydraulic Loading Rate
Basin Infiltration Test	≤ 15% of minimum measured infiltration rate
Cylinder infiltrometer or air entry permeameter	≤ 5% of minimum measured infiltration rate
Vertical Saturated Hydraulic Conductivity	≤ 10% of measured value of most restrictive soil horizon

† The above adjustment factors are intended for systems which will be designed and operated for use on a regular schedule throughout the entire operational year.

3. Loading cycles in the table below are recommended for the purpose of maximizing either the wastewater infiltration rate, or enhancing nitrification or nitrogen removal.

Recommended Loading Cycles†				
Loading Cycle Objective	Applied Wastewater	Season	Application Period (day)	Drying Period (day)
Maximize infiltration or nitrification	Primary	Summer	1-2	5-7
		Winter	1-2	7-12
	Secondary	Summer	1-3	4-5
		Winter	1-3	5-10
Maximize nitrogen removal	Primary	Summer	1-2	10-14
		Winter	1-2	12-16
	Secondary	Summer	7-9	10-15
		Winter	9-12	12-16

† Where wastewater has been treated to a level at or below Ground Water Quality Standards, N.J.A.C. 7:9-6, prior to rapid infiltration, application and drying periods are selected relative to the soils hydraulic capacity and vegetative tolerance concerns.

4. Application rate can be calculated from the annual hydraulic loading rate, the loading cycle and total loading cycle time as shown below.

$$Ra = \frac{Hl}{(C_t)\ (D_c)}$$

where:

Ra = Application rate (in/day)
Hl = Annual hydraulic loading rate (in/yr)
C_t = Number of cycles per year [365 d/y ÷ (# application days + # drying days per loading cycle)]
D_c = Number of application days per loading cycle

NOTE: Application rate may need to be reduced for the purposes of complying with ground water quality standards as per NJDEP Technical Manual for NJPDES-DGW Permits.

5. Land area requirements may be assessed with the following equation:

$$A = \frac{0.0084\,(Q)}{Hl}$$

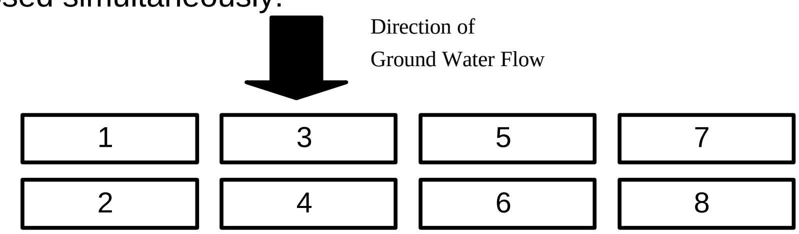
where:

A = Field area for treatment (ac)†
Q = Design daily flow (ft^3/d)
Hl = Annual design hydraulic loading rate (ft/yr)

† The resultant area calculated by this formula represents the minimum infiltrative area and does not include area occupied by dikes, berms, etc.

D. LAGOON, LOCATION, DESIGN AND CONSTRUCTION:

1. Infiltration/percolation lagoons are configured in such a way so as to reduce the effects of ground water mounding. This can be accomplished by arranging the lagoons in a strip configuration perpendicular to the direction of ground water flow as shown below, with staggered lagoon dosing to prevent adjacent lagoons from being dosed simultaneously:



Suggested Dosing Sequence: 1,4,5,8,2,3,6,7 or 1,6,3,8,2,5,4,7

2. Where the soils at the level of the lagoon infiltrative surface contain a significant fraction of fines (silts and/or clay > 10%) then stabilization grass is required. This will prevent suspension and re-deposition of particles of the colloidal fraction of the soil along lagoon surfaces, which can contribute to reduction of soil infiltrative capacity.

3. Lagoons are equipped so that incoming wastewater can be either diverted to other lagoons or completely shut off should a lagoon(s) be unable to treat and/or dispose of additional wastewater.

4. Dikes should not extend more than five (5) feet above the existing ground surface. Where daily application rate exceeds the design hydraulic conductivity or infiltration rate for the system, the application period should be lengthened or the hydraulic loading rate should be reduced rather than providing the dikes with

additional freeboard. Where dikes extend greater than five (5) feet above existing ground surface, the requirements of N.J.A.C. 7:20-1 *et seq*. must be satisfied.

5. Dikes need to be compacted to prevent seepage and should be pitched to the outside so that all drainage and run-off goes away from the lagoon. Vegetation is recommended for the stabilization of the dike slopes.

6. Dikes need have sufficient structural integrity to prevent failure. Earthen dikes need a protective cover to minimize wind and water erosion and to preserve the structural integrity of the dike. It is recommended that placement of topsoil and seeding with grass or a thin layer of gravel may be used for this purpose.

7. The dikes are free of vegetation which causes root systems which could displace the earthen materials upon which the structural integrity of the dike is dependent. Rodent protection should also be recognized to protect against the likelihood of development of leaks and destruction of the dikes due to animal burrows. Broken concrete or other rip rap that does not completely cover the dike soil can become a home for burrowing rodents.

8. Seepage collars must be provided around any pipes penetrating the dike. The seepage collars should extend a minimum of 2 feet from the pipe.

9. Erosion protection should be provided on all slopes. If winds are predominantly from one direction, protection should be emphasized for those areas that receive the full force of the wind-driven waves. Side slope protection from wave energy should extend from at least 1 foot below the minimum water level to 1 foot above the maximum water level.

10. Infiltration/percolation lagoons are equipped such that an unauthorized discharge can be immediately shut down to prevent hazards to human health or the environment.

E. OPERATION, MONITORING AND MAINTENANCE

1. Proper thermal protection are provided for pipes, pump stations, valves, etc. for winter operation of infiltration/percolation lagoons. The critical concern for rapid infiltration during freezing conditions is the prevention of a permanent, impermeable ice barrier at, or in, the near surface soils in the basin. The following methods can be used to address this problem:

    - Ridge and furrow configuration on the basin bottom combined with a floating ice sheet. The ice provides thermal protection, and rests on the ridge tops.
    - Inducing snow drifting using snow fences in the basins while flooding beneath the snow cover. The snow acts to retard freezing, and the water equivalent of the melted snow is a negligible contribution to the hydraulic load in the basin.

- ♦ Based on thermal and hydraulic calculations, adjust the wet/dry ratio during the critical periods so the near surface soil never irreversibly freezes.

2. Infiltrative surfaces within lagoons need to be scarified periodically through scraping and removing accumulated organic material, and/or disking or harrowing the surface soil layer, in or to maintain the infiltrative capacity of the lagoon. All maintenance activities, either schedules or emergency, should be conducted when the lagoon is dry and the moisture content of the surface soil layer is drier than optimum.

3. Where lagoon surfaces are vegetated, the grass are cut and removed once per year. It is recommended that harvesting occur in the late fall in order to prevent ice from forming on the vegetation and thereby cooling the applied wastewater.

4. In addition to the monitoring required in N.J.A.C. 7:14A-7, soil conditions within the root zone will need to be monitored on an annual basis. At a minimum, soil pH and exchangeable sodium percentage (ESP) should be monitored.

5. The ESP of the soil should not exceed fifteen (15) percent. ESP of the soil may be lowered when necessary through addition of calcium sulfate (gypsum) as approved by the Department.

Section 4. SURFACE IMPOUNDMENTS

A. INTRODUCTION

Surface Impoundments are frequently a wastewater treatment alternative when there is some need or desire to retain the pollutants within a leak proof lined device. This can be necessary when the chemical quality of the pollutants is of a nature such that it could create a high risk of water pollution. Alternatively, some circumstances may exist where the owner of a facility does not want to create a discharge because of its characteristic to pollute, or to enhance some treatment alternative, or because of a need to conserve the liquid or solid waste for future use or disposal.

B. GENERAL CONSIDERATIONS:

1. Ignitable or reactive wastes are never placed in a surface impoundment unless:

    - The waste is treated prior to discharge to the impoundment such that the resultant waste no longer meets the definition of ignitable or reactive under N.J.A.C. 7:26-8.9 and N.J.A.C. 7:26-8.11; or
    - Compliance with N.J.A.C. 7:26-9.4(e) can be achieved; or
    - The impoundment is intended solely for emergencies.

2. Incompatible wastes do not belong in the same surface impoundment. Incompatible wastes include wastes which may cause corrosion or decay of containment materials, or when co-mingled with another waste under uncontrolled conditions, may produce heat or pressure, fire or explosion, violent reactions, toxic dusts or gases. The successful operation of a surface impoundment should always result in odors being detected off-site.

3. Areas of irregular bedrock topography, deep weathering or outcrops of fractured bedrock are unsuitable for surface impoundments. Exceptions to this will be based on the applicant's ability to demonstrate that the structural integrity of the impoundment foundation will not be affected by seepage.

C. GENERAL DESIGN CONSIDERATIONS:

1. Impoundment liners are placed on a foundation or base capable of providing support to the liner and resistance to pressure gradients (including static head and external hydrogeologic forces) above and below the liner to prevent failure due to settlement, compression, or uplift.

2. The liners are constructed of materials having appropriate chemical properties such that there is sufficient strength and thickness to prevent failure due to physical contact with the waste, climatic conditions, and the stress of installation.

3. During construction and installation of the impoundment, liners are inspected for uniformity, damage, and imperfections (holes, cracks, thin spots and foreign material) as follows:

- Earth material liner systems are tested for compactness density, moisture content, and permeability after placement;
- Earth material liner systems are inspected for lenses, cracks, channels, root holes, and other structural non-uniformity; or
- Synthetic liner materials (membrane sheets and coatings) are inspected to ensure tight seams and joints and the absence of tears and blisters.

4. The bottom surface of the secondary liner should be no less than five feet (2.28 meters) above the seasonally high ground water table. Exceptions to this will be based on the applicant's ability to adequately demonstrate that seasonal changes in ground water elevations will not compromise the structural integrity of the liner.

5. The surface impoundment are designed and constructed to prevent overtopping resulting from normal or abnormal operations, overfilling, wind or wave action, rainfall, run-on, human error, malfunctions of level controllers, alarms and other equipment. At least two (2) feet of freeboard should be allotted.

6. The impoundment should be designed with a run-on control system capable of preventing flow into the surface impoundment during peak discharge from at least a 24 hour, 25 year storm.

7. Erosion protection should be provided on all slopes. If winds are predominantly from one direction, protection should be emphasized for those areas that receive the full force of the wind-driven waves. Side slope protection from wave energy should extend from at least 1 foot below the minimum water level to 1 foot above the maximum water level.

8. The surface impoundment should be equipped such that an unauthorized discharge can be immediately be shut down to prevent hazards to human health or the environment.

D. DESIGN CONSIDERATIONS FOR SURFACE IMPOUNDMENTS WITH LEACHATE COLLECTION SYSTEMS

1. The following design requirements are a prerequisite for a surface impoundment which is considered by the Department to be subject to the monitoring requirements outlined in N.J.A.C. 7:14A-7.6(b)1.

    (a) A properly constructed surface impoundment has two or more liners installed to cover all surrounding earth likely to be in contact with the wastewater, waste or leachate and has a leachate collection system between such liners.
    (b) Liners should have properties of such a nature to ensure that the prevention of liquid flow through the liner is maintained throughout the active life, closure, and post-closure period of the impoundment. The following are the specifications for the liner system:

- A primary liner consists of a synthetic material at least 30 mils (.03 inches) thick which is designed to prevent the flow of liquids through the liner.
- A secondary or lower liner consists of soil at least three (3) feet (.091 meters) thick with a maximum saturated hydraulic conductivity of 3.28 x 10^{-9} ft/sec (1 x 10^{-7} cm/sec) under maximum anticipated hydrostatic head, or consists of a synthetic material at least 30 mils (.03 inches) thick which is designed to prevent the flow of liquid through the liner.

(c) The surface impoundment is designed with a leachate collection system (leak detection system) that is designed to monitor for any failure of the primary liner and to collect and remove all leachate that may pass through as a result of a primary liner failure.

- Leachate collection and removal systems are installed between the liners and be able to detect any leakage from the primary liner.
- The leachate collection system is designed to satisfy the following:
  - The bottom slope of the collection system is at least 1 percent or more;
  - Constructed of granular drainage materials with a hydraulic conductivity of 1 x 10^{-1} cm/sec or more and at least 12 inches (30.5 cm) in thickness. The materials utilized in the leachate collection system are an open-graded material of clean aggregate which meet the cumulative grain size distribution curves below:

    $D_{85} < 4D_{15}$; and

    $D_{2} < 0.1$ inch
  - Constructed of materials that are chemically resistant to the wastewater or waste managed in the surface impoundment and the leachate expected to be generated;
  - The material is of sufficient strength to prevent collapse under the pressures exerted by overlying wastes or equipment used at the surface impoundment;
  - Designed to minimize clogging throughout the active life and post-closure period.
  - Constructed with sumps and liquid removal methods (pumps) of sufficient size to collect and remove liquids from the sump and prevent liquids from backing up into the drainage layer. Each unit must have its own sump(s). The design of each sump and removal system must provide a method for measuring and recording the volume of liquids present in the sump and of liquids removed.

E. DIKE CONSTRUCTION

1. The surface impoundment is designed with dikes which have sufficient structural integrity to prevent massive failure without dependence on any liner system included in the impoundment design. Where dikes extend greater than five (5) feet above existing ground surface, the requirements of N.J.A.C. 7:20-1 *et seq*. must be satisfied.

2. Earthen dikes have a protective cover to minimize wind and water erosion and to preserve the structural integrity of the dike. Placement of topsoil and seeding with grass or a thin layer of gravel may be used for this purpose.

3. The dikes are free of vegetation which possesses root systems which could displace the earthen materials upon which the structural integrity of the dike is dependent. Rodent protection should also be recognized to protect against leaks and destruction of the dikes due to animal burrows. Broken concrete or other rip rap that does not completely cover the dike soil can become a home for burrowing rodents.

4. Seepage collars must be provided around any pipes penetrating the dike. The seepage collars should extend a minimum of 2 feet from the pipe.

F. OPERATION, MONITORING AND MAINTENANCE:

1. Surface impoundments designed in accordance with the guidelines in C above will qualify for the monitoring program specified in N.J.A.C. 7:14A-7.11. Surface impoundments which do not meet the design criteria specified in part C above, are subject to the monitoring program in N.J.A.C. 7:14A-7.12.

2. The operator needs to collect and remove pumpable liquids in the sumps of the leachate collection system to minimize the head on the bottom liner.

3. During the operation of the surface impoundment, the permittee needs to inspect synthetic liner materials (membrane, sheets, and coatings) to ensure tight seams and joints and the absence of tears and blisters.

4. Earth material liner systems are inspected for lenses, cracks, channels, root holes, and other structural non-uniformity during the operation of the impoundment.

Section 5. REFERENCES

Daniels, Walter H. Case Study No. 6: Kenbridge Virginia Overland Flow. Prepared for the U.S. EPA Center for Environmental research Information. March, 1986.

Frevert, R.K., et al. Soil and Water Conservation Engineering. John Wiley and Sons, Inc. New York, NY. 1966.

Overcash, Michael R. and Dhiraj Pal. Design of Land Treatment Systems for Industrial Wastes: Theory and Practices. Ann Arbor Science Publishers Inc., Ann Arbor, MI. 1979.

Proceedings on International Symposium on State of Knowledge in Land Treatment of Wastewater: Volume 1. U.S. Army Corps of Engineers, Cold Regions Research and Engineering Laboratory, Hanover, NH. August, 1978.

New Jersey Administrative Code, Title 7: Chapter 26. Hazardous Waste Regulations. July 19, 1993.

New Jersey Administrative Code, Title 7, Chapter 20. Dam Safety Standards. June 4, 1990.

U.S. Army Corps of Engineers. Land Treatment Systems Operation and Maintenance. EM 1110-2-504. Washington, D.C. November, 1983.

U.S. Environmental Protection Agency. Technology Transfer Seminar Publication: Land Treatment of Municipal Wastewater Effluents - Case Studies. EPA 625/4-76-010. U.S. EPA, Center for Environmental Research Information, Cincinnati, OH. January, 1976.

U.S. Environmental Protection Agency. Technology Transfer Seminar Publication: Land Treatment of Municipal Wastewater Effluents - Design Factors I, II. EPA 625/4-76-010. U.S. EPA, Center for Environmental Research Information, Cincinnati, OH. January, 1976.

U.S. Environmental Protection Agency. Technology Transfer Process Design Manual for Land Treatment of Municipal Wastewater. EPA 625/1-77-008. U.S. EPA, Center for Environmental Research Information, Cincinnati, OH. October 1977.

U.S. Environmental Protection Agency. Assessment of Current Information on Overland Flow Treatment of Municipal Wastewater. EPA 430/9-80-002. U.S. EPA Office of Water Systems Operations, Washington, DC. May, 1980.

U.S. Environmental Protection Agency. Technology Transfer Process Design Manual for Land Treatment of Municipal Wastewater. EPA 625/1-81-013. U.S. EPA, Center for Environmental Research Information, Cincinnati, OH. October 1981.

U.S. Environmental Protection Agency. Technology Transfer Process Design Manual for Land Treatment of Municipal Wastewater: Supplement on Rapid Infiltration and Overland Flow. EPA 625/1-81-013a. U.S. EPA, Center for Environmental Research Information, Cincinnati, OH. October 1984.