North Carolina Surface Irrigation System Operators Training Manual

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Water Pollution Control System Operators Certification Commission
North Carolina Division of Water Resources
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Purpose

The purpose of this manual is simply to provide operators of surface (spray and drip) irrigation of wastewater systems the basic understanding needed to operate these systems in an efficient and environmentally sound manner. The purpose of this manual is not to provide all of the technical details for the complete evaluation and design of a surface irrigation system for wastewater. There are many good reference materials that have been published on this subject that can provide more detailed information on the various topics discussed. Many of these materials will be referenced in this manual and it is hoped that you will make use of them during this course and as you continue to work with surface irrigation.

Notes About This Manual

This manual has been written based on the current laws, rules, and technical guidance available at the time. It is possible, indeed likely, that there will be changes in the laws and technical guidance that apply to spray irrigation of wastewater. You should keep yourself aware of these changes. The organizations and government agencies that are involved in surface irrigation of wastewater will make efforts to inform individuals who own and operate surface irrigation of wastewater systems of these changes as they occur. However, you are ultimately responsible for ensuring that you are operating in compliance with current laws and rules. If you have questions, you should contact the appropriate resource people listed in Appendix B-1.

Acknowledgements

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Introduction

Surface irrigation systems are wastewater treatment facilities that use spray or drip irrigation technologies to apply wastewater to land surfaces. These systems include some form of onsite wastewater pretreatment, ranging from simple septic tank/sand filter systems to sophisticated million gallon treatment plants.

Wastewater irrigation is a practical and environmentally friendly method of wastewater disposal. It provides water and nutrients to golf courses, lawns, forests, and crops. At the same time, it reduces or eliminates the need for wastewater discharges to local surface waters. Instead, as wastewater moves through the soil, naturally occurring processes provide additional treatment. Purified wastewater then recharges valuable groundwater resources.

Mismanagement of any waste treatment process, however, can have negative consequences. Over-application of wastewater can result in runoff or leaching (downward movement) of contaminants to surface waters and groundwater. The result is that the system is no longer providing beneficial reuse of the wastewater, but is causing negative consequences. Nutrients, metals, pathogens, salts, and chemicals in wastewater can cause environmental problems or health concerns if not properly managed.

The goal of any wastewater treatment system is to treat the wastewater to a sufficient level to protect the public health and the environment, particularly surface and groundwater quality. The purpose of this manual and this training course is to educate operators of surface irrigation of wastewater systems in the proper operation and maintenance of these systems. These systems can effectively serve for many years and will gain public acceptance if properly operated.

A committee of experts in the wastewater, regulatory, soils, agronomy, engineering, and associated fields developed these training materials. The manual is based on a list of topics that should be familiar to each operator of a surface irrigation of wastewater system. This list of objectives is called the "Needs-to-Know".

The manual is relevant to the regulations and technology that existed at the time it was written. It is periodically updated to reflect changes in laws and technology. For example, interest in odor reduction from wastewater irrigation fields is increasing the use of application equipment that distributes wastewater at or close to the ground surface. Distribution techniques such as low-drop nozzles on center pivot equipment and drip irrigation systems meet some of these needs in special cases.

This manual cannot cover every possible type of hardware that is used in the field. The basics of wastewater treatment, distribution, and site management, applicable to all sites, are discussed in some detail Special and unique systems may be briefly mentioned. Operators of such systems are encouraged to obtain more specific operation and maintenance information from the system manufacturer, designer, and/or installer.

There is also technical assistance available in the operation and maintenance of land-based wastewater and residuals treatment systems. References throughout the manual will refer the user to specialists for more information.

North Carolina Surface Irrigation of Wastewater
Needs-To-Know

Chapter 1 – Wastewater Characteristics

1-1. Identify the sources of wastewater.

1-2. Describe the difference between domestic and industrial wastewater and list concerns with application of high strength industrial waste.

1-3. Define inorganic and organic as they relate to wastewater treatment.

1-4. Describe several important physical characteristics of wastewater and identify unusual conditions that could affect system operation.

1-5. Define total, suspended, and dissolved solids and explain their importance in wastewater treatment.

1-6. Define influent.

1-7. Define pathogen and explain its relevance with wastewater treatment.

1-8. Define effluent.

1-9. Identify what fecal coliform bacteria are and explain the role they play in wastewater treatment.

1-10. Define BOD (Biochemical Oxygen Demand) and explain the importance of BOD in wastewater treatment.

1-11. Define organic loading rate.

1-12. Define dissolved oxygen, describe its importance in wastewater treatment and describe methods for measuring it.

1-13. Describe the difference between aerobic and anaerobic wastewater treatment.

1-14. Define nutrients and how they affect the treatment of wastewater. Describe their role in the efficiency of wastewater treatment.

1-15. Define hydraulic loading rate.

1-16. Describe the effects of fats, oils and grease on wastewater treatment systems.

1-17. Define pH, alkalinity and acidity and explain how these factors affect the treatment of wastewater.

1-18. Define sodium adsorption ratio and explain its importance with land application of wastewater.

Chapter 2 – Pretreatment of Wastewater

Lagoons

2-1. List the four types of stabilization lagoons.

2-2. Explain the differences between, and describe the general operating parameters for the following:
- aerobic lagoons
- aerated lagoons
- anaerobic lagoons
- facultative lagoons

2-3. Explain the difference between a stabilization lagoon and a storage lagoon.

2-4. Define freeboard and explain the importance of maintaining adequate freeboard.

2-5. Define short-circuiting and explain why it is undesirable.

2-6. Define detention time and explain its importance in wastewater treatment.

2-7. List the advantages of multiple cell lagoons and describe the difference between lagoons operated in series and lagoons operated in parallel.

2-8. List the factors that influence lagoon performance and describe their importance.

2-9. Define photosynthesis and describe why is it important in stabilization lagoons.

2-10. Describe the daily fluctuation in dissolved oxygen in a normally functioning facultative lagoon.

2-11. List probable causes and corrective actions to be taken for each of the following:
- emergent and suspended aquatic vegetation
- erosion
- scum formation
- excessive algae
- solids accumulation
- odor production
- insufficient freeboard
- short-circuiting
- septicity

2-12. Describe the maintenance procedures for stabilization and storage lagoon dikes.

2-13. Describe the advantages of baffles/curtains in a lagoon system.

Tanks

2-14. Identify the components and functions of a septic tank.

2-15. List the factors that affect septic tank performance.

2-16. Explain the effect of hydraulic and organic overloading on septic tanks.

2-17. Define infiltration and exfiltration and explain why each is undesirable.

2-18. Describe the procedure for inspecting a septic tank for infiltration or exfiltration.

2-19. Describe the problems that can occur with septic tanks and the visible signs that can indicate these problems.

2-20. Describe why, when, and how solids should be removed from septic and dosing tanks.

2-21. Describe how scum depth is measured in a septic tank.

2-22. Describe how solids (septage) accumulation is measured in a septic tank.

2-23. Identify the agency that permits the removal of solids from septic and dosing tanks.

2-24. Identify the function of a dosing tank.

2-25. Describe the different types of dosing mechanisms and list the advantages and disadvantages of each.

2-26. Describe the types of establishments that require the use of grease traps or oil/water separators.

2-27. List the three forms of fats, oils, and greases.

2-28. Describe the components and the functions of a grease trap.

2-29. Describe, in general terms, the operation of grease traps associated with food service operations.

2-30. List the factors that affect grease trap performance.

2-31. Describe the importance of routine servicing of grease traps and identify who is authorized to dispose of grease from these units.

2-32. List the different types of oil/water separators associated with industrial operations and describe, in general terms, their operation.

Sand Filters

2-33. Describe the purpose of a sand filter.

2-34. Describe the basic design of sand filters.

2-35. List the different types of treatment processes that occur within sand filters.

2-36. Explain why intermittent dosing of sand filters is important.

2-37. List three types of sand filters.

2-38. Explain recirculation and how it affects filter treatment efficiencies.

2-39. List the variables that affect sand filter operation and performance.

2-40. Describe the relationship between pretreatment and sand filter performance.

2-41. Explain how media size, uniformity and depth affect treatment.

2-42. Explain the effects of high hydraulic and/or organic loads on sand filters.

2-43. Describe methods for distributing effluent over a sand filter and explain why even distribution is important.

2-44. Describe the routine maintenance procedures that are required for proper operation of a sand filter.

2-45. Explain why vegetation is undesirable in a filter and how to properly control it.

2-46. Describe the importance of controlling infiltration/inflow and how it affects sand filters.

Disinfection

2-47. Identify the purpose of wastewater effluent disinfection.

2-48. Explain the difference between disinfection and sterilization of wastewater.

2-49. List the three major types of disinfection.

2-50. List the advantages and disadvantages of chlorination.

2-51. Identify the types of chlorine commonly used to disinfect treated effluent.

2-52. Define chlorine dosage, chlorine demand and chlorine residual.

2-53. Identify the approved methods for determining chlorine residual.

2-54. List and briefly describe the factors that affect chlorination effectiveness.

2-55. Briefly describe the methods of chlorination.

2-56. Describe procedures for chlorine leak detection and the importance of fixing leaks immediately.

2-57. Explain why petroleum products and solid chlorine compounds should not be stored in the same area.

2-58. Briefly describe ultraviolet radiation as a method of disinfection.

2-59. List the advantages and disadvantages of ultraviolet radiation.

2-60. List the factors that affect the effectiveness of ultraviolet radiation as a method of disinfection.

2-61. Briefly describe ozonation as a method of disinfection.

2-62. List the advantages and disadvantages of ozonation.

Chapter 3 – The Natural Treatment System

Soils and Agronomy

3-1. Describe the components that make up soil.

3-2. Define soil profile.

3-3. Describe (in general terms) the following soil physical characteristics and explain the relationship of these factors to the operation of a surface irrigation system:
- soil texture
- soil structure
- organic matter content
- soil depth
- soil color
- soil drainage/wetness

3-4. Identify specific topography or landscape positions and describe how water movement is influenced by landscape position.

3-5. Explain the difference between infiltration and permeability.

3-6. Define the term colloid and explain the importance of colloids in waste treatment.

3-7. Define the following terms:
- cations
- anions

- adsoprtion
- exchangeable cations
- soil solution
- cation exchange capacity

3-8. Explain the relationship between pH and cation exchange capacity.

3-9. List the three major ways soil can treat or renovate wastewater.

3-10. Name the various physical, chemical, and biological treatment processes that occur in soils.

3-11. Describe the fate of these waste constituents once they enter the soil/plant system:
- nitrogen
- phosphorus
- heavy metals
- pathogens
- persistent organic chemicals

3-12. List the functions that vegetation plays in surface irrigation systems.

3-13. Define macronutrient and micronutrient and list examples of each.

3-14. List three factors that influence nutrient availability and describe their importance.

3-15. As related to nutrient availability, define:
- sufficiency
- toxicity
- deficiency

3-16. Describe the five things that can happen to nutrients when applied to soils.

3-17. Describe the importance of a crop nutrient management plan for waste application sites.

3-18. List the four components of a nutrient management plan.

3-19. Define agronomic rate.

3-20. Define realistic yield expectation (R.Y.E.)

Groundwater and Hydrology

3-21. Define hydrologic cycle and describe (in general terms) its relationship to surface irrigation system operation and function.

3-22. Define evapotranspiration and describe its importance to surface irrigation system operation.

3-23. Define runoff and describe the impact it can have on surface waters.

3-24. Define eutrophication.

3-25. Define the following:
- saturated zone
- unsaturated zone
- water table
- groundwater

3-26. Explain the importance of depth to the water table at surface irrigation sites.

3-27. Explain the following concepts and their relationship to surface irrigation system function and operation:
- wastewater mounding
- lateral movement of groundwater and wastewater

Chapter 4 – Equipment

Pumps and Controls

4-1. Describe the purpose of a pump.

4-2. Define each of the following:
- suction head (lift)
- total dynamic head (TDH)
- friction head
- water horsepower
- discharge head
- brake horsepower
- total pump capacity
- motor horsepower

4-3. Explain how to calculate pump delivery rate.

4-4. Define dosing volume and describe how it is calculated.

4-5. Explain pump efficiency.

4-6. Describe a pump curve, where can it be obtained, and how can it be used.

4-7. Identify the problems which are associated with the condition that occurs when either the suction or discharge head exceeds the pump capacity.

4-8. Using diagrams, be able to identify the components of the following types of pumps. Describe applications for each type of pump and list the advantages and disadvantages of using the pump in each application. Describe the hydraulic and solids handling capacity of each type of pump:
- centrifugal
- positive displacement, plunger type

- turbines
- positive displacement, diaphragm
- peristaltic pumps
- positive displacement, progressive cavity (screw-flow) type

4-9. Identify the importance of maintaining a water level equal to or above the top of a submersible pump.

4-10. Describe the effect of improper (too loose or too tight) pump packing on the operation and efficiency of a pump.

4-11. Describe the effect of improper lubrication on the operation and efficiency of pumps.

4-12. Identify which pumps must normally be primed in order to operate.

4-13. Identify situations that would cause a loss of prime and explain how to re-prime the pump.

4-14. Describe cavitation and how it affects a centrifugal pump.

4-15. Describe how a water hammer is created and how it affects pumps and piping.

4-16. Identify the proper location for and protection of electrical connections and controls.

4-17. Identify the purpose and function of simplex and multiplex controls.

4-18. Describe how each of the following pump controls work:
- bubble tubes
- float switches
- electrode switches
- pressure bulbs
- pump alternator
- irrigation controller

4-19. Explain the purpose of alternating the operation of two or more pumps.

4-20. Identify and describe the various types of water level alarms commonly used and explain how they work.

4-21. Identify the purpose and function of each the following control panel components:
- elapsed time meters
- run cycle timers
- relays
- telemetry
- alternators
- time delay relays
- microprocessors

4-22. Explain the importance of flow meters, pump run timers, and run counters and the requirements for their calibration.

4-23. Describe how to use pump control records to determine system performance.

Distribution Network and Devices

4-24. Define the following term and abbreviations as they relate to piping:
- I.D.
- O.D.
- I.P.S.
- P.I.P.
- Class
- S.D.R.

4-25. Explain how to interpret SDR values.

4-26. Identify the following common types of irrigation pipes, fittings, connections, and valves and state the application of each in a surface irrigation system:

- Pipe
  - cast iron
  - steel
  - cement asbestos
  - aluminum
  - DIP (ductal iron pipe)
  - PVC (Schedule 40 & 80)
- Fittings
  - elbow
  - tees
  - adapter
  - reducer
  - sleeve
  - wye
  - union
- Connections
  - flange
  - mechanical joint
  - bell and spigot
  - threaded
- Valves (Manual or Motor Activated)
  - gate
  - plug
  - butterfly
  - check (ball and flapper)

- solenoid
- air relief valve
- pressure relief
- globe

4-27. Explain the difference between Schedule 40 and 80 PVC pipe.

4-28. Describe a typical pipe cleanout and explain how and why it would be used.

4-29. Describe the importance of anchoring pipes securely and how thrust blocking is used.

4-30. Explain how PVC cement works and where it should be used.

4-31. Identify the following common types of distribution devices:
- nozzle
- full circle
- gun
- micro spray heads
- rotary impact
- partial circle
- drip emitters

4-32. Describe the following types of irrigation systems, and list several advantages and disadvantages of each:
- stationary or solid set
- travelers
- center pivot and linear move

4-33. Explain the difference between a ring nozzle and taper bore nozzle on an irrigation gun.

4-34. Explain where all underground system components are located and the importance of maintaining plans or maps of these components.

4-35. Describe appropriate places for checking pressure heads in a surface irrigation system.

4-36. Identify the proper steps to take if you discover that the actual flow exceeds the system design flow.

Chapter 5 – Proper Waste Application

Irrigation Scheduling

5-1. Define irrigation scheduling.

5-2. List the three questions that must be answered before irrigating treated wastewater.

5-3. Explain the importance of soil moisture monitoring as it relates to operations at land-based waste treatment systems.

5-4. List three methods to estimate the amount of water present in the soil at the start of irrigation and describe each one in general terms.

5-5. Describe tensiometers and granular matrix sensors and discuss some advantages and disadvantages of each.

5-6. Explain why wastewater application must be adjusted seasonally.

5-7. List five factors that may influence the amount of wastewater that can be irrigated.

5-8. Describe how infiltration rate affects wastewater application.

5-9. Explain how to determine how much wastewater to irrigate.

5-10. Explain why the "permitted" application amount or rate is not feasible at all times.

5-11. Define discharge rate, precipitation rate, and application volume.

5-12. Explain why stationary sprinklers are designed to overlap.

5-13. Calculate the precipitation rate for a stationary sprinkler irrigation system.

5-14. Calculate the application volume for a stationary sprinkler irrigation system.

5-15. Determine the precipitation rate and effective coverage from manufacturer's literature for a traveling gun sprinkler.

5-16. Calculate the precipitation rate and application volume for a traveling gun sprinkler.

5-17. Calculate the required travel speed for a traveling gun sprinkler to apply the desired application volume.

5-18. Explain what effect changing nozzle diameter can have on discharge rate and wetted diameter.

5-19. Explain the effects of changing pressure on droplet size, drift, precipitation rate, and wetted sprinkler diameter.

5-20. Explain why sprinkler systems should be field calibrated.

5-21. Explain calibration procedures for stationary and traveling sprinklers.

Sampling

5-22. Describe how to determine permit sampling requirements and frequencies.

5-23. Describe how to take a soil sample and submit for analysis.

5-24. Describe, in general terms, the information available on a soil test report.

5-25. Describe the proper procedure for taking soil and plant tissue samples for analysis by an agronomy lab such as NCDA.

5-26. Describe the role of plant tissue analysis in managing and monitoring cover crops at a surface irrigation facility.

5-27. Describe how to take a waste sample from a lagoon and submit it for analysis.

5-28. Define the following terms:
- representative sample
- grab sample
- composite sample
- flow proportional composite
- timed composite
- split sample
- duplicate sample

5-29. Describe the need for proper sampling techniques and holding times.

5-30. Describe the importance of sampling groundwater at a surface irrigation site.

5-31. Describe how to minimize contamination risks while collecting groundwater samples.

Operations and Maintenance and Site Management

5-32. List several situations that might require an operator to vary the hydraulic loading rate.

5-33. Identify situations that may indicate that a system's malfunction is related to a "soil-related problem" rather than a mechanical one and describe management techniques that can be used to correct or minimize these problems.

5-34. Describe the relationship between hydraulic loadings and surface crusting, surface ponding and surface runoff.

5-35. Describe the importance of limiting traffic on spray fields.

5-36. List several soil characteristics that affect a soil's ability to assimilate heavy metals.

5-37. Explain the relationship between soil pH and metal solubility in the soil.

5-38. Define the range of Sodium Adsoprtion Ratio's (SAR's) encountered in wastewater treatment and identify the SAR action level.

5-39. Explain why someone should call for technical assistance when the SAR level of the effluent is greater than 5.

5-40. Define Exchangeable Sodium Percentage (ESP) and describe the levels of ESP that should be of concern to a surface irrigation system operator.

5-41. Describe the importance of good cover crop management.

5-42. List the factors that should be considered when selecting crops for a surface irrigation system and describe why these factors are important.

5-43. Explain why perennial grass sods are effective in reducing erosion and nutrient losses.

5-44. Identify the proper time to irrigate or not to irrigate specific crops to optimize production and wastewater treatment efficiency.

5-45. Explain why harvesting the cover crop at a surface irrigation system is essential.

5-46. Explain why maintaining proper soil pH is critical to the management of a surface irrigation system.

5-47. Describe proper handling of pesticides at a surface irrigation site and the agency responsible for pesticide application.

5-48. Define Best Management Practice (BMP) and list BMP's commonly used at a surface irrigation site.

5-49. List the agencies or groups that can be contacted for technical assistance with crop and/or site management.

5-50. Describe how to recognize poor crop health.

5-51. List the steps that should be taken if a suitable vegetative cover is not present at a land application site.

5-52. Describe how soil test and plant tissue analysis information can be used in site management.

5-53. Explain why uniform distribution of effluent in fields is important.

5-54. Explain bleed-off within the system and describe the procedures for minimizing negative impacts.

5-55. Identify site conditions that indicate hydraulic overload and list possible actions to minimize hydraulic overload.

5-56. Explain how to determine leakage around piping and valves.

5-57. Identify evidence of damaged or improperly constructed appurtenances including groundwater monitoring wells.

5-58. Given precipitation and flow data from a system, determine what this information might imply about potential system problems (in/exfiltration).

5-59. Describe the need to periodically calibrate flow-measuring devices.

5-60. Explain where to find manufacturers literature on site-specific components and the need to perform service on these components.

5-61. Explain how to inspect and maintain the following:
- French drain or curtain drain
- Open drainage ditch and tiled ditches
- Terrace or other surface water diversions (e.g.. grass waterways)

5-62. List conditions under which an operator may need to look for expansion sites.

5-63. Explain the contents of the site operation and maintenance manual.

5-64. Identify the information that should be recorded in a daily site maintenance log book.

5-65. Describe an emergency action plan.

5-66. List the four basic steps that should be followed in the event of a chemical spill or a release of wastes at a surface irrigation facility.

5-67. Explain which agencies should be contacted in the event of a spill or release.

5-68. Describe the importance of controlling access to spray fields.

Chapter 6 – Math

Common Abbreviations

L	=	liter	PAN	=	plant available nitrogen
A	=	area (ft^2)	lbs	=	pounds
V	=	Volume (ft^3, gallons, etc)	conc	=	concentration
ft	=	feet	gal	=	gallons
ft^2	=	square feet	cm	=	centimeter
ft^3	=	cubic feet	mph	=	miles per hour
Q	=	quantity of flow per unit of time	MGD	=	million gallons per day
in	=	inches	m^3	=	cubic meters

gpm	=	gallons per minute	C	=	carbon
gpd	=	gallons per day	DO	=	dissolved oxygen
cfs	=	cubic feet per second	%	=	percent
ac	=	acre	=	=	equal to
ppm	=	parts per million (mg/L)	>	=	greater than
ppb	=	parts per billion (µg/L)	<	=	less than
psi	=	pounds per square inch	≈	=	approximately
min	=	minute	hrs	=	hours
mL	=	milliliter			
mg/L	=	milligrams per liter			

Definitions

Area - the measurement of a surface in square units such as feet squared, yards squared, etc.

Circumference of a Circle - the length of the external boundary of a circle; for example, the rim of a basketball goal is 62".

Concentration (mg/L) - the amount of a substance in a given volume such, as 1 mg/L.

Diameter of a Circle - distance from one side of a circle to the other, such as a 3 inch inside diameter of a pipe.

Radius of a Circle - one half the diameter of a circle.

Flow Rate - the volume of a substance that would pass a point in a given amount of time, such as 2 gallons per minute flowing out of the end of a hose.

Field Flow Rate - total gpm for a field (unit area).

Friction - the energy lost by any system in motion due to the rubbing of molecules; for example, friction losses in a pipe.

Head - the distance that water under pressure would rise in a pipe if allowed to do so, such as two feet of head in the distribution lateral.

Hydraulic Soil Loading Rate - the number of inches of wastewater applied to an area of soil in a day, such as 0.5 in/day.

Hourly Loading Rate - the number of inches of wastewater applied to an area of soil in an hour, such as 0.2 in/hr.

Pi (π) - a known ratio that is constant in the geometry of circles ($\pi = 3.14$).

Pressure - the force applied to a unit area, such as the pressure in a water pipe.

Volume - the capacity of a container, such as a 1 gallon bucket.

Conversion Factors

1 acre (ac)	=	43,560 square feet (ft^2)
1 acre-inch (ac-in)	=	27,152 gallons per acre (gal/ac)
1 cubic foot (ft^3)	=	7.48 gallons
1 gallon of water	=	8.34 pounds of water
1 horsepower (hp)	=	0.746 kilowatts (kw)
1 milligram/Liter (mg/L)	=	0.226 pounds per acre-inch (lbs/ac-in)

Important Equations

6-1. Calculate the area of squares, rectangles and circles.

6-2. Calculate volume of tanks, cylinders, storage ponds, and lagoons.

6-3. Calculate the detention time of a structure given the volume and flow data.

6-4. Calculate pump delivery rate.

6-5. Convert concentration (mg/L) to pounds.

6-6. Calculate pounds of a substance given wastewater flow and concentration.

6-7. Calculate flow given velocity and area.

6-8. Calculate average flow rates.

6-9. Calculate the hydraulic loading rate given flow and area.

6-10. Calculate horsepower.

6-11. Calculate hydraulic soils loading rate given flow and area.

6-12. Calculate flow rate given hydraulic soils loading rate and area.

6-13. Calculate area given hydraulic soils loading rate and flow rate.

6-14. Calculate hourly hydraulic soils loading rate given flow and area.

6-15. Convert flow data (GPD) to application depth (acre-inches).

6-16. Calculate plant available nitrogen (PAN).

6-17. Calculate sodium adsorption ratio (SAR) from a wastewater analysis.

6-18. Calculate exchangeable sodium percentage (ESP) from a soil analysis.

6-19. Calculate the application rate (precipitation rate) for various types of wastewater application systems.

6-20. Determine time of system operation given application depth and application rate.

6-21. Calculate travel speed for traveling application equipment to meet a desired application rate.

Chapter 7 – Health and Safety

7-1. List the federal and state agencies that oversee worker safety in North Carolina.

7-2. Describe the health and safety responsibilities of the following:
- surface irrigation system owners
- site supervisors
- employees

7-3. List the components of a typical health and safety program.

7-4. Describe the information and training employers are required to provide regarding in-house chemicals.

7-5. Describe the types of personal protective equipment needed for working in and around surface irrigation facilities.

7-6. List the health and safety hazards associated with surface irrigation facilities.

7-7. List the health and safety measures that should be used to reduce health and safety hazards at surface irrigation facilities.

7-8. Explain when a process safety management and/or risk management program may be necessary.

7-9. Define the two types of confined spaces and describe the hazards associated with each.

7-10. Define “oxygen-deficient atmosphere” and describe the equipment required to enter such an atmosphere.

7-11. Describe “lockout/tagout” policies.

7-12. List the types of first aid training that are important for employees of a surface irrigation facility.

7-13. Describe the routine safety measures that should be followed when servicing surface irrigation equipment.

7-14. Explain the safety concerns of using traveling guns on sloping terrain.

7-15. Explain machine guarding.

7-16. Describe the safety procedures that should be followed when working around lagoons.

7-17. Describe the public health significance of vectors that may come into contact with wastewater.

7-18. Explain how to avoid contamination of ditches, waterways, and adjoining properties.

Chapter 8 – North Carolina Regulations

Permit Regulations and Requirements

8-1. Identify the regulations that govern the permitting of surface irrigation systems.

8-2. Identify the division of state government that is responsible for permitting surface irrigation systems.

8-3. Define non-discharge system.

8-4. Describe, in general, the application process for a new surface irrigation facility.

8-5. Describe the renewal requirements for a surface irrigation system permit.

8-6. Explain when a permit modification is required and give examples of changes that would require a modification.

8-7. Explain the requirement for an annual permit fee and describe the consequences for not paying it.

8-8. Describe the need to have a copy of the non-discharge permit and the importance of reading and understanding it.

8-9. Identify who is ultimately responsible for the violation of a permit condition.

8-10. Describe the minimum setback distances that must be maintained for surface irrigation systems.

8-11. List the operation and maintenance requirements contained in a typical spray (or drip) irrigation system permit.

8-12. Describe the importance of maintaining an inspection log.

8-13. Identify what state agency must be notified in the event of non-compliance with permit conditions and within what time period this notification must take place.

8-14. Describe situations or events that would require non-compliance notification.

8-15. List the types of monitoring that may be required in a surface irrigation system permit.

8-16. List the two types of activities that require monthly reporting.

8-17. Identify the form on which irrigation data must be reported, describe when the report is due, and list the information that must be reported on the form.

8-18. Identify the form on which wastewater or effluent monitoring data must be reported, describe when the report is due, and list the information that must be reported on the form.

8-19. Identify the state agency to which reports must be sent.

8-20. Describe the consequences for failing to comply with all monitoring and reporting requirements contained in a surface irrigation system permit.

8-21. Describe the possible consequences of not operating a surface irrigation system in accordance with its permit conditions.

Groundwater Regulations and Requirements

8-22. Identify the regulations that govern the maximum acceptable levels for parameters in groundwater.

8-23. Describe how to determine if a system's non-discharge permit requires monitoring wells and how to find out where they are located at the site.

8-24. Define compliance boundary and explain what actions are necessary if groundwater standards are exceeded at this boundary.

8-25. Define review boundary and explain what actions are necessary if groundwater standards are exceeded at this boundary.

8-26. Describe the proper exterior condition and labeling of a groundwater monitoring well.

8-27. Describe the importance of obtaining background or baseline groundwater samples prior to waste disposal activities.

8-28. Describe routine maintenance for groundwater monitoring wells.

8-29. Identify the report form that must be used to report groundwater monitoring data.

8-30. Describe how to complete a groundwater monitoring form.

8-31. Identify the state agency to which groundwater monitoring report forms must be sent.

Operator Regulations and Requirements

8-32. Identify the regulations that govern the actions of certified operators.

8-33. Identify the state agency that administers the operator certification program.

8-34. Identify the Commission that oversees the operator certification program.

8-35. Describe the responsibilities of the permittee with regards to designating an Operator in Responsible Charge (ORC) and Back-up Operator(s) in Responsible Charge (Back-up ORC).

8-36. Describe the basic requirements to obtain a surface irrigation system operator certificate.

8-37. List the responsibilities that all certified operators must fulfill to maintain their certification.

8-38. List the responsibilities of a certified operator that has been designated as the Operator in Responsible Charge for a surface irrigation system.

8-39. Describe the minimum visitation required from the ORC for a surface irrigation system.

8-40. Describe the difference between the ORC's responsibilities and the owner's responsibilities.

8-41. Describe the need to keep the permittee informed of any necessary repairs or maintenance.

8-42. Describe the responsibilities of a certified operator that has been designated as the Back-up ORC for a surface irrigation system.

8-43. Describe the circumstances under which a designated Back-up ORC may act as a surrogate for the ORC.

8-44. Define contract operations firm and describe their responsibilities.

8-45. Describe the types of disciplinary action the Certification Commission may take against a certified operator.

8-46. Describe the grounds for action by the Certification Commission against a certified operator.

8-47. Describe the terms for recertification following a disciplinary action by the Certification Commission.

Chapter 1
Wastewater Characteristics

To properly operate and maintain a surface irrigation system for the disposal of wastewater, you need to understand some basic characteristics of wastewater. Typical domestic wastewater is composed of 99.94% water and only 0.06% waste or pollutants. However, wastewater characteristics are important factors in the design, operation, and management of any wastewater treatment system. Wastewater conveyed by a collection system to a wastewater treatment facility can originate from different sources and can differ in physical and biological characteristics and chemical composition.

The constituents of raw wastewater depend on the characteristics of the water supply and the nature of the residents of a residential community or an industry. Wide variations can be encountered between waste streams; seasonal variations will be noted within any single waste stream. Frequent analyses must be performed on a particular waste stream to develop useful trend data.

Sources of Wastewater

Wastewater comes from either domestic sources or industrial sources. Domestic sources include residences, non-industrial businesses, and institutions, such as schools. Wastewater from restrooms, laundries, and kitchens is considered domestic wastewater. Wastewater from domestic sources is fairly uniform in composition.

Industrial wastewater is the water discharged from industrial or commercial users. Industrial wastewaters are much more variable than domestic wastewaters and may contain toxic substances, such as metals and persistent organic chemicals.

A particular waste stream can contain wastewater from domestic sources, industrial sources, or a combination of both, although the most common sources of wastewater are domestic.

Types of Wastewater

Wastewater contains two primary types of waste: organic and inorganic. Organic waste is composed of plant or animal material. All organic wastes contain carbon and is readily consumed and decomposed by bacteria and other organisms. Inorganic waste is composed of mineral materials such as sand, salt, iron, and calcium. This type of waste is only slightly affected by biological activity.

The amount of organic and inorganic waste in a particular waste stream depends on the type of operation generating the wastewater. For example, wastewater from a meat processing plant will contain high levels of organic waste. On the other hand, wastewater from a gravel washing operation will contain high levels of inorganic waste.

Two other types of waste are thermal and radioactive wastes. Thermal power stations and industrial cooling processes may produce wastewater with temperatures exceeding the requirements of the enforcing agency. Hospitals, research labs, and nuclear power plants generate radioactive wastes that are usually controlled at their source.

Characteristics of Wastewater

Physical characteristics of wastewater include color, odor, temperature, and solids. Changes in these physical characteristics can indicate unusual influent or operating conditions.

Color

Fresh or raw wastewater (prior to any treatment) is usually gray in color. Wastewater that has undergone some type of pretreatment will have a color that is indicative of the pretreatment system. Wastewater treated in a septic tank will have a gray/black color, but wastewater that has been treated in an aerobic process will have little color. The color of wastewater can also be affected by inputs from industrial sources. Color contributed from industrial sources may not be removed by the pre-application treatment system.

Odor

Fresh or raw wastewater usually has a musty odor. Odor in wastewater is generally caused by anaerobic decomposition of organic material. Hydrogen sulfide is frequently the source of a rotten-egg odor in wastewater. Other volatile sulfur-containing compounds, such as mercaptans, can also cause noxious odors. When wastewater is aerated or comes into contact with the land surface or water, these odors are released into the air. Unusual odors, such as petroleum or solvent odors can indicate abnormal industrial discharges.

Temperature

Wastewater is generally somewhat warmer than unheated tap water. A significant increase in wastewater temperature over a short period of time may indicate an unusual industrial discharge; a significant decrease may indicate inputs of storm water into the treatment system.

Temperature influences microbial activity, an important mechanism of wastewater treatment. Up to a point, an increase in wastewater temperature will increase microbial activity. However, when wastewater reaches high temperatures, microbial activity will be inhibited. The temperature of irrigated wastewater can also have a negative effect on cover crops.

Solids

One of the primary functions of a wastewater treatment system is to remove organic and inorganic solids from wastewater. During pretreatment, a significant amount of solids must be removed; otherwise, solids can reduce the effectiveness of disinfection processes and clog surface irrigation equipment. Knowing the forms and concentrations of solids present in wastewater can provide an operator with useful data for the control of treatment processes.

Solids are divided into several different fractions: total solids, dissolved solids and suspended solids. The different fractions of solids are shown in Figure 1-1.

- **Total Solids (Residue)**

  Total solids are those that remain after the wastewater is evaporated at a temperature of 103°C to 105°C. Imagine that an operator collects a one-liter sample of influent (wastewater entering a treatment system). This sample is heated to evaporate all of the water. The remaining solids weigh 1000 milligrams. Thus, the total solids (residue) concentration in the sample is 1000 milligrams per liter (mg/L). This weight includes both dissolved and suspended solids.

- **Dissolved Solids**

  Dissolved solids are those solids that will pass through a very fine (0.45-mm) membrane filter. Again, imagine that an operator collects a one-liter sample of raw wastewater and filters it through a very fine mesh filter such as a fiberglass filter. The dissolved solids will pass through the water. The operator can now evaporate the water and weigh the residue. In Figure 1-1, the amount of dissolved solids is 800 mg/L. Dissolved solids are also called filterable residue.

For normal municipal wastewater that contains domestic wastewater as well as some industrial wastes, the concern of an operator is usually to remove the dissolved organic solids from the waste stream. Removal of dissolved inorganic solids is difficult to achieve.

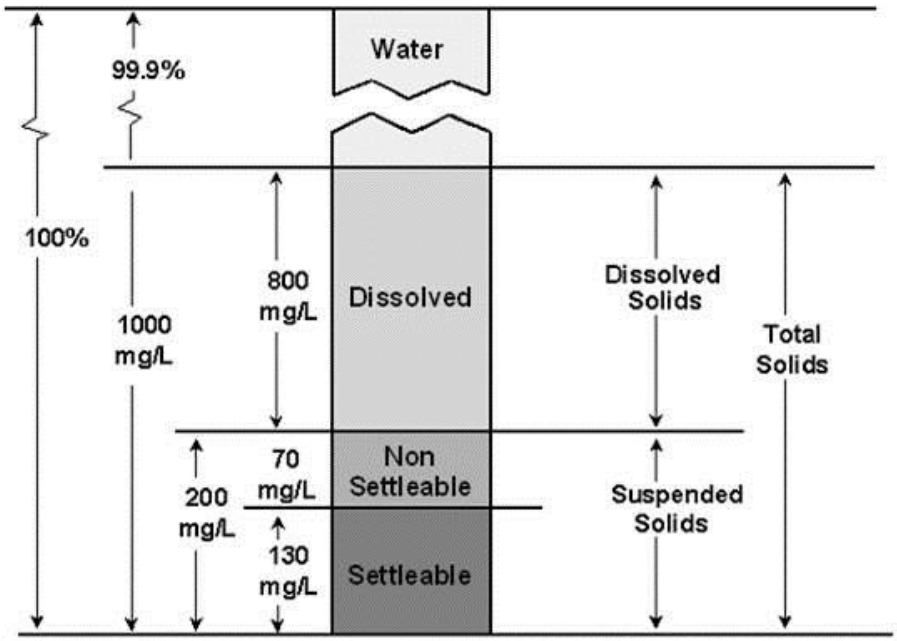

Figure 1-1. Typical composition of solids in raw wastewater.

- **Suspended Solids**

  Suspended solids (SS) are the solids retained by a filter. They can be removed from a waste stream by physical, biological, or chemical processes. Suspended solids are composed of two parts: settleable and nonsettleable (or colloidal). The difference between settleable and nonsettleable solids depends on the size, shape, and weight of the solid particles. Larger particles tend to settle more rapidly than smaller particles.

  Settleable solids are measured using a device called an IMHOFF CONE. Measuring the amount of settleable solids entering and leaving a treatment unit allows an operator to calculate how efficiently the treatment unit is removing settleable solids.

  The weight of nonsettleable solids is calculated by subtracting the weight of dissolved and settleable solids from the weight of total solids. In Figure 1-1, the nonsettleable solids concentration is shown as 70 mg/L. Suspended solids are also called nonfilterable residue.

Pathogens

Untreated wastewater contains many billions of microorganisms per gallon. Most of these organisms are not harmful to humans. Some of them are even helpful in wastewater treatment processes. However, some can cause serious diseases such as typhoid, cholera, shigellosis, dysentery, polio, and hepatitis.

Disease-causing microorganisms are called pathogens and include bacteria, viruses, and parasites. Humans with diseases caused by these pathogens may discharge some of these harmful organisms in their body wastes. Many serious outbreaks of communicable diseases have been traced to direct contamination of drinking water or food supplies by the body wastes from a human disease carrier.

Fortunately, the pathogens that grow in the intestinal tract of diseased humans do not find wastewater treatment systems favorable environments for growth and reproduction. Many pathogenic organisms are removed by natural die-off during the normal treatment processes. However, enough can remain in the effluent (wastewater leaving the treatment system) to cause a threat to any downstream use involving human contact if adequate disinfection is not accomplished in the treatment process.

It is impractical to test for all pathogens. The presence of pathogens is determined with indirect evidence by testing for indicator organisms, such as fecal coliform bacteria. Fecal coliform bacteria are always present in the digestive system of warm-blooded animals, including humans. These bacteria are relatively easy to identify and are usually present in higher concentrations than pathogens. Therefore, fecal coliform bacteria are used as an indicator organism for pathogens. If there is a large concentration of fecal coliform bacteria present in a water body, the potential for the presence of pathogens is high.

Wastewater treatment processes remove pathogenic organisms in several ways:

- physical removal through filtration and sedimentation;
- natural die-off of organisms due to unfavorable environments; and
- destruction of organisms by disinfection.

Proper disinfection of well-treated wastewater will usually result in essentially a complete kill of the pathogenic organisms. Disinfection processes will be discussed in more detail in Chapter 2.

Biochemical Oxygen Demand

Biochemical oxygen demand (BOD) is the rate at which organisms use oxygen to stabilize or break down the organic matter in wastewater. High levels of BOD indicate high levels of organic matter in wastewater. The BOD level of influent wastewater is an important consideration when determining the type of pretreatment used in a surface irrigation system.

Biochemical oxygen demand is measured using a biochemical oxygen demand test (BOD_5 test), a procedure that measures the amount of oxygen used by a wastewater sample incubated at 20°C for five days. The typical range of BOD in domestic wastewater ranges from 100 to 300 mg/L. The amount of organic material, measured as BOD_5, applied to a given treatment process is referred to as the organic loading rate.

Chemical Oxygen Demand

Chemical oxygen demand (COD) is the amount of organic matter in wastewater that can be oxidized by a strong chemical oxidant. It is expressed as the amount of oxygen consumed from a chemical oxidant in mg/L. Results for COD can be obtained in 3 to 4 hours rather than the 5 days required for BOD.

Chemical oxygen demand results cannot be directly related to BOD, because the chemical oxidant used may react with compounds other than the bacteria. However, if BOD to COD ratios are developed for a particular system, COD can be used as a means of rapidly estimating the BOD of a sample.

Chemical oxygen demand results are typically higher than the BOD values and the correlation between the two will vary from system to system. The BOD to COD ratio is typically 0.5 to 1 for raw wastewater and may drop to as low as 0.1 to 1 for well-stabilized secondary effluent.

Dissolved Oxygen

Dissolved oxygen (DO) is the amount of oxygen dissolved in water. The amount of oxygen that can be dissolved in water is dependent on temperature. As water temperature increases, DO content decreases and visa versa.

The distribution of oxygen in treatment units determines whether aerobic (with oxygen) or anaerobic (without oxygen) treatment processes are involved. Although some microorganisms can survive in anaerobic conditions, many of the beneficial microorganisms that stabilize wastewater require aerobic conditions.

Maintaining adequate oxygen levels allows the biological process to take place and prevents objectionable odors. Low DO concentrations (less than 1.0 mg/L) can indicate inadequate aeration or an excessive amount of organic material entering the system.

Dissolved oxygen is measured using an oxygen meter and a membrane-covered probe. It is usually expressed in milligrams per liter (mg/L).

Nutrients

A nutrient is any substance that promotes growth and can be taken up by plants or consumed by organisms. Wastewater generally contains nutrients such as nitrogen, phosphorus, potassium, calcium, magnesium, iron, and sulfur. In a surface irrigation system, wastewater can provide essential nutrients to cover crops. If present at excessive levels, however, some nutrients can become pollutants.

Wastewater from domestic sources generally contains low concentrations of nutrients. This means that the amount of wastewater that can be applied annually to a given site is hydraulically limited; that is, limited by the amount of water that can be applied to the soil (the hydraulic loading rate). Since the concentration of nutrients is not high enough to be harmful, the limiting factor is how much wastewater the soil can physically accept without runoff.

However, in some cases, the quantity of wastewater that can be applied is nutrient limited. This means that the amount of wastewater that can be applied is limited by the nutrient content of the wastewater rather than by the amount of water the soil can handle.

- **Nitrogen**

  Nitrogen in wastewater occurs in four different forms: organic nitrogen, ammonia (NH_3) or ammonium (NH_4^+), nitrite (NO_2^-), and nitrate (NO_3^-). In fresh wastewater, organic nitrogen and ammonia levels are generally higher than nitrite and nitrate levels.

  Organic nitrogen includes such natural materials as proteins and peptides, nucleic acids and urea, and numerous synthetic organic materials. As organic nitrogen is metabolized or broken down, it changes first to ammonium. If suitable environmental conditions exist and nitrifying bacteria are present in sufficient numbers, ammonium will be converted biologically to nitrite and nitrate.

  Total nitrogen is the sum of organic nitrogen, ammonia, nitrite, and nitrate. Total Kjeldahl nitrogen (TKN) is the sum of organic nitrogen and ammonia. To determine the concentration of organic nitrogen, ammonia must be measured separately. The ammonia concentration is then subtracted from the TKN value. Typical ranges of nitrogen concentrations in raw domestic wastewater are 20 to 85 mg/L for total nitrogen, 8 to 35 mg/L for organic nitrogen, and 12 to 50 mg/L for ammonia.

  Plant available nitrogen (PAN) is nitrogen that exists in forms that are readily available for uptake by plants (NH_4^+ and NO_3^-). Surface irrigation systems that handle wastewater with high nitrogen concentrations may need to base wastewater application rates on supplying crop nitrogen needs rather than on the amount of water the soil can handle. The approach is to apply nitrogen at rates no greater than the crop can use because the nitrate form of nitrogen can move

through the soil and threaten groundwater quality. Permits for nitrogen-limited systems have PAN monitoring requirements.

- **Phosphorus**

  Phosphorus, like nitrogen, occurs in several forms in wastewater and is an essential element for biological growth and reproduction. Phosphorus can be present as orthophosphate, polyphosphate, and organic phosphate. These forms are often measured in combination as total phosphate. In domestic wastewater, total phosphorus levels generally range from two to 20 mg/L, including 1 to 15 mg/L of organic phosphorus and 1 to 15 mg/L of inorganic phosphorus.

Metals

Metals are inorganic chemical elements present in varying amounts in most waste streams. A typical domestic wastewater has low concentrations of metals, but an industrial wastewater may be very high in metals. Although some metals are essential for proper human and plant nutrition, over time they can accumulate in soils and become toxic to plants, humans and other animals.

Metals of concern include cadmium, copper, lead, nickel, zinc, selenium, arsenic, mercury, and molybdenum. Cadmium, arsenic, chromium, and mercury are extremely toxic; nickel, molybdenum, and lead are moderately toxic; and copper, manganese, and zinc are relatively low in toxicity.

The primary concern with using the soil to dispose of heavy metals is that these compounds are stable and often resist weathering and decomposition. Plants generally resist the uptake of metals from the soil, but their accumulation on plant leaves through irrigation may permit them to enter various food chains. Once they become part of the life cycle of soil, plants, animals, and humans, they can accumulate in animal and human body tissue to toxic levels. This situation is especially critical for humans.

Because of the potential health effects of metals, wastewater applications sites must be properly managed to minimize the effects of metals on human health and the environment. The paramount questions facing cities or industries contemplating land application of wastes containing heavy metals or toxic substances are:

- How many acres of land are required to dispose of this waste?
- What is the anticipated `life expectancy' of the site given the accumulation of heavy metals or other toxic substances?

Persistent Organic Chemicals

Although microorganisms can readily decompose most organic wastes, some organic chemicals are not readily biodegradable and can persist in wastewater and soil for many years.

These persistent organic chemicals can reach the soil in many ways. They are sometimes a component of pesticides (insecticides and herbicides) or may be found in the waste stream that is being treated at the surface irrigation site. These products are also found where old underground storage tanks have leaked petroleum products into the soil.

With a municipal or domestic waste source, persistent organic chemical concentrations are likely to be extremely low or nonexistent. These chemicals may be present in higher concentrations, however, in an industrial waste source. Like metals, persistent organic chemicals can be toxic to animals and humans.

Fats, Oils, and Greases

Fats, oils, and greases (FOG) are another category of pollutant commonly associated with both domestic

and industrial wastewater. The most common form comes from animal or vegetable oils used in cooking. Food service/preparation establishments typically generate high levels of this type of fats, oils, and greases. This material can enter a treatment system as floatable particles, as emulsified material or in solution. Although microorganisms can break this type of FOG down, it can cause problems during the pumping of the wastewater by clogging pumps and spray devices in both a treatment facility and in the fields. Fats, oils, and greases can seal soil surfaces if land-applied.

Another type of FOG found less commonly in wastewater comes from petroleum-based products. This material is not readily stabilized by biological activity and can cause toxic effects on the biological community in the treatment system. It is usually associated with industry and/or automobile repair facilities.

pH

pH is the log of the concentration of the hydrogen ions (H+) in a solution. A pH of 7 is neutral, a pH reading below 7 indicates acidic conditions, and a pH reading above 7 indicates basic conditions. The pH of domestic wastewater typically ranges from 6.5 to 7.5, depending on the pH of potable water in the service system. Significant departures from these values may indicate industrial or other non-domestic discharges.

In surface irrigation systems, the bacteria that perform most of the wastewater treatment prefer a pH of neutral (or 7) for best performance. Any rapid increase or decrease in pH can cause death in the bacteria population, resulting in poor treatment.

Note: Acidity is the capacity of wastewater to neutralize bases. Alkalinity is the capacity of wastewater to neutralize acids. Wastewater does not have to be strongly acidic (low pH) to have a high acidity or strongly basic (high pH) to have a high alkalinity.

Salts

Chlorides, sulfates, potassium, calcium, sodium, and manganese are soluble salts (ionic compounds) that are present in wastewater. Some of them may be removed during wastewater treatment prior to effluent irrigation. Other salts, such as ferric chloride and alum, are sometimes added to aid in wastewater treatment.

Soluble salts, especially sodium (Na+), are important constituents of wastewater. When wastewater containing high levels of sodium or other salts is land-applied, there may be some swelling of clay minerals, which can reduce water movement through the soil.

This tendency occurs when the ratio of sodium to other cations (positively charged particles) is high. This relationship is called the sodium adsorption ratio (SAR) of a wastewater sample.

The SAR of wastewater should be evaluated frequently, especially when irrigating heavy clay soils. Salts and their effects on land treatment systems will be discussed in greater detail in Chapters 3 and 5.

Industrial Wastewater Characteristics

Systems treating wastewater from industrial sources must closely evaluate the pollutants that may be discharged from these industries. These possible pollutants are too varied and industry-specific to discuss in detail here. However, operators should give special attention to industries that discharge salts, which can drastically affect soil structure, or metals and organic chemical compounds, which can cause groundwater contamination.

Chapter 2
Pretreatment of Wastewater

Prior to surface irrigation, wastewater normally undergoes some form of preliminary or pre-application treatment. Pre-application treatment is used as a means of flow equalization, solids separation, physical, chemical and biological treatment, pathogen reduction, and wastewater and sludge storage. Pre-application treatment can consist of one or more of the following components:

- lagoons;
- tanks;
- sand filters; and
- disinfection.

2.1 Wastewater Lagoons

Wastewater stabilization lagoons are pond-like bodies of water that are used throughout the United States to collect, treat and store wastewater. In North Carolina, lagoons are widely used in farming communities as a means to handle animal waste from animal feed lots, hog houses, and poultry buildings. However, stabilization lagoons also serve as a means of treatment for the wastewater industry (both domestic and industrial).

Lagoons are generally used for systems with flows of more than 15,000 to 20,000 gallons per day (flows that surpass reasonable tank design). They may be used as a means of flow equalization, initial separation, primary and secondary treatment, and emergency storage.

Types of Lagoons

There are four types of stabilization lagoons:

- aerated;
- aerobic;
- anaerobic; and
- facultative.

Aerobic Lagoons

Aerobic lagoons are not common in the southeastern United States. Aerobic lagoons are designed shallow (12 to 18 inches) in order to maintain a constant DO throughout the entire depth. Oxygen is supplied by natural surface aeration and algal photosynthesis. Algae exists throughout the depth of the lagoon and is sometimes enhanced by mixing to prevent anaerobic conditions. The success of these lagoons is dependent on the balance of heterotrophic and autotrophic organisms. Aerobic bacteria and algae biologically degrade waste.

Aerated Lagoons

Many aerated lagoons are former facultative lagoons that have failed. Oxygen is introduced into these lagoons artificially through mechanical-type aerators (Figure 2-1) or diffused air from air blowers, thus eliminating the need to maintain an algae population. Generally, these lagoons can handle high-strength wastes using less land. Higher operating costs are common due to the electrical costs associated with continuously operating the aerators or mixers. These lagoons are typically designed to be deeper than other lagoons to provide additional volume for sludge storage below the mixing and aerated zone.

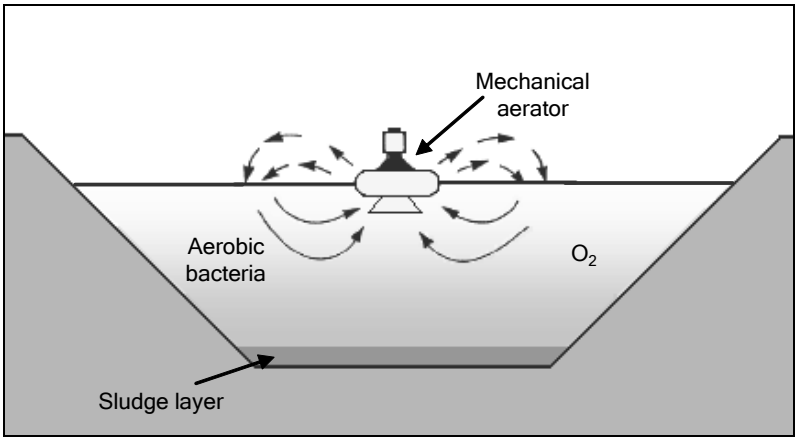

Figure 2-1. Diagram of an aerated lagoon.

Anaerobic Lagoons

As discussed in Chapter One, anaerobic means "without oxygen." There is little to no dissolved oxygen present throughout the entire depth of an anaerobic lagoon (Figure 2-2). The organic and hydraulic loading rates for anaerobic lagoons are typically very high compared to other lagoons.

The goal of anaerobic treatment is the destruction and stabilization of organic matter, rather than nutrient recycling (as in oxidation ponds). The principal biological activity is the loss of carbon as carbon dioxide by acid and methane fermentation. Similar processes occur in anaerobic digesters and septic tanks. Anaerobic lagoons are generally used for treatment of industrial or agricultural waste and are not widely used for the treatment of domestic wastewater.

Although these lagoons are highly efficient in destroying organic wastes, the processes involved can be highly odorous. A dense scum mat often forms over the entire surface of an anaerobic lagoon, promoting anaerobic conditions and limiting odor emissions. Plastic covers are also used to promote anaerobic digestion and control odors; however, such covers must provide some means of capturing methane gas and allowing sludge removal.

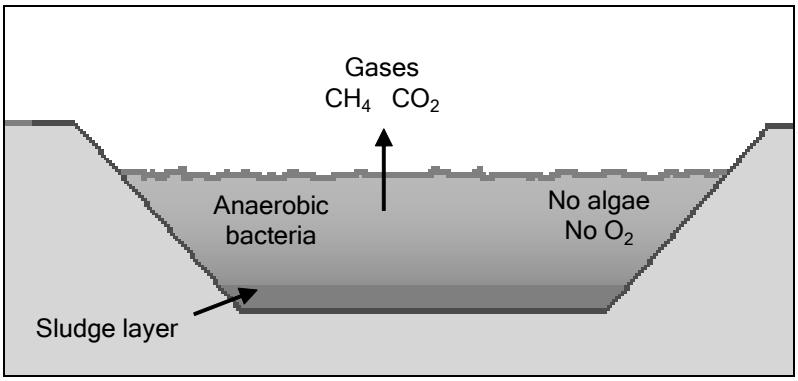

Figure 2-2. Diagram of an anaerobic lagoon.

Facultative Lagoons

Facultative lagoons are one of the most commonly used lagoons. The purpose of these lagoons is to recycle nutrients while providing waste treatment. Nutrients are removed by photosynthetic algae, while organic matter is stabilized by heterotrophic bacteria (bacteria that cannot synthesize its own food). Facultative lagoons are designed to have three zones or layers of wastewater – aerobic, facultative and anaerobic (Figure 2-3).

The aerobic zone is the upper layer of wastewater where sunlight fully penetrates. In the presence of sunlight, photosynthetic algae use carbon dioxide and nutrients to produce oxygen. The depth of the aerobic zone depends on how far light can penetrate and how much oxygen can be produced and stored there (generally around two feet).

Beneath the aerobic zone is the facultative zone. Although some sunlight penetrates, oxygen production is much lower and is much more variable than in the aerobic zone. Bacteria in this zone must be able to decompose waste both in the presence and in the absence of oxygen (facultative).

The bottom layer is the anaerobic zone where no sunlight penetrates and no oxygen is produced; therefore, waste must be degraded by anaerobic or facultative bacteria. This zone includes a layer of sludge composed of solids, bacteria and algae that settle to the bottom of the lagoon. In this zone, anaerobic and facultative bacteria decompose organic matter into volatile organic solids and gases during anaerobic fermentation.

Facultative lagoons usually range from four to eight feet deep. Detention times range from five to 30 days, although in North Carolina permitted systems are typically required to have a minimum 30-day detention time.

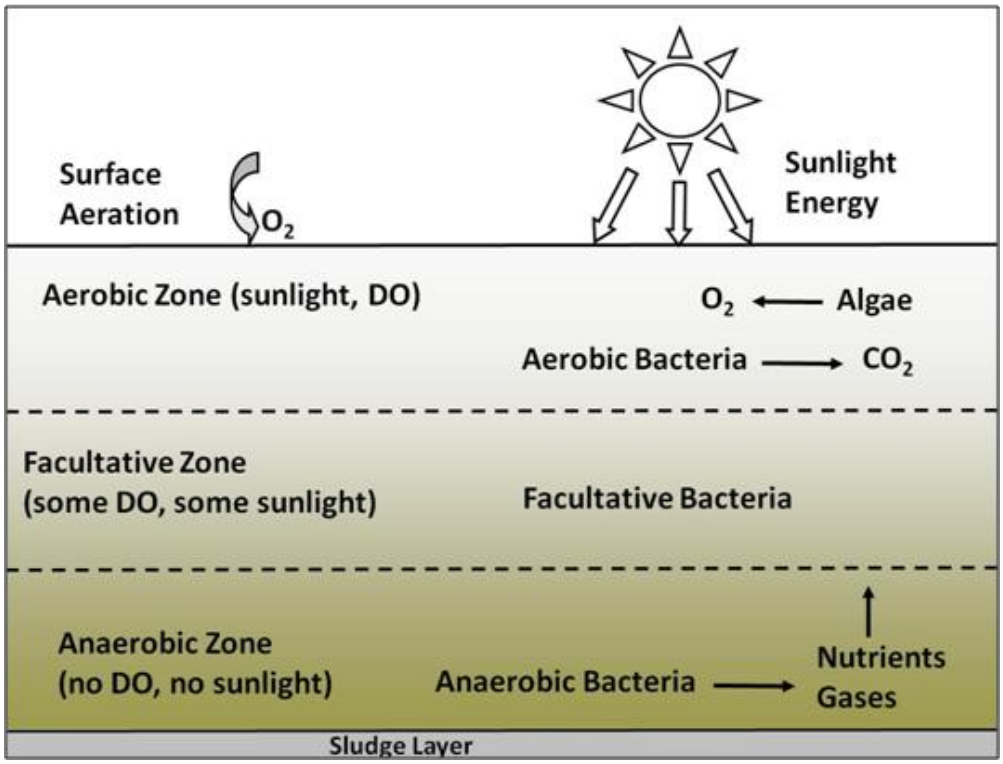

Figure 2-3. Diagram of a facultative lagoon.

The key to successful operation of these lagoons is the proper balance of oxygen-producing algae and surface aeration. Any imbalances such as excessive oxygen consumption during algae respiration, reduced oxygen production (as experienced at nighttime and during cloudy days), water temperature changes, and chemical and biological upsets can result in non-productive, "dead," odorous lagoons.

Storage Lagoons

A fifth type of lagoon is a storage lagoon. Storage lagoons are not considered stabilization lagoons since their primary function is to provide temporary storage (not treatment) of wastewater. Since no surface irrigation system can operate continuously, a lagoon can provide wastewater storage where tank storage is unrealistic. Although a limited amount of treatment may occur in storage lagoons, they are designed primarily for storage.

Lagoon Design and Components

Lagoons are generally designed with earthen dams or dikes. Figure 2-4 shows a typical lagoon design. To allow mowing of outer banks, outside slopes are usually no more than 3 units horizontal to 1 unit vertical.

Lagoons must be designed for a minimum freeboard (the distance between the top of the dike at its lowest point and the highest allowed wastewater level within the lagoon). This provides for stability and a heavy rainfall factor. The inside slopes may be protected again wave erosion by riprap from one foot below the minimum water surface to the top of the freeboard.

Liners are used to reduce the permeability of the bottom and sidewalls of earthen lagoons. The three types of liners commonly used are clay, bentonite, and synthetic membranes. Clay liners must be carefully installed with proper compaction at the proper moisture content.

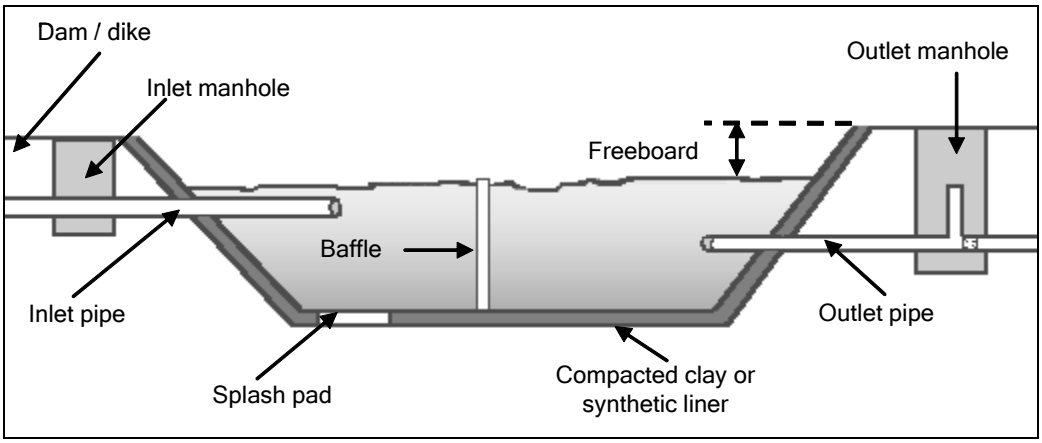

Figure 2-4. Schematic of a typical stabilization lagoon.

Bentonite is a natural material that is mixed with existing soil. It must be transported from outside North Carolina and can be expensive to install. Synthetic membranes normally consist of some type of plastic. Again, careful installation is essential as they are easily damaged.

Wastewater enters and leaves a lagoon through inlet and outlet pipes. Inlet structures should be located so that wastewater is distributed evenly in the pond. If wastewater is gravity fed to the lagoon, a concrete pad is often placed at the end of the inlet pipe to protect the lagoon liner. The outlet pipe is located as far as possible from the inlet pipe to increase detention time and prevent short-circuiting (a condition where some of the wastewater in a tank or lagoon travels faster than the rest of the flowing water).

Lagoons are designed for a specific detention time (the amount of time wastewater is retained in a treatment system). Time allows solids and many disease-causing bacteria, parasites, and viruses to settle out or die. Time also allows biological treatment to reduce the overall organic strength (BOD) of the wastewater.

Several smaller lagoons usually provide better treatment than one large lagoon. Surface irrigation systems often have multiple cells (lagoons) that are designed to operate either in series mode, parallel mode, or both (Figures 2-5 and 2-6). Lagoons that operate in series (wastewater flows from a primary lagoon to a secondary lagoon and so forth) allow more solids to settle out than in a single lagoon.

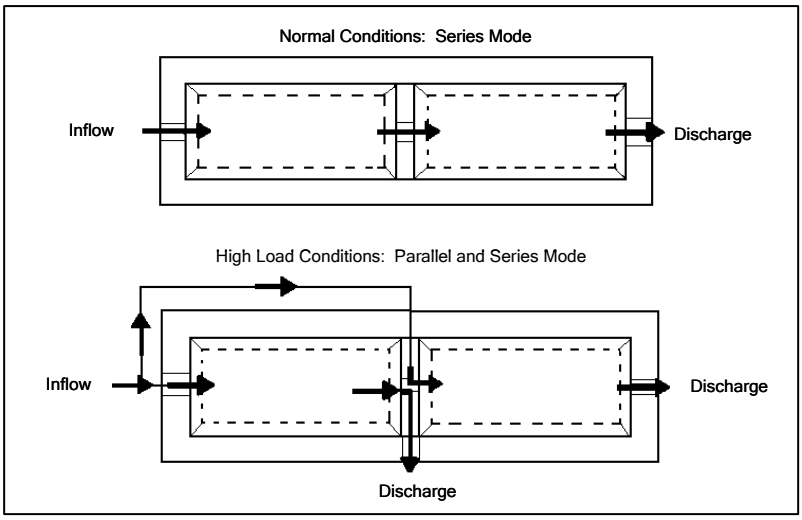

Figure 2-5. Two-cell lagoon system operated in series mode during normal conditions and in series and parallel modes during overload conditions.

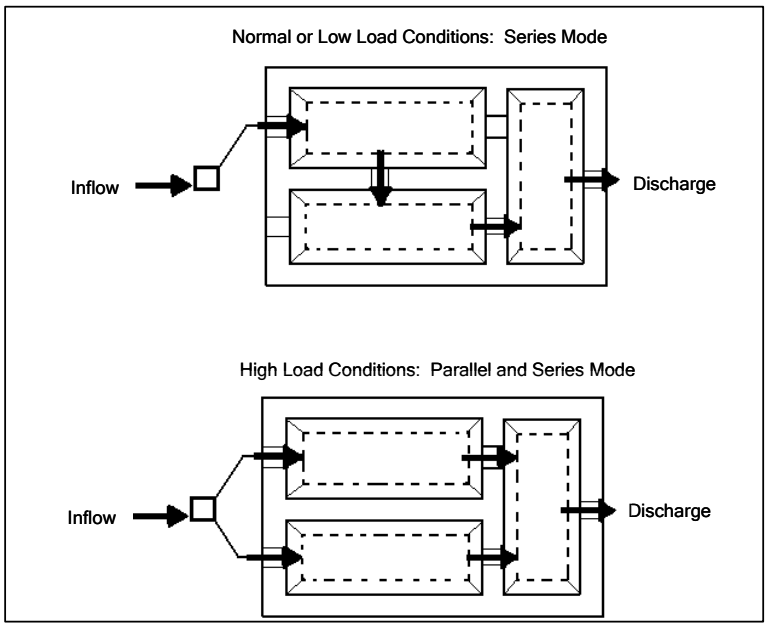

Figure 2-6. Three-cell lagoon system operated in series mode during low load or normal conditions and in parallel and series modes during high load conditions.

Sedimentation of solids and anaerobic decomposition of settled organic material occur in the first or primary cell. Organic matter is oxidized into stable products in both the primary and secondary cells, reducing BOD and SS. Tertiary or polishing lagoons can remove additional BOD and suspended matter. Because each cell provides additional treatment, a higher quality effluent results with series operation than with parallel operation.

Lagoons operated in parallel receive wastewater that is at the same stage of treatment. Wastewater with high organic loads can be distributed evenly to different cells using distribution chambers or splitter boxes with adjustable weirs or splitter arrangements. Operating lagoons in parallel allows one or more cells to be taken out of operation for maintenance and repair. A parallel configuration can also be used during winter to handle extra loads when treatment efficiencies are lower due to cold weather.

Placing lagoons in series may cause the first lagoon to become overloaded. The overload then may be carried to the next lagoon in the series. Feeding lagoons in parallel allows distribution of the incoming load evenly between units. Whether lagoons are operated in series or in parallel should depend on the loading situation and permit requirements. Table 2-1 summarizes design parameters for the four types of stabilization lagoons.

Parameter	**Type of Lagoon**			
	Aerobic	**Aerated**	**Anaerobic**	**Facultative**
Dissolved O_2	Aerobic without sludge storage	Aerobic with sludge storage	Anaerobic	Stratified, aerobic / anaerobic
Depth	12 – 18 inches	6 – 20 feet	10 – 20 feet	4 – 8 feet
Detention time	3 – 5 days	3 – 10 days	30 – 75 days	≥ 30 days
pH	6.5 – 10.5	6.5 – 8.0	6.5 – 7.2	6.5 – 8.5
BOD loading, (lb/acre/day)	Summer: 225 Winter: 110	50 – 200	650 – 850	20 – 50

Table 2-1. Typical design parameters for stabilization lagoons.

Lagoon Performance

Factors affecting lagoon performance include:

- biology;
- loading rates; and
- hydraulics.

Biology

A critical factor influencing individual lagoon performance is the formation and presence of biological organisms, particularly algae due to its ability to produce oxygen during photosynthesis. In aerobic and aerated lagoons and in the aerobic zone of facultative lagoons, the process of photosynthesis is critical.

During this process, photosynthetic algae use carbon dioxide in the presence of sunlight to produce oxygen. Aerobic bacteria then use the oxygen to stabilize the organic waste and generate carbon dioxide and other inorganic constituents, such as ammonia, nitrate and orthophosphates, as by-products. In turn, these constituents are used by algae during photosynthesis. This cycle is illustrated in Figure 2-7.

In anaerobic lagoons or the anaerobic layer of facultative lagoons, organic waste is converted to carbon dioxide by anaerobic organisms known as "acid producers" because they also produce nitrogen and organic acids. Another group of anaerobic organisms, "methane fermenters," then break down the organic acids to form methane gas. Many of the by-products generated by the anaerobic bacteria are then used as food by both the aerobic bacteria and algae in the layers above, converting them to dissolved sulfate, nitrate, phosphate and carbonate compounds. These compounds, in turn, are a source of energy for the anaerobic bacteria. The oxygen produced by the algae is used to support certain waste-stabilizing bacteria.

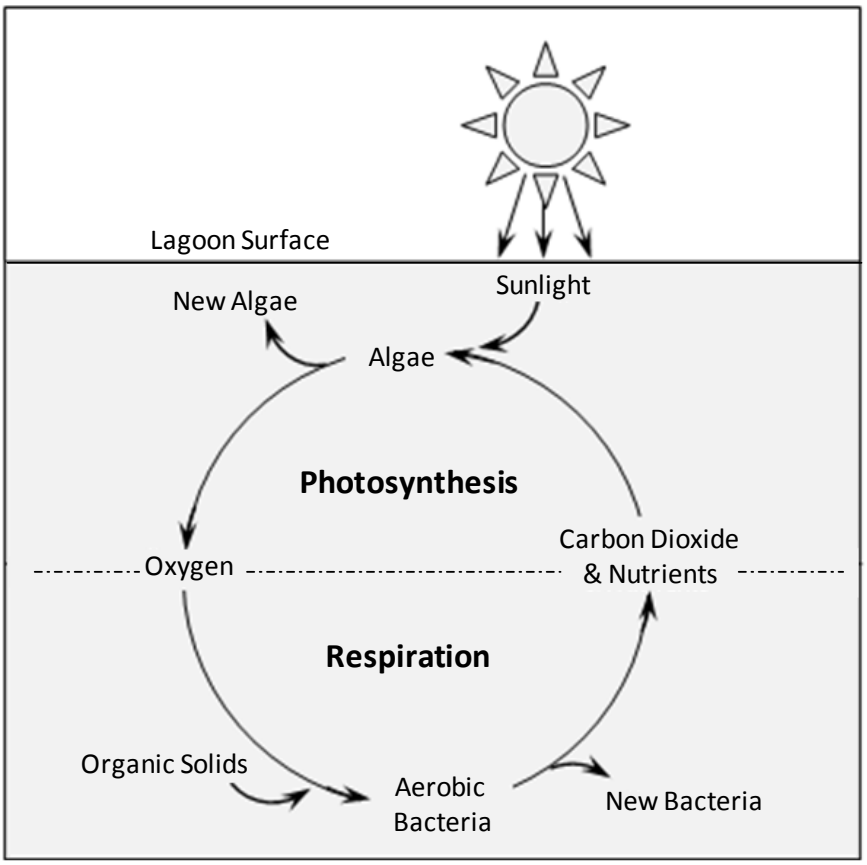

Figure 2-7. Relationship between algae and aerobic bacteria.

A major characteristic of facultative lagoons, is the drastic change in DO from daytime to nighttime (Figure 2-8). During the day, algae produce oxygen and consume carbon dioxide during photosynthesis. Carbon dioxide consumption increases pH. At night the algae breathe, consuming oxygen, producing carbon dioxide and decreasing pH. Therefore there can be a significant day-night variation in DO content.

Day-night variation in pH may also be experienced (Figure 2-8). Extended periods of cloudy weather or high levels of algae may result in die-off of the algae. This results in the formation of a floating mat of dead algae, low DO effluent, odorous and noxious smells, and general poor effluent quality.

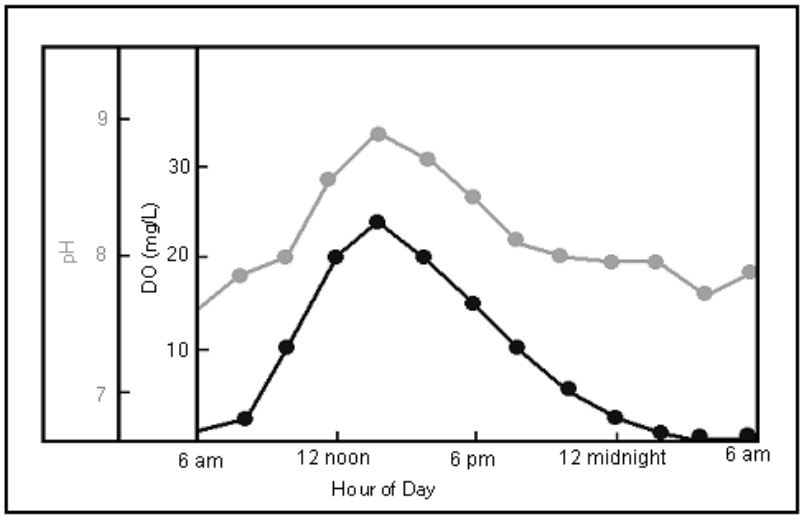

Figure 2-8. Day-night (diurnal) variation in DO and pH in a facultative lagoon.

Organic and Hydraulic Loading

Because lagoons are designed to handle specific organic and hydraulic loads, organic and hydraulic loading significantly affect lagoon performance. Overloading can result from factors such as poor design, short-circuiting, infiltration, population increases, industrial growth, industrial dumps, or from diverting too much flow from one lagoon to another. Overloading results in incomplete treatment of wastewater and poor effluent quality.

If a lagoon is organically overloaded, it may not generate sufficient DO for the biological cycle to function properly. Offensive odors, sludge mats on the surface of the lagoon, or changes in color may indicate that the lagoon is organically overloaded. Aerobic, aerated and facultative lagoons may become anaerobic and septicity (a condition where organic matter decomposes to form noxious-smelling products indicating the absence of oxygen) may occur. Although sludge accumulation is normally a gradual process, organic overloading can accelerate sludge deposits. Hydraulic overloading reduces detention time and wastewater moves through the lagoon too quickly, resulting in poor effluent quality.

Hydraulics

In addition to hydraulic loading, there are other factors that influence the hydraulics of a lagoon, such as wind and temperature. Wind affects lagoon hydraulics by directing flow in a common wind direction or even in circulatory flow patterns. Water temperatures are commonly stratified and change throughout the season. In the winter months, inflow (which is warmer than the lagoon contents) rises and flows towards the outlet. In the summer, the reverse occurs when the inflow is cooler and sinks. The effects of wind and temperature may reduce the effective volume, alter the detention time, change the lagoon's ability to achieve certain levels of treatment, and cause short-circuiting.

Some hydraulic situations can be adjusted and modified while others cannot. Modifications such as changes in inlet and outlet configuration, multiple inlets, inlet diffusers, recirculation capabilities, and changes in inlet and outlet location have a dramatic affect on effluent quality.

However, the number of treatment cells and their configuration may have the greatest impact on wastewater quality. Treatment cells can be configured by using separate interconnected lagoons, dikes, and baffles or curtains with flow-through openings. Siphons may also be used to help direct flow if proper allowable elevations are available.

Other Performance Issues

Studies show that bacteria, parasite and virus removal is very effective in multiple cell wastewater lagoons. Nitrogen, phosphorous and BOD are also reduced through the use of lagoons and lagoon systems. BOD removal is thought to be a function of climate, loading rate, and biological activity. Nitrogen reduction in wastewater lagoons has been observed for many years and is thought to be a function of algal uptake, sludge deposition adsorption by lagoon bottoms (if unlined), nitrification, denitrification, and volatilization (loss of ammonia gas to the atmosphere).

Although phosphorous removal is not generally required for spray systems, chemical treatment such as hydrated lime, alum, and ferric chloride are effective means of lowering phosphorous levels when necessary. Operators should also expect elevated levels of total suspended solids in lagoon effluent due to the presence of plants and animals (fish, waterfowl, etc.). Many times a final screening (a micro strainer) or a filter system is used prior to surface irrigation to minimize solids in the effluent and prevent blockages in surface irrigation equipment.

Lagoon Operation and Maintenance

Regardless of how well designed or how appropriate the hydraulic and organic loading, lagoons will not perform to their optimum potential unless properly operated and maintained. Inspections and sampling must, at a minimum, be conducted as required by the system permit. In addition, routine operation and maintenance practices should address and control the following conditions and situations:

- emergent and suspended vegetation;
- erosion;
- scum formation;
- excessive algae;
- sludge buildup;
- odor production;
- low pH;
- insufficient freeboard;
- short-circuiting; and
- septicity.

Vegetation

Controlling vegetation in and around lagoons is very important. Long weeds and grasses on dams and dikes block wind, provide sheltered areas for insects and burrowing animals interfere with the establishment and maintenance of a desirable vegetative cover, and hinder visual inspection of dikes. Trees and other deep-rooting vegetation can impair the structural integrity of lagoon dikes. Regular mowing, weeding, and maintaining well-established vegetative covers are required to avoid these problems.

Emergent and suspended vegetation in lagoons takes up valuable space that could be occupied by algae, provides a breeding ground for mosquitoes, stops sunlight from penetrating wastewater, and hinders pond circulation. In addition, dead vegetation can contribute to increased BOD levels. Emergent growth will only occur when sunlight is able to reach the lagoon bottom and therefore should not be a problem for lagoons over three feet deep. (If multiple lagoons are operated in series, the clarity of the wastewater will be greater in the secondary and tertiary lagoons and emergent weeds may be a problem, even for deeper lagoons).

For more shallow lagoons, emergent growth can be controlled by:

- immediate removal of young plants (including roots);
- drowning weeds by raising the water level, lowering the water level and cutting the weeds, then

raising the water level again;
- by installing pond liners; and
- as a last resort, using herbicides (which should only be used with the approval of DWR).

Suspended vegetation, such as duckweed and water meal, can occur in any lagoon regardless of depth. Often mistaken for algae, duckweed floats on a lagoon surface and has long hair-like roots that hang down into the water. It grows rapidly and can cover the entire surface of a lagoon if not controlled. Duckweed and other surface weeds are generally not a problem if a lagoon is exposed to a clean sweep of wind. If suspended vegetation is a problem, it should be skimmed off with rakes or other tools or mechanically harvested. Ducks eat duckweed (hence, the name) and may control a light growth. As a last resort, a herbicide can be used.

Erosion

Erosion can wash away clay liner material on inside banks or create cracks and crevices in outer banks. Both situations reduce the structural integrity of lagoon dams or dikes and can result in leaks and dike failure. Erosion is caused by wave action, surface runoff from precipitation, or burrowing animals.

Installing riprap or broken concrete along banks and dikes can minimize erosion (this also discourages weed growth). Diversion ditches must be installed to carry all surface water away from the lagoon.

Burrowing animals, such as moles, groundhogs, and muskrats, can usually be controlled by regular mowing of banks and removal of heavy underbrush. Since they like their tunnels partially submerged, muskrats can be discouraged by alternately raising and lowering water levels. Otherwise, animals should be trapped and relocated. Burrowed holes should be repaired immediately.

Scum Formation

Like suspended vegetation, scum that collects on lagoon surfaces can block sunlight, reducing oxygen production by algae. It can clog inlet and outlet pipes. Algae can grow on it and cause odors. Scum accumulation is usually higher in the spring when water temperatures are warmer and biological activity accelerates.

If exposed to a clean sweep of wind, scum usually dissipates and settles. If not, scum can become dry and crusted, forming floating mats. These scum mats should be broken up with rakes or other tools or by jets of water from pumps or tanks trucks. Mats tend to reform, so repeated efforts may be necessary. If a system has multiple lagoons operated in parallel, letting a cell "rest" may solve the problem.

Excessive Algae

Although algae is critical to the biological cycle of a lagoon, excessive algae can create serious problems. The sudden explosion of algae growth (an algae bloom) is composed primarily of blue-green algae. Blue-green algae is stringy, forms clumps or mats, and has a characteristic odor. The growth and dominance of blue-green algae can be caused by organic overloading, pond turnover, shutdown, poor conditions, and by protozoa eating all of the green algae.

Algae blooms die off as suddenly as they appear, blocking sunlight and causing foul odors. The die-off of algae blooms also causes a very high BOD loading. Dissolved oxygen is depleted and the lagoon may become anaerobic or septic. Like scum mats, algae mats should be broken up and dispersed or physically removed like duckweed.

Surface agitation is a simple method of limiting the amount of algae present in a lagoon. Ripples created by simple mechanical devices help refract some of the sunlight that hits the surface of the water. This

limits the amount of sunlight that can penetrate the water column.

Algae can also be controlled by chemical and biological means. Chemical products that color lagoon water act as a shade to minimize algae growth. Because large quantities are often needed, costs may be prohibitive. There is also a residual color issue. Herbicides are another possible chemical means of controlling algae growth; but, again, costs may be prohibitive. Algaecides and copper sulfate should not be used since algaecides can kill off all algae and copper sulfate may contaminate groundwater and sludge.

Duckweed was identified as a potential problem earlier in this section. Yet, it is sometimes used as a biological deterrent to algae growth, as are other aquatic plants such as water hyacinth and pennywort. These plants take up nutrients and shade the lagoon surface, lowering algae growth rates and minimizing DO swings. It should be noted that the use of plants to combat algae growth creates additional management considerations and their growth must be controlled by regular harvesting to avoid equipment blockages (bar screens, pumps, piping, etc.)

Fish have also been used to control algae growth in some lagoons. The use of fish to consume algae also requires additional management techniques including fish harvesting and possible oxygen supplementation.

Note: When considering any chemical or biological means of algae control, an operator must make sure that the action is approved by the Division of Water Resources and is not a violation of permit conditions.

Low pH

Depending on the type of lagoon, pH can range from 6.0 to around 10. In general, most lagoons function best if they are a little on the alkaline side, around a pH of 8. A decreasing trend in pH can be corrected or reversed by adding lime. When using lime, make a slurry of 100 pounds of hydrated lime per 50 gallons of water. Using a dosage rate of one pound of lime per 10,000 gallons in the lagoon, add the slurry around the inlet of the lagoon so that it mixes well throughout the lagoon.

Solids Accumulation

As discussed earlier, solids accumulation is normally a gradual process in anaerobic and facultative lagoons because anaerobic bacteria break down wastes into products that are used by algae. Heavily loading or overloading lagoons can speed up solids accumulation. Eventually, solids accumulate to a point where they must be removed.

Solids accumulation reduces detention time (by reducing the effective volume of the lagoon) and may cause short-circuiting, odors, sludge mats, and solids carryover to the second lagoon (if operated in series). Solids accumulation should be measured at least once a year using a "sludge judge", a clear hollow tube or a long stick wrapped with rough, white toweling. Solids are generally removed when their depth exceeds one foot. These solids must be disposed of in a manner permitted by DWR.

Odor Production

Regardless of how well maintained or operated, most lagoons will produce odors from time to time. Anaerobic lagoons produce more odors than other types of lagoons, odors that can be reduced by the use of plastic covers.

In other types of lagoons, odors may be particularly noticeable for a short period in spring, when warmer temperatures accelerate biological activity, depleting oxygen and creating anaerobic conditions. However, persistent odor problems indicate more serious problems such as overloading, extended

periods of cloudy weather, poor pond circulation, and floating sludge mats.

Odors can be reduced by increased mechanical aeration or by chemical methods as outlined in Appendix A-2.

Insufficient Freeboard

Overflow from lagoons for any reason is a violation of state regulations and subject to enforcement action. Waiting until a lagoon has reached its maximum storage capacity before starting to irrigate does not leave room for storing excess wastewater during extended wet periods. By late summer/early fall a lagoon should be pumped down as far as possible.

For an anaerobic lagoon, efforts should be made to maintain the lagoon close to the minimum liquid level as long as the weather and permit conditions allow. In North Carolina, most lagoons are required to have a minimum of two feet of permanent freeboard. The system permit should be reviewed to determine the exact freeboard requirement.

Natural surface water or stormwater should be diverted away from the lagoon by surface water diversions. They are usually designed with a gentle slope so they can be vegetated and mowed, and so that rainwater runoff leaves gently without causing erosion. Their purpose is to keep all excess water out of the lagoon so that this excess water does not have to be pumped to the spray fields. Natural surface water can be safely diverted away from the lagoon without special permits; but once this surface water enters the treatment system, it must remain in the treatment system.

Short-circuiting

Short-circuiting is a condition that occurs when some of the wastewater in a lagoon or basin travels faster than the rest of the flowing water. This problem can be caused by such factors as poor design, sludge accumulation in the lagoon bottom, vegetation that hinders lagoon circulation, temperature and overloading. It can result in shorter detention, reaction, and settling times.

Short-circuiting can be verified by the use of dye tests. It may be corrected or prevented by the use of curtains or baffles to redirect flow, relocation of inlet and outlet pipes, controlling vegetation, preventing overloading, and removing excessive sludge deposits from the lagoon.

Septicity

Septicity is the condition where organic matter decomposes to form noxious-smelling products indicating the absence of oxygen. If severe, wastewater turns black, gives off foul odors, contains little to no dissolved oxygen and creates a high oxygen demand. This condition is undesirable in aerated, aerobic and facultative lagoons and may result in the failure of these lagoons.

Septicity can be caused by overloading, short-circuiting, poor operation, or toxic discharges. Corrective actions include reducing flow to the lagoon, changing from series to parallel operation (if multiple lagoons), increasing recirculation, adding supplemental aeration, changing inlet and outlet arrangements, and eliminating sources of toxic discharges.

With proper design and good management practices, lagoons can be expected to achieve high quality effluent. Maximization of lagoon performance by using all available technology, coupled with good operation and management techniques, will have positive results in lagoon performance. Be aware of all potential effects on performance, determine performance goals and implement procedures necessary to achieve these goals. Troubleshooting guides contained in Appendices A-1 and A-2 should help operators identify problems and possible solutions.

2.2 Tanks

Tanks (septic tanks, dosing tanks, grease traps and oil/water separators) are other possible pre-application treatment components of surface irrigation systems.

Septic Tanks

A septic tank is a buried, watertight receptacle designed and constructed to receive wastewater. The functions of a septic tank are to:

- separate solids, oils and greases from the liquid;
- provide limited digestion of organic matter by anaerobic bacteria;
- provide flow equalization; and
- store solids.

Wastewater enters the tank through an inlet pipe (Figure 2-9). Settable solids and partially decomposed septage settle to the bottom of the tank and accumulate. These solids are often retained by baffle walls built into the septic tank and by an outlet tee.

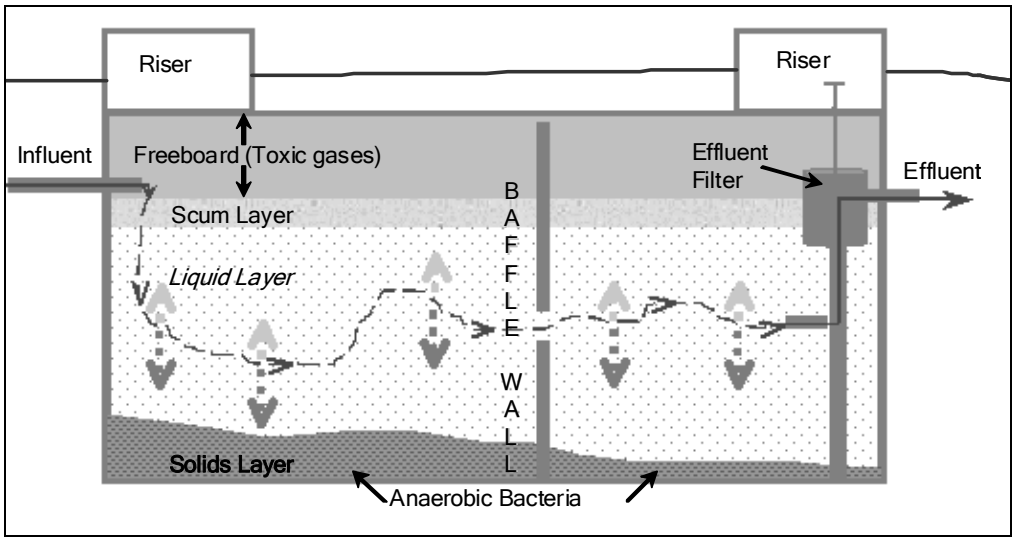

Figure 2-9. Septic tank schematic.

A scum layer, consisting of lightweight material including fats and greases, rises to the top. The partially clarified liquid then flows through an outlet structure (typically a sanitary tee outlet) below the floating scum layer and exits the tank as effluent.

Access ports or risers should be located above each compartment and should extend to finish grade to allow for regular inspections and solids removal.

Septic Tank Performance

Septic tank performance is affected by hydraulic loading, organic loading, inlet and outlet arrangements, number of compartments, and operation and maintenance practices. Septic tanks are designed to handle both a specific flow rate (hydraulic load) and a specific amount of organic material (organic load).

If the septic tank is hydraulically overloaded, the detention time may be too short and solids may not settle or float properly. If the tank is organically overloaded, septic tank performance can be reduced and

the need for pumping and other forms of maintenance can be increased.

Septic tanks with properly designed and installed baffles and outlet tees produce a higher quality effluent than those tanks without these structures. Improper design and placement of baffles can create turbulence in the tank, seriously impairing settling efficiency. In addition, poorly designed or constructed baffles or outlet devices may allow scum or septage to enter discharge pipes.

Outlet filters are an excellent means of providing additional protection against solids exiting the septic tank and are a requirement on all septic tanks installed on or after January 1, 1999. Multi-compartment tanks provide better treatment than single compartment tanks of the same total capacity. Multi-compartment tanks provide better protection against solids carryover into discharge pipes during periods of surges or upsets.

If a septic tank is not water tight, leakage from the tank (exfiltration) can result in direct discharge of wastewater to groundwater and potential contamination. Infiltration (seepage of groundwater or stormwater into the tank) may result in hydraulic overloading and decreased treatment efficiency.

Septic Tank Operation and Maintenance

One of the major advantages of the septic tank is that it has no moving parts; therefore, it needs little routine maintenance. However, improper operation and maintenance can impair tank performance. Routine inspections are required to ensure proper functioning. At a minimum, a tank must be accessible, must be visually inspected for signs of damage or deterioration, and solids and scum must be removed as needed.

Accessibility

The location of a septic or dosing tank should be easily identifiable for inspection and maintenance. Septic tanks should be buried or protected sufficiently to prevent damage from vehicle traffic or constructed to withstand excessive traffic or soil loads. Ideally, septic and dosing tanks should have elevated access covers (or risers) to allow for easy access. If not, operators must unearth access ports for inspection and maintenance. Manhole risers and access covers should be watertight and structurally sound. Access covers should be removable by one person.

Visual Inspection

All tanks must be watertight. Otherwise, infiltration can result in hydraulic overloading. A system that is hydraulically overloaded will not function efficiently. Evidence of groundwater infiltration would be wall mud stains, cracks, openings, and observation of groundwater flowing into the tank. Excessive pump run times may also indicate system infiltration such as ground or stormwater inflow.

Conversely, if a tank is not watertight, exfiltration can occur, resulting in groundwater contamination. Signs of exfiltration are observation of a constant liquid level below the outlet, wetness around the outside of the tank area, or groundwater contamination. Therefore, inlet and outlet pipes or tees should be inspected for cracks, loose grout, or other indications of problems that may result in infiltration/exfiltration. (Note that these problems are often a result of a tank settling.)

Also, outlet baffles and sanitary tees often deteriorate, become damaged, or are simply missing and should be replaced or repaired. Baffle walls (if present) should be inspected for structural integrity, clear openings, and clear venting (at the top of the baffle).

Removal of Solids and Scum

Failure to regularly pump out accumulated solids and scum (or septage) is a major cause of tank

problems. As septage depth increases, the effective liquid volume and detention time decrease. This decreases treatment efficiency and allows more solids to escape from the tank and into other treatment components, clogging pipes and causing the system to fail.

When a tank is inspected, the depth of septage and scum should be measured in all compartments of the tank, including the vicinity of the outlet baffle. The tank should be cleaned whenever the bottom of the scum layer is within three inches of the bottom of the outlet device or the septage level is within 12 inches of the bottom of the outlet device (Figure 2-10).

Generally, solids should be removed from the tank when the septage level in the tank reaches one third of the total depth of the tank or 25 to 33 percent of the liquid capacity of the tank. However, the efficiency of suspended solids removal may decrease before these conditions are reached.

Scum can be measured with a stick that has a hinged, weighted flap, or with any device that can be used to feel the bottom of the scum mat, such as a probe. The stick is forced through the mat, the hinged flap falls into a horizontal position, and the stick is raised until resistance from the bottom of the scum is felt. The distance to the bottom of the outlet device can be determined with the same tool.

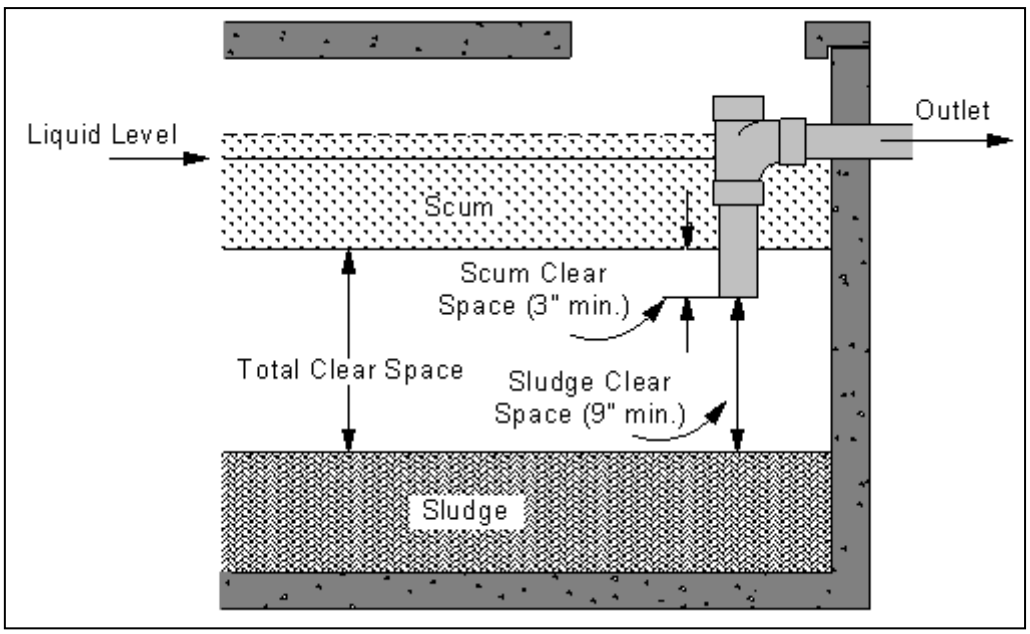

Figure 2-10. When to pump a septic tank.

As with lagoons, the sludge depth in a septic tank can be measured using a “sludge judge”, a clear core tube or a long stick wrapped with rough, white toweling (see Appendix A-3). Lowering this device to the bottom of the tank will show the depth of septage and the liquid depth of the tank. The stick or tube should be lowered behind the outlet device to avoid the scum layer. (The clear core tube could also include a check ball at the bottom to hold a column of liquid in order to view a cross section of the tank's contents.

- When removing septage from a septic tank or dosing tank, the following should be considered.
- When using access openings for pumping, care should be taken to minimize the risk of harm to the inlet and outlet baffle.
- When a septic tank is pumped, it does not need to be disinfected, washed or scrubbed unless

repairs are necessary or the tank is to be inspected for leakage.

- A small amount of solids may be left in the tank to provide a seed of the anaerobic bacteria that will decompose the waste in the tank.
- Septic tank effluent quality monitored in the dosing tank may provide indications about conditions in the septic tank. Excessive solids or high BOD may indicate the need for increased pumping frequencies.
- Septic tanks are considered confined spaces and are subject to confined space entry regulations (OSHA Standard 1910.146). A septic tank or pump tank should never be entered without first having an approved confined space entry program in place. This program should include testing the air for oxygen content, lower explosive limit, and hydrogen sulfide. Because they are full of toxic gases such as methane and hydrogen sulfide, climbing into septic tanks is very dangerous.

Appendix A-3 contains more detailed information on inspecting and pumping septic tanks.

Note: The safety measures mentioned here are not all-inclusive and OSHA should be contacted regarding specific confined space safety regulations.

Dosing Tanks

A dosing tank is basically a modified septic tank that stores pretreated wastewater for periodic discharge to subsequent treatment units or disposal areas. Effluent is gravity fed from the septic tank to the dosing tank. Effluent in the dosing tank is then periodically pumped to a sand filter or spray or drip field. Dosing tanks can also provide storage and limited pretreatment and solids separation. Dosing tanks usually have no baffle wall and have larger access ports to facilitate pump removal and inspection.

As with septic tanks, one of the most important details in dosing tank construction and inspection is water-tightness, since the internal liquid level is often below surrounding groundwater levels. Any infiltration in the form of groundwater or stormwater can result in hydraulic overloading of the tank or spray or drip fields.

There are two types of dosing mechanisms – pumps and siphons. The vast majority of surface irrigation systems use pumping mechanisms rather than siphon mechanisms. Pumps can be set with float switches or timers to run an exact amount of time, dosing volumes can be easily adjusted, and pumps are generally simple to install and replace. Pumps do require power, however, and will not function during power outages, resulting in possible sewage overflows. Pumps wear with use, resulting in reduced dosing efficiency, and must eventually be replaced or rebuilt. Dosing volumes are dependent on both proper pump and float or timer operation.

Siphons, on the other hand, do not require power to function, require little to no maintenance and are relatively inexpensive. However, siphons must be set perfectly if using dual or alternating siphons. Siphons can also rust, causing trickling effluent discharge rather than dosing.

Dosing Tanks with Pumping Mechanisms

A dosing tank with a pumping mechanism is often called a pump tank and consists of the tank, a pump and pump controls (Figure 2-11). The control system for the pump tank consists of a "pump off" switch, a "pump on" switch, and a high water alarm. The switches should withstand the humid and potentially corrosive atmosphere inside the tank. Pump failures can usually be traced to switch failures resulting in pump burnout. Therefore, high quality switches are a good investment. All electrical contacts and relays must be mounted outside the tank to protect them from corrosion. Provisions should be made to prevent gases from the tank escaping into the control box.

The tank should have sufficient volume to provide the desired dosing volume, plus a reserve volume. The reserve volume is the volume of the tank between the high water alarm switch and the invert of the inlet pipe. It provides storage during power outages or pump failure. A reserve capacity equal to the estimated daily wastewater flow is typically used for residential applications. In large flow applications, duplex pump units can be used as an alternative to provide reserve capacity.

Pump selection is based on the wastewater characteristics, the desired discharge rate, and the pumping head. If the liquid pumped is free from suspended solids, the pump may be set on a pedestal. This provides a zone below the pump where any solids entering the chamber can settle, thus reducing pump damage or malfunction. These solids must be removed periodically.

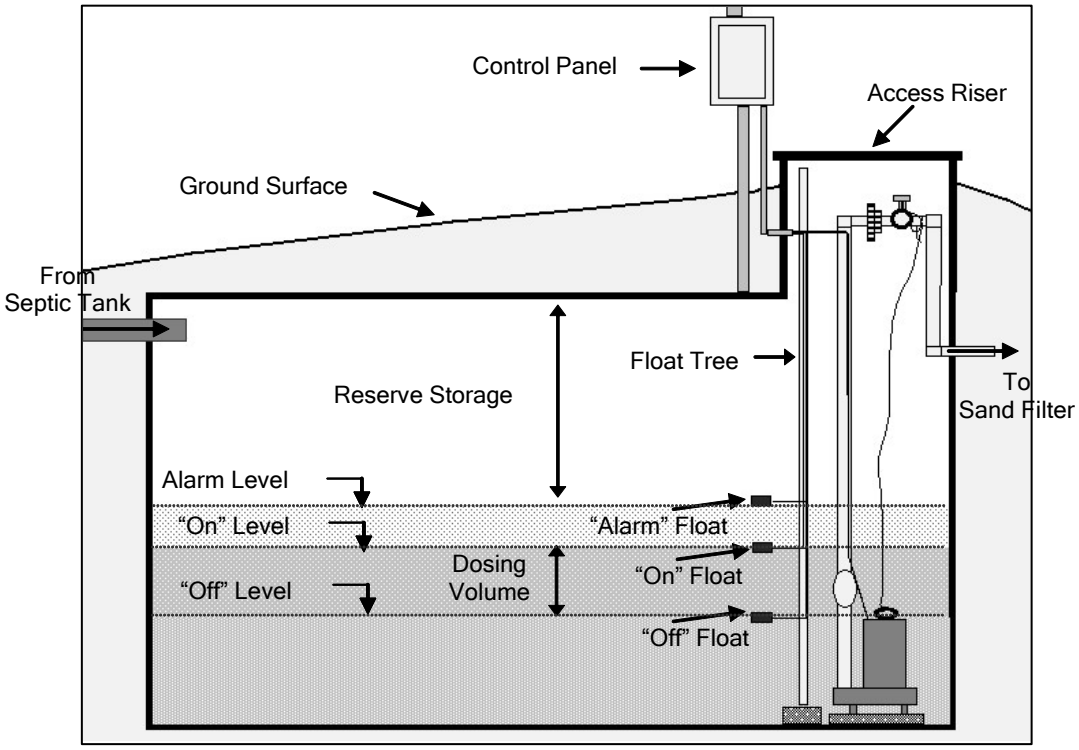

Figure 11. Dosing tank with pumping mechanism.

Dosing Tanks with Siphon Mechanisms

Siphon mechanisms can only be used if the dosing tank is at a higher elevation than the discharge point and if the settleable and floatable solids have been removed from the waste stream. A tank using a siphon consists of only the tank and the siphon (Figure 2-12). No mechanical or electrical controls are necessary since the siphon operation is automatic. Two siphons may be placed in a tank and automatically alternate, providing a simple method of dividing the wastewater flow between two treatment or disposal units.

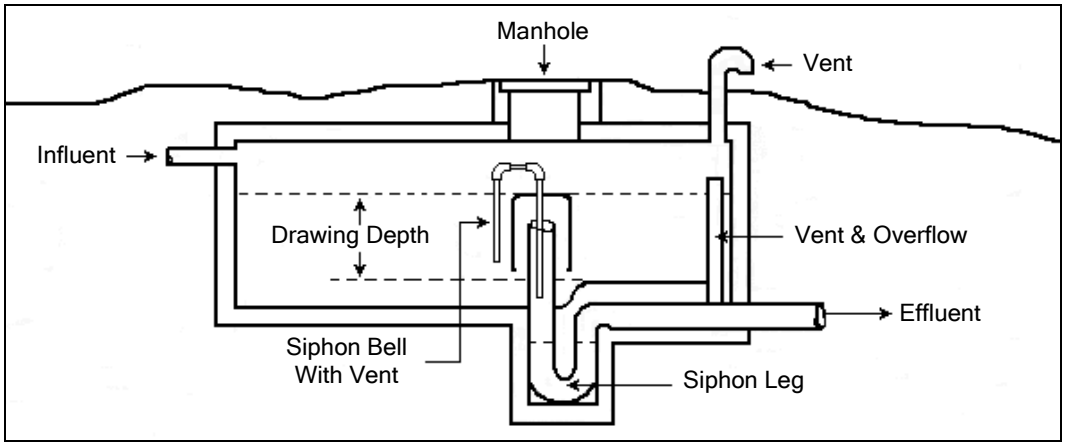

Figure 12. Dosing tank with siphon mechanism.

The design of the dosing tank is determined by the siphon selected and the head against which it must operate. The required dosing volume determines the length and width of the tank. No reserve capacity is necessary when siphons are used. When the tank fills, the siphon automatically discharges the water.

The size of the siphon is determined by the average desired flow rate. The siphon manufacturer should specify the "drawing depth" (the depth from the bottom of the siphon bell to the high water level necessary to activate the siphon).

Siphons are made of either cast iron or fiberglass. Cast iron siphons are the most common, but are subject to corrosion. Their advantage is that the bell is merely set on the discharge pipe so they can be easily removed and inspected. Fiberglass siphons do not corrode, but they must be bolted to the tank floor because they are so lightweight.

Dosing Tank Performance, Operation and Maintenance

Performance and operation and maintenance issues for dosing tanks are similar to those for septic tanks. In addition, if a pumping mechanism is used, the system should be cycled to observe the operation of the pump and switches.

If a siphon is used, the water level in the tank should be noted over a period of time to determine if the siphon is operating properly. If it is, the water level will fluctuate from the bottom lip of the siphon bell to several inches above the bell. If the water elevation does not change despite additions of wastewater, the siphon is "dribbling," indicating that the vent tube on the bell requires cleaning.

Grease Traps and Oil/Water Separators

Wastewater from restaurants and certain industries and commercial establishments may contain high levels of fats, oils and greases. Heavy concentrations of these materials can clog pipes and interfere with the proper operation of a surface irrigation system. It is desirable to remove fats, oils and greases from the waste steam by installing grease traps or oil/water separators as part of the pre-application treatment system.

Food establishments and laundries handling laundry items from food establishments generate fats, oils

and greases of animal and vegetable origin. The molecules of these materials have an unequal electrical charge and are polar in composition. They are readily biodegradable and can be metabolized by microorganisms. However, if not removed from the waste stream they are the greatest contributor to pipe blockages and mechanical interference with treatment components.

Machine shops, service garages and other similar establishments (along with laundries which wash items from such facilities) generate oils and greases consisting of hydrocarbons or petroleum-based wastes. These molecules have a neutral charge and are therefore non-polar in composition. Unlike the fats, oils and greases of animal and vegetable origins, they degrade relatively slowly and generally pass through a treatment system without being significantly removed.

Fats, oils and greases can exist in three forms: floatable (floating on the surface of the wastewater); soluble (small particles of grease and oils suspended in the wastewater); and emulsified (oils and grease dissolved into the wastewater) Although floatables are the most obstructive to lines and pipes, they can be easily removed from the waste stream by the use of gravity. Soluble and emulsified oils and greases interfere with filtration units and are much more difficult to capture than the floatables.

In general, chemical additions that emulsify, disperse or dissolve fats, oils and greases will impair grease trap or oil/water separator performance. Examples of such chemical additions are soaps, detergents or hydrocarbon solvents used at establishments such as laundries, car washes and truck and engine degreasing facilities.

Grease Traps

Grease traps are modified septic tanks that slow the flow of hot, greasy water and allow it to cool. As the wastewater cools, the fats, oils and greases separate, congeal, and float to the top of the grease trap. Grease traps should receive only kitchen waste; no toilet waste should be plumbed into these devices. Restaurants and other food establishments handling oils and grease of a polar composition normally install small under-the-counter grease traps or large outdoor/underground grease interceptors.

Grease traps provide:

- grease and solid separation;
- heat dissipation;
- a mechanism for grease removal;
- BOD and TSS reduction; and
- additional storage.

Grease traps have a deeper outlet sanitary tee (50 percent of liquid depth) and larger access openings than septic tanks (Figure 2-13). Typically, grease traps and interceptors have two chambers separated by an upper baffle extending from the ceiling and a lower baffle rising up from the floor of the unit.

As wastewater flows into the unit, fats, oils and greases float to the surface and solids settle to the bottom and are retained by the baffles. A slit in between the baffles or a space developed from overlapping baffles allows the treated wastewater to pass through to the second chamber. Floatable fats, oils and greases carried over to the second chamber are usually captured by a baffled or T-shaped discharge pipe.

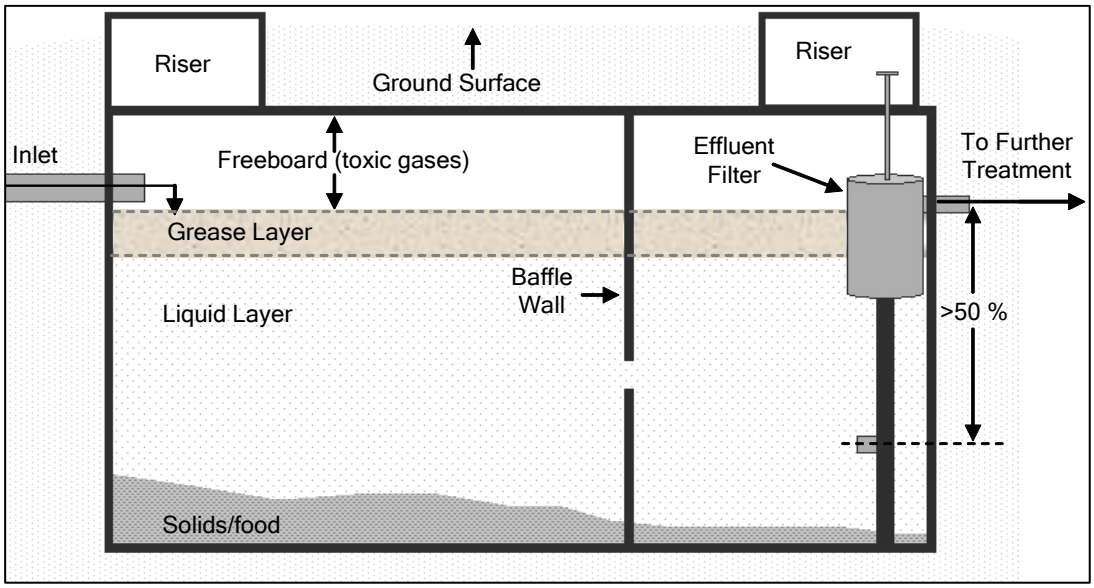

Figure 13. Typical two compartment grease trap.

The under-the-counter traps normally have a capacity range from 30 to 100 gallons. They are usually set directly beneath the source of wastewater, be it a wash sink, automatic dishwasher or other process operation discharging greasy wastes. Because of the size of the trap and the minimal grease retention capacity, these units need to be cleaned and serviced on a more frequent schedule than the outdoor grease interceptors.

Outdoor grease interceptors typically have the capacity in the range of 1,000 to 5,000 gallons. They usually are buried in the ground outside near the source of the greasy wastewater. Viewing and servicing are made possible through opening ports extending to the ground surface. Unlike the under-the-counter traps, they receive the discharge from nearly all the drainage lines in the food processing areas, including floor drains. The exception, in most cases, is the food garbage disposal. The particles of food deriving from this drain tend to load the retention capacity for solids too quickly. The required frequency of servicing the interceptor then becomes a burden to the food service establishment.

Grease Trap Performance

Factors affecting grease trap performance include the distance of the grease trap from the grease-producing area, temperature, hydraulic loading, detention time and operation and maintenance. If the unit is too close to the source of grease and the temperature of the wastewater is extremely high, fats, oils and greases will remain suspended and pass through the unit. On the other hand, if the unit is too far from the source, the material can separate in the lines before reaching the unit and cause blockages. If the recommended hydraulic loading discharged to the unit is exceeded, not enough detention time is provided for the fats, oils and greases to separate. Again, they will pass through the unit.

Grease Trap Operation and Maintenance

One of the most common reasons that fats, oils and greases pass through a grease trap is the failure to routinely check and service the unit. Servicing means removing the captured grease, oil and solids by pumping them out and disposing of them properly. Therefore, all traps and interceptors must be easily accessible with means to inspect and service both chambers. Each unit has the capacity to retain a limited amount of floatable fats, oils and greases or settled solids.

The more of these materials that accumulate, the less detention time is available. Eventually, the retention capacity is exceeded and any additional material passes straight through the unit. As with septic tanks, grease tank septage can only be removed and disposed of by someone permitted to do so by the Division of Waste Management, such as recycling companies and rendering operations.

Oil/Water Separators

Facilities handling oils and grease of a non-polar composition (machine shops, service garages, and car washes) use oil/water separators. Many are similar to grease traps in design and function, removing free or floatable oils by means of gravity (Figure 2-14).

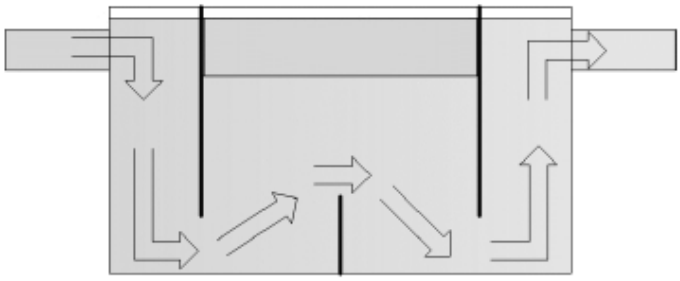

Figure 2-14. Schematic of a gravity oil/water separater.

Conventional gravity separation can be enhanced by the use of coalescing oil/water separators that contain plastic or other oil-attracting media. Oil and grease particles are drawn to the surface of the media as the wastewater passes through. The oil particles coalesce, forming beads of oil. These beads eventually float to the water surface (Figure 2-15).

Most oil/water separators continually remove the floating oils rather than have the separator pumped out periodically. This is accomplished by using skimmers to pull the floating oils off the surface of the wastewater and channel the recovered oils to a holding tank. Waste oil haulers then pick up the waste oil and take it to refineries to be recycled or dispose of it by burning.

Some skimmers consist of a standing pipe in the chamber of the unit. As wastewater flows into the separator, the water level rises and any floating oils drain into the standing pipe. Another variation is a tray or trough located in the chamber. As the water level rises, the floating oils overflow into the trough and are carried to a holding tank.

As mentioned earlier, gravity oil/water separators are not effective in removing suspended or emulsified oils and greases. Secondary forms of treatment are necessary to remove suspended or emulsified oil particles and include a variety of chemical, electrical, biological and physical methods.

A common means of removing suspended oils is through filtration, often referred to as an ultrafiltration unit. Measured in microns, the filter pores are designed to permit water to pass through but not oils. The treated water flows on to the distribution system. The captured oils are sent to a holding tank. Eventually, the surface of the filters becomes saturated and clogged with waste oils and must be back-flushed in order to continue operating.

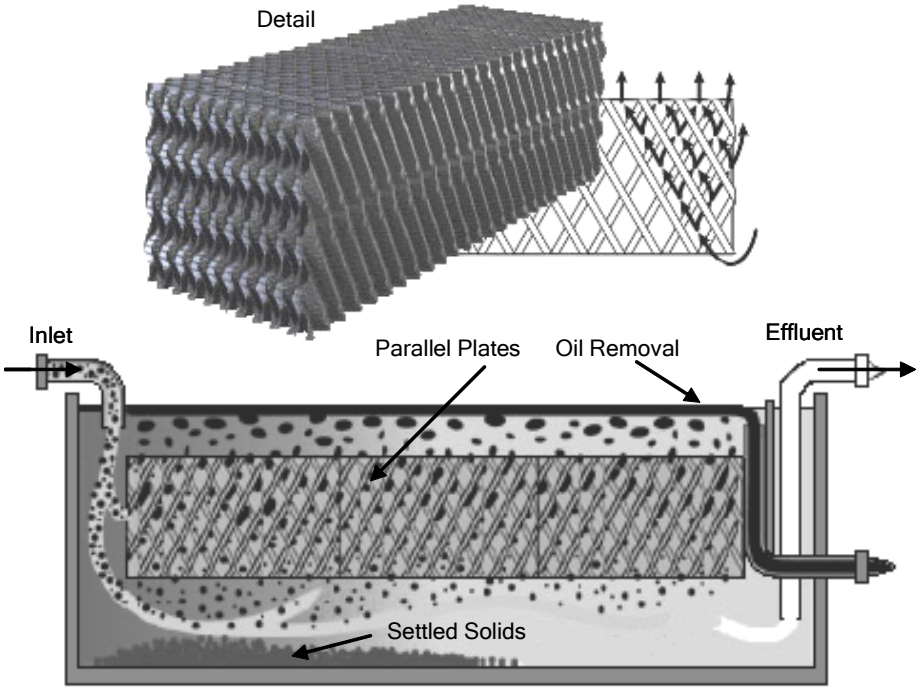

Figure 2-15. Coalescing oil/water separator with parallel plates.

Ultrafiltration units require more frequent servicing and inspection than other oil/water separators, but are capable of removing a much greater amount of waste oil from the wastewater. Another method is dissolved air flotation. Pressurized air is pumped into the tank; oil and grease particles cling to the air bubbles and float to the surface where they are skimmed off.

Carbon filtration is a tertiary form of removing oils from the wastewater. Oils and oily wastes readily adhere to carbon particles. Because of the limited surface area of the carbon particles, eventually the filter must be changed. This form of oil removal is too costly to be used as the primary means of treatment.

2.3 Sand Filters

Because effluent from septic tanks normally requires further treatment prior to surface irrigation, sand filters are often the second step in pre-application treatment. Although larger solids are removed by septic tanks, sand filters are an excellent means of removing particulate matter and reducing total suspended solids, therefore reducing blockages of spray heads.

Sand filters are ordinarily constructed of masonry walls that separate the sand filter from contact with ambient soil. They are filled with clean sand 24 to 36 inches deep and are underlain with gravel and effluent collection drains. Septic tank effluent is usually intermittently applied to the surface and percolates down through the sand to the bottom of the filter. The under drains collect the filtrate and convey it to additional treatment processes.

In passing through the filters, much of the organic matter that does not float or settle out in the septic tank is removed. The effluent that drains from properly constructed and operated sand filters is usually clear and free of solids. In addition to physically filtering out organic matter, sand filters also treat wastewater chemically and biologically.

The treatment process is complex, involving physical, chemical, and biological mechanisms. Suspended

solids are removed by filtration and sedimentation. Chemical adsorption (adherence) on the grain surfaces also plays a role in the removal of some material. However, it is the biological transformations that occur within the filter which are the most significant. Bacteria living on surfaces of sand particles decompose filtered solids, resulting in reduction of BOD_5 and the conversion of ammonia to nitrate (nitrification).

Since these processes are most efficient under aerobic conditions, intermittent application of wastewater and venting of the under drains helps insure that aerobic conditions are maintained. Some conversion of nitrate to nitrogen gas also occurs, probably as the result of anaerobic micro-sites within the sand. Table 2-2 shows a comparison of septic tank and sand filter effluent quality.

	Septic Tank	Recirculating Sand Filter
BOD_5	130 – 150	2 – 15
TSS	30 – 150	5 – 20
NO_3^-	0 – 2	15 – 30
NH_3	25 – 60	0 – 5
Total N	25 – 70	15 – 30
Fecal Coliform (MPN/100ml)	10^5 – 10^6	10 - 10^3

Table 2-2. Comparison of septic tank and sand filter effluent quality.

There will be a slight accumulation of solids on the surface of the sand that must be periodically removed and disposed of in an approved manner. If there is a large accumulation of solids on the surface of the sand, the pretreatment equipment (e.g. septic tank) should be inspected to determine if it is operating properly. If the septic tank does not have an effluent filter, one should be installed. With time accumulations of biomass and other particulate matter may build up near the filter surface to such a degree that the sand bed must be replaced to restore the hydraulic capacity of the filter to an acceptable level.

Sand filters can be installed either below or above ground. In addition, they can either be gravity-dosed or pressure-dosed, and can be single-pass or recirculating.

Below Ground Sand Filters

Buried or below ground sand filters are constructed below grade and covered with backfill material (Figures 2-16 and 2-17). A four to five foot deep excavation is generally made. The under-drains are surrounded by graded gravel or crushed rock and the upstream ends are brought to the surface and vented. A thin layer of fine gravel is commonly placed over the larger gravel to prevent infiltration of the fine filter sand into the under-drains.

After placement of the filter sand, another layer of washed graded gravel or crushed rock is laid over the filter surface along with the distribution piping for wastewater application. These pipes are vented to the ground surface at their downstream end. The entire filter is then backfilled. The disadvantage to these filters is that they are not accessible to the operator and no maintenance can be performed. These filters are usually dosed by a gravity dosing-type mechanism. Buried filters are commonly used for very small applications.

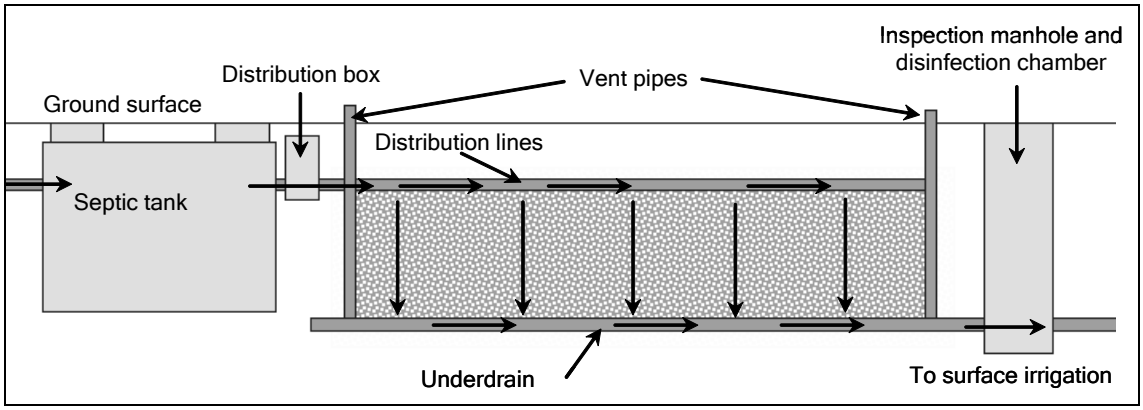

Figure 2-16. Profile view of a below ground sand filter.

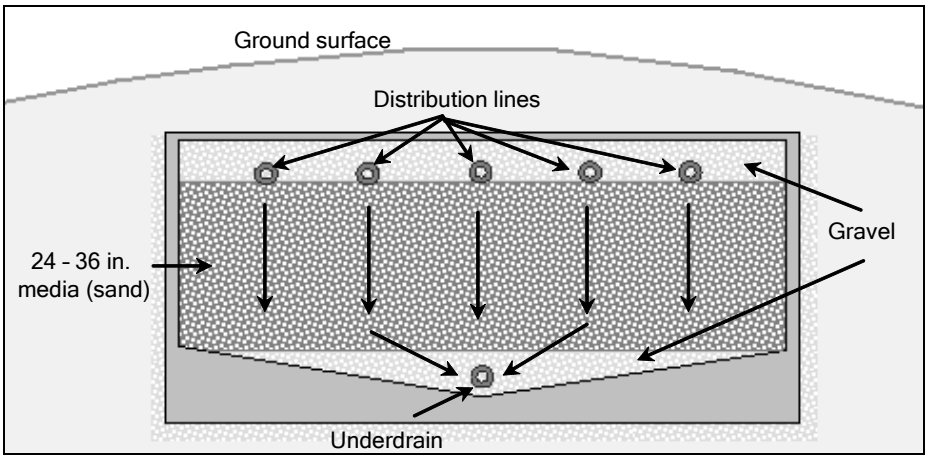

Figure 2-17. Cross-section of a typical below ground sand filter.

Above Ground Sand Filters

Above ground single pass sand filters are similar to buried sand filters except their surface is left exposed with open access for operation and maintenance (Figure 2-18). These filters usually have a higher organic and hydraulic loading rate than below ground filters. Above ground filters may be covered to prevent access by unauthorized personnel or to keep debris from accumulating on the sand. If covered, filters should be constructed to allow air to circulate through the filter to maintain aerobic conditions for biological activity.

Filters that are not covered should be fenced in to prevent unauthorized personnel from coming into contact with the non-disinfected wastewater. Wastewater can be applied to the surface of the filter by gravity, through a dosing bell assembly, or pressure-dosed by a pump mechanism. These filters are used for individual homes and flows from small communities, schools and industries.

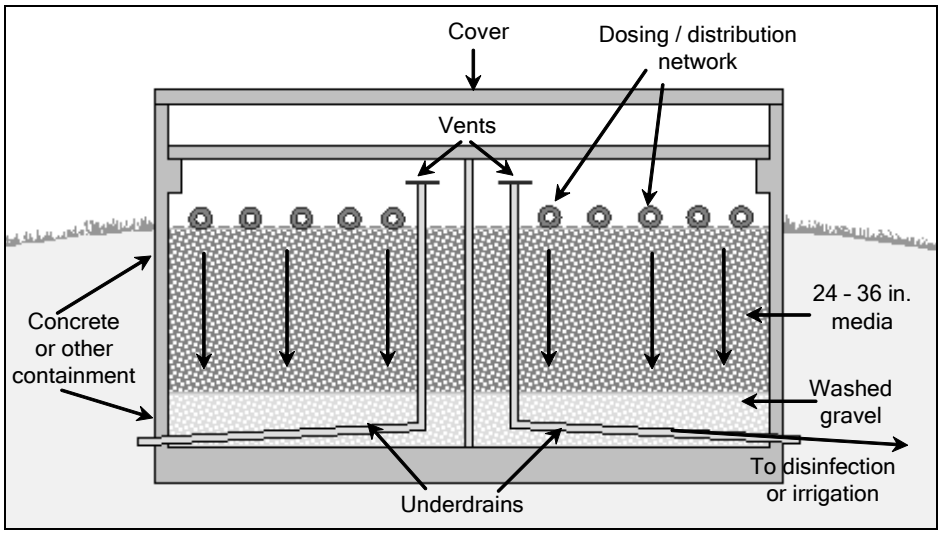

Figure 2-18. Above ground single pass sand filter.

Recirculating Sand Filters

As their name indicates, recirculating sand filters employ filtrate recirculation. A recirculation tank blends septic tank effluent and filtrate that has already passed through the filter (Figure 2-19). The filter is intermittently dosed with this mixture of septic tank effluent and filtrate. After every dose, a portion of the filtrate is returned to the tank for additional passes through the filter while a portion is diverted for final disposal

A recirculation rate of 3:1 to 5:1 is typical. Recirculating sand filters minimize odors and improve treatment efficiency as the result of more uniform loading cycles, decreased organic strength of septic tank effluent, and more frequent dosing. Because recirculating sand filters produce a higher quality effluent, DWR promotes their use for new installations and requires justification for installation of a sand filter that is not recirculating.

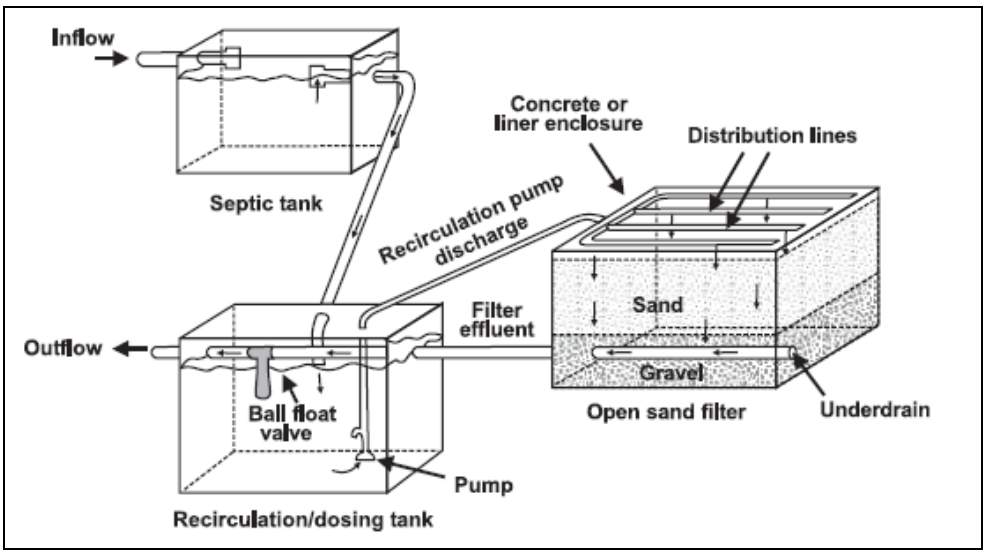

Figure 2-19. Recirculating sand filter system (from EPA Onsite Wastewater Treatment Systems Technology Fact Sheet 11: Recirculating Sand/Media Filters).

Sand Filter Performance

The degree of stabilization attained by a sand filter is dependent upon the characteristics of the wastewater applied to the filter and the environmental conditions within the filter. Since sand filtration is largely a biological process, the characteristics of the applied wastewater affect the treatment achieved. Domestic wastewater is very amenable to sand filtration, whereas wastewater resistant to biodegradation may result in poor performance.

Variables that affect the operation and performance of sand filters include:

- pretreatment;
- media size, uniformity and composition;
- media depth;
- hydraulic loading rate;
- organic loading rate;
- temperature; and
- dosing techniques and frequency.

Pretreatment

Sand filter performance is directly related to the degree of pretreatment achieved prior to the introduction of wastewater to the sand filter. Most of the solids must be removed to prevent clogging of the filter. Septic tanks are the most common pretreatment method for sand filters.

Operation and maintenance practices conducted on the septic tank will impact sand filter performance. If a septic tank is hydraulically overloaded, the design flow rate of the sand filter may be exceeded, leading to system failure. Studies have shown a direct relationship between degree of pretreatment and both hydraulic longevity and effluent quality of sand filter systems.

Media

The size, uniformity and depth of the granular media (sand) used in a sand filter have a large impact on its performance. The effective size (the grain size for which 10 percent of the particles are smaller) of the granular media affects the quality of wastewater that may be filtered, the rate of filtration, the penetration depth of particulate matter, and the quality of the filter effluent. Granular media that is too coarse lowers the wastewater retention time to a point where adequate biological treatment is not attained. Too fine a media limits the quantity of wastewater that may be successfully filtered due to early filter clogging and can keep oxygen from reaching certain parts of the media.

Effective size alone can be misleading when describing media size. Sand of similar effective size but different uniformity coefficients (the ratio of the size for which 60 percent of the particles are smaller to the size for which 10 percent are smaller) can produce significantly different performance characteristics. Each sand filter type has its own recommended media size. The Division of Water Resources accepts an effective size of 0.35 to 0.50 mm for fine filter sand and 0.8 to 1.5 mm for coarse filter sand. The Division requires a uniformity coefficient of 3 or less and a dust content of less than 0.5 percent.

Media depth depends on the type of filter and media used. Studies have shown that most treatment occurs within the top 9 to 12 inches of the bed. However, greater depth allows for better drainage, pathogen removal and maintenance. For these reasons most media depths used today range from 24 to 36 inches. Although the use of more shallow filter beds may lower installation costs, deeper beds tend to produce a more constant effluent quality, are not affected as severely by rainfall, and permit the removal of more media before media replacement becomes necessary.

Hydraulic Loading Rate

Hydraulic loading rates for sand filters are dependent on the specifications of the filter media, on whether or not the filter is buried or has free access, and whether the filter is single pass or recirculating. Organic loading rates and dosing patterns should also be taken into consideration.

Recommended loading rates vary throughout the literature and range from 0.75 to 5.0 gpd/ft^2. For filters whose media size ranges between 0.35 and 0.50 mm, whose media uniformity coefficient is less than 3.0, and whose media dust content is less than 0.5, DWR generally recommends the following hydraulic loading rates:

- above ground single pass filters: less than or equal to 3.4 gpd/ft^2;
- below ground single pass filters;
- vented: less than or equal to 2.44 gpd/ft^2;
- unvented: less than or equal to 1.44 gpd/ft^2; and
- recirculating: less than or equal to 5.0 gpd/ft^2 (with a minimum 3:1 recycle ratio).

Other recommended loading rates may also be accepted by the Division with supporting documentation.

Hydraulic overloading of a sand filter results in less efficient removal of pathogens and other wastes and in a shorter filter runs (the service time during which the filter successfully accepts and treats the design flow of the system). In all cases, the hydraulic loading rates specified in the system permit must be followed.

Organic Loading Rate

Sand filter performance is affected by the accumulation of organic material in the filter bed. An organic loading rate of less than 0.005 lbs BOD_5/ft^2/day is generally recommended. Like hydraulic overloading, organic overloading produces correspondingly shorter filter runs, reducing the filter's performance and increasing the need for maintenance. Hydraulic loading rates are often adjusted to account for differences in the organic loading rate.

Temperature

Temperature directly affects the rate of microbial growth, chemical reactions, adsorption mechanisms, and other factors that contribute to the stabilization of wastewater within the sand filter media. Treatment slows during colder temperatures and therefore organic and hydraulic loading rates and dosing frequencies must be lowered to maintain adequate treatment. Some research shows that filters started in warm weather significantly outperformed those started in cold weather with regards to hydraulic longevity as well as effluent quality.

Alkalinity

The amount of alkalinity present in the wastewater affects a sand filter's treatment efficiency. Normal nitrogen activity in the filter will cause a drop in the alkalinity present for the use by the biomass. Artificial feeding of alkalinity for pH adjustment to the septic tank and/or the dosing chamber effluent may assist the filter's biomass in the nitrification process. Several types of pH adjustment are available and the safety of the operator must be considered when choosing the best type. The pH at no time should be raised above 8.0. The common pH adjustment chemicals used for wastewater treatment are sodium bicarbonate, sodium hydroxide and lime. Liquid chemicals are easier to dose and maintain consistent pH than powdered chemicals.

Dosing Technique and Frequency

Dosing methods include drain tile distribution, low-pressure pipe, and spray distribution. The dosing

system used should provide uniform distribution of wastewater throughout the filter cross-section. Uneven distribution can result in sections of the filter becoming overloaded and result in inadequate treatment of wastewater.

Sufficient time must also be provided between doses to allow for drainage and reaeration of pore space. Availability of oxygen within the pores allows for aerobic decomposition of the wastewater and almost complete stabilization of substances that are readily biodegradable. Under aerobic conditions the major end products of biochemical stabilization of carbonaceous and nitrogenous substances are water, carbon dioxide, bicarbonates, sulfates, and nitrates. In the absence of oxygen, carbonaceous material may be converted to carbon dioxide and methane, but nitrogenous substances degrade only to ammonia and cannot be oxidized to nitrate.

The frequency of dosing is important to sand filter performance. Early studies used a dosing frequency of once per day, but better performance and treatment has been obtained with two doses per day on sands with effective sizes ranging form 0.25 to 0.45mm. Other studies have shown that dosing frequencies beyond two per day provide no additional benefit for fine to medium sand sizes.

For filters with media greater than about 0.45mm, better purification is obtained when the frequency of dosing is increased beyond twice per day. The coarser media retains less water, limiting the amount of wastewater that should be applied at one time. This multiple dosing concept is successfully used in recirculating sand filter systems that employ a dosing frequency of once every 30 minutes. In general, more frequent dosing can allow higher loading rates with no decrease in treatment efficiency and without accelerated clogging of the filter.

Sand Filter Operation and Maintenance

Intermittent sand filters require an operational strategy that requires attention by the operator. Once wastewater is first applied to the filter it takes time before the sand has matured. Biochemical Oxygen Demand (BOD) and Total Suspended Solids (TSS) concentrations in the effluent will normally drop rapidly after maturation. Depending upon the media size, rate of application, and ambient temperature, maturation may take from 2 weeks up to 6 months.

A sand filter should be raked at least once per week after removing any dried sludge crust from the surface of the filter. The removed crust must be disposed of in an approved manner. The raking performs several tasks that will assist the filter in treating the wastewater to its optimum performance. Raking allows the operator to break up the film of solids trapped on surface of the filter and levels the sand surface, allowing uniform distribution of wastewater. Raking also prevents weeds and grasses from gaining a foothold in the sand thus causing the wastewater to short-circuit by way of the root holes.

Efforts should be taken to prevent the accumulation of soil, clay, leaves, and trash on the sand filter. Such material, with the accumulation of wastewater solids, can lead to ponding. Ponding is a condition where wastewater accumulates on the surface of the filter due to the clogging of spaces between the sand grains. Ponding on the filter can indicate such problems as overloading, uneven distribution, the need for resting of the filter between doses and the need to remove the solids in the septic tank.

Excessive rainfall or runoff entering a sand filter increases hydraulic loading and reduces aeration. These sources of inflow should be diverted away from the filter. Distribution laterals should be flushed every 6 to 12 months to prevent solids accumulation. The performance of pumps, floats, timers and other appurtenances should be routinely checked. The area of the sand filter should always be left untrafficked and undisturbed to prevent both contact with non-disinfected wastewater and interference with sand filter performance.

Clogging of the filter eventually occurs as the pore spaces between the media grains begins to fill with inert and biological materials. The operational period before clogging occurs is a function of the design factors, the amount of wastewater being treated, and the characteristics of the wastewater being treated. Once hydraulic conductivity falls below the average hydraulic loading, permanent ponding occurs. Although effluent quality may not initially suffer, anaerobic conditions within the filter result in further rapid clogging and a cessation of nitrification. Application of wastewater to the filter should be discontinued when continuous ponding occurs.

Eventually, filter clogging requires media regeneration. Raking of the surface will not eliminate the need for more extensive rehabilitation. The removal of the top layer of sand, as well as replacement with clean sand when sand depths are significantly depleted, appears to be very effective for filters clogged primarily near the surface. Resting of the media for a period of months has proven effective in restoring filter hydraulic conductivity.

2.4 Disinfection

Disinfection is generally the last form of pre-application treatment prior to surface irrigation of wastewater. The purpose of wastewater effluent disinfection is to destroy disease-producing microorganisms or pathogens. As discussed in Chapter 1, pathogens can cause many illnesses such as typhoid fever, amoebic dysentery and infectious hepatitis.

It is important to note that wastewater disinfection is not the same as sterilization. Disinfection is the reduction of pathogenic microorganisms to a tolerable threshold, while sterilization is the destruction of all microorganisms. Fortunately, disinfection is effective because pathogenic organisms are more sensitive to destruction than nonpathogenic organisms.

The disinfection process should be economical, operationally practical and environmentally acceptable. The three major types of disinfection used are:

- chlorination;
- ultraviolet radiation; and
- ozone.

Chlorination

Because of its simple feed and control procedures, its ability to disinfect wastewater with low dosages and its relatively low cost, chlorination is the most prevalent form of disinfection in the United States today. However, heightened awareness of the safety issues and environmental concerns associated with chlorine use may decrease its popularity in the future.

Several forms of chlorine can be used in wastewater disinfection:

- liquid/gas chlorine (Cl_2) – available in pressurized containers that maintain chlorine in a liquid state;
- calcium hypochlorite ($Ca(OCl_2)$) – a white powder or tablet; and
- sodium hypochlorite (NaOCL) – a pale yellow solution in water.

Chlorine in either the gaseous or liquid state is considered to be 100% available chlorine for disinfection purposes. Calcium hypochlorite, purchased in powder or tablet form, generally contains approximately 65% or 70% available chlorine. Sodium hypochlorite is usually purchased as a solution containing approximately 15% available chlorine. (The manufacturer's label should contain this information.)

Chlorine reacts with many compounds present in wastewater. Nitrogen compounds (including ammonia) react with chlorine to produce chloramines. These chloramines are considered to be relatively

effective disinfectants. However, many of the compounds formed when chlorine reacts with non-nitrogen compounds are ineffective as disinfectants. Chlorine reacts with non-nitrogen compounds before it reacts with nitrogen compounds.

Enough chlorine must be added to react with the non-nitrogen compounds and ensure that there is enough chlorine still available for the formation of chloramines. Less chlorine is required to disinfect a higher quality effluent than a poorer quality effluent because there are fewer compounds with which the chlorine may react.

Chlorine dosage is the amount of chlorine that is added to a given volume of wastewater. Chlorine demand is the amount of chlorine that is not available as a disinfectant because of reactions with various compounds in the effluent. Chlorine residual is the amount of chlorine in the effluent that is available for disinfection after a specific contact time. A minimum chlorine residual must be maintained to ensure that enough chlorine has been added to meet all of the chlorine demand.

The relationship between chlorine dosage, chlorine demand, and chlorine residual can be expressed as follows (although this is true only if the chlorine dose is equal to or greater than the demand):

$$\text{Chlorine residual} = \text{Chlorine dose} - \text{Chlorine demand}$$

Measurement of chlorine residuals must be performed by approved methods. Amperometric titration provides the most convenient and most repeatable results, but is more expensive than other methods. A less expensive method is the DPD test.

Factors affecting the effectiveness of chlorination include:

- injection point and method of mixing;
- design of contact chambers;
- contact time;
- effectiveness of upstream treatment processes;
- temperature;
- dose rate and type of chemical;
- pH; and
- the number and types of organisms present in the effluent.

Chlorine contact chambers should be designed so that the chlorine injection point is below the surface of the effluent to prevent volatilization. Chambers should also be designed to prevent short-circuiting of effluent. Higher chlorine concentrations, longer contact times (chlorine contact basins should be designed for a minimum of 30 minutes of contact time) and higher temperatures increase the effectiveness of chlorination while higher pH (above 7.0), TSS and organic content decrease effectiveness.

Chlorine disinfection is generally accomplished by one of the following methods:

- gas chlorination;
- hypochlorination; and
- tablet chlorination.

Gaseous chlorine is usually delivered by a vacuum-solution feed chlorinator that creates a vacuum, pulling chlorine into the water supply. Because this type of chlorinator uses pure chlorine, which is toxic, the manufacturer's operation instructions must be carefully followed. You should never attempt to operate a gas chlorinator without first reading the manufacturer's operation manual.

Hypochlorinators (Figure 2-20) are pumps or devices used to feed chlorine solutions made from sodium or calcium hypochlorite. The basic components are a storage reservoir or mixing tank, a metering pump,

a feed-rate adjustment device, and an injection device.

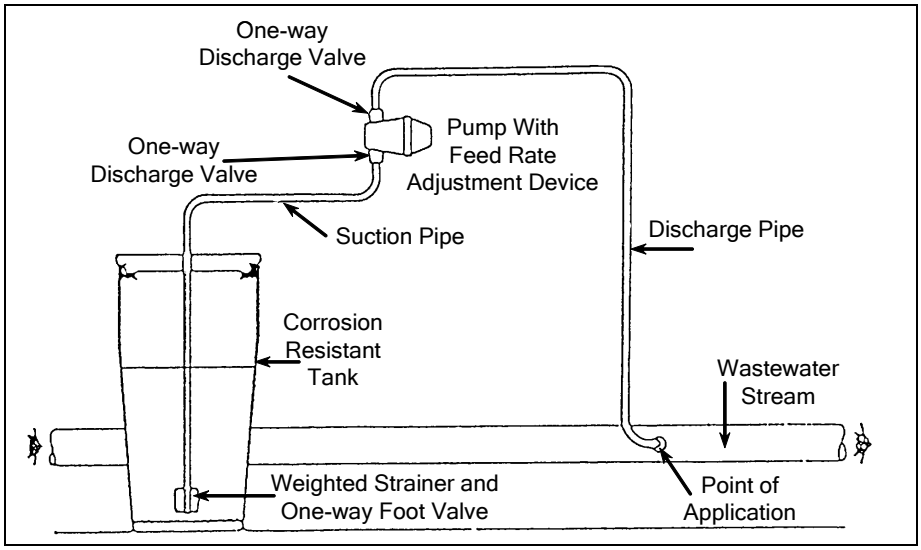

Figure 2-20. Schematic of a typical hypochlorinator.

Tablet chlorinators (Figure 2-21) use calcium hypochlorite tablets (around 70% available chlorine). The chlorinator has several slotted tubes where the tablets are placed in vertical stacks. As wastewater flows through the slotted tubes, the tablets dissolve in the effluent stream. Dosage is determined by the number of tubes containing tablets and the height of water in the chlorinator.

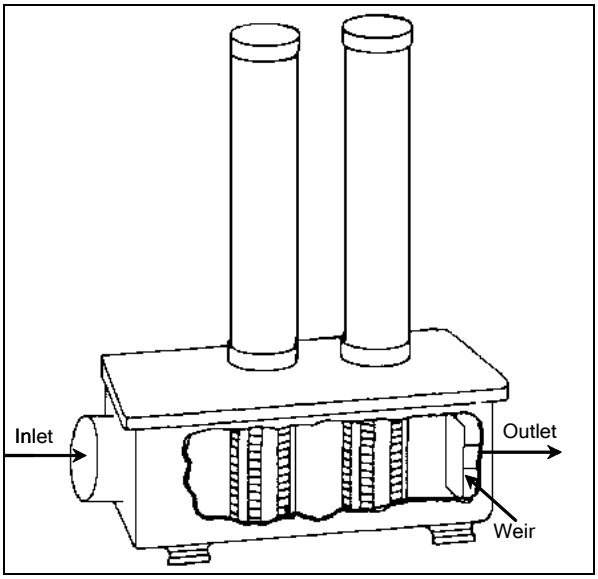

Figure 2-21. Tablet chlorinator.

Leak Detection and Chlorine Safety

Chlorine is a highly toxic gas and is corrosive in moist atmospheres. Because of the corrosive nature of chlorine, leaks should be repaired as quickly as possible to prevent a minor leak from becoming a major leak. Small leaks can be found by using a rag soaked with an ammonia solution. A "squeeze bottle" filled with ammonia water may also be used. The vapors from the cloth or squeezed from the bottle will form a white cloud to indicate a chlorine leak. Care must be taken to avoid spraying ammonia water on any leak or touching the ammonia-soaked cloth to any metal.

As mentioned earlier, chlorine reacts with water to form hypochlorous acid. If inhaled, chlorine gas is absorbed by moisture that coats the lungs and destroys cell tissue. Chlorine that comes into contact with skin can cause mild to severe burns. If chlorine comes into contact with skin or clothing, the affected body parts should be flushed with water for at least 15 minutes. Symptoms of chlorine exposure are:

- burning of the eyes, nose, mouth and throat;
- coughing and choking;
- nausea and vomiting; and
- headache and dizziness.

All enclosed areas which house chlorine cylinders or equipment should have operating leak detectors. These detectors should be located outside the enclosed area and their wiring should be checked regularly. Chlorine should never be stored near gasoline, oils or similar materials. Chlorine reacts violently with these substances. Water should never be applied to a chlorine leak, as the leak will only become larger. Do not store or use chlorine cylinders where they will be exposed to the sun.

When changing chlorine tanks, these minimum precautions must be followed:

- wear safety goggles, rubber gloves, and a long sleeved shirt;
- have two operators present: one to perform the work and one to assist should a leak develop; and
- allow only trained personnel to enter a contaminated area.

Always remember that chlorine is a hazardous chemical and must be handled with respect. Every person working with chlorine should know the proper ways to handle it, should be trained in the use of appropriate respiratory protective devices and methods of detecting hazards, and should know what to do in case of emergencies. All facilities that use chlorine should develop an emergency response plan. Emergency response plans will be covered in Chapter 5.

Note: The safety measures mentioned here are not all-inclusive and OSHA should be contacted regarding specific chlorine safety regulations.

Ultraviolet Radiation

Ultraviolet (UV) radiation uses lamps that emit wavelengths of light that are invisible to humans. Ultraviolet radiation kills bacteria and viruses in wastewater effluent by destroying their cellular genetic material, thereby preventing cell replication. Unlike chlorine, UV radiation leaves no residual in the wastewater and adds nothing except energy that produces some heat. Ultraviolet (UV) light is generally considered as an alternative to chlorine disinfection when the permit requires very low or no chlorine residual or because of safety concerns. A typical ultraviolet disinfection unit is shown in Figure 2-22.

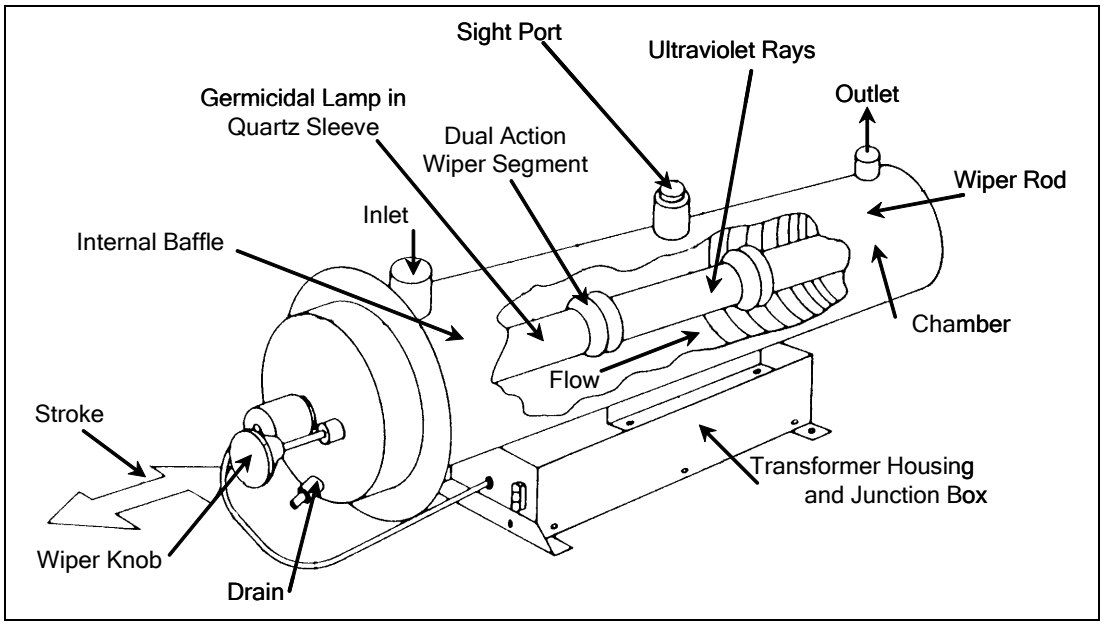

Figure 2-22. Ultraviolet radiation unit.

The advantages of UV disinfection are: there is no toxic residual, it is effective on a variety of microorganisms, UV equipment occupies little space, and is relatively inexpensive. The disadvantages of UV are the lack of a measurable residual (which makes immediate control of the process difficult), the lack of methods for measuring dosage and the need for a lower suspended solids and color concentration in order for it to be effective. For UV disinfection to be effective, wastewater must be relatively clean and clear, UV tubes must be kept submerged and cleaned periodically, and organisms must come into direct contact with the UV light.

Ozone Disinfection

Ozone is not widely used in wastewater disinfection. Ozone is an unstable gas that is produced when oxygen molecules are disassociated into atomic oxygen and then collide with another oxygen molecule. Like chlorine, ozone is a strong oxidizing agent and destroys microorganisms by attacking the cell walls.

Because it is chemically unstable and decomposes to oxygen very rapidly, ozone must be produced continuously and must be used as it is produced. Ozone is bubbled through the effluent in a closed contact chamber with fine bubble diffusers covering the bottom of the chamber. Contact time is generally around 5 minutes. Ozone is then collected off the top of the contact chamber and destroyed.

Ozone is a toxic chemical that can cause severe lasting effects with exposure of more than 1 mg/L. To be effective ozone disinfection requires high transfer efficiency, good mixing, adequate contact time and minimal short-circuiting in the contactor.

The advantages of using ozone as a disinfectant include the lack of a toxic residual, an increase in effluent dissolved oxygen levels, almost instantaneous disinfection action, and is relatively insensitive to pH. Disadvantages include higher capital and operational costs and a lack of reliable automatic control systems.

Chapter 3

The Natural Treatment System

3.1 Soils

The final treatment component of a surface irrigation system is the soil. Along with its associated vegetation, the soil functions as a natural treatment system for the renovation of wastewater. Because many of the constituents in wastewater are nutrients that can be used productively by plants and microorganisms, surface irrigation of wastewater can actually benefit the soil/plant system.

Soil Components

Soil is a porous mixture of:

- organic material (highly decomposed plant and animal material (humus);
- mineral material (weathered rock, sand, silt and clay); and
- pore space (water and air).

A medium-textured mineral soil contains around half soil solids (mineral and organic material) and around half pore space (air and water). The approximate volume occupied by each component in a medium-textured soil is approximately 45% mineral matter, 25% air, 25% water, and 5% organic matter (Figure 3-1).

The relative proportions of these components vary within any given soil and from soil to soil. The amount of pore space in a soil determines the volume of air or water that can occupy a given soil. The proportion of pore space occupied by air or water varies as rainfall or wastewater is added to and lost from a soil. The types and amounts of solids determine the physical and chemical filtering capacity of the soil. This filtering capacity makes soil an excellent medium for wastewater treatment.

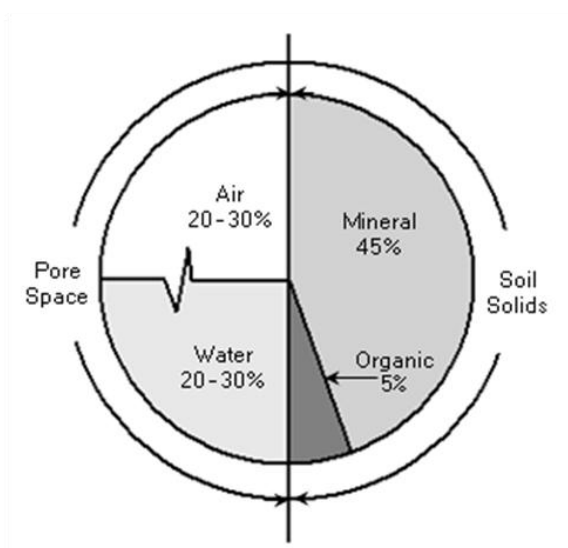

Figure 3-1. Composition of a medium-textured mineral soil.

Soil Profiles

The soil is a three-dimensional body resulting from the physical, chemical, and biological weathering of bedrock, or from the accumulation of materials weathered elsewhere and transported to a site. As soil develops on the landscape, distinct layers or bands are formed parallel to the earth's surface.

These layers or bands are called soil horizons. Soil horizons are soil layers that differ from the overlying and underlying layers in some property, such as color, clay content, abundance of cracks, etc. A soil profile is a vertical slice of the soil showing the different horizons and their thickness (Figure 3-2).

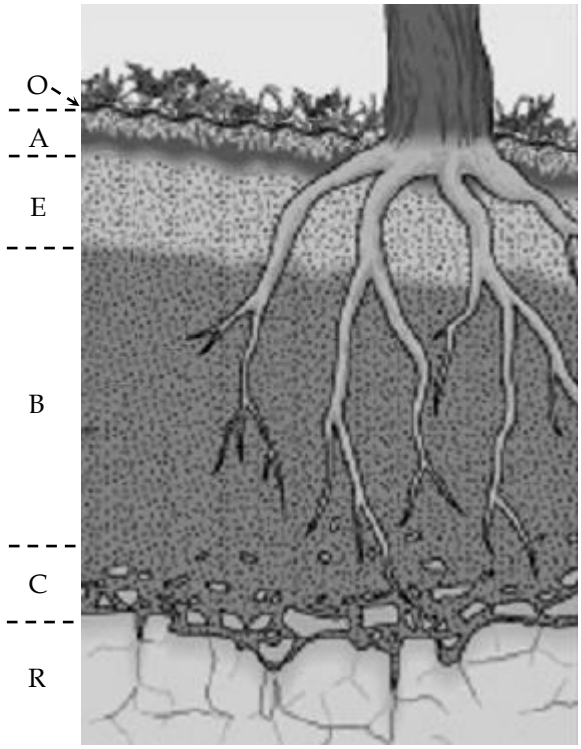

Figure 3-2. Soil profile typical of a NC Piedmont soil.

Master horizons are major layers designated by capital letters such as O, A, E, B, C, and R:

O Horizon: The O horizon is dominated by organic material from plants and animals. It is usually present on the soil surface except in the case of peats and mucks, where the O horizon extends almost to the bottom of the soil.

A Horizon: The A horizon occurs at the soil surface or just below the O horizon. It is a mixture of organic and mineral material. Properties of an A horizon reflect plowing, pasturing or similar activities. It is the zone of maximum biological activity in a soil.

E Horizon: The major characteristic of the E horizon is loss of clay, iron, and aluminum oxides by leaching. Sand and silt-sized particles of resistant minerals, such as quartz, remain. It is usually lighter in color than the overlying A horizon.

B Horizon: The B horizon is a layer of accumulation of clay, iron, and aluminum oxides that have migrated from overlying E horizon. It is the zone of maximum chemical activity in the soil.

C Horizon: The C horizon consists of unconsolidated, partially weathered material that is neither rock nor soil. Little to no biological activity takes place in this horizon. The upper portion may become part of the B horizon as weathering continues.

R Horizon: This layer consists of underlying bedrock. It may not occur in coastal plain soils or other soils formed in transported material, such as flood plains.

Soil profiles with similar characteristics or properties are classified as a soil series. A soil series includes soil that has developed from similar materials and processes resulting in similar soil profiles. Because soil profiles vary so widely from place to place, many different soil series have been identified (in fact there are approximately 17,000 soil series in the United States alone). The characteristics of the soil series present at a proposed treatment site will determine if the site is suitable for the application of wastewater.

Soil Physical and Chemical Characteristics

There are a number of physical and chemical soil characteristics that affect wastewater treatment at a surface irrigation site. While some of these characteristics can be altered, others cannot.

Physical characteristics include:

- soil texture;
- soil structure;
- organic matter content;
- soil depth;
- soil color;
- soil drainage/wetness; and
- topography and landscape position.

Soil Texture

The mineral particles in a soil are divided by size into three groups: sand, silt and clay (Figure 3-3).

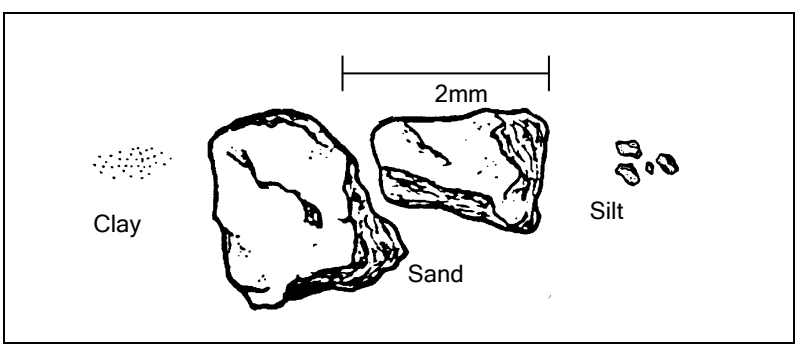

Figure 3-3. Comparative sizes and shapes of sand, silt, and clay-sized particles.

Soil texture refers to the relative proportion of sand, silt, and clay in a given soil. The diameters and characteristics of these soil particles are described in Table 3-1.

Particle Type	Particle Size	General Characteristics
Sand	2.0 - 0.05 mm	Individual grains visible to the eye, gritty when soil is rubbed between the thumb and fingers.
Silt	0.05 - 0.002 mm	Smooth and baby-powder feel when rubbed between the thumb and fingers. Not plastic or sticky when moist.
Clay	<0.002 mm	Smooth, sticky and plastic feel when moist. Forms very hard clods when dry. Particles may remain suspended in water for extended periods of time.

Table 3-1. Size and general characteristics of the three soil particle sizes.

The United States Department of Agriculture (USDA) currently recognizes twelve distinct textures or textural classes, as shown in the USDA Soil Textural Triangle (Figure 3-4). The three sides of the triangle are broken into percentage units (0 - 100%) of sand, silt and clay. To use the triangle, you first locate the percentage of clay and project inward as shown by the arrow. Do likewise for the percent silt (or sand). The point at which the two projections intersect identifies the textural class name.

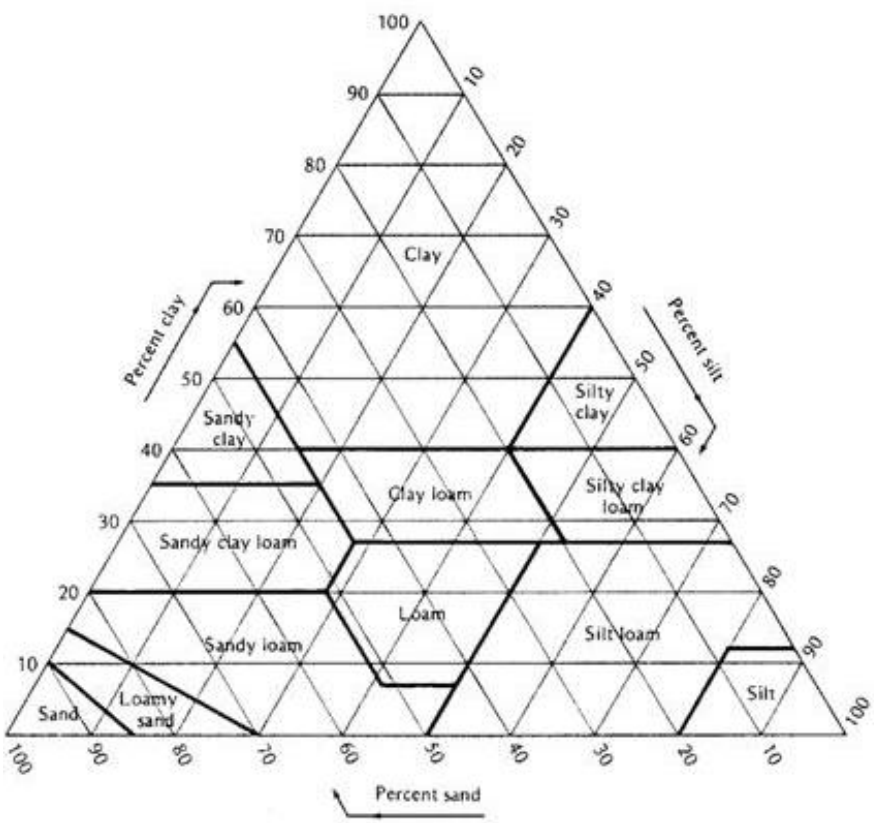

Figure 3-4. The USDA soil textural triangle showing the percentages of sand, silt, and clay in the basic textural classes.

Four of the textural classes are considered to be major groups: sand, silt, clay, and loam. Note that all of the textural classes contain some sand, silt or clay. For example, a soil containing over 55% clay-sized particles is considered a clay soil regardless of the fact that it also contains significant

proportions of silt- and sand-sized particles. The remaining eight textural classes are combinations of two or three of the major groups.

A textural class can consist of one, two, or three names. Classes with two or three names, such as sandy loam or sandy clay loam, fall in between the major groups. The last word in the name always represents one of the four major groups. The first or the first and second words are modifiers that tell where the soil texture lies on the triangle relative to the other major groups.

For example, a sandy loam is a loam that is sandy. It lies on the side of the loam nearest the sand group. By keeping the four main groups of the textural triangle in mind, the modifiers can be used to judge where the textural class of a material lies in relation to the four major groups. With this in mind, answers to questions such as "What contains more sand, a sandy loam or a loamy sand?" should be obvious.

Texture can be determined in a laboratory using either sieve or hydrometer analysis. Sieve analysis is based on physical passage of soil particles through a series of standard mesh screens, while hydrometer analysis is based on variations in settling time for the different soil particle sizes. Texture can also be determined in the field by using the "feel method" (Figure 3-5).

Texture is an important soil characteristic because it strongly influences the retention of water, nutrients and pollutants. Coarsely-textured soils, such as sands and loamy sands, have large spaces (macropores) between their soil particles. Water and air pass through these macropores rapidly. Therefore, coarsely-textured soils are usually well-aerated and well-drained.

However, wastewater often passes through these soils too quickly for significant treatment to occur. In addition, these soils may not hold sufficient water and nutrients to support a healthy vegetative cover. A poor vegetative cover can result in an increased potential for erosion and reduced uptake of water, nutrients and pollutants.

Finely-textured soils such as clays, sandy clays, and silty clays have smaller spaces (micropores) between soil particles. Due to cohesive and adhesive forces, micropores hold water, nutrients and pollutants more tightly than macropores. Therefore, water tends to move into and through finely-textured soils more slowly.

Wastewater may pond on the soil surface, causing runoff. If a sandy soil horizon is underlain by a clayey horizon, wastewater may move into the sandy surface horizon but not through the clayey subsoil. Wastewater may “perch” on top of the clayey horizon and move laterally, emerging downslope and causing runoff.

Therefore, when evaluating a soil for wastewater application, the texture of all the horizons needs to be considered. Water movement, wastewater treatment and plant rooting patterns are often influenced by several horizons. Many problems associated with wastewater application can be predicated by determining soil textures throughout the profile.

Because texture of a soil horizon is the relative proportion of sand, silt, and clay, it may be changed only through the addition of one of these soil separates. The addition of organic matter will not change the soil texture but may change the way the soil feels. It is common for people working in greenhouses or small garden plots to change the texture of their soil. However, modification of soil texture is not practical on a large scale.

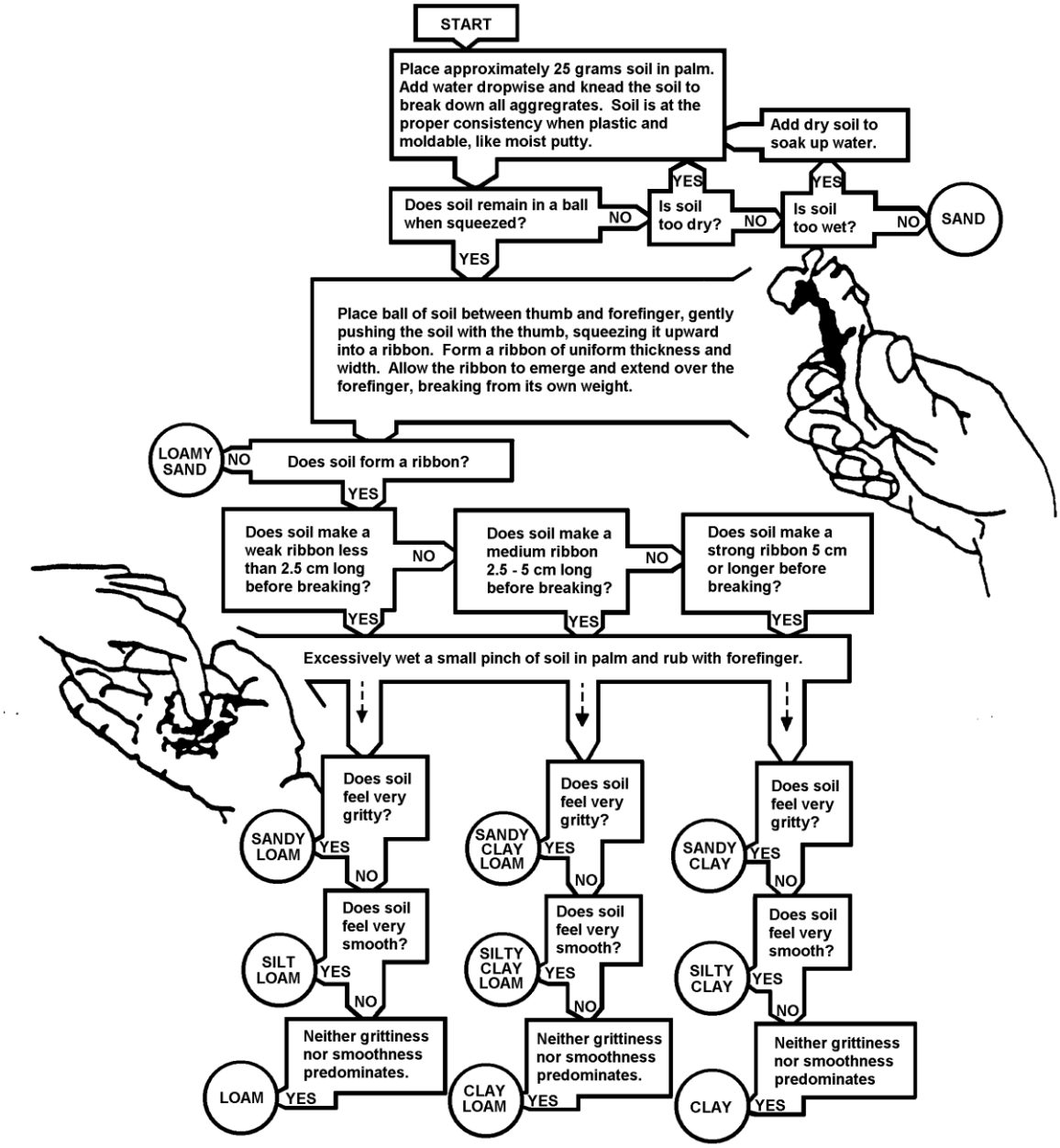

Figure 3-5. Flow chart for determining soil textural class by "feel".

Soil Structure

Along with soil texture, soil structure is one of principle factors that influences the rate of water movement. Soil structure refers to the arrangement of individual soil particles (sand, silt, and clay) into more complex aggregates or "peds". These peds can be separated from each other along natural planes, zones or surfaces of weakness into distinct units. These units may be granular, blocky, subangular blocky, columnar, prismatic, or platy (Figure 3-6).

Soils that do not form structural units, such as very sandy soils, are considered structureless. Soils that do not naturally separate into structural units, such as very sticky clayey soils, are considered to have massive structure. Granular structure is often present in the A and E horizons while other types of structure are generally found in the lower horizons.

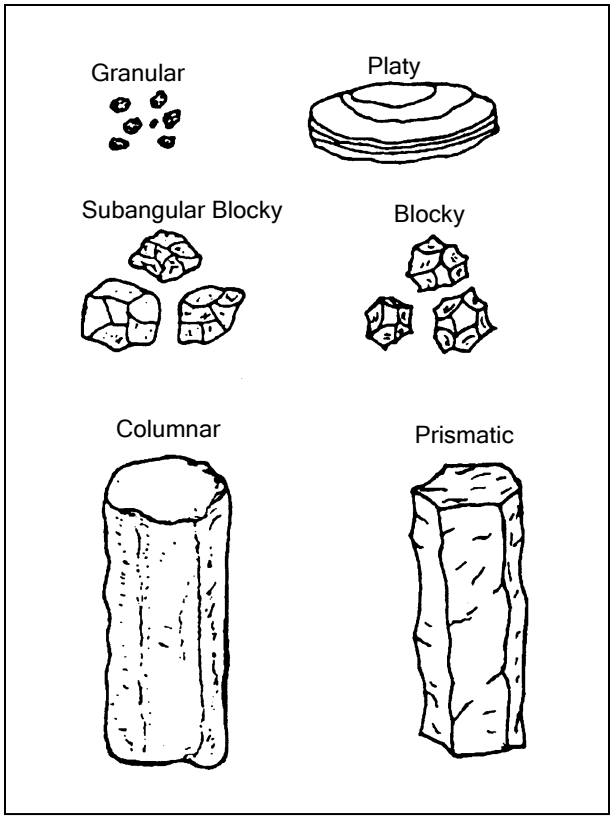

Figure 3-6. Structural units found in mineral soils.

Soil structure affects water movement both into and through the soil. Because water moves primarily between peds, soil structure can modify the influence of soil texture on water movement. As just discussed, water movement in finely-textured soils can be very slow. However, clayey soils with well-developed blocky and subangular blocky structure can transmit reasonably large volumes of water between peds, even though these soils are finely-textured.

In finely-textured soils with massive structure (the clay is so sticky that individual peds do not form), water movement can be expected to be slow and restricted. Water movement can also be slow in soils with some platy, prismatic, or columnar structure.

Unlike texture, structure can be easily altered by management practices. Additions of organic matter can improve soil structure by acting as a binding agent for soil particles. Unfortunately, however, changes in soil structure are usually negative. If finely-textured soils are traveled with heavy equipment, tilled, or otherwise worked when wet, soil aggregates are destroyed and macropores disappear, resulting in soil compaction. In this condition, water and air cannot move through the soil. Even after the soil dries, structure remains destroyed. It is very important to keep heavy equipment off surface irrigation fields when wet to avoid compacting the soil.

Organic Matter Content

Soil organic matter (humus) is composed of decomposing plant and animals and waste materials produced by soil microorganisms. The organic matter content of most mineral soils is generally less than five percent. However, organic matter serves several important functions in soil/plant treatment systems:

1. Organic matter promotes soil structure formation in finer-textured soils. Good soil structure aids water movement in soil by increasing the pore space.

2. In sandy soils, organic matter helps fill larger pores and increases the soil's ability to hold water, nutrients, and pollutants, thus increasing its treatment potential.

3. Organic matter is a food source for soil microorganisms. Microbial activity, in turn, produces waste products that promote soil structure formation.

Organic matter contains several plant nutrients, particularly nitrogen, phosphorus, and sulfur. As organic matter decays, these nutrients become available for use by plants and microorganisms. Organic matter has a high negative charge, which increases a soil's ability to retain water, nutrients, and pollutants.

Soil Depth

Soil depth refers to the thickness of the soil horizons, from the soil surface to a depth that restricts plant root growth or otherwise limits biological activity. This limiting depth is often caused by a restrictive horizon in the soil. A restrictive horizon could be a seasonal or permanent water table, a layer of gravel, weathered or unweathered bedrock, a chemical change, or a soil structural change that limits the depth of biological activity. Soil depth is a soil characteristic that cannot be modified or altered.

Soil depth is important because:

- it determines the volume of soil that is available for the treatment of waste; and
- it affects the type of plants that can be grown on the site.

Soil Color

Soil color is an indicator characteristic that is used to predict soil/water relationships in a soil profile. Soil color is an extremely useful tool when evaluating a site for suitability as a waste treatment system.

Soils that are well drained typically have rather bright colors due to oxidized or ferric iron (Fe^{+3}). Ferric iron imparts a reddish/orange color to the soil. When soil drainage is impeded and the soil is saturated, the ferric iron contained in the soil is chemically reduced to ferrous iron (Fe^{+2}). Ferrous iron is soluble in water and as the water table recedes, this soluble iron is removed, leaving behind soil that is gray in color.

As the water table rises and falls, a characteristic pattern called mottling usually develops. Mottled soils generally contain bright orange and red areas mixed with light gray areas. These mottle patterns are impressed upon the original background or matrix color of the soil.

The presence or absence of gray mottles or color in a soil is an indication of the wetness or aeration status of the soil. Bright uniform colors indicate that a soil is well drained and that a seasonal high water table is not present for a significant time during the year. The presence of light grayish mottles usually indicates a high water table or poorly drained soil. The depth to gray colors can be used to define the drainage class of a soil and indicate the depth of the seasonal high water table.

Soil Drainage/Wetness

Soil drainage or wetness refers to the depth of the water table and to the period of time a particular part of the soil profile is saturated. A soil may be classified as well drained, moderately well drained, somewhat poorly drained, poorly drained, or very poorly drained.

Poorly drained soils have a water table at or within 12 inches of the soil surface for most of the year. Well drained soils have a water table depth of 60 inches or more during much of the year.

The drainage class of a soil can usually be determined by observing both the color patterns of the soil profile and the soil's relative position on the landscape. Poorly drained and very poorly drained soils are not generally considered suitable for the surface irrigation of wastewater for several reasons:

- wet soils do not provide adequate treatment capacity and waste constituents may move directly to groundwater;
- seasonally wet soils may limit the type of plants that can be grown on the site and can impact the quality of the vegetative cover; and
- wet soils are subject to compaction by equipment traffic that destroys soil structure and reduces the infiltrative capacity of a site.

The drainage class of a soil refers to water table depth, not permeability (which will be discussed later in this chapter). Consequently, even though a soil might be coarsely-textured and relatively easily drained, a high water table due to landscape position can render the soil poorly drained. If an outlet or a drainage system is provided for soil water, then this poorly drained sandy soil may be modified. However, installing any type of drainage way or drainage system at a surface irrigation site is not recommended since it could be a violation of the system's permit conditions.

Topography and Landscape Position

Topography refers to the configuration of the land surface and is usually defined by the slope of the land (steepness) and the landscape position. Landscape position refers to a specific "setting" on the landscape.

Examples of landscape positions are:

- upland or ridgetop;
- sideslope;
- shoulder slope;
- footslope;
- depression ; and
- floodplain.

The topography and landscape position of a site are important because they influence the types of soils that may be present, the respective depth of those soils, and the water movement characteristics of the site. Slope considerations also dictate how a site can be managed and whether surface irrigation applications are even possible.

Steep slopes encourage runoff and erosion, while nearly level sites may encourage seasonal high water tables. Landscape position influences surface water removal as well as groundwater flow. Figure 3-7 shows cross-sectional and plan views of different landscape positions.

In foot slope and head slope positions, surface water converges with a corresponding increase in groundwater flow. These are the positions at which you might expect to find springs or seeps of water coming out of the ground. Since these sites accumulate water, they are often saturated. Additional flow from wastewater irrigation will compound the problems on these areas. Such areas may need reduced loading rates, or may be excluded from surface irrigation.

The landscape positions called ridge, shoulder, and nose slope are typically the best suited for wastewater treatment. These positions shed water in a divergent manner, so that flow is not concentrated. This results in better infiltration and less runoff and saturation potential.

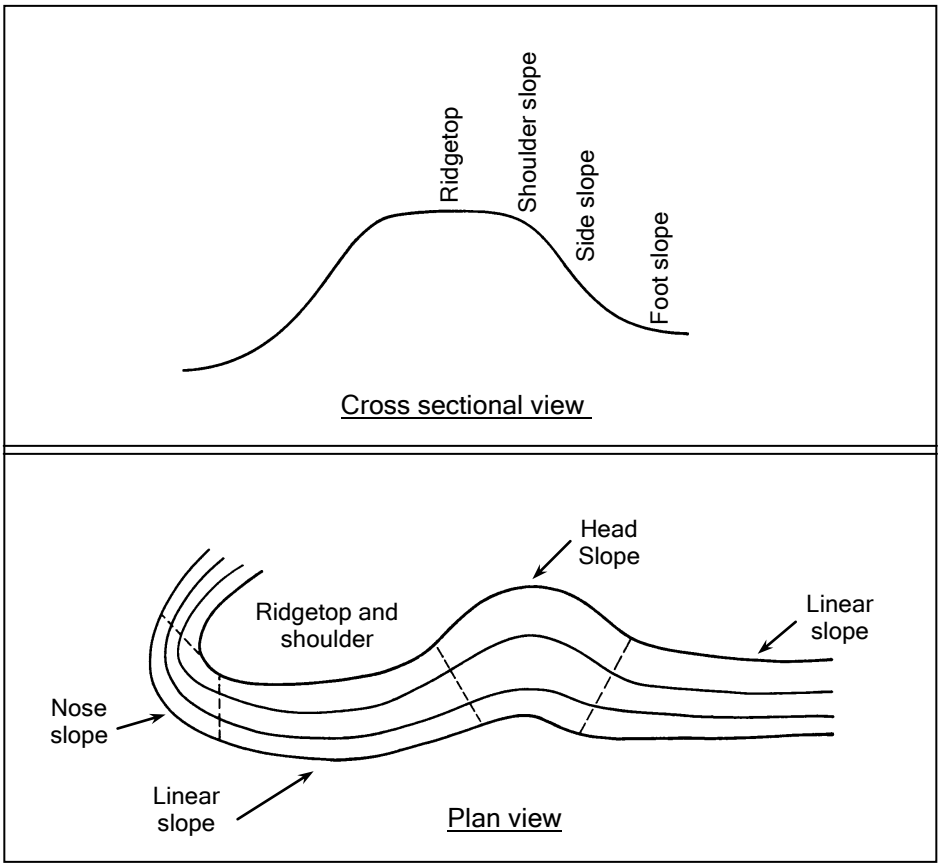

Figure 3-7. Cross sectional and plan view of various landscape positions. (From Soil Systems in NC).

On a small scale, microtopography refers to minor variations across a landscape. A localized circumstance such as a rock outcropping or wet depressional area may require buffers, but often may not be extensive enough to rule out the usefulness of an entire site. Detailed site evaluations should define the topography and discuss any limitations of the site that are a function of topography.

Infiltration

Infiltration is the movement of water *into* the soil. Infiltration rate is the maximum rate at which water enters the soil and is expressed in "inches per hour". Infiltration rate is a function of:

- soil texture;
- soil structure;
- soil moisture;
- vegetative cover; and
- topography and landscape position.

The effects of texture and structure on water movement have already been discussed. The more moisture a soil contains, the lower its infiltration rate will be. Infiltration rates decrease with the duration of rain or irrigation and increasing soil moisture. When the soil is completely saturated, the infiltration rate will be quite low.

A vegetative cover protects soil structure and increases infiltration rates. Without a cover, water falling on or flowing over the soil destroys the soil's structure, resulting in an impervious surface crust. Level or gently sloping soils will have a higher infiltration rate than steeply sloping soils, which promote runoff.

Therefore, a dry sandy soil on a level slope with a good vegetative cover would be expected to have a high infiltration capacity, whereas a wet finely-textured surface soil on a sparsely covered steep slope would be expected to have a low infiltration capacity and to promote runoff.

Permeability

Permeability refers to the movement of water *through* soil. Permeability is also expressed in "inches per hour". Soil texture and structure are the factors that most strongly influence permeability. Generally, finely-textured soils have slower permeabilities than coarsely-textured soils. Permeability may also be called hydraulic conductivity. Hydraulic conductivities can be measured as saturated or unsaturated, and measurement devices are available for field or laboratory use. Values for various soil permeabilities can also be found in Natural Resources Conservation Service interpretation sheets or county soil surveys.

Cation Exchange Capacity

Cation exchange capacity is a chemical characteristic of the soil. Clay-sized mineral particles and organic matter particles are both extremely small. Because of their small size, these particles expose a large external surface per unit mass.

Put another way, their surface area to volume ratio is very large. In fact, the external surface area of one gram of clay is at least 1000 times that of one gram of coarse sand. Therefore, it is not surprising that these mineral and organic particles, called colloids, account for essentially all of the chemical reactivity of soils.

Mineral colloids are crystalline in nature and consist primarily of alumino-silicate clays and oxides and hydroxides of aluminum and iron. Organic colloids (humus) are composed of highly decomposed residues of plant and animal remains. Instead of silica and aluminum, organic colloids are composed of carbon, hydrogen, and oxygen, along with minor amounts of nitrogen, phosphorus, sulfur and other elements.

Mineral and organic colloids carry both positive and negative electrical charges. In North Carolina soils, negative charges greatly exceed positive charges, resulting in a net negative charge on soil colloids.

The charge and surface area of organic colloids greatly exceed that of mineral colloids. Organic colloids often contribute 30 to 90 percent of the total charge present in surface soils, even when present in relatively low amounts. The charged surfaces of all colloids are extremely important because of their ability to attract and repel both nutrients and waste constituents.

Ions are atoms, groups of atoms, or compounds that are electrically charged as a result of the loss or gain of electrons. Cations are ions that have lost electrons and are therefore positively charged. Anions are ions that have gained electrons and are therefore negatively charged. Soil colloids act like magnets, attracting and retaining anions and cations against the downward movement of water through the soil profile.

The chemical attraction of cations and anions to soil colloid surfaces is called adsorption (not to be confused with absorption, which is the process by which ions are taken into plant roots). Since

soil colloids in North Carolina have a net negative charge, they generally attract significantly more cations than anions (Figure 3-8).

Soil colloids are therefore generally surrounded by a swarm of adsorbed cations. The capacity of a soil to retain cations such as ammonium (NH_4^+), potassium (K^+), calcium (Ca^{2+}), magnesium (Mg^{2+}), zinc (Zn^{2+}), and copper (Cu^{2+}) increases with increasing negative charge of the soil colloids.

These adsorbed cations are also called exchangeable cations because they are subject to exchange with cations that are present in the soil solution (water or wastewater moving through the soil). For example, a calcium ion (Ca^{2+}) adsorbed to a soil colloid can be replaced by two hydrogen ions (H^+) that are present in the soil solution. The cations forced into the soil solution by this exchange can then used as nutrients by plants and microorganisms. If not assimilated by plants or microorganisms, these cations can leach or percolate downward to groundwater.

The sum total of the exchangeable cations that a soil can adsorb is called the cation exchange capacity (CEC) of that soil. Cation exchange capacity is expressed in units of milliequivalents per 100 grams of soil (meq/100g). The CEC of a soil is related to its texture, clay mineralogy, organic matter content and pH.

Sandy soils have lower CECs than clay soils because sandy soils contain fewer colloidal particles than clay soils. As mentioned earlier, different types of clays have different structures and are able to adsorb different amounts of ions, thus affecting their CEC values. Soils with higher organic matter contents generally have higher CECs. The effect of pH on CEC values will be discussed in the next section.

Soils with high cation exchange capacities are able to adsorb more cations. They are better able to buffer or avoid rapid changes in levels of these cations or nutrients in the soil solution by replacing them as the soil solution becomes depleted of cations. Therefore, CEC values greatly influence the inherent fertility and long-term productivity of a soil. These values should be integrated with other site-related features to determine overall site suitability and application rates for surface irrigation.

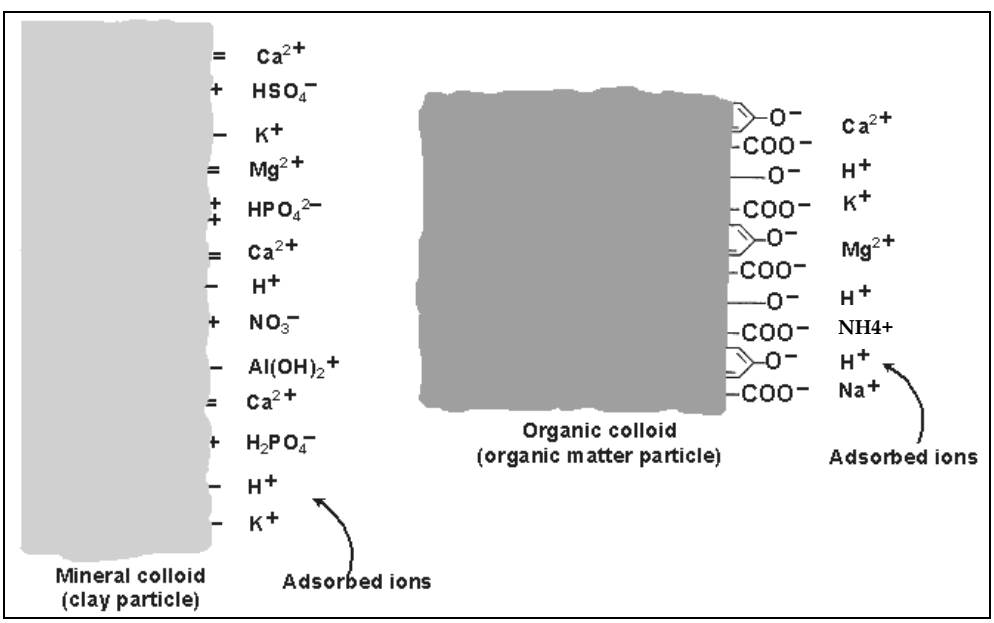

Figure 3-8. Mineral and organic colloids with adsorbed ions. (From The Nature and Properties of Soils).

Variations in the types of clays (clay mineralogy) may also be a factor in the soil's ability to treat wastes. Different types of clays have different structures that determine how the clay particles will absorb water and minerals. Expansive clays (also called shrink/swell clays or 2:1 clays), have a large internal surface area, resulting in a higher net negative charge than other types of clay particles. Therefore, these clays may hold a higher volume of waste constituents. However, they are subject to more wetness and site workability problems and generally are less suitable for waste treatment.

pH

pH is another chemical characteristic of the soil. As discussed in Chapter One, pH is the measure of the concentration of the hydrogen ions in a solution and indicates whether a soil is acidic, alkaline, or neutral. pH is a critical soil property because it influences many of the chemical and biological reactions that take place in the soil.

Nearly all soils in the southeast are acidic. These soils were acidified over thousands of years by the natural processes of leaching, inputs of acids from atmospheric sources (carbonic, sulfuric, and nitric acid), acid plant exudates, and decay of plant and animal residues.

The CEC of a soil is directly influenced by its pH. When the pH is below 6.0, the charge on a mineral colloid is relatively constant. However, a portion of the charge is pH dependent and increases when the pH is 6.0 or higher. The charge on organic colloids is almost completely pH dependent. Therefore, the CEC of most soils increases with an increase in pH.

Soil pH also influences the solubility of heavy metals and other nutrient cations and affects the ability of plants to uptake these metals and nutrients. Soils that are very acid (pH of less than 5.5) are more likely to release metals. Plant uptake of these metals is prevented and the potential for metals to move into the groundwater is increased. Soil pH is important for maximizing crop use of other available nutrients. Mineral soils with a pH near 6.0 are generally the most efficient providers of plant nutrients.

The bacteria that perform wastewater treatment in the soil are also strongly affected by soil pH. These bacteria prefer a pH of neutral (or 7) for best performance. Any rapid increase or decrease in pH can cause mortality in the bacteria population, resulting in poor wastewater treatment.

Soil pH must be determined by laboratory analysis, although tools used to estimate pH in the field can be useful for general guidance. Soil pH is not a constant and can be changed with soil amendments. A typical soil amendment used to raise the pH is calcium carbonate (limestone), although many other possibilities exist.

3.2 Agronomy – The Role of Plants

Plants are an integral part of the natural treatment system. It is important, therefore, that operators have a basic understanding of agronomy. Agronomy is the study of the various physical and biological factors related to crop production.

While the production of crops is not the primary concern of a surface irrigation system operator, a healthy vegetative cover is essential for the natural treatment system to function properly.

Important functions that plants perform include:

- take up nutrients;

- take up water;
- stabilize soil and prevent erosion; and
- provide food and habitat for soil organisms that break down and use waste constituents.

Plant Nutrients

Although many factors affect the growth of plants, one that an operator has a great deal of control over is the supply of essential nutrients. Plants require at least 16 elements for normal growth and for completion of their life cycle. Carbon, hydrogen and oxygen are those used in the largest amounts. These are non-mineral elements that are supplied by air and water. Plants must obtain the other 13 elements from the soil or from amendments added to the soil (fertilizers or wastewater).

Plants need relatively large amounts of nitrogen, phosphorus, and potassium. These nutrients are the ones most frequently supplied to plants by fertilizers. Calcium, magnesium, and sulfur are required in somewhat smaller amounts. These six elements, along with carbon, hydrogen and oxygen, are considered macronutrients.

The micronutrients consist of seven essential elements: boron, copper, chlorine, iron, manganese, molybdenum, and zinc. These elements occur in very small amounts in both soils and plants, but their role is equally as important as the macronutrients. A deficiency of one or more of the micronutrients can result in severe reductions in growth, yield, and crop quality.

Some soils do not contain sufficient amounts of these nutrients to meet the plant's requirements for rapid growth and good production. In such cases, supplemental micronutrient applications in the form of commercial fertilizers or foliar sprays must be made. Table 3-2 lists the macro- and micronutrients required for plant growth.
Included in this group are eight metals: cadmium, chromium, copper, lead, mercury, molybdenum, nickel, and zinc. In addition to these metals, two non-metals, arsenic and selenium, are also included in EPA's pollutant concentration list. These two elements are often inaccurately included or referred to as heavy metals.

The heavy metals contain three micronutrients, copper, molybdenum and zinc, all of which are required for plant growth. It may seem like a contradiction for an element to be an essential nutrient on the one hand and be considered toxic or a pollutant on the other. At low concentrations these elements are required for growth, but at higher levels they can become toxic. It is important for operators to understand this difference in order prevent too much of a good thing from becoming a problem.

While the use of the term micronutrient has been common in agricultural circles for some time, the use of the term heavy metal is becoming more common because of environmental concerns. Heavy metals are a group of elements that are associated with industrial and municipal wastewater residuals. At certain levels or concentrations, these elements pose toxicity problems to plants and animals.

Nutrient Availability

All essential nutrients must be available, continuously and in balanced proportions, to support photosynthesis and other metabolic processes of plants. If any one of these essential elements is missing, plant productivity will be limited, or the plant may cease to grow entirely. The principle of limiting factors, which states that the level of production can be no greater than that allowed by the most limiting of the essential plant growth factors, applies in both cropping systems and in natural ecosystems.

Although the soil contains large amounts of nutrients, only a very small percentage of these amounts exist in chemical forms that are available to plants. Nutrients can exist in several forms in the soil. When they occur in organic form or as part of an insoluble compound, nutrients are not available to plants.

Nutrient	Chemical Symbol	Macro/Micro
Nitrogen	N	Macronutrient (Primary)
Phosphorus	P	Macronutrient (Primary)
Potassium	K	Macronutrient (Primary)
Calcium	Ca	Macronutrient (Secondary)
Magnesium	Mg	Macronutrient (Secondary)
Sulfur	S	Macronutrient (Secondary)
Iron	Fe	Micronutrient
Manganese	Mn	Micronutrient
Boron	B	Micronutrient
Molybdenum	Mo	Micronutrient
Copper	Cu	Micronutrient
Zinc	Zn	Micronutrient
Chlorine	Cl	Micronutrient

Table 3-2. Essential macro- and micronutrients.

Generally, plants can only absorb nutrients when they are in the form of an ion. Remember from our earlier discussion that ions are elements or groups of elements that are electrically charged as a result of having lost or gained an electron. For example, soil nitrogen occurs in organic and inorganic forms, in solution and as a gas, and as the cation ammonium (NH_4^+) and the anion nitrate (NO_3^-). Plant roots absorb only ammonium and nitrate forms of nitrogen.

Plant-available forms of potassium, calcium, magnesium, manganese, zinc, iron and copper occur as cations. Potassium and ammonium both have a single positive charge, while the remaining cations have two or more positive charges. In general, these positively charged nutrients are adsorbed onto soil colloids and are not subject to leaching under normal conditions. The higher the charge of a cation, the more strongly it is attracted to the negative charge sites of the soil. However, when the sum of the positively charged nutrients exceeds the soil's capacity to hold nutrients, these nutrients may be lost through leaching.

As just mentioned, one form of plant-available nitrogen is nitrate (NO_3^-). The plant-available form of chlorine is the anion chloride (Cl^-). Both of these anions are repelled by the negative charges of soil colloids. Therefore, they are readily leached when water passes through the soil.

The plant-available forms of sulfur (sulfate (SO_4^{2-})) and molybdenum (molybdate (MoO_4^{2-})) have two negative charges and are also repelled by negatively charged soil colloids. However, these anions may react weakly with positively charged sites, such as occur on iron oxides. Even though these elements are not strongly bound to soil colloids under normal conditions, they do not leach as readily as nitrate and chloride, and are frequently observed to increase in subsoil horizons having higher clay content and lower pH.

Plant-available phosphorus occurs as an anion with either one or two negative charges, depending on soil pH. Although other anions normally leach readily, phosphorus does not. Phosphorus reacts very strongly with iron, aluminum, and calcium in soil solution, with soil solids such as iron oxides, iron and aluminum hydroxides, and with lime. The strength of these reactions limits the movement of phosphorus to less than a few inches even in very sandy soils. Boron occurs as a leachable, uncharged molecule (boric acid, H_3BO_3), which reacts very weakly with soil clays.

The availability of nutrients is influenced by the following factors:

- pH
- soil texture
- the form of nutrient present in wastewater
- the amount of nutrient present in the soil and soil/water solution

pH

Nutrient availability is strongly tied to the pH of the soil solution. Decreasing soil pH directly increases the solubility of manganese, zinc, copper, and iron, thereby increasing the availability of these nutrients. At pH values less than 5.5, toxic levels of manganese, zinc, or aluminum (a non-nutrient element common in soils) may be released. On the other hand, the availability of nitrogen, potassium, calcium, magnesium, and sulfur tends to decrease with decreasing pH.

Phosphorus and boron availability decreases at both very low and very high pH, with maximum availability in the range of pH 5.5 to 7.0. Outside of this pH range, phosphorus and boron tend to form insoluble compounds with other elements such as aluminum, iron, manganese, and calcium. These reactions bind phosphorus much more strongly than boron, with the result that available boron can be readily leached from soils.

Soil pH can be altered relatively easily with amendments. A typical soil amendment used to raise the pH is calcium carbonate (limestone), although many other possibilities exist. Increasing soil pH, however, is not the primary reason for liming. As just mentioned, aluminum and manganese are toxic to plants at relatively low concentrations in the soil solution. Low pH is an indicator that aluminum and manganese toxicity is likely. Liming decreases the solubility of aluminum, manganese, and iron (as well as zinc and copper), causing them to precipitate as relatively insoluble silicate clays, oxides and hydroxides. Figure 3-10 shows the relationship between pH and nutrient availability.

Depending on the source, lime also supplies significant amounts of calcium and magnesium. Indirect effects of liming include increased availability of phosphorus, molybdenum and boron, the creation of more favorable conditions for microbiological processes such as nitrogen fixation and nitrification, and in some cases, improved soil structure. By increasing soil pH, liming also improves the effectiveness of several herbicides.

Since lime applications decrease availability of zinc, iron, manganese, and copper, excessive lime applications can cause deficiencies of these elements, with manganese deficiency being the most common in southeastern soils. Heavy applications of lime have also caused decreased uptake of boron in some cases.

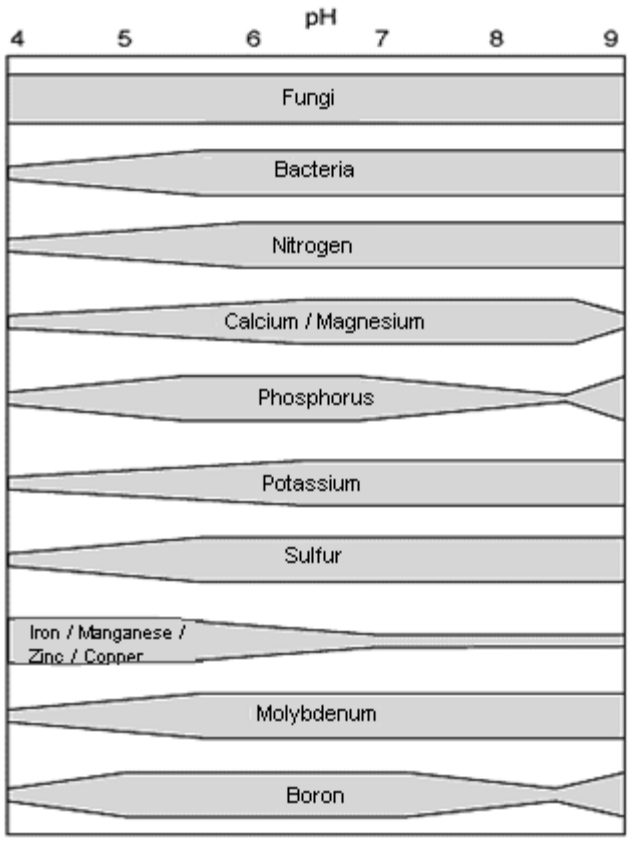

Figure 3-9. Relationship between pH on the one hand and microorganism activity and nutrient availability. The wide portions of the band indicate the zones of greatest microbial activity and the most ready availability of nutrients. [From The Nature and Properties of Soils]

Soil Texture

All soils are not susceptible to the same nutrient deficiencies. Differences in soil texture will affect a soil's capacity to retain nutrients. Nutrients are more apt to leach through a coarsely-textured sandy soil than through a finely-textured clayey soil. For example, coarsely-textured soils low in organic matter are susceptible to sulfur deficiencies, while sulfur is usually in adequate supply in clayey soils or soils high in organic matter.

Form of Nutrient Applied in Wastewater

Another factor that influences the plant availability of nutrients is the form in which a nutrient is present in the wastewater applied to soil. Some nutrients in wastewater are largely present as organic compounds that must be broken down by soil microorganisms before plants can use the nutrients. Other nutrients are present as water-soluble salts that are immediately available for plant uptake.

Note: Soil testing should be done to determine which nutrients are needed and how much of each should be applied. Excessive applications of the following nutrients may lead to toxicity: boron, copper, iron, manganese, and zinc.

Levels of Nutrient Availability

There are three levels of nutrient availability (Figure 3-11):

1. Deficiency: marked increases in yield occur with increasing amounts, or availability, of the nutrient, i.e., supply of the nutrient is inadequate and is limiting yield. An addition of the nutrient will increase yield.

2. Sufficiency: the maximum economic yield has been reached and the nutrient is not limiting crop yield, so increasing the supply or availability of the nutrient has no effect on yield.

3. Toxicity: further additions or availability of a nutrient beyond the sufficiency range causes marked decreases in yield and eventually no growth.

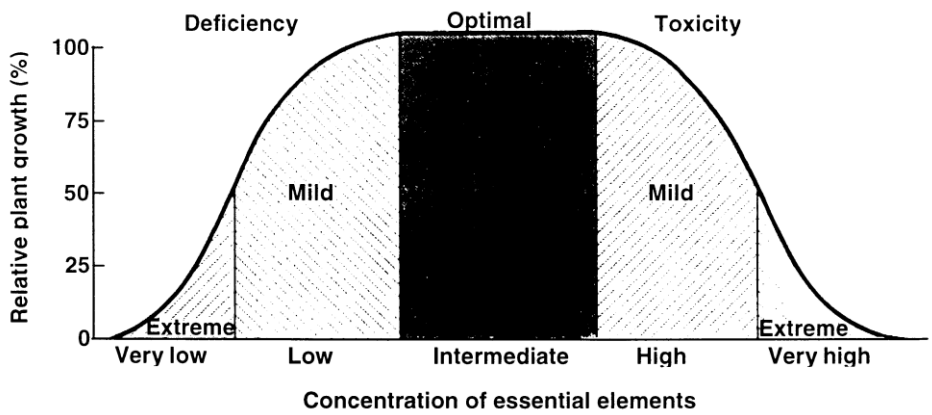

Figure 3-11. Relationship between plant growth and concentration in the soil solution of elements that are essential to plants. Nutrients must be released (or added) to the soil solution in just the right amounts if normal plant growth is to occur. [from The Nature and Properties of Soils]

Symptoms of nutrient deficiency usually appear on the plant when one or more nutrients are in short supply. In many cases, a deficiency may occur because a nutrient is not in a plant-available form. Deficiency symptoms for specific elements are listed below in Table 3-3.

Nutrient Management

When plant nutrients are applied to soils as wastewater, wastewater residuals, animal manure, or commercial fertilizers, five things can happen to these nutrients:

1. Plants grown on the site can use the nutrient.
2. The nutrient can stay in the soil.
3. Some nutrients can be lost as water washes them down through the soil profile in a process called leaching.
4. If fertilizers or wastes are left on the soil surface, runoff water may carry nutrients away in solution or as part of eroded sediments.
5. Some nutrients can be lost as a gas to the air (through volatilization or denitrification).

To maximize nutrient use, an operator should develop a nutrient management plan. Developing such a plan requires information on the amount of nutrients that can be safely applied, the form

or source of nutrients, the placement of nutrients on the field, and the timing of nutrient applications. Nutrients can be managed by adjusting these four components.

Nutrient	Symptoms of Nutrient Deficiency
Nitrogen	General chlorosis (yellowing). Chlorosis progresses from light green to yellow. Entire plant becomes yellow under prolonged stress. Growth is immediately restricted and plants soon become spindly and drop older leaves.
Phosphorus	Leaves appear dull, dark green, blue green, or red-purple, especially on the underside, and especially at the midrib and vein. Petioles may also exhibit purpling. Restriction in growth may be noticed.
Potassium	Leaf margins tanned, scorched, or have necrotic spots (may be small black spots, which later coalesce). Margins become brown and cup downward. Growth is restricted and die back may occur. Mild symptoms appear first on recently matured leaves, then become pronounced on older leaves, and finally on younger leaves. Symptoms may be more common late in the growing season due to translocation of K to developing storage organs.
Calcium	Growing points usually damaged or dead (die-back). Margins of leaves developing from the growing point are first to turn brown.
Magnesium	Marginal chlorosis or chlorotic blotches, which later merge. Leaves show yellow chlorotic interveinal tissue on some species, reddish purple progressing to necrosis on others. Younger leaves affected with continued stress. Chlorotic areas may become necrotic, brittle, and curl upward. Symptoms usually occur late in the growing season.
Sulfur	Leaves uniformly light green, followed by yellowing and poor spindly growth. Uniform chlorosis does not occur.
Copper	Leaves wilt, become chlorotic, then necrotic. Wilting and necrosis are not dominant symptoms.
Iron	Distinct yellow or white areas appear between veins, and veins eventually become chlorotic. Symptoms are rare on mature leaves.
Manganese	Chlorosis is less marked near veins. Some mottling occurs in interveinal areas. Chlorotic areas eventually become brown, transparent, or necrotic. Symptoms may appear later on older leaves.
Zinc	Leaves may be abnormally small and necrotic. Internodes are shortened.
Boron	Young, expanding leaves may be necrotic or distorted followed by death of growing points. Internodes may be short, especially at shoot terminals. Stems may be rough, cracked, or split along the vascular bundles.

Table 3-3. Key to nutrient disorders.

The term agronomic rate means that nutrients will be applied in accordance with the needs of the plants. Thus, rates and timing of application must be adjusted to optimize plant response to the applied nutrients. When this occurs, the plant's ability to use the nutrients is maximized, so fewer nutrients can escape into the environment. Efficient nutrient management is a goal for all plant producers, whether they are growing trees or vegetables or managing pasture at a surface irrigation site.

Priority Nutrients

Wastewater from domestic and commercial sources generally contains low concentrations of the major plant nutrients. This means that the amount of wastewater that can be applied annually to a given site is hydraulically limited, that is, limited by the amount of water the soil can handle (the hydraulic loading rate).

In such cases, it is likely that major plant nutrients such as nitrogen, phosphorus and potassium will have to be added as supplements to get expected crop yields (optimum crop growth). Insufficient nutrients may result in reduced crop yield and nutrient uptake efficiencies, thereby causing possible stress on the receiving crop. The addition of supplemental nutrients should be based on soil test recommendations and realistic crop yield expectations.

For some surface irrigation systems, however, the quantity of wastewater that can be applied is nutrient limited. This means that the amount of wastewater that can be applied is limited by the nutrient content of the wastewater rather than by the amount of water the soil can handle. For example, too much nitrogen may result in nitrate accumulation in crops, groundwater contamination, and potential surface water contamination. Therefore, the amount of wastewater that can be applied to the site is based on the nutrient content of the wastewater.

If wastewater application is limited by nutrient concentration, you must determine which nutrient is the priority nutrient. The priority nutrient is the nutrient most likely to cause an adverse environmental or plant health effect. Soil tests are used to help determine the priority nutrient.

Generally, nitrogen is determined to be the priority nutrient. Consequently, wastewater application rates are based on supplying crop nitrogen needs. The idea is to not apply nitrogen at rates greater than the crop can use, because the nitrate form of nitrogen can move through the soil and threaten groundwater quality. To achieve this, you must be able to calculate the amount of plant available nitrogen (PAN) contained in the wastewater. Permits for nutrient limited systems have PAN monitoring requirements. Plant available nitrogen (PAN) calculations will be discussed in Chapter 6.

Crop Nutrient Requirements

An operator must also be knowledgeable of the nutrient requirements and growth cycles of the plants being grown. Crops vary in their ability to use nutrients. Coastal bermudagrass has very high nutrient requirements, whereas a mature forest has much lower requirements. Crop requirements will be discussed in greater detail in Chapter 5.

Soil sampling should be a standard practice to determine the availability of non-mobile soil nutrients. Soil sampling is not a standard practice for determining the availability of mobile nutrients, such as nitrate. Nitrogen requirements should be based on realistic yield expectations (R.Y.E.). Realistic yield expectation is the estimated crop yield for a given field. A number of factors can affect the realistic yield expectations of a particular site. One of the most obvious is the soil. Soil related factors that can influence yields include:

- depth to subsoil;
- depth to rock or root-confining zone;
- texture of surface soil and water-holding capacity;
- organic matter content;
- infiltration and permeability;
- drainage: aeration, water availability;
- clay mineralogy: charge, nutrient pools, workability;
- structure;
- slope: erosion potential, drainage; and
- local climate: drought, soil temperatures, excessive water.

Realistic Yield Expectations for crop types and specific fields or soils types must be determined by using any the following methods:

- North Carolina Historical Data for specific crop and soil types as provided by North Carolina State University Department of Soil Science Webpage at: http://www.soil.ncsu.edu/programs/nmp/yields/index.php
- Site Specific Historical Data for crop types on specific fields or soil types by calculating the mean of the best three yields of the last five consecutive crop harvests for each field.
- If the RYE cannot be determined using methods above, RYE can be established from specially developed soil interpretation records for Nutrient Management Planning, Farm Service Agency Records, university trials, or inference from crop performance on soil with very similar physical and chemical features.
- Realistic Yields Expectations and acceptable nitrogen application rates that use the above methodology are required parts of many agricultural planning documents. The Permittee may use the RYE and appropriate agronomic rates reported in any of the following documents:
  - **Crop management plan** as outlined by the local Cooperative Extension Office, the North Carolina Department of Agriculture and Consumer Services, the Natural Resource Conservation Service, or other agronomist.
  - **Waste Utilization Plan** as outlined by Senate Bill 1217 Interagency Group- Guidance Document: Chapter 1. Guidance for the completion of the plan can be found at: http://www.enr.state.nc.us/DSWC/pages/guidance_docs.html.
  - **Certified Nutrient Management Plan** as outlined by Natural Resources Conservation Services (NRCS). These plans must meet the USDA-NRCS 590 Nutrient Management Standards, which are available at: ftp://ftp-fc.sc.egov.usda.gov/IA/technical/N590_03-2001.pdf.
- For any crop type for which the RYE and appropriate nitrogen application rate cannot be determined, the Permittee shall contact the Division to determine necessary action.

Operators should consult the local Cooperative Extension Service, Natural Resource Conservation Service, or agricultural consultants for assistance in interpreting soil test results, determining fertilization rates, and developing nutrient management plans.

3.3 Groundwater and Hydrology

To determine if the natural treatment system is functioning properly, a surface irrigation system operator needs a basic understanding of groundwater and hydrology. Hydrology is simply the study of water as it occurs on and below the surface of the earth as well as in the atmosphere. The movement of water on the land, in the ground, and through the air is termed the hydrologic cycle.

Hydrologic Cycle

The hydrologic cycle is the continuous process of water leaving the earth's surface and eventually returning in the form of precipitation (Figure 3-12). Water falling from the atmosphere as rain or snow can do one of three things:

1. evaporate and return to the atmosphere;
2. runoff to streams, rivers, lakes and oceans; or
3. infiltrate into the soil.

Wastewater sprayed onto the soil surface acts in much the same way as natural precipitation and becomes a part of the hydrologic cycle. In a properly operated surface irrigation system, however, wastewater should either evaporate or infiltrate into the soil. Runoff of wastewater from surface irrigation is not acceptable. Percolation of untreated or partially treated wastewater below the root zone is also undesirable.

Therefore, one of the most important goals for a surface irrigation system operator is to apply wastewater at rates that will not only supply the nutrient needs of crops or vegetative covers, but will not exceed the rate at which the soil will accept and hold waste constituents.

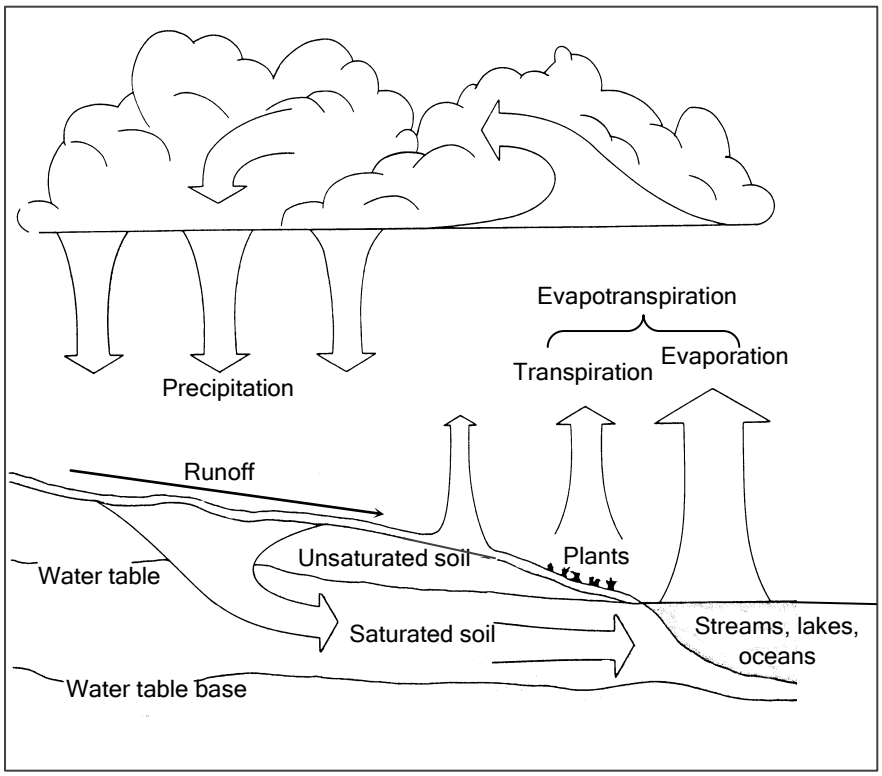

Figure 3-12. The hydrologic cycle. (from the Nature and Properties of Soils).

Evaporation and Evapotranspiration

Precipitation and wastewater can evaporate in several ways. When the humidity is low, water may evaporate before it even reaches the ground. More importantly for the purposes of surface irrigation, water can also evaporate from the soil surface and from leaf surfaces. The evaporation at leaf surfaces of water moving upward and through a plant is called transpiration. The combined loss of water to the atmosphere by evaporation from the soil surface (E) and by transpiration (T) is called evapotranspiration (ET).

Evapotranspiration is responsible for most of the water removal from soils during a crop's growing season. Evapotranspiration rates are influenced by the following factors:

- sunlight: solar radiation provides the energy necessary for evaporation to take place; ET is higher on a bright sunny day than on a cloudy day.
- atmospheric vapor pressure: evaporation occurs when the atmospheric vapor pressure is low compared to the vapor pressure at the soil and leaf surfaces; ET is higher in arid climates than in humid regions.
- temperature: a change in temperature has a much greater effect on the vapor pressure at soil and leaf surface than on the atmospheric vapor pressure; ET increases with an increase in temperature.
- wind: the movement of air sweeps away vapor moisture from wet surfaces; high winds will intensify ET.soil moisture content: water must be present for evaporation to occur; ET is higher from moist soils compared with soils with a low moisture content.

After evapotranspiration occurs, water vapor in the atmosphere condenses into clouds. Eventually precipitation falls in the form of rain or snow and the cycle begins again.

Runoff to Surface Waters

Precipitation or wastewater that does not evaporate to the atmosphere or infiltrate into the soil is called runoff. Runoff travels over the soil surface, eventually reaching surface waters (streams, rivers, lakes, and oceans). Factors affecting runoff are the same as those affecting infiltration (discussed earlier in this chapter).

Runoff from precipitation can negatively affect both soil and water quality. These negative impacts, which include soil erosion and surface water pollution, can be significantly increased by runoff from wastewater application.

Soil Erosion

Whether the result of precipitation or improper application of wastewater, runoff carries with it suspended soil particles. This loss or movement of soil is called soil erosion. Around five billion metric tons of soil are moved annually in the United States, some two thirds being moved by water (the remainder being moved by wind).

Unfortunately, much of this eroded soil ends up in surface waters. Sediment carried by runoff clogs streams, fills lakes, and often carries nutrients and pollutants to these waters. The lifetime of water storage reservoirs can be significantly shortened, river channels can be filled in, and water treatment plants can be damaged by sediment from upstream.

Sedimentation causes turbidity, which can smother aquatic life and shade out desirable aquatic vegetation. Sediment also may carry pesticides—such as herbicides and insecticides—that may be toxic to aquatic plants and animals. The varying chemical properties of pesticides—for example, their solubility, toxicity, and chemical breakdown rate—determine the potential damage to water quality.

Reducing soil erosion is the key to reducing the damaging effects of sedimentation. Fortunately, with current technology, erosion can be reduced to acceptable levels. The challenge is to match the appropriate technology to each situation.

Surface Water Pollution

In addition to soil particles, runoff can carry with it other waste constituents that affect water quality. Bacteria, viruses, organics, and a variety of other chemicals may impact plant and animal life in surface waters. These pollutants also have the potential to impact humans who use these surface waters for fishing, recreation, or drinking water supply.

Nutrients carried by runoff to surface waters can also result in accelerated eutrophication. Natural eutrophication is the slow nutrient enrichment of streams and lakes and is responsible for the "aging" of ponds, lakes, and reservoirs.

Rapid eutrophication is usually associated with increased algae growth or “blooms”. In freshwater ecosystems developed under very low phosphorus conditions, large additions of nutrients, especially phosphorus, can stimulate the production of these algae blooms. As the algae die, organisms in the aquatic system decompose the algae to use as a food source. In the process, they also use significant amounts of oxygen.

As more and more algae grow and then decompose, dissolved oxygen levels are depleted in slow moving water. This condition can result in fish kills, offensive odors, unsightliness, and reduced attractiveness of the water for recreation and other public uses. Unfortunately, these conditions have been observed in eastern North Carolina rivers.

Infiltration

Water that does not either evaporate or move as surface runoff into streams, rivers, and lakes infiltrates into the soil and percolates downward. As discussed earlier, some of this water is used by plants and is removed from the soil environment by evapotranspiration. The remaining water flows through the unsaturated portion of the soil until it reaches the saturated zone (Figure 3-13). This is the zone in which all of the pores in the soil or bedrock are filled with water.

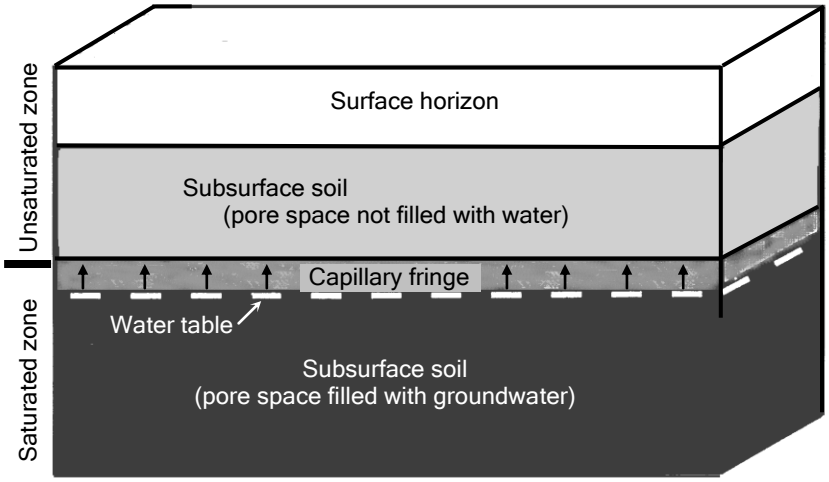

Figure 3-13. Divisions of soil water.

The surface or uppermost level of the saturated zone is called the water table. When water percolating through the soil reaches the water table, it becomes groundwater. Groundwater is any water contained in interconnected pores located below the water table.

Although we often think of groundwater occurring in large underground lakes or streams, it does not. Instead, it occupies spaces within rock fractures or between particles of sand, gravel, silt, or clay and flows through underground formations called aquifers.

An aquifer is the rock or sediment in a formation, group of formations, or part of a formation that is saturated and sufficiently permeable to transmit economic quantities of water to wells and springs. Groundwater does not move rapidly in an aquifer. It may move only a few feet per month or even per year, whereas surface streams flow several feet per second.

Water table depths vary across the landscape and are determined by the confining layers present below the soil surface. These confining layers have little to no permeability, and therefore restrict water movement. These layers may be very deep and cover a large area, such as a bedrock layer. A water table that results from such a confining layer is called an apparent or permanent water table. Water table depths can be determined by measuring the depth to free water in a shallow, unlined auger hole.

A water table may also be caused by a shallow restrictive horizon in the soil that creates saturated conditions above it, while unsaturated conditions exist below it. This type of water table is called a perched water table, and usually occurs over a small area Figure 3-14). Perched water table depths are quite variable and are usually of shorter duration than an apparent water table.

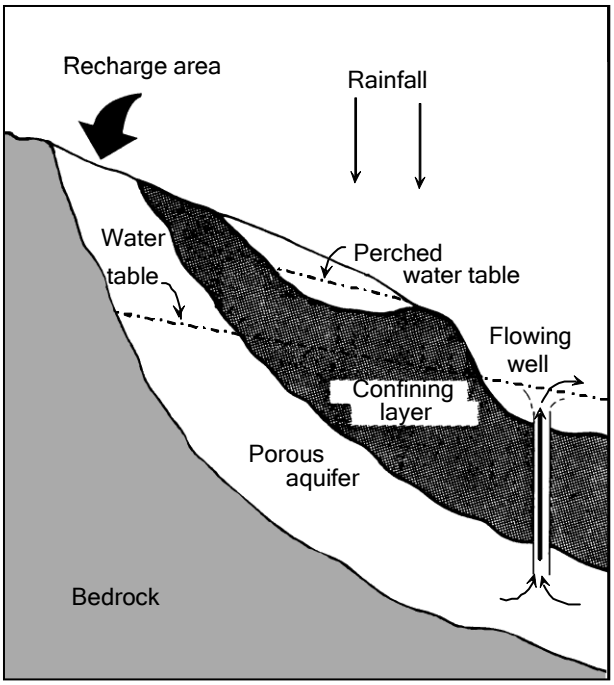

Figure 3-14. Porous aquifer and perched water table above an impermeable layer. [from Hydrology and the Management of Watersheds]

Water table depths also move up and down in response to precipitation and evapotranspiration patterns. The unsaturated zone can become saturated during periods of excessive precipitation. Saturated conditions in the unsaturated zone, however, are temporary and are usually seasonal (see Figure 3-15).

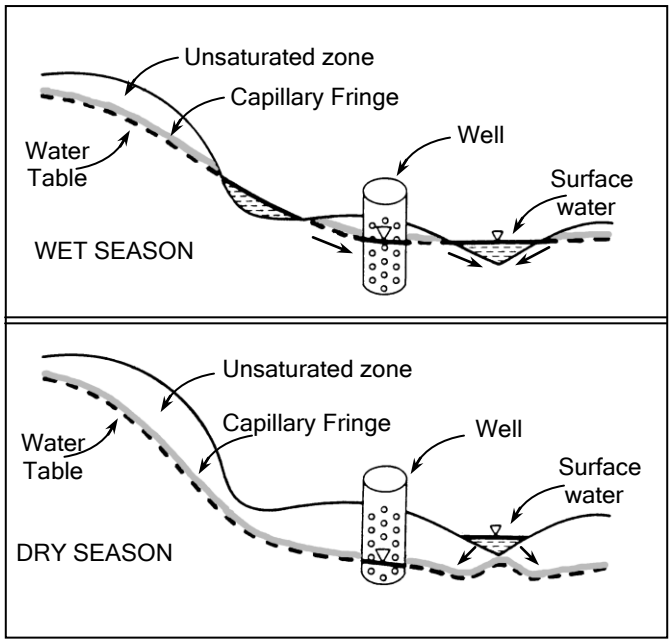

Figure 3-15. Groundwater characteristics and water table changes from wet to dry season. [from Hydrology and the Management of Watersheds]

The goal of a surface irrigation system is to use the unsaturated zone of the soil, in conjunction with a suitable vegetative cover, to adequately treat wastewater before it reaches the saturated zone (i.e., groundwater). These systems are designed to operate in aerobic environments. Therefore, depth to the water table is important because it determines both the volume of unsaturated soil through which waste constituents must travel before reaching groundwater and the amount of time that waste constituents are in contact with unsaturated soil.

The potential for groundwater contamination increases where the soils are thin and the underlying bedrock or confining layer is permeable, or where the water table is near the soil surface. Such sites would not be considered suitable for surface irrigation systems. Generally, at least four feet of unsaturated soil are needed for adequate waste treatment.

Even when the water table is sufficiently deep, the potential for groundwater contamination exists. Over-application of wastewater can alter the hydrology of a site and create saturated conditions in what would normally be the unsaturated zone. The water table can rise closer to the soil surface, creating a situation called wastewater mounding (Figure 3-16).

This situation, if close enough to the soil surface, is undesirable. It can cause anaerobic conditions in the root zone and limit the growth potential of the vegetative cover. It can also result in poor treatment of the wastewater. Insufficiently treated wastewater can pond on the soil surface, can flow laterally as shallow groundwater until it reaches a surface water body, or can percolate to deeper groundwater.

Pumping water from a well can also alter the natural hydrology of a site. Although no drinking water wells are allowed within 100 feet of the wetted area of a surface irrigation system, it is important to understand that pumping water from a well can change the natural flow of groundwater in its vicinity. The net result can be a complete reversal of groundwater flow on the down gradient side of the well. Thus, a down gradient contaminant may actually be drawn against the natural flow into an up gradient well. The possible range of such an effect depends on the rate of pumping and the ability of water to move within the aquifer.

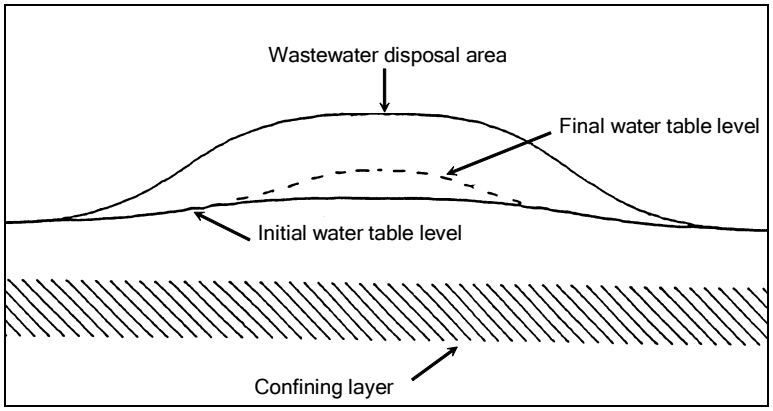

Figure 3-10. Wastewater mounding under treatment system. [from Soil Science Society of North Carolina Proceedings 32nd Annual Meeting, 1989]

Artificial surface and subsurface drainage can also affect groundwater levels. Surface drainage is sometimes used where upslope runoff may impact a site. Surface water is diverted by means of dikes or berms that carry surface water runoff safely away from a treatment site. Installation of any surface drainage structures would require approval of your local DWR regional office.

Subsurface drainage is often used in agricultural settings. Ditches or porous pipes withdraw water from the soil and carry it to an off-site waterway, such as a road ditch or stream. However, installation of subsurface drainage at a surface irrigation site would be a violation of the system's nondischarge permit and is unacceptable.

In conclusion, the soil/plant system can treat effectively wastewater constituents and prevent them from reaching groundwater if the system is properly sited, operated and maintained. It is important to remember that soils vary tremendously in their treatment capacity.

Under some conditions, waste constituents may take months or years to move from the soil surface to the groundwater. Under other conditions, they can flow almost directly into the groundwater. Once waste constituents reach the saturated zone, they are subject to withdrawal from a drinking water well or discharge to adjacent surface waters, possibly jeopardizing both public health and environmental quality.

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Chapter 4

Equipment

So far, we have discussed the basic characteristics of wastewater as well as the treatment components of a spray irrigation system. In this chapter, we will look at the equipment that is used to pump and distribute wastewater through the system. In most cases, operators will be operating and maintaining equipment and systems that were chosen and designed by someone else. If the equipment was properly chosen and the system properly designed, operating the system will be much easier.

A "good design" does not guarantee that wastewater will be properly applied. Poor operation can ruin the performance of a well-designed system; likewise, a poorly designed system can sometimes provide good performance with proper, intensive operation. Therefore, operators of spray irrigation systems need a basic understanding of pumps and their controls as well as an understanding of distribution networks and their devices.

4.1 Pumps and Controls

A pump is a mechanical device that imparts energy to liquids in order to move the liquids from one location to another. All pumps operate on the following principals:

- air is exhausted from the working chamber;
- atmospheric pressure then forces water or other liquid into the chamber;
- the pump mechanism forces the water out of the chamber, creating a partial vacuum; and
- additional water fills the chamber to repeat this cycle.

General Concepts

Before discussing specific types of pumps, it is important to understand the following general concepts:

- pump head;
- horsepower;
- pump capacity; and
- pump performance curves.

Head

Pumps are designed to deliver liquid against a specific pressure. We know that water has a specific weight of 8.34 lbs/gallon. This weight resting on a surface exerts a force on that surface. Force (or weight) on a specific area is called pressure. Pressure is usually expressed in terms of pounds per square inch (PSI).

Pressure can also be expressed in terms of feet of water. When pressure is measured in feet, it is called head. Pump head is defined as the resistance against which a pump will operate. It is the

distance a pump can move a liquid vertically before the pressure of the liquid above the pump stops it from adding new liquid to the output side of the pump. To convert pressure to head, multiply the pressure in psi by 2.31. To convert head to pressure, divide the head in feet by 2.31.

In most cases, pumps must be installed to provide the pressure necessary to move water from one location or elevation to another in a waste treatment system. Since the function of a pump is to add pressure to the system, the pressure on the discharge side of the pump will always be higher than the pressure on the suction side of the pump.

In pump systems, measurements are taken from the point of reference to the centerline of the pump, a horizontal line drawn through the center of the pump (Figure 4-1). Pump heads include both static head (when the pump is off) and dynamic heads (when the pump is on). Dynamic heads are discussed below.

Friction Head

Friction head is the pressure needed to overcome the resistance to flow within the pump components. All straight pipe, fittings, valves, etc. have a friction factor that must be considered. These friction factors are converted to, and expressed as, equivalent feet of straight pipe, which can then be translated to friction head based on the flow and pipe size. The greater the flow, the higher the friction.

Dynamic Suction Head

Suction head exists when the source of supply is above the centerline of the pump. Dynamic suction head (DSH) is defined as the vertical distance between the water level on the suction side and the centerline of the pump, minus friction head.

Dynamic Suction Lift

Suction lift exists when the source of supply is below the centerline of the pump. Dynamic suction lift (DSL) is the vertical distance between the pump centerline and the water level on the discharge side, plus friction head. It will register as negative pressure on a gage on the suction side of the pump.

Dynamic Discharge Head

Discharge head is the pressure at the discharge from an orifice or sprinkler. When liquid is discharged through an orifice or sprinkler nozzle, pressure head is converted to a velocity and this velocity is the force that gives water its trajectory. Dynamic discharge head (DDH) is defined as the vertical distance between the pump centerline and the water level at the point of free discharge, plus friction head.

Total Dynamic Head

The total dynamic head (TDH) of a pump system is defined as the difference between the

dynamic discharge head and the dynamic suction head (when the source of supply is above the centerline of the pump) or as the difference between the dynamic discharge head and the dynamic suction lift (when the source of supply is below the centerline of the pump). Remember that friction head must be taken into account on both sides of the pump.

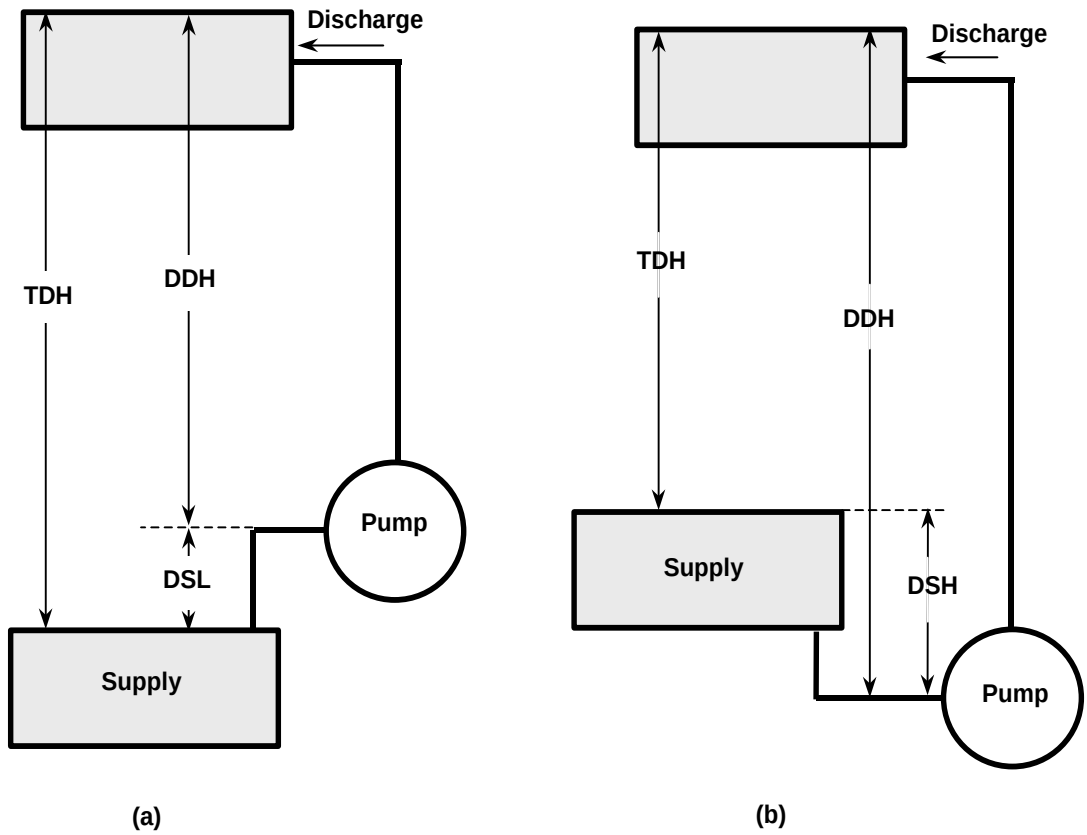


Figure 4-1. (a) Schematic of a system where the source of supply is below the centerline of the pump. (b) Schematic of a system where the source of supply is above the centerline of the pump.

Horsepower

In order to purchase the appropriate pump for the job needed, you must determine how much work the pump will be required to do. In this context, work is the energy it takes to lift a weight a certain vertical distance. Work is expressed in units of foot pound. One foot-pound is the amount of work required to lift a one-pound object one foot off the ground.

Power is the rate at which work is being done – in other words, how fast the work is being done. Power is expressed as foot pound per second or foot pound per minute. Large units of power are called horsepower. One horsepower is 550 foot-pounds per second.

Water, brake, and motor horsepower are terms used to indicate where the horsepower is measured (Figure 4-2). The horsepower required to lift a specific flow of water a specific vertical distance is called water horsepower (whp). It is the minimum power required to move water. In other words, it is the power a pump would require if the pump was 100% efficient. Water horsepower is calculated by the following equation:

$$\text{whp} = \frac{\text{flow (gpm)} \times \text{TDH (ft)}}{3960}$$

Pumps, however, are never 100% efficient. Power is lost in the pumping process due to friction and heat, which reduces the pump's efficiency. We have to correct for the pump's inefficiency by increasing the amount of horsepower that goes to the pump. Brake horsepower is the amount of power that must go into the pump to produce the required water horsepower. It is calculated by the following equation:

$$\text{bhp} = \frac{\text{water horsepower}}{\text{pump efficiency}}$$

Finally, we need to correct for the inefficiency of the motor that drives the pump. The motor also loses power due to friction and heat. We have to correct for the motor's inefficiency by increasing the amount of energy that goes to the motor. The amount of electrical energy that must go into the motor to produce the required bhp is called motor horsepower (mph). It is calculated by the following equation.

$$\text{mhp} = \frac{\text{brake horsepower}}{\text{motor efficiency}}$$

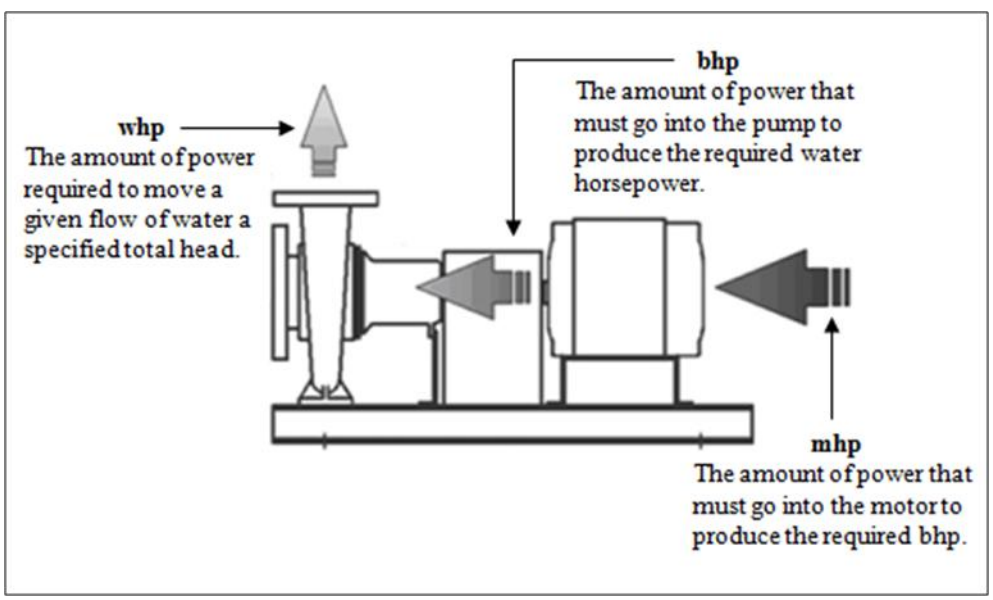


Figure 4-2. Water, brake, and motor horsepower.

For example, a pump that is 80% efficient requires 10 bhp to generate 8 whp. If the motor is also only 80% efficient, the motor requires 12.5 horsepower to generate 10 bhp.

The equations for water, brake, and motor horsepower can be combined into one equation that accounts for pump and motor inefficiency:

$$\text{horsepower} = \frac{\text{flow (gpm)} \times \text{TDH (ft)}}{3960 \times \text{pump efficiency (\%)} \times \text{motor efficiency (\%)}}$$

Pump Capacity and Pump Delivery Rates

Each pump is designed to deliver a designated amount of flow against a specific head. This is the design pump capacity or design pump delivery rate (gpm). Actual pump capacity or delivery rates can vary, depending on the efficiency of a pump and the conditions under which it is operated.

The pump capacity and quantity of flow, in turn, determine the time required for each pumping or dosing cycle and the length of time between cycles. The amount of wastewater pumped to a sand filter or spray irrigation field during a pump cycle is called the dosing volume (in gallons).

The pump delivery rate is the amount of wastewater pumped during a pump cycle divided by the pump run time (in minutes). The pump delivery rate efficiency is the measured pump delivery rate (in gallons per minute) divided by the design pump delivery rate times 100%. These calculations will be discussed in Chapter 6.

Pump Performance

Pumps can deliver a wide range of flows depending on design, speed, and total dynamic head. The best source of information on a particular pump is the manufacturer's pump performance curve, which provides information on discharge, power requirements, and head characteristics.

Pump performance is measured in gallons per minute delivered (pump capacity), height to which water is lifted (head), and efficiency. Each pump is manufactured to operate most efficiently at a designated amount of head and flow. Operating a pump as close to peak efficiency as possible allows it to operate with the least amount of strain possible. Operating a pump well off peak efficiency can result in excessive energy use and shortened pump life.

In order to better understand the performance and operating characteristics of pumps, operators should become familiar with the pump curve that is supplied by the manufacturer for each pump. A pump curve shows the relationships between pump head, flow, efficiency, and horsepower. Pump curves can be used in case you need to modify your operating conditions from the original irrigation design. A typical pump curve is shown in Figure 4-3.

Pump curves usually show three curves on one sheet. The head-capacity curve shows the discharge in gallons per minute (gpm) which the pump will deliver against various heads when operated at the proper speed. This curve shows that as the head increases the discharge

decreases, until there is no further discharge. Conversely, as head decreases, flow increases.

The second curve, also plotted against flow, shows the efficiency at which the pump operates at various points on the head capacity curve. This curve shows that no pump is 100% efficient, due to internal friction losses. The highest efficiency is around 85%. Efficiency can be expected to decrease with age and wear.

The third curve, the brake horsepower curve, shows power consumed plotted against flow. If we know the total head at which the pump is operating, we can use the curve to find the gallons pumped. The power required by the pump as well as the pump efficiency can also be read from the curve for any set of conditions.

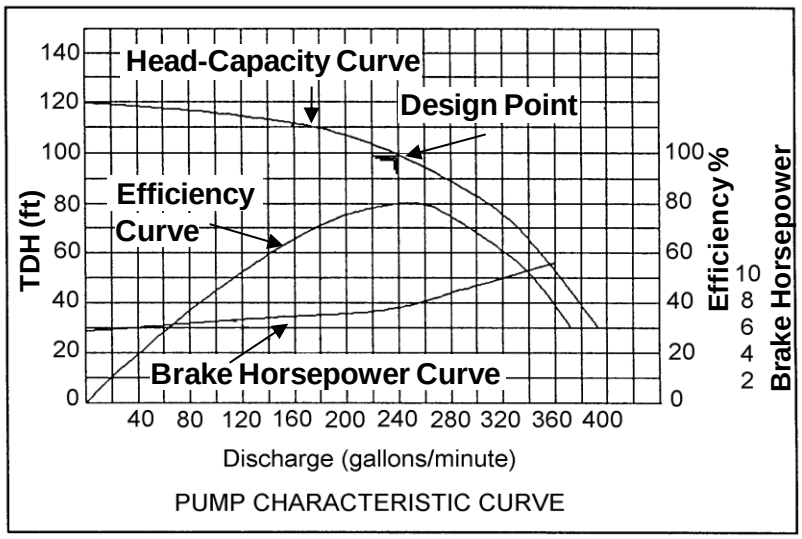


Figure 4-3. Characteristic curve [modified from Practical Hydraulics Handbook, 1991]

This curve shows that it usually takes more horsepower to pump more water: the lower the flow, the lower the horsepower required and the higher the flow, the higher the horsepower required.

As discussed earlier, a pump operates most efficiently at the flow and head it was designed and rated for. This is sometimes called the design point or best efficiency point. This point normally falls in the middle of the pump performance curve. Operation at either extreme of the curve should be avoided.

Operating a pump below the manufacturer's specified minimum head (at the high flow end of the curve) can result in overloading the motor. Operating a pump in the extreme high head region of the curve can result in decreased efficiency, increased noise and vibration, and low flows.

Types of Pumps

There are a variety of pumps that you may encounter at your waste treatment facility. Centrifugal pumps are volute pumps that can be used for most wastewater pumping activities.

Turbine pumps are generally used for applications where the intake is below the liquid levels. Positive displacement pumps are usually associated with waste that contains high levels of solids. Peristaltic pumps are used for wastewater sampling or chemical feed.

Pumping system components include the pump itself, electrical connections to a motor, a shaft to drive the pump, a seal between the water chamber and the motor, an impeller with inlet and outlet ports, and a mounting stand. Rail systems are recommended when using large submersible pumps to access pumps for repair or replacement.

Centrifugal Pumps

A centrifugal pump is one of the simplest of mechanical pumps. It consists of one or more impellers rotating in a casing, or volute (Figure 4-4a). The impeller, shaped to force water outward at right angles to its axis, is mounted on a shaft that is supported by bearings and connected to a drive (Figure 4-4b).

The drives are usually electric, or sometimes engine-driven. The driving source may be either constant speed or variable speed, depending on the specific requirements of a particular installation.

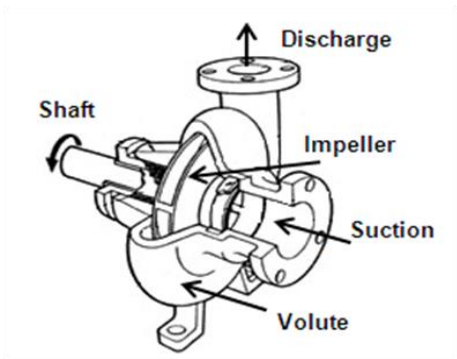


Figure 4-4(a)

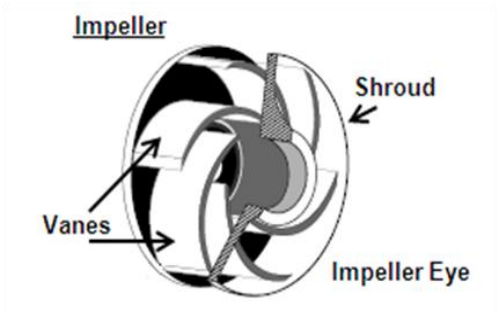


Figure 4.4(b)

A centrifugal pump is a radial flow pump. As wastewater enters the center (eye) of the impeller, it is picked up by the vanes and by the rotation of the impeller and is thrown out by centrifugal force into the discharge. More wastewater moves into the impeller through the eye, as wastewater in the impeller moves outward (Figure 4-5).

Impellers may be of the open, semi-open, or closed type. Open impellers do not have a front or back shroud and are normally used for wastewater applications while closed impellers are normally used for irrigation waters that are relatively clean (Figure 4-6). Semi-open impellers are designed to handle liquid containing moderate amounts of solids.

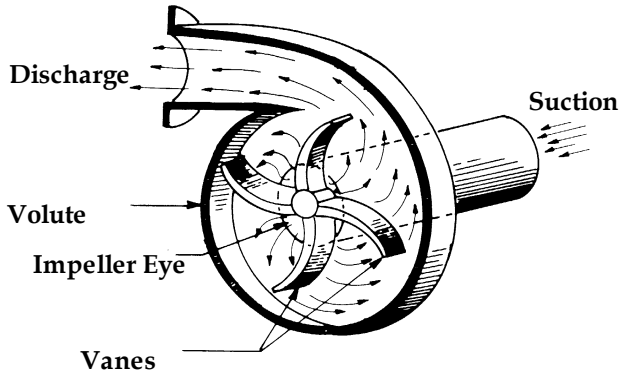


Figure 4-5.

Centrifugal pumps generally have a maximum suction of 34 feet. The practical suction is generally 20 feet or less. These pumps are primed by evacuating air from the pump casing and then forcing water into the casing. With straight centrifugal pumps this is done manually. To accomplish this, a valve must be closed on the discharge side of the pump, either manually or automatically. Suction lines must be air-tight.

Generally, most pump problems arise on the suction side of the pump when lines are not completely air-tight.

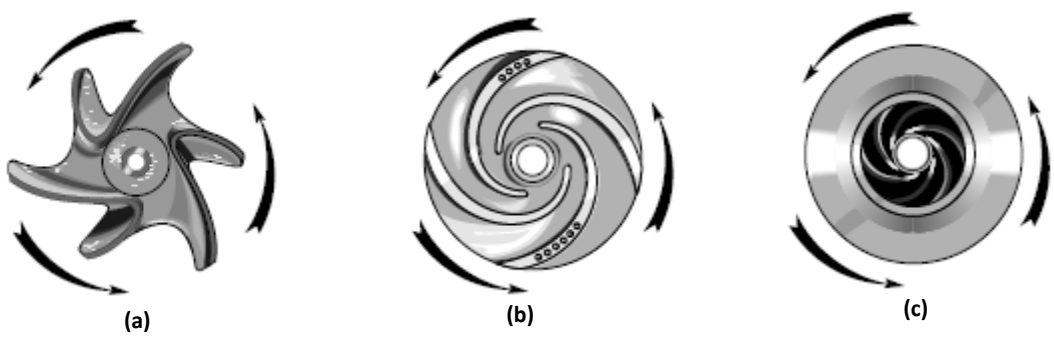


Figure 4-6. Impellers: (a) open; (b) semi-open; (c) closed.

A modification of the centrifugal pump is the self-priming centrifugal pump, which is characterized by a large casing. This type of pump has an end suction and a top discharge and priming is accomplished by the pump mechanism itself. The maximum head that can be obtained with a self-priming centrifugal pump is generally less than that which can be obtained with a straight centrifugal pump. (Priming a pump will be discussed in more detail later is this section.)

Turbine Pumps

Turbine pumps are basically centrifugal pumps that are stacked on top of each other. These pumps have a bowl design instead of a volute design for impeller housing. Therefore, these

pumps can be constructed with small diameters, similar to those used in water-supply wells (Figure 4-7). Turbine pumps are readily adaptable because additional bowls and impellers can be attached to the turbine shaft.

Pumps with more than one impeller are called multi-stage pumps. Turbine pumps may have up to 25 stages, depending on the type of impellers used. Each stage adds pressure, not volume. They are generally used for deep well irrigation systems or other applications where the intake is below the liquid level and where high discharge pressures are needed.

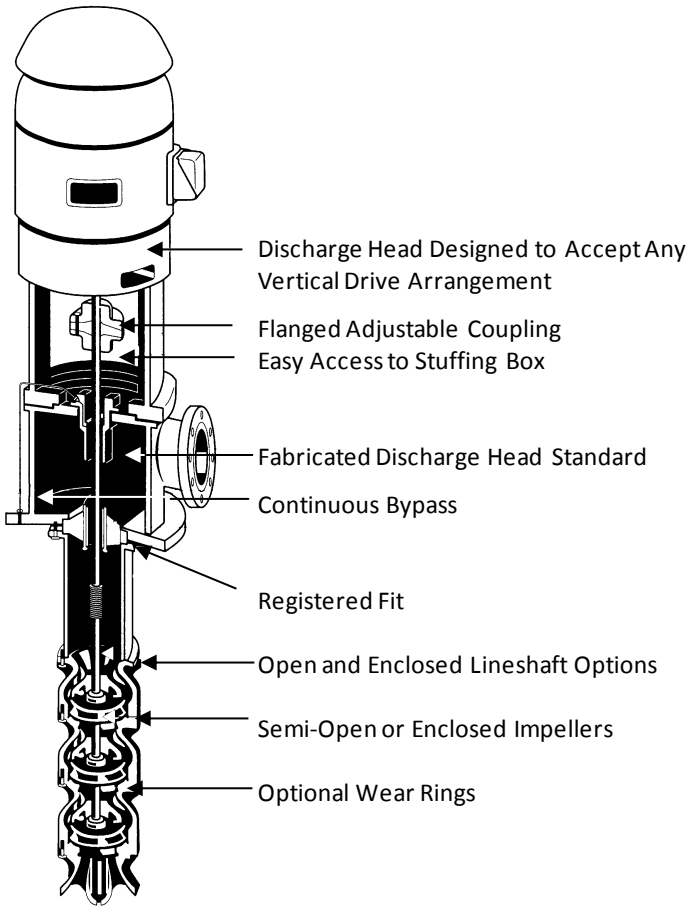


Figure 4-7. Turbine pump.

Submersible Pumps

Another type of centrifugal pump is the submersible pump. Submersible pumps are vertical, heavy-duty centrifugal pumps designed to work while immersed in the water that they are pumping (Figure 4-8). There is no suction piping, and the impeller is at the very bottom of the unit. The watertight motor is also submerged. The surrounding water helps cool the pump and motor, extending their life and efficiency.

To assure proper cooling, the manufacturer normally specifies recommended minimum submergence for continuous operation. If this minimum submergence is not maintained, the motor and pump can overheat. Cavitation, vortexing, and siphoning can also result.

Cavitation, the formation and collapse of vapor bubbles, can cause severe mechanical damage as well as loss of head, reduction in pump efficiency, and noise.

Vortexing, the creation of a vortex that can reach the surface and pull air into the pump, can result in cavitation and reduced performance. Siphoning "assists" fluid flow, resulting in the reduction of the head against which the pump must operate and possible overloading of the pump.

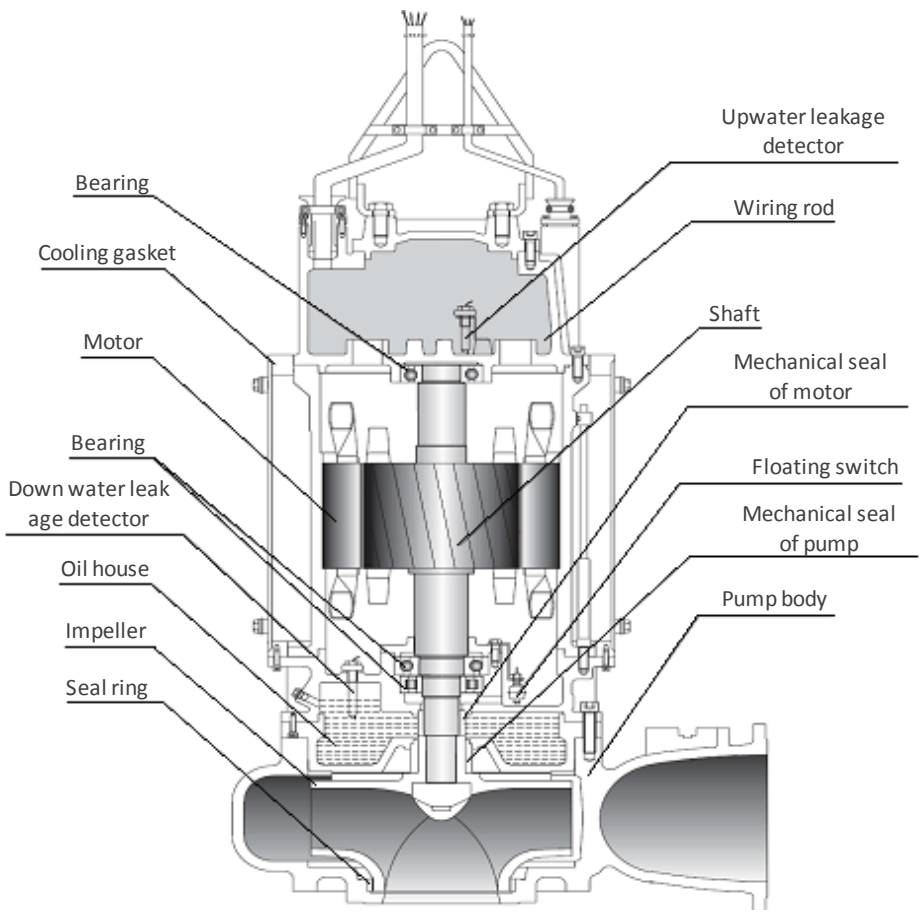


Figure 4-8. Submersible pump.

Reciprocating, Piston or Plunger Pumps

Positive displacement pumps are pumps that must be operated with an open discharge valve. One such pump is the reciprocating pump. The word “reciprocating” means moving back and forth, so a reciprocating pump (also called a piston or plunger pump) is one that moves wastewater or sludge by a piston or plunger that moves back and forth. The movement of the piston or plunger forces wastewater from the suction side to the discharge side of the pump.

There is a check valve (often simply a ball) on both the suction and the discharge sides of the pump. The check valves keep the liquid moving in the desired direction (Figure 4-9).

The piston or plunger moves up and down or back and forth horizontally in the cylinder. As the

piston or plunger moves in one direction, a check valve opens and wastewater enters the pump and fills the casing. This is referred to as the 'suction cycle' of the pump. When the piston or plunger moves in the opposite direction, the first check valve closes, the other check valve opens, and wastewater is forced out of the exit line. This is the 'discharge cycle' of the pump.

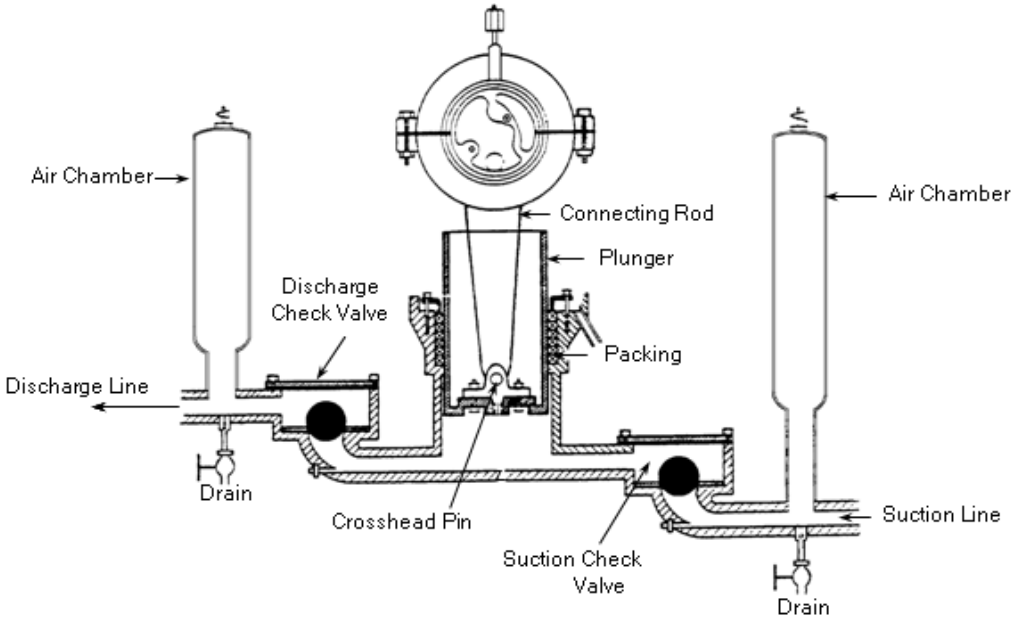


Figure 4-9. Major components of a plunger pump. [From WEF Pumps Operation and Maintenance]

Because the movement of the plunger or piston creates pressure inside the pump, this kind of pump should never be operated against any closed discharge valve.

To prevent a build-up of pressure that could damage the pump or burst pipes, all discharge valves must be open before the pump is started. Because force is exerted during the suction cycle also, the suction valve too should be always left at least partly open.

Diaphragm Pumps

Another type of positive displacement pump is the diaphragm pump, often used for chemical feed. Instead of using a piston or a plunger, a diaphragm (a flexible membrane) is used to force wastewater from the suction to the discharge side of the pump (Figure 4-10). In a diaphragm pump, wastewater does not come in contact with moving metal parts, an advantage over the reciprocating pump. This can be important when pumping abrasive or corrosive liquids.

Progressive Cavity Pumps

Another type of positive displacement pump, a progressive cavity pump uses a rotor and an elastic stator to force liquid from the suction to the discharge side of the pump. Its operation is similar to that of a precision incline screw pump. The screw-shaped rotor fits snugly in a non-

moving stator or housing (Figure 4-11). The gaps between the rotor threads are called cavities. Wastewater is pumped through an inlet valve where it enters a cavity. As the rotor turns, the waste material is moved along until it leaves the rotor at the discharge end of the pump.

These pumps should never be operated without liquid in the cavities, nor should they be run against a closed discharge valve.

Progressing cavity pumps are used to pump materials with very high solids content. Smaller progressing cavity pumps are normally used to pump chemical slurries. Larger ones are used to pump sludge.

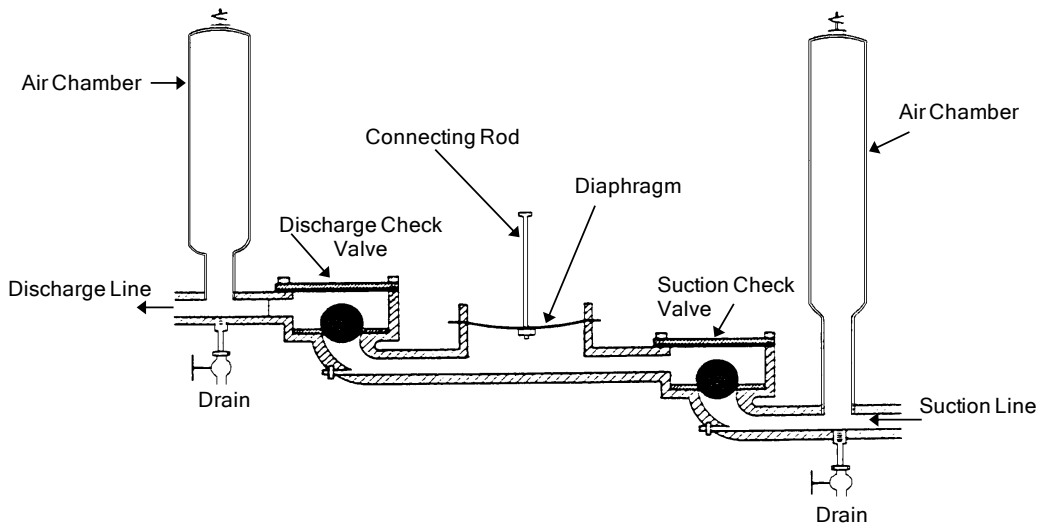


Figure 4-10. Major components of a diaphragm pump. [From WEF Pumps Operation and Maintenance]

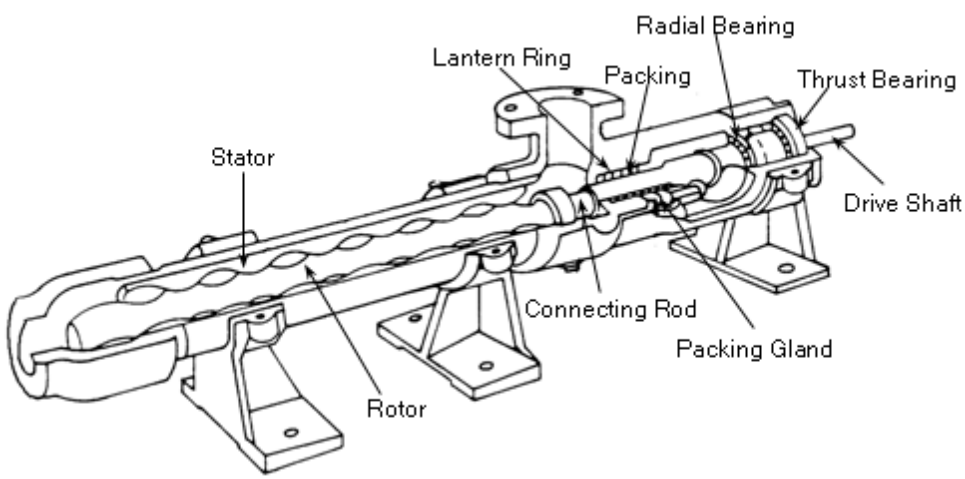


Figure 4-11. A typical progressive cavity pump.

Peristaltic Pumps

Peristaltic pumps, the oldest pumps in existence, are another type of positive displacement pump. Wastewater is moved through flexible tubing by advancing rollers that squeeze the tubing (Figure 4-12). As the tubing recovers to its normal size, more wastewater is drawn into the tubing, which is then trapped by the next roller and finally expelled, from the pump. Nothing but the tube touches the wastewater, thus eliminating any risk of contamination. Pump design prevents backflow and siphoning without valves. Peristaltic pumps are often used for chemical feed or for wastewater sampling.

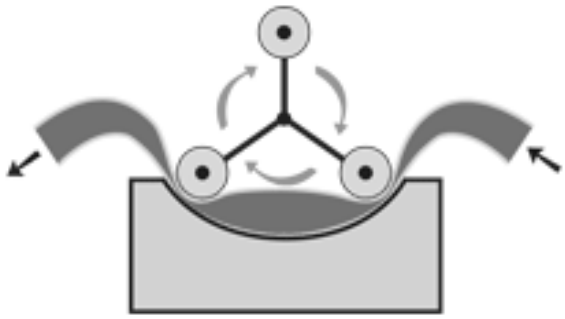


Figure 4-12. Peristaltic pump.

Bearings

There are several types of bearings used in pumps – such as ball bearings, roller bearings, and thrust bearings. Each bearing has a special purpose. The type of bearing used in each pump depends on the manufacturer's design and application.

Bearings are machine parts designed to reduce friction between moving parts or to support moving loads. There are two main kinds of bearings:

- the antifriction type, such as the roller bearing and the ball bearing, operating on the principle of rolling friction; and
- the plain or sliding type, such as the thrust bearing, employing the principle of sliding friction; thrust bearings are used to support the pump shaft.

Pump bearings usually should last for years if serviced properly and used in their proper application. Whenever a bearing failure occurs, the bearing should be examined to determine the cause and, if possible, eliminate the problem. Many bearings are ruined during installation or pump startup.

Packing

Pump packing reduces or eliminates internal liquid leakage within a pump. This is important because the objective is to pump water, not air, and because air leakage can cause a pump to lose suction. To keep air from being drawn into the pump, stuffing boxes are used.

Each stuffing box consists of casing, rings of packing and a gland at the outside end. Each ring of packing should be placed separately and seated firmly before adding the next. These rings

are removable and replaceable when wear enlarges the tiny gap between them and the impeller. In addition to increasing the efficiency of the pump by reducing air leakage, pump packing can prolong the life of the pump and shaft by reducing friction.

The manufacturer's recommendations should be followed in choosing a packing.

Mechanical Seals

Many pumps use mechanical seals in place of packing. Mechanical seals serve the same purpose as packing: they prevent leakage between the pump casing and shaft. Like packing, they are located in the stuffing box where the shaft goes through the volute; however, they should not leak.

Mechanical seals have two faces that mate tightly and prevent water from passing through them. One half of the seal is mounted in the pump or gland with an "O" ring or gasket, thus providing sealing between the housing and seal face. This prevents water from going around the seal face and housing.

The other half of the mechanical seal is installed on the pump shaft. This part also has an "O" ring or gasket between the shaft and seal to prevent water from leaking between the seal part and shaft. There is a spring located behind one of the seal parts, which applies pressure to hold the two faces of the seal together and keeps any water from leaking out. One half of the seal is stationary, and the other half is revolving with the shaft.

Some of the advantages of mechanical seals are:

- they last from three to four years without one having to touch them, resulting in labor savings;
- usually there is no damage to the shaft sleeve when they need replacing; and
- continual adjusting, cleaning, or repacking is not required.

Some of the limitations are:

- high initial cost;
- a competent mechanic is needed for installation;
- when they fail, pump must be shut down; and
- pump must be dismantled to repair.

Lubrication

Pumps, motors and drives should be oiled and greased in strict accordance with the recommendations of the manufacturer. The best quality oils and grease obtainable should be used. Over-greasing should be avoided, as too much grease will cause as much damage as lack of lubrication.

It is especially important not to over-lubricate motor bearings as this can lead to bearing seal failures. This has been the cause of an untold number of motor failures. The present trend is toward the use of more sealed bearings that require no additional grease for their lifetime.

Oil should not be put in the housing while the pump shaft is rotating because the rotary action of the ball bearings will pick up and retain a considerable amount of oil. When the unit comes to rest an overflow of oil around the shaft or out of the oil cup will result.

Pump packing should be well lubricated since it increases the efficiency of the pump by reducing air leakage and prolongs the life of the packing and shaft by reducing friction. A trickle of water should be allowed to keep the gland cool. If the packing box leaks excessively, remove the packing and repack with fresh packing.

Never repack with part new and old packing and when repacking be sure that the water seal ring is in proper position in the stuffing box to receive the seal water. A water seal ring serves a dual purpose in that, as well as lubricating, it keeps gritty material from entering the packing box (thus increases the life of the packing and shaft.)

Mechanical seals are always flushed in some manner to lubricate the seal faces and minimize wear. This may be the liquid being pumped and is referred to as "source lubrication". If fresh water is used, it is connected from the high-pressure side and back to the stuffing box low-pressure side. In some lift stations, wastewater is used in this matter, but it must be filtered. Still another way of lubricating the seal is to use a spring-loaded grease cup.

Whatever the method, mechanical seals should be inspected frequently. The seal water is adjusted to 5 PSI above maximum discharge pressure to keep the wastewater and grit from entering the seal housing and contaminating the seal faces. If grease cups are used they must be kept full at all times and inspected to make sure they are operating properly.

When a pump is fitted with a mechanical seal, it must never run dry, or the seal faces will be burned and ruined. Mechanical seals are not supposed to have any leakage from the gland. If a leak develops, the seal may require resurfacing, or it may have to be replaced.

Priming a Pump

A pump will not operate unless it has been properly primed. A pump is considered primed when the pump casing and the suction piping are completely filled with liquid. A pump that has a positive suction head will seldom lose its prime, whether the pump is on or off, and will likely only need to be primed after it has been opened or replaced.

For pumps with a negative suction head (suction lift), the water tends to run back out of the pump and down the suction line when the pump stops. If the casing is filled with air, the impeller cannot create enough vacuum upon starting to draw water back into the unit, and the air will just circulate around in the pump. In this situation, both the pump and motor will overheat in a short time.

If a positive suction head cannot be provided, the pump must be separately primed (filled with water) each time it is started unless it is equipped with some type of self-priming device, such as a foot valve, a vacuum pump or ejector, or a priming chamber.

A foot valve is a specialized check valve at the end of the suction line. The valve is open when the pump is operating but shuts as the pump stops, holding the water in the pump and suction

line after the pump has been initially primed.

Vacuum pumps and ejectors are separate units attached to the main pump casing. They create the vacuum needed to fill the pump before startup. These are often installed where suction life is great.

A priming chamber is a large chamber at the top of the pump. This chamber is an air separator that ensures that the air in the pump will be removed through the discharge line when the pump is started.

Some self-priming pumps have a wide suction inlet that is higher than the pump. When the pump stops, the discharge valve closes and the water in this suction inlet runs back into the pump, rather than down the suction line. A vent exhausts any air that remains.

Cavitation

Cavitation is the formation and collapse of a gas pocket or bubble on the blade of an impeller. This condition results from unusually low pressures that can occur when pump inlet pressures drop below the design inlet pressures or when the pump is operated at flow rates considerably higher than design flows. At very low pressure, the water in the pump starts to boil and vapor bubbles form. These bubbles then collapse with great force that can knock metal particles off and pit the impeller. The same action can occur on pressure reducing valves and partially closed gate and butterfly valves.

Cavitation is accompanied by loud noises that sound like someone is pounding on the impeller or valve with a hammer. Damage caused by cavitation can be severe, resulting in replacement of the impeller and/or volute.

Water Hammer

Also known as hydraulic shock, water hammer is an oscillation in pressure that results from a too rapid acceleration or retardation of flow, such as when a valve is opened or closed very rapidly. When a valve position is changed quickly, the water pressure in a pipe will increase and decrease back and forth very quickly. This rise and fall in pressures can cause serious damage to the system as well as producing a noise like someone hammering on a pipe. Surge tanks installed in the areas where water hammer is a problem can absorb some of the pressure.

Air release (sometimes called air relief) valves can also help minimize water hammer damage. These devices allow the release of air in the distribution network while the system is pressurizing. The valve is open allowing air to escape. When water fills the pipe, it forces a ball into the valve and closes it, preventing escape of effluent. These valves are usually installed at high elevation points in a distribution network, as well as at the end of laterals and trunk lines where air might be forced to a dead end.

Pump Controls

A variety of controls are used to operate wastewater pumping systems. These controls are used

to activate pumps, valves, water level sensing devices, alarms, timers, counters, and meters. Controls are contained in protected enclosures called control panels. Control panels can be simplex (control one pump), duplex (control two pumps), or multiplex (control more than two pumps).

All control panels should have a ground rod and a hand-off-automatic (HOA) switch that allows the operator to override the control system and manually activate the pump. Panels should have visual and audible alarms and an alarm silence switch.

Water Level Sensing and Pump Control

Accurate sensing of high and low water levels is critical for proper timing of pump operation. Control of pumping systems is achieved by an ON/OFF type of control, which starts and stops pumps according to a level, pressure, or flow measurement. Usually an ON/OFF pump control system responds to level changes in a tank of some type. Water level can be sensed directly with a float or by a pressure change at the tank or pump site. The pump is thus turned off or on as tank level rises above or falls below predetermined level or pressure limits. These controls can either be single-point detection or continuous detection.

To prevent the pump from running after a loss of level signal, electrical circuitry should be designed so the pump will turn OFF on an OPEN signal circuit, and ON only with a CLOSED circuit. Larger pump systems also will often have a low-pressure cutoff switch on the suction side to prevent the pump from running when no water is available, such as with an empty tank or closed suction valve.

Controls may also protect against overheating a pump (as happens when continuing to pump against a closed discharge valve) by high-pressure or low-flow cutoff switch on the discharge piping. Both the high- and low-pressure switches should shut off the pump through a time delay circuit so that short-term pressure surges (dips and spikes) in the pumps' piping can be tolerated.

Types of ON/OFF pump controls include:

- float switches;
- pressure bulbs and diaphragm switches;
- bubble tubes;
- electrode switches; and
- ultrasonic sensors.

Float Switches

The simplest and most common type of control unit is a counter-weighted float that triggers a mercury switch. The float is fixed at a desired depth. When the wastewater level is below the float, the float hangs down. As the wastewater level rises, the float is raised. When it reaches a predetermined level, the switch is tripped to start the pump. When the wastewater level falls to the cutoff level, the float switch stops the pump.

Pressure Tubes and Diaphragm Switches

Pressure-sensing controls entail the small movement of some flexible element subjected to a force. The most common types are the Bourdon tube, bellows, or diaphragm arrangements. As the water level rises and reaches a specific depth, the pressure generated by the water depth pushes the flexible element inward, compressing the volume of air inside. The increased air pressure is registered on a sensor and transmitted to the pump to turn on. As the water level goes down, pressure decreases, the flexible element extends outward again, and the pump switches off.

Bubbler Tubes

The pressure created by the liquid level is sensed, but not directly as with a liquid pressure element. Air pressure is created in a bubble tube to just match the pressure applied by the liquid above the open end of the tube when it is immersed to a precisely determined depth in a tank or basin. The air pressure in the tube is then measured as proportional to the liquid level above the end of the tube.

Bubbler systems are adjusted so air just begins to bubble slowly out of the submerged end of the sensing tube. They automatically compensate for changes in liquid level by providing a small, constant flow of air through the bubbler tube by means of a constant flow of air regulator.

Electrode Level Sensing Switches

An alternative to mechanical level-sensing systems is the electrical probe. The probes can be small-diameter stainless steel rods inserted into a tank through a fitting, usually through the top, but at times in the side of a vessel. A small voltage is applied to the probe by the system's power supply, with current flowing only when the probe becomes immersed. When current flow is sensed, a switch turns the pump on. When the wastewater level falls and the probe is no longer immersed, current ceases to flow and the pump is turned off.

Ultrasonic Level Detecting Switches

This type of level detecting system is based on high frequency sound waves. A mounted transmitter sends sound waves to the wastewater surface. The time is takes for the sound waves to bounce back is measured and converted to a signal that is proportional to the time and to the water level.

Alternators

Alternators are relay devices designed for alternating the run cycle or duplexing action of two or more motors automatically. They are used to automatically or manually divert flow to be pumped through two or more pumps in a cycle in accordance with a predetermined sequence. Duplex or multiplex control panels include automatic or manual pump alternators (two pumps) or sequences (more than two pumps).

In a station with multiple pumping units, an automatic alternator or sequencer regularly changes the order of the pumps' start-up to maintain similar operating times for all pumps (to provide even wear). To protect the pump's electric motor from overheating, level controls should be set so that the pump starts as few times as possible.

Alarms

Alarms are visual and audible signals that a variable is out of bounds, or that a condition exists in the system requiring the operator's attention. They can vary from a simple high water level alarm to a multiple system. The most common and necessary is the high water alarm. High water alarms can be activated using the same ON/OFF controls used to sense water level changes. Other alarms that may be necessary include pump failure alarms, power failure alarms, seal failure alarms, and motor head sensor alarms.

Timers

Timers are devices that allow an operator to control pumps or controls in specified ways at predetermined times. Run cycle timers are timers that repeatedly open and close contacts according to preset time cycles.

Counters

Counters provide flow indication for timer panels. They count the number of times the pump has been activated.

Relays

Relays are electric devices designed to interpret input conditions in a prescribed manner and, after specified conditions are met, to respond and cause contact, operation or similar abrupt changes in associated electrical control circuits. Time delay relays (TDR) are relays with either mechanical or solid state output contacts that perform timing functions upon energization or control signals.

Telemetry

Telemetry is the automatic transmission of data on wastewater system characteristics between two widely separated locations, typically an isolated, unattended facility and a central, attended facility. The electrical link between a field transmitter and the receiver. Telephone lines are commonly used to serve as the electrical line.

A variety of telemetry systems are available to communicate an alarm condition to a desired remote location. These systems range from simple single signal devices to complex systems. The transmitter portion is usually installed in the control panel and may have its own battery back-up power system.

Meters

Meters are instruments for measuring some quantity such as the amount or rate of flow of wastewater. It is necessary to know the quantity of wastewater flow so adjustments can be made to pumping rates, chlorination rates, and other processes in the system. Flow rates must be known also for calculating loadings on treatment processes, treatment efficiency and to satisfy the non-discharge permit.

Elapsed time meters are used to record the amount of time each pump runs. This is a good way to monitor the hours per day that a pump runs. One elapsed time meter is used per pump.

Flow measuring devices must be periodically calibrated. Most manufacturers and dealer representatives will offer a service and maintenance agreement with a flow meter for its periodic calibration. Typically, once per year is required. Comparing flow measurement against other methods of flow estimation can also help to calibrate pump discharge rates.

For example, knowing the discharge rate from a sprinkler based on nozzle size and pressure (which gives gallons per minute) and multiplying by the total pump run time can give a good estimate of total flow in a pump cycle. Another standard to check against is pump drawdown in a tank or wet well, or lagoon level drawdown. Both of these methods require the ability to valve off influent flow into the tank or lagoon, or have it precisely measured.

An operator should use all appropriate techniques to help with flow management in a spray irrigation system

Microprocessors

Microprocessors and computers are now commonly used in many wastewater applications, including individual instruments and entire digital computer-based control systems. Microprocessors can do extremely complex functions at high speeds with low power consumption. The most significant example of the utility of the microprocessor is the personal computer (PC). These microprocessors are relatively inexpensive stand-alone computer systems that can help an operator enter, store, retrieve, and manipulate enormous amounts of data quickly and easily.

4.2. Distribution Networks and Devices

To ensure the appropriate amount of wastewater is uniformly applied to spray fields, operators must be familiar with correct pressure settings, sprinkler spacing, and time of operation needed. This section discusses distribution system components and general operational procedures for common types of wastewater irrigation systems follows

Pipes

A piping system is a system of pipes, fittings, and appurtenances within which a fluid flows. Before discussing specific types of pipes, we need to define some terms that will be used in our discussion of piping:

- O.D. - outside diameter;
- I.D. - inside diameter;
- I.P.S. - iron pipe size;
- P.I.P. - plastic irrigation pipe size;
- Class - a pipe's pressure rating (PR); and
- S.D.R. - Standard Dimensional Ratio number: the outside diameter divided by the minimum wall thickness; the larger the SDR number, the thinner the wall is in the pipe.

Piping used in spray irrigation systems can either be made of metal (iron, stainless steel, copper, aluminum) or plastic (PVC or polyethylene). Several of these are discussed below:

Cast Iron - Cast iron pipe is some of the oldest piping material in use today. It is now manufactured by a process called spin casting, during which molten iron is injected into a spinning mold. The result is a pipe of consistent diameter and wall thickness. Cast iron pipe can withstand high working pressures. Pressure ratings of 350 psi are common. However, the material cannot withstand sharp shock loads either internally or externally.

Steel - Steel pipe is made by extruding or welding sections of steel to form a pipe. This pipe falls into two categories, mill pipe and fabricated pipe. Steel pipe is classed as a flexible conduit. That means that is has the ability to withstand a 3% deflection of the diameter without damage to the pipe. Steel pipe is commonly manufactured to meet very high pressures (up to 700 psi is not uncommon). However, under a vacuum it will collapse.

Because steel pipe is a flexible conduit, it requires a selection of wall thickness suitable to withstand external loads as well as internal loads. Steel can easily be shaped into various sizes and shapes, which is one of its major advantages. It has a high tensile strength and high ductility. These characteristics give it the ability to withstand high internal and external loads.

The main disadvantage is that it is easily attacked by corrosive elements, which results in high maintenance costs. An additional disadvantage is that it will collapse under a vacuum. Epoxy coated steel is more resistant to corrosion and offers longer life spans.

Aluminum - Aluminum pipe is used in above ground situations as portable pipe. It is often used to pipe water to a traveling irrigation device such as a center pivot tower or traveling gun hose-reel. It is sometimes used in solid set systems as well. It is lightweight, very portable, and easily connected. It does not offer good strength and is easily damaged by machinery or fallen trees. Often, leaks can occur until the distribution system is fully pressurized. Above ground pipe is not suitable where winter operation is necessary – as freezing causes pipe damage as well as poor function of the sprinkler heads attached to the pipe due to ice clogging.

Ductile Cast Iron Pipe (DIP) - Ductile cast iron pipe is made by injecting magnesium into the cast iron during the molding process. The magnesium alters the shape of the carbon structure of the cast iron. This gives the pipe superior beam strength. It will resist high impacts and is more corrosion resistant than gray cast iron. Ductile iron pipe is classed by wall thickness.

The common thickness class ranges from 50 through 56. The higher the number, the thicker the wall. However, wall thickness also varies with the size of the pipe. The thickness class needed

for a particular condition is based on the internal working pressure, the depth of the cover, the pipe size and the type of bedding condition to be used.

Because of its ability to withstand high stress, extreme beam and crush loads, unusual shock, unstable bedding and deep fills, it is one of the few materials that can be used in extreme conditions. Its disadvantages are its weight and its susceptibility of corrosion.

PVC - PVC pipe is made from unplasticized polyvinyl chloride. This material only gained wide acceptance in the wastewater industry when a thicker walled material was developed and an acceptable standard was adopted. The standard that governs most of this thick-walled PVC pipe is called C-900. This distinguishes it from other PVC pipe that has a thinner wall. PVC is manufactured in various sizes and wall thicknesses. There are three groupings of pipe material commonly used in the wastewater industry.

Scheduled Pipe - First there is the "scheduled pipe". "Schedule" refers to the wall thickness of the pipe; a higher number denotes a thicker pipe. The two common schedules are schedule 40 and schedule 80. This material is not normally placed in a trench. It is used as piping in small pump stations and in chlorine stations. The wall thickness, I.D., and O.D. of scheduled pipe are based on steel pipe dimensions. Thus, the working pressure will vary from 600 psi from ½ inch schedule 40 to 160 psi for 8 inch schedule 40.

Pressure Pipe - Second there is what is called "pressure pipe". This material is manufactured in iron pipe O.D. sizes (I.P.S). The common classifications of this pipe are 160 psi, 200 psi and 315 psi. This material can be joined by either push-on gasket fittings or solvent welds.

Class Pipe - Third, there is "class pipe", which is manufactured in both iron pipe O.D. sizes and cast iron OD sizes. There are three classes of this material based on a standard working pressure. The classes are 100, 150, and 200. The wall thickness of the pipe increases as the pipe diameter increases. Class 200 PVC pipe with cast iron pipe outside dimensions is the most common Class pipe used in the wastewater industry.

The primary advantages of this material are its light weight, the ease with which it can be cut, and its ability to resist corrosion. One of its disadvantages is its inability to withstand high impact and shocks. It is also sensitive to sunlight if stored outside too long and will elongate in high ambient temperatures, making installation difficult.

Plastic pipe should not be used in areas where petroleum products may be present. Finally, in cold weather it becomes brittle, requiring special handling.

Fittings

Pipe fittings are joints or connectors between pieces of pipe. Examples are elbows that alter the direction of a pipe, tees and crosses to connect a branch with a main, plugs and caps to close an end, and bushings, diminishers, or reducing sockets to couple two pipes of different dimensions. It is important to remember that Schedule PVC fittings do not have the same rating as the pipe. Types of fittings include:

- **elbow** - connects two pipes at an angle; the angle is always 90 unless another angle is

stated; also called an ell.

- **tee** - either cast or wrought iron or PVC, that has one side outlet at right angles to the run; a single-outlet branch pipe.
- **reducing tee** - any tee having two different sizes of opening; it may reduce on the run or branch.
- **adapter** - a fitting that is used to connect pipes of different types or sizes.
- **reducer** - pipe fitting having an opening at one end smaller than that at the other end.
- **sleeve** - pipe fitting for uniting two pipes of the same nominal diameter in a straight line; a tube into which a pipe is inserted.
- **wye** - pipe fitting with three branches positioned in one plane in a pattern of the letter Y.
- **union** - the usual trade term for a device used to connect pipes; commonly consists of three pieces:
  - the thread end, fitted with exterior and interior threads;
  - the bottom end, fitted with interior threads and a small exterior shoulder; and
  - the ring, which has an inside flange at one end while the other end has an inside thread like that on the exterior of the thread end.

Pipe cleanouts should be used whenever wastewater has a solids content that causes the potential for solids buildup and clogging in piping. They are also advised at sharp turns in piping such as elbows, where water tends to slow down. A pipe cleanout is typically a wye fitting that is installed several feet up-flow from the appropriate area to be cleaned.

The "dead end" of the wye is at the ground surface or above for easy access, and is capped off with a threaded plug. This access must be protected from equipment and traffic. It allows the operator to clean the piping with plumbing snakes, augers, or water pressure cleaners.

Thrust blocking is used in irrigation systems using moderate to high water pressures to protect the distribution system from damage that could be caused by water pressure. Thrust blocking is used at all points at which water flow either changes direction (such as tees and elbows) or comes to a dead end (ends of laterals or field valves). The thrust block, which is typically a mass of concrete, must lie against natural ground to offer the most protection.

Pipe excavation for repair at any of these points is likely to encounter concrete thrust blocks, which must be replaced when replacing pipe or fittings where water changes direction.

Connections

A connection is a collar or coupling that fits over adjacent ends of pipe to be joined, and which, when drawn tight, holds the pipe together either by friction or by mechanical bond. Connections include:

- **flange** - a connection made by flanges bolted together; the joint is made water-tight by a gasket placed between the two flanges.

- **mechanical joint** - any form of flexible joint involving lugs and bolts; uses a bell and spigot arrangement. A rubber gasket is placed around the spigot. The gasket is forced into the bell by a metal ring (called a follower ring) that is held to the bell by a series of bolts.
- **bell and spigot** - a form of joint used on pipes that have an enlarged diameter or bell at one end, and a spigot at the other that fits into and is laid in the bell. The joint is then made tight by lead, cement, rubber "O"ring, or other jointing compounds or materials.
- **threaded** - a connection made by threading a male end section of pipe or fitting into a female fitting or adapter. With metal threads, pipe compound is typically required for a waterproof seal. Teflon thread tape may be used on metal or PVC pipe threads.

PVC cement, also called "solvent weld", uses a special primer and glue to physically mate (connect) pipe and fittings. The glue causes the PVC to bond by a chemical reaction that melts the two pipes, allows them to combine, then cools and solidifies into the banded pipe.

Valves

A valve is a device installed in a pipeline to control the magnitude and direction of the flow. It consists essentially of a shell and a disk or plug fitted to the shell. Valves vary in construction and size depending upon their function. Some are classified according to their method of operation or design and some are named for the functions they perform. Valves can be operated automatically or manually.

Types of valves encountered in a surface irrigation system include:

- **gate valve** - typically used as a shut off valve. A disc in the valve is raised and lowered by a threaded stem or sliding stem to open and close the valve. Gates valves are used in pressure distribution systems to regulate the rate of wastewater flow. Gate valves are designed to operate fully open or fully closed.
- **plug valve** - often used in multiple outlet valves, such as diversion valves. Like a gate valve, a plug valve has an unobstructed flow, yet requires only a 90° turn to open it. The movable control element is a cylindrical or conical plug, in contrast to a flat disk. The valve is turned directly with a key to change the less-than-fully open port.
- **butterfly valve** - has a disc that turns sideways to open the valve. It is a one-quarter turn valve and can be used for throttling relatively clean water. The disk, as it opens or closes, rotates about a spindle supported by the frame of the valve. The valve is opened at a stem. At full opening, the disk is in a position parallel to the axis of the conduit.
- **check valve** - allows wastewater to flow in only one direction. Check valves either have ball or flapper mechanisms that prevent backflow of effluent. A valve provided with a disk hinged on one edge so that it opens in the direction of normal flow and closes with reversal of flow.
- **solenoid valve** - uses a solenoid (an electric coil) to open and close small openings to divert fluid from one side of a diaphragm to the other. When the pressure on top of the diaphragm is equal to the inlet pressure, the valve will remain closed. When pressure is

released from on top of the diaphragm, a pump can then open the device. Solenoids can operate small valves or other electrical switches.

- **air relief valve** - designed to allow the release of air pressure in an irrigation system. Air relief valves are typically installed at the distal ends of long runs of piping, at high elevation points in fields, and at other places where air may be trapped, such as at a field valve or sharp turn in the piping. These valves have a ball or some mechanism that allows air to escape, but shuts tightly when water pressure enters them. Their purpose is to allow air that is in the piping system to escape when water is being pumped into the system and to help eliminate damage to pipes and sprinklers from excessive air pressure.
- **pressure relief valve** - valve that, when actuated by static pressure above a predetermined level, opens in proportion to the excess above this level and reduces the pressure to it.
- **pressure reducing valve** – valve that provides a steady pressure into a system that operates at a lower pressure than the supply system. A reducing valve can normally be set for any desired downstream pressure within the design limits of the valve. Once the valve is set, the reduced pressure will be maintained regardless of changes in supply pressure (as long as the supply pressure is at least as high as the reduced pressure desired) and regardless of the system load, providing the load does not exceed the design capacity of the reducer.
- **pressure regulating valve** - valve that automatically cuts off the flow of a liquid or gas at a certain pressure. Regulators are used to allow high-pressure fluid supply lines or tanks to be reduced to safe and/or usable pressures for various applications. Cannot adjust in field.
- **globe valve** - water is directed through the valve in a specific direction, then is forced to change direction and go through a large orifice, hit a disk and again change direction to exit the valve. This induces head loss and makes it a good throttling device. It has a round, ball-like shell and horizontal disk.

See Appendix D-1 for information on pipe weights and dimensions, pressure ratings, installation procedures, fittings and connections.

Sprinklers

Sprinklers, drip emitters, and other devices are used to distribute wastewater to the designated waste application fields. Many people consider the distribution system to be the heart of a spray or drip irrigation system. Of course, if the pumping system is not designed or is not working properly, then the sprinklers cannot make a bad situation good. However, most operators of spray irrigation systems will spend much of their time dealing with sprinkler management, maintenance, and repair. Sprinkler maintenance and operation is a key component of managing a waste application system.

There are many types of distribution devices available. Most are not designed for wastewater application, but some have been adapted for wastewater. Many function well where wastewater is very dilute and has few solids or chemicals.

It is beyond the scope of this manual to discuss all types of equipment available. The operator should be familiar with the basic terms describing irrigation equipment and the factors that affect the operation of that equipment. When purchasing irrigation equipment, always notify the dealer that the equipment will be used in a wastewater setting.

The following are the major components of the distribution system:

- **nozzle** - the part of the sprinkler where the wastewater discharge occurs. Important factors are nozzle type (plastic, brass, taper bore, ring, etc.) and nozzle size at the opening (in inches).
- **full circle sprinkler** - a sprinkler that turns 360 degrees and wets a total circle. These are used in the interior and exterior positions of sprayfields.
- **partial circle or partial turn sprinkler** - a special sprinkler that allows the operator to direct discharge to a select portion of the field. Devices such as clips or threaded stops cause the sprinkler to rotate part circle (less than 360 degrees). These are often used to prevent irrigation into buffers, roadways, ditches, or problem areas in the field. Using part turn sprinklers, without changing other parameters such as nozzle size or pressure, results in an increased wastewater application rate.

  For example, a ¼ turn sprinkler with the same settings as a full turn sprinkler will apply four times as much water per hour to the area it irrigates. Part turn sprinklers must be operated very carefully to avoid ponding and runoff.
- **gun** - usually refers to a large sprinkler with nozzle opening exceeding ½ inch. A gun is usually mounted onto a permanent riser of two-inch pipe size or larger, a traveling gun cart, or the distal end of a center pivot system.
- **rotary head sprinkler** - a sprinkler whose head rotates around the base due to a swinging, spring-loaded impact arm. The water pressure throws the arm to the side, it returns due to the spring, and intercepts the water stream, causing the sprinkler to rotate several degrees. These sprinklers are much more moderately priced than guns.
- **micro spray heads** - devices that distribute effluent in a variety of patterns other than the rotary impact sprinkler head described above. Water is deflected via vanes, grooves, wobbling weights, and other devices that allow for effluent distribution. Usually, these are used with lower pressures (5 to 30 psi), and often are used to reduce wind drift. The length of effluent throw is limited, resulting in close spacing required.
- **drip emitters** - installed in flexible (PVC, polyethylene) tubing (hoses). They allow water that is under pressure inside the tubing to be emitted at low pressures. Usually, this type of piping is installed at the ground surface or slightly under the ground surface to provide water uptake by plant roots. The drip emitter consists of a labyrinth inside the hose that allows for pressure drop as the water is emitted. The orifice size is about 1/16 to 1/8 of an inch and distributes less than one gallon per minute.

Solid Set Irrigation Equipment

Solid set or stationary systems for the spray irrigation of wastewater are usually permanent installations (lateral lines are PVC pipes permanently installed below ground). One of the main advantages of stationary sprinkler systems is that these systems are well suited to irregularly shaped fields. It is difficult to give a standard layout, but there are some common features between systems.

Sprinkler spacing is based on nozzle flow rate and desired application rate. To provide proper overlap, sprinkler spacings are normally 40 to 60 percent of the sprinkler wetted diameter, or in the range of 80 feet by 80 feet. Other spacings can be used and some systems are designed to use gun sprinklers (higher volume) on wider spacings. A typical layout for a permanent irrigation system is shown in Figure 4-13.

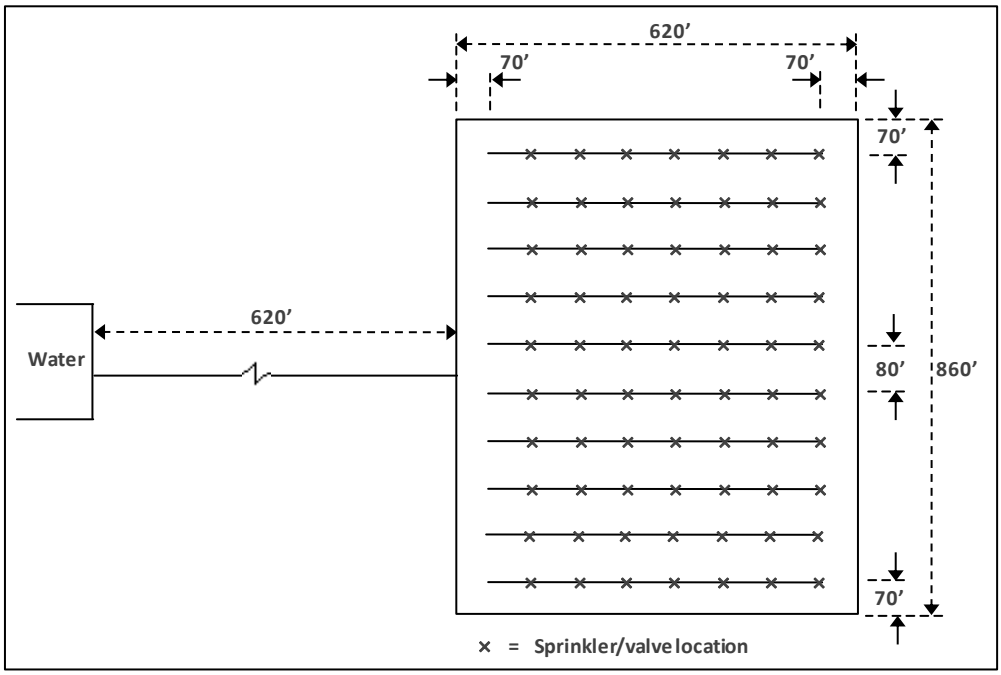


Figure 4-13. Schematic layout of a typical solid set irrigation system.

The minimum recommended nozzle size for wastewater is ¼ inch. Typical operating pressure at the sprinkler is 25 to 60 psi. Sprinklers can operate full or partial circle. The system should be zoned (any sprinklers operated at one time constitutes one zone) so that all sprinklers are operating on about the same amount of rotation to achieve uniform application.

Gun sprinklers typically have higher application rates; therefore, adjacent guns should not be operated at the same time (referred to as "head to head"). Most permanent systems use Class 160 PVC plastic pipe for mains, submains, and laterals and either 1-inch galvanized steel or Schedule 40 or 80 PVC risers near the ground surface where an aluminum quick coupling riser valve is installed (Figure 4-14). In grazing conditions, all risers must be protected (stabilized) if left in the field with animals.

The advantages of fixed irrigation equipment include:

- flexible irrigation rates;
- suitability for irregularly shaped fields; and
- suitability for tree crops.

Disadvantages include high capital costs and limited use for row crops.

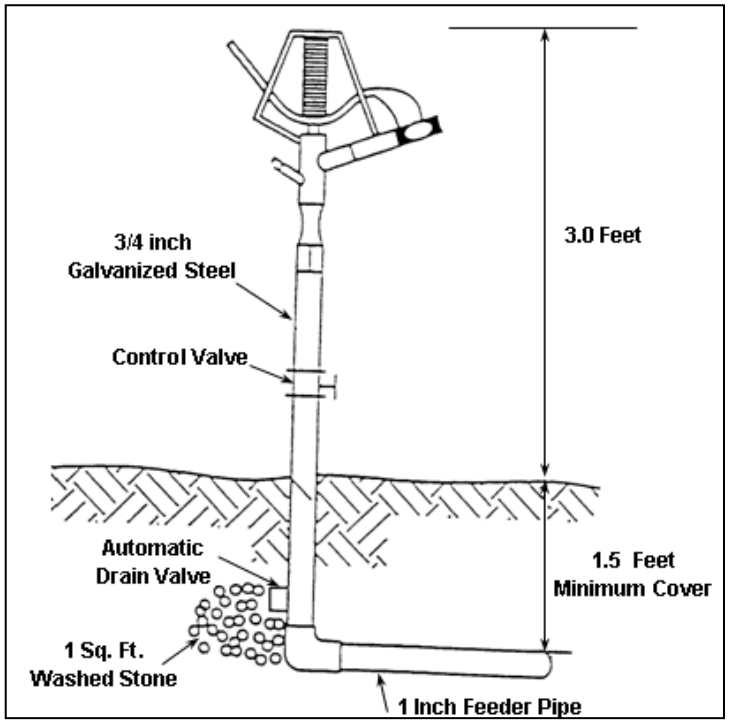


Figure 4-14. Stationary sprinkler.

Mobile Irrigation Equipment

Mobile or traveling sprinkler systems are either cable-tow or hose-drag travelers, center pivot, or linear-move systems.

Travelers

The cable-tow traveler consists of a single-gun sprinkler mounted on a trailer with water being supplied through a flexible, synthetic fabric, rubber- or PVC-coated hose. A steel cable is used to guide the gun cart.

The hose-drag traveler consists of a hose drum, a medium-density polyethylene (PE) hose, and a gun-type sprinkler. The hose drum is mounted on a multi-wheel trailer or wagon. The gun sprinkler is mounted on a wheel or sled type cart referred to as the gun cart. Normally, only one gun is mounted on the gun cart. The hose supplies wastewater to the gun sprinkler and also pulls the gun cart toward the drum (Figure 4-15).

Figure 4-15. Hard hose traveler showing reel and gun cart.

The distance between adjacent pulls is referred to as the lane spacing. To provide proper overlap, the lane spacing is normally 70 to 80 percent of the gun wetted diameter. Operating pressures range from 100 to 150 psi. Like stationary sprinklers, traveling guns can operate full or partial circle. A typical layout for a hard-hose traveler irrigation system is shown in Figure 4-16.

The hose drum is rotated by a water turbine, water piston, water bellows, or by an internal combustion engine. Regardless of the drive mechanism, the system should be equipped with speed compensation so that the sprinkler cart travels at a uniform speed from the beginning of the pull until the hose is fully wound onto the hose reel. If the solids content of the wastewater exceeds one percent, an engine drive should be used.

Nozzle sizes on gun-type travelers range from ½ to 2 inches in diameter. There are three types of nozzles: taper bore, ring or taper ring. The ring nozzle provides better breakup of the wastewater stream, resulting in smaller droplets with less impact energy (less soil compaction) and providing better application uniformity throughout the wetted radius.

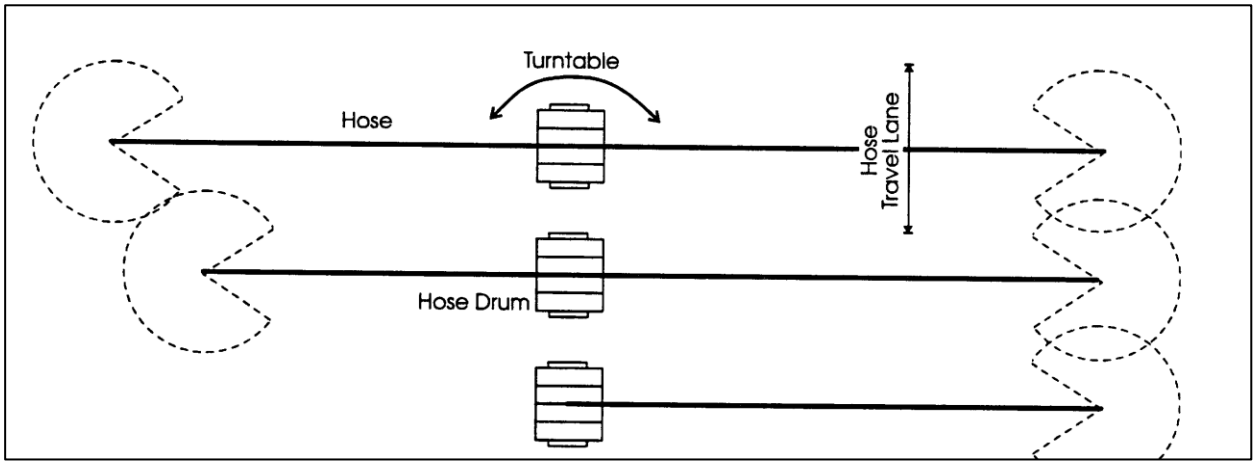


Figure 4-16. Schematic layout of a hose-drag traveler. Travel lanes are 100 to 300 feet apart, depending on sprinkler capacity and diameter coverage.

But, for the same operating pressure and flow rate, the taper bore nozzle throws water about five percent further than the ring nozzle, i.e. the wetted diameter of a taper bore nozzle is five percent wider than the wetted diameter of a ring nozzle. This results in about a ten percent larger wetted area such that the precipitation rate of a taper bore nozzle is approximately ten percent less than that of a ring nozzle.

A gun sprinkler with a taper bore nozzle is normally sold with only one size nozzle whereas a ring nozzle is often provided with a set of rings ranging in size from ½ to 2 inches in diameter. This allows the operator flexibility to adjust flow rate and diameter of throw without sacrificing application uniformity.

However, you should be aware that using a smaller ring with a lower flow rate will not normally reduce the precipitation rate. Rather, the precipitation rate remains about the same because while a smaller nozzle results in a lower flow, it also results in a smaller wetted radius or diameter. The net effect is little or no change in the precipitation rate.

Furthermore, on water drive systems, the speed compensation mechanism is affected by flow rate. There is a minimum threshold flow required for proper operation of the speed compensation mechanism. If the flow drops below the threshold, the travel speed becomes disproportionately slower, resulting in excessive application even though a smaller nozzle is being used.

System operators should be knowledgeable of the relationships between nozzle size, flow rate, wetted diameter, and travel speed before interchanging different nozzle sizes.

Advantages of traveling irrigation systems include:

- lower capital costs; and
- adjustable speed with no interruption of irrigation.

Disadvantages include:

- high precipitation rates on large units (0.5 to 1.0 inch per hour);
- runoff from traveler lanes;
- high operating costs (energy);
- requires two people to operate; and
- limited use on forested sites (can result in debarking unless diffusers are used).

Center Pivots and Linear Move Systems

The use of center-pivot systems for wastewater irrigation is increasing. Center pivots are available in both fixed-pivot point and towable machines. They are available in size from single tower machines that cover around 10 acres to multi-tower machines that can cover several hundred acres.

Center pivots use either rotary sprinklers, small guns, or spray nozzles. Operating pressures range from 25 to 60 psi. Drop-type spray nozzles offer the advantage of applying wastewater close to the ground at low pressure, which results in little wastewater drift due to wind.

A center pivot device applies wastewater along an elevated distribution pipe that is anchored at one end. Wastewater is supplied at the anchored end and distributed from sprinkler heads mounted to the distribution pipe. The unit is driven by an electrical motor mounted at the fixed end. The application rate of each gun increases with its distance from the fixed center, so that there is uniform application of water as the pivot moves in a circular motion (Figures 4-17 and 4-18).

Linear-move systems are similar to center pivot systems, except that neither end of the distribution pipe is anchored and travel is in a straight line. Drives at each end move the distribution pipe across the spray field. Wastewater is supplied through a feeder hose to one end of the distribution pipe.

Depending on the type of sprinkler used, operating pressure ranges from 10 to 50 psi. Low-pressure systems reduce drift at the expense of higher application rates and greater potential for runoff.

Advantages of center pivot and linear move systems include:

- excellent irrigation control (programmable);
- wide range in precipitation rates (0.07 to 1.0 inch per hour);
- low operating costs (energy, people); and
- bad weather options (rain, wind).

Disadvantages include:

- high capital costs;
- center pivots fixed to one side (towable pivots available); and
- wheel tracks are potential source of runoff.

Figure 4-17. Center pivot system.

Figure 18. Center pivot control panel.

Operational Issues

By understanding the irrigation system components and their relative location and by using monitoring devices, the irrigation system operator can effectively operate the system. Troubleshooting problems early can also prevent significant and expensive equipment problems and possible environmental degradation.

An operator should be familiar with all system components that make up a spray irrigation facility. This is most easily done by maintaining a set of approved, as-built plans for the facility.

Design plans do not always reflect what was actually installed in the ground. The plans should provide sufficient detail so the operator can determine where all pipes and their respective sizes and types are; and where all valves and fittings are located. This will allow the operator to perform quick service and repair, and to keep spare parts on hand. If as-built plans are not available, they may be obtained from the design engineer for the facility, or possibly the permitting branch of the Division of Water Resources.

The operator must be familiar with pump discharge rates and flow rates as described earlier in the chapter. Knowledge of operating pressures in the field is crucial to understanding flow rates and system efficiency. Pressure is often measured at the pump, with the assumption that the same pressure exists throughout the distribution system. It is good to know pressure at several locations, but the location that will tell you the most about the flow is the pressure at the discharge point (sprinkler or gun).

Most guns have a fitting where a pressure gauge can be easily mounted. Rotary impact sprinklers can be easily fitted with a pressure gauge by installing a tee in the sprinkler riser. On an irrigation system or zone with multiple sprinklers, several pressure readings across the field give the best picture.

However, at least one reading near mid-field and one near the higher sprinklers give a good average pressure for the system. This is the pressure that dictates the flow rate (gallons per minute) through each sprinkler. Significant elevation changes within one field or zone can result in higher discharge pressure and rate in the lower portions of the field.

Knowledge of pump pressure and field pressure can help an operator determine if pumps are running efficiently. Gathering baseline data can also help determine when pipes are beginning to clog. Blockages, as well as broken or separated pipes, can cause pressure reductions in the distribution system. These problems often result in extremely wet areas that will be obvious to the operator. Wet and soggy areas near valves and fittings may indicate that the pipe has been damaged or improperly installed such that leaks are causing the soil in the area to remain saturated.

Close monitoring of effluent pumping rates by use of flow meters and pump delivery rates will help with operational decisions at the facility. Such things as pump, piping and sprinkler wear can be predicted with accurate flow records. These records can also help the operator determine

if infiltration and inflow from the collection system are contributing to the waste stream. Accurate flow monitoring helps maintain compliance with state record keeping requirements, and may indicate when a system expansion is necessary.

If wastewater flows exceed design flow, then a detailed examination of the system should be conducted and necessary steps should be taken to maintain compliance with the system permit. Pump monitoring records, such as pump run time and number of pump cycles, can be used to monitor pump efficiency and proper working of float switches or relays.

If a pump cycles on and off frequently, motor and starter life can be shortened. This can happen when float switches are improperly set, or if wave action in a pump tank or lagoon causes floats to trip on and off in short cycles. Floats should be adjusted or replaced as necessary to prevent burn out of pump controllers.

In summary, an operator should maintain detailed records of all equipment and operational parameters at the facility. In conjunction with a detailed set of plans, operational and maintenance decisions can be made to provide long equipment life and efficient overall system operation. Operation and maintenance of spray irrigation equipment will be discussed in more detail in Chapter 5.

Chapter 5

Proper Wastewater Application

This chapter deals with the operation of the surface irrigation system on a daily basis. As you have learned, the system consists of many components, from the influent pipe to the soil/plant system, and everything in between. An operator must understand the entire system in order for it to perform properly. This is not to say that the operator must be a specialist in all facets of wastewater system design and soil or crop science. However, an operator needs to understand day-to-day management, and also understand what situations call for technical assistance. Technical assistance references are found throughout this chapter and manual, and Appendix B-1 lists available resources.

A main function of a land application system for wastewater is to provide for adequate treatment of a waste product while protecting the quality of the receiver environment. Another function is to provide for beneficial reuse of the water and nutrients to produce a crop. The operator of a land-based wastewater treatment system must ensure that all aspects of the system are properly operated and maintained.

Soil and crops must be protected so that continued use of the receiver site is ensured. Surface and groundwater must be protected to ensure the integrity of these resources. Sites must be protected from poor field operations that destroy soil structure. They must also be protected from over-application of metals, nutrients, salts and other waste constituents that can adversely effect the soil/plant system.

This chapter discusses three important aspects of proper waste application:

- irrigation scheduling;
- soil, plant, wastewater, and groundwater sampling; and
- operation and maintenance of system components and site management.

5.1. Irrigation Scheduling

Proper land application of wastewater involves the use of water management strategies to ensure that wastewater is applied at the proper time and in the correct amounts. This involves achieving a balance between:

- optimizing the timing of nutrient application to match crop uptake;
- maintaining adequate storage in the lagoon to handle extreme rainfall without overtopping; and
- applying wastewater at a rate and amount such that no direct surface runoff or deep percolation below the root zone occurs.

It is not economically feasible to design a waste management system that can satisfy all three criteria one hundred percent of the time. Rather, design criteria have been established to achieve a balance between costs and the risk associated with an undesirable discharge. A responsible system operator must understand how wastewater should be managed, have knowledge of the capacity of the system to store and apply wastewater when appropriate, and be able to make prudent management decisions concerning when and how much wastewater to land apply.

For a liquid waste management system using surface irrigation, this decision-making process is called irrigation scheduling, and is generally based on the following flowchart (Figure 5-1).

Irrigation scheduling is the process of answering two basic questions:

- When to irrigate?
- How much to irrigate?

Effective scheduling requires knowledge about soil properties, soil-water relationships, the crop, climate, and application equipment. The purpose of this section is to discuss the interaction of these factors and how to incorporate them into an effective irrigation schedule to properly land apply wastewater. Keep in mind that maximum wastewater loadings are established by the facility permit and must never be exceeded. An operator must be familiar with these permitted amounts when planning irrigation events.

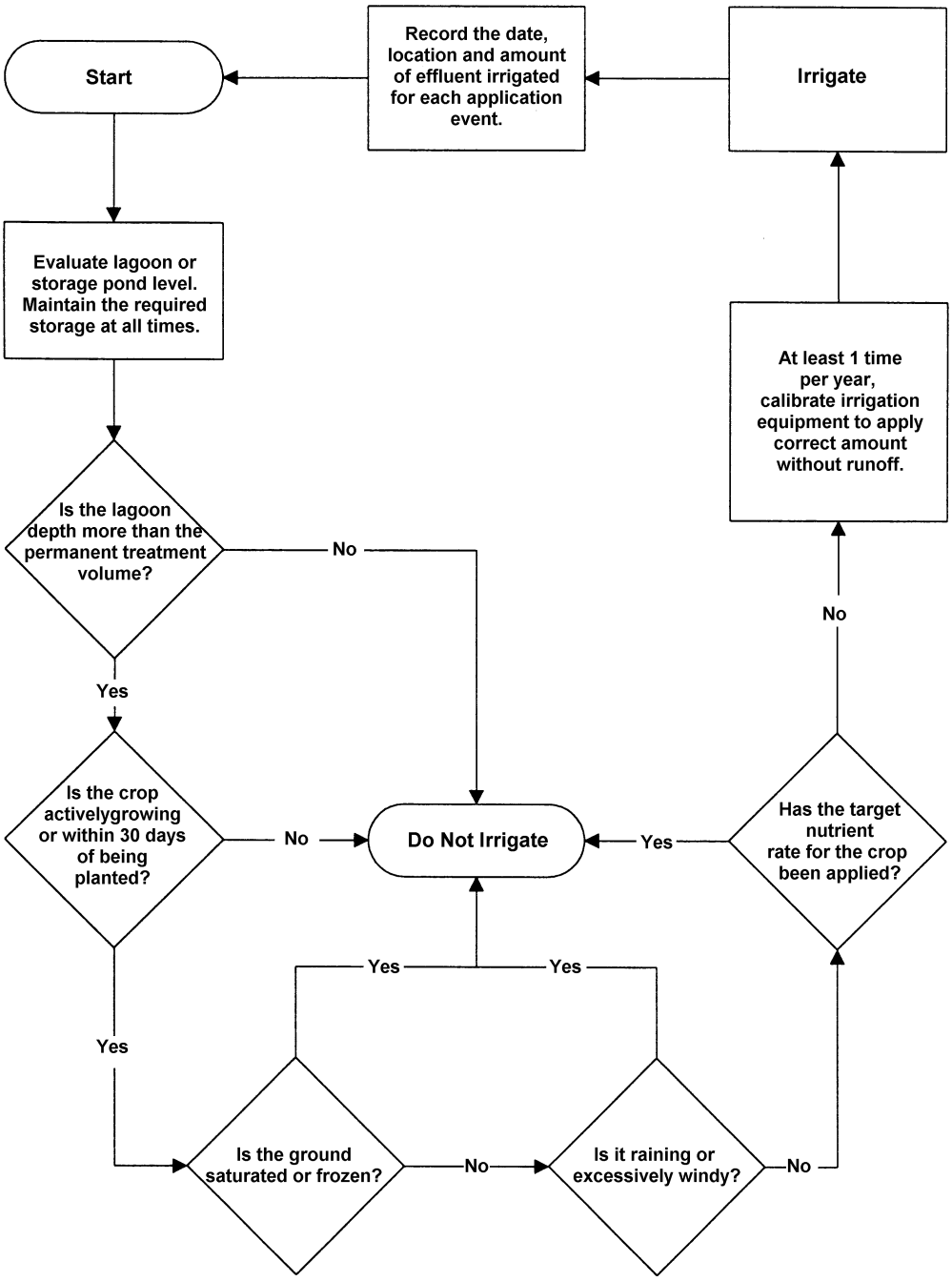


Figure 5-1. Nutrient management and irrigation scheduling decision-making flowchart.

Determining When To Irrigate

There are three basic questions that should be answered when deciding to irrigate treated wastewater:

1. Can the wastewater be applied to an actively growing crop (or will a crop be planted or actively start growing within 30 days?
2. Is there a nutrient deficit remaining for this crop cycle for the limiting nutrient?
3. Are the land application fields dry enough to be irrigated?

If the answer to all three questions above is yes, then an irrigation event should be scheduled. The answer to Question 1 should be obvious to an operator. Question 2 requires knowledge of the amount of nutrients that should be applied and the amount that has already been applied, if it is a nutrient limiting system. This was addressed in Chapter 3 and will be discussed later in this chapter.

Determining the answer to Question 3, whether or not the field is "dry" enough to be irrigated, is not always obvious. It was mentioned earlier that soil saturation can be determined by observing free water in an auger hole. However, there are other methods of determining whether a soil is saturated or not. If the soil is not saturated, these methods can also be used to determined how "dry" the soil is:

1. a subjective method that involves "feeling" the soil;
2. objective methods using soil-moisture measuring devices; and
3. an accounting approach (checkbook method) to estimate soil-water.

Basic Soil-Water Relationships

Before attempting to measure or estimate soil-water content, you should recall the basic soil-water relationships discussed in Chapter 3. Important terms to remember include: saturation, field capacity, wilting point, gravitational water, and plant-available water. For a more detailed discussion, refer to Extension Service publication AG-452-1: Soil, Water and Crop Characteristics Important to Irrigation Scheduling.

Not all of the water added to soil is necessarily retained in the soil for use by plants. Wastewater containing nutrients requiring further treatment by the soil/crop system should be applied to soil such that it remains in the root zone for uptake by the crop. Any wastewater not retained in the root zone will likely transport waste constituents to wherever it goes, resulting in a pollution threat to either surface water, groundwater, or both.

To interpret soil-water measurements and apply them to irrigation scheduling, you must be able to distinguish between two categories of soil-water:

1. **Gravitational Water**—the water in the soil that is free to drain or move by the force of gravity. Gravitational water is computed as the volume of water in the soil between saturation and field capacity. When gravitational water is present in the root zone, the soil is "too wet" to be irrigated with wastewater.

2. **Plant-Available Water (PAW)**—the amount of water held in the soil that is available to plants. It is computed as the difference between the water content at field capacity (referred to as upper limit water content) and the permanent wilting point (often referred to as the lower limit water content). Irrigation should be scheduled to maintain the water content of the soil between these two extremes. If there is no PAW deficit (i.e., the soil-water content is above the upper limit), gravitational water is present and wastewater irrigation should be delayed under normal operating conditions.

Soil texture influences the portion of the soil pore volume that can be occupied by gravitational water or plant-available water; therefore, it is important to know the soil texture to determine how much water can be irrigated.

The amount of plant-available water (PAW) that exists in the soil at any given time is commonly expressed as the depth of water per unit depth of soil. Typical units are inches of PAW per foot of soil depth. Estimates of PAW for various soil textural classes are given in published soil survey reports. These estimates range from less than 0.2 inch of PAW per foot of soil for coarse sandy soils to nearly 2 inches of PAW per foot of soil for silty clay and clay soils (Table 5-1).

Table 5-1. Average Estimated Plant-Available Wter for Various Soil Textural Classes.

Textural Class	Plant-Available Water	Maximum Recommended Application Depth
	inches of water per foot of soil	
Coarse sand and gravel	0.2 to 0.6	0.2
Sand	0.5 to 1.0	0.4
Loamy sand	0.8 to 1.5	0.6
Sandy loam	1.0 to 1.8	0.7
Loams	1.3 to 2.0	0.8
Silt loam	1.3 to 2.2	0.8
Silty clay loam	1.3 to 1.8	0.8
Clay loam	1.1 to 1.9	0.8
Sandy clay loam	1.1 to 1.8	0.8
Silty clay	1.2 to 1.9	0.8
Clay	1.2 to 1.9	0.8

At the start of irrigation, the water content in the soil should be lower (drier) than field capacity (upper limit). The difference between the existing water content and the field capacity water content is the maximum amount that should be irrigated. The drier the soil, the more wastewater that can be safely applied per application, provided this amount does not exceed the required nutrient application rate or violate any permit conditions. Determining the water content of the soil tells you if the soil is dry enough to be irrigated and if so, how much wastewater can be applied.

Determining How Much To Irrigate

For systems that are not nutrient limited, the amount of wastewater that can or should be applied during any single irrigation cycle is dictated by how much water the soil can "soak up." This varies from day to day and is influenced by:

- rainfall - when and how much it last rained;
- crop maturity - water uptake rate of the crop;
- soil type - texture, structure, depth, and cover;
- effective root depth; and
- evapotranspiration - which is influenced by temperature, wind, and relative humidity.

Wastewater irrigation should replace the water that has evaporated from the soil or been removed by plants. This is referred to as the plant-available water deficit. Most water taken up by plants is removed in the upper half of the root zone. For the purpose of scheduling irrigation, this zone is referred to as the effective root depth.

Soil conditions in North Carolina limit maximum rooting depths of most crops to 24 to 36 inches so that the effective root depth is typically only 12 to 18 inches. It is within this depth that we estimate or measure the plant-available water deficit to be replaced by irrigation. If the irrigation

volume applied exceeds the PAW deficit, the excess either runs off or leaches below the root zone and could potentially contaminate groundwater.

Therefore, irrigation should be scheduled and timed so that:

- no surface runoff occurs during irrigation;
- the root zone is not completely saturated at the conclusion of irrigation; and
- leaching of the irrigated water below the root zone is minimized.

If the soil is completely dry, the plant-available water deficit would be the value shown in Table 5.1. In reality, the soil is rarely completely dry so that the amount to be replaced will be less than the values shown in Table 5-1. At any given time, the plant-available water deficit could range from none to the maximum values shown in Table 5-1. Recommended wastewater irrigation volumes for a range in soil-water contents and soil textures are shown in Table 5-2.

Wastewater irrigation objectives and recommendations are different from fresh water recommendations. When irrigating with fresh water, the objective is to keep the soil moist for optimum growing conditions. Depending on the nutrient content of the wastewater, it may not be appropriate to apply all of the water needed by the crop from wastewater during dry periods. The deciding factor is the nutrient content of the wastewater.

Highly concentrated waste, such as from animal operations, may only allow 2 to 5 inches of wastewater be applied during the entire growing season. Less concentrated waste allows for more water additions. Treated municipal wastewater typically contains less than 30 ppm total nitrogen. At this low concentration, wastewater application rates are usually hydraulically limited rather than nutrient limited. As much as 50 or more inches of wastewater may need to be applied to achieve the nutrient requirements of the crop. In this case, freshwater requirements of the crop can be applied from the dilute wastewater.

However, even with dilute wastewater, it is generally NOT recommended to apply more than 1 inch of wastewater irrigation during any single irrigation cycle. Even this amount may be too high for some soils. This is because a large amount of the applied wastewater may leach below the root zone of the crop, bypassing the opportunity for nutrients contained in the wastewater to be utilized by the crop. Table 5-1 shows maximum recommended wastewater irrigation amounts as influenced by soil texture.

Another factor affecting irrigation amount is the infiltration rate. Remember from Chapter 3 that the infiltration rate is the rate that the soil can "soak up" the irrigated wastewater. The infiltration rate decreases the longer water is applied. The intake capacity of most clayey or silty soils begins to be exceeded by the time 0.5 to 0.6 inch has been applied. Continuing to irrigate could result in surface ponding and possible runoff of the irrigated wastewater, which is a water quality violation that could result in penalties or fines.

Infiltration rate is also dependent on the crop type and thickness of the stand and slope of the land. Some typical ranges for various soil textures are shown in Table 5-2. Application rates in excess of these values could result in ponding and runoff.

Table 5-2. Approximate Water Infiltration Rates for Various Soil Texture and Slopes.

	Slope		
	0 to 3%	3% to 9%	9+%
	inches per hour		
Sands	>1.00	>0.70	>0.50
Loamy sands	0.70 to 1.00	0.50 to 1.00	0.40 to 0.70
Sandy loams and fine sandy loams	0.50 to 1.00	0.40 to 0.70	0.30 to 0.50
Loams and silt loams	0.30 to 0.70	0.20 to 0.50	0.15 to 0.30
Sandy clay loams and silty clay loams	0.20 to 0.40	0.15 to 0.25	0.10 to 0.15
Clays, sandy clays, and silty clays	0.10 to 0.20	0.10 to 0.15	<0.10

Source: Sprinkler Irrigation Association Journal. For poor vegetative cover or surface soil conditions, actual rates may be as much as 50 percent less than shown.

Sandy soils have high infiltration capacity and runoff is not much of a concern. But, sandy soils also have low plant-available water-holding capacity. For example, consider a Lakeland sand that has only 0.5 inch of plant-available water per foot of soil depth. For an effective root depth of 1.5 feet, the maximum plant-available water deficit is only 0.75 inch.

$$1.5 \text{ ft} \times 0.5 \text{ in PAW/ft} = 0.75 \text{ inch PAW}$$

For this example, if the application amount during any single irrigation cycle exceeds 0.75 inch, some of the applied wastewater will leach below the root zone and potentially pollute groundwater.

Taking all of the above factors into account, recommended wastewater irrigation amounts for a single irrigation cycle are in the range of 0.25 to 0.75 inch per foot of effective root zone depth. There may be occasions when the appropriate irrigation amount falls outside this range such as when irrigation must occur during cold periods when PET is low, when the soil has an unusually deep root zone providing a greater amount of plant available water storage, or to satisfy emergency action guidelines. But, these situations are exceptions and should not occur on a regular or frequent basis.

Regardless of the calculated rate, the system operator should monitor each waste application to verify adequate infiltration of the waste into the soil. An irrigation cycle should be stopped if ponding and runoff start to occur. Rarely will the "practical" irrigation amount as influenced by the various factors discussed in this chapter equal the "permitted" amount.

Permitted amounts typically establish the upper limit under best case scenarios and are established to give the operator the flexibility to irrigate the maximum possible under ideal conditions. In reality, conditions are rarely ideal on a day to day basis. The operator must consider and incorporate site, crop, soil and climatic factors into the daily irrigation strategy.

Operational Considerations

A key component of the irrigation design is to select the proper combination of system components so that the system precipitation rate does not exceed the infiltration rate of the soil. Knowledge of the system design is important for day-to-day irrigation scheduling. Several terms may be used to express the rate at which water is being applied to a field during irrigation. Terms you should be familiar with include discharge rate and precipitation rate.

Discharge rate is the volume of water exiting a sprinkler per unit of time. Discharge rates are normally expressed in terms of gallons per minute (gpm). Manufacturers publish discharge rates for their sprinklers as a function of operating pressure and orifice diameter of the nozzle. You

should always have a copy of the manufacturer's discharge specifications for the sprinklers on your system.

Discharge characteristics for three typical sprinklers used for wastewater irrigation are given in Table 5-3. For example, a Rainbird Model 70 sprinkler operated at 55 PSI with a 9/32-inch diameter nozzle has a discharge rate of 17.2 gpm.

Table 5-3. Discharge Characteristics for Rotary Impact Sprinklers Used with Permanent Stationary Irrigation System

Nozzle Size	Operating Pressure (PSI)					
(inch)	50		55		60	
	Flow GPM	Diameter FT	Flow GPM	Diameter FT	Flow GPM	Diameter FT
Nelson F70APV						
1/4	12.8	128	13.6	131	14.0	134
9/32	16.0	134	16.8	137	17.6	140
Rain Bird 70 CWH						
1/4	12.9	124	13.6	126	14.2	128
9/32	16.3	131	17.2	133	18.0	135
Senniger 7025 RD-1-DFF						
1/4	13.0	127	13.6	131	14.2	138
9/32	16.3	133	17.1	137	17.8	142

Discharge characteristics for typical big guns are shown in Table 5-4. For contrast, notice how much higher discharge rates are for the gun sprinklers than the rotary impact sprinklers.

Table 5-4. General Flow Rates and Coverage Diameter for Big Gun Sprinklers.

Taper Bore Nozzle										
	Gun Model									
	100T		150T		150T		200T		200T	
	Nozzle Diameter (inch)									
Pressure	0.5		0.75		1.0		1.5		2.00	
PSI	GPM	DIA	GPM	DIA	GPM	DIA	GPM	DIA	GPM	DIA
50	50	205	115	260	205	310	—	—	—	—
60	55	215	126	275	225	325	515	430	912	512
70	60	225	137	290	245	340	555	450	980	528
80	64	235	146	300	260	355	590	470	1047	548
90	68	245	155	310	275	365	625	485	1105	568
100	72	255	164	320	290	375	660	500	1167	592
110	76	265	172	330	305	385	695	515	1220	607
120	—	—	180	340	320	395	725	530	1277	622
Ring Type Nozzle										
	Gun Model									
	100R		150R		150R		200R		200R	
	Nozzle Diameter (inch)									
Pressure	0.71		0.86		0.97		1.56		2.00	
PSI	GPM	DIA	GPM	DIA	GPM	DIA	GPM	DIA	GPM	DIA
50	74	220	100	245	130	265	350	370	640	435
60	81	235	110	260	143	280	385	390	695	455
70	88	245	120	270	155	290	415	405	755	475
80	94	255	128	280	165	300	445	420	805	490
90	99	265	135	290	175	310	475	435	855	505
100	105	270	143	300	185	320	500	445	900	520
110	110	275	150	310	195	330	525	455	945	535
120	-	-	157	315	204	335	545	465	985	545

Precipitation rate is normally expressed as unit depth of water (inch) per unit of time, (usually an hour). The precipitation rate (inches per hour) depends upon discharge rate and coverage diameter. The precipitation rate (in/hr) is computed by converting the discharge rate to a unit depth of water (inch) per unit time (hr), by dividing by the wetted area of the sprinkler.

Another important parameter is total application depth (inch) which is computed based on the amount of time the system operates at a given rate on a given field.

Wastewater analyses are expressed in terms of pounds of plant available nitrogen (lbs PAN) per 1000 gallons of wastewater or in mg/L. When irrigating, it is often preferable to express irrigation amounts as an equivalent depth of water, for example, 1/2 inch. Therefore, it is often necessary to convert between application volume expressed as gallons per acre and application depth expressed as inches.

You should remember that one inch of water over an acre, referred to as acre-inch, is equal to 27,152 gallons.

Another helpful conversion is 1mg/L = 1ppm = 0.226 lbs/ac-in.

To attain acceptable application uniformity, stationary sprinklers are typically arranged in a square pattern at a spacing of 50 to 65 percent of the wetted diameter. A typical layout for stationary sprinklers is shown in Figure 5-2. The orifice size, spacing, and operating pressure are selected from manufacturer's literature to achieve the desired overlap and uniformity of coverage.

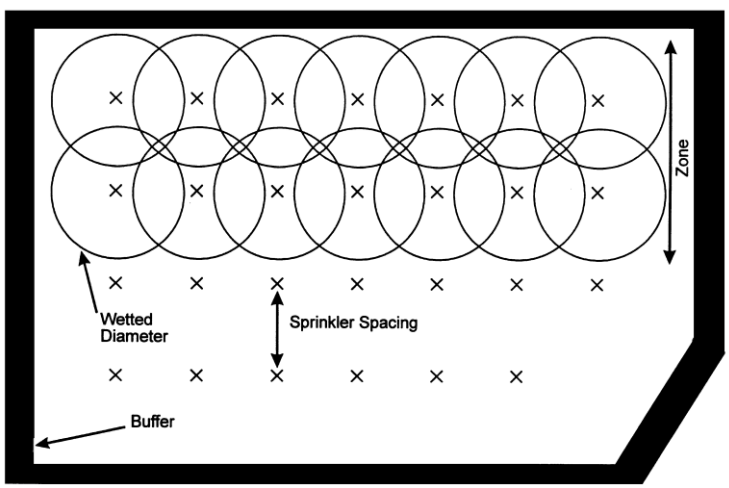


Figure 5-2. Typical layout of a stationary sprinkler system. Sprinkler spacing is typically 50 to 65 percent of wetted diameter.

Determination of Precipitation Rate for Stationary Sprinklers

The precipitation rate for stationary sprinklers is computed from the formula:
Procedure for computing precipitation rate:

$$\text{Precipitation rate (in/hr)} = \frac{96.3 \text{ x discharge rate (gpm)}}{\text{sprinkler spacing (ft) x lateral spacing (ft)}}$$

1. Determine the discharge rate (sprinkler flow rate) and wetted diameter from manufacturer's literature.

   From Table 5-6, RainBird Model 70 with a 9/32-inch diameter nozzle operated at 55 psi.

   Discharge rate = 17.2 gpm

   Wetted Diameter = 133 feet

2. Recommended sprinkler spacing is 50 to 60 percent of wetted diameter. Using a value of 60 percent:

   Design sprinkler spacing = 0.6 x 133 feet = 79.8 feet

   Sprinklers are normally spaced in equal multiples of 20 feet based on typical pipe length. Therefore, the design spacing would be 80 feet, i.e., the sprinkler spacing along the lateral would be 80 feet and the lateral spacing would be 80 feet such that the effective area of a sprinkler would be 80 feet by 80 feet.

3. Precipitation rate is then computed as:

$$\text{Precipitation rate (in/hr)} = \frac{96.3 \times 17.2 \text{ gpm}}{80 \text{ ft} \times 80 \text{ ft}} = 0.26 \text{ in/hr}$$

   The precipation rate of the sprinkler should be less than the infiltration rate of the soil as given in Table 5-2.

4. Application depth is then computed as the precipitation rate multiplied by the operating time. In most cases, you will select the desired application depth based on one of the above methods. You then compute the time required to operate the system to achieve the desired application depth. For example, if the required application depth is 0.6 inch, then the selected operating time for the system would be computed as follows:

5. Time of operation is computed as:

$$\text{Time of Operation (hours)} = \frac{\text{target application depth (in)}}{\text{precipitation rate (in/hr)}}$$

   So:

$$\text{Time of Operation (hours)} = \frac{0.6 \text{ in}}{0.26 \text{ in/hr}} = 2.3 \text{ hours}$$

Determination of Precipitation Rates for Traveling Gun Sprinklers

The precipitation rate in inches per hour for a traveling gun sprinkler is generally not affected by travel speed. This situation occurs because at any given position within the wetted diameter, water is usually being applied for at least an hour or longer. The precipitation rate is affected by the angle of rotation of the gun sprinkler.

For example, if the gun only makes a half circle (180 degrees of rotation), the precipitation rate is twice that of a gun making a full circle (360 degrees of rotation). The precipitation rate for a traveling gun sprinkler is computed by the formula:

$$\text{Precipitation rate (in/hr)} = \frac{96.3 \times \text{sprinkler discharge rate (gpm)}}{3.14 \times [0.9 \times \text{sprinkler radius (ft)}]^2} \times \frac{360}{w}$$

Precipitation (application) rate for traveling gun; inches per hour,where "w" is the angle of rotation expressed in degrees. If the gun sprinkler rotates a full circle, then w is 360 degrees, whereas if the rotation is only a half circle, w is 180 degrees. In practice, the angle of rotation is typically in the range of 315 to 330 degrees.

Example:

What is the precipitation rate for a gun sprinkler if the operating pressure is 80 psi, the taper bore nozzle diameter is 1.0 inch, and the angle of rotation is 320 degrees?

From Table 5-7, for a gun sprinkler operated at 80 psi with a 1.0 inch diameter taper bore nozzle, the discharge rate is 260 gpm and the wetted diameter is 355 feet.

For a wetted diameter of 355 feet, the wetted radius is:

$$355 \text{ ft} \div 2 = 177.5 \text{ ft}$$

The precipitation rate is then computed as:

$$\text{Precipitation rate (in/hr)} = \frac{96.3 \times 260 \text{ gpm}}{3.14 \times (0.9 \times 177.5 \text{ ft})^2} \times \frac{360}{320} = 0.35 \text{ in/hr}$$

Example:

What would be the precipitation rate in the previous example if the angle of rotation was only a half circle?

$$\text{Precipitation rate (in/hr)} = \frac{96.3 \times 260 \text{ gpm}}{3.14 \times (0.9 \times 177.5 \text{ ft})^2} \times \frac{360}{180} = 0.62 \text{ in/hr}$$

Note: The precipitation rate for a traveling gun sprinkler increases rapidly as the angle of rotation decreases. Since the infiltration capacity of many soils is less than 0.5 inch per hour, it is important that the gun sprinkler rotate as much of a full circle as possible so that the precipitation rate does not exceed the infiltration capacity of the soil.

Determination of Application Depth for a Traveling Gun Sprinkler

The depth of wastewater applied by a traveling gun depends on the flow rate, lane spacing and travel speed. The travel lane spacing should be approximately 70 to 80 percent of the sprinkler's wetted diameter as shown in Figure 5-3.

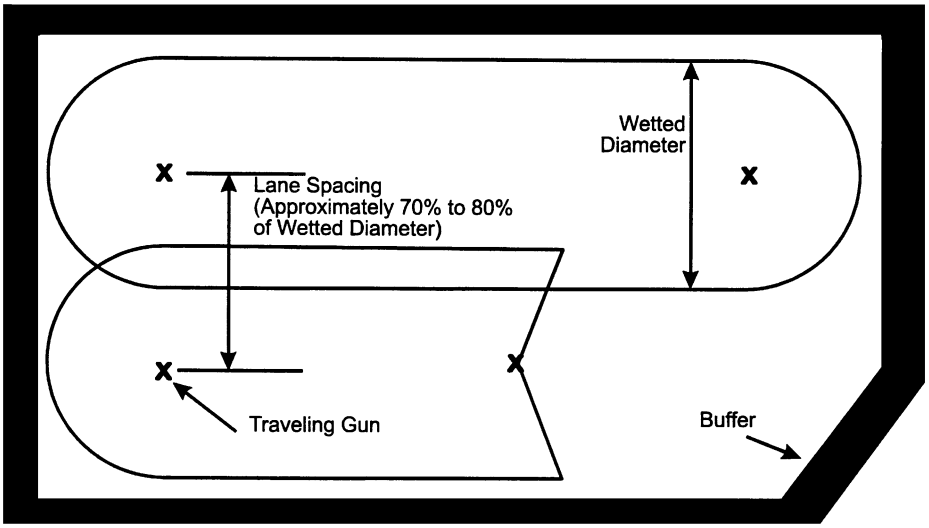


Figure 5-3. Typical layout of a traveling gun irrigation system. Lane spacing is typically 70 to 80 percent of wetted diameter.

The application depth is computed by the formula:

$$\text{Application depth (in)} = \frac{19.3 \times \text{sprinkler discharge rate (gpm)}}{\text{lane spacing (ft)} \times \text{travel speed (in/min)}}$$

Example:

What is the application depth for a gun sprinkler if the operating pressure is 80 psi, the taper bore nozzle diameter is 1.0 inch, and the travel speed is 3 feet per minute?

From Table 5-7, for a gun sprinkler operated at 80 psi with a 1.0 inch nozzle, the discharge rate is 260 gpm and the wetted diameter is 355 feet.

If the lane spacing is 75 percent of the wetted diameter, the lane spacing is

$$0.75 \times 355 \text{ ft} = 266 \text{ ft}$$

The travel speed needs to be expressed in inches per minute. A travel speed of 3 feet per minute is equal to 36 inches per minute.

$$3 \text{ ft/min} \times 12 \text{ in./ft} = 36 \text{ in./min}$$

The application depth is then computed to be:

$$\text{Application depth (in)} = \frac{19.3 \times 260 \text{ gpm}}{266 \text{ ft} \times 36 \text{ in/min}} = 0.52 \text{ in}$$

Determination of Travel Speed for a Traveling Gun Sprinkler

In many cases, you may desire to determine the travel speed required to apply a desired wastewater application depth. The travel speed is computed by the formula:

$$\text{Travel speed (in/min)} = \frac{19.3 \times \text{sprinkler discharge rate (gpm)}}{\text{lane spacing (ft)} \times \text{application depth (in)}}$$

Example:

What travel speed is necessary to apply 0.6 inch with a gun sprinkler if the operating pressure is 80 psi and the taper bore nozzle diameter is 1.0 inch?

From Table 5-7, for a gun sprinkler operated at 80 psi with a 1.0-inch nozzle, the discharge rate is 260 gpm and the wetted diameter is 355 feet.

If the lane spacing is 75 percent of the wetted diameter, the lane spacing is:

$$0.75 \times 355 \text{ ft} = 266 \text{ ft}$$

$$\text{Travel speed (in/min)} = \frac{19.3 \times 260 \text{ gpm}}{266 \text{ ft} \times 0.6 \text{ in}} = 31.4 \text{ in/min}$$

Center Pivot Systems

Center pivot systems come in a variety of designs and with many operational considerations. The newer models use a controller device that allows the operator to set application rates, and to vary application rates based on field variability or crop types over which the system is run. Since these systems are able to cover a large area, the sprinkler components are typically designed and installed for each individual situation. Therefore, there is no standard formula to determine the precipitation rate or travel speed for these systems. The manufacturer's literature will explain the settings to achieve desired precipitation rates and volumes. Like any other type of irrigation equipment, it should be field calibrated periodically to verify that field application rates are consistent with manufacturer's design.

Estimating Soil-Water Content

There are three general methods for estimating the amount of water present in the soil:

- feel method;
- soil moisture measurement devices; and
- checkbook method.

One of these methods should be used to estimate the amount of water present in the soil at the start of irrigation.

Feel Method

The feel method involves estimating soil-water by feeling the soil. This method is easy to use, and many operators schedule irrigation this way. This method is "subjective" since the results depend on the experience of the person doing the measurement. Therefore, the value of this method

depends on the experience of the operator. Some "feel" guidelines for estimating soil-water content by the feel method are given in Table 5-5.

Use of the feel method is demonstrated in the following example. Suppose your irrigation field is a sandy loam soil with a 15-inch root zone. You feel the soil and observe that it forms a weak ball which falls apart. Based on the guidelines given in Table 5-5, you can irrigate 0.3 to 0.4 inches of water per foot of root zone depth. For a 15-inch (1.25 feet) root zone depth, the permissible irrigation amount is:

0.38 in (0.3 in/ft x 1.25 ft) to 0.5 in (0.4 in/ft x 1.25ft)

Table 5-5. "Feel" guidelines for Estimating the Amount of Plant-Available Water to be Replaced with Wastewater Irrigataion as a Function of Soil Texture.

Available Water Remaining in the Soil	Sands Loamy Sand	Sandy Loam	Clay, Clay Loam, Sandy Clay Loam	All Other Textures
	Maximum Recommended Wastewater Irrigation (per foot of effective root zone depth)			
100% (i.e., field capacity)	When ball is squeezed, no free water appears on soil but wet outline of ball is left in hand			
Wastewater Irrigation	None	None	None	None
75% to 100%	Sticks together only slightly	Forms a ball that breaks easily	Forms a ball; very pliable	Easily ribbons between thumb and forefinger; feels slick
Wastewater Irrigation	0.1 to 0.2 inch	0.2 to 0.3 inch	0.2 to 0.4 inch	0.2 to 0.4 inch
50% to 75%	Appears dry, will not form a ball	Forms weak ball which falls apart	Forms ball; slightly plastic; slightly slick	Forms ball; forms ribbon
Wastewater Irrigation	0.2 to 0.3 inch	0.3 to 0.4 inch	0.3 to 0.5 inch	0.3 to 0.6 inch
25% to 50%	Appears dry, will not form a ball	Appears dry, will not form a ball	Somewhat crumbly but holds under pressure	Forms ball under pressure; somewhat pliable
Wastewater Irrigation	0.3 to 0.5 inch	0.3 to 0.6 inch	0.3 to 0.6 inch	0.3 to 0.7 inch
0 to 25%	Dry, loose, single-grained, flows through fingers	Dry, loose, flows through fingers	Powdery, dry; easily breaks into powdery condition	Hard, cracked; may have loose crumbs on soil surface
Wastewater Irrigation	0.3 to 0.5 inch	0.3 to 0.6 inch	0.3 to 0.7 inch	0.3 to 0.7 inch

Soil Moisture Measurement Devices

There are many different methods or devices for measuring soil water. These include the gravimetric method, tensiometer, electrical resistance blocks, and time domain reflectometer. These methods differ in reliability, cost, and labor intensity. A general description of each method is given below. For more information on the operation, reliability, and cost of these methods, refer to Extension Publication AG-452-2: Measuring Soil-Water for Irrigation Scheduling: Monitoring Methods and Devices.

Gravimetric Method

With the gravimetric method, soil moisture is determined by taking a soil sample from the desired soil depth, weighing it, drying it in an oven (for 24 hours at 220˚F), and then reweighing the dry sample to determine how much water was lost. This method is simple and reliable. Unfortunately, it is not practical for scheduling irrigation because it takes a full day to dry the sample. In a sandy soil that dries quickly, irrigation may be needed before the results of the measurement are obtained. The gravimetric method is most useful for calibrating other devices for measuring soil-water.

Tensiometer

A tensiometer is a sealed, airtight, water-filled tube (barrel) with a porous tip on one end and a vacuum gauge on the other (Figure 5-4). A tensiometer measures soil-water suction (negative pressure), which is usually expressed as tension. This suction is equivalent to the force or energy that a plant must exert to extract water from the soil.

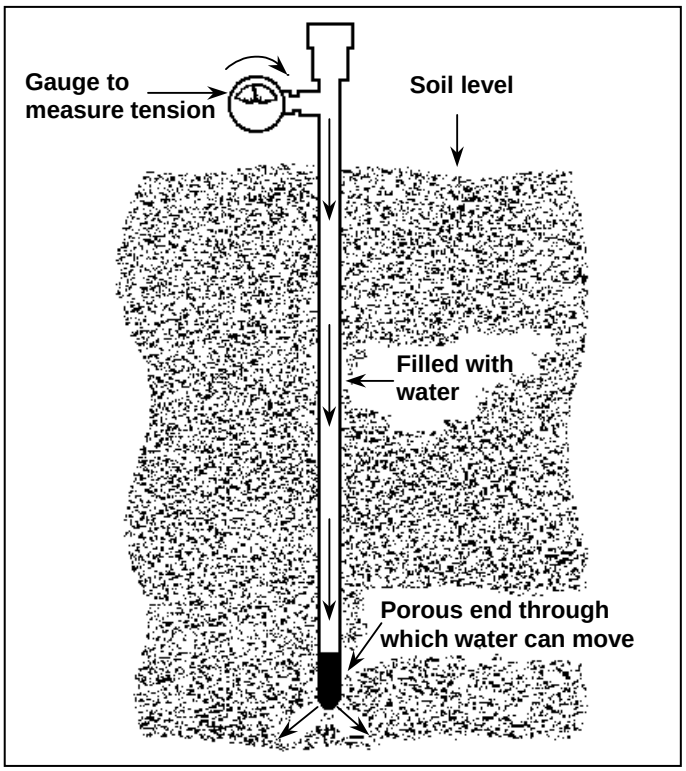


Figure 5-4. Tensiometer method of determining soil-water content.

The instrument must be installed properly so that the porous tip is in good contact with the soil, ensuring that the soil-water suction is in equilibrium with the water suction in the tip. The suction force in the porous tip is transmitted through the water column inside the tube and displayed as a tension reading on the vacuum gauge. Soil-water tension is commonly expressed in units of bars or centibars. One bar is equal to 100 centibars (cb).

The suction at the tip is transmitted to the vacuum gauge because of the cohesive forces between adjacent water molecules. As the suction approaches approximately 0.8 bar (80 cb), the cohesive forces are exceeded by the suction and the water molecules separate. When this occurs, air can

enter the tube through the porous tip and the tensiometer no longer functions correctly. This condition is referred to as breaking tension. Tensiometers, therefore, work in the range from 0 to 0.8 bar. The suction scale on the vacuum gauge of most commercial tensiometers reads from 0 to 100 cb.

Tensiometers are quite affordable. The cost ranges from $25 to $50 each, depending on length of the barrel, which can range from 6 to 72 inches. The only other equipment required is a small hand-held vacuum pump used for calibration and periodic servicing. Tensiometers are easy to use but may give faulty readings if they are not serviced regularly. They are best suited for use in soils that release most of their plant-available water (PAW) at soil-water suctions between 0 and 80 cb. Soil textures in this category are those that consist of sand, loamy sand, sandy loam, and the coarser-textured range of loam and sandy clay loam.

Many clayey and silty soils still retain over 50 percent of their plant-available water at suctions greater than 80 cb, which is outside the working range of a tensiometer. Tensiometers are not recommended for clayey and silty soils unless irrigation is to be scheduled before 50 percent depletion of the plant-available water, which is very common for many surface irrigation systems. It is also the normal practice for some vegetable crops such as tomatoes.

Granular Matrix Sensors

Granular matrix sensors are another indirect method of measuring soil water tension. The sensor consists of two corrosion resistant electrodes embedded in a porous material, surrounded by a synthetic membrane and a protective stainless steel mesh (Figure 5-5).

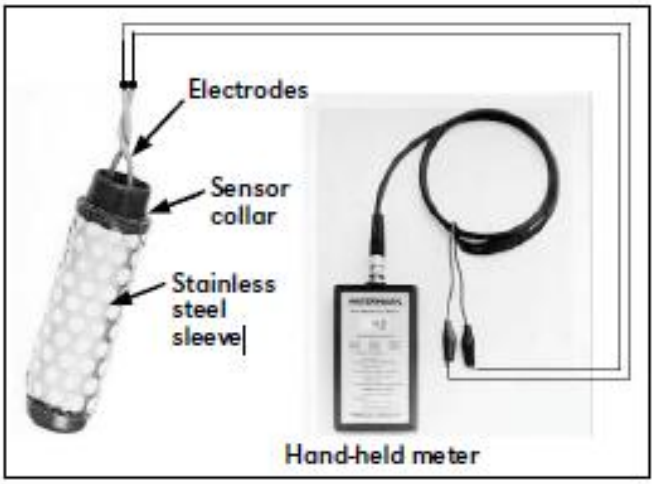


Figure 5-5. Granular matrix sensor and meter.

These sensors work on the principle that water conducts electricity. Movement of water between the soil and the sensor results in changes in electrical resistance between the electrodes in the sensor. Electrical resistance increases as soil water suction increases, or as soil moisture decreases. Electrical resistance decreases as soil water suction decreases, or as soil moisture increases.

Granular matrix sensors are designed to be permanent sensors, placed in the soil to be monitored and "read" as often as necessary with a portable or stationary device. Although the electrical resistance is measured in ohms, the meter automatically converts readings to centibars.

Compact, easily installed, and low maintenance, granular matrix sensors are relatively inexpensive. Readings should be calibrated to reflect the same values that would be generated by a tensiometer for a specific soil.

Time Domain Reflectometer

The time domain reflectometer (TDR) is a new device developed to measure soil-water content. Two parallel rods or stiff wires are inserted into the soil to the depth at which the average water content is desired. The rods are connected to an instrument that sends an electromagnetic pulse (or wave) of energy along the rods. The rate at which the wave of energy is conducted into the soil and reflected back to the soil surface is directly related to the average water content of the soil. One instrument can be used for hundreds of pairs of rods.

Selecting the Appropriate Device

In general, tensiometers and granular matrix sensors offer the best combination of cost-effectiveness and reliability for measurement of soil-water for wastewater irrigation in North Carolina. Tensiometers are best suited for sandy, sandy loam, and loamy soil textures while electrical resistance blocks work best in silty or clayey soils. Manufacturers of these devices provide calibration charts and recommended ranges for traditional "fresh" water irrigation. You should be aware that the calibration curves and recommendations supplied by the manufacturer for these devices were developed for general conditions and are not adequate for specific soil conditions and fields.

You should also be aware that wastewater objectives and recommendations are different from fresh water recommendations. For irrigating wastewater, you will get better results if all soil-water measuring devices you use are calibrated for the major soils you are irrigating. Calibration procedures for soil-water measuring devices are outlined in Extension Publication AG-452-3: Calibrating Soil-Water Measuring Devices (Appendix B-2).

Checkbook Method

The checkbook method is an accounting approach for estimating how much soil-water remains in the effective root zone based on water inputs and outputs (like a daily balance on a bank account based on deposits and withdrawals). Wastewater irrigation is scheduled when the soil-water content in the root zone drops below a threshold level. Some of the simpler checkbook methods keep track of rainfall, evapotranspiration, and irrigation amounts. More sophisticated methods require periodic measurements of the soil-water status and moisture use rates of the crop.

Checkbook methods require detailed daily record keeping which can become time consuming for the more complex methods. One of the advantages of the checkbook approach is that it can be programmed on a computer. Computer programs have been developed to handle the accounting and provide timely and precise scheduling recommendations. A simple spreadsheet can also be developed to handle the day-to-day calculations involved in using this method.

To use the checkbook method, you must be able to estimate the rate that water stored in the soil is being "used up". Remember from Chapter 3 that water is removed from the root zone by direct evaporation from the soil and transpiration by plants. Collectively, this is referred to as evapotranspiration (ET).

Evapotranspiration is affected by many factors and varies seasonally and from day to day. On a hot and rainless day, ET may approach 0.3 inches per day. Thus during dry, summer periods, one inch of water could be removed from the soil every three to four days. On the other hand, more than a month may elapse before an inch is removed during prolonged cold-wet winter periods.

For these reasons, wastewater irrigation amounts should be adjusted seasonally in response to variation in evapotranspiration. Average daily potential evaopotranspiration (PET) estimates for several locations are shown in Table 5-6. These values can be used in the checkbook method on rainless days. When rainfall is characterized by thunderstorms of short duration, the daily values given in Table 5-6 are also appropriate. On days that are mostly cloudy or with rain during much of the daylight hours, assume the daily ET for that day is zero.

The local Natural Resource Conservation Service (NRCS) maintains average daily values for each county. Actual values can also be obtained from the National Weather Service and are available on the internet for a few locations.

Table 5-6. Average Evapotranspiration from Vegetation Growing in Moist Soils.

	Average Potential Evapotranspiration (in./day)				
Month	**Asheville**	**Charlotte**	**Raleigh**	**Plymouth**	**Wilmington**
January	0.03	0.03	0.03	0.03	0.04
February	0.05	0.05	0.05	0.06	0.08
March	0.07	0.08	0.09	0.10	0.11
April	0.11	0.12	0.13	0.13	0.15
May	0.12	0.15	0.16	0.16	0.17
June	0.15	0.17	0.17	0.17	0.18
July	0.14	0.16	0.17	0.17	0.18
August	0.12	0.14	0.15	0.15	0.16
September	0.10	0.11	0.12	0.13	0.13
October	0.06	0.07	0.08	0.09	0.10
November	0.04	0.04	0.05	0.06	0.06
December	0.02	0.02	0.03	0.04	0.05

Values computed from long-term daily maximum and minimum temperature records using the Thornthwaite method, corrected for measured pan evaporation. Single day value may be higher than shown (up to 0.25 inch/day) but values shown represent long-term average daily values for each month.

To use the checkbook method, you must begin computations when the soil is at a known water content. Field capacity is the usual starting point and should be assumed to occur soon after a rainfall or irrigation of an amount large enough to wet the effective root zone. For many of the well-drained loamy soils found in North Carolina (root zone textures consisting of loamy sand, sandy loam, loam, or sandy clay loam), field capacity can be assumed to occur one day after a rainfall or irrigation in excess of one inch.

Example calculations for the checkbook method are shown in Table 5-7. In this example, the soil is a sandy loam with an effective root zone of 12 inches. The allowable irrigation volume is the depleted plant available water content given in Table 5-1, not to exceed the recommended maximum of 0.7 inches for a sandy loam soil. Irrigation would normally be scheduled when about fifty percent of the plant available water had been depleted.

From Table 5-1, fifty percent depletion for a sandy loam soil ranges from 0.5 to 0.9 inches. Assume the maximum plant-available water content for this soil is 1.4 inches (sandy loam soil in Table 5-1) so that the target depletion value for this soil is 0.7 inches, which corresponds to the maximum recommended for a sandy loam. The crop grown is coastal bermudagrass and irrigation is recommended during the period from May to October. Since no irrigation was planned prior to May, it is not necessary to maintain a checkbook balance of the soil-water

content prior to May. In this example, the checkbook balance begins May 1 and continues throughout the irrigation period.

Table 5-7. Use of the Checkbook Method for Irrigation Scheduling (Raleigh location).

Date	PAW [1] in soil at start of day		Daily PET	Rainfall	Irrigation	Drainage	PAW in soil at end of day		Depletion [2]	Comments
	inches	% of PAW	inches				inches	% of PAW	inches	
5-01	-	-	-	-	-	-	-	-	-	Don't know initial conditions at this time
5-02	-	-	-	-						
5-03	-	-	-	1.5		0.1	1.40	100	0.00	Assume FC reached at end of day after rain
5-04	1.40	100	0.16	-	-	-	1.24	89	0.16	
5-05	1.24	89	0.16	-	-	-	1.08	77	0.32	
5-06	1.08	77	0.16	-	-	-	0.92	66	0.48	
5-07	0.92	66	0.16	-	-	-	0.76	54	0.64	OK to irrigate
5-08	0.76	54	0.16	-	0.64	-	1.24	89	0.16	Irrigated 0.64 inch
5-09	1.24	89	0.16	-	-	-	1.08	77	0.32	
5-10	1.08	77	0.16	0.75	-	0.27	1.40	100	0.00	Rain exceeded storage so had 0.27 inch of drainage or seepage
5-11	1.40	100	0.16	-	-	-	1.24	89	0.16	
5-12	1.24	89	0.16	-	-	-	1.08	77	0.32	
5-13	1.08	77	0.16	-	-	-	0.92	66	0.48	Lagoon marker indicates need to irrigate
5-14	0.92	66	0.16	-	0.48	-	1.24	89	0.16	Irrigated storage at start of day (0.48 inch)
5-15	1.24	89	0.16	-	-	-	1.08	77	0.32	
5-16	1.08	77	0.16	0.22	-	-	1.14	81	0.26	
5-17	1.14	81	0.16	-	-	-	0.98	70	0.42	
5-18	0.98	70	0.16	-	-	-	0.82	59	0.58	Would like to irrigate
5-19	0.82	58	0.16	-	0.50	-	1.16	83	0.24	Irrigated 0.5 inch
5-20	1.16	83	0.16	0.63	-	0.23	1.40	100	0.00	Rain exceeded storage so had 0.23 inch of drainage or seepage
5-21	1.40	100	0.16	-	-	-	1.24	89	0.16	
5-22	1.24	89	0.16	-	-	-	1.08	77	0.32	
5-23	1.08	77	0.16	-	-	-	0.92	66	0.48	
5-24	0.92	66	0.16	0.08	-	-	0.84	60	0.56	Lagoon marker indicates need to irrigate
5-25	0.84	60	0.16	-	0.56	-	1.24	89	0.16	Irrigated 0.56 inch
5-26	1.24	89	0.16	-	-	-	1.08	77	0.32	
5-27	1.08	77	0.16	-	-	-	0.92	66	0.48	
5-28	0.92	66	0.16	1.32	-	0.68	1.40	100	0.00	Rain with 0.68 inch drainage
5-29	1.40	100	0.16	-	-	-	1.24	89	0.16	
5-30	1.24	89	0.16	-	-	-	1.08	77	0.32	
5-31	1.08	77	0.16	-	-	-	0.92	66	0.48	Lagoon marker indicates need to irrigate

[1] Based on a maximum plant-available water content of the example soil of 1.4 inches.
[2] Depletion (end of day) = Depletion (previous day) + PET - rainfall - irrigation + drainage or PAW at field capacity - PAW (end of day)

Since no records were being maintained, the water content on May 1 is not known. The initial content on May 1 can be estimated using the feel method (Table 5-5) or a starting value can be assumed one day after a one-inch or greater rainfall (i.e., field capacity value). Using the latter approach, 1.5 inches of rain occurred on May 3. Since the maximum plant-available water content is 1.4 inches, we can assume that the soil storage is "full" one day after the 1.5 inch rainfall.

Therefore, we start the water balance on May 4, assuming the plant-available storage on that day is 1.4 inches. Each day thereafter, a balance is computed based on additions to the root zone (rainfall or irrigation) and removal from the root zone (ET, drainage, or seepage).

As we have seen, soil-water can be measured or computed reliably by several different methods. Success results from selecting the method that is appropriate for the soils and crops being irrigated and that the operator feels confident in using.

System Calibration

Information presented in manufacturers' charts is based on average operating conditions with relatively new equipment. Discharge rates and application rates change over time as equipment gets older and components wear. In particular, pump wear tends to reduce operating pressure and flow. With continued use, nozzle wear results in an increase in the nozzle opening which will increase the discharge rate while decreasing the wetted diameter.

You should be aware that operating the system differently than assumed in the design will alter the application rate, diameter of coverage, and subsequently the application uniformity. For example, operating the system with excessive pressure results in smaller droplets, greater potential for drift, and accelerated wear of the sprinkler nozzle. Clogging of nozzles can result in pressure increase. Plugged intakes or crystallization of mainlines will reduce operating pressure. Operating below design pressure greatly reduces the coverage diameter and application uniformity.

For the above reasons, you should field calibrate your equipment on a regular basis to ensure proper application rates and uniformity. Field calibration at least once every three years is recommended.

Calibration involves collecting and measuring flow at several locations in the application area. Any number of containers can be used to collect flow and determine the application rate. Rain gauges work best because they already have a graduated scale from which to read the application amount without having to perform additional calculations.

However, pans, plastic buckets, jars, or anything with a uniform opening and cross-section can be used provided the liquid collected can be easily transferred to a scaled container for measuring.

For stationary sprinklers, collection containers should be located in a grid pattern throughout the application area at several distances from sprinklers. Collection gauges should be spaced 1/4 the effective sprinkler spacing apart.

For traveling guns, sprinklers should be located along a transect perpendicular to the direction of pull. Set out collection containers no further than 25 feet apart along the transect on both sides of the gun cart. You should compute the average application rate for all collection containers and the application uniformity for the system.

You should obtain a uniformity coefficient of 0.5 or greater for stationary sprinkler systems and the uniformity coefficient for a traveling gun system should exceed 0.7. If the uniformity coefficient computed for your system is less than these values, you should contact your irrigation dealer for assistance.

Summary of Irrigation Scheduling

In this section, you have been introduced to a number of soil-water terms and irrigation formulas used to help determine how to properly apply wastewater. The use of these terms and formulas requires that you know the following items about your system and land application site:

- Soil types and infiltration rates by field.
- Weekly and annual irrigation depths.

- Soil-water relationships and properties.
- Acreage of each field to receive waste applications.
- Type and specifications of waste application equipment, including:
  - operating pressure;
  - nozzle diameter;
  - flow or delivery rate in gallons per minute per sprinkler (GPM);
  - diameter of throw of sprinkler;
  - travel speed settings for traveling equipment; and
  - number of sprinklers.

With the information presented in this section, you can make the calculations that will allow you to properly operate your waste application equipment so that wastewater is applied without surface runoff and agronomic rates are not exceeded.

5.2. Sampling

Another important facet of proper system operation is sampling. Most surface irrigation system permits require soil, plant tissue, effluent and groundwater analyses. If such monitoring is required, the system permit will specify which parameters to monitor, when to monitor, and when results must be submitted. Although such sampling may not be required by every permit, all surface irrigation system operators should have a basic understanding of the different types of analyses available, proper sampling techniques, and how to interpret sample results.

Soil Sampling

It is not possible to look at a soil and predict if the soil is too acid or if there are proper amounts of the essential nutrients present. Soils in North Carolina vary in their need for lime and other nutrients, depending on soil characteristics, previous fertilization levels, and nutrient requirements of the crop. Therefore, periodic soil sampling is recommended, even if the system's permit does not require it.

The goal of soil testing is to find out enough about the soil to provide economically and environmentally sound nutrient and lime recommendations. Soil testing is not a perfect science, but it provides the most reasonable approach for operators to assess soil pH and plant-available nutrients, to determine the need for lime and fertilizers, and to avoid losses and environmental damage from improper lime and fertilization practices.

In North Carolina, soil analysis is service provided by the North Carolina Department of Agriculture and Consumer Services (NCDA & CS) Agronomic Division. The Agronomic Division can analyze soil samples and make agronomic recommendations for lime and fertilizer applications. During April through November there is no fee for a standard soil test. During the months of December through March there is a $4.00 fee.

Sampling instructions, information sheets, and boxes are provided at no charge and can be obtained from county Cooperative Extension Service centers, from Regional Agronomists of the Agronomic Division, and from many businesses selling lime or fertilizer. Samples and completed information sheets should be sent to the Agronomic Division, NCDA & CS, 4300 Reedy Creek Road, Raleigh, NC 27607-6465.

However, it is important to note that your permit may require that you use a private North Carolina certified laboratory to satisfy monitoring requirements rather than the NCDA & CS Agronomic Laboratory.

The following discussion of where, when and how to take and submit soil samples is taken from SoilFacts: Careful Soil Sampling (North Carolina Cooperative Extension Service Publication Number AG-439-30).

Where to Take Samples

Every soil sample you submit for testing should consist of about 15 to 20 cores taken at random locations throughout one field or area. A sample should include cores from no more than about 20 acres even if the soil appears to be uniform over a larger area.

Keep in mind that each sample should represent only one general soil type or condition. If the field you are sampling contains areas that are obviously different in slope, color, drainage, and texture and if those areas can be fertilized separately, submit a separate sample (consisting of 15 to 20 cores) for each area (Figure 5-6).

When collecting samples, avoid small areas where the soil conditions are obviously different from those in the rest of the field—for example, wet spots, old manure and urine spots, places where wood piles have been burned, severely eroded areas, old building sites, fence rows, spoil banks, and burn-row areas. Also avoid the fertilizer bands in fields where row crops have been grown. Because samples taken from these locations would not be typical of the soil in the rest of the field, including them could produce misleading results.

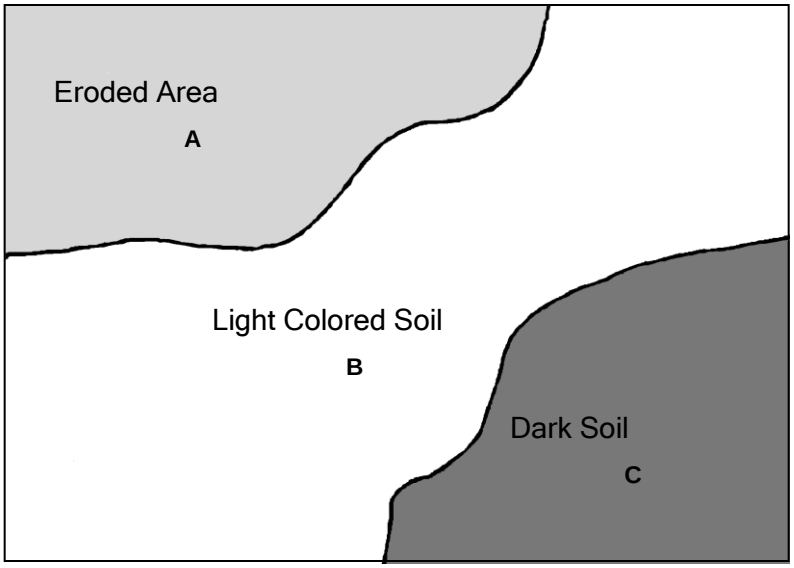


Figure 5-6. Within each field, collect a separate sample from each area that has a different type of soil.

Areas within a field where different crops have been grown in the past should be sampled separately, even if you now plan to grow the same crop in the whole field. Areas that have been limed and fertilized differently from the rest of the field should also be sampled separately.

Sampling Problem Areas

In fields or areas where fertility problems appear to be the cause of abnormal crop growth, samples should be collected in a somewhat different way from samples used for routine testing. At the same time you collect topsoil samples, collect subsoil samples at a depth from 8 to 16 inches, but keep the two types of samples separate.

Follow the guidelines for collecting a good, representative sample, taking cores at random locations throughout the problem area even though it may be relatively small. At the same time, collect a representative sample from normal areas of the same field. More detailed information on collecting samples from problem areas is given in form AD2, "Problem Area Soil Sample Information" (see Appendix B-3).

When to Take Samples

Collect samples three to six months before planting time. You will then have the test report in time to plan your liming and fertilization program before the busy planting season. If you submit samples immediately after harvest in the fall, you are likely to receive the results promptly because the laboratory workload is lighter at that time than in the spring. If possible, try to collect your samples at the same time every year.

Do not collect samples when the soil is too wet because it will be difficult to mix the cores. As a rule, if the soil is too wet to plow, it is too wet to sample.

Sample the soil from perennial or sod-crop areas three to four months before establishing the crop or applying lime or fertilizer.

How Often to Sample

If the system permit requires soil sampling, the sampling frequency will be established in the permit and must be strictly followed. Otherwise, if your waste application system is in the coastal plain region, it is best to test the soil every two to three years. The sandy soils in that region do not hold nutrients as long as soils in the other parts of the state and are more apt to become acid through the addition of nitrogen. The nutrient levels in the silt and clay loam soils of the piedmont and mountain regions change less rapidly with lime and fertilizer applications. In these areas, soil testing once every four years is usually sufficient.

A good plan is to sample one-third to one-half of your fields each year if your system is in the coastal plains region and one-fourth of your fields each year if you are in the piedmont or mountain regions.

How to Collect a Good Sample

Collect your samples with stainless steel or chrome-plated sampling tools and plastic buckets to avoid contaminating the samples with traces of chemical elements (micronutrients) from the sampling tools. Avoid brass, bronze, or galvanized tools.

Make sure that the buckets and sampling tools are clean and free of lime and fertilizer residues. Even a small amount of lime or fertilizer transferred from the sampling tools to the soil can seriously contaminate the sample and produce inaccurate results.

For areas in which field crops are grown, collect samples to the same depth that the field is plowed (usually about 8 inches) because this is the zone in which lime and fertilizer have been incorporated (see Figure 5-7).

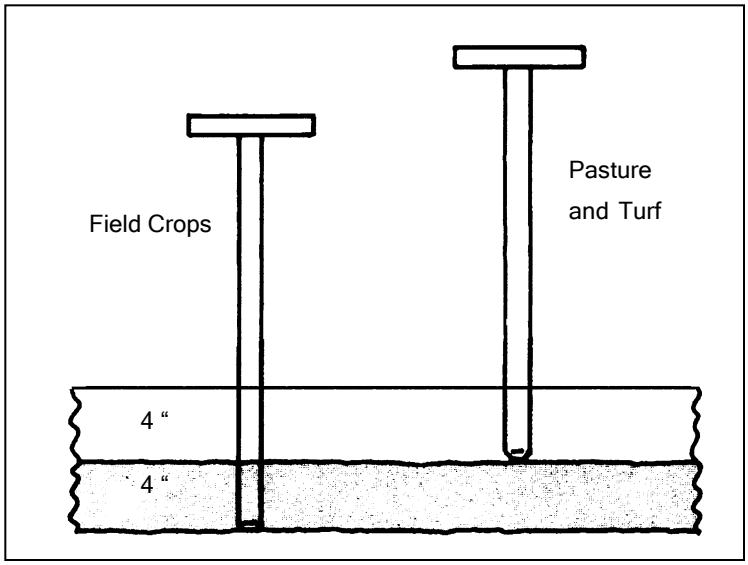


Figure 5-7. Sample to a depth of 8 inches in fields plowed for row crops and 4 inches where perennial pasture or turf crops are grown.

For fields where perennial crops such as fescue, alfalfa, and turf are being maintained, samples taken to a depth of 4 inches will best represent the crop's lime and fertilizer needs. Where these perennial crops are to be established however, sample to the regular plow depth. For more detailed instructions on soil sampling basics, see Appendix B-3.

Submitting the Sample

If your soil samples are to be analyzed by the Agronomic Division of the NCDA & CS, each sample must be submitted in a standard soil sample box and accompanied by a completed copy of form AD-1, "Soil Sample Information" (Figure 5-8 and Appendix B-3).

Submit your samples only in the standard boxes provided by NCDA & CS. Samples sent in bags or other containers will not be compatible with the processing system used in the laboratory. Do not put a plastic bag inside the sample box. Seal the shipping box if the soil samples are from a quarantined area.

The 15- to 20-core sample you have collected will most likely be more soil than the box will hold. Before filling the box, pulverize the cores and mix them thoroughly in the bucket. Then fill the sample box about two-thirds full with this mixture.

Label the box with the code you have assigned to the area sample. Please note that the identification can consist of no more than three numbers, letters, or a combination of the two.Directions for filling out the soil information sheet are printed on the back of the form (Figure 5-8). To get the most value from your soil test, take the time to fill in the blanks completely and be sure to list the crop or crops to be grown. Also check to make sure that the code you put on the form corresponds to the code on the sample box and the site map. Mail the completed form with the sample box, keeping a copy for your future reference. See Appendix B-3 for more detailed information on packing samples for shipment.

Form AD-1 (March 2010)

SOIL SAMPLE INFORMATION

NCDA&CS Agronomic Division Soil Testing Section
Mailing Address: 1040 Mail Service Center, Raleigh NC 27699-1040
Physical Address (UPS/FedEx): 4300 Reedy Creek Road, Raleigh NC 27607
Phone: (919) 733-2655 Web Address: www.ncagr.gov/agronomi

FOR OFFICE USE ONLY
REPORT #
DATE REC'D
INITIAL

SAMPLE TYPE
Routine samples only — no fee

SAMPLE INFORMATION
FARM ID
SAMPLE DATE
COUNTY *(where collected)*
NUMBER OF SAMPLES

Reminders
Fill sample box to red line.
Select the proper crop code(s) from the list on the back of this form.
Pack samples securely for shipment.

GROWER INFORMATION *(please print)*
LAST NAME FIRST NAME
ADDRESS
CITY STATE ZIP
PHONE (___) ___ - ____
E-MAIL ADDRESS ☐ Do Not notify me when report is available.

CONSULTANT/OTHER RECIPIENT
LAST NAME FIRST NAME
ADDRESS
CITY STATE ZIP
PHONE (___) ___ - ____
E-MAIL ADDRESS ☐ Do Not notify me when report is available.

LAB NUMBER (Leave blank)	SAMPLE IDENTIFICATION	LIME APPLIED WITHIN PAST 12 MONTHS			You must specify a crop CODE to receive a recommendation (see reverse side of form)			
		Tons/Acre	Month	Year	FIRST CROP	CODE	SECOND CROP	CODE
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								

Thank you for using agronomic services to manage nutrients and safeguard environmental quality. — Steve Troxler, Commissioner of Agriculture

Figure 5-8. Soil Sample Information Sheet, page one.

What Does My Soil Test Report Tell Me?

The most immediate need for a soil test is to ensure that soil pH is within the desired range for the soil and for the crops you are growing. In addition, a soil test can be used to monitor nutrient accumulation and provide other information that will help you do a better job of managing the surface irrigation site. Only the most essential items will be discussed here. For more information, see your Cooperative Extension Service Agent, an NCDA & CS Agronomist, or refer to "Understanding the Soil Test Report" located in Appendix B-3.

Soil pH and Lime

As discussed in Chapter 3, soil pH affects the availability of nutrients required for plant growth. An incorrect soil pH will reduce crop growth and yield, resulting in less nutrient uptake and greater potential for environmental problems. Low pH increases the availability of metals such as aluminum, zinc, copper, and manganese, all of which are toxic to plants at high concentrations. Depending on how much nitrogen is applied, soils with high metal concentrations and low pH may require annual additions of lime in order to maintain the pH in a range suitable for plant growth. Lime also supplies calcium and magnesium, which are essential for crop growth.

The soil test report indicates the amount of lime (in tons) that is required to achieve the target pH for your soil type and crop. Soils with high amounts of organic matter can tolerate a much lower pH than soils with low organic matter contents. For this reason, soil samples received at the lab are separated into Mineral, Mineral-Organic, and Organic classes based on their Humic Matter content (HM% on the report), weight per volume (W/V) and color. For most crops, the desired pH is 6.0 for Mineral soils, 5.5 for Mineral-Organic soils, and 5.0 for Organic soil classes (Figure 5-9).

Taking a Soil Sample

A soil test is only as good as the soil sample!

Use iron or stainless steel tools. Sample dry soil in areas of 10 acres or fewer. Avoid combining soils of different types and/or treatment histories. Avoid fertilizer bands and corners or end-turn areas. For each sample, collect 20 or more cores at the appropriate depth (0–8" for plowed soils; 0–4" for no-till, sod & lawns). Mix cores in a plastic bucket, then fill the sample box.
DO NOT PUT SOIL IN PLASTIC BAGS.

Filling out the Sample Information Form

EXAMPLE

LAB NUMBER (Leave blank)	SAMPLE IDENTIFICATION	LIME APPLIED WITHIN PAST 12 MONTHS Tons/Acre	Month	Year	FIRST CROP	CODE	SECOND CROP	CODE
1	| | |J |1	1	9	2002	Corn	001	Small Grain	004
2	| | |S |1	2	9	2002	Clover / Grass, M	050	Clover / Grass, M	050
3	| | |S |2	0			Bermuda Hay, E	043	Bermuda Hay, M	044

REQUIRED INFORMATION
The lab **MUST** have this information.

SAMPLE & GROWER INFORMATION — Provide as much information as possible. Print neatly.
CONSULTANT/OTHER RECIPIENT — List name & contact information for anyone else who needs to know about the report.
SAMPLE IDENTIFICATION — Print an identifier (use numbers and/or letters) for each sample on a separate line. The identifier should help remind you where the sample came from (Example: J1, S1). Make sure the sample identifers on the boxes and on the information form are the same. Use **pencil or waterproof markers**.
FIRST CROP — List the crop for which you want lime and fertilizer recommendations. Be sure to include the appropriate **CODE** from the list below (*e.g.*, Bermuda hay or pasture establishment, 043).
A. Use **Lawn** (code 026) for all lawn grasses except **Centipede**. Use one of the **Fine Turf** codes only for golf and athletic field turf.
B. Use **Shrubbery** (code 029) for all shrubs, except azalea, camellia, rhododendron and mountain laurel.
C. For all home garden vegetables, use code 024.

DESIRABLE INFORMATION
The lab can make better suggestions if this information is provided.

LIME APPLIED WITHIN PAST 12 MONTHS — Provide the amount of lime applied in tons/acre, as well as the year and month of the last application, if made during the past 12 months. (50M is equivalent to one ton per acre.)
SECOND CROP — List the name of the crop that will follow the one listed as **FIRST CROP**. Include its **CODE** from the list below. This will enable us to make suggestions for this crop, assuming that the field is treated as suggested the first year. List the second crop even if it will be grown the same year as **FIRST CROP**.

CROP CODES

E = establishment (1st year)
M = maintenance
SG = small grain

000 No Crop

Field Crops
001 Corn, grain
002 Corn, silage
003 Cotton
004 Small Grain
006 Milo (Grain Sorghum)
007 Peanut
010 Soybean
011 Sunflower
012 Tobacco, burley
013 Tobacco, flue-cured
014 Tobacco, greenhouse
015 SG silage/ Soybean
016 SG silage/ Corn silage
017 Kenaf
018 SG/ Soybean (double crop)

Home Lawn & Garden
020 Azalea
021 Camellia
022 Centipede
023 Flower garden
024 Vegetable garden
025 Mountain laurel
026 Lawn
027 Rhododendron
028 Rose
029 Shrubbery
030 Berries/ Fruit/ Nuts
031 Tree, shade

Christmas Trees
034 Leyland cypress
035 Line-out/ Seed Beds
036 Fir/ N Spruce/ Hemlock, E
037 Fir/ N Spruce/ Hemlock, M
038 Pine, White or Virginia
039 Blue Spruce/ Red Cedar

Forage & Pasture
040 Alfalfa, E
041 Alfalfa, M
042 Common bermuda/ Bahia

Forage & Pasture (cont.)
043 Bermuda hay/ pasture, E
044 Bermuda hay/ pasture, M
047 Bluegrass pasture
048 Bluegrass/ White Clover
049 Clover/ Grass, E
050 Clover/ Grass, M
051 Gamagrass
053 Legumes, misc.
054 Fescue/ Orchard/ Timothy, E
055 Fescue/ Orchard/ Timothy, M
056 Prairiegrass
057 Switchgrass
059 Sudan/Sorghum/Millet/Red Crabgrass
060 Sudan/ Sorghum silage

Roadside Areas
061 Critical area
062 Roadside grass, E
063 Roadside grass, M

Wildlife Areas / Food Plots
066 Deer / Turkey
067 Upland game
068 Waterfowl
069 Fish pond

Commercial Hort Crops ONLY
[024 = all Home Vegetables]
070 Asparagus, E
071 Asparagus, M
072 Beans/ Peas
074 Beet
072 Beans/ Peas
074 Beet
075 Blueberry, E
076 Blueberry, M
077 Broccoli/ B. sprouts/Cauliflower
079 Cabbage
080 Cantaloupe/ Watermelon
084 Corn, sweet
085 Cucumber
088 Grape, E
089 Grape, M
090 Kale/ Mustard/ Spinach
093 Okra
095 Pea, southern
096 Pepper
097 Plant bed, vegetable
098 Potato, Irish
099 Sweetpotato

Commercial Hort Crops (cont.)
100 Radish
101 Rape/ Canola
102 Raspberry/ Blackberry, E
103 Raspberry/ Blackberry, M
107 Squash/ Pumpkin
108 Strawberry, E
109 Strawberry, M
110 Tomato
111 Tomato, greenhouse
115 Turnip
116 Vegetables, other

Commercial Nursery & Flowers
120 Dahlia
121 Gladiolus
122 Greenhouse
123 Gysophila (Baby's Breath)
124 Flower, bulbs
125 Flower, roots
126 Nursery, container
132 Rhododendron/ Ginseng/ Native ornamentals
136 Nursery/ Trees

Orchard, Fruit & Nut
130 Apple, E
131 Apple, M
138 Peach, E
139 Peach, M
140 Pecan, E
141 Pecan, M

Forest Trees & Seed
133 Hardwood, E
134 Hardwood, M
137 Nursery, pine
142 Pine, E
143 Pine, M
144 Hardwood, seed
145 Fir/ Spruce, seed
146 Pine, seed

Fine Turf
150 Fairway/ Athletic turf
151 Tee
152 Greens

Figure 5-9. Soil Sample Information Sheet, page two.

CEC

Remember from Chapter 3 that the cation exchange capacity (CEC) is an indication of a soil's ability to hold nutrients. In North Carolina, CEC increases with increasing clay content or increasing organic matter content. Soils with a low CEC (1 to 5 meq/100g) have low clay and organic matter contents, and nutrients such as nitrogen, potassium, and magnesium may leach from these soils during periods of excess rainfall. These soils require more frequent application of nutrients at lower rates to ensure adequate availability throughout the growing season. Micronutrients applied to soils with low CEC can become toxic to plants at lower concentrations than on soils with a CEC above 5 milliequivalents per 100 grams.

Soil Test Report

Grower: **Educational Sample-Swine Waste**
4300 Reedy Creek Rd.
Raleigh, NC 27607

Copies to: County Extension Director

Farm:

1/26/96 **SERVING N.C. CITIZENS FOR OVER 50 YEARS**

Agronomist Comments: C – 12

Field Information		Applied Lime			Recommendation												
Sample No.	*Last Crop*	*Mo*	*Yr*	*T/A*	*Crop or Year*	*Lime*	*N*	*P_2O_5*	*K_2O*	*Mg*	*Cu*	*Zn*	*B*	*Mn*	*See Note*		
NB1	Bahiagrass				1st Crop: Berm Hay/Pas,E	1.7T	60-80	90-110	40-60	0	0	0		0	12		
					2nd Crop: Berm Hay/Pas,M	0	180-220	80-100	120-140	0	0	0		0	12		

Test Results

Soil Class	*HM%*	*W/V*	*CEC*	*BS%*	*Ac*	*pH*	*P-I*	*K-I*	*Ca%*	*Mg%*	*Mn-I*	*Mn-AI (1)*	*Mn-AI (2)*	*Zn-I*	*Zn-AI*	*Cu-I*	*S-I*	*SS-I*	*NO_3-N*	*NH_4-N*	*Na*
MIN	0.41	0.84	3.8	53.0	1.8	4.5	21	44	34.0	13.0	2089	1263	1263	48	48	77	78	24			0.1

Field Information		Applied Lime			Recommendation												
Sample No.	*Last Crop*	*Mo*	*Yr*	*T/A*	*Crop or Year*	*Lime*	*N*	*P_2O_5*	*K_2O*	*Mg*	*Cu*	*Zn*	*B*	*Mn*	*See Note*		
W2	Bahiagrass				1st Crop: Berm Hay/Pas,E	1.2T	60-80	0	0-20	0	0	0		0	12		
					2nd Crop: Alfalfa, E	0	10-30	0	50-70	0	0	0	3	0	12		

Test Results

Soil Class	*HM%*	*W/V*	*CEC*	*BS%*	*Ac*	*pH*	*P-I*	*K-I*	*Ca%*	*Mg%*	*Mn-I*	*Mn-AI (1)*	*Mn-AI (2)*	*Zn-I*	*Zn-AI*	*Cu-I*	*S-I*	*SS-I*	*NO_3-N*	*NH_4-N*	*Na*
MIN	0.36	0.82	3.8	66.0	1.3	4.9	870	71	44.0	13.0	2353	1421	1421	683	683	1492	60	17			0.1

Figure 5-10. NCDA & CS Agronomic Division Soil Test Report for two forage fields.

Nutrient Index Values

The soil nutrient concentrations on an NCDA & CS soil test are reported as index values. Index values can be used as a means of predicting soil fertility levels or potential heavy metal toxicities. Essentially, the index system was developed to relate soil fertility levels to the likelihood of a crop yield increase resulting from a fertilizer application (Table 5-8).

Table 5-8. Relationship Between Soil Test Indes and Crop Responses.

Soil Test Index	Expected Crop Response to Nutrient Application			
Range	Rating	P *,**	Zn	Cu
0 to 25	Low	High	High	High
26 to 50	Medium	Low	None	None
51 to 100	High	None	None	None
100+	Very High	None	None	None

* *For soils in the ORG class, the range for P Ratings are: Low 0 to 16, Medium 16 to 30, and High 30+.*

** *Phosphate recommendations above the 50 index are designed to replenish nutrients removed by crops and for building purposes.*

Phosphorus and potassium, a crop response to nutrient additions is not expected when the index value is above 50. Micronutrients are required in much lower amounts, so crop responses are not expected when index values are above 25. When soil test index values are less than these critical levels, the soil test report will indicate the amount of nutrient to apply for optimum plant growth in the Recommendations Section of the report. For more information on understanding the index system, see Appendix B-3.

Note: Soil test index values above 100 indicate excessive amounts are present in soil.

How Can a Soil Test Be Used to Determine the Priority Nutrient?

In situations where wastewater application is limited by nutrients rather than by hydraulics, soil tests can be used to help determine the priority nutrient. The priority nutrient is the nutrient most likely to cause an adverse environmental or plant health effect. Generally, nitrogen is found to be the priority nutrient and application rates should be based on supplying crop nitrogen (N) needs. The idea is to not apply N at rates greater than the crop can use, because the nitrate form of nitrogen can move through the soil and threaten groundwater quality.

Plant Tissue Sampling

Healthy plants contain predictable concentrations of the essential elements. If these elements are present in inadequate amounts then the plant suffers from a nutrient deficiency. In some cases, these nutrients are present in higher concentrations than required and the plant may suffer from a nutrient toxicity. In either case, the plant is not healthy and is not efficiently removing nutrients from the soil. Plant tissue sampling can be used to distinguish between nutrient deficiency, nutrient sufficiency, and nutrient toxicity.

A recent soil test result can be helpful when interpreting a plant analysis. When visual symptoms of a suspected nutrient deficiency are present, take a soil sample at the same time from root zones of plants sampled. In this way, an evaluation of the soil in the affected area can be made along with an evaluation of the plant tissue. Sampling healthy and unhealthy plants, and their respective soil, is very effective in problem solving.

A plant analysis may indicate that a nutrient deficiency or toxicity does not exist. Therefore, a factor other than nutrition may be responsible for poor plant growth or visual symptoms. This information is invaluable in problem solving. In order to use the plant analysis technique effectively, take care when collecting, preparing, and sending plant tissue to the laboratory.

Sampling instructions, information sheets, and shipping envelopes are provided at no charge and can be obtained at county Cooperative Extension Service centers or from Regional Agronomists of the Agronomic Division. Samples, the completed information sheets (Form AD4, Appendix B-3), and a $5.00 fee should be sent to the Agronomic Division, NCDA & CS, 4300 Reedy Creek Road, Raleigh, NC 27607-6465.

If plant tissue monitoring is required by your system permit, the permit will specify which parameters to monitor, when to monitor, and when results must be submitted. It is important to note that your permit may require that you use a private North Carolina certified laboratory to satisfy monitoring requirements rather than the NCDA & CS Agronomic Laboratory.

The following discussion of where, when and how to take and submit plant tissue samples is taken from Sampling for Plant Analysis (NCDA Agronomic Sampling Folder No. 5).

Plant analysis results can:

- indicate the nutritional status of plants;
- identify deficiencies and toxicities;
- provide an accounting of nutrient utilization; and
- provide a mechanism for optimizing yield, quality, and efficiency.

Plant analysis evaluates the status of 13 nutrients required for plant growth along with certain potentially toxic elements. Plant analysis assesses nutrient uptake while soil testing predicts nutrient availability. The two tests are complementary as crop management tools, but each has limitations. Plant analysis cannot predict lime requirement. Soil testing is not always a good indicator of nutrients such as nitrogen and sulfur that leach easily. Plant analysis is also a better tool for assessing some micronutrients, such as boron, iron, and molybdenum.

Deciding When to Sample

To monitor plant nutrient status most effectively, sample during the recommended growth stages for your specific crop (Table 5-9). Take samples weekly or biweekly during critical periods, depending on management intensity and crop value. However, to identify a specific plant growth problem, take samples whenever you suspect the problem.

Although it is not critical, the best time to collect samples is between mid-morning and mid-afternoon. Nitrate nitrogen varies with time of day and prevailing conditions but generally not enough to alter interpretation. Sampling during damp conditions is acceptable but requires extra care to prevent tissue from decomposing during shipping. Keep samples free of soil and other contaminants that can alter results.

Taking a Representative Sample

Proper sampling is the key to reliable plant analysis results. A sample can represent the status of one plant or 20 acres of plants. In general, a common-sense approach works well. When problem solving, take samples from both “good” and “bad” areas. Comparison between the groups of samples helps pinpoint the limiting element. Comparative sampling also helps factor out the influence of drought stress, disease, or injury. Take matching soil samples from the root zones of both “good” and “bad” plants for the most complete evaluation.

When monitoring the status of healthy plants, take samples from a uniform area. If the entire field is uniform, one sample can represent a number of acres. If there are variations in soil type, topography, or crop history, take multiple samples so that each unique area is represented by its own sample.

Table 5-9. Best time to sample when monitoring nutritional status.

Alfalfa, clover, peanut, pea, soybean	early bloom
Apple, cherry, grape, peach, pear, pecan, sweetpotato	mid-season
Bean	early growth and bloom
Cotton	from 2 weeks before first bloom through 6 weeks after bloom
Corn, sorghum, sweet corn	lay-by and bloom (tasseling)
Cucumber, squash, tomato	from 2 weeks before first bloom through fruiting
Flowering plants & foliage plants	early growth through bloom
Irish potato	early bloom
Leaf and root crops	early growth
Small grain	full tillering and bloom
Strawberry	spring vegetative growth through fruiting
Tobacco	early growth through bloom for nutritional status; one week prior to harvest for flue-cured harvest readiness
Turfgrass	monthly
Woody ornamentals	current year's growth

Selecting the Best Indicator Sample

The appropriate part of the plant to sample varies with crop, stage of growth, and purpose of sampling. When sampling seedlings less than 4 inches tall, take whole plants from 1 inch above the soil line. For larger plants, the most recent mature leaf (MRML) is the best indicator samples.

The MRML is the first fully expanded leaf below the growing point (Figure 5-11). It is neither dull from age nor shiny green from immaturity. For some crops, the MRML is a compound leaf. The MRML on soybean and strawberry, for example, is a trifoliate compound leaf: three leaflets comprising one leaf.

For cotton, grape, and strawberry, petioles provide an additional indication of nitrogen status. When sampling these crops, collect MRMLs and their petioles. Detach leaves from petioles in the field to stop the translocation of nutrients. Put petioles in a separate envelope inside the leaf sample container.

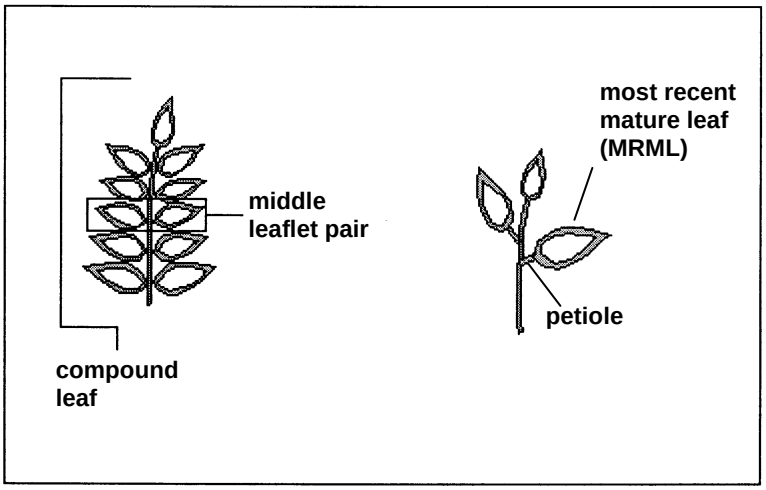


Figure 5-11. Some best indicator samples.

Choosing Sample Size

The actual laboratory analysis requires less than one gram of tissue. However, a good sample contains enough leaves to represent the area sampled. Therefore, the larger the area is, the larger the sample size needs to be.

Sample size also varies with crop. For crops with large leaves, like tobacco, a sample of three or four leaves is adequate. For crops with small leaves, like azalea, a sample of 25 to 30 leaves is more appropriate. For most crops, 8 to 15 leaves is adequate. For crops requiring petiole analysis, collect at least 15 to 20 leaves.

Submitting the Sample

Send the completed plant analysis information sheet (form AD-4) and $4 processing fee with each sample. Use permanent ink or pencil on sample forms and envelopes. Tissue sample envelopes and information sheets are available from local Cooperative Extension offices, agribusinesses, regional agronomists, or the Agronomic Division laboratory. See Appendix B-3 for a copy of form AD-4, the plant analysis information sheet.

Pay attention to detail when filling out the information sheet (Figures 5-12 and 5-13). Supply the information requested in all shaded areas on the form. Note any conditions—drought, disease, injury, pesticide or foliar nutrient applications—that might be relevant.

When identifying the plants that you sampled, give the exact name using the list inside the information sheet, if possible. Give each sample a unique identifier that will help you remember the plants or area it corresponds to—such as HOUSE1, 15B, GOOD, or BAD. You can use up to six letters and/or numbers. Put the identifier on both the information sheet and the sample envelope.

Diagnostic interpretations require more details than predictive. When sending matching soil, solution, or waste samples, indicate the matching sample ID in the designated areas on the information sheet. Be sure the grower name and address are exactly the same on all matching

information sheets. Ship all matching samples in the same container addressed to the Plant Advisory Section.

Form AD-4 (March 2010)

PLANT SAMPLE INFORMATION

NCDA&CS Agronomic Division Plant/Waste/Solution/Media Section
Mailing Address: 1040 Mail Service Center, Raleigh NC 27699-1040
Physical Address (UPS/FedEx): 4300 Reedy Creek Road, Raleigh NC 27607
Phone: (919) 733-2655 Web Address: www.ncagr.gov/agronomi

FOR OFFICE USE ONLY
REPORT #
DATE REC'D
INITIAL

SAMPLE TYPE
(circle designation(s) / instructions on back)

Predictive	Diagnostic
Research	Out of State

SAMPLE INFORMATION	PAYMENT	GROWER INFORMATION *(please print)*	CONSULTANT/OTHER RECIPIENT
FARM ID	FEE TOTAL _____ AMT PAID _____	LAST NAME FIRST NAME	LAST NAME FIRST NAME
SAMPLED BY ☐ Grower ☐ NCDA&CS Agronomist ☐ Advisor ☐ Coop. Ext. Agent	METHOD OF PAYMENT ( ) CASH ( ) CHECK *(payable to NCDA&CS)* ( ) MONEY ORDER ( ) ESCROW *(provide account name below)*	ADDRESS	ADDRESS
SAMPLE DATE		CITY STATE ZIP	CITY STATE ZIP
COUNTY *(where collected)*		PHONE (___) ___ - ____	PHONE (___) ___ - ____
NUMBER OF SAMPLES		E-MAIL ADDRESS ☐ Do Not notify me when report is available.	E-MAIL ADDRESS ☐ Do Not notify me when report is available.

LAB NUMBER (leave blank)	SAMPLE ID	CROP NAME	GROWTH STAGE	WEEK	PLANT PART	PLANT POSITION	CORRESPONDING SAMPLE ID SOIL	SOLUTION	WASTE	PLANT APPEARANCE	SPECIAL TESTS ($2 EACH) Mb	Cl	NO_3	other
1														
2														
3														
4														
5														

GROWING CONDITIONS

Planting date:
How long have symptoms been present?
Are plants infected with disease? Yes No
Are plants infested with insects? Yes No
Environmental conditions in last three weeks:
Rainfall Below normal Normal Above normal
Temperature Below normal Normal Above normal

IRRIGATION (AMOUNT): TYPE:
FUNGICIDES USED: DATE:

PROBLEM SAMPLE COMMENTS

FERTILIZER HISTORY

	Date	Material	Rate	Comments
Preplant:				
Postplant:				
Micronutrient:				
Other:				

Thank you for using agronomic services to manage nutrients and safeguard environmental quality. — Steve Troxler, Commissioner of Agriculture

Figure 5-12. Plant Analysis Information Sheet, page one.

INSTRUCTIONS FOR COMPLETING THE INFORMATION FORM

SAMPLES WILL NOT BE ANALYZED UNLESS ALL INFORMATION REQUESTED IN THE SHADED AREAS ON THE FRONT OF THIS FORM IS PROVIDED.

SAMPLE TYPE

Predictive analysis checks nutrient content and provides interpretation and general recommendations.
Diagnostic analysis identifies nutritional problems and provides interpretation and specific recommendations.
Research is for samples submitted in connection with an approved research contract agreement.
Out of state is for samples submitted by non–North Carolina residents.

SAMPLE INFORMATION — Provide FARM ID (if applicable); details about sample collection (collector, date, number of samples and county where collected); and PAYMENT details: **Cost per sample = Base fee** [$5 for N.C. residents; $25 for out-of state samples; $12 for research samples] + **$2 for each mandatory special test** [a petiole nitrate test is required for cotton and plasticulture strawberry; a molybdenum test is required for alfalfa, broccoli, all kinds of cabbage, cauliflower, collards, kale, poinsettia, spinach and turnip greens] + **$2 for each optional test requested** [petiole nitrate, molybdenum and/or chloride). Be sure to indicate payment TYPE: check, money order, cash or escrow.

GROWER INFORMATION — Provide phone number with area code, mailing address and e-mail address (as an additional way for the lab to contact you, if necessary).

CONSULTANT/OTHER RECIPIENT — Provide indicated contact information for any partner/advisor who may need access to your test results.

SAMPLE ID — Provide sample identification (no more than six digits or letters). Put the same ID on the sample envelope.

CROP NAME — Enter the name of the crop sampled. You can use the common and/or botanical name.

GROWTH STAGE — Identify plant growth stage by one of these letter codes: **S = Seedling, E = Early growth, B = Bloom, F = Fruiting, M = Mature.**

WEEK — Indicate the estimated number of weeks that the crop has been in the current growth stage.

PLANT PART — Identify the part of the plant that was sampled by one of these letter codes: **W = Whole plant** (from 1" above the soil line), **T = Top three inches, E = Ear leaf, M = Most recent mature leaf** (including petioles for appropriate crops), **H = Harvested leaf**. For most plants, the most recent mature leaf (M) is the proper plant part to sample.

PLANT POSITION — Identify the position on the plant where the sample was taken by one of these letter codes: **U = Upper, M = Middle, L = Lower**. For most plants, the upper (U) position is the proper place to sample.

CORRESPONDING SAMPLE ID — List the IDs of any matching soil, solution or waste samples submitted.

PLANT APPEARANCE — Describe the symptoms of the plant at sampling. **If this space is left blank, we assume growth is normal.**

SPECIAL TESTS — Indicate additional mandatory or desired tests. Read the information above under SAMPLE INFORMATION for details.

GROWING CONDITIONS — Provide all requested information.

IRRIGATION (AMOUNT) — Provide this information, if applicable.

FUNGICIDES USED — Provide this information, if applicable.

PROBLEM SAMPLE COMMENTS — Provide additional information needed to help diagnose specific problems.

FERTILIZER HISTORY — Provide all requested information.

Please do not place samples in plastic bags.
Leave ample air space in paper containers to promote drying and avoid sample deterioration.

Figure 5-23. Plant Analysis Information Sheet, page two.

Ship the tissue sample in a paper envelope or cardboard box so it can begin drying during transport. Samples put in plastic bags will rot, and decomposition may alter test results.

Interpreting the Report

Samples are analyzed within two days of their arrival. The prompt turnaround makes it possible for growers to take any corrective action needed to salvage the current crop. The report is mailed to the grower, but a copy is also immediately posted on the internet at: http://www.ncagr.gov/agronomi/.

A cover sheet that explains the technical terms and index values accompanies the report. Cover sheets and other information about plant analysis are also available on the internet at: http://www.ncagr.gov/agronomi/pdffiles/uplant.pdf..

Consult an agricultural advisor if you need additional information or refer to Appendix B-3.

Waste and Wastewater Sampling

Waste analysis is the most accurate and efficient way to measure the nutrient or lime value of different waste products. Because the amount of these beneficial components can vary among waste products, laboratory analysis lets an operator know the proper amount of the waste material to apply to meet the specific plant needs for each site. When management decisions are made without waste analysis information, even well-intentioned users can reduce plant growth and yields or endanger the environment.

Waste users who fail to test each waste material are faced with a number of questions they simply cannot answer. Are they supplying plants with adequate nutrients? Are they building up excess nutrients that may ultimately move to streams or groundwater? Are they changing the soil pH to levels that will not support plant production? Are they applying heavy metals at levels that may be toxic to plants and permanently alter soil productivity?

Because environmental damage and losses in plant yield and quality often happen before visible plant symptoms, waste users should always have their wastes analyzed by a competent laboratory and their application rates determined by a knowledgeable agronomist.

A good analytical service should always determine the concentrations of essential plant nutrients, including nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulfur (S), iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), and boron (B). Analyses of certain municipal and industrial wastes should also include tests for heavy metals like nickel (Ni), cadmium (Cd), and lead (Pb), as well as elements such as sodium (Na) and chlorine (Cl). The neutralizing value (calcium carbonate equivalent, CCE) of lime-stabilized products or materials suspected of having liming characteristics should also be determined.

The Waste Advisory Section of the NCDA & CS Agronomic Division analyzes wastes, interprets analytical results, and provides management recommendations for citizens of North Carolina. The fee for a standard waste analysis is $8.00 per sample. Private laboratories also offer some of these services and their fees vary. It is important to note that your permit may require that you use a private North Carolina certified laboratory to satisfy monitoring requirements rather than the NCDA & CS Agronomic Laboratory.

Wastewater Sampling Terminology

A surface irrigation system operator should be familiar with the following wastewater sampling terms:

- **Grab Sample** - A grab sample is a sample collected over a period of time not exceeding 15 minutes. A grab sample is normally associated with water or wastewater sampling. However, soil, sediment, etc., may also be considered grab samples; no particular time limit would apply for the collection of such samples. Grab samples are used to characterize the medium at a particular instant in time and are always associated with instantaneous water or wastewater flow data, where appropriate. Grab sampling is conducted when:
  - the water or wastewater stream is not continuous;
  - the characteristics of the water or waste stream are know to be constant;
  - the sample is to be analyzed for parameters whose characteristics are likely to change significantly with time (e.g. dissolved gases, bacteria, etc.);
  - the sample is to be collected for analysis of a parameter such as oil and grease where the compositing process could significantly affect the observed concentrations;
  - data on maximum/minimum concentrations are desired for a continuous water or wastewater stream; and
  - when the permit monitoring requirements specify grab collections. The following parameters are always collected by grab samples:
    - pH
    - phenol
    - temperature
    - oil and grease
    - dissolved oxygen
    - bacteria
    - sulfide
    - volatile organics
    - chlorine residual
    - dissolved gases

- **Composite Sample** - Composite samples are used when average concentrations are of interest and are always associated with average flow data (where appropriate). Composite sampling is employed when the water or wastewater stream is continuous or it is necessary to calculate mass/unit time loadings or when analytical capabilities are limited.
  - **Timed composite** - A timed composite sample contains a minimum of eight equal volume discrete samples taken at equal time intervals over the compositing period. A timed composite may be collected continuously. Time composites shall be collected where water or wastewater flows do not vary more than +/- 15 percent of the average daily flow rate. Timed composite samples should be considered where wastewater flows are constant. A timed composite shall be collected continuously or with a constant sample volume and a constant time interval between samples.
  - **Flow proportional composite** - A flow proportional composite contains a minimum of eight discrete samples taken proportional to the flow rate over the compositing period. Flow proportional samples should be collected where water or wastewater flows vary more than +/- 15 percent from the average daily flow rate. Flow proportional composites are used when wastewater flow is highly variable (greater than +/- 15 percent of the average daily flow). A flow proportional composite should be collected with constant sample volume and time between samples proportional to stream flow or with a constant time interval between samples.

- **Split Sample** - A split sample is a sample that has been portioned into two or more containers from a single container. Portioning assumes adequate mixing to assure the "split samples" are, for all practical purposes, identical.

- **Duplicate Sample** - Duplicate samples are samples collected simultaneously from the same source, under identical conditions and into separate containers.

- **Control Sample** - A control sample is collected upstream or upgradient from a source or site to isolate the effects of the source or site on the particular ambient medium being evaluated.

- **Background Sample** - A background sample is collected from an area, water body, or site similar to the one being studied but located in an area known or thought to be free from pollutants of concern.

- **Sample Aliquot** - A sample aliquot is a portion of a sample that is representative of the entire sample.

Sampling Procedures

Proper sampling is the key to reliable waste analysis. Although laboratory procedures are extremely accurate, they have little value if the samples fail to represent the waste product. The importance of careful sampling becomes clear when one recognizes that laboratory determinations are made on a portion of the sample submitted that is as little as 0.02 pound (1 gram) for solid materials or less than a tablespoon (10 milliliters) for liquid materials.

Waste samples submitted to a laboratory should represent the average composition of the material that will be applied to the field. Reliable samples typically consist of material collected from a number of locations. The wide variety of field conditions always requires judgement regarding the methodology and procedures for collection of wastewater samples. Important considerations for obtaining a representative wastewater sample include the following items:

- If possible, the sample should be collected where the wastewater is well-mixed. Therefore the sample should be collected near the center of the flow channel, at a depth of approximately half the total depth, where the turbulence is at a maximum and the possibility of solids settling is minimized. Skimming the water surface or dragging the bottom should be avoided.
- In sampling from a mixing zone, cross-sectional sampling should be considered. Dye may be use as an aid in determining the most representative sampling points.
- If manual compositing is employed, the individual sample bottles must be thoroughly mixed before pouring the individual aliquots into the composite container.

Where applicable, wastewater samples should be collected at the location specified in the permit:

- **Influent** - Influent wastewaters are preferably sampled at points of highly turbulent flow in order to insure adequate mixing.
- **Effluent** - Effluent samples should be collected at the site specified in the permit, or if no site is specified, at the most representative site downstream from all discharges into the receiving waters.
- **Pond and lagoon sampling** - Generally, composite samples should be employed for the collection of wastewater samples from ponds and lagoons. Even if the ponds and lagoons have a long retention time, composite sampling is necessary because of the tendency of ponds and lagoons to short circuit. However, if dye studies or past experience indicate a homogenous discharge, a grab sample may be taken as representative of the waste stream. But in all cases, sampling should be consistent with all permit requirements.

For more detailed information about sampling wastewater, see Appendix B-4.

Lagoon Sampling

Ideally, some liquid wastes should be sampled after they are thoroughly mixed. Because this is sometimes impractical, samples can also be taken in accordance with the suggestions that follow.

Premixing the surface liquid in the lagoon is not needed, provided it is the only component that is being pumped. Operators with two-stage systems should draw samples from the lagoon they intend to pump.

Samples should be collected using a plastic container similar to the one shown in Figure 5-14. One pint of material should be taken from at least eight sites around the lagoon and then mixed in a plastic container. Waste should be collected at least 6 feet from the edge of the lagoon at a depth of about a foot. Shallower samples from anaerobic lagoons may be less representative than deep samples because oxygen transfer near the surface sometimes alters the chemistry of the solution. Floating debris and scum should be avoided.

One quart of mixed material should be sent to the laboratory. Galvanized containers should never be used for collection, mixing, or storage due to the risk of contamination from metals like zinc in the container.

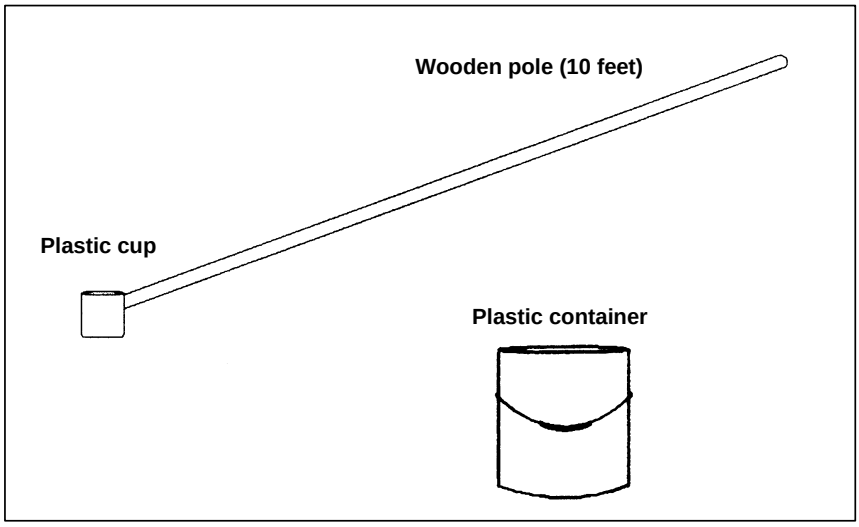


Figure 5-14. Liquid waste sampling device

Submitting Liquid Waste Samples

Liquid waste samples submitted for analysis should meet the following requirements:

- Place sample in a sealed plastic container with about a one-quart volume. Glass is not suitable because it is breakable and may contain contaminants.
- Leave 1 inch of air space in the plastic container to allow for expansion caused by the release of gas from the waste material.
- Refrigerate samples that cannot be shipped on the day they are collected; this will minimize chemical reactions and pressure buildup from gases.

Groundwater Sampling

Groundwater monitoring is sometimes required by the system permit to ensure that deterioration of groundwater quality does not occur. One of the most critical parts of groundwater monitoring is the sample collection process. The best lab in the state cannot produce accurate results from a sample that was contaminated before the lab received it. It would take a lot of time to cover all of the different types of monitoring systems and wells. This discussion will concentrate on the most common monitoring systems for land application of waste. However, no matter what type of well is being sampled, the procedures and important concepts covered should be followed consistently throughout the monitoring process.

Groundwater is sampled from specially designed wells that are carefully located. The wells must be sampled immediately after construction and before waste disposal begins. This determines background levels of constituents that are to be monitored. The system permit gives the frequency for all sampling after the first event, based on facility and site conditions.

Before beginning compliance monitoring, you should do the following:

- determine the sampling schedule and parameters to be monitored as specified in your permit;
- select a laboratory with NC DWR certification that can meet your permit requirements; and
- provide the lab with a copy of the monitoring requirements in your permit.

An updated list of certified laboratories is available from the DENR, Division of Water Resources Chemistry Laboratory, 4405 Reedy Creek Road, Raleigh NC 27607, (919)733-3908.

Equipment and Supplies

Prior planning and careful preparation of field equipment before sampling will ensure good results from the laboratory. The following is a list of supplies and equipment to be used when sampling groundwater:

- disposable gloves;
- documentation (forms, log books and tags, etc.);
- well lock keys;
- water level monitoring device and supplies (batteries, chalk and paste as needed);
- properly calibrated pH, temperature, and conductivity meters with calibration standards;
- decontaminated sampling pump with proper tubing and power supply;
- bailers with line;
- sample containers;
- filtering apparatus;
- cooler with cold packs or ice;
- cleaning buckets and containers;
- plastic garbage bags;
- small sealable plastic bags;
- plastic sheeting;
- paper towels and hand soap;
- cleaning brushes;
- phosphate-free laboratory soap;
- deionized organic-free water and hand sprayers; and
- high purity laboratory grade hexane, acetone, or isopropanol (all available from laboratory supply companies).

Customized kits for sample collection may be supplied by your laboratory. These kits include all the items needed for collection and shipment of samples. Follow laboratory instructions and read

container labels. Be careful not to discard preservatives that may have already been added to some containers.

If you are not using a kit, use only new containers or sanitized reusable containers supplied by a lab of the appropriate types for the required parameters. Select and prepare them according to your laboratory's instructions. Label sample containers before sample collection and record the type and amount of preservative required on each sample tag.

Ensure that all sampling equipment such as bailers, containers and tubing has been selected and thoroughly cleaned based on the parameters to be monitored. Disposable bailers of the appropriate composition may be used. Use Teflon, stainless steel, or glass when sampling for organics such as solvents and petroleum product contamination. Do not use PVC or other plastics. Use polyethylene, Teflon or glass when sampling for trace metals.

Minimizing Contamination Risks

Minimize contamination risks while collecting samples by doing the following:

- ensure that all sampling equipment (bailers, tubing, containers, etc.) has been thoroughly cleaned and selected based on compatibility with parameters to be monitored;
- use Teflon, stainless steel or glass when sampling for organics; do not use PVC or other plastics;
- use Teflon or glass when sampling for trace metals;
- use new sample containers when sampling for compliance monitoring; do not reuse containers;
- keep containers closed before filling and do not touch the inside of containers or caps;
- wear a new pair of disposable gloves or decontaminated reusable gloves for each sampling site;
- place new plastic sheeting on the ground near each well to hold the sampling equipment; do not step on the sheeting.
- place small samples which require cooling, such as volatile organics, in sealable plastic bags immediately after collection and before submerging in ice;
- do not smoke while collecting or handling samples since volatile residues in the smoke can cause sample contamination;
- do not leave your vehicle running near the sample collection area, to prevent contamination from engine exhaust fumes,;
- when using a pump, set up the generator about 15 feet away and downwind from the well; perform all generator maintenance and fueling off-site and away from samples; and
- avoid unnecessary handling of samples;
- if dedicated monitoring systems (those permanently installed in wells) are not used, clean equipment to be reused thoroughly before sampling each well to minimize the risk of cross contamination; bailers left in wells are **not** dedicated systems;
- take enough pre-cleaned equipment to the field to sample each well so that cleaning between wells is unnecessary; if field cleaning is necessary, an equipment blank may be used to make sure that no contamination results.

Blanks should be used to check for contamination. Blanks consist of organic-free deionized water which must obtained from laboratories. Types of blanks include:

- a trip blank (a sealed container of organic-free deionzed water that must be taken to the field and sent back to the lab unopened with the samples); include at least one trip blank per cooler for volatiles to check for sample contamination during transportation;
- a field blank consists of organic-free deionized water taken to the field and handled in the same manner as the samples to check for contamination from handling, from added preservatives, or from air-borne contaminants at the site which are not from the waste being disposed of at the treatment facility; and

- an equipment blank (organic-free deionized water which is passed through the cleaned sampling equipment with added preservatives) may be used to detect any contamination from equipment used for more than one well.

Measure Static Water and Calculate Well Volume

From a permanent reference at the top of the well casing, lower a clean weighted steel tape or electric sounder into the well. Record the wet level mark on the tape and subtract it from the reference point to obtain the depth of water. Use the same reference point each time a water level measurement is made at the well.

Subtract the depth to water level measurement from the known total depth of the well to obtain the height of the water column. Calculate one well volume in gallons by multiplying the inside area of the well (measured in square feet) times the height of the water column (measured in feet) times 7.48 gallons per cubic foot. Or you may use Table 5-10 for a quick conversion of well volume in gallons:

Table 5-10. Well Diameter Conversion Table

Well Casing Diameter	Gallons per foot of Water Column Height
2 inches	0.163
4 inches	0.652
6 inches	1.5
8 inches	2.6

Purge the Well

Before collecting any groundwater samples, you must adequately remove stagnant water from the wells. In order to purge a sufficient amount of water from a well, you must first calculate the well volume. Based on the calculated well volume, pump or bail at least one, but no more than three, well volumes from the well. Overpumping can cause the unintentional movement of contaminants toward the well. In low-yielding wells, one purge to dryness is adequate. Following well recovery, samples may be collected using a positive displacement bladder pump or bailer. Dispose of purged water appropriately according to state and federal regulations.

Purging with a Pump

Low rate pumping is the preferred method for purging because bailing may increase turbidity by stirring up sediment in the well. When purging with a pump, slowly lower the pump to just below the top of the standing water column. Continue lowering it as the water level drops and the stagnant water is removed, until you remove a minimum of one, but not more than three, well volumes.

Dedicated monitoring systems are permanently installed pumping systems, and do not require placement or removal of equipment into or out of wells to purge or obtain samples. No cleaning is required because parts in contact with the water are sealed away from the atmosphere and handling.

Purging with a Bailer

Using low flow pumps for purging generally produces high quality representative samples. However, if a pump is not available or cannot be used, use a bottom emptying bailer to purge

and collect samples. Bailer lines of braided nylon or cotton cord must not be reused, even if clean, in order to avoid the probability of cross-contamination.

Lines must consist of Teflon-coated wire, single strand stainless steel wire, or other monofilament line. Do not leave bailers in wells. Contamination can occur when they are handled outside the wells and placed back inside. Contamination can also occur as a result of deterioration of bailer lines.

Lower the bailer slowly to just below the water level and retract slowly to reduce aeration and turbidity. Collect the purged water in a graduated bucket to measure a minimum of one well volume.

Collecting Samples

After wells are purged, collect samples using a positive displacement bladder pump or bottom emptying bailer. Do not use peristaltic or vacuum pumps to collect samples for volatiles. These pumps remove volatile contaminants from the groundwater.

Sample containers obtained from commercial labs or laboratory suppliers may already contain the appropriate preservatives. Check with your laboratory and follow their instructions. If preservatives are required for volatiles, make sure that they are added to vials prior to filling.

Sampling with a Pump

When pumps of any type are used for sampling volatiles, the flow rate must be adjusted low enough (that is, less than 100 mL/minute) to fill a volatiles vile without aerating the sample.

Collect the sample directly into the appropriate containers in the following order:

- volatiles;
- total organics halides;
- total organics carbon;
- other organics;
- metals;
- inorganics; and
- coliforms.

Sampling with a Portable Pump

When sampling with a portable pump, lower the pump slowly to the desired depth in the well. Have sample containers ready before turning on the pump. Adjust the flow rate to less than 100mL per minute to reduce agitation and minimize the loss of volatiles. Discard the first volume of water. Place volatiles viles and those samples that require storage at 4˚C (39.2˚F) in sealable plastic bags and store in an ice chest immediately after collection. Collect the remaining samples in order. Decontaminate the pump before moving to the next well.

Sampling with a Bailer

To collect a sample, lower the bailer slowly into the well, avoiding agitation, and allow it to fill. Retract the bailer slowly and discharge the sample carefully into the container until the correct volume has been collected. Add preservative if required, cap the container, and mix according to laboratory instructions. Take precautions to minimize turbidity and sediment in samples. Use purging and sampling techniques previously described to minimize turbidity and agitation of sediment in wells.

In low-yielding wells and those containing high levels of suspended solids, slowly lower a bailer to the lowest standing water level and allow the water to flow into it. Carefully lift the bailer out of the well without allowing it to scrape or bang against the well casing.

Minimum Cleaning Techniques

Portable sampling systems are used more frequently than dedicated systems because of lower costs. However, they require the use of much of the same equipment from well to well, increasing the possibility of cross contamination unless strict cleaning procedures are followed. Cleaning procedures must be selected based on the equipment composition and the parameters to be monitored. The following is a summary of minimum cleaning techniques for bailers and is applicable for other equipment of the same composition.

For stainless steel bailers and equipment, use:

- phosphate-free soap and hot tap water wash;
- hot tap water rinse;
- deionized water rinse;
- isopropyl alcohol rinse;
- deionized water rinse; and
- air dry.

Wrap the bailer with aluminum foil or other material to prevent contamination before use. Consider target contaminants when selecting a wrap material.

To clean Teflon or glass bailers and equipment use:

- phosphate-free soap and hot tap water wash;
- hot tap water rinse;
- ten percent nitric acid rinse;
- deionized water rinse;
- isopropyl alcohol rinse;
- deionized water rinse; and
- air dry.

Wrap to prevent contamination before use. Again, consider the target contaminants when selecting wrapping material.

Special Handling Procedures

Use extra care in selecting and cleaning all equipment, including pumps, bailers, sample containers, etc. associated with samples collected for trace metal analysis.

Use stainless steel or Teflon bailers to collect volatiles, if using a pump for sample collection that has a flow rate which cannot be adjusted to less than 100 mL per minute. Collect duplicate samples for volatile organics in special 40 mL septum vials, with Teflon lined disks in the caps to prevent contamination.

Fill the vials to capacity, with no headspace, to prevent volatilization. Carefully pour the sample down the inside of the vials to minimize aeration and agitation until the containers are overflowing. Ensure that no air bubbles are trapped in the vials by applying the caps so that some overflow is lost. If bubbles are noted when the vials are inverted and tapped, set those aside to be discarded. Repeat the collection procedure using new vials. Include a trip blank of organics-free water which must be obtained from your laboratory with each cooler containing samples collected for volatile organics.

Collect coliform samples directly into sterilized glass or sterilized plastic bottles that have been kept closed until ready to be filled. The sterilized containers often contain a preservative. Do not rinse prior to filling. Hold the bottles near the base until filled. Recap the bottles immediately using care not to contaminate the bottles or lids. Store as required.

Filtering Samples

Do not filter samples for:

- volatile or semi-volatile organics;
- metals; or
- coliforms.

All groundwater samples for metals analysis required by DWR must be collected unfiltered, then field-acidified with five mL of concentrated nitric acid per liter of sample or ten mL of commercially prepared one-to-one diluted nitric acid per liter of sample. Metal samples must be submitted to the lab within 24 hours of collection.

If there is a special request for the collection of a filtered sample for any analysis use the appropriate type of filtering apparatus and filters.

In low yielding wells and those containing high levels of suspended solids, lowering a bailer to below the static water level and allowing the well to recover into the bailer should produce a cleaner sample. Use purging and sampling techniques previously described to minimize agitation of sediment in affected wells and reduce the need for filtering. A pump used for purging and sampling will produce better samples from such wells.

General Procedures for Packing Samples

The following general procedures apply for packing samples prior to shipment by courier or by personal transport to the laboratory:

1. line a clean cooler with a large heavy duty plastic bag and add bags of ice;
2. place the properly tagged samples in individual sealable plastic bags and seal the bags with Chain-of-Custody tape to ensure sample integrity;
3. place bagged samples in the cooler, arranging bags of ice between samples to help prevent breakage, and add sufficient ice to maintain the temperature of at 4˚C (39.2 ˚F) while the samples are in transit;
4. enclose the appropriate forms in a sealable plastic bag, place with samples in the chest, and seal the large bag with chain of custody tape;
5. minimize transport time and ensure that samples will reach the laboratory without being exposed to temperature variations and without exceeding holding times.

Detailed information on sample containers, preservation, holding times, and sampling procedures is located in Appendix B-4.

Once the laboratory has completed the sample analysis, a report containing the analytical results will be sent to the person requesting the analysis. The information should be used to complete the groundwater monitoring compliance report form designated as form GW-59 or to satisfy other reporting requirements. Carefully fill out monitoring forms, making sure that all information is included and the data transferred from laboratory reports are recorded in the correct concentration units.

Include complete identification information, such as permit number and facility or permit name on all correspondence and additional laboratory reports. Be sure to submit the forms and lab

reports on time. Groundwater monitoring and reporting requirements are covered in more detail in Chapter 8.

Remember, you are the critical link in the groundwater sampling process. It is vitally important that the procedures demonstrated be followed carefully to avoid costly resampling and to ensure that any groundwater contamination is quickly detected and remediated. This is so important, in fact, that failure to carry out any or all of these activities or comply with the terms and conditions of the permit is a violation of North Carolina General Statute 143.215.1 and may subject the permittee to enforcement action and/or a civil penalty assessment.

If your facility uses a contractor for groundwater sampling, you should still be familiar with the sampling frequencies and parameters, and general requirements of the sampling protocol. If you have any questions regarding your monitoring requirements, contact DWR personnel in the appropriate regional office for your area.

5.3. Operation and Maintenance and Site Management

The main function of a surface irrigation system is the beneficial reuse of a waste product while protecting the quality of the receiver environment. Operators must ensure that all aspects of the operation are addressed. Reconnaissance of the site by the operator is vitally important, not only in site selection, but also to inspect the site for evidence of run-off and to collect samples and inspect crops. Soil and crops must be protected so that continued use of the receiver is ensured. Ground and surface water must be protected to ensure the integrity of these resources. Sites must be protected from poor field operations that can result in destruction of soil structure. They must be protected from over-application of metals, nutrients, salts and other waste constituents that may adversely affect the soil/crop system. Adequate monitoring must be established in order to track the volume of applied wastewater and nutrients, as well as protect against the application of potential toxins, particularly persistent organic compounds and leachable metals. Each facility should maintain an Operations and Maintenance Manual specific to that facility. The maintenance and management of the soils and crops at the facility should be specifically addressed in the manual, since the overall function of the system relies on these components.

The operation and maintenance of preapplication treatment components was covered in Chapter 2. This section will focus on the operation, maintenance and management of the soil/crop system and surface irrigation equipment. Areas addressed include:

- soil management;
- crop management;
- management of wastewater application;
- system component management;
- environmental management; and
- management of human disease and nuisances.

Soil Management

A properly designed surface irrigation system should make maximum use of each soil/crop system on the site. Existing soil limitations must be addressed either by limiting loading rates (hydraulic, salts, etc.) or totally eliminating certain areas due to unsuitable soils or inadequate buffers. Factors that should be taken into account when selecting a site and designing a surface irrigation system include:

- soil surface texture;
- soil slope;
- cover crop health;
- crop type; and
- wastewater patterns.

Even when a site has been carefully selected and investigated, soil-related problems can arise. The following situations may indicate that a problem is soil-related:

- seasonal ponding or surfacing of effluent, when wastewater application rates remain consistent;
- groundwater compliance problems;
- problems in segregated areas of a field; or
- effluent surfacing away from the sprayfield.

If these problems are noticed, the operator should adjust wastewater application rates with some of the methods described earlier in this chapter. However, not all conditions can be remedied by such adjustments in operations. Some situations must be remedied by expansion of the surface irrigation site. This would involve a permit modification and detailed soil information on the proposed area of expansion.

Waste application should be governed not only by weather conditions and soil moisture, but also by the condition of the soil/crop system at the site. If the soil/crop system changes, application rates must change accordingly. Examples of changes that might occur in the soil/crop system include:

- change of cover crops or management schemes;
- chronic saturation;
- buildup of thatch;
- presence of soil crusting;
- increased soil compaction;
- health of the cover crop; and
- chemical changes in the soil.

The soil/crop system must be carefully managed to avoid or minimize the following soil-related problems:

- ponding, runoff, surfacing, or prolonged saturation;
- wastewater mounding;
- surface crusting;
- compaction;
- excess nutrients; and
- excess waste constituents including metals, salts, oil and grease, and organic and inorganic chemicals.

Ponding, Runoff, Surfacing or Prolonged Saturation

The goal of proper waste application is to apply wastewater at a rate that will result in neither runoff nor saturated flow conditions. This means that the wastewater will slowly soak into the soil and be useful to the crop as both a water and nutrient source. Ponding, runoff, surfacing or prolonged periods of saturation are undesirable. If mechanical causes for these problems are ruled out, the problem may be a soil condition that can be corrected.

Periodic wetness, runoff, or ponding of effluent are typically the result of over-application of wastewater. The fact that a given site is permitted for 50 inches of wastewater application per year, or for 0.5 inches per irrigation event, is no guarantee that these application rates can be maintained every year or at all times during the year. Low areas that naturally receive more runoff must be loaded differently than areas on smooth upland positions. Effluent must be distributed to avoid localized ponding or overloading of a specific area. For example, if 30 percent of the spray nozzles are not working, the remaining portion of the field must treat an increased volume of effluent. This localized hydraulic overloading may result in either wastewater runoff (Figure 5-15) or insufficient treatment of wastewater in the soil/crop system.

Figure 5-15. Runoff from a waste application site.

Wastewater Mounding

Even if wastewater soaks into the soil surface as desired, its downward movement may be impeded by a restrictive layer (a layer in the soil that reduces permeability). If so, additional irrigation events can cause the subsurface saturated zone to rise in the soil, resulting in wastewater mounding (discussed in Chapter 3). Depending on soil type, one to three feet of unsaturated soil are typically needed for wastewater renovation. If mounding results in saturated conditions within three feet of the soil surface, anaerobic conditions in the root zone can limit the growth potential of crops. It also may result in insufficient treatment of wastewater because the water may flow laterally or surface at the ground.

An operator can readily check the level of a perched water table in fields or areas of concern. During times of expected high water levels in soils, you can use an auger or post-hole digger to open a hole in the soil to the depth of your interest. Usually, a hole 18 inches deep will be sufficient to indicate whether there is saturation to the soil surface. Sufficient time should be allowed for the soil water to move into the hole, generally an hour or so. If the water level is within 12 inches of the soil surface you are in a situation where water additions (rainfall or irrigation) may result in rapid lateral subsurface flow, ponding, anaerobic conditions for the crop roots, and potential for runoff or discharge of wastewater.

A more permanent monitoring device can be established by inserting a piece of perforated plastic pipe with a removable cap into the soil. This monitoring device should be marked so it is not damaged by mowing equipment, or set at grade level and marked with flagging or orange paint. Such simple devices can easily assist the operator in making irrigation decisions that protect the soil/crop system from saturation.

Surface Crusting

Poor management practices can result in surface crusting, or the formation of a relatively impermeable layer at the soil surface. One cause of surface crusting that is often overlooked is the accumulation of thatch, or unharvested grass clippings. It is common in situations where a cover grass is mowed without removal of the mowed grass. Excessive thatch buildup can result in

reduced infiltrative capacity of the soil. Thatch remaining on the soil surface acts as a barrier to added water. It can also serve to block the transfer of air (oxygen) to plant roots, causing further stress to the cover crop. In extreme conditions, anaerobic activity or algae growth can occur on the thatch buildup. An organic or slime layer may form a clogging mat and further decrease water infiltration. If a large enough portion of the site is affected, the result is increased load on the remainder of the site. For all these reasons, thatch buildup should be monitored, and removed promptly if a problem is noted.

It is easier to prevent thatch buildup than to try to remove it. Prevention can be accomplished by frequent mowing, removal of mowed vegetation, and operating the site so that wet conditions at the soil surface are not chronic. Removal of thatch may be performed with special rakes or soil aeration tools. In extreme cases, disking of the field or completely replanting may be necessary. Since these activities result in significant damage or removal of the cover crop, there will be some start-up time required with a new crop during which irrigation volumes must be reduced due to the potential of increased runoff and soil erosion.

As we have learned, organic matter is found in all wastewater. It may be in the form of large suspended solids, dissolved carbonaceous compounds, or both. If improperly applied to the soil surface, suspended solids in wastewater may also generate a clogging mat, composed primarily of anaerobic bacteria, on the soil surface. Once established, this slime limits the exchange of oxygen in the soil, and anaerobic conditions will develop under the soil surface. Oxygen transport into and through the soil is critical for the degradation of organic additions. If wastewater is to receive sufficient treatment, it is essential that the soil drain adequately. Under waterlogged conditions, oxygen diffusion may be severely restricted. Sufficient time is needed for the oxygen to diffuse into the soil and for the microbial degradation to occur. Hence, the irrigation frequency is quite important and organic overloading can occur if the above loading factors are not properly managed.

Soil crusting can also be caused by destruction of surface soil aggregates, especially when soil is exposed and left bare to heavy rains. Fine soil particles disperse and seal the soil surface, which can become quite impermeable to infiltration if areas of bare soil occur at the wastewater application site. Once soils become crusted it can be difficult to establish plants or seedlings.

In areas where crusting has occurred, it is important to restore aeration to the plant root zone and to provide favorable conditions for crops as well as for soil microorganisms involved in the treatment of the wastewater. Surface crusting can be easily reversed by mechanical tillage to break up the soil surface or by raking to remove thatch. However, additional traffic increases the potential for compaction of subsurface layers. Therefore, the crust should be broken with as light of equipment as possible and the area must be reseeded. Any efforts to re-establish cover crops on areas of crusted soils or thatch buildup should be performed at the most ideal time for planting the crop that is to be used. Crusting can be minimized by maintaining a healthy cover crop and by the removal of mowed or diseased vegetation.

Compaction

As discussed in Chapter 3, heavy traffic (especially on wet soils) can cause soil compaction, thereby destroying soil pores and reducing aeration and the effective permeability of the soil profile. Both surface and subsurface drainage and aeration are essential to maintain an aerobic soil environment suitable for wastewater treatment. The maintenance of a stable soil structure is an important means of maintaining good drainage and aeration. Therefore, traffic over a spray field should be limited only to equipment or vehicles that are absolutely necessary for maintenance.

Once soil is compacted, tillage of the soil may be necessary. One of the principal objectives of tillage operations is to maintain or enhance the water infiltration capacity of the soil surface and as well as the air exchange within the entire soil profile. It may be necessary to chisel very deeply (1.5 to 2.0 feet) to loosen the subsoil. Impermeable pans formed by vehicular traffic (plow pans) or by cementation of fine particles (hard pans) can be broken up by subsoiling equipment that leaves the surface undisturbed and protected by vegetation or stubble. To be effective, however, the subsoiling equipment must completely break through the pan layers. This is difficult if the pan layers are more than one foot thick. Local soil conservation district personnel should be consulted regarding tillage practices appropriate for specific crops, soils, and terrain.

Excess Wastewater Constituents

Wastewater characteristics should be analyzed prior to site evaluation and periodically during operation of a surface irrigation system. Metals such as copper, zinc, manganese or other wastewater components such as salts, pH, oils and grease, organic and inorganic chemicals may prove to be limiting, depending on the plants used at the receiver site. Likewise, if plant species at the receiver sites are changed, wastewater characteristics must be assessed to determine if selected plants are appropriate. When selecting crops, the amount of water that the crop will be subjected to must also be considered.

Significant levels of these wastewater constituents may indicate the need for pretreatment of the wastewater prior to final disposal to a receiver site. It is beyond the scope of this manual to discuss all possible limitations that may be encountered with an industrial waste. Operation of systems permitted with these limitations should focus on consistent waste analyses and operation of the treatment units prior to final disposal to the receiver sites. A summary of the potential consequences of these constituents follows.

Excess Nutrients

By monitoring soil test index values for various nutrients (discussed earlier in this chapter), you can take steps to avoid the buildup of nutrients to undesirable levels. In general, wastewater should be applied as a priority in fields where there is evidence of the greatest need for nutrients. The upper limits indicated below should be used as guidelines. With so many factors involved, there is no certainty that crops or surface waters will be affected by levels even higher than these guidelines. On the other hand, sensitive crops such as peanuts and some vegetables may be affected at much lower values than shown here. Peanuts are sensitive to zinc at a 500 index if pH decreases below 6.0. Although a surface irrigation system operator may not wish to grow sensitive crops today, at some time in the future those crops may be profitable. Since reclamation of high nutrient soils may be a lengthy process, operators should take precautions to preserve the productivity of their soil resources.

Priority for wastewater application should be given to fields that meet the following criteria:

- soil test Zn-I (NCDA & CS) less than 700
- soil test Cu-I (NCDA & CS) less than 700
- soil test P-I (NCDA & CS) less than 150

If wastewater must be applied to fields that exceed the above criteria, these options should be considered:

- If the soil test Zn-I is greater than 700, meet with a North Carolina Department of Agriculture and Consumer Services Regional Agronomist or Cooperative Extension Service Technical Specialist to select a crop that is tolerant of high zinc soils.
- If the soil test Cu-I is greater than 700, meet with a North Carolina Department of Agriculture and Consumer Services Regional Agronomist or Cooperative Extension Service Technical Specialist to select a crop that is tolerant of high copper soils.

- If the soil test P-I is greater than 150, then potential for erosion and distance to surface water becomes important. Where soil movement from the field into nearby waters is likely, apply no more phosphorous to the site than the crop will remove to avoid further accumulation of phosphorus.

Excess Metals

As discussed in Chapter 3, excessive application of heavy metals to soils can result in:

- metal uptake by crops;
- metal leaching if soil pH is lower than recommended levels or if high application rates occur;
- yield reduction or crop death caused by high levels of metals in the soil;
- yield reduction in turn may result in reduced nutrient uptake, increased runoff, erosion and potential surface and ground water contamination; and
- food chain accumulation of metals that adversely affect animals and humans (cadmium).

Cadmium, lead, copper, zinc, chromium, and nickel are the metallic ions of most concern to public health officials. Guidelines for permissible levels of heavy metals have been developed by the NC Division of Water Resources in conjunction with the EPA. Table 5-11 shows maximum regulatory allowable metals loadings for land application of biosolids (sludge). These loadings are also suggested as a guideline for wastewater application systems.

Remember that a soil's ability to assimilate heavy metals and other toxic substances is directly related to the cation exchange capacity (CEC), clay content, pH, and organic matter content of the soil. The higher the CEC the more metals a soil can bind, thus reducing the potential for off-site movement. When applying wastewater and sludge to land, special attention must be paid to pH of the soil of the site. If the soil is allowed to become acidic (pH < 6.5), the solubility of heavy metals increases, resulting in excessive accumulation of certain metals in the vegetation.

Metals accumulation rates in soils can be monitored by doing the following:

- analyzing wastewater to determine the concentration of metals;
- analyzing soil pH; if soil pH is less than 6.0, lime should be added to adjust the pH;
- analyzing soils for metals; and
- recording total metal loadings over the life of the site.

Table 5-11. Maximum allowable metal loadings for land application of biosolids (sludge).

Pollutant	Cumulative Pollutant Loading Rate (lb/acre)
Arsenic	36
Cadmium	34
Chromium	2677
Copper	1388
Lead	267
Mercury	15
Nickel	374
Selenium	89
Zinc	2498

The easiest way to monitor metal buildup is by reviewing the results of the annual soil test. You should follow trends from year to year with metal accumulations. If crop health problems are noted (Figure 5-16), a plant tissue analysis can determine if the problem is metal related. An operator should be able to calculate metal application rates from the annual wastewater application rate and the metal analyses of the wastewater. These calculations will be covered in Chapter 6.

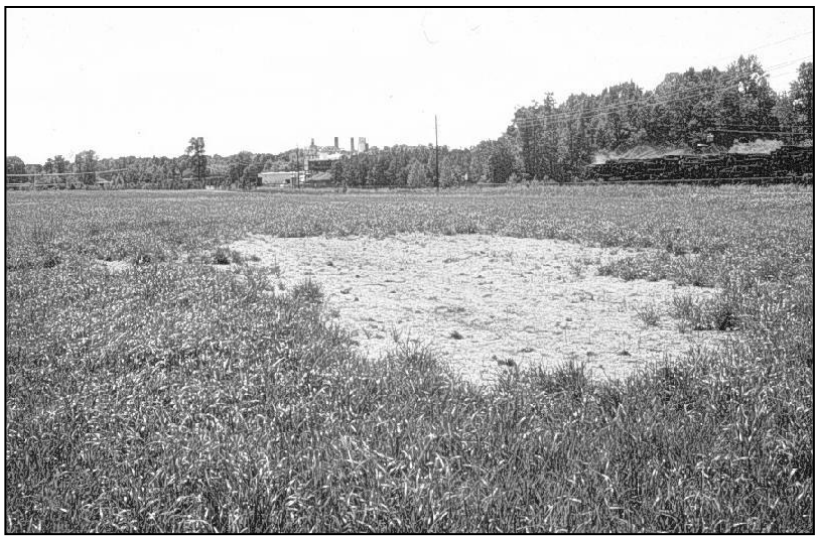


Figure 5-16. Heavy metal toxicity in the sandy portion of a field.

Excess Salts

The application of wastewater containing soluble salts, such as chlorides, sulfates, potassium, calcium, manganese, and especially sodium, can be detrimental to not only the crops being grown on the wastewater receiver site, but to the soils as well. A buildup of sodium in the soil can reduce the permeability of the soil by causing dispersion of the clay minerals. Reduced permeability often results in poor internal soil drainage and aeration, which can cause stress to the cover crops as well as ponding and waterlogged soils that do not provide adequate wastewater renovation. It may be possible (but difficult) to renovate soils with high sodium concentrations. However, the much preferred method of operation is to minimize the risk of possible sodium overload.

Salts in soil can:

- adversely affect soil structure;
- upset soil-water balance and interfere with plant root growth and the plant's ability to use water and nutrients;
- leach to groundwater; and
- affect or reduce seed germination.

The detrimental effects on plants result not only from the high salt contents, but also from the level of sodium in the soil, especially in relation to levels of calcium and magnesium. In order to understand the management options to restore or prevent damage to the soil, you must first understand the difference between saline and sodic soils.

Saline soils contain concentrations of neutral soluble salts sufficient to interfere with the growth of most plants. When large amounts of dissolved salts are brought into contact with a plant cell, water will pass by osmosis from the cell into the more concentrated salt solution. The cell then collapses, ultimately leading to cell death and eventually plant death.

Sodic soils, dominated by active sodium, exert a detrimental effect on plants in four ways:

1. caustic influence of the high pH induced by the formation of sodium carbonate and bicarbonate;
2. toxicity of the bicarbonate and other anions;
3. the adverse effects of the active sodium ions on plant metabolism and nutrition and the low micronutrient availability due to high pH; and
4. oxygen deficiency due to breakdown of soil structure in sodium dominated soils.

Tolerance of higher plants to saline and sodic soils depends on a number of interrelated factors, including the physiological constitution of the plant, its stage of growth, and its rooting habits. It is interesting to note that old alfalfa is more tolerant of salt-affected soils than young alfalfa, and that deep-rooted legumes show a greater resistance to such soils than the shallow-rooted ones.

In terms of the soil, the nature of the various salts, their proportionate amounts, their total concentration, and their distribution in the soil profile must be considered. The structure of the soil and its drainage and aeration are important as well.

Prevention of the problem is very important. Once sodium and salt damage occurs to the soil, it is a slow and tedious procedure to restore the soil to its original condition. To prevent such damage, an operator must know the sodium concentration in the irrigated wastewater. As discussed in Chapters 1 and 3, a ratio of the sodium concentration to the concentrations of calcium and magnesium in the wastewater is called the sodium adsorption ratio (SAR) and is a good indicator of potential soil problems.

Calculations for SAR utilize the liquid concentrations (in mg/L) of sodium, calcium, and magnesium in the wastewater. The formula for Sodium Adsorption Ratio is as follows, with all concentrations expressed in milliequivalents:

$$SAR = \frac{Na}{\sqrt{0.5 \times (Ca + Mg)}}$$

The milliequivalents of a given element or ion can be calculated by dividing the concentration, in milligrams per liter (mg/L), by the equivalent weight of the ion. The equivalent weights of sodium, calcium, and magnesium are, respectively, 23, 20, and 12.

Example: What is the SAR for a wastewater that has the following ion concentrations:

Sodium (Na^{+})= 54 mg/L
Calcium (Ca^{+2}) = 36 mg/L
Magnesium (Mg^{+2}) = 8 mg/L

Step 1) Change concentrations into milliequivalents (meq) using the conversions:

$$\text{Na meq} = \frac{54 \text{ mg/L}}{23} = 2.34$$

$$\text{Ca meq} = \frac{36 \text{ mg/L}}{20} = 1.8$$

$$\text{Mg meq} = \frac{8 \text{ mg/L}}{12} = 0.67$$

Step 2) Use formula to calculate SAR:

$$SAR = \frac{2.34}{\sqrt{0.5 \times (1.8 + 0.67)}}$$

$$SAR = \frac{2.34}{\sqrt{1.235}} = 2.10$$

Sodium adsorption ratios in wastewater range from very low (less than 1) to several hundred. Facilities that are especially prone to having SAR problems are the food processing industry, industries that use sodium hydroxide as a wash or disinfectant, or other operations using a form of sodium. A SAR of 10 is generally considered an upper level for safe operation. There are, however, many variables that go along with the SAR that will determine if problems will be expressed in the soil.

A SAR of 5 in a wastewater should be a "red flag" to an operator. At this level, there should be some attention to the sodium issue to ensure that future problems can be minimized. If the SAR exceeds 5, an operator should determine if excess sodium in the wastestream can be reduced. Soil samples should also be analyzed and handled as a problem sample to help determine if the soil sodium activity level is approaching a problem level. Individuals with technical expertise should be contacted if the operator is not experienced with these issues.

While SAR evaluates the sodium status of wastewater, exchangeable sodium percentage (ESP) is an evaluation that can be used to determine possible excess sodium concentration in the soil itself. The ESP is the percentage of the soil's cation exchange capacity (CEC) that is occupied by the sodium cations. This determination can be made from a typical soil fertility evaluation.

Example:

The CEC of a soil is 8.9 meq/100 cm^3 and the Na is 0.2 meq/100 cm^3. What is the exchangeable sodium percentage?

$$ESP = \frac{\text{Na concentration}}{\text{CEC}} \times (100\%)$$

$$ESP = \frac{0.2}{8.9} \times 100\% = 2.25\%$$

An ESP level of 15 percent or higher is typically used to denote a level of concern where salt damage may occur both to the crop and to the soil structure. Levels from 10 to 15 percent should cause the operator some concern, and should justify the need to take remedial action (described above) before long range problems occur. The ESP ratio evaluation should be used in conjunction with calculating the SAR of the wastewater to ensure that salt buildup does not limit or restrict the long-range use of the site.

Three kinds of general management practices have been used to maintain or improve the productivity of saline and sodic soils:

- flushing of the salts;
- conversion of some of the salts to harmless forms; and
- designated tolerance.

In the first two methods, an attempt is made to eliminate some of the salts or render them less toxic. In the third, the salts concentrations are not manipulated; rather, crops tolerant of high salt concentrations are grown.

Flushing (Salt Removal) - The most common methods used to free the soil of excess salts are installation of drainage systems and leaching or flushing. A combination of the two, flooding after field drainage ditches have been installed, is the most thorough and satisfactory. The salts that dissolve are leached from the soil profile and drained away. However, the irrigation water used must not be high in soluble salts, especially sodium.

Conversion - The use of gypsum on sodic soils is commonly recommended for the purpose of exchanging Ca^{2+} for Na^{+} on the clay surface and removing bicarbonates from the soil solution. Several tons of gypsum per acre are usually necessary. The soil must be kept moist to hasten the reaction, and the gypsum should be thoroughly mixed into the surface by cultivation, not simply plowed under. The treatment must be supplemented later by a thorough leaching of the soil with low-salt irrigation water to leach out some of the sodium sulfate.

Tolerance - The use of salt-resistant crops is another important management tool. Although, salt-tolerant crops are not considered "traditional" recipients of wastewater, many of the crops are high in value and could have the added advantage of income for a wastewater facility. For example, cotton, sorghum, barley, rye, sweet clover, and alfalfa are particularly tolerant. A crop such as alfalfa, once it is growing vigorously, may maintain itself in spite of the salt concentrations that may develop later. The root action of tolerant plants is exceptionally helpful in improving the condition of sodic soils. Aggregation is improved, and root channels are left through which water and oxygen can penetrate the soil. Table 5-12 lists forage grasses and legumes that are salt-tolerant.

Excess Oil and Grease

Oils and grease are organic compounds, and in concentrations typically seen in domestic wastewater they pose no problem to the soil organisms that ultimately break down the organic compounds. However, significant inputs of oil and grease can cause problems in a surface irrigation system, both with equipment operation and the soil/plant environment. If oils and grease are allowed to build up in the soil, the result is the clogging of soil pores to the extent that infiltration of water and air into the soil are reduced. This results in stress to the cover crop as well as increased potential for wastewater ponding and runoff. If oil and grease in the effluent exceeds 50 mg/L, then a process for oil/grease separation should be used as a method of preapplication treatment (see Chapter 2).

Table 5-12. Salt tolerance of forage grasses and legumes. (From National Range and Pasture Handbook).

Good salt tolerance, 12 to 6 millimhos/cm	
Alkali sacaton	Rescuegrass
Barley	Rhodesgrass
Bermudagrass	Saltgrass
Birdsfoot trefoil	Tall fescue
Canada wildrye	Tall wheatgrass
Nuttall alkaligrass	Western wheatgrass
Moderate salt tolerance, 6 to 3 millimhos/cm	
Alfalfa	Perennial ryegrass
Beardless wildrye	Reed canarygrass
Big trefoil	Rye
Blue grama	Smooth bromegrass
Dallisgrass	Sour clover
Hardinggrass	Strawberry clover
Hubam clover	Sudangrass
Meadow fescue	Tall meadow oatgrass
Milkvetch, cicer	Wheat
Mountain bromegrass	White sweetclover
Oats	Yellow sweetclover
Orchardgrass	
Poor salt tolerance, 3 to 2 millimhos/cm	
Common white clover	Red clover
Meadow foxtail	Ladino clover
Alsike clover	Burnet

1/ Source: Bernstein, L. 1958. Salt tolerance of grasses and forage legumes. USDA Agricultural Information Bulletin 194.
2/ Within each category, the species are ranked in order of decreasing salt tolerance. The low in a higher category may be only marginally better than the high in the next lower category.

Organic and Inorganic Chemicals

If an irrigation system is properly operated with no runoff conditions or chronic saturation, most chemicals will be bound to soil particles, volatilized, physically or chemically degraded, and decomposed by soil microbes. Therefore, such chemicals will not present a major problem. However, some facilities may be pre-disposed to certain chemicals in the wastewater resulting from industrial processes. Many of these constituents do not necessarily cause problems to the site, but the breakdown period can be very long (many years), and therefore the operator should be aware of the occurrence of such chemicals and track the buildup or depletion of these chemicals over the years.

If an operator has these chemicals in the waste stream, or suspects that such chemicals might exist in the soils due to past site management, there are tests that can be run to help determine levels of these constituents. Various laboratories may be able to analyze the soil for these chemicals. The standard TCLP test of 40 parameters will note some but not all of the possible chemicals that could reach the land application site. There are also simple assay kits available from several manufacturers that can be used as field tests for these chemicals. These kits are usually specific to the type or family of chemicals that you are targeting.

There are many possible chemicals that could possibly be found in the waste stream at a surface irrigation facility, and it is beyond the scope of this manual to discuss all possible situations.

However, an often-discussed persistent organic chemical is poly-chlorinated biphenyl, or PCB. Sites where wastewater contains PCBs must be carefully managed to prevent runoff into surface waters and to prevent grazing animals from ingesting ponded wastewater or wastewater contaminated vegetation. If wastewater analyses indicate PCB concentrations of 10 to 50 mg/kg, wastewater must be incorporated into the soil, not just spray irrigated. If PCB concentrations are greater than 50 mg/kg, wastewater cannot be land applied.

As with other pollutants that find their way to the soil and cropping system, maintenance of good soil fertility, soil pH, and a healthy crop stand are the best defenses to ensure that organic and inorganic chemicals are treated or stored in the soil such that surface water or groundwater quality is not jeopardized. A trained agronomist should be consulted to ensure that the chemical component in question does not pose a problem to the health of the cover crop or the animals or end consumers of that crop. The operator is encouraged to seek out additional information with the aid of the technical resources found in Appendix B-1.

Crop Management

As discussed in Chapter 3, there are several reasons why cover crops are useful in protecting soil, water, and the environment. The majority of cover crops are forages such as grasses. They are dense and grow close to the ground, providing a cover above the soil surface and a fibrous root system below the surface that:

- tends to result in better soil tilth, water holding capacity, cation exchange capacity, and soil microorganism populations, including earthworms, rhizobia, and bacteria;
- reduces the impact of raindrops on the soil surface, decreasing soil crusting, water runoff, and movement of soil particles off-site, thus less movement of fertilizer and pesticides into streams;
- extends the amount and depth of root exploration of the soil volume, which indirectly relates to plant water use and nutrient uptake.

Therefore, the establishment and maintenance of a vegetative cover should be one of the highest priorities of the system operator. The operator should routinely examine the health of the vegetative cover and take immediate action should there be a problem. Once plants begin to show stress, the problem is often well established and may require significant time and effort to correct. As with other management issues, prevention of problems is almost always easier than repairing problems.

Crops can be stressed by excessive water (very common at spray sites) or by a lack of sufficient water (rarely common at spray sites). As discussed earlier in this section, crops can be stressed by excessive nutrient or salt applications. Conversely, crops can be stressed or damaged by insufficient plant nutrients or improper soil pH. Other factors include soil compaction and damage by maintenance equipment. The operator must be aware of the requirements of the cover crops and attempt to meet these requirements with a crop management plan. Such a plan will minimize the potential that the cover crops will be the limiting factor for the operation of the system (Figure 5-17).

Maintaining good crop growing conditions will reduce both surface runoff losses and subsurface losses of plant nutrients, and will allow the wastewater system to perform as designed. Crop management involves:

- crop selection;
- nutrient and physical management;
- soil fertility management;
- pest control;

- best management practices; and
- troubleshooting.

Figure 5-17. Poor crop stand in a fescue pasture. The lighter areas indicate stunted or dying vegetation.

Crop Selection

Important factors in the selection of crops for surface irrigation systems include:

- nutrient requirements of the crops;
- time and length of the growing season;
- end use of the crop;
- crop management requirements;
- water tolerance of the crop;
- use of seasonal overseeds;
- soil type; and
- local climate conditions.

Nutrient Requirements

The nutrient (fertilizer) requirements of a crop impact system operation, both in terms of expense and time. If crops can be economically grown for harvest such as in a commercial farming setting, then the time and cost expended fertilizing crops can be justified. However, if the crop is simply used as a waste receiving point, then a crop with minimal requirements should be satisfactory. Some crops are more tolerant of nutrient imbalances than others, but all crops will need some attention to maintain the health of the plants and assure proper system operation. In selecting crops, one should consult an agricultural manual that shows crop nutrient needs and timing during the growing season. Table 5-13 lists nitrogen fertilization guidelines for various forage crops.

Table 5-13. Nitrogen Fertilization Guidelines (from Managing Pasture and Hay Fields, NCSU CES)

Commodity	PAN /RYE[1]
Corn (silage)	10-20 lb N/ton
Bermudagrass (hay[2,3])	40-50 lb N/dry ton
Tall fescue (hay[2,3])	40-50 lb N/dry ton
Orchardgrass (hay[2,3])	40-50 lb N/dry ton
Small grain (hay[2,3])	50-60 lb N/dry ton
Sorghum—sudangrass (hay[2,3])	45-55 lb N/dry ton
Millet (hay[2,3])	45-55 lb N/dry ton

[1]PAN=plant-available nitrogen. RYE=realistic yield estimate.
[2]Annual maintenance guidelines.
[3]Reduce nitrogen rate by 25 to 30 percent when grazing.

Time and Length of the Growing Season

Selected crops should be actively growing and able to accept wastewater applications at the time that wastewater is generated. For a typical municipal system, year-round applications are common, depending on available storage. For industrial, resort, or recreational facilities, wastewater generation may occur seasonally or sporadically.

The crops grown should be selected to fit the times when wastewater application is required. For example, a cool season grass may not be the best selection for a wastewater system that serves a campground near a lake, when the majority of the usage is April through September. Where wastewater applications need to be made throughout the year, a mixture of crop types offers the operator flexibility in system management. Use of trees has also been increasing, as trees offer nutrient and water uptake throughout the year.

The End Use of the Crop

To keep a cropping system viable, it must be harvested at regular intervals. If there is no end use for the crop, less attention may be given to the crop's needs, possibly resulting in poor system management. Therefore, having a use for the crop should be a goal of the system owner and operator. Often, forage crops are mowed and baled, and simply left in the field to rot. In such cases, the nutrients are returned back to the waste receiver site and not removed. Examples of uses for hay bales include use as a mulch to give away to local residents or for use on municipal property or as feed to livestock. Another use could be to make compost that can be used by the public. Crops with higher cash value can simply be sold as is. Wood products have infrequent harvest intervals, but there should be a planned market for those products if selected for use at the site.

Crop Management Requirements

Crops should be selected with a good understanding of their maintenance requirements. Is the crop perennial, or must it be re-planted every year or two? Does the crop require nutrient applications two times per year or eight times per year? Are there other tedious tasks that need to be performed in order for the crop to stay healthy?

Generally, the simpler the maintenance scheme for a crop, the better it can be managed. The use of trees as opposed to hay crops has increased largely because hay requires mowing, drying,

raking, and baling, which must be done during dry periods with no irrigation. Annual crops are those that are planted every year. Annual crops generally consist of the row crops such as corn, cotton, small grain, and soybeans. These are typically not used in wastewater irrigation. Such crops require high maintenance, may have restrictions on end use, and result in long periods of time where the soil is without cover vegetation.

Water Tolerance of the Crop

A crop that cannot tolerate the extra water it will receive from wastewater irrigation should not be used. Typically, a spray application site is designed to take an amount of water that can be feasibly handled by the soils. To save on initial costs, the site is usually pushed to the maximum hydraulic loading. The result is that the crops receive more water than needed, and may have to endure saturated soil conditions for extended periods of time. Some crops cannot tolerate soil saturation for very long, while other crops and grasses may even thrive in such conditions. Examples of crops, grasses, and trees that are water-tolerant include reed canarygrass, ryegrass, common Bermudagrass, tall fescue, sweetgum, sycamore, and bald cypress. Examples of crops that are very susceptible to soil wetness problems include alfalfa, coastal Bermuda, and corn.

Use of Seasonal Overseeds

Forage grasses that are commonly used in North Carolina can be classified as cool season or warm season. No grass crop covers both categories. Cool season grasses grow actively in the spring and fall, and slowly during the winter. They may go dormant in the summer. Warm season grasses grow actively from mid-April through October 1, and are dormant through the winter. If these crops are to be used for yearly wastewater applications, other grasses may be used temporarily as an overseed to help with nutrient uptake and waste treatment. An example is to overseed winter rye (a cool season grass) into Bermudagrass. Some forage species are not tolerant of this arrangement, and an overseeded species may seriously damage the main crop. Examples of grasses, forages, or grains that should be avoided as an overseeding include gamagrass, switchgrass, or bluestems.

When using a winter overseed, you must be careful to protect the warm-season grass. Controlled grazing or harvesting may be necessary to keep the winter overseed from becoming overly aggressive over the warm-season grass. Attempting to harvest a winter small grain or annual ryegrass in the seed head stage can result in shade damage to a warm-season grass.

Soil Type

The crop selected must be adapted to the soil types on the site. On a large site, it is likely that several soil types exist; therefore, it may be necessary to use several crop types. Soils with heavy clay will stay wet longer after irrigation and rainfall events, and the crops must be able to handle these conditions. Sandy soils do not hold water and nutrients, therefore a drought-tolerant crop will survive better, and split applications of fertilizer are needed. Table 5-14 shows the performance of hybrid and common Bermudagrass on two different soil types.

Local Climatic Conditions

The crop must also be adapted to the local area. Sometimes, crops are selected for their nutrient removal ability or ability to stand wet conditions, but they may not tolerate the soils or climate. All factors must be considered to select a crop that can be adapted to the site and wastewater applications, and can be managed efficiently.

Table 5-14. Performance of Hybrid and Common Bermudagrass on Two Soil Types (From Bermudagrass Management in North Carolina).

	Lee County[1] Lakeland Sand	Wake County[2] Cecil Clay Loam		
		1st yr[3]	5th yr	5-yr avg
	Tons/Acre			
Coastal	6.0	—	—	—
Common	2.3	—	—	—
Tifton 44	—	2.6	7.2	6.1
Tifton 78	—	2.8	6.1	4.7
Pasto Rico (common)	—	3.3	6.5	5.5

[1] 100 lb N, 50 lb P_2O_5, and 100 lb K_2O applied per acre in April and on July 1. Source: D. S. Chamblee, North Carolina State University.

[2] 75 lb N, 50 lb P_2O_5, and 100 lb K_2O applied per acre in April, July, and August. Source: Forage Variety Test Report, North Carolina State University.

[3] Year of establishment.

Using Trees as Receiver Crops

Using trees as receiver crops at surface irrigation systems is increasing in popularity. Application of wastewater to forestland offers a viable alternative to dispose of nutrients, waste, and pollutants while producing large quantities of marketable wood products. In North Carolina, several dozen new forestland systems and systems converted from turf or agricultural receiver crops have been installed during the last five years. Additional systems are in various stages of planning and implementation.

Hardwood plantations have been shown to have numerous advantages over both natural forests and other plant crops for wastewater treatment. Species can be matched to specific sites to ensure rapid growth. Growth response of hardwoods to irrigation and nutrients such as provided in wastewater is high and hardwoods rapidly concentrate nutrients in juvenile tissues. Under short rotations, trees can be whole-tree harvested, removing the nutrients from the site in a non-food chain product. Under medium to longer rotations, high value solid-wood products such as lumber or veneer can be grown.

Other crop possibilities include ornamental trees and shrubs (ball and burlap) grown for three to six years and removed as thinnings or as an entire crop. For harvested tree crops, a second rotation will result from coppice (sprouts) from the existing root systems. Coppicing will result in intermediate tree cover and a continuance of vegetative cover on the site without replanting. Phosphorus uptake in tree plantations also compares favorably to high yield grass crops. More information about using trees as receiver crops is contained in Appendix B-5.

Nutrient and Physical Management

Once a cover crop has been selected, it must be established and properly managed in order to ensure that the crop thrives and functions as an efficient component of the treatment system. It should be planted at the best possible time. Time of planting is important because the survival rate of developing seedlings is related to the time at which stress occurs from drought, freezing, or competition for light and nutrients. If no such stress occurs, or if it occurs after seedlings are

well established, survival and production losses can be minimized. Years of field research and experience under North Carolina's varied growing conditions have made it possible for researchers to recommend planting dates that will most likely lead to success or minimize risk. Seeding rates and planting depth are also important. See Appendix B-6 for recommendations on planting forage crops.

Although many of the nutrients required by crops can be supplied through the application of wastewater, rarely will wastewater supply all the necessary plant nutrients. Nutrient application rates and timing of applications must be appropriate for the selected cover crop. Receiver crops vary in their ability to utilize nutrients. Crops such as coastal Bermudagrass have very high nitrogen requirements, while crops such as mature forest have much lower nutrient requirements. Rarely are nutrients the limiting factor in most wastewater irrigation systems, either domestic or industrial. However, in systems where wastewater is concentrated, nutrients may limit the application rates. Wastewater application systems that are nutrient limited must time application events to appropriate stages in plant growth.

Corn, for example, is typically planted from late March through April and is harvested in September and October. If wastewater is applied from November to March, another crop must be planted to use the nutrients applied during these months. Similarly, wastewater applications must be applied a minimum of 30 days prior to grazing or harvest. Operators must understand the agricultural operations and time their wastewater application events to allow for these windows during which no wastewater can be applied to a receiver site. Sampling to assist in nutrient management decisions is recommended even if not required by the system permit. Table 5-15 describes rates and timing of nitrogen applications for optimum uptake by various cover crops.

Table 5-15. Nitrogen Rates and Timing of Effluent Application to Minimize Soil Leaching Losses and Luxury Consumption by Forage Plants. (From Managing Pasture and Hay Fields).

Forage type	Typcial Annual Yield Range (tons/A)	Pounds of PAN N per Ton of Yield	Timing of Applications
Bermudagrass			
All pasture	4-5	30-40	At green-up in mid April, thereafter at 3 to 5 week intervals until Sept. 15
All hay or silage	5-8	40-50	At green-up in mid April, thereafter at 4 to 5 week intervals until Sept. 15
Pasture + overseeded	5-6	30-40	For bermudagrass same as above. For rye, Oct. and Feb. with rye in Sept. or Oct.
Fescue			
All pasture	2-4	30-40	1/3 Feb. 15-28; 1/3 April 1-15; 1/3 Sept. 1-15.
All hay or silage	3-5	40-50	1/3 Feb 15-28; 1/3 after first cut; 1/3 in Sept.

Cover crops must be managed to reduce soil erosion and nutrient losses. Perennial grass sods are particularly effective in this regard. When a field has a thick perennial cover, there is far less runoff, therefore less chance for fertilizers to be washed away. In addition, most perennial grasses form dense root systems, which effectively serve as filters to remove contaminants before they can seep into the ground water. Even if a given field is used for row crop production, forages may be used in conjunction to reduce erosion. Grassed waterways, grassed terraces, strip cropping, and long term rotations utilizing forages are good examples.

The soil/crop system completes the renovation of wastewater. Many of the nutrients and other waste constituents supplied to the crops through the application of wastewater end up being incorporated into plant tissue. Therefore, it is important that the crop and its nutrients be removed through harvest. The soil can store some nutrients and metals, but its capacity is limited. Removal of the crop and its stored nutrients is essential. Otherwise, nutrients are returned to the soil as crop residues decompose. Failure to remove the crop can lead to excessive nutrient levels on the site, potential plant toxicity, and surface water or groundwater contamination problems.

Soil Fertility Management

The single most important component of maintaining a fertile soil for good crop management is the soil pH. Proper soil pH gives the best range of nutrient availability for the crops, reduces toxicity from aluminum or salts in the soil, and reduces leaching of wastewater constituents (refer back to Figure 3-11). Soil fertility can be managed with periodic soil sampling and by following the recommendations given in a soil test report.

Since liming materials are relatively immobile in the soil, surface applications affect only the top two or three inches and are an inefficient means of amending the soil. Thorough incorporation in the rooting zone increases the rate of reaction and treats a larger volume of the soil, maximizing the benefits of lime. However, this is not feasible in a permanent sod or wooded site, and increases the potential for erosion and runoff. If any sprayfields are to be refurbished or planted to a new crop, this is the ideal time to adjust soil pH to the proper depth for good mixing potential. Otherwise, surface liming is the best option for a permanent crop at a surface irrigation site.

Fall liming has many advantages. Lime has more time to react with the soil before the period of most rapid growth begins in the spring. Lime may also react more rapidly due to lower pH in the fall. In addition, soils are generally drier and more accessible in the fall than in the spring.

Pest Control

Crops must be periodically scouted for pests. A discussion of all possible pests on all crops that may be grown on wastewater application sites is beyond the scope of this manual. There are good resource guides and technical experts with the Department of Agriculture and the Cooperative Extension Service that can assist with this problem. Any individual responsible for purchasing and applying restricted pesticides must be licensed by the State of North Carolina. The pesticide registration and application program is managed through the North Carolina Department of Agriculture and Consumer Services. Education and training are provided by North Carolina State University. Restricted use pesticides must be use in accordance with label directions and only licensed applicators can apply certain restricted use products.

Pesticides in groundwater may result from problems that occur when pesticides are mixed or loaded, such as spills or backsiphoning. These are "point sources," or small areas of high concentrations of pesticides that can contaminate large areas of groundwater over time. Point source contamination can be located and cleaned up. Good construction and maintenance of the pesticide mixing and loading area can prevent most of these problems. However, pesticides may also be making their way into groundwater from fields where they are applied. Applied pesticides can leach or move through the soil with water as it percolates down to groundwater. The likelihood of a pesticide moving downward depends largely on its solubility, or its ability to dissolve in water. If a pesticide is highly soluble, it is more likely to reach the groundwater. On

the other hand, many pesticides, even some that are soluble, are likely to stick to soil particles by adsorption. Thus, if the probability of adsorption is high, less of the pesticides will leach.

Proper management of pesticides should be practiced in order to protect our water supplies. When applying pesticides:

- read container labels correctly;
- use the lowest effective rate listed on the label for any one application; the thought that "if a little will do a little good, a lot will do a lot of good" is a fallacy;
- correctly identify pests so that you use the proper pesticide and do not wastefully apply inappropriate materials;
- sweep granules of fertilizer or pesticide that may fall on impervious areas such as sidewalks and driveways into a vegetated area;
- calibrate spreaders and sprayers so that you know how much pesticide you are applying to an area; and
- learn about alternative pest control measures, such as beneficial insects, crop rotation, residue destruction, varietal resistance, proper planting dates, and companion cropping systems that may be good alternatives for your pest management problem.

For more information about pesticides application, contact your local Cooperative Extension Service Center, regional agronomist with the North Carolina Department of Agriculture and Consumer Services, or consult the North Carolina Agricultural Chemicals Manual, which is published annually.

Best Management Practices

A best management practice (BMP) can be any practice that reduces the movement of waste products (including odors) away from the receiving site, and into ground or surface water or to other properties. Best management practices are structural or operational practices that help you operate a waste management system with the least chance of negative impacts on the environment. Crops as well as crop residues, cultural practices and structures are used alone or in combination to hold the soil in place and allow water to move into it rather than to run off the surface.

Best management practices relating to nutrient management are those practices that optimize nutrient uptake by plants and minimize nutrient impact on the environment. These are very site specific and a BMP in one place may not offer the same benefits in another location. Therefore, specific BMPs may or may not be mandated in regulatory documents. A trained agronomist or soil scientist is the best resource to assess whether a particular BMP is appropriate for your situation if it is not already included as a condition of the system permit.

BMP'S at a surface irrigation site may include:

- **Performing Soil Tests**. Nutrients should be applied to soils only as necessary. To know the soil's nutrient-supplying capacity, you must have it analyzed by a soil test laboratory. Soil samples should be sent to a laboratory that uses testing procedures developed specifically for your soil conditions.

- **Follow Soil Test Recommendations**. A soil test report indicates the amount of nutrients that the soil can supply and recommends the amount, if any, needed from other sources. The test also recommends appropriate amendments (such as lime or sulfur) to adjust soil pH to the proper range for plant growth. All of the recommendations should be followed

because a deficiency of one nutrient or an undesirable soil pH will limit crop response to the other nutrients.

In North Carolina, a reliable soil test for nitrogen has not been developed, but a range of nitrogen rates are given on the soil test report for non-legume crops. Within the range given, the actual amount of nitrogen added should be based on crop yield goals and adjusted for specific soil, weather, and crop circumstances. Your county Cooperative Extension Service agent or other professional agronomist can help you determine the proper application.

- **Set Realistic Yield Goals**. All fertilizer recommendations assume a certain yield goal for the crop to be grown. Some laboratories ask for your goal, whereas others use an average number. The yield history of a field is the best guide to realistic expectations. Also, county soil surveys include crop yield estimates by soil series. Factors such as the soil's moisture supplying capacity should be considered.

  Do not over apply nutrients in the quest for unrealistic yields. Applying excessive amounts of nutrients is a waste of money and can contribute to water pollution. Over applying nitrogen is especially risky since it can easily be lost from the soil.

- **Apply Nitrogen and Phosphorus Correctly**. Nitrogen and phosphorus are less likely to be lost by erosion or runoff if they are banded directly into the soil or applied to the soil surface and promptly mixed into the soil by disking, plowing, or rotary tilling. Subsurface banding also makes it possible for nutrients to be placed directly where the crop can make the best use of them.

  Surface application of nitrogen and phosphorus without incorporation is the least desirable method of applying fertilizer, but it is often used for pastures, lawns, turf, and other perennial crops. Because phosphorus is relatively immobile, phosphorus should be incorporated into the soil before perennial crops are established. Where surface application is unavoidable, minimize the use of phosphorus. Aeration equipment can be used to improve soil infiltration and nutrient movement into the soil. The application method (surface applied or banded) has little effect on losses of nitrogen by leaching.

- **Time Nitrogen Applications Appropriately.** The timing of application is more important with nitrogen than with any other nutrient because nitrogen is applied in large amounts to many crops and is very mobile. Phosphorus, on the other hand, is very stable once it is mixed into the soil and can be applied when most convenient. Timing of nutrient application to coincide with plant growth requirements increases uptake efficiency and reduces exposure of applied nutrients to surface runoff and subsurface leaching. Optimum time of application depends on type of crop, climate, soil conditions, and chemical formulation of the fertilizer. Fall application of nitrogen can result in surface and subsurface losses of nitrogen, especially on sandy soils.

- **Control Erosion**. All nutrients can be lost when soil is eroded, but phosphorus is especially vulnerable. The primary way to prevent phosphorus loss is to control erosion. With few exceptions, if no sediments leave the land, little phosphorus leaves. Many erosion-control BMPs can be used in various cropping systems across North Carolina. A conservation farm plan providing for erosion control should be developed with assistance from the Natural Resources Conservation Service, USDA, and your county Cooperative Extension Service agent. Some specific practices are:

- **Maintain vegetation on ditch banks and in drainage channels**. Try not to disturb vegetation in drainage channels such as ditches and sod waterways. If necessary, construct ditches larger than needed so the bottoms can be left vegetated to trap sediment and other possible pollutants. Seed ditch banks and prevent ditch bank erosion by proper sloping and by diversion of field runoff water.
- **Slope field roads toward the field; seed roads with a permanent grass cover**. Water erosion and dust from traffic on field roads contribute significantly to soil loss and potential pollution. Do not plow field roads when preparing land. Shape roads for good drainage, and seed them with a perennial grass where possible. Direct field road runoff toward the field or into a sodded waterway and away from any bordering ditch or canal.
- **Shape and seed field edges to filter runoff as much as possible**. Do not plow up to the edge of the field, especially along ditches or canals. Leave a buffer strip along drainage ways, and establish a perennial sod. Shape and seed hoe drain outlets to filter runoff.
- **Use windbreaks and conservation tillage to control wind erosion**. Wind erosion can be minimized by leaving the soil surface rough, maintaining crop residue on the soil surface, bedding to trap wind-blown sediments, keeping the soil wet, or maintaining a cover crop.
- **Maintain a soil cover.** Leave crop residues on the soil surface during the winter. Do not till too early in the spring. Where feasible, use no-till methods, which may be the only way highly erodible land can be cropped without excessive soil loss. On soils that are subject to erosion or leaching, use a winter cover crop to reduce erosion and to take up nutrients, thereby reducing leaching. A cover crop used in this way is called a "trap crop" since it "traps" and recycles nutrients for use by later crops.
- **Manage the soil for maximum water infiltration**. Maintain crop residues on the soil surface. If there is little crop residue left in the fall, establish a winter cover crop, but leave the soil surface rough enough to help trap wastewater. These goals can be accomplished by using high-residue crops in the rotation and by tilling carefully to prevent soil compaction.
- **Manage Water Flow**. Water management is closely related to erosion control, and some practices overlap. In this section we are referring to water from rainfall, not wastewater irrigation. In general, erosion is minimized when water flow is slowed or stopped. Some specific practices are :
- **Slow water flow**. Use contour tillage, diversions, terraces, sediment ponds, and other methods to slow and trap rainfall rainfall runoff. The carrying capacity of running water is directly proportional to the flow rate. When water is still, sediments can settle out. Production practices such as installing water-control structures, such as flashboard risers, on field ditches in poorly drained soils benefit water quality significantly by reducing downstream sediments, phosphorus, and nitrogen. Sediments and associated phosphorus settle out of the drainage water, and nitrogen can be denitrified or used by stream vegetation. It is estimated that water-control structures have been installed on about 200,000 acres of land in eastern North Carolina during the last few years, and that nitrogen runoff has been reduced by over one million pounds per year.
- **Preserve buffer strips**. Leave buffer areas between fields and environmentally sensitive areas (see Figure 5-18). The amount of buffer needed varies with the cropping activity and the nature of the adjacent area. In some cases, buffers are mandated by law.

- **Use appropriate crops.** Deep rooted crops, including alfalfa and to a lesser extent soybeans, will scavenge nitrates that leach past the usual soil rooting zone. Used in crop

rotation following shallow rooted or heavily fertilized row crops, deep-rooted crops will recover excess nitrate from the soil and reduce the amount of nitrate available for leaching to groundwater.

No single set of BMPs applies in all situations but when properly carried out, BMPs can improve water quality. Many studies document water quality improvement in streams adjacent to where BMPs have been used in surrounding agricultural areas. If BMPs are not performing their functions as designed, you should contact a trained agronomist, soil scientist, or conservationist for advice on appropriate remedies.

Figure 5-18. Riparian buffer zones lining stream banks.

Troubleshooting

Diagnosing the needs of plants is comparable in many ways to diagnosing human ills. The medical doctor observes the patient, obtains all the information possible with his questions, and then makes the appropriate tests, all of which are helpful in diagnosing the case. Similarly, the wastewater operator observes the plants, obtains information on past management, and may make tests on the soil or the plant. The success of the diagnosis depends on the understanding of the fundamentals of plant and soil science and on a correct interpretation of the test results.

Diagnostic measurements of the ailing plant or soil are often classed as troubleshooting. Plant and soil samples can and are being used for this purpose, but a more important application is in preventive measures. By the time a plant is showing stress, it may be too late. Consider the analogy of closing the barn door after the horse has left. In order to be proactive in the crop management, you need to know stress symptoms of plants.

Many of the methods for evaluating soil fertility are based on observations of or measurements on growing plants. These methods have considerable merit because the plants act as integrators of all growth factors (aeration, fertility, moisture, pH) and are the products in which the operator is interested. An abnormal appearance of the growing plant may be caused by a deficiency of one

or more nutrient elements (Figure 5-19). If a plant is lacking in a particular element, characteristic symptoms may appear. This visual method of evaluating soil fertility is unique in that it requires no expensive or elaborate equipment and can be used as a supplement to other diagnostic techniques.

Examples of stress symptoms are as follows:

1. Complete crop failure at seedling stage.
2. Severe stunting of plants.
3. Specific leaf symptoms such as changes in coloration appearing at varying times during the season.
4. Delayed or abnormal maturity.
5. Obvious yield differences, with or without leaf symptoms.
6. Poor quality of crops.
7. Poor germination, resulting in reduced stand coverage.

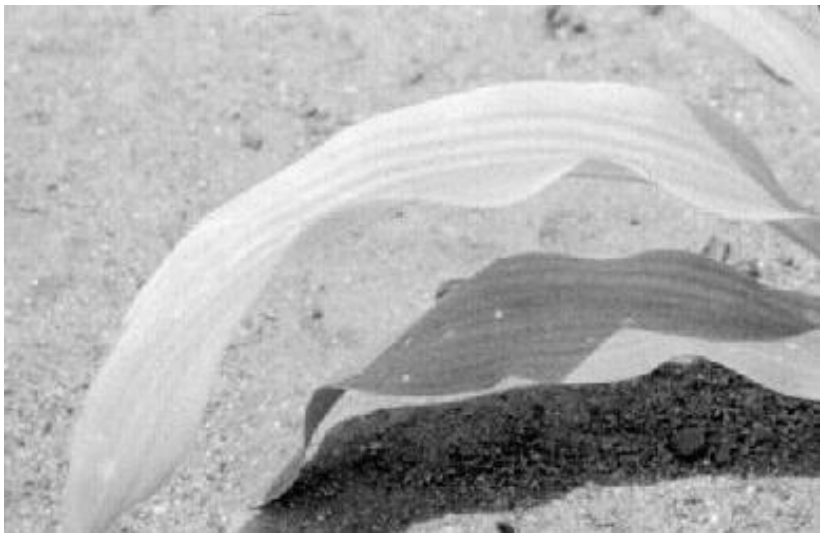


Figure 5-19. Sulfur deficiency in corn.

Be aware that in the field it is often difficult to distinguish among the cause of the symptoms. Disease or insect damage frequently resembles certain micronutrient deficiencies. An example is the confusion of leaf hopper damage with boron deficiency in alfalfa. If symptoms are observed early and are correctly diagnosed, they might be corrected during the growing season. Crop health may suffer during the first year, but if the trouble is properly diagnosed, the symptoms may be fully corrected the following year.

If a cover crop is not present, or is in poor health, the operator should start the troubleshooting process. The following steps should be included when attempting to establish a cover crop or repair an existing cover crop:

- obtain a representative soil sample;
- if crop is present but in poor shape, obtain a plant tissue analysis;
- check the area to see if prolonged saturation or soil compaction is a problem;
- select a crop or combination of crops suitable for the soil and site conditions, and one that can be managed in a wastewater application environment;
- select a crop that can be utilized locally or has some return value;
- apply recommended nutrients and/or pH adjustments from the soil test results;

- prepare to plant or seed the crop following all recommendations from the supply store, or contact local experts with the Cooperative Extension Service (CES) or North Carolina Department of Agriculture and Consumer Services (NCDA & CS&CS); and
- implement BMPs recommended by a trained agronomist, soil scientist, or conservationist.

See Appendix B-1 for a list of state and federal agencies that may be able to provide technical assistance for land application programs. Each agency is listed with a summary of its primary responsibilities, and the local or area offices that the agency maintains throughout the state. You are encouraged to use the expertise of the staff of these agencies as you manage your waste application site.

Management of Wastewater Application

Runoff can be avoided by ensuring the hydraulic loading is maintained within the levels acceptable by the soil system. For systems that are not nutrient limited, application events can occur as necessary to provide the nitrogen or phosphorous requirements, but should not exceed the hydraulic capacities of receiver sites. In addition, irrigation is not permitted during wet weather conditions or when the ground is frozen. The permits that are issued in North Carolina for wastewater irrigation typically require the suspension of land application activities during inclement weather or until 24 hours following a rainfall event of 1/2 inch or greater during a 24 hour period.

Irrigation Rates

As discussed in Chapter 3, wastewater application rates are typically dictated by the hydraulic loading rate or the hydraulics of the site. This scenario implies that if the site is capable of handling the wastewater without saturated soil conditions or without runoff, acceptable treatment of the wastewater has occurred. This situation is often true of domestic wastewaters, but may not necessarily be true of industrial or process wastewaters, which may contain higher levels of nutrients and other waste constituents. It also implies that preapplication treatment units are working properly and that there are no unusual concentrations of nutrients, salts, metals, etc., which may impact the receiver site or which may not be properly treated by the receiver site. Irrigation scheduling recommendations discussed earlier in this chapter should be followed.

Uniformity of Distribution

Uniform distribution of wastewater effluent at the irrigation site is necessary to ensure that the entire receiver site is used to renovate the wastewater, and to minimize overloading of any particular area. An operator should be familiar with the design plans for the facility. However, there may be design features in the irrigation equipment that are intended <u>not</u> to apply effluent evenly across a field. These design features may be required due to changes in soil conditions, slopes, or nearby drainageways.

In other cases, a site may be designed to receive uniform application across an entire field. The operator, however, knows that he/she cannot operate the system on that field or area at a uniform application rate without runoff or ponding of wastewater. Ultimately, it is the operator's responsibility to operate the system within the requirements of the permit, which includes no ponding or runoff. Any design modifications must be agreed upon by the system operator, the system designer, and the Division of Water Resources.

Areas that are prone to wetness, or hydraulic overload, include the heads of drainageways, soils with less permeable layers, compacted soil areas, areas with poor cover crops, and areas at the base of slopes. In most irrigation systems, a condition known as "bleed-off" is experienced when an operator ends an irrigation cycle. The water remaining in the distribution system will typically run to the lowest lateral and spray nozzle, and effluent will trickle out of this nozzle, sometimes for many minutes before the distribution lines are clear. This condition can result in local overloading of effluent, and the possibility of ponding or runoff. An operator can account for bleed-off in one of two ways:

- the irrigation cycle can be stopped early enough to anticipate the bleed-off and still have the soil in the bleed-off area absorb the effluent; or
- the operator can install hardware to stop or spread out the bleed-off condition to minimize any localized overload.

An area that is continually overloaded hydraulically will soon be obvious to the operator. The crop in that area may be taller or greener than in surrounding areas. If the situation is very bad, the local area may exhibit signs of crop stress or death due to chronic saturation. Another problem with chronic saturation is that it will eventually break down the soil structure, making the area even less permeable than it originally was. Crop harvest or maintenance procedures may have to be delayed or ignored if wet spots in the field are a problem.

Operational items that can help minimize the potential for hydraulic overload include:

- changing nozzles in wet areas to nozzles that deliver less wastewater per unit time;
- valving or capping individual risers so that they can be turned off to limit wastewater application or to reduce bleed-off;
- valving individual lateral or manifold lines to accomplish wastewater application reduction;
- using directional sprinklers to avoid slowly permeable areas or landscape positions;
- using subsoiling equipment to revive the soil permeability; and
- enhancing soil infiltration rate with good crop management and conservation practices.

Winter Operation

Most surface irrigation systems in North Carolina operate throughout the winter months. Some facilities, such as summer camps or resorts, operate on a seasonal basis and may generate little to no wastewater during the winter and so may not need to operate their surface irrigation equipment during this time. If a system is to shut down completely during the winter, necessary precautions for freezing must be taken. Appendix B-7 addresses the winterization of irrigation equipment.

Systems that operate through the winter also need to be aware of the effects of cold weather on surface irrigation operation. Foremost, surface irrigation onto frozen ground is prohibited. Frozen soil is much more of a problem in an open field than in a wooded site. A dense stand of grass also helps reduce the extent of frozen ground. During cold weather operation, the operator should walk the fields prior to any irrigation events and verify that the entire field has thawed and can accept wastewater. Cold temperatures also result in slower drying times, and therefore reduced application depths, as discussed in the irrigation scheduling section, must be considered. This may necessitate more frequent irrigation cycles of briefer duration when using a solid set or drip system, and different settings on mobile units such as traveling guns or center pivots.

If water is allowed to remain in the irrigation lines on very cold nights, problems with freezing and equipment damage can result. The vulnerable areas are the risers, exposed valve boxes, above-ground piping, and suction or discharge piping from the pump (if not protected in a pump

house or underground pump vault). On mobile systems, gun carts and center pivot towers are very vulnerable to freeze damage. Most irrigation risers are equipped with underground drain or weep holes that allow the water in the riser to soak into the soil after the pump has been turned off and the pressure in the line decreases. The operator must be sure that any above-grade valves are opened so that water is not trapped in the equipment.

Other units such as traveling gun carts and center pivots have caps or plugs that must be removed to allow drainage of the above-ground piping. Where above-ground piping is used, this pipe should be separated in several places, especially low areas, and allowing water to drain from the pipe. Traveling gun hose reels should be moved under shelter if possible. Some units recommend purging some of the water with forced air; others do not require special freeze protection for the hose. All, however, require drainage of all fittings, turbines, and feed lines to protect the components and the warranty. Usually, cold spells in North Carolina are of short duration. The operator simply needs to be aware of weather forecast in order to implement the above recommendations when necessary.

Management of System Components

The operator of a wastewater irrigation system must be familiar with the physical components that make up the system, how they work, and a schedule of maintenance and troubleshooting to ensure proper operation of the system. This section focuses on the following system components:

- surface irrigation equipment;
- drainage systems;
- soil and site components;
- operation and maintenance manuals; and
- records.

Surface Irrigation Equipment

An irrigation system is an expensive investment. Regular maintenance procedures will help keep your system operating properly for many years. Following these procedures also reduces the risk of equipment failures that may lead to lost production time or crop loss. These procedures are particularly critical in wastewater application systems, where equipment failures could result in a discharge of liquid wastes and damage to the environment.

The original operation and maintenance manual for a piece of irrigation equipment is your primary source of information regarding its required maintenance procedures. If the manual can not be located, ask your local dealer or equipment manufacturer for a replacement. Appendix B-7 contains an excellent publication that outlines the maintenance procedures for various types of surface irrigation equipment:

- annual maintenance procedures for sprinklers;
- lubrication and fluids schedule for hard-hose travelers;
- seasonal maintenance checklist for center-pivots and linear-move systems;
- weekly, quarterly, and annual maintenance for pumps;
- inspection and maintenance schedule for electric motors that power irrigation pumps;
- inspection and maintenance schedule for diesel motors that power irrigation pumps; and
- winterization and storage procedures for hard-hose travelers, center-pivot and linear-move system, pumps, and engines that power pumps.

Very wet spots in a field or along the piping to a field can indicate a leak or break in the distribution network. Valve junction boxes are a common place to find leaks in the system. Leaks can be caused by freezing water in the lines or spray risers, damage from equipment, or

failure of the part. Usually, a leak in the distribution system is easy to spot, as there will be a chronic wet area regardless of the amount of spraying. Not only could this lead to a violation due to wastewater ponding and runoff, but it also affects the performance of the rest of the system where flow has been reduced.

Rotating sprayheads can be another place for equipment damage or malfunction. A sprayhead that is stuck in one position can easily result in a large amount of effluent being applied to a small area, soon resulting in runoff of wastewater. Sprayheads should be monitored frequently for proper operation. Something as simple as a piece of trash can cause a small diameter sprayhead to clog or remain stuck in one position. Sprayheads should be cleaned and maintained regularly. Where rust or corrosion prevents proper operation, replacement may be the best option.

The area around groundwater monitoring wells must be protected. Highly visible markers may be used to warn equipment operators of the presence of the well. Using posts cemented into the ground to surround the well offers added protection to ensure that a well will not be hit with equipment. Damage from equipment includes cracked grouting, cracked or broken well piping, or broken locks or casings. This type of damage can result in the intrusion of surface water into the well and the contamination of groundwater. Such a well may have to be abandoned and another well constructed, costing much time and expense.

There are two important tools can assist an operator with irrigation scheduling. The first is a rain gauge (or set of gauges). The other is a well-calibrated flowmeter. The flowmeter shows the operator the volume of water that is being applied to the irrigation fields. Often flow is measured by multiplying the pump capacity (gallons per minute) times the pump run time (minutes). The flaw in this technique is that it assumes that the pump is operating at full or "rated" capacity. This rarely is the case, due to such issues as pump wear, design of the system, friction losses that increase with pipe and nozzle wear or clogging, etc. A flowmeter gives a much more accurate reading of applied wastewater, assuming that the flowmeter is properly and frequently calibrated. This information tells the operator how much applied wastewater is being combined with the measured rainfall and will help with irrigation scheduling and overall operation. Using a flow meter is also crucial in helping to determine the amount of nutrients, salts, or other wastewater constituents that are being applied.

Another place where the use of a flowmeter is recommended is on the influent side of the wastewater treatment system. Monitoring this flow shows if the system is being operated in compliance with permit limits, and whether there are additional inputs of wastewater coming to the system. Additional inputs can include illegal attachments to the collection system or infiltration and inflow. If flow measurements are higher in response to rainfall, then there are leaks into the collection system that should be repaired. Such leaks can usually be located with a smoke test. Removal of surface water inputs is often quickly remedied. Leaks in underground piping due to old or broken collection lines can be very difficult and expensive to repair. Monitoring these items helps the operator be aware of the overall system operation, and gives the operator information that should be used for irrigation scheduling. Knowledge of additional flows is also important to minimize the potential hydraulic overloads to the sprayfields that could cause ponding, runoff, or crop stress.

Flowmeters must be regularly calibrated to the manufacturer's specifications. Using a flowmeter that has not been calibrated can create more problems than not having a flowmeter at all. Flowmeters should be installed where the risk of corrosion from such devices as chlorinators or other chemical injection systems is minimized. Usually, the dealer who sells the flowmeters has a specialist who can perform the calibration.

As an operator, you should have a set of system plans and specifications that specify the equipment at the facility. These documents may specify the flow rate or application rate of the irrigation equipment with which you are working. However, those specifications are only valid as long as the pump is run at a certain speed, the equipment is new, the valves are all in the appropriate position, and there are no changes made to the system (such as adjusting valves or replacing sprayheads). Information presented in manufacturer's charts is based on average operating conditions with relatively new equipment.

Discharge rates and application rates change over time as equipment gets older and components wear. In particular, pump wear tends to reduce operating pressure and flow. Nozzle wear results in an increase in the nozzle opening, which will increase the discharge rate while decreasing the wetted diameter. Extreme nozzle wear can result in pressure decreases substantial enough to affect sprinkler roatation. To ensure proper placement and rate of wastewater delivery, proper calibration of equipment is necessary. Improper calibration and equipment maintenance will result in over or under application of wastewater and uneven nutrient distribution. Equipment calibration was discussed earlier in this chapter.

When replacing equipment, be sure that the replacement unit is satisfactory for the job. Replacement equipment must have the same rating, require the same power requirements, etc. so that it can be interchanged without affecting the overall functioning of the system.

All mechanical components will have some type of servicing requirements. Failure to perform regular maintenance results in equipment that does not last as long, and the possibility of premature failure during operation. Equipment failure at the wrong time could lead to a significant spill or leak of wastewater, causing a permit violation and possible threat to the surrounding environment.

Drainage Systems

The operator of a land-based wastewater treatment system needs to know if a drainage system exists either in the area being irrigated or the areas surrounding the irrigation site. Drainage can be a subsurface tile drainage system, surface ditching, or a combination of both. The operation of the wastewater system may be dependent on proper functioning of the drainage system. If such a drainage system exists, there should be references to it either in the permit or the design plans and specifications, and possibly both. Often a drainage system is used to shed surface water away from a wastewater receiver site.

Drainage systems need periodic attention to ensure proper operation. The most important component is the management of the drainage outlet. The operator should be aware of all drainage outlets. These should be well marked and maintained and kept free of vegetation that could obstruct the outflow of water from the drainage system. Piped drainage outlets should be protected by an animal guard to prevent stoppage from animals that may move into the outlet pipe. Proper erosion control is also needed at the outlet to stabilize the drainage water and ensure that erosion does not damage the outlet area.

Another maintenance responsibility is simply to ensure that the drainage system is performing its function. After a soaking rainfall, inspect the outlets to ensure that the system is working. Clogging could occur at any length of the pipe. Drainage pipes can become clogged with sediment or broken by heavy equipment. If the drainage system is not moving water as expected, the operator should walk the system to look for places where clogs may have occurred. These may appear as wet spots along the drainage lines. Subsurface drainage systems can fail when the pipe is crushed or if holes or breaks occur. Also, if the system does not have the proper grade for

water flow, as can happen with uneven settling, there can be problems with the drainage system working as designed. Uneven ground surface along the drain lines can also be an indication of a break in a subsurface piping network.

Terraces and surface water diversions are designed to shed surface water. In addition, some may have a gravel or "French" drain incorporated into them in order to help with subsurface water removal (Figure 5-20). These surface water diversions must be properly vegetated to minimize erosion caused by the moving water. Erosion can readily change the slope or grade of the structure and affect its operation.

On the other hand, if a surface water terrace or diversion becomes filled with sediment and loses its depth, runoff water designed to be trapped in the diversion may eventually overtop the structure. The original design criteria for all such structures should be maintained on the site, and the structure should be periodically monitored to ensure that it is at or near design specifications. If necessary, remove sediment or repair eroded areas to keep the structure at design criteria.

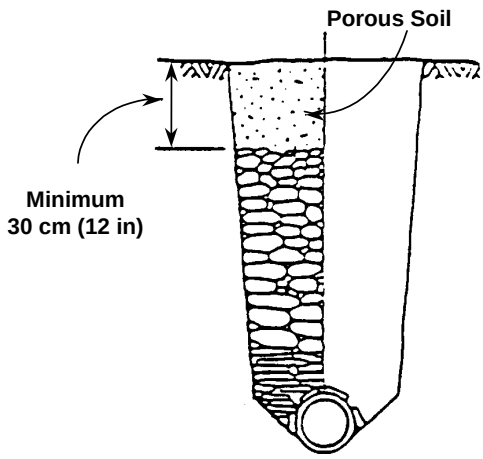


Figure 5-20. Cross section of a french drain.

Soil and Site Components

To better accommodate the wastewater and ensure proper treatment, you may need to consider expansion of the site if you experience one or more of the problems below:

- saturated soils;
- ponding or runoff of wastewater;
- excess flow as noted on facility flowmeters;
- crop stress due to excess soil moisture; or
- inability to maintain storage or freeboard in a lagoon, pond, or storage tank.

Before resorting to an expansion, however, you should first determine that chronic wetness conditions are not a result of excess infiltration and inflow into the collection system or a correctable soil-related condition (discussed earlier in this chapter).

Operation and Maintenance Manual

Each facility should maintain an Operations and Maintenance Manual specific to that facility. The maintenance and management of the soils and crops on the facility should be specifically addressed in the manual, since the overall function of the system relies on these components. All crop management issues should be addressed in this manual, along with timing recommendations for the relevant maintenance procedures.

Such manuals are commonly written by the system designer during the permitting stage. Older facilities may not have such a manual; if not, one should be developed. An operations and maintenance manual should specify the following:

- as-built plans (layout) of the entire system;
- system components and specifications for each unit (i.e. pumps, piping, valves, sprayheads, etc.);
- service and maintenance intervals for each piece of equipment;
- theoretical irrigation scheduling plan;
- application rates as specified in the permit (hourly and yearly loadings);
- record keeping or log book requirements (not necessarily those in the permit);
- list of crops suitable for the waste application area;
- crop management plan (including soil sampling and fertilization);
- odor control plan;
- emergency action plan; and
- list of technical resources.

All system components should have specification sheets showing details of the units as well as operation and maintenance requirements. These are usually included in the O&M manual or attached as a supplement. If this information is not present, the operator should contact the manufacturers directly. Typically, equipment will have a specification plate mounted somewhere that shows the company name, location, and model or serial number of the component. The manufacturer can be called for information on servicing the units. If the manufacturer is no longer in business, a local repair service may be able to provide service or information. If no information is available, you should service units similar to other units with like components.

Records

System operation is enhanced by good recordkkeeping. Maintaining records helps ensure that all permit conditions are met, that equipment is maintained at necessary intervals, and that the operator can make prudent wastewater application decisions. Good recordkeeping can help an operator to review system performance, identify problem areas, and to provide data in the event that permit modifications are needed.

The operator should review the system permit to determine recordkeeping requirements. Typically, these include:

- daily irrigation times and volumes, by field or zone;
- daily weather conditions;
- flow measurements (inflow);
- influent or effluent sampling data (periodic, usually three times per year);
- groundwater monitoring well sampling data (periodic, usually three times per year);
- cover crop maintenance activities; and
- storage lagoon or pond freeboard measurements.

Additionally, it is recommended that the operator keep a record or logbook of the following:

- equipment maintenance procedures;
- equipment replacement;
- documentation of site visits from inspectors or technical assistance professionals;
- documentation of complaints and how they were addressed;
- dates and locations of soil samples taken;
- dates and locations of vegetation samples taken; and
- minor modifications to spray patterns.

Environmental Protection

Although proper location of surface irrigation sites is important, it is no assurance that surface and groundwater contamination problems will be eliminated. Waste application activities must be planned and managed to prevent adverse impact on the groundwater, surface water, and public health. Adverse environmental impacts of surface irrigation can be minimized by proper management of:

- irrigation application rates;
- timing of irrigation;
- setbacks/isolation;
- wastewater constituents; and
- irrigation system performance.

Adverse affects are minimized by maintaining buffer zones, controlling the quantity and quality of wastewater applied, and maintaining a healthy crop/soil system for final adsorption and treatment of the wastewater. During the site selection and identification process and throughout the wastewater application operation, setback distances between surface water bodies and receiver sites must be clearly identified and maintained.

Emergency Action Plans

Using resource lists in Appendix B-1, you should develop an emergency action plan for your waste management system. This plan must be implemented in the event that wastes from your operation are leaking, overflowing, or running off the site. You should NOT wait until wastes reach surface waters or leave your property to consider that you have a problem. You should make every effort to ensure that this does not happen. This plan should be available to all employees at the facility, since accidents, leaks, and breaks can happen at any time.

Your plan should follow this format: (1) stop the release of wastes; (2) assess the extent of the spill and note any obvious damages; (3) contact the appropriate agencies; and (4) implement procedures to rectify the damage and repair the waste treatment system.

1. **Stop the release of wastes.** Spills must be contained immediately and waste should be pumped back to the treatment system, if possible. Facilities should have the necessary equipment and supplies to respond to a spill. Suggested responses to several problems are listed below:
    (a) lagoon or storage pond overflow*:
        i. add soil to berm to increase elevation of dam;
        ii. pump wastes to fields at an acceptable rate;
        iii. stop all additional flow to the structure;
        iv. call a pumping contractor; and
        v. make sure no surface water is entering storage structure.

        *Note. These activities should be started when your lagoon level has exceeded the maximum design storage level.

(b) Runoff from waste application field:
   i. immediately stop waste application;
   ii. create a temporary diversion or berm to contain the waste on the field;
   iii. incorporate waste to reduce further runoff;
   iv. evaluate and eliminate the reason(s) that caused the runoff; and
   v. evaluate the application rates for the fields where runoff occurred.

(c) Leakage from the waste distribution system (pipes and sprinklers):
   i. stop irrigation pump;
   ii. close valves to eliminate further discharge;
   iii. separate pipes to create an air gap and stop flow; and
   iv. repair all leaks prior to restarting pumps.

(d) Leakage from base or sidewall of lagoon or earthen storage structure (includes seepage as well as flowing leaks):
   i. dig a small well or ditch to catch all seepage, put in a submersible pump, and pump back into lagoon;
   ii. if holes are caused by burrowing animals, trap or remove animals and fill holes and compact with a clay type soil; and
   iii. other holes may be likewise temporarily plugged with clay soil.
   Note: Problems with lagoons and earthen storage structures require the consultation of an individual experienced in the design and installation of lagoons for permanent repair measures.

2. **Assess the extent of the spill and note any obvious damages.**
   (a) Did the waste reach any surface waters?
   (b) Approximately how much was released and for what duration?
   (c) Any damage noted, such as employee injury, fish kills, or property damage?
   (d) Did the spill leave the property?
   (e) Does the spill have the potential to reach surface waters?
   (f) Could a future rain event cause the spill to reach surface waters?
   (g) Are potable water wells in danger (either on or off the property)?

3. **Contact appropriate agencies** (see Appendix B-1).
   (a) Contact DWR for advice/technical assistance if required.
      i. All spills, regardless of volume, that reach surface waters must be reported to DWR.
      ii. Spills of less than 1,000 gallons that do not reach surface waters and are contained on-site, do not have to be reported. However, records must be retained documenting spill and action taken to address the spill.
      iii. Spills of 1,000 gallons or greater, regardless of whether or not they reach surface waters, must be reported to DWR.
   (b) During normal business hours, call your DWR regional office; after hours, call this emergency number: 1-800-858-0368. Your phone call should include: your name, facility, telephone number, the details of the incident from item 2 above, the exact location of the facility, and the location or direction of movement of the spill, weather and wind conditions, what corrective measures have been undertaken, and the seriousness of the situation.
   (c) If spill leaves property or enters surface waters, call local EMS.
   (d) Instruct EMS to contact local Health Department.
   (e) If none of the above works, call 911 or the Sheriff 's Department and explain your problem to them. Ask them to contact the agencies as listed above.

4. **Implement procedures** as advised by DWR and technical assistance agencies to rectify the damage, repair the system, and reassess the waste handling system to keep problems with release of wastes from happening again.

The emergency action plan must include provisions for emergency spraying or transfer of waste from all waste storage structures in the system. This may include emergency pumping (to prevent overtopping of a storage structure) during periods when the soil or crop conditions are not conducive to normal application. **DWR must be contacted for guidance to irrigate waste in such instances**. You should consider which fields are best able to handle the waste without further environmental damage. Application rates, methods, and minimum buffer distances must all be addressed.

The emergency action plan should be available and understood by all employees at the facility. The main points of the plan (order of action) along with the relevant phone numbers should be posted by all telephones at the site. A copy should also be available in remote locations or vehicles if the land application sites are not close by the facility office. It is the responsibility of the owner or manager of the facility to ensure that all employees understand what circumstances constitute an imminent danger to the environment or to the health and safety of workers and neighbors. Employees should be able to respond to such emergencies and notify the appropriate agencies of conditions at the facility.

Management of Human Disease and Nuisances

The spread of human disease can be compared to a chain. Each link in the chain must be present for disease to occur. The separate links are:

- agent;
- pathway; and
- susceptible host.

If these links come together to form a chain, disease occurs:

Agent + Pathway + Susceptible Host = DISEASE

The medical profession refers to these events as "The Chain of Transmission." To control the spread of disease, one of these links must be broken.

Agents

Wastewater constituents or agents that cause human disease include:

- chemical agents
  - metals;
  - persistent organic chemicals (e.g., PCBs); and
  - nitrates.
- biological agents
  - bacteria (e.g., salmonellosis; tuberculosis);
  - viruses (e.g., polio, hepatitis, meningitis);
  - protoza (e.g., intestinal parasites); and
  - helminths (e.g., tape worm, intestinal parasites).

Agents can be controlled by:

- proper wastewater treatment and
- pretreatment of industrial waste.

Pathways

The routes or pathways by which agent can reach hosts include:

- soil (through crops and animals);
- direct contact with wastewater;
- contaminated objects;
- water (through runoff to surface water or leaching to groundwater); and
- wastewater constituents on crops.

Control of pathways can be accomplished by:

- restricting crop use;
- site isolation (maintain setbacks);
- application at proper rates;
- timing of application;
- access control;
- application on suitable sites;
- runoff control; and
- disinfection of wastewater.

Control of crop use, isolation, access control and timing are discussed in further detail.

Crop Use

Prior to wastewater application on the following types of crops, additional treatment and disinfection of wastewater and careful timing of wastewater applications may be required:

- **Food chain crops** - any crop for human consumption, or feed for animals whose products are consumed by humans. These include corn, soybeans, small grains, forage crops or tobacco.
- **Direct consumption crops** - crops that are not processed prior to consumption. These include vegetables or fruit that are sold fresh (i.e., sweet corn, green beans, carrots, melons, radishes)
- **Pasture/forage crops** - crops grown for grazing or harvesting into hay.

Isolation

If surface irrigation systems are not isolated to some degree, infringement on adjacent properties can result in:

- nuisances;
- unauthorized access; and
- potential disease spread to animals and humans.

These potential problems can be controlled by:

- controlling applications so wastewater stays off road right-of-ways and on the property to which it is being applied; and
- isolating surface application sites with proper buffers (such as 400 feet from residential dwelling or place of public assembly).

Access

Public access to surface irrigation sites should be prevented by:

- signs;
- fences; and
- remoteness.

The site used for land application of wastewater should be controlled to restrict public access. This may be done by fencing or posting of signs, the specifics of which may be spelled out in the system permit. Regardless of the method, public access needs to be restricted due to the potential for public health implications such as the spread of disease. Also, there are other hazards that are associated with a wastewater treatment facility that could injure an individual (see Chapter 7). Controlling access can reduce the permittee's liability. Access from the public to a wastewater application site could also result in damage to equipment or sprayfields from vehicles. Broken pipes and sprayheads, as well as field rutting and crop damage, have been known to occur at spray sites with open access to the public.

Timing

Surface irrigation of wastewater should be scheduled to minimize adverse impacts on surface waters, crops, soil, and animal and human health. Timing of application is influenced by the seasons and weather conditions, the needed frequency of application, crop selection and use, land use, and access restrictions. Applying wastewater under the wrong conditions can result in runoff, groundwater contamination, soil compaction, plant disease, and reduced crop yield. Options to minimize these impacts include:

- providing adequate wastewater storage;
- having several different site/crops that can be used throughout the year; and
- careful scheduling and planning of application events.

Susceptible Hosts

Both animals and humans are susceptible to contracting diseases. Protection of hosts can be accomplished by:

- isolation (maintaining buffers);
- access control;
- personal protection (proper hygiene);
- natural immunity;
- acquired immunity through shots or previous exposure.

Chapter 6

Math

6.1. Introduction

A number of calculations are used in the operation of a waste treatment system. Some, such as the surface area and volume of the various treatment process tanks and equipment, need to be made only once and recorded for future reference. It may be necessary to perform others, such as run time or travel speed each day. In either case, you should be familiar with the calculations and understand specific formulas.

It is important that the appropriate units be written with each number used in all waste treatment calculations. This allows the units to be multiplied and divided as though they were numbers and allows the correct units to be included in the results. Carrying units properly through a calculation also serves as a check on the calculation as well as indicating units that need converting. In the following examples, note that all numbers have units with them: square feet, inches, gallons, etc. In several cases, factors have been supplied to simplify calculations. These factors have no units but supply the proper unit conversions.

Inaccurate measurements and calculations can result in erroneous reports and costly operational decisions. Accurate measurements and calculations are important tools an operator can use to properly control and manage waste treatment processes.

6.2. Types of Calculations

A spray irrigation system operator must be familiar with a variety of calculations. In addition to calculations relevant to water flow and waste treatment management, there are calculations relevant to the management of soils, crops, fertilizers, salt and nutrient loadings, and spray irrigation equipment.

Calculations needed for wastewater treatment include:

- fractions, decimals and percentages
- measurements (length, area, volume);
- detention time and storage;
- concentration of wastewater constituents (pounds formula);
- flow and hydraulic loading rates;
- horsepower; and
- pump delivery rate.

Calculations needed for soil and crop management include:

- hydraulic soils loading rates;
- plant available nitrogen calculations; and
- salt application from wastewater constituents.

Calculations needed for management of irrigation equipment include:

- application rate for stationary sprinkler systems;
- application run time for stationary sprinkler systems;
- application rates for traveling sprinkler systems;
- application depths for traveling sprinkler systems; and
- travel speed for traveling gun sprinkler systems.

Mathematical Relationships and Conversions

Fractions, decimals, and percentages are related to each other and may be mathematically manipulated to convert from one to another.

The following conversion chart is a good reference to refresh your understanding of basic relationships and is expanded to include concentrations, parts per million (PPM) (mg/L), and parts per billion (PPB) (μg/L).

Fraction	Decimal	Percent	PPM*	PPB*
1/1	1.0	100	1,000,000	1,000,000,000
1/10	0.1	10	100,000	100,000,000
1/100	0.01	1	10,000	10,000,000
1/1000	0.001	0.1	1,000	1,000,000
1/10,000	0.0001	0.01	100	100,000
1/100,000	0.00001	0.001	10	10,000
1/1,000,000	0.000001	0.0001	1	1,000

* For Water Only

$$\text{PPM} = \frac{1 \text{ part}}{1{,}000{,}000 \text{ parts}} = \frac{1 \text{ inch}}{1{,}000{,}000 \text{ inches}} = \frac{1 \text{ inch}}{15.78 \text{ miles}}$$

$$\text{PPB} = \frac{1 \text{ part}}{1{,}000{,}000{,}000 \text{ parts}} = \frac{1 \text{ inch}}{1{,}000{,}000{,}000 \text{ inches}} = \frac{1 \text{ inch}}{15{,}780 \text{ miles}}$$

The above chart shows the relationships of numbers in multiples of ten. However, the same relationships occur for all fractions but without the simplicity of base ten. The following sequence may be used to develop the fraction, decimal, percent, etc. relationships. Let's try the fraction one-fourth (¼)

Step 1: Divide the fraction to obtain the decimal equivalent:

$$\frac{1}{4} = 0.25$$

Step 2: Multiply the decimal by 100 to obtain the percent:

$$0.25 \times 100 = 25\%$$

What about problem fractions with repeating decimals? Lets try $1/3$:

Step 1: Divide the fraction to obtain the decimal equivalent and round:

$$\frac{1}{3} = 0.333333\ldots \longrightarrow \text{round to } 0.333$$

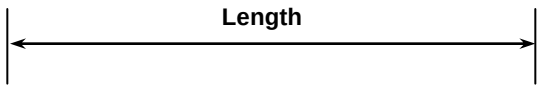
Step 2: Multiply the decimal by 100 to obtain the percent:

$$0.333 \times 100 = 33.3\%$$

Wastewater Calculations

Length

Length is one dimensional linear measurement of the distance between points. Length is expressed in units such as inches, feet, miles (English system) or millimeters, centimeters, meters, kilometers (metric system).



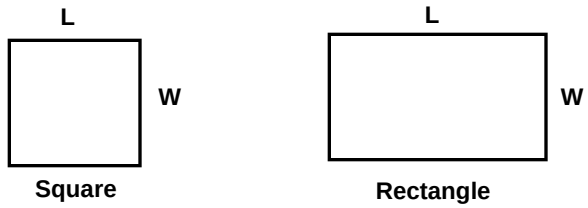
Area

Area is a two dimensional measurement that is expressed in units that are the square of linear units, for example, square feet or square meters. An area may be uniform or irregular and can occur in a variety of shapes. The most common types of areas are square, rectangular, circular and triangular.

<u>Square and Rectangle</u>

A = L x W

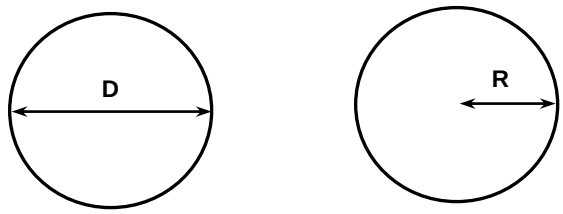
A = area
L = length
W = width



<u>Circle</u>

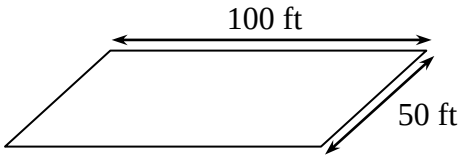
$A = \pi \times r \times r = \pi r^2$

A = area
π = 3.14
r = radius (1/2 diameter)
D = diameter



Example 1: (Area)

- A sand filter is 100 ft long by 50 ft wide. What is the surface area of the sandfilter?



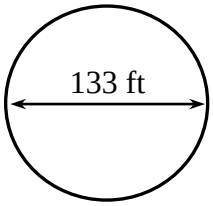
Area (ft^2) = (length) (width)

= (100 ft) (50 ft)

= $\boxed{5{,}000\ ft^2}$

Example 2: (Area)

- The diameter of the wetted area of a stationary sprinkler head is 133 feet. What is the surface area of the wetted area in square feet?



r = D ÷ 2 = 133 ft ÷ 2 = 66.5 ft

Area (ft^2) = πr^2

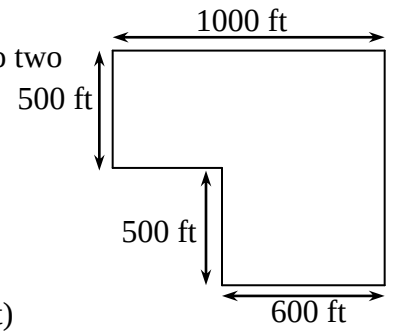
= (3.14) (66.5 ft) (66.5 ft)

= (3.14) (4,422.3 ft^2)

= $\boxed{13{,}885.9\ ft^2}$

Example 3: (Area)

- A spray irrigation field has the dimensions shown in the diagram. What is the total acreage of the field?



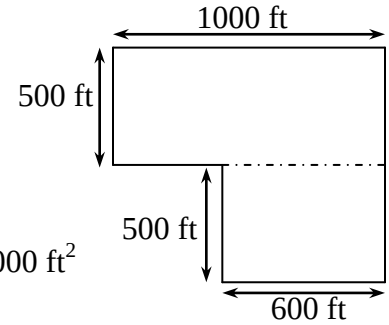
1. Begin by dividing the area into two squares or rectangles.

2. Find the area of both areas

   Area (ft^2) = (length) (width)

   Area A (ft^2) = (1000 ft) (500 ft)
   = 500,000 ft^2

   Area B (ft^2) = (500 ft) (600 ft)
   = 300,000 ft^2



3. Add Area A and Area B

   Area (ft^2) = 500,000 ft^2 + 300,000 ft^2
   = 800,000 ft^2

4. Convert square feet to acres

   Area (ac) = 800,000 ft^2 ÷ 43,560 ft^2/acre

   = $\boxed{18.4 \text{ acres}}$

Volume

Volume is the amount of space that an object or substance occupies. Volume is a three dimensional measurement and is expressed in units that are the cubes of linear units, such as cubic inches and cubic centimeters, or in units of dry and liquid measure, such as bushels, gallons, and liters.

Note: In practical applications, most volumes will be calculated in cubic feet (ft^3) and then converted to gallons by the conversion factor of 7.48 to obtain volume in gallons.

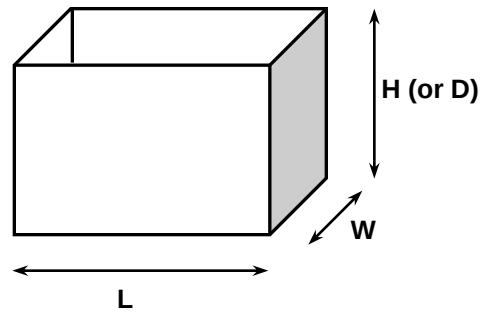
Rectangular Tank or Box

$$V = A \times H$$

or

$$V = L \times W \times H$$

V = volume
A = area (length x width)
H = height (or depth (D))



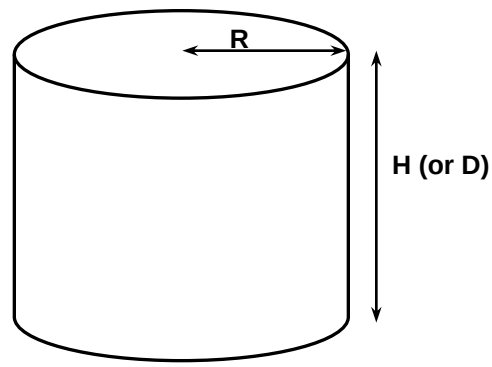
Cylindrical Tank

$$V = A \times H$$

or

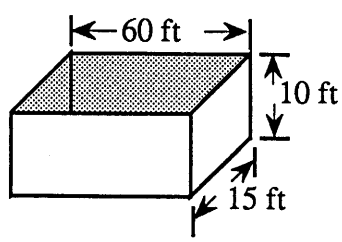
$$V = \pi r^2 \times H$$

A = area
π = 3.14
r = radius (1/2 diameter)
H = height (or depth (D))



Example 1: (Tank Volume) *

❑ The dimensions of a tank are given below. Calculate the volume of the tank in cubic feet.



$$\text{Vol. (ft}^3) = (lw)(d)$$

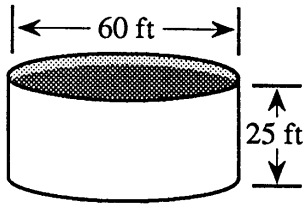
$$= (60 \text{ ft})(15 \text{ ft})(10 \text{ ft})$$

$$= \boxed{9000 \text{ ft}^3}$$

* From Applied Math for Wastewater Treatment Operators, 1991.

Example 2: (Tank Volume)*

❑ The diameter of a tank is 60 ft. When the water depth is 25 ft, what is the volume of water in the tank, in gallons?



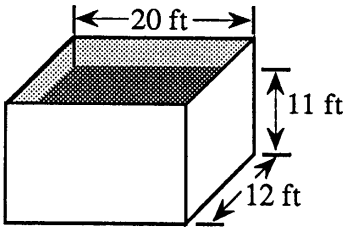
$$\text{Vol. gal} = (\pi)\ (r^2)\ (d)\ (7.48\ \text{gal/ft}^3)$$

$$= (3.14)\ (30\text{ft})\ (30\text{ft})\ (25\ \text{ft})\ (7.48\ \text{gal/ft}^3)$$

$$= \boxed{528{,}462\ \text{gal}}$$

Example 3: (Tank Volume)*

❑ A tank is 12 ft wide and 20 ft long. If the depth of water is 11 ft, what is the volume of water in the tank?



$$\text{Vol.(gal)} = (lw)\ (d)\ (7.48\ \text{gal/ft}^3)$$

$$= (20\ \text{ft})\ (12\ \text{ft})\ (11\ \text{ft})\ (7.48\ \text{gal/ft}^3)$$

$$= \boxed{19{,}747\ \text{gal}}$$

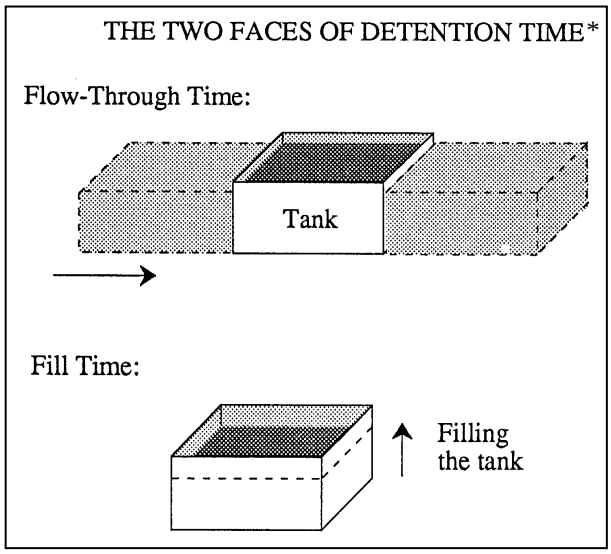
*From Applied Math for Wastewater Plant Operators

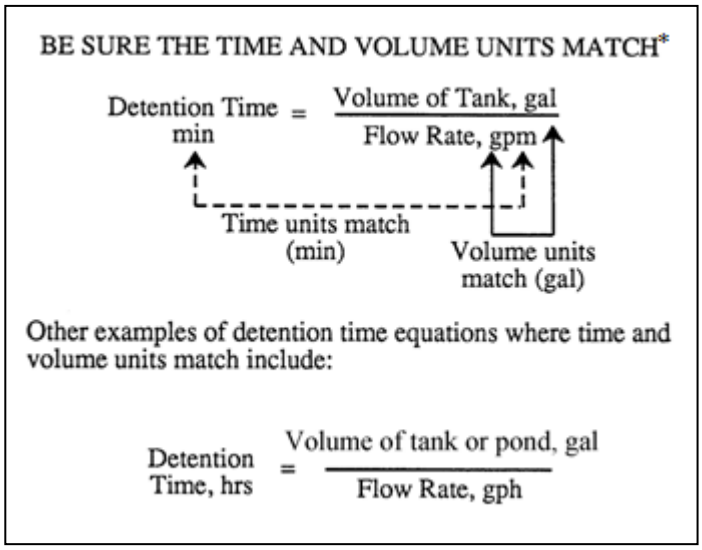
Detention Time and Storage

Detention time is the average time it takes for a particle to travel through a tank, lagoon or other treatment or storage structure. Put another way, detention time indicates the amount of time a given flow of water is retained by a treatment or storage structure. Detention time is calculated as the tank or structure volume divided by the flow rate and is expressed in units of time, such as minutes, hours, days, etc. Detention time can also be thought of as storage time or as fill time.

$$\textbf{D.T.} = \frac{\textbf{Volume}}{\textbf{Flow}}$$

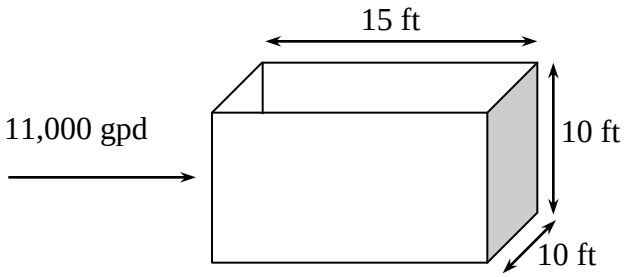
D.T. = detention time
Volume = volume of structure (in gallons or ft^3)
Flow = flow (volume/unit time)





Example 1: (Detention Time)

❑ A tank is 15 feet long, 10 feet wide, and 10 feet deep. The flow through the tank is 11,000 gpd. Calculate the detention time in hours.



Volume (feet) = (15ft) (10 ft) (10 ft) = 1500 ft^3

Volume (gallons) = (1500 ft^3) (7.48 gal/ ft^3) = 11,220 gallons

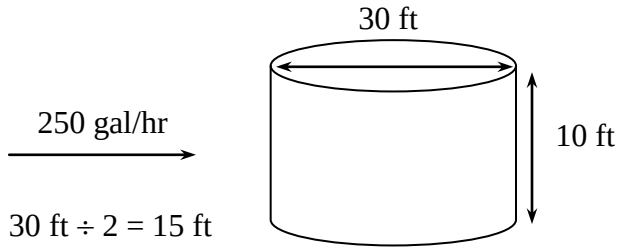
Flow (gal/hr) = (11,000 gpd) ÷ (24 hours/day) = 458.3 gal/hr

$$\text{Detention Time (hours)} = \frac{\text{Volume}}{\text{Flow}} = \frac{11{,}220 \text{ gal}}{458.3 \text{ gal/hr}}$$

$$= \boxed{24.5 \text{ hours}}$$

Example 2: (Detention Time)

❑ A tank is 30 feet in diameter and 10 feet deep. The flow through the tank is 250 gal/hour. What is the detention time in days?



r = D ÷ 2 = 30 ft ÷ 2 = 15 ft

Volume (feet) = (3.14) $(15\ ft)^2$ (10 ft) = (3.14) (225 ft^2) (10 ft)

= 7,065 ft^3

Volume (gallons) = (7,065 ft^3) (7.48 gal/ ft^3) = 52,846.2 gallons

Flow (gal/day) = (250 gal/hr) (24 hr/day) = 6000 gal/day

$$\text{Detention Time (days)} = \frac{\text{Volume}}{\text{Flow}} = \frac{52{,}846.2 \text{ gal}}{6000 \text{ gal/day}}$$

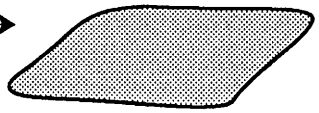
$$= \boxed{8.8 \text{ days}}$$

Example 3: (Detention Time) *

❑ A waste treatment pond is operated at a depth of 5 feet. The average width of the pond is 375 ft and the average length is 610 ft. If the flow to the pond is 570,000 gpd, what is the detention time in days?

(610 ft) (375 ft) (5 ft) (7.48 gal/cu ft) = 8,555,250 gal Volume

570,000 gpd →



$$\text{Detention Time, days} = \frac{\text{Volume of Pond, gal}}{\text{Flow Rate, gpd}}$$

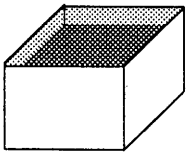
$$= \frac{\text{8,555,250 gal Volume}}{\text{570,000 gpd}}$$

$$= \boxed{\text{15 days}}$$

Example 4: (Detention Time) *

❑ A basin 4 ft square is to be filled to the 3 ft level. If the flow to the tank is 3 gpm, how long will it take to fill the tank (in hours)?

(4 ft) (4 ft) (3 ft) (7.48 gal/cu ft) = 359 gal Volume



(3 gpm) (60 min/hr) ↑
= 180 gph

$$\text{Fill Time, hrs} = \frac{\text{Volume of Tank, gal}}{\text{Flow Rate, gph}}$$

$$= \frac{\text{359 gal Volume}}{\text{180 gph}}$$

$$= \boxed{\text{2 hrs}}$$

*From Applied Math for Wastewater Plant Operators

Concentration

Concentration is the measurement of the strength of a known constituent or substance (solid, liquid, or gas) dissolved in another substance. Concentration is usually expressed as a percent, as pounds per gallon, as milligrams per liter (mg/L or PPM), or as micrograms per liter (μg/L or ppb). All of these units are interchangeable if proper conversion factors are used (see conversion list in Needs-To-Know). One of the most frequently used calculations in wastewater mathematics is the conversion of milligrams per liter (mg/L) concentration to pounds (lbs) dosage or loading.

The following two formulas are useful in determining loading rates from concentration or in determining concentration from loading rates:

1. **To convert mg/L to lbs:**

lbs/day = concentration (mg/L) x Flow (million gallons per day) x 8.34 lb/gal

or

lbs/day = mg/L x MGD x 8.34 lb/gal

or

lbs/year = mg/L x MGD x 8.34 lb/gal x 365 days/year

2. **To convert lbs to mg/L:**

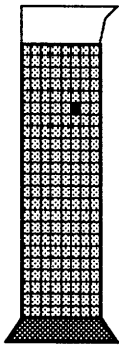
$$\text{Concentration (mg/L)} = \frac{\text{lbs}}{\text{flow (million gallons per day)}} \times 8.34 \text{ lb/gal}$$

or

$$\text{mg/L} = \frac{\text{lbs}}{\text{MGD} \times 8.34 \text{ lb/gal}}$$

MILLIGRAMS PER LITER IS A MEASURE OF CONCENTRATION *

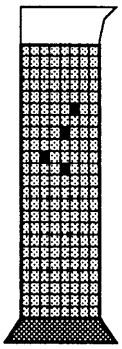
Assume each liter below is divided into 1 million parts. Then:



A

= 1 mg/*L* solids or 1 ppm solids

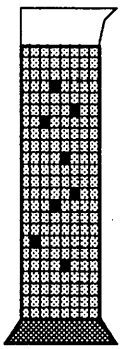
1 liter = 1,000,000 mg



B

= 4 mg/*L* solids or 4 ppm solids

1 liter = 1,000,000 mg



C

= 8 mg/*L* solids or 8 ppm solids

1 liter = 1,000,000 mg

Assuming the liter in these three examples has been divided into 1 million parts (each part representing 1 milligram, mg), the **concentration of solids** in each liter could be expressed as:

- The number of mg solids per liter (mg/*L*) or
- The number of mg solids per 1,000,000 mg (ppm).

The concentration of solids shown in diagram A is 1 milligram per liter (1 mg/*L*). The solids concentration shown in diagrams B and C are 4 mg/*L* and 8 mg/*L*, respectively.

*From Applied Math for Wastewater Plant Operators

Example 1: (Chemical Dosage) *

❑ Determine the chlorinator setting (lbs/day) needed to treat a flow of 3 MGD with a chlorine dose of 4 mg/*L*.

First write the equation. Then fill in the information given:

(mg/*L*) (MGD) (8.34) = lbs/day
Conc. flow lbs/gal

(4 mg/*L*) (3 MGD) (8.34 lbs/gal) = lbs/day

= **100 lbs/day**

Example 2: (Chlorine Dose, Demand, Residual)*

❑ What should the chlorinator setting be (lbs/day) to treat a flow of 3.7 MGD if the chlorine demand is 9 mg/*L* and a chlorine residual of 2 mg/*L* is desired?

First calculate the chlorine dosage in mg/*L*:

Chlorine Dose = **Chlorine Demand** + **Chlorine Residual**

= 9 mg/*L* + 2 mg/*L*

= 11 mg/*L*

Then calculate the chlorine dosage (feed rate) in lbs/day:

(mg/*L* Cl_2) (MGD flow) (8.34 lbs/gal) = lbs/day Cl_2

(11 mg/*L*) (3.7 MGD) (8.34 lbs/gal) = 339 lbs/day Chlorine

*From Applied Math for Wastewater Plant Operators

Example 3: (Concentration)

❑ The effluent at a spray irrigation facility averages 16 mg/L of potassium (K). If the average daily hydraulic load to the spray fields is 0.7 MGD, how many pounds of K are being applied per year?

lbs/day = (mg/L) (MGD) (8.34)
Conc. flow lbs/day

= (16 mg/L) (0.7MGD) (8.34 lbs/day)

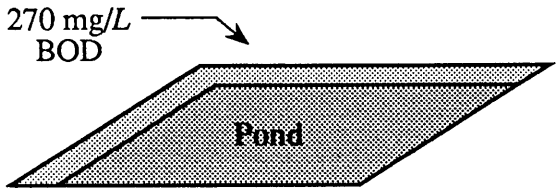
= 93.4 lbs/day

lbs/year = (93.4 lbs/day) (365 days/year)

= 34,094 lbs/year K

Example 4: (BOD Loading)*

❑ The flow to a waste treatment pond is 155 gpm. If the BOD concentration of the water is 270 mg/*L*, how many pounds of BOD are applied to the pond daily?



Before the mg/*L* to lbs/day equation can be used the gpm flow must be expressed in terms of MGD flow:

$$\left(155\ \frac{\text{gal}}{\text{min}}\right)\left(1440\ \frac{\text{min}}{\text{day}}\right) = 223{,}200 \text{ gpd}$$

$$\text{or} = 0.223 \text{ MGD}$$

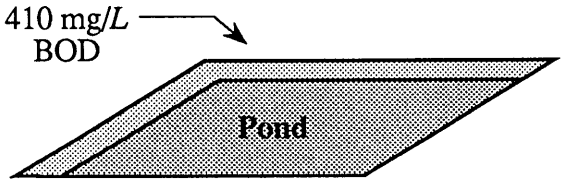
Now use the mg/*L* equation to solve the problem:

(mg/*L*) (MGD flow) (8.34 lbs/gal) = lbs/day

(270 mg/*L* BOD) (0.223 MGD) (8.34 lbs/gal) = **502 lbs/day BOD**

Example 5: (BOD Loading)*

❑ The daily flow to a pond is 310,000 gpd. If the BOD concentration of the wastewater is 410 mg/L, how many pounds of BOD are applied to the pond daily?

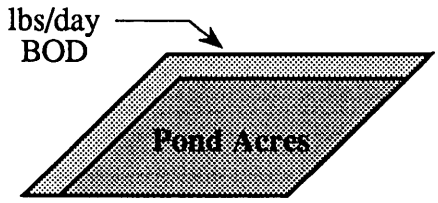


(mg/*L*) (MGD flow) (8.34 lbs/gal) = lbs/day

(410 mg/*L* BOD) (0.31 MGD) (8.34 lbs/gal) = **1060 lbs/day BOD**

*From Applied Math for Wastewater Plant Operators

ORGANIC LOADING RATE IS
BOD LOADING PER ACRE OF POND *



Simplified Equation:

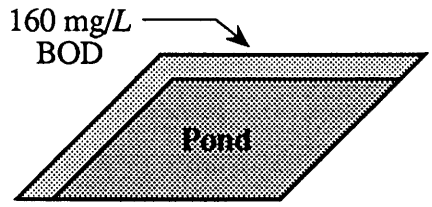
$$\text{Organic Loading Rate} = \frac{\text{BOD, lbs/day}}{\text{Area, acres}}$$

Expanded Equation:

$$\text{Organic Loading Rate} = \frac{(\text{mg}/L\ \text{BOD})\ (\text{MGD Flow})\ (8.34\ \text{lbs/gal})}{\text{Area, acres}}$$

Example 6: (Organic Loading Rate)*

❑ A 5.5-acre pond receives a flow of 170,000 gpd. If the influent flow has a BOD content of 160 mg/*L*, what is the organic loading rate on the pond in lbs BOD/day/ac?



5.5-ac Pond

$$\text{Organic Loading Rate} = \frac{(160\ \text{mg}/L\ \text{BOD})\ (0.17\ \text{MGD})\ (8.34\ \text{lbs/gal})}{5.5\ \text{ac}}$$

$$= \boxed{41\ \frac{\text{lbs BOD/day}}{\text{ac}}}$$

*From Applied Math for Wastewater Plant Operators

Flow Rates

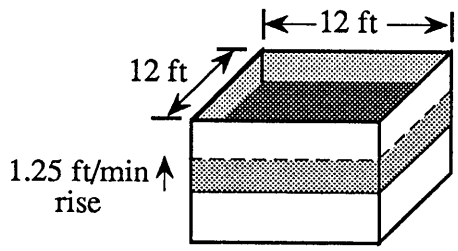
Flow rates are unit volumes per unit time, such as gallons per minute (GPM), million gallons per day (MGD), etc. Flow rates can be measured in several ways. Various flow metering devices may be used to measure wastewater flows at a specific moment (instantaneous flow) or over a specified time period (total flow). The following equation can be used to estimate instantaneous flow rates:

Q = A x V

Q = flow rate (cubic feet per minute - cfm)
A = area (ft^2)
V = velocity (feet per minute - fpm)

Example 1: (Instantaneous Flow) *

❑ A tank is 12 ft by 12 ft. With the discharge valve closed, the influent to the tank causes the water level to rise 1.25 feet in one minute. What is the gpm flow into the tank?



First, calculate the cfm flow rate:

$$Q_{cfm} = AV_{fpm}$$

$$= (12\text{ ft})(12\text{ ft})(1.25\text{ fpm})$$

$$= 180\text{ cfm}$$

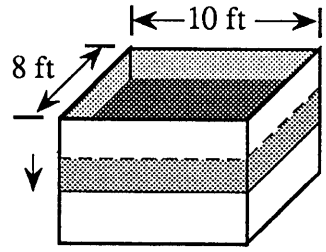
Then convert cfm flow rate to gpm flow rate:

$$(180\text{ cfm})(7.48\text{ gal/cu ft}) = \boxed{1346\text{ gpm}}$$

*From Applied Math for Wastewater Plant Operators

Example 2: (Instantaneous Flow) *

❑ A tank is 8 ft wide and 10 ft long. The influent valve to the tank is closed and the water level drops 2.8 ft in 2 minutes. What is the gpm flow from the tank?



$$\underline{\text{Drop:}} = \frac{2.8 \text{ ft}}{2 \text{ min}}$$

$$= 1.4 \text{ ft/min}$$

First, calculate the cfm flow rate:

$$Q_{\text{cfm}} = AV_{\text{fpm}}$$

$$= (10 \text{ ft})\ (8 \text{ ft})\ (1.4 \text{ fpm})$$

$$= 112 \text{ cfm}$$

Then convert cfm flow rate to gpm flow rate:

$$(112 \text{ cfm})\ (7.48 \text{ gal/cu ft}) = \boxed{838 \text{ gpm}}$$

Example 3: (Average Flow Rates)*

❑ The following flows were recorded for the week: Monday—8.6 MGD; Tuesday—7.6 MGD; Wednesday—7.2 MGD; Thursday—7.8 MGD; Friday—8.4 MGD; Saturday—8.6 MGD; Sunday—7.5 MGD. What was the average daily flow for the week?

$$\text{Average Daily Flow} = \frac{\text{Total of all Sample Flows}}{\text{Number of Days}}$$

$$= \frac{55.7 \text{ MGD}}{7 \text{ Days}}$$

$$= \boxed{8.0 \text{ MGD}}$$

*From Applied Math for Wastewater Plant Operators

Horsepower

Horsepower is a unit of power equivalent to 0.746 kilowatts. In order to select a pump with sufficient pumping power, you must know both the desired flow rate and the feet of head against which the pump must pump. Horsepower is calculated by the following formula:

$$\text{H.P.} = \frac{\text{Flow (gpm)} \times \text{TDH}}{3960 \times \text{Pump Eff.} \times \text{Motor Eff.}}$$

TDH = total dynamic head
GPM = gallons per minute
3960 = conversion factor
Pump Eff. = pump efficiency expressed as a decimal
Motor Eff. = motor efficiency expressed as a decimal

Example 1: (Horsepower)

- What horsepower is required to pump 50,000 gph if the TDH is 28.3 ft and the pump and motor efficiencies are 90%?

First, convert flow from gallons per hour to gallons per minute:

Flow gpm = (50,000 gph) ÷ (60min/hr)

= 833.3 gpm

Now, compute horsepower using the formula:

$$\text{H.P.} = \frac{(\text{Flow(gpm)})\ (\text{TDH})}{(3960)\ (\text{Pump Eff.})\ (\text{Motor Eff.})}$$

$$= \frac{(833.3\ \text{gpm})\ (28.3\ \text{ft})}{(3960)\ (.90)\ (.90)}$$

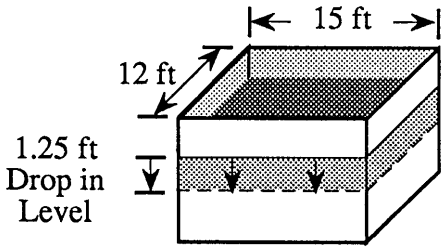
$$= \frac{(23{,}582.4)}{(3{,}207.6)}$$

$$= \boxed{7.4}$$

Pump Delivery Rate

Example 1: (Pump Delivery Rate)

- A dosing tank is 15 ft long and 12 feet wide. The influent valve to the tank is closed. If a pump lowers the water level 1.25 ft during a 5 minute pumping test, what is the pump delivery rate in gpm?



First, determine the volume of water pumped in gallons:

Volume (ft) = (12 ft) (15 ft) (1.25 ft) = 225 ft^3

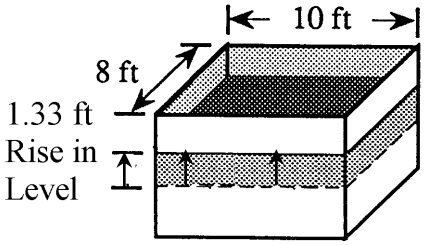
Volume (gal) = 225 ft^3 x 7.48 gal/ ft^3 = 1683 gal

Next, determine pump delivery rate using the following formula:

$$\text{Pump Delivery Rate} = \frac{\text{Volume pumped (gal)}}{\text{Time of pumping}} = \frac{1683 \text{ gal}}{5 \text{ min}} = \boxed{336.6 \text{ gpm}}$$

Example 2: (Pump Delivery Rate)

- A pump is rated at 300 gpm. A pump test is conducted for 5 minutes. What is the actual pump delivery rate if the tank is 10 ft long and 8 ft wide and the water level in the tank rises 1.33 ft during the test?



First, determine the volume of water pumped in gallons:

Volume (ft) = (10 ft) (8 ft) (1.33 ft) = 106.4 ft^3

Volume (gal) = 106.4 ft^3 x 7.48 gal/ ft^3 = 795.9 gal

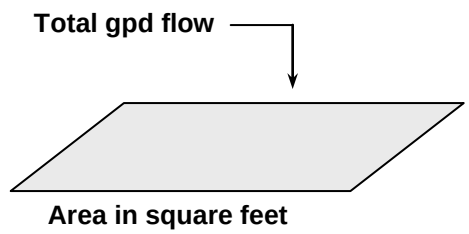
Next, determine pump delivery rate using the following formula:

$$\text{Pump Delivery Rate} = \frac{\text{Volume pumped (gal)}}{\text{Time of pumping}} = \frac{795.9 \text{ gal}}{5 \text{ min}} = \boxed{159.2 \text{ gpm}}$$

Hydraulic Loading Rates

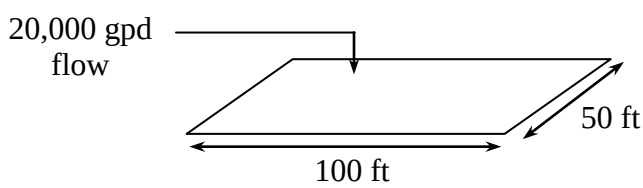
Hydraulic loading rate is the amount of wastewater applied to an area for a specified time. The most common expression of hydraulic loading rate is gallons per day per square feet (gpd/ft^2). Recirculated flows are included as part of the gpd flow to the system.

$$\textbf{Hydraulic Loading Rate} = \frac{\textbf{Flow (gpd)}}{\textbf{Area (ft}^2\textbf{)}}$$



Example 1: (Hydraulic Loading)

- If 20,000 gpd are pumped to a sand filter that is 100 feet by 50 feet, what is the hydraulic loading rate on the filter?



$$\text{Hydraulic Loading Rate} = \frac{\text{Flow (gpd)}}{\text{Area (ft}^2\text{)}}$$

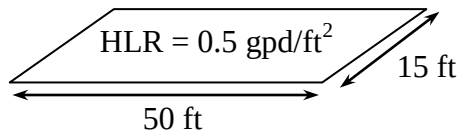
$$= \frac{20{,}000 \text{ gpd}}{(100 \text{ ft})\,(50 \text{ ft})} = \frac{20{,}000 \text{ gpd}}{5000 \text{ ft}^2}$$

$$= \boxed{4 \text{ gpd/ft}^2}$$

*From Applied Math for Wastewater Operators

Example 2: (Hydraulic Loading)

❑ A sandfilter is 50 feet long by 15 feet wide. The loading rate under normal conditions is 0.5 gpd/ft^2. How many gallons could be applied to achieve the appropriate loading rate?



$$\text{Hydraulic Loading Rate (gpd/ft}^2) = \frac{\text{Flow (gpd)}}{\text{Area (ft}^2)}$$

Rearrange equation to solve for flow:

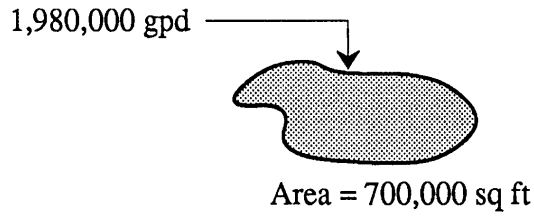
$$\text{Flow (gpd)} = \text{Hydraulic Loading Rate (gpd/ft}^2) \times \text{Area (ft}^2)$$

$$= (0.5 \text{ gpd/ft}^2)\ (50 \text{ ft})\ (15\text{ft})$$

$$= \boxed{375 \text{ gpd}}$$

Example 3: (Hydraulic Loading)*

❑ A pond receives a flow of 1,980,000 gpd. If the surface area of the pond is 700,000 sq ft, what is the hydraulic loading in in./day?



$$\text{Hydraulic Loading Rate} = \frac{1{,}980{,}000 \text{ gpd}}{700{,}000 \text{ sq ft}}$$

Convert gpd flow to ft^3/day flow (1,980,000 gpd ÷ 7.48 gal/cu ft):

$$= \frac{264{,}706 \text{ ft}^3\text{/day}}{700{,}000 \text{ ft}^2}$$

$$= 0.4 \text{ ft/day}$$

Then convert to in/day:

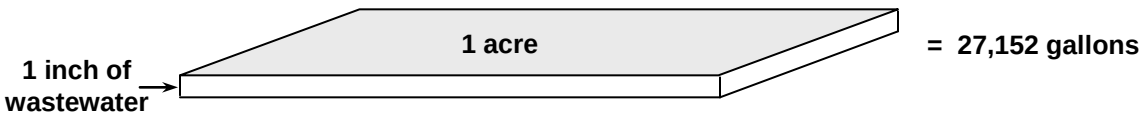
$$(0.4 \text{ ft/day})\ (12 \text{ in./ft}) \qquad \boxed{5 \text{ in./day}}$$

Soil and Crop Calculations

Hydraulic Soils Loading Rates

Hydraulic Soils Loading Rate is measured in inches of wastewater applied to an area of soil in a day. To calculate the hydraulic soils loading rate, you must use the following conversion factor: one inch of water per acre (1 ac-in) = 27,152 gallons.

$$\textbf{Hydraulic Soils Loading Rate (in/day)} = \frac{\textbf{Flow (gal/day)}}{\textbf{27,152 gal/acre-in} \times \textbf{Area (acres)}}$$



Hourly Hydraulic Soils Loading Rate is inches of wastewater applied to an area of soil in an hour. To calculate Hourly Hydraulic Soils Loading Rate, use the Hydraulic Soils Loading Rate formula and convert from inches per day to inches per hour as follows:

$$\textbf{Hourly Hydraulic Soils Loading Rate (in/hr)} = \frac{\textbf{Flow (gal/day)}}{\textbf{27,152 gal/acre-in} \times \textbf{Area (acres)}} \times \frac{\textbf{1 day}}{\textbf{24 hours}}$$

Example 1: (Hydraulic Soils Loading Rate)

- What is the hydraulic soils loading rate for a spray irrigation system that pumps 50,000 gallons in one day equally over a 4.28 acre site?

$$\text{Hydraulic Soils Loading Rate (in/day)} = \frac{\text{Flow}}{(27{,}152\ \text{gal/acre-in})\ (\text{Area})}$$

$$= \frac{50{,}000\ \text{gpd}}{(27{,}152\ \text{gal/acre-in})\ (4.28\ \text{acres})}$$

$$= \frac{50{,}000\ \text{gpd}}{(116{,}210.6\ \text{gal/in})}$$

$$= \boxed{0.43\ \text{in/day}}$$

Example 2: (Hydraulic Soils Loading Rate)

- What is the hydraulic soils loading rate for a spray irrigation system that pumps 175,000 gallons in one day equally over a 10.5 acre site?

$$\text{Hydraulic Soils Loading Rate (in/day)} = \frac{\text{Flow}}{(27{,}152\ \text{gal/acre-in})\ (\text{Area})}$$

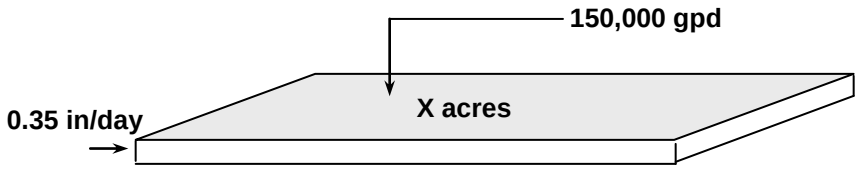
$$= \frac{175{,}000\ \text{gpd}}{(27{,}152\ \text{gal/acre-in})\ (10.5\ \text{acres})}$$

$$= \frac{175{,}000\ \text{gpd}}{(285{,}096\ \text{gal/in})}$$

$$= \boxed{0.61\ \text{in/day}}$$

Example 3: (Hydraulic Soils Loading Rate)

- How many acres would be needed to achieve a hydraulic soils loading rate of 0.35 in/day if the flow is 150,000 gpd?



$$\text{Hydraulic Soils Loading Rate (in/day)} = \frac{\text{Flow}}{(27{,}152 \text{ gal/acre-in})\ (\text{Area})}$$

$$0.35 \text{ in/day} = \frac{150{,}000 \text{ gpd}}{(27{,}152 \text{ gal/acre-in})\ (\text{X acres})}$$

Rearrange the equation to solve for X:

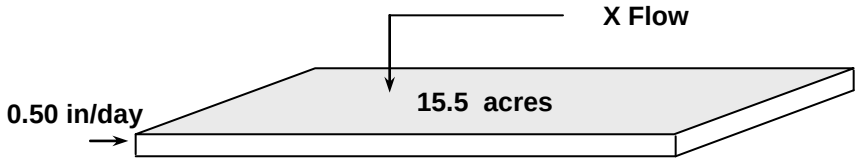
$$\text{Acres} = \frac{150{,}000 \text{ gpd}}{(27{,}152 \text{ gal/acre-in})\ (0.35 \text{ in/day})}$$

$$= \frac{150{,}000 \text{ gpd}}{(9{,}503.2 \text{ gpd/acre})}$$

$$= \boxed{15.8 \text{ acres}}$$

Example 4: (Hydraulic Soils Loading Rate)

- If a spray irrigation field is 15.5 acres and receives 0.50 in/day of wastewater, what is the flow in gal/day?



$$\text{Hydraulic Soils Loading Rate (in/day)} = \frac{\text{Flow}}{(27{,}152 \text{ gal/acre-in})\ (\text{Area})}$$

$$0.50 \text{ in/day} = \frac{\text{X gal/day}}{(27{,}152 \text{ gal/acre-in})\ (15.5 \text{ acres})}$$

Rearrange the equation to solve for X:

$$\text{X gal/day} = (0.50 \text{ in/day})\ (27{,}152 \text{ gal/acre-in})\ (15.5 \text{ acres})$$

$$= \boxed{210{,}428 \text{ gal/day}}$$

Plant Available Nitrogen

Some spray irrigation systems handle wastewater with high nitrogen concentrations. These systems need to base wastewater application rates on supplying crop nitrogen needs rather than on the amount of water the soil can handle. Permits for nitrogen limited systems have PAN monitoring requirements. Plant available nitrogen is calculated as follows:

$$\mathbf{PAN = [MR \times (TKN - NH_3)] + (0.5 \times NH_3) + NO_3 + NO_2}$$

PAN = Plant Available Nitrogen

MR = Mineralization Rate

- 0.4 for primary treatment
- 0.3 for aerated lagoons and sand filters
- 0.2 for aerobic treatment/activated sludge systems

VR = 0.5 for surface application/irrigation

TKN = Total Kjeldhal Nitrogen

NH_3 = Ammonia Nitrogen Concentration. Sometimes expressed as NH_4^+ (Ammonium)

NO_3 = Nitrate Nitrogen Concentration

NO_2 = Nitrite Nitrogen Concentration

Note: You usually see the different forms of nitrogen reported or expressed in this manner:

NH_3-N
NH_4-N
NO_3-N
NO_2-N

The "-N" ending does not mean "minus N" in this case. It just means nitrogen in the form of ammonia, ammonium, nitrate, or nitrite, etc.

Some labs report nitrate and nitrite as a combined value, which may be expressed as: $NO_3 + NO_2$, NO_3-N + NO_2-N, etc.

Example 1: (PAN)

- You are applying 15.0 in/acre to your spray fields. Your irrigation wastewater contains the following concentrations:
  TKN: 56 mg/L
  Ammonia: 18 mg/L
  Nitrate: 10.5 mg/L
  Nitrite: 0.5 mg/L
  Assume a mineralization rate of 0.40. How much PAN are you applying per year to each acre?

$PAN = [MR \times (TKN - NH_3)] + (0.5 \times NH_3) + NO_3 + NO_2$

$PAN = [0.40 (56 - 18)] + (0.5 \times 18) + 10.5 + 0.5$

$PAN = (0.40 \times 38) + 9 + 11$

$PAN = 15.2 + 9 + 11 = 35.2$ mg PAN/L

Now, we need to convert mg/L to lbs using the formula:

lbs = concentration (mg/L) x Flow (million gallons per day) x 8.34 lb/gal

To do this we first need to convert our hydraulic soils loading rate (HSLR (in/year)) to flow (in million gallons per day).

Flow = (15 in/acre) (27,152 gal/acre-in) (1 acre) = 407,280 gal/acre = 0.407 MG/acre

We can now solve for lbs PAN per year on each acre:

lbs PAN/acre = (35.2 mg/L) (0.407 MG/acre) (8.34 lb/gal)

= **119.5 lbs PAN/acre**

Sodium Adsorption Ratio

The ratio of the sodium concentration to the concentrations of calcium and magnesium in the wastewater is called the *sodium adsorption ratio* (SAR). Calculations for SAR utilize the liquid concentrations (in mg/L) of sodium, calcium, and magnesium in the wastewater.The formula for Sodium Adsorption Ratio is as follows, with all concentrations expressed in milliequivalents (meq):

$$\text{SAR} = \frac{\text{Na}}{\sqrt{0.5 \times (\text{Ca} + \text{Mg})}}$$

Where sodium, calcium, and magnesium are in milliequivalents/liter (meq/L)

$$\text{meq} = \frac{\text{concentration}}{\text{equivalent weight}}$$

Example 1: (SAR)

- What is the SAR for a wastewater that has the following ion concentrations:
  - Sodium (Na^+) = 84 mg/L
  - Calcium (Ca^{2+}) = 23 mg/L
  - Magnesium (Mg^{2+}) = 14 mg/L

The equivalent weights of sodium, calcium, and magnesium are, respectively, 23, 20, and 12.

First, convert concentrations to milliequivalents (meq):

$$Na^+ = \frac{84 \text{ mg/L}}{23} = 3.7$$

$$Ca^{2+} = \frac{23 \text{ mg/L}}{20} = 1.2$$

$$Mg^{2+} = \frac{14 \text{ mg/L}}{12} = 1.2$$

$$\text{SAR} = \frac{\text{Na}}{\sqrt{0.5 \times (\text{Ca} + \text{Mg})}}$$

$$\text{SAR} = \frac{3.7}{\sqrt{0.5 \times (1.2 + 1.2)}} = \frac{3.7}{\sqrt{0.5 \times (2.4)}}$$

$$= \frac{3.7}{\sqrt{1.2}} = \frac{3.7}{1.1} = \boxed{3.4}$$

Exchangeable Sodium Percentage

Exchangeable sodium percentage (ESP) is an evaluation that can be used to determine possible excess sodium concentration in the soil itself. The ESP is the amount of adsorbed sodium on the soil exchange complex expressed in percent of the cation exchange capacity (CEC) in milliequivalents per 100 cm^3 of soil. This determination can be made from a typical soil fertility evaluation and calculated as follows:

$$\text{ESP} = \frac{\text{Na}}{\text{CEC}} \times 100$$

Where Na and CEC are in milliequivalents (meq) per 100 cm^3 of soil.

Example 1: (ESP)

- The CEC of a soil is 5.4 meq/100 cm^3 and the Na is 0.7 meq/100 cm^3. What is the exchangeable sodium percentage?

$$\text{ESP} = \frac{\text{Na} \times 100}{\text{CEC}}$$

$$= \frac{0.7 \times 100}{5.4}$$

$$= \frac{0.7 \times 100}{5.4}$$

$$= 13.0\%$$

Wastewater Application Rates

The formulas for correctly determining wastewater application rates were covered in Chapter 5 and are included again here.

Precipitation Rate for Stationary Sprinklers

Example 1: (Precipitation Rate for Stationary Sprinklers)

- A stationary sprinkler has a discharge rate of 17.6 gpm and a wetted diameter of 140 ft. If the sprinkler spacing is set at 60% of the wetted diameter and lateral spacing is 84 ft, what is the precipitation rate in in/hr?

First, determine the design sprinkler spacing:

Sprinkler spacing = 140 ft x 0.6 = 84 ft

Next, determine the precipitation rate using the following formula:

$$\text{Precipitation rate (in/hr)} = \frac{96.3 \times \text{discharge rate (gpm)}}{\text{sprinkler spacing (ft)} \times \text{lateral spacing (ft)}}$$

$$= \frac{96.3 \times 17.6 \text{ gpm}}{84 \text{ ft} \times 84 \text{ ft}} = \boxed{0.24 \text{ in/hr}}$$

Example 2: (Precipitation Rate for Stationary Sprinklers)

- A stationary sprinkler has a discharge rate of 13.0 gpm and a wetted diameter of 127 ft. If the sprinkler spacing is set 70 ft and the lateral spacing is set at 80 ft, what is the precipitation rate in in/hr?

$$\text{Precipitation rate (in/hr)} = \frac{96.3 \times \text{discharge rate (gpm)}}{\text{sprinkler spacing (ft)} \times \text{lateral spacing (ft)}}$$

$$= \frac{96.3 \times 13.0 \text{ gpm}}{70 \text{ ft} \times 80 \text{ ft}} = \boxed{0.22 \text{ in/hr}}$$

Time of Operation or Application Run Time for Stationary Sprinklers

Example 2: (Run Time for Stationary Sprinklers)

- If a stationary sprinkler has a precipitation rate of 0.26 in/hr and your target application depth is 0.25 inches, what is the run time for the sprinkler?

$$\text{Time of Operation (hours)} = \frac{\text{target application depth (in)}}{\text{precipitation rate (in/hr)}}$$

$$= \frac{0.25 \text{ in}}{0.26 \text{ in/hr}}$$

$$= \boxed{1 \text{ hr}}$$

Example 2: (Run Time for Stationary Sprinklers)

- If a stationary sprinkler has a precipitation rate of 0.22 in/hr and your target application depth is 0.75 inches, what is the run time for the sprinkler?

$$\text{Time of Operation (hours)} = \frac{\text{target application depth (in)}}{\text{precipitation rate (in/hr)}}$$

$$= \frac{0.75 \text{ in}}{0.22 \text{ in/hr}}$$

$$= \boxed{3.4 \text{ hr}}$$

Precipitation Rates for Traveling Gun Sprinklers

Example 1: (Precipitation Rate for Traveling Gun Sprinkler)

- A traveling gun has a discharge rate of 155 gpm and a wetted diameter of 310 ft. If the angle of rotation is 315 degrees, what is the precipitation rate in in/hr?

First, determine the wetted radius:

Wetted radius = 310 ft ÷ 2 = 155 ft

Next, determine the precipitation rate using the following formula:

$$\text{Precipitation rate (in/hr)} = \frac{96.3 \times \text{sprinkler flow rate (gpm)}}{3.14 \times [0.9 \times \text{sprinkler radius (ft)}]^2} \times \frac{360}{w}$$

$$= \frac{96.3 \times 155 \text{ gpm}}{3.14 \times (0.9 \times 155 \text{ ft})^2} \times \frac{360}{315}$$

$$= \frac{14926.5}{3.14 \times 19460.25} \times \frac{360}{315} = \boxed{0.28 \text{ in/hr}}$$

Example 2: (Precipitation Rate for Traveling Gun Sprinkler)

- A traveling gun has a discharge rate of 900 gpm and a wetted diameter of 520 ft. If the angle of rotation is 345 degrees, what is the precipitation rate in in/hr?

First, determine the wetted radius:

Wetted radius = 520 ft ÷ 2 = 260 ft

Next, determine the precipitation rate using the following formula:

$$\text{Precipitation rate (in/hr)} = \frac{96.3 \times \text{sprinkler flow rate (gpm)}}{3.14 \times [0.9 \times \text{sprinkler radius (ft)}]^2} \times \frac{360}{w}$$

$$= \frac{96.3 \times 900 \text{ gpm}}{3.14 \times (0.9 \times 260 \text{ ft})^2} \times \frac{360}{345}$$

$$= \frac{86670}{3.14 \times 54756} \times \frac{360}{345} = \boxed{0.53 \text{ in/hr}}$$

Application Depth for a Traveling Gun Sprinkler

Example 1: (Application Depth for Traveling Guns)

- The discharge rate for a traveling gun is 120 gpm and the wetted diameter is 270 ft. If the lane spacing is 75% of the wetted diameter and the travel speed is 2 feet per minute, what is the application depth in inches?

First, determine the lane spacing:

0.75 x 270 ft = 202.5 ft

Next, convert travel speed from feet per minute, to inches per minute:

2 ft/min x 12 in/ft = 24 in/min

Now, determine the application depth using the following formula:

$$\text{Application depth (in)} = \frac{19.3 \times \text{sprinkler discharge rate (gpm)}}{\text{lane spacing (ft)} \times \text{travel speed (in/min)}}$$

$$= \frac{19.3 \times 120 \text{ gpm}}{202.5 \text{ ft} \times 24 \text{ in/min}} = \boxed{0.48 \text{ in}}$$

Example 2: (Application Depth for Traveling Guns)

- The discharge rate for a traveling gun is 90 gpm and the wetted diameter is 225 ft. If the lane spacing is 80% of the wetted diameter and the travel speed is 4 feet per minute, what is the application depth in inches?

First, determine the lane spacing:

.80 x 225 ft = 180 ft

Next, convert travel speed from feet per minute, to inches per minute:

4 ft/min x 12 in/ft = 48 in/min

Now, determine the application depth using the following formula:

$$\text{Application depth (in)} = \frac{19.3 \times \text{sprinkler discharge rate (gpm)}}{\text{lane spacing (ft)} \times \text{travel speed (in/min)}}$$

$$= \frac{19.3 \times 90 \text{ gpm}}{180 \text{ ft} \times 48 \text{ in/min}} = \boxed{0.20 \text{ in}}$$

Determination of Travel Speed for a Traveling Gun Sprinkler

Example 1: (Travel Speed for Traveling Gun)

- A traveling gun has a discharge rate is 155 gpm and a wetted diameter of 290 ft. If the lane spacing is 75% of the wetted diameter, what travel speed is necessary to apply 0.4 inches of wastewater?

First, determine the lane spacing:

0.75 x 290 ft = 217.5 ft

Next, determine the travel speed using the following formula:

$$\text{Travel speed (in/min)} = \frac{19.3 \times \text{sprinkler discharge rate (gpm)}}{\text{lane spacing (ft)} \times \text{application depth (in)}}$$

$$= \frac{19.3 \times 155 \text{ gpm}}{217.5 \text{ ft} \times 0.4 \text{ in}} = \boxed{34.4 \text{ in/min}}$$

Example 1: (Travel Speed for Traveling Gun)

- A traveling gun has a discharge rate is 260 gpm and a wetted diameter of 355 ft. If the lane spacing is 75% of the wetted diameter, what travel speed is necessary to apply 0.5 inches of wastewater?

First, determine the lane spacing:

0.75 x 355 ft = 266.3 ft

Next, determine the travel speed using the following formula:

$$\text{Travel speed (in/min)} = \frac{19.3 \times \text{sprinkler discharge rate (gpm)}}{\text{lane spacing (ft)} \times \text{application depth (in)}}$$

$$= \frac{19.3 \times 260 \text{ gpm}}{266.3 \text{ ft} \times 0.5 \text{ in}} = \boxed{37.7 \text{ in/min}}$$

Chapter 7

Health and Safety

Accidents and injuries don't just happen – they are caused. Behind every accident is a chain of events that leads up to an unsafe act; unsafe conditions or a combination of both. Safety in the workplace should be everyone's concern. Communication between supervisors and employees generates ideas and safety awareness that leads to accident prevention. Safety programs, safety manuals and safety meetings are essential in providing the lines of communication that lead to a safe, accident-free workplace.

Regulatory Overview

A variety of federal and state laws and regulations exist to protect workers in both the private and public sectors. At the federal level, the regulatory agency that oversees worker safety is the U.S. Occupational Safety and Health Administration (OSHA). In North Carolina, the Division of Occupational Safety and Health (OSH) has adopted federal OSHA standards, making them more restrictive in some cases. Areas covered by NC OSH:

- General Industry (29 CFR 1910)
- Construction (29 CFR 1926)
- Maritime Operations (29 CFR 1915, 1918)
- Agricultural Operations (29 CFR 1928)

Employer Responsibilities

The following items are the responsibility of the employer or owner:

- Provide a workplace that is free from recognized hazards that are causing or likely to cause serious injury or death;
- Furnish and require use of safety devices and safeguards, safe work practices and procedures, operation and processes that are adequate to ensure employees are safe while performing their jobs; and
- Comply with all NC OSH standards.

Site Supervisor Responsibilities

The following items are the responsibility of the site supervisor:

- Establish and supervise a Health and Safety Program that is designed to improve the safety and health skills and competency of all employees;

- Conduct preliminary investigations to determine the cause of any accident that results in injury. The results of this investigation should be documented for reference;
- Establish and maintain a system for maintaining records of occupational injuries and illnesses;
- Provide new employees with a safety orientation on the special hazards and precautions of any new job;
- Conduct job briefings with employees before starting any job to acquaint employees with any unfamiliar procedures;
- Issue any needed safety equipment and manuals; and
- Conduct periodic group safety meetings.

Employee Responsibilities

The following items are the responsibility of the employee:

- Comply with OSHA standards and rules that are applicable to his or her own actions and conduct;
- Keep informed of current safe work practices and procedures;
- Be responsible for his or her own safety;
- Request instruction from the site supervisor if there is a question as to the safe performance of work assigned;
- Use appropriate safety devices and wear suitable clothing and appropriate personal protective equipment (PPE); and
- Report to the site supervisor any unsafe conditions, practices or procedures.

Health and Safety Program

As mentioned above, it is the site supervisor's responsibility to develop a Health and Safety Program. This program should include:

- procedures for reporting incidents, injuries, and unsafe conditions or practices;
- instructions on identification and safe use of hazardous gases, chemicals and materials and emergency procedures following exposure; and
- use and care of personal protective equipment.

Incident Reporting

As part of the Health and Safety Program, all facilities should develop a formal incident reporting and investigation program. All incidents, including injuries, accidents and near misses should be reported to the site supervisor immediately. These incidents should be

investigated as soon as possible to determine their root cause.

The information gained from an investigation should then be used to change work practices and to eliminate hazardous activities. Injuries requiring treatment other than first aid treatment must be reported on OSHA 200 form (Log and Summary of Injuries and Illnesses).

Hazard Communication Standard

The Hazard Communication Standard, mandated by OSHA, is another important component of any Health and Safety Plan. The goal of the Hazard Communication Standard is to reduce injuries and illnesses resulting from improper use, storage, etc., of chemicals in the workplace. Employers must inform or instruct employees about the following regarding chemicals that are used in the workplace

- safety and health standards for the safe use of those chemicals
- known health hazards of the chemicals used in the workplace
- methods of hazard control
- proper labeling of containers
- maintaining current material safety data sheets (MSDS) on all chemicals
- chemical inventory
- procedures to use in normal use or a foreseeable emergency
- training in recognizing, evaluating and controlling hazards

Chemical Hygiene Plan

Another standard that goes hand-in-hand with the Hazard Communication Standard is the Laboratory Standard, or more exactly, the Occupational Exposure to Hazardous Chemicals in Laboratories Standard. Facilities that have a laboratory that performs analytical tests may need to develop a chemical hygiene plan.

A chemical hygiene plan includes the following:

- how laboratory personnel handle and work with hazardous laboratory chemicals;
- how employee exposure to these chemicals will be minimized;
- what personal protective equipment will be used in the laboratory; and
- specifications for working with particularly hazardous substances, such as cancer causing chemicals, and certain other requirements.

The requirements of the laboratory standard can be found in the OSHA regulation 29 CFR 1910.1450, including the appendices. This plan must be a written plan and must be evaluated on a regular basis for effectiveness.

Personal Protective Equipment

Another important component of a Health and Safety Program is a written program covering the appropriate selection, use, and maintenance of personal protective equipment (PPE). The proper selection and use of personal protective equipment is one of the most effective methods for preventing occupational injuries and illnesses.

Types of personal protective equipment include:

- head protection;
- eye and face protection;
- hearing protection;
- foot and leg protection;
- body protection; and
- respiratory protection.

Head Protection

Any head injury has the potential to be serious. Any injury that results in brain damage can cause memory loss, affect the ability to reason, and cause changes in personality and emotions. Any of these changes can result in disability and interfere with the ability to earn a living.

Fortunately, there is a wide variety of protective equipment suitable for the activities normally associated with wastewater treatment facilities.

Bump caps are lightweight plastic caps designed to protect the head from bumps and scrapes encountered in tasks such as building and machinery maintenance. However, a bump cap will not provide protection from impact, such as a dropped tool or other heavy object. Bump caps are also recommended for tasks where cleanliness and sanitation are high priorities, such as in food processing plants or when handling pesticides. A bump cap or hard hat can be decontaminated with soap and water; but a baseball cap or cowboy hat cannot be completely decontaminated of chemicals.

Safety helmets (commonly referred to as 'hard hats') are primarily intended to protect the head from falling objects, although they can also provide protection from flying objects. A hard hat consists of a sturdy shell, usually made of plastic, and a suspension that holds the shell at least 1¼ inches from the head. When an object strikes the hat, the force is distributed through the suspension to a large area of the head and neck, preventing puncture wounds and concussion injuries in most cases.

Hard hats are recommended for all construction and timber harvesting activities and any other

tasks involving the risk of bumps or falling objects. While a hard hat may not be able to protect a person from a severe, direct blow, it can deflect many glancing blows that might otherwise result in serious injury or death.

Accessories that can be mounted on a hard hat include welding helmets, face shields, hearing protectors and communications devices. These are useful because several personal protective items needed for a particular task can be kept together. For example, a hard hat with a face screen and hearing protectors is ideal for chain saw operation.

Although hard hats are heavier than baseball caps, they are cooler than baseball caps because there is an air space between the head and shell. This coolness is welcomed in summer, but a liner is often needed in winter to maintain comfort.

Accidents, abuse or improper care can damage any type of protective headgear. Remember these points.

- Always replace any protective headgear that has received a hard blow, because it may have sustained damage that is not visible.
- Never wash any protective headgear with anything stronger than mild detergent and water. Solvents can weaken or destroy the plastics used for protective headgear.

NOTE: Use safety helmets that comply with the American National Standards Institute (ANSI) Z89.1 criteria. Never use a metal hard hat when working around electrical systems.

Eye and Face Protection

Our eyes are one of the most vulnerable parts of our bodies. Chemical burns, flying particles, cuts, heat, light, and blows to the head or face can cause eye injuries. Eye and face protective devices include face shields, safety glasses, and goggles.

Safety glasses are available in a wide variety of styles and can be equipped with or without side shields. Lenses can be made of plastic or heat treated or chemically treated glass. Metal frames should not be worn in an electrical hazard area.

Goggles can be worn over regular prescription eyewear. The frames are made of molded synthetic rubber, natural rubber or vinyl. Lenses are made of plastic, acetate, or glass. Goggles with ventilation should be used where fogging is a problem. In areas where dust, smoke, aerosols, chemical splashes or fumes can irritate eyes, goggle without ventilation should be used.

Face shields provide additional protection for eyes and should only be worn over primary eye

protection. They also provide protection for the nose, mouth and throat. Face shields are generally made of plastic but are available in reflecting metal screen where radiant heat is a problem. Face shields can be attached directly to a hard hat.

Hearing Protection

Noise is a fact of life; however, noise above a certain level can be harmful and cause permanent hearing damage. Noise can come from a variety of sources, such as gasoline or diesel engines, gas or electric blowers, mechanical equipment, spreaders, and other types of machinery.

Each employer is required to determine if noise above what is called the "action level" exists in the workplace. If so, actions must be taken to reduce the noise level and protect the employees. The employer is required to develop a "hearing conservation program" which is designed to effectively limit employee exposure to harmful levels of noise. OSHA regulation 1910.95 stipulates what a minimum level hearing conservation program must contain and provides guidance for employers to develop their own effective program.

In essence, the hearing conservation program states that employees must wear proper ear protecting devices whenever they are working in a noise hazard area. Hearing protection devices include earplugs, earmuffs, and semi-aurals or canal caps.

Hand and Arm Protection

In this section we will discuss barrier creams and gloves. However, one of the best methods of protecting the hands (and preventing dermatitis elsewhere) is to thoroughly wash the hands with soap and water and dry them with single-use towels when finishing a task, before eating and after using the restroom.

Barrier creams protect the hands by forming a protective film on the skin that reduces contact with irritating or harmful chemicals. The barrier cream is applied like a hand lotion, and can be washed off with soap and water.

There are at least four types of barrier creams available: one for oils and solvents; one for caustics, coolants and fertilizers; another for epoxies; and one for water-based hazards. A barrier cream will not provide protection from cuts and scrapes, nor will it protect your hands from strong chemicals or from prolonged exposure to milder chemicals.

However, barrier creams are an excellent choice for certain maintenance tasks because they permit normal use of hand tools and they do minimize exposure to chemicals such as used engine oil.

Gloves are available in a wide variety of styles and materials, each having its advantages and disadvantages. Since there is no single type of glove that is suitable for all tasks, it is important to understand a few basics of selecting gloves.

When determining the types of gloves to use you may want to ask yourself the following questions:

- Do you need protection from cuts and scrapes, protection from heat or protection from chemicals?
- Are the hazards low, moderate or high?
- Do you need to wear them all day, or intermittently?
- Do you need good manual dexterity for handling controls, tools or small objects?

Glove selection becomes complicated when a situation involves several hazards or types of tasks. Pesticide labels are required to give specific recommendations for personal protective equipment, including gloves. You must use the PPE stated on the pesticide label to comply with federal and state regulations.

For products other than pesticides, check the label for PPE recommendations or refer to a chemical resistance chart (featured in safety product catalogs) and select a material that provides good to excellent resistance from the chemicals you will be exposed to. Never use leather or fabric gloves when handling toxic chemicals since the chemicals readily penetrate these materials, and they can never be fully decontaminated.

Gloves are made from many materials. You may need three to four types of gloves to meet your needs. Choices will depend on the your specific needs for protection from chemical and physical hazards.

Fabric (jersey, cotton flannel, knit, etc.) gloves are inexpensive and suitable for many tasks where protection is needed from minor cuts and scrapes. Cloth gloves are also ideal for tasks where protection is needed from friction or when a glove might aid in gripping objects. Gloves with dimples or rubberized fabric on the palms and fingers are excellent when using hand tools and other similar tasks.

Some fabrics are also used for high temperature applications, such as welding gloves. These may be more flexible than leather welding gloves, but can result in serious burns if they are wet when a hot object is picked up, unless they have a moisture barrier. A significant advantage of cloth gloves is that they breathe well, minimizing perspiration buildup.

Leather is possibly the best all-around choice for protection from cuts, scrapes, friction and other physical hazards. It is tough, flexible, inexpensive, and breathes well. Leather can be sewn into a wide variety of gloves and may be used in conjunction with other materials for specialized purposes.

For example, Kevlar® (the material used in body armor for police officers) is used in gloves for chain saw operators to provide extra protection from cuts should the left hand come in contact with the moving chain. Another example is the insulating materials sewn inside gloves used by welders to protect them from burns.

Rubber gloves are needed for protection from the wide variety of chemicals that may be used at a surface irrigation site. However, there are several 'rubber' materials used for gloves today, and it is important that the correct material be used. Using the wrong material can allow chemicals to penetrate through the gloves or cause the gloves to deteriorate.

Always refer to the manufacturer's chemical resistance chart and glove selection guidelines when selecting rubber gloves. Cut-resistant materials such as Kevlar®, steel reinforced fabrics, and chain link mesh are used in gloves designed for tasks where cuts are a major risk, such as handling glass and other sharp objects. Although these materials can be cut, they offer superior protection while permitting the user to grasp tools and other objects. Cut-resistant gloves often feature slip-resistant materials or textures on the fingers and palm to minimize the risk of sharp objects slipping through the hands, thus reducing the risks of a cut.

Whatever type of gloves you chose, remember these points:

- Gloves should be thick enough to provide adequate chemical resistance and prevent punctures or tears, yet thin enough to provide a good grip and manual dexterity. Examination gloves (like doctors use) are not adequate for protection from most chemicals, especially pesticides.
- Unlined gloves are normally recommended when using chemicals since they can be easily washed and decontaminated. Flock-lined gloves are more comfortable, however, and often cost less than unlined gloves. Any lined gloves should be disposed of if contaminated inside by chemicals.
- Gloves should be thick enough to provide adequate chemical resistance and prevent punctures or tears, yet thin enough to provide a good grip and manual dexterity. Examination gloves (like doctors use) are not adequate for protection from most chemicals, especially pesticides.
- The color of the gloves will affect comfort, especially outdoors. Black gloves will absorb

heat from the sunlight, making them uncomfortable, so select a lighter color for outdoor work.

- Cut, length and thickness affect the comfort and performance of any glove. Some gloves may be so heavily constructed that they will last forever - because they are too stiff or otherwise uncomfortable to be used on a routine basis.

  Gloves that are too heavy or uncomfortable, or which do not fit well, can significantly reduce a worker's productivity by making it difficult to handle tools and other objects. Those gloves can also be dangerous in certain situations. Other gloves may be very comfortable, but not durable enough to provide satisfactory performance and economy.

  The ideal glove fits well, provides the needed protection, permits good productivity and is economical. If there are several workers, it is likely that several styles or sizes of gloves will be needed. Try several styles of gloves to determine which provides the best comfort, grip and dexterity needed for the intended tasks.

Foot and Leg Protection

Injuries to the feet are uncomfortable at best, and they can seriously interfere with the ability to accomplish work activities. Although most foot injuries are not serious, they do result in pain and lost production. Injuries resulting from dropped objects, punctures and strains or sprains due to slips and falls are probably the most common. Most of these can be prevented through a combination of safe work practices and use of proper footwear.

While you may not always need to wear high-top steel-toe boots with steel shank and lug soles, you probably should wear them some of the time. Sneakers and smooth soled shoes are not good because they do not provide protection from commonly encountered hazards.

Perhaps the most important aspect of good footwear is a non-slip sole. Good traction is needed to prevent slips and falls while walking on various surfaces, and especially when climbing ladders and stairs. Smooth leather soles common on western boots and dress shoes may be too slippery on many surfaces. Soles with lugs or texture may provide better traction, especially when made of the soft, yet long wearing materials found in quality boots. A steel shank can provide improved puncture resistance as well as improved support in activities that place concentrated loads on the feet, such as prolonged work on ladders or repeatedly pressing machinery brake pedals.

Steel toe safety shoes are intended to protect the toes from injuries caused by dropped objects. While steel toecaps are very effective in preventing injuries to the toes, they will not protect the rest of the foot. Like any shoes or boots, safety shoes will not be comfortable unless they fit

properly.

Most reputable safety shoe dealers can fit all sizes and widths from AAAA to EEE. If they fit properly, the steel toe cap will only be noticed if it prevents an injury, when you are squatting or otherwise have your toes bent far back, or if you kick something and push your toes against the toe cap.

Safety shoes are available in a wide variety of styles, including dress shoes, western boots as well as leather and rubber work boot styles. Some special purpose boots are available which incorporate instep guards to prevent injuries behind the toes, Kevlar® pads to prevent cuts from chain saws, and with caulks (screw-in spikes) to prevent slips when working on logs or ice.

Rubber boots are recommended for tasks involving prolonged contact with water or whenever there is a risk of exposure to hazardous chemicals, such as pesticides. Just as when selecting rubber gloves, make sure the material is suitable for the exposure. To prevent water and chemicals entering the top of the boot, place the coveralls outside the boot to shed water onto the ground.

A consideration that is often overlooked when using rubber boots is perspiration removal. Because rubber boots do not breathe, perspiration cannot readily escape, so the socks and feet will eventually be soaked with perspiration. Keeping the feet dry is essential for good health, so proper measures must be taken. Socks of polypropylene and cotton blends can help wick the moisture away, and moisture absorbent liners are available as well. Remove the boots and allow the feet to 'breathe' and dry occasionally.

To help prevent foot health problems always wash and dry the feet at the end of each day, allow footwear to dry and air out between uses, and begin each day with clean, dry socks.

Body Protection

The skin is your body's largest organ and performs a number of vital functions: keeping moisture in; sweating to cool your body; and keeping harmful agents from entering the body. Because the skin is exposed to so many hazards, it is important to protect it. While the skin can adequately protect the body from many hazards (such as most bacteria), it can easily be penetrated or damaged by many chemicals.

Another alarming fact is the increased incidence of skin cancers resulting from sun exposure. People who spend long hours in the sun are at increased risk of developing skin cancer unless they take protective measures.

Friction, scrapes and cuts are also common sources of skin injuries and irritation. Properly selected clothing can prevent or minimize the chances of many skin disorders. 'Normal' clothing can prevent many types of skin problems. For example, a light colored long-sleeve shirt can protect the arms and upper body from sunburn and reduce the risks of skin cancers, and the long-sleeve shirt may actually be cooler than a short-sleeve shirt when working in the sun because it will reflect the sunlight. Other clothing that helps prevent sunburn and skin cancer includes a wide-brimmed hat to protect the ears, face and neck and long pants to protect legs.

Coveralls should be made of a tightly woven fabric such as cotton or polyester or of a non-woven fabric. They should fit loosely. Unless there is a layer of air between the coverall and the skin, any chemical that gets through the coverall will be in direct contact with the skin. Each layer of clothing worn under the coverall adds not only a layer of material, but also a protective layer of air. Well-designed coveralls have tightly constructed seams and snug, overlapping closures that do not gap or become easily unfastened.

Rubber or chemical-resistant aprons are needed when handling liquids for prolonged periods of time, or when handling concentrated chemicals. Wear an apron even if other protective clothing is also being worn. Keeping the skin clean and dry is always important, but the groin area is especially sensitive. Chemicals can penetrate the skin of the groin area more than 11 times more readily than through the forearm. A splash of a concentrated chemical here could result in a high dose of toxins entering the body very quickly.

Choose an apron that extends from the neck to at least the knees. Some aprons have attached sleeves, which can also protect the arms. Be aware that an apron can be a safety hazard in some situations. It can get in the way or get caught in machinery. In these situations, consider wearing a chemical-resistant suit instead.

Chain saw safety chaps or pants minimize the risk of cutting the legs when operating a chain saw. The chaps will not prevent all cuts, but have been proven effective in reducing the severity of leg injuries from chain saw cuts.

Made from Kevlar® or other ballistic materials, the chaps prevent many cuts by covering the cutters with fibers to reduce their cutting efficiency, giving the operator a small amount of additional time to regain control of the saw. Some people use chain saw chaps when loading square bales of hay to reduce the number of scratches and scrapes on their legs from carrying and boosting the bales upward with their knees. The chaps also help protect the legs from thorns when walking through brushy areas.

Respiratory Protection

Operators are exposed to irritating and potentially harmful airborne contaminants while working at a surface irrigation facility. Examples of air contaminants include particles of pollen, bacteria, mold spores, wastewater aerosols, hazardous chemicals, engine exhausts and welding fumes. The respiratory system is one of the easiest ways contaminants can enter our bodies.

One problem with occupational illnesses is that the worker may not associate the illness with job-related exposures. Symptoms of respiratory illness may be mistaken for the flu, common cold or simple exhaustion.

Another problem is that people may perform a particular task for years without experiencing adverse health effects, but suddenly experience a severe reaction to even slight exposures to contaminants. The body can become 'sensitized' and no longer tolerate even small exposures to a substance. Additionally, some exposures can lead to permanent lung injury and disability.

Selecting and using a respirator involves more than simply purchasing one and putting it on. Using the wrong respirator, or using a respirator improperly, can result in serious illness or death. The respirator must be selected for the specific contaminant(s) in your workplace and it must fit properly. In addition, the respirator must be properly cleaned, inspected and stored after each use to prolong its life and help ensure protection for later uses.

The best way to select a respirator is to consult an industrial hygienist or other similarly qualified professional. If respirators are needed, these professionals can assist with selection, fit testing and training you and your employees to use the respirator properly. Additionally, a written respiratory protection program must be developed that specifies how these tasks will be accomplished.

There are two basic types of respirators: air-purifying respirators and air-supplying respirators.

- Air-purifying respirators remove contaminants from the air by filtering dust, mists, and particles or by removing gases and vapors. These respirators will not protect an operator from fumigants, from high concentrations of vapor, or when the oxygen supply is low. Air-purifying respirators pass air through the air purifying material in two ways. Negative-pressure respirators depend on the wearer's lungpower to draw air through the purifying material. Powered air-purifying respirators (PAPR's) assist the wearer by forcing air through mechanically. PAPR's purify contaminated air as it passes through the filter; they do not supply oxygen. There are several styles of air-purifying respirators:

- Cup-style respirators filter out dust, mists, powders and particles. They are usually shaped filters that cover the nose and mouth.
- Cartridge respirators are half-mask or full-face respirators that have chemical cartridges containing air-purifying materials. Many chemical cartridge respirators can be fitted with particulate pre-filters. By using the proper cartridges and pre-filters, it is possible to use chemical cartridge respirators in a variety of situations. Chemical cartridges are color-coded so you can determine at a glance whether the correct respirator is in use. The cartridge needed depends on the particular contaminants present since different filter materials must be used for the various chemical hazards.
- Canister respirators (gas masks) are full-face respirators with attached canisters containing air-purifying materials. Canisters usually contain more air-purifying materials than cartridge respirators. The face-piece is designed to be cleaned and reused. Canisters can be replaced.

- Air-supplying respirators supply clean, uncontaminated air from an independent source. These are the only respirators that provide oxygen and can be used in oxygen deficient atmospheres or atmospheres that are immediately dangerous to life or health. There are two types: the supplied-air respirator and the self-contained breathing apparatus (SCBA). A supplied-air respirator provides breathing quality air from an approved air pump located in a safe atmosphere or from a remote tank of breathing air. An SCBA supplies clean air from cylinders that are carried with the operator, usually on the back. Air-supplied respirators must be inspected and tested regularly and should only be used by specially trained individuals. Use by untrained persons could lead to serious injury or death.

WARNING: Use only respirators approved by NIOSH or MSHA for the hazards present in the workplace.

Health and Safety Hazards

As an operator of a surface irrigation facility, you will be exposed to numerous common hazards:

- physical injuries;
- infections and infectious diseases;
- oxygen deficiency;
- toxic or suffocating gases or vapors;
- chemical contamination;

- explosive gas mixtures;
- fire;
- electrical shock;
- noise-induced hearing loss;
- dust, fumes and mists; and
- heat exhaustion and heat stroke.

Health and Safety Measures

There are numerous safety practices, training and equipment that an operator can use to minimize the risk of the hazards listed above. These include:

- process safety management and risk management programs;
- confined space safety;
- general site safety;
- lockout/tagout policies;
- electrical safety;
- mechanical safety;
- vehicle safety;
- lagoon safety;
- fire prevention and protection;
- excavation and shoring safety;
- medical safety.

OSHA Process Safety Management & EPA Risk Management Programs

These two programs regulate how certain highly hazardous chemicals are to be used, stored, or manufactured. The goal of both programs is to prevent accidental releases of the substances that can cause serious harm to the public and the environment. If you store or have on site at any one time more than a "threshold quantity" (TQ) of the chemicals listed below, then a process safety program and/or a risk management program may be needed. EPA and OSHA have slightly different listings and slightly different threshold quantities and exemption from one program does not necessarily mean exemption from the other.

Generally, if a wastewater treatment facility uses the chemicals in the amounts listed in Table 7-1, the facility will need to develop a program. Specific information on the OSHA program can be found in 29 CFR 1910.119 and specific information on the EPA program can be found in 40 CFR 68.

Chemical	EPA TQ	OSHA TQ
Chlorine	2,500	1,500
Anhydrous Ammonia	10,000	10,000
Aqueous Ammonia	>20% 20,000	> 44% 15,000
Anhydrous Sulfur Dioxide	5,000	1,000 (liquid)
Methane	10,000	10,000
Propane	10,000	10,000

Table 7-1. Threshold quantities for chemicals requiring a process safety program or risk management program (all quantities are in pounds).

Confined Space Safety

Many different areas in wastewater treatment facilities are considered confined spaces. There are two types of confined spaces. The first, a confined space, is defined as a space that has limited means of access (entry) and egress (exit), has an adequate size and configuration for employee entry and is not designed for continuous worker occupancy. The second type, a permit-required confined space, requires a permit for entry.

A permit-required confined space is a confined space that may have a potentially hazardous atmosphere, may have an engulfment hazard, may have an entrapment hazard, or it may contain any other recognized hazard.

If a facility has permit-required confined spaces, a written confined space entry program must be developed and implemented in order to be in compliance with OSHA regulations. Enclosed facilities that are used to handle wastewater or wastewater solids, such as the tanks and/or tanker trucks, would fall under the permit-required confined space regulations. **Do not enter a permit-required confined space without proper training, equipment and support personnel.** (The confined space regulations can be found in the Code of Federal Register 29 CFR 1910.147.)

The atmosphere of a confined space may be extremely hazardous because of the lack of natural ventilation. This can result in the following dangerous situations:

- oxygen-deficient atmospheres;
- flammable atmospheres; and
- toxic atmospheres.

An oxygen-deficient atmosphere has less than 19.5% available oxygen (Figure 7-1). Any

atmosphere with less than 19.5% oxygen should not be entered without an approved self-contained breathing apparatus (SCBA). Oxygen-deficient atmospheres may be found in sewers, manholes, septic tanks, and pump tanks.

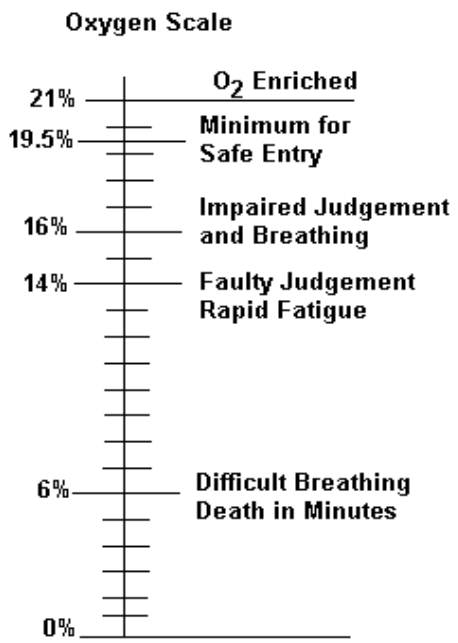


Figure 7-1.Oxygen scale (from Confined Spaces, 1988).

When working in a confined space that does not require a permit, the a number of safety actions must be taken.

- Use a ladder, hoist or other device when accessing these work areas.
- Verify that the confined space is clean and well ventilated. Test the atmosphere of the space, from the top of the work space to the bottom, for flammable/toxic gases and oxygen deficiencies PRIOR to entering the work space and repeat testing during the work period.
- Use lifelines and always assign a standby person to remain on the outside of the confined space. It is the standby person's responsibility to be in constant contact (visually and/or verbally) with the workers inside the confined space as long as anyone is in the space.
- Wear ear protection, as needed. Noise within a confined space can be amplified because of the design and acoustic properties of the space.
- Be mindful of the possibility of falling objects when working in confined spaces.
- SCBA should be used in confined spaces where there is insufficient oxygen.

General Site Safety

A surface irrigation application site should be restricted to authorized personnel. This is necessary to prevent mishaps involving the public and to help ensure that the site and all equipment are protected from vandalism and theft. Maintaining the surface irrigation application site promotes a safe, well-kept working environment. Site maintenance includes the following:

- Keep walks, aisles and access ways clear of tools and materials. It is also important to maintain clear access to electrical panels, control valves and fire extinguishers.
- Clean up puddles of oil, sludge, wastewater, or fuel promptly and thoroughly. Use absorbent material if necessary.
- Dispose of dirty and oily rags, used absorbent materials, trash and other waste materials in approved containers. The waste should be removed from the site and disposed of properly.
- Provide scrap containers or scrap collection area where needed.
- Keep the sanitary facilities clean.
- Keep supply areas organized and free of hazards.
- Provide adequate illumination and ventilation.

Lockout/Tagout Policy

A lockout is a padlock placed on a power source to block the release of hazardous energy that could set a machine in motion or otherwise endanger an employee working on the machine. Locks are usually used with a lockout device that holds an energy control point, such as a switch lever or valve handle in the "off" position and prevents machines or equipment from being operated while the machine is being worked on.

A tagout is a written warning that tells other workers not to operate a switch or valve that could release hazardous energy or set a machine in motion. Lockout is preferred because it is a more secure method of controlling and isolating hazardous energy sources. Although lockout/tagout policies most commonly refer to electrical energy, the following types should also be covered:

- mechanical;
- hydraulic;
- pneumatic;
- stored;
- chemical; and
- thermal.

A written lockout/tagout program should be developed that specifies how individual machines

or equipment will be taken out of and returned to service. Once the program has been developed, all employees who use or perform maintenance on any of the affected equipment must be properly trained.

Electrical Safety

Treat all electricity and electric power equipment with caution. Ordinary 120 V electricity can be fatal. Most wastewater treatment systems operate from 120 V to 4000 V or more. In case of electrocution, turn off power to the electrical source or use an insulated implement, such as a piece of wood to separate the person from the source. Do not attempt to pull a victim away from the electrical source with your bare hands.

The following is a list of general electrical safety practices (from Operation of Municipal Wastewater Treatment Plants, WEF):

Allow only qualified and authorized personnel to work on electrical equipment and wiring or to perform electrical maintenance.

- Provide and use lockout devices and tags at all locations.
- Always assume electrical equipment and lines to be energized unless they are positively proven to be de-energized and properly grounded. If it is not grounded, it is not dead.
- Prohibit use of metal ladders or metal tape measures around electrical equipment.
- Ensure that two people always work as a team on energized equipment.
- Use approved rubber gloves on voltages more than 300 V.
- Do not open an energized electrical control panel.
- Before work is done on a line or bus that operates at 440 V or higher, be sure it is de-energized, locked out, and grounded in an approved manner.
- Do not test a circuit with any part of the body.
- Prevent grounding by avoiding body contact with water, pipes, drains, or metal objects while working on electrical equipment or wiring.
- Do not bypass or render inoperative any electrical safety devices.
- When working in close quarters, cover all energized circuits with approved insulating blankets.
- Use only tools that have insulated handles.
- Never use metal-cased flashlights.

- Do not wear jewelry when working with or near electric circuitry.
- Ground or double-insulate all electrical tools.
- Use rubber mats at control centers and electrical panels.
- Always keep electric motors, switches, and control boxes clean.

Mechanical Safety

Always make sure that sprinklers, guns, hydrants, valves, and plugs are not pressurized when servicing or repairing surface irrigation equipment. Pressure can cause parts to blow off equipment, resulting in injuries. When servicing, always turn pumps off and de-pressurize lines by opening drain valves or opening discharge points to relieve water pressure. If you must clean a nozzle, operate an isolation valve and clean the nozzle when not under pressure. Always use the proper tools when working in valve boxes. These areas can be pinch points and are favorite havens of spiders and snakes, so be alert!

Equipment such as traveling guns and center pivots (tractors) have many pinch points and moving parts. Always keep equipment guards in place, always tie back long hair, and do not wear loose clothing when operating this type of equipment. Be familiar with operational parameters from manufacturers' literature. Have a qualified electrician install and service all electrical systems for this type of equipment.

Operating traveling guns (or hard-hose travelers) on steep and complex terrain can present safety concerns. Slopes up to 15 percent (and possibly slightly higher) can be effectively managed with traveling guns. However, the guns should be traversed across the slopes in an "up and down" fashion as opposed to pulling the gun sideways across the slope. If the gun is pulled sideways across the slope, the potential for a flipped gun cart is much greater.

Should a gun cart flip, the system continues to apply wastewater from whatever position the sprinkler gun is in, creating a safety hazard. Gun carts typically have an adjustment that allows the wheel or track width to be increased. The widest footprint possible should be used on sloping terrain. Side slopes above eight percent should be avoided if a sideways pull must be used. Travel lanes for gun carts should be inspected for steeply sloping areas, gullies, tree roots, rocks, or any other disturbances in a field. These all have the potential to cause the gun cart to come off track or flip over. These situations must be corrected, or another travel lane selected, in order to use the field safely.

Machine Guarding

Any machine part, function, or process, which may cause injury, must be safeguarded. Safeguards are needed in the following locations:

- at the point of operation, where the machine contacts the material and performs operations such as cutting, punching, grinding, boring, forming or assembling;
- near power transmission components such as pulleys, belts, connecting rods, cams, chains, sprockets, cranks, and gears; and
- at other parts of the machine that move (rotation, reciprocating movement, transverse movement) while the machine is working.

Operate machinery only if you have been trained and authorized to use it. Don't wear jewelry on the job. While gloves are recommended for many tasks, don't wear them in situations where they could get caught and draw you into a machine. Don't try to adjust or reposition material while a machine is running. Wear the appropriate PPE equipment. Always operate machinery with the safeguards in place. Report missing or damaged safeguards to the site supervisor.

Pressure/Vacuum Equipment

The proper venting of storage tanks is imperative. Pressure relief valves must be kept in good working condition. In addition, venting procedures should be used when operating equipment.

- Vent tank (so there is no pressure or vacuum) by opening hatches or manholes.
- Do not go on top of a tank when it is under pressure, as the pressure relief valve can operate at any time.
- When opening a pressurized tank's manhole cover after the pressure has been relieved, always open the clamping devices next to the hinge first. Open the clamp with the safety catch last.
- Relieve the pressure in the hose before disconnecting it to avoid possible injury from unrestrained action of the hose or spill of wastewater.
- Do not restrict or block off safety valves or blow-down lines.
- The accumulation of gases within a confined space offers the potential for the vessel to explode or relieve the pressure at a weak point. ALWAYS stay to the side of all covers when opening. NEVER stand with your head or body over the cover when opening.

Hydraulic Systems

- Do not open pressurized lines. Hydraulic fluid can cause severe burns, eye injury, or skin irritation.
- Search for leaks in the line using a piece of cardboard or wood, not your hands.
- If anyone is injured by hydraulic fluid: first, administer first aid; then contact a physician.
- Stay clear of leaky hydraulic lines.

Vehicle Safety

Only employees with a current, valid N.C. driver's license can drive vehicles. In the case of specialized vehicles, only trained operators should operate the vehicles. The driver of the vehicle should inspect the vehicle prior to operating it and follow these guidelines while operating it:

- All vehicles should be operated within the legal speed limit at all times or at slower speeds where conditions warrant.
- Vehicles should not be used to transport unauthorized personnel.
- The driver should be familiar with the capacity and required clearances for safe use of the vehicle.
- Vehicle windshields and windows should be kept clear of obstructions.
- Objects or persons being transported should be located so that they do not obstruct the driver's view.
- Always know the proper operating procedures for each piece of equipment used.

Heavy Equipment Vehicles

Make sure everyone is clear of the vehicle before starting. Slight steering movement can occur as the engine starts, causing machine movement. Stay clear of the engine when it is running. Work on the engine only when it is off. Do not move the steering wheel until everyone is clear of the vehicle.

Heavy Over-The-Road Vehicle Operation

Carefully inspect trucks or trailers before moving to ensure that material and equipment are

properly loaded and secure. Loads on trucks and trailers should not exceed rated capacities. Securely couple trailers to the towing vehicle when towing. Secure all trailers with safety chains or cables, except those attached to a tractor by a "fifth wheel."

Heavy Off-The-Road Vehicle Operation

Drive at a safe, legal speed to ensure safety and complete control of the vehicle, especially over rough terrain. Unless the vehicle is designed for more than one person, no one other than the operator should be on the vehicle. Always observe the speed limits of local landowners. Yield the right-of-way to local trucks and local road maintenance machinery. Use chock blocks by the tractor and trailer when the driver leaves the vehicle.

Lagoon Safety

Never go out on the lagoon to sample or for other purposes by yourself. Another worker should always be standing by in case of emergency. Always wear an approved life jacket when you are working from a boat on the surface of the lagoon. Never stand up in a boat while performing work. If it is necessary to drive a vehicle on a dam, make sure the roadway is maintained and is in good driving condition. Do not allow potholes or ruts to develop. Be extremely cautious when driving on dams during wet weather. If you must walk on the inside sideslope, you should be harnessed and attached to prevent sliding into the lagoon.

Fire Prevention and Protection

It is important to be fire-conscious in the outdoor environment. Employees should be knowledgeable of the fire conditions at the site and operate accordingly. Poor site maintenance, worn or defective electrical systems, and welding and cutting may contribute to dangerous situations.

The following precautions should be observed:

- do not smoke near equipment or fuel trailers;
- no open flame should be allowed near wastewater storage tanks;
- do not allow wastepaper, rags and other combustible materials to accumulate;
- do not tamper with or remove fire-fighting equipment from designated locations for purposes other than fire-fighting or rescue operations;
- access to fire equipment should not be hindered;
- if fire extinguishers are used they should be promptly recharged; and

- inspect fire extinguishers monthly to be sure they are in good operating condition.

Excavation and Shoring Safety

Working at a surface irrigation facility, you or your co-workers may have to excavate sewer lines periodically. You should be familiar with the fundamentals of excavating and the proper, safe methods of shoring a ditch.

The first step is to have the soil compressive strength measured by a competent person on site. Shoring/bracing is required when the depth of an excavation or trench is greater than five feet. Material taken from the excavation or trench must be stored more than two feet from the edge of the excavation. No heavy equipment or vibration should be allowed beside of the excavation. The excavation or trench needs to be checked periodically for change in conditions, especially after rainy or wet weather.

Medical Safety

First Aid Training

There should be present, or available at all times, a person (or persons) with first aid training. If the surface irrigation site is more than fifteen minutes away (including transport time) from a clinic, hospital, or physician, OSHA requires a designated person qualified in first aid and CPR training to be present at all times.

The training should include but not be limited to:

- bleeding control and bandaging;
- artificial respiration, including mouth-to-mouth resuscitation;
- poisons;
- shock, loss of consciousness, stroke;
- burns;
- heat stress, heat stroke;
- frostbite, hypothermia;
- strains, sprains, hernias;
- fractures and dislocations;
- bites and stings;
- transportation of the injured; and
- specific health hazards likely to be encountered by co-workers.

There should be adequate first aid kits and supplies on site and readily available. A list of all employees with first aid qualifications should be posted, along with a list of emergency telephone numbers.

Blood-borne Pathogen Awareness

All workers at a surface irrigation facility should be aware of the potential for contracting a blood-borne disease, such as hepatitis A or tetanus. Human Immunodeficiency Virus (HIV) is also considered a blood-borne pathogen and precautions should be taken when in direct contact with wastewater or sewage. One study has shown that HIV can survive in wastewater for up to twelve hours.

OSHA requires an employer to provide specific training and personnel protective equipment for your job if a blood-borne pathogen exposure is expected by job classification. Components of such a program are:

- safe work practices;
- use and care of PPE;
- housekeeping;
- employee training;
- incident reporting; and
- employee medical monitoring.

Eyewash Stations

Suitable facilities for quick drenching or flushing of the eyes and body should be provided in areas where the eyes or body of any person may be exposed to injurious chemicals and materials. Eyewash equipment can either be portable or permanently installed. Both styles of dispensers allow a gentle trickle of water to flow across the eye. If someone's eyes have been exposed to a chemical, such as chlorine gas, the eyes should be flushed for at least 15 minutes to dilute and remove as much of the chemical as possible. Medical professionals should be consulted for any eye injury.

Immunization

Each facility may want to consult a physician or the local health department to determine the need for immunizations for the employees working at the site. Adult tetanus and diphtheria should be given routinely every 10 years, or at shorter intervals when injury occurs.

Personal Hygiene

Because wastewater contains pathogens, good personal hygiene is very important. Good hygiene is one important way to reduce your exposure to these pathogenic organisms.

- Keeping your hands away from your nose, mouth, eyes and ears to avoid ingestion of wastewater.
- Wearing protective clothing (such as non-permeable gloves) when handling any equipment covered with wastewater.
- Taking special care (e.g., protective, waterproof dressing) to keep any area of broken skin covered to avoid possible infection. If a worker suffers an injury that results in an open wound or laceration, they should be given a tetanus booster.
- Washing hands thoroughly with soap before smoking, eating, drinking, or after work.
- Changing and washing work clothing daily.
- Washing any areas that come into contact with wastewater thoroughly with water and soap. Sponging any cuts with an antiseptic solution and covering with a clean, dry gauze dressing and waterproof adhesive.

Safe Lifting and Carrying Techniques

Everyone should observe the following guidelines to avoid possible injury when lifting and carrying objects:

- test the load first and do not move more than is comfortable;
- set your feet far enough apart to provide good balance and stability (approximately the width of your shoulders);
- get help for large, bulky or heavy items;
- get as close to the load as practical and bend the legs about 90 degrees at the knees;
- straighten your legs to lift the object, and at the same time, bring your back to a vertical position - the objective is to use your legs to lift rather than your back;
- never carry a load that blocks forward vision;
- to lower the object, repeat the stance and position for lifting, bend the legs to 90 degrees and lower the object; and
- when lifting an object with another person, be sure that both individuals lift at the same time and put the load down together.

Public Health and Safety

In addition to striving to protect the health and safety of employees, coworkers, and themselves, surface irrigation system owners and operators also have a responsibility to protect the health and safety of the public. The general public is often unaware of the dangers associated with a surface irrigation facility. A surface irrigation facility and application site should be restricted to authorized personnel to prevent exposure of the public to physical injuries and to possible contamination from pathogens and vectors (animals or organisms capable of transporting infectious agents).

By properly operating and maintaining the system (thereby reducing the risk of spills, overflows and runoff), an operator reduces the risk of contaminating ditches, waterways, and adjoining properties. This, in turn, protects the public from contact with contaminated surface waters or groundwater.

If spills or discharges do occur, rapid mobilization of a well-thought out and well-practiced emergency response plan (Chapter 5) can minimize the health and safety threat to the public.

Chapter 8
North Carolina Regulations

This chapter discusses the North Carolina statutes and regulations that govern the surface irrigation of wastewater. There are several sets of regulations that you must be familiar with.

The first set of regulations discussed below (15A NCAC 2T) contains surface irrigation permitting and operational requirements. The 2T rules were enacted on September 1, 2006, and replaced 15A NCAC 2H .0200.

The second set of regulations (15A NCAC 2L) applies to groundwater classification and standards. These regulations will be important if the surface irrigation system you operate is required to have groundwater monitoring wells.

The third set of regulations (15A NCAC 8G) contains specific requirements for certified surface irrigation system operators, as well as other certified water pollution control system operators.

Permit Regulations and Requirements: 15A NCAC 2T

According to North Carolina General Statute 143-215.1(a)(2), any system that collects, treats, or disposes of waste cannot be constructed or operated without a permit. This statute gives the North Carolina Environmental Management Commission (EMC) the authority to issue permits for the surface irrigation of reclaimed water and wastewater.

The EMC delegates its permitting authority to the North Carolina Department of Environment and Natural Resources (DENR). The DENR Division of Water Resources (DWR) reviews applications and issues surface irrigation system permits.

Surface Irrigation System Permits

Surface irrigation systems are permitted as "non-discharge systems". They are not allowed to discharge wastewater to surface waters of the State. Any intentional or unintentional diversion of untreated wastewater from a surface irrigation system or bypassing of a surface irrigation system is considered a discharge and is prohibited.

Non-discharge systems are regulated under 15A NCAC 2T (Appendix C-1). These regulations apply only to systems that involve application of wastewater to the land surface. Subsurface wastewater disposal systems are covered under separate regulations and are administered by the Department of Environmental Health and local health departments.

Systems permitted for surface irrigation of wastewater include:

- single-family residence systems;
- municipal wastewater systems;
- commercial and industrial wastewater systems; and
- reclaimed water/reuse systems (golf courses).

A detailed review of the process involved in applying for and receiving a surface irrigation permit is

beyond the scope of this manual. Many of you may never be involved in this process. However, the following discussion will give you an overview of the process in the event that you are involved in obtaining a permit for a new facility, an expanding facility, or a permit renewal for an existing facility.

The Division of Water Resources's Non-Discharge Permitting Unit reviews permit applications and issues permits for a variety of non-discharge systems, including surface irrigation systems. Applications must be made on state supplied application forms. An application for a surface irrigation system permit is located in Appendix C-2.

Although every effort is made to process applications as quickly as possible, applicants should be prepared for a wait of sixty to ninety days from the date the Non-Discharge Permitting Unit receives a complete application package until the permit is acted upon. Therefore, it is extremely important that all applications be submitted as far in advance of the planned construction start-date as possible to ensure that the permit is issued by that time.

Permit Applications for New Systems

A complete permit application package for a new domestic, commercial or industrial surface irrigation system includes:

- a completed application form (signed by the applicant and signed and sealed by a professional engineer);
- a check for the annual fee;
- an operational agreement;
- a signed and sealed N.C. licensed soil scientist's report;
- a hydrogeologist's report;
- a signed agronomist's report;
- final engineering plans, specifications, and calculations for the entire collection, treatment and disposal system;
- a description of the treatment system; and
- a complete chemical analysis of the effluent or expected concentrations in the effluent.

A complete permit application package for a new reclaimed water/reuse system includes all of the above except the agronomist's report. The original application package and four copies must be submitted to the Non-Discharge Permitting Unit. Incomplete application packages will be returned to the applicant.

Surface irrigation permits are generally issued for 5 years. If DWR has concerns with either the application site or the effluent that will be applied, the permit may be issued for a shorter time period.

Permit Renewals

When requesting permit renewal, only a completed application form is required. To allow time for processing, the application must be submitted to Non-Discharge Permitting Unit at least 180 days prior to the expiration date of the permit. Otherwise, the permit may expire before DWR issues the permit renewal.

Permit Modifications

A permit modification includes any change to an existing system as described in the surface irrigation permit. The specific definition of a permit modification can also be found in NCGS 143-215.1(a). Examples of permit modifications include:

- an increase in flow;
- the addition of surface irrigation fields;
- increases in pipe, pump sizing, or sprinkler head design; and
- the addition of treatment components to the system.

All system modifications must be approved prior to the initiation of the modification. If you have any questions about what is considered a modification, check with the Land Application Unit before any action is taken.

Permit Fees

All surface irrigation permits have annual permit fees. For new systems, the annual permit fee is due at the time the permit application is submitted. Failure to include the annual fee with a new permit application will result in the return of the application to the applicant without processing.

There is no additional fee for permit renewals that involve no modifications or for minor permit modifications (such as name changes).

A major permit modification is subject to a fee in addition to the annual permit fee. Examples of major permit modifications are the addition of new irrigation fields or new sources of waste.

Permit Revocations

The Division of Water Resources can revoke, or take away, a permit if the annual permit fee is not paid. Permit revocation means that the system no longer has a permit and cannot be operated. A permit can also be revoked for improper operation of the system.

Permit Rescissions

When a permitted surface irrigation system is no longer needed or can no longer be operated, the permittee must request that DWR rescind or nullify the permit. The permittee cannot simply shut the system down and walk away from it. To get a permit rescinded, the permittee must submit a written rescission request to DWR.

Before rescinding a permit, DWR must be satisfied that the system is not and will not become a threat to the environment or public health. A permitted system remains the permittee’s responsibility until DWR issues a written permit rescission.

The Issued Permit

A surface irrigation permit addresses the compliance needs and operational requirements of the system. It is also a legal and binding agreement and is enforceable by law. Therefore, it is extremely important for the permittee to maintain a copy of the permit and to be familiar with and fully understand the conditions of the permit. An example of a surface irrigation system permit is located in Appendix C-3.

It is the permittee's responsibility to ensure that the system is properly operated, properly maintained and is in compliance with permit conditions. Ultimately, it is the permittee who is responsible for any violation of a permit condition, regardless of who is actually operating the system. The consequences for violating a permit condition will be discussed later in this section.

If someone other than the permittee is designated to actually operate the system (as is often the case), it is extremely important that the operator also be familiar with and understands the conditions of the permit. Specific operator responsibilities will be discussed in detail at the end of this chapter.

Permit conditions vary from permit to permit, but all surface irrigation permits contain requirements concerning the following:

- engineer's certification;
- setbacks;
- operation and maintenance;
- inspections;
- non-compliance notification; and
- monitoring and reporting.

Depending on specific concerns at a surface irrigation system, additional conditions are sometimes added to protect the environment or public health. Examples of additional requirements include:

- effluent monitoring (for reuse systems located on public access areas, such as golf courses);
- site limitations; or
- groundwater monitoring.

Engineer's Certification

Upon completion of a surface irrigation system and prior to its operation, DWR must receive a certification from a professional engineer. In this certification, the engineer verifies that construction was completed in accordance with the approved plans and specifications.

Setbacks

Setback means the minimum separation in linear feet, measured on a horizontal plane, required between a treatment works, disposal system, or utilization system and physical features such as building, roads, property lines, or water bodies. In general, surface irrigation permits require the setback distances outlined below (Tables 8-1 and 8-2). However, you should always consult the system permit for specific requirements.

Physical Feature	**Minimum Setback (feet)**
Habitable residence or place of public assembly under separate ownership or not to be maintained as part of the	100
Private or public water supply source	100
Surface waters (streams – intermittent and perennial, perennial waterbodies, and wetlands)	50
Wells with exception to monitoring wells	100
Property lines	50

Table 8-1. Setback requirements for treatment and storage units (2T).

Physical Feature	Wastewater *(feet)*	
	Spray	Drip
Habitable residence or place of public assembly under separate ownership or not to be maintained as part of the project site	400	100
Habitable residence or places of public assembly owned by the permittee to be maintained as part of the project site	200	15
Private or public water supply source	100	100
Surface waters (streams – intermittent and perennial, perennial waterbodies, and wetlands)	100	100
Groundwater lowering ditches (where the bottom of the ditch intersects the SHWT)	100	100
Surface water diversions (ephemeral streams, waterways, ditches)	25	25
Wells with exception to monitoring wells	100	100
Property lines	150	50
Subsurface groundwater lowering system	15	15
Top of slope of embankments or cuts of two feet or more in vertical height	10	10
Any water line from a disposal system	100	100
Swimming pools	100	100
Public right of way	50	50
Nitrification fields	20	20
Building foundations or basements	15	15

Table 8-2. Setbacks for wastewater application areas (2T).

Achieving the reclaimed water effluent standards shall permit the system to use the setbacks located in 15A NCAC 02U for property lines and the compliance boundary shall be at the irrigation area boundary.

Setback waivers shall be written, notarized, signed by all parties involved and recorded with the County Register of Deeds. Waivers involving the compliance boundary shall be in accordance with 15A NCAC 02L .0107.

Operation and Maintenance Requirements

The following are some of the permit conditions found in a typical surface irrigation permit:

- a suitable vegetative cover must be maintained on the irrigation field;
- no irrigation shall be performed during inclement weather or when the ground is in a condition what will cause runoff;

- the facility shall be effectively maintained and operated as a non-discharge system to prevent the discharge of any wastewater resulting from the operation of the facility;
- freeboard in the lagoon(s) shall not be less than two feet (in most cases) at any time;
- diversion or bypassing of untreated wastewater from any component of the treatment facility is prohibited;
- the application rate shall not exceed the permitted rate;
- no traffic or equipment shall be allowed on the irrigation area except while installation occurs or while normal maintenance is being performed;
- the irrigation area shall be restricted from public access; and
- a set of approved plans and specifications for the system must be retained by the permittee and a copy of the permit should be retained on site for the life of the facility.

Inspections

The permittee or designee must conduct regular inspections of the surface irrigation system to prevent malfunctions and deterioration, operational errors and discharges. A log of these inspections must be maintained at the site for a period of 5 years from the date of the inspection. At a minimum, the log must include:

- date and time of inspection;
- visual observations of the irrigation storage structure(s) and surface irrigation site;
- needed maintenance, repairs, or preventative action; and
- other information as specified in the permit.

Permitted systems are also subject to inspection by DWR. Any DWR representative can, upon presentation of credentials, inspect any surface irrigation system at any reasonable time for the purpose of determining compliance with the system permit. Division representatives may inspect or copy any records that must be maintained under the terms and conditions of the permit and may obtain samples of groundwater, surface water or leachate.

DWR regional office staff usually conducts compliance inspections prior to the initial start-up of the system, the initial operation of groundwater monitoring wells, or the renewal of the permit. Inspections also occur periodically in between. Systems that are not in compliance with permit conditions are subject to more frequent inspections.

Non-compliance Notification

Non-compliance with permit conditions must be reported to DWR. The permittee must report to the appropriate DWR regional office as soon as possible, but in no case more than 24 hours or on the next working day, following the occurrence or first knowledge of the occurrence of the following:

- any occurrence that results in the treatment of significant amounts of wastes that are abnormal in quantity or characteristic, such as the known passage of a slug of hazardous substance through the facility, or any other unusual circumstances; or
- any process unit failure, due to known or unknown reasons, that renders the facility incapable of adequate wastewater treatment, such as mechanical or electrical failures of pumps, sprinkler heads, emitters etc.; or

- any failure of the system resulting in a by-pass directly to receiving waters without treatment of all or any portion of influent to such station or facility; or
- self-monitoring information indicates that the facility has gone out of compliance with its permit limitations.

A written report must be filed with the appropriate DWR Regional Office within 5 days following first knowledge of the occurrence. This report must outline the actions taken or actions proposed to ensure that the problem does not recur.

All permit conditions are important in the operation of a surface irrigation system. Ignorance of and failure to adhere to permit conditions will most likely result in non-compliance and the possible assessment of penalties against the permittee.

Monitoring and Reporting Requirements

The surface irrigation permit contains monitoring and reporting requirements deemed necessary by DWR. All surface irrigation systems with a design capacity of 1000 gallons per day or more require some type of monitoring and reporting. Smaller systems (with a design flow of less than 1000 gallons per day) may or may not be subject to these requirements, depending on the specific permit.

Monitoring may include:

- wastewater irrigation data collection;
- wastewater or effluent monitoring;
- soil and plant tissue analyses; and
- groundwater or surface water monitoring.

The permit also establishes the monitoring and reporting schedule that must be followed.

Wastewater or Effluent Monitoring Data

Influent flow-monitoring data and wastewater monitoring results are reported monthly using the Non-Discharge Wastewater Monitoring Report Form (NDMR). The following flow-monitoring requirements have been implemented in all new, modified or renewed permits issued after June 1, 2000:

- systems permitted for 1,000 gallons per day or more, but less than 10,000 gallons per day, are allowed to monitor influent flow either by a flow-measuring device or by potable water usage;
- systems permitted for 10,000 gallons per day or more are required to install an influent flow-monitoring device (if one is not already in place) and calibrate the device on an annual basis.

The NDMR is due 30 days after the end of the month. If no wastewater monitoring takes place during the month, the completed NDMR report form must still be submitted with Operator in Responsible Charge visitation and daily flow information.

Wastewater Irrigation Data

Wastewater irrigation data for systems permitted as surface irrigation must be reported monthly using the Non-Discharge Application Report Form for Spray Irrigation Sites (NDAR-1). Systems permitted as high-rate infiltration systems must use the Non-Discharge Application Report Form for High-rate Infiltration Sites (NDAR-2). Systems permitted as conjunctive use of reclaimed water must use the Non-Discharge Application Report Form for Conjunctive Use of Reclaimed Water Sites (NDAR-3).

The NDAR is due at the same time as the NDMR, 30 days after the end of the month. If no irrigation takes place during the month, the report must be still be submitted indicating that no irrigation occurred.

If irrigation did occur, the following data must be recorded on the NDAR:

- weather conditions;
- lagoon freeboard levels;
- date of irrigation;
- volume of wastewater irrigated;
- field on which wastewater was irrigated;
- length of time field was irrigated;
- continuous weekly, monthly, and year-to-date hydraulic loadings (inches/acre) for each field; and
- maintenance of cover crops (i.e. type, when seeded, harvested and mowed).

Each irrigation field in the permit must be referenced on an NDAR. There is space on the form to record data from two separate irrigation fields. If the surface irrigation system has more than two irrigation fields, an additional NDAR form (or forms) must be attached and submitted each month. The number of fields, field names, and associated acreage must remain constant from month to month, unless a permit modification is issued.

Submitting the NDMR and NDAR

Completed forms (the original and two copies) must be submitted within 30 days of the end of the month to:

DENR
Division of Water Resources
ATTN: Information Processing Unit
1617 Mail Service Center
Raleigh, N.C. 27699-1617
Phone: 919-733-3221

Following the instructions below will minimize the chance of your reports being returned:

- The state-supplied NDMR and NDAR forms are the only forms that are approved and accepted. Reports submitted on unapproved adaptations will be returned without being processed.
- The current version of the state-supplied forms must be used. Reports submitted on outdated forms will be returned without being processed.
- Report forms must be filled out correctly and completely or they will be returned without being processed.
- All required forms must be completed and submitted. If all forms are not submitted, those submitted will be returned without being processed.

Copies of the NDMR and NDAR forms are included in Appendix C-4. Forms can be downloaded from DWR's website (http://portal.ncdenr.org/web/wq/aps/lau/reporting) or obtained from your DWR regional office or from the Non-Discharge Permitting Unit.

Soil and Plant Tissue

Surface irrigation permits require periodic monitoring of soil, and sometimes plant tissue. Sampling

protocol and laboratory reports were discussed in Chapter 5. As with wastewater monitoring, the permit specifies when to sample, which parameters to have analyzed, and when to submit the results.

Some permits require a soil scientist or agronomist to review the test results and prepare a report to submit to DWR with the test results.

Test results and/or must be submitted to the same address as the NDMR and NDAR forms:

DENR
Division of Water Resources
ATTN: Information Processing Unit
1617 Mail Service Center
Raleigh, N.C. 27699-1617
Phone: 919-733-3221

Groundwater Monitoring

Some surface irrigation permits require periodic monitoring groundwater. The results are reported using the Groundwater Quality Monitoring Form For Permitted Facilities (Form GW-59) and the Compliance Report Form (Form GW-59a). Copies of these forms are located in Appendix C-4.

Completed forms must be submitted to the address above. These forms can be downloaded from DWR's website (http://portal.ncdenr.org/web/wq/aps/gwpro/reporting-forms).

Groundwater regulations and reporting requirements are discussed in further detail later in this chapter.

Surface Water

Infrequently, surface irrigation permits may require surface water monitoring. For example, the permit may require surface water bodies near a particular field to be sampled. If required, the permit will specify when, where, and what to sample, and when to submit results. Submit completed reports to the address above.

Permit Violations and Enforcement Action

All permit conditions are important in the operation of a surface irrigation system. Ignorance of permit conditions and failure to adhere to them will most likely result in non-compliance and the possible assessment of penalties against the permittee.

As discussed at the beginning of this chapter, the Environmental Management Commission (EMC) has the authority to require and issue permits for surface irrigation systems. The EMC also has the authority to ensure that all permitted surface irrigation systems are properly operated and maintained in accordance with their permit conditions.

The enforcement powers of the EMC are outlined in General Statute 143-215.6, which authorizes the EMC to initiate enforcement actions. It also describes the types of actions and establishes the protocols upon which enforcement procedures and policies are based. As with permit issuance, the EMC delegates its enforcement authority to the Director of the Division of Water Resources.

Notice of Violation

A Notice of Violation (NOV) is a letter sent to the permittee giving notice of non-compliance with environmental law(s). The letter is designed to notify the permittee of the specific violation and associated regulation. In addition, the NOV describes the requirements that the permittee must take to correct the violation or must take as a result of the violation. Generally, the NOV indicates that the permittee must complete the corrective actions and notify the regulatory agency within a certain period of time.

Examples of possible violations are:

- violation of water quality standards or limits;
- failure to secure a permit;
- failure to act in accordance with the requirements of the permit;
- failure to file, submit or make available any documents or data required; or
- refusing to allow a designated representative of the state to inspect the system.

Enforcement Actions

There are three types of enforcement actions that can be used to prompt or maintain compliance with environmental regulations. These are civil penalties, injunctive relief and criminal penalties. The action most commonly taken is the assessment of civil penalties.

Civil penalties are fines assessed against a permittee for violation(s) of environmental regulations. The assessment of a penalty is based on the specifics of each civil penalty case. The law requires consideration of specific assessment factors by the assessor for each case. General Statute 143-215.6A allows the assessment of civil penalties of up to $25,000 per day per violation. Each day that a violation occurs may be considered as a separate violation.

Injunctive relief is a court order to discontinue or prevent an existing or potential violation. This court order is often used if a permittee demonstrates consistent non-compliance with regulations or if an imminent danger exists to health or the environment.

General Statute 143-215.6B allows for the assessment of criminal penalties, imprisonment, or both. A criminal penalty, or investigation leading to criminal prosecution, may be used if a violator willfully, knowingly or negligently fails to comply with environmental laws.

Groundwater Regulations and Requirements: 15A NCAC 2L

In 1984, North Carolina implemented the "Classification and Water Quality Standards Applicable to the Groundwaters of North Carolina". This regulation, also known as 15A NCAC 2L, recognizes that unpolluted groundwater is suitable or potentially suitable for use as drinking water.

Fresh (non-brackish) groundwater is assigned the highest and best classification, Class GA. Brackish groundwater is considered potentially usable as drinking water and is classified as Class GSA. Polluted groundwater is generally unusable as drinking water and is classified as Class RS or restricted.

Most of the numerical and narrative standards are health-based, although the standards do recognize properties such as taste and odor, which are non-health related but define suitability. Table 8-3 lists some of the contaminants that can be introduced into the environment by surface irrigation systems.

To determine if groundwater is being contaminated, some permits require groundwater monitoring. Monitoring activities include installation of monitoring wells, sample collection and analysis of groundwater, and reporting analytical data to DWR.

Contaminant	Maximum Groundwater Concentration	Fate If Properly Treated	Results if not treated
Pathogens (bacteria, viruses, etc.)	1/100 ml	Filtered by soil and / or die off prior to reaching groundwater.	Sand and fractures likely speed contaminants in unpredictable directions and distances. Various human sicknesses as minor as diarrhea or as serious as infectious Hepatitis and Typhoid Fever.
Solids	NA	Reduced to acceptable levels by septic tank and soil treatment.	Most organisms and other contaminants are contained in solids.
Nitrate	10 ppm	Taken up by plants, escapes to atmosphere in gaseous form, diluted by groundwater to non-hazardous levels.	Possible leaching to groundwater: Blue Baby Syndrome (methemoglobinemia) Cardiac malfunction
Phosphorus	NA	Bound by the soil.	Algae blooms in rivers, lakes and other surface waters.
Heavy Metals Cadmium Zinc Nickel Copper	 0.005 mg/l 5.0 mg/l 0.15 mg/l 1.0 mg/l	Bound by the soil.	Possible leaching to groundwater. Kidney damage and pulmonary emphysema.

Table 8-3. Contaminants that can be introduced into the environment by surface irrigation systems.

It is in best interest of the permittee that monitoring wells be properly located and constructed and that monitoring data be reported accurately and timely. To determine if a surface irrigation system has groundwater monitoring requirements, you should consult the permit and associated plans.

If monitoring wells are required, a qualified hydrogeologist must prepare a report describing the depth of the groundwater and must collect samples to establish background levels for the parameters of interest. As with other types of monitoring, the system's permit will specify what parameters to monitor, when to

monitor, and when results must be submitted. Information concerning proper groundwater monitoring and sampling techniques is contained in Chapter 5 and Appendix B-4.

Well Location

In order to achieve their intended purpose, monitoring wells must be located along the path of groundwater flowing underneath the disposal system. There must be at least one well hydraulically upgradient and at least one well hydraulically downgradient of the disposal system, as shown in Figure 8-1.

Analysis of groundwater sampled from the upgradient well establishes the quality of groundwater unimpacted by the disposal operation (i.e., background quality), while groundwater samples from the downgradient well establish (by comparison with upgradient samples) the impact of disposal operations on groundwater quality.

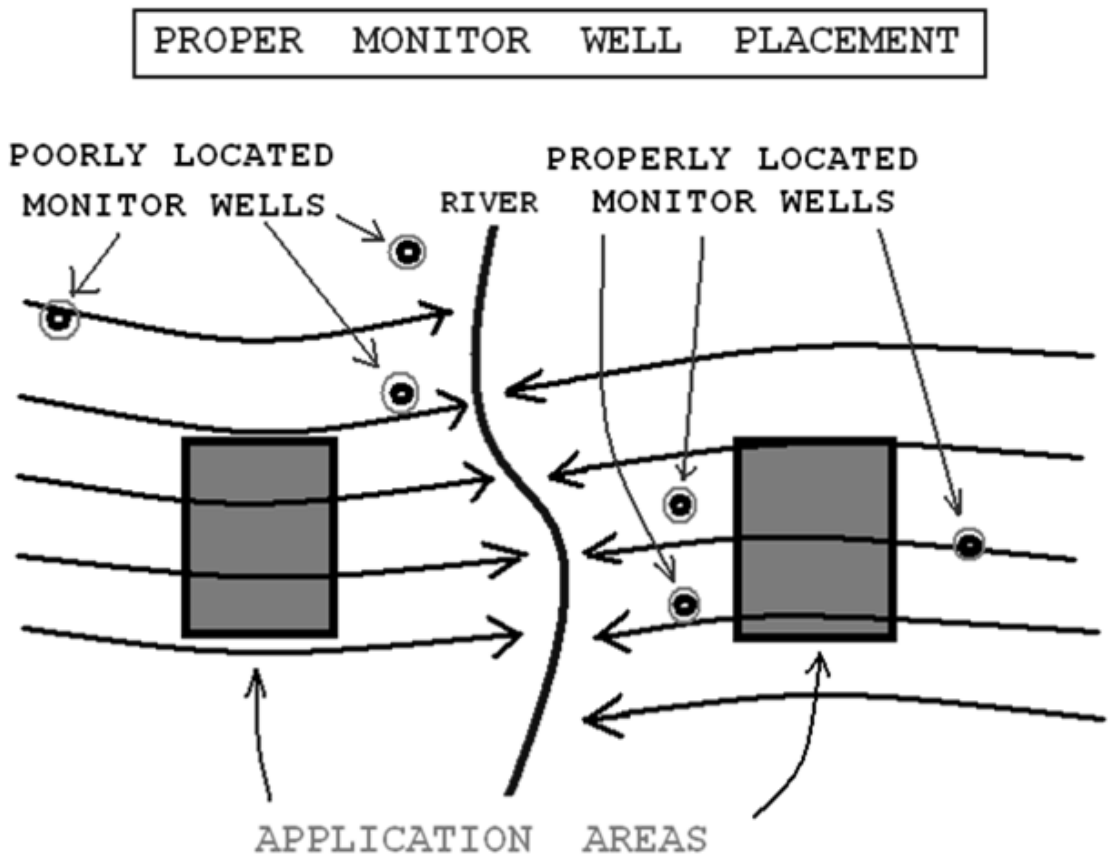


Figure 8-1. Proper well placement.

Monitoring wells must be located at the Review Boundary (Figure 8-2). The Review Boundary is the boundary around the disposal system, midway between the waste disposal boundary and the Compliance Boundary. Monitoring at the Review Boundary serves as a warning of the possible spread of contamination to the Compliance Boundary.

Exceedance of Groundwater Quality Standards at the Review Boundary requires the permittee to implement a plan that will prevent a violation of standards at the Compliance Boundary. This plan must

include installation of monitoring wells at the Compliance Boundary.

The Compliance Boundary is a boundary around the disposal system at and beyond which groundwater quality standards may not be exceeded. It is established at either 250 feet from the waste disposal area or 50 feet within the property boundary, whichever is closest to the waste disposal area. Exceedance of Groundwater Quality Standards at or beyond the Compliance Boundary is subject to immediate remediation action in addition to the penalty provisions applicable under General Statute 143-25.6A(a)(1).

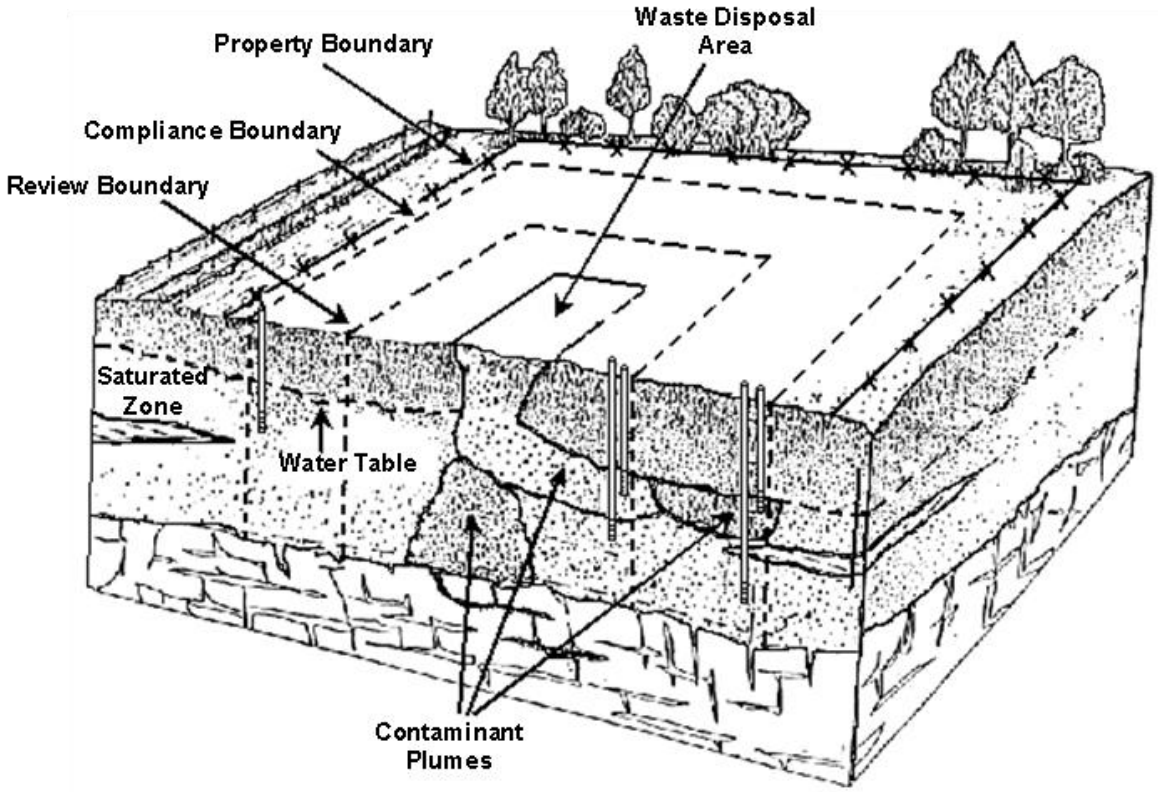


Figure 8-2. Compliance and review boundaries where North Carolina Groundwater Standards apply.

Well Construction

Along with proper location, proper well construction is critical to a valid and acceptable monitoring network. The construction requirements are specified in 15A NCAC 2C.0108(c)(1)(A-K). Some of the most important requirements include:

- The well casing and screen must be made of materials compatible with the constituents of the waste being monitored. Poly-vinyl chloride (PVC) is generally a good choice because of its ease of handling and low cost. However, the pieces of casing and screen must be joined using threaded couplings. **Glues of any sort cannot be used**, since volatile/semi-volatile elements in glues will leach into the groundwater.
- The length and positioning of the well screen below land surface must be such that the static water table is never above or below the uppermost and lowermost screen openings, respectively, at any time of the year (Figure 8-3). Screen settings that do not meet this criteria result in either "dry" wells (i.e., the water table is below the screen, precluding collection of a sample) or a situation where the layer of dissolved contaminants in the groundwater may be above the zone

where the sample is collected (i.e. the water table is above the uppermost screen openings).

- The well casing must be grouted from the land surface to a depth no more than three feet above the top of the well screen. Because of shrinkage when dry, bentonite grouts may not be used except as a plug to keep cement grout away from the well screen (Figure 8-4).
- A permanent, easily visible label or tag must be attached to each well denoting that the well is for monitoring and thus water from the well should not be used for drinking. There should also be a permanent label containing details about the construction of the well (date installed, installer, depth, etc.).
- The well must have a watertight lockable cap to prevent unauthorized access.

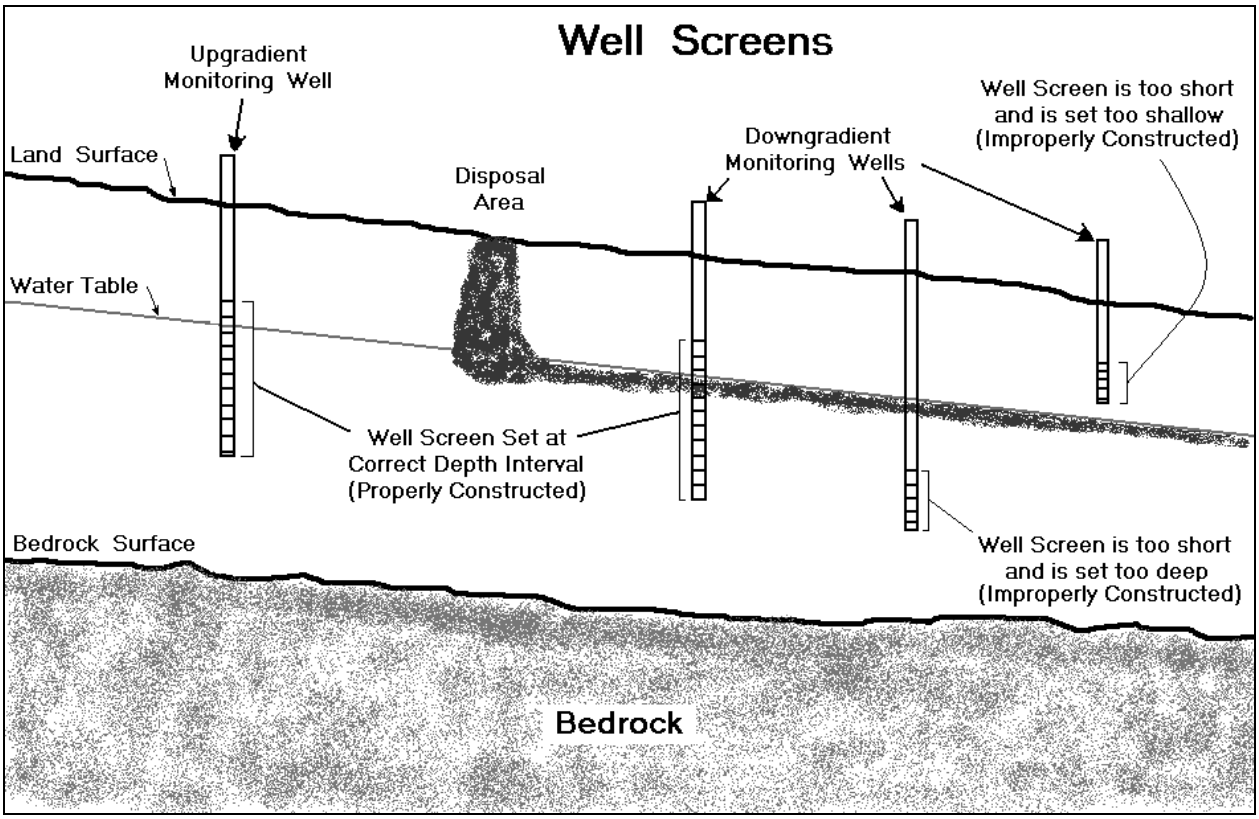


Figure 8-3. Proper and improper placement of screens in monitoring wells.

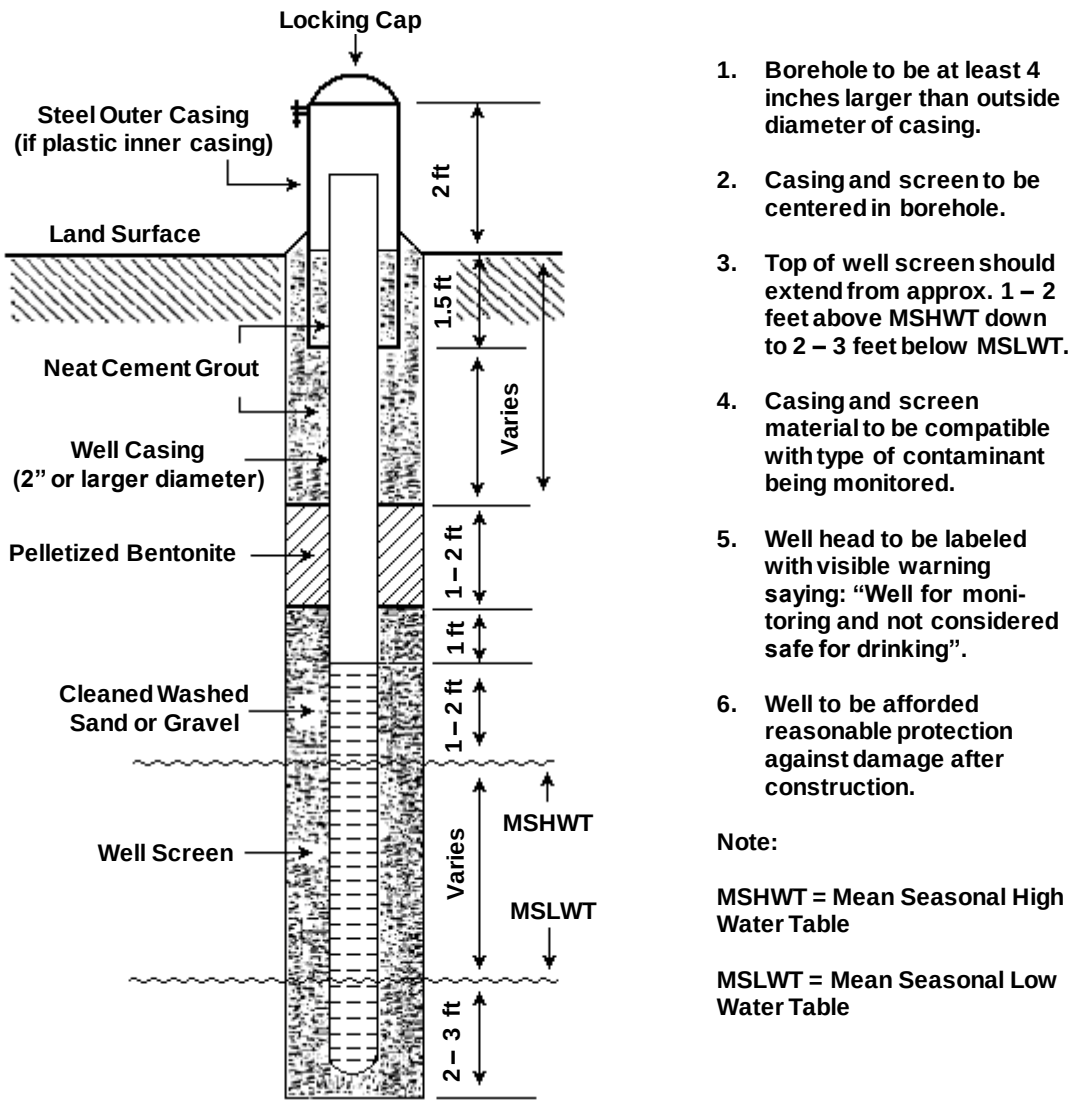


Figure 8-4. Construction details for groundwater monitoring well.

Baseline Well Characteristics

Since the purpose of installing monitoring wells is to determine the condition of groundwater based on the analyses of groundwater samples, it is essential that good quality samples be obtained. Prior to accepting a newly installed monitoring well, permittees should verify that the well has been properly developed. Suspended particles and sediment in groundwater samples due to improper well development interfere with some chemical analyses and can lead to compliance problems and additional financial outlays.

All wells should be sampled initially after construction and prior to waste disposal activities in order to establish a valid background concentration for constituents requiring routine monitoring. Thereafter monitoring frequency will be determined by the schedule specified in the non-discharge permit.

Well Maintenance

Monitoring wells require regular maintenance, which includes making sure that:

- caps are rust-free and locked at all times;
- the outer casing is upright and undamaged; and
- a clear, unobstructed path exists leading to each well.

While the primary function of groundwater monitoring is to ensure compliance with the groundwater rules, it can also serve other important functions. For example, interpretation of the water level information may reveal that the system is being hydraulically overloaded. Therefore more land may be needed to accommodate the design capacity of the system or monitoring may indicate that the ability of the crop cover to uptake nutrients is more limited than anticipated.

Reporting Requirements

As mentioned earlier, groundwater monitoring data must be reported using the Groundwater Quality Monitoring Form for Permitted Facilities (Form GW-59) and the Compliance Report Form (Form GW-59a). Copies of these forms are located in Appendix C-4.

This form must be printed or photocopied on yellow paper. A separate GW-59 form must be completed for each monitoring well according to the schedule set out in the system permit. Unless the permit specifies another address, the GW-59 should be submitted to the address printed on the form. A copy of a GW-59 is shown in Figure 8-5. Include the complete and correct Non-Discharge permit number from the permit in effect at the time of sampling. Also identify the type of permitted system being monitored by checking the appropriate category.

Be consistent in reporting well location and identification numbers, and designate each well as upgradient or downgradient in relation to the waste disposal site. Identify wells using the identification numbers designated in the current Non-Discharge permit.

To minimize confusion, make sure that wells covered under the same permit do not have the same identification numbers.

The field measurements and analyses required provide information about the conditions under which samples were taken. This information is also used to establish that a representative sample was taken and to detect signs of sample deterioration or contamination when compared with the laboratory analyses.

To ensure that sample holding times have not been exceeded, sample collection and analyses dates must be recorded. The name and certification number of the North Carolina certified laboratory that collected and/or analyzed samples must be recorded in the designated area.

The Laboratory Information section lists the groundwater parameters commonly monitored at permitted facilities. Since the bulk of analytical compliance information is recorded in this section, the following areas require special attention.

- Permittees must refer to individual permits to ensure that all required parameters applicable to their operation are being monitored.
- Analytical data must be properly recorded in the correct spaces and in the correct units. If uncertain of the concentration units of constituents included in a laboratory report, consult with the laboratory before filling out form GW-59. Constituents reported as “not detected” or “below

detection limit" should indicate the detection limit used. For example, "Not Detected" or "Below Detection Limit" at a detection limit of .001mg/L should be recorded on the form as "<.001mg/L" or "less than .001mg/L".

- Parameters listed on the form should not be crossed out and unlisted parameters inserted. If a required parameter is not listed, record it in the space marked "other".
- When organic analyses, such as Volatile Organic Compounds (VOC's), are required the laboratory reports must be attached to the GW-59 and "Yes" must be checked to indicate that the forms are attached.
- Based on detection of contaminants in the initial samples, follow-up analyses may be required. In such cases, the follow-up analyses must be performed immediately after initial detection and all results must be submitted simultaneously.

SUBMIT FORM ON YELLOW PAPER ONLY

GROUNDWATER QUALITY MONITORING: COMPLIANCE REPORT FORM

Mail original and 1 copy to: DEPARTMENT OF ENVIRONMENT & NATURAL RESOURCES DIVISION OF WATER QUALITY-INFORMATION PROCESSING UNIT 1617 MAIL SERVICE CENTER, RALEIGH, NC 27699-1617 Phone: (919) 733-3221

FACILITY INFORMATION (Please Print Clearly or Type)
Facility Name:
Permit Name (if different):
Facility Address:
(City) (State) (Zip) County
Contact Person: Telephone#:
Well Location/Site Name: No. of wells to be sampled: (from Permit)

PERMIT Number: Expiration Date:
Non-Discharge UIC
NPDES Other
TYPE OF PERMITTED OPERATION BEING MONITORED
☐ Lagoon ☐ Remediation: Infiltration Gallery
☐ Spray Field ☐ Remediation:
☐ Rotary Distributor ☐ Land Application of Sludge
☐ Water Source Heat Pump ☐ Other:

SAMPLING INFORMATION
WELL ID NUMBER (from Permit): Date sample collected:
Well Depth: ft. Well Diameter: in.
Depth to Water Level: ft. below measuring point Screened Interval: ft. to ft.
Measuring Point is ft. above land surface Relative M.P. Elevation: ft.
Volume of water pumped/bailed before sampling: gallons
Samples for metals were collected unfiltered: ☐ YES ☐ NO and field acidified: ☐ YES ☐ NO

FIELD ANALYSES:
pH units Temp. °C
Spec. Cond. µMhos
Odor
Appearance

If WELL WAS DRY at time of sampling, check here: ☐

LABORATORY INFORMATION
Date sample analyzed: Laboratory Name: Certification No.
PARAMETERS NOTE: Values should reflect dissolved and colloidal concentrations.

COD	mg/l	Nitrite (NO_2) as N	mg/l	Pb - Lead	mg/l
Coliform: MF Fecal	/100ml	Nitrate (NO_3) as N	mg/l	Zn - Zinc	mg/l
Coliform: MF Total (Note: Use MPN method for highly turbid samples)	/100ml	Phosphorus: Total as P	mg/l		
		Orthophosphate	mg/l	Other (Specify Compounds and Concentration Units):	
Dissolved Solids: Total	mg/l	Al - Aluminum	mg/l		
pH (when analyzed)	units	Ba - Barium	mg/l		
TOC	mg/l	Ca - Calcium	mg/l		
Chloride	mg/l	Cd - Cadmium	mg/l		
Arsenic	mg/l	Chromium: Total	mg/l		
Grease and Oils	mg/l	Cu - Copper	mg/l	ORGANICS: (by GC, GC/MS, HPLC)	
Phenol	mg/l	Fe - Iron	mg/l	(Specify test and method #. ATTACH LAB REPORT.)	
Sulfate	mg/l	Hg - Mercury	mg/l	Report Attached? ☐ Yes (1) ☐ No (0)	
Specific Conductance	µMhos	K - Potassium	mg/l	VOC , method #	
Total Ammonia (Ammonia Nitrogen; NH_3as N; Ammonia Nitrogen, Total)	mg/l	Mg - Magnesium	mg/l	, method #	
		Mn - Manganese	mg/l	, method #	
TKN as N	mg/l	Ni - Nickel	mg/l	, method #	

For Remediation Systems Only (Attach Lab Reports): Influent Total VOCs: mg/L Effluent Total VOCs: mg/L VOC Removal%

I certify that, to the best of my knowledge and belief, the information submitted in this report is true, accurate, and complete, and that the laboratory analytical data was produced using approved methods of analysis by a DWQ-certified laboratory. I am aware that there are significant penalties for submitting false information, including the possibility of fines and imprisonment for knowing violations.

Permittee (or Authorized Agent) Name and Title - Please print or type
Signature of Permittee (or Authorized Agent) (Date)
GW-59 Rev. 1/2007

Figure 8-5. Groundwater Quality Monitoring: Compliance Report Form (Form GW-59).

The permittee's or authorized agent's (ORC's) name, signature and date must be provided. Remember to include complete identification (facility name, county, permit number, etc.) on all forms and correspondence. Submit in accordance with the sampling schedule established in the permit. Completed forms must be submitted to:

DENR
Division of Water Resources
ATTN: Information Processing Unit
1617 Mail Service Center
Raleigh, N.C. 27699-1617
Phone: 919-733-3221

Operator Regulations and Requirements: 15A NCAC 8G

In North Carolina, all systems that use surface irrigation for the reuse or disposal of wastewater are subject to classification as surface irrigation systems. All classified surface irrigation systems must be operated by certified surface irrigation system operators. The rules that govern the actions of certified operators, 15A NCAC 8G, are located in Appendix C-5.

The operator must understand the permittee's legal responsibilities and keep the permittee informed concerning the daily operation of the system. If any problems occur with operations, equipment, etc., the operator must notify the permittee so decisions can be made and problems can be corrected.

Water Pollution Control System Operators Certification Commission

The regulating body responsible for the classification of surface irrigation systems is the Water Pollution Control System Operators Certification Commission. The Certification Commission is also responsible for the classification of other water pollution control systems, such as biological water pollution control systems, collection systems, physical/chemical systems, land application of residuals systems, subsurface systems and animal waste management systems.

In addition to the classification of systems, the Certification Commission is also responsible for the certification of water pollution control system operators and, if warranted, for taking disciplinary actions against certified operators.

The Certification Commission has 11 members. Two members represent the animal agriculture industry and are appointed by the Commissioner of Agriculture. The remaining 9 members are appointed by the Secretary of Environment and Natural Resources and represent other areas of the water pollution control system industry.

The Commission is located in the Department of Environment and Natural Resources and is assisted by Division of Water Resources Staff.

Classification of Surface Irrigation Systems

Systems that use surface irrigation for the reuse or disposal of wastewater are subject to classification by the Certification Commission as surface irrigation systems. Classified systems are required to have one Operator in Responsible Charge (ORC) and one or more back-up operators who hold active surface irrigation system operator certifications.

Those systems that contain only preliminary treatment processes such as septic tanks, sand filters, oil/water separators, lagoons, storage basins, physical screening, or sedimentation processes are classified as surface irrigation systems only. A surface irrigation system that has, as a part of its treatment process, treatment components other than those specified above is subject to dual classification as either a grade 2, 3, or 4 biological water pollution control system ***and*** as a surface irrigation system.

Once a system is classified as a surface irrigation system, it is the responsibility of the permittee to designate an Operator in Responsible Charge. One or more back-up(s) must also be designated. To be designated, the ORC and back-up(s) must hold currently valid surface irrigation system operator certificates.

If a system is classified as both a surface irrigation system and a biological water pollution control system, the permittee must designate an ORC who holds a biological water pollution control system certificate (of the same grade as the classification of the system) as well as a surface irrigation system operator certificate. The designated back-up must hold a biological water pollution control system operators certificate no more than one grade lower than the classification of the system as well as a surface irrigation system operator certificate.

The owner must submit a completed designation form:

- 60 calendar days prior to wastewater being introduced into a new system; or
- within 120 calendar days following:
  - receiving notification of a change in the classification of the system requiring the designation of a new Operator in Responsible Charge (ORC) and Back-up Operator in Responsible Charge (Back-up ORC) of the proper type; or
  - a vacancy in the position of Operator in Responsible Charge (ORC) or Back-up Operator in Responsible Charge (Back-up ORC); or
- within seven calendar days of vacancies in both ORC and Back-up ORC positions, replacing or designating at least one of the responsibilities.

An ORC designation form is included in Appendix C-5.

Certification of Surface Irrigation System Operators

To become certified as a surface irrigation system operator, you must complete an approved training program, meet the examination eligibility requirements for the certification examination and pass the examination. Applications for examinations must be postmarked 30 days prior to the desired examination date. Examinations will be given only to those applicants that have been approved by the staff of the Certification Commission. A passing examination score is 70% or higher.

To take the examination for certification as a surface irrigation system operator, you must meet all of the following eligibility requirements:

- have a high school diploma or a general educational development equivalent (GED);
- be at least 18 years of age;
- have a general knowledge of typical wastewater characteristics and treatment processes;
- be able to:
  - read and understand the statutes and rules that govern surface irrigation systems;
  - perform mathematical calculations required to operate these systems;
  - complete and maintain logs and regulatory reporting forms required to document the proper operation of these systems;
  - describe general maintenance requirements for the equipment employed in the operation these systems; and
- have successfully completed an approved surface irrigation system operator training school.

In addition, you must have one of the following:

- one year of actual experience in surface irrigation operation; or
- a two or four year college degree with a minimum of six courses in the basic sciences; or
- a valid grade III or higher biological water pollution control system operator certification.

If you fail to achieve a passing score on the certification examination after three consecutive attempts, you must satisfactorily complete another approved surface irrigation system operator training school before you will be approved to sit for the examination again.

Responsibilities of Certified Operators

Once you are certified, you must fulfill certain responsibilities in order to maintain your certification (regardless of whether or not you are designated as an ORC or backup:

- notify the Certification Commission in writing within 30 days of a change of address;
- pay an annual renewal fee;
- complete six contact hours of approved continuing education training annually; and
- comply with all terms and conditions of your certification and with all statues and rules regarding the operation of water pollution control systems.

Responsibilities of Operators in Responsible Charge

If you are designated as the ORC of a surface irrigation system, you must:

- possess a currently valid surface irrigation system operator certificate;
- visit the system as often as necessary to ensure the proper operation of the system, but in no case less than weekly (with the exception of domestic wastewater systems with a treatment capacity of 1500 gallons per day or less, in which case visitation will be twice per year with a six month interval between visits);
- operate and maintain the system efficiently and attempt to ensure compliance with the permit and all applicable local, state, and federal requirements;
- certify, by signature, the validity of all monitoring and reporting information performed on the system as required by the permit, and provide the owner a copy;
- document the operation, maintenance, and all visitation of the system in a daily log that must be maintained at the system;
- notify the owner of the system as soon as possible, and in writing within five calendar days of first knowledge, of any:
    - overflows from the system or any treatment process unit;
    - bypasses of the system or any treatment process unit; or
    - violations of any limits or conditions of the permit;
- notify the owner, in writing, of the need for any system repairs and modifications that may be necessary to ensure the compliance of the system;
- be available:
    - for consultations with the system owner and regulatory officials;
    - to handle emergency situations; and
    - to provide access to the facility by regulatory agencies; and

- upon vacating an ORC position, notify the Commission and the appropriate DWR regional office of the vacancy, in writing within 14 calendar days.

As ORC, you must have a detailed working knowledge of the surface irrigation permit to ensure the facility is not in violation of any permit conditions or state regulations. A copy of the surface irrigation permit and a copy of the approved blueprint plans should be kept on site. Also, phone numbers of DWR contacts and the design engineer for the system should be handy if a question should arise.

Responsibilities of Backup Operators

A designated back-up may act as a surrogate for the ORC for a period not to exceed 40 percent of the system visitation required per calendar year. If the ORC is absent due to a vacancy in the ORC position or due to personal or familial illness, the back-up may act as surrogate for the ORC for up to 120 consecutive days.

When acting as the ORC, a designated back-up ORC must fulfill all of the requirements of the ORC listed above.

Responsibilities of Contract Operators

Any operator or operations firm that enters into a contractual agreement with the owner of a surface irrigation system to operate the system must notify the owner within 5 calendar days of:

- any change in the designation of the ORC or back-up ORC(s); or
- becoming aware of any situation, which may interfere with the proper operation of the system and necessitate corrective action by the owner.

Disciplinary Actions

Under certain circumstances, the Certification Commission may take disciplinary actions against a certified operator. The Certification Commission can issue a written reprimand, suspend or revoke a certificate.

These actions may be taken if the Commission finds that an operator:

- has practiced fraud or deception in the performance of his/her duties;
- has failed to use reasonable care or judgment in the performance of his/her duties;
- has failed to apply their knowledge or ability in the performance of his/her duties;
- is incompetent or unable to perform his/her duties;
- intentionally supplied false information to obtain or maintain certification; or
- has cheated on a certification examination.

If a certificate is revoked, an operator must wait 2 years after revocation before petitioning the Commission for any new certification. The Certification Commission will only consider certification if there is substantial evidence that the conditions leading to the revocation have been corrected.

If the Certification Commission determines that the operator is eligible for a new certification, the operator will be required to take and pass another examination for certification. All examination eligibility requirements must be met. Operational experience accrued prior to the revocation of any previously held certification(s) cannot be used to meet examination eligibility requirements. In addition to revocation, an operator can also face civil and criminal penalties for practicing fraud or deception.

Taking disciplinary action against a certified operator is one of the most unpleasant tasks ever performed by the Certification Commission. All certified operators should view their certificates with a sense of pride and professional ethics.

Unfortunately, permittees or employers may sometimes pressure an ORC or back-up to keep quiet about necessary repairs and maintenance, to falsify records, or in some other way to jeopardize their certificates. Failure to follow the regulations and permit conditions can result in permittees being fined.

However, failure to follow regulations can result in certified operators losing their certification and, in many cases, their livelihood. For those of you who become certified, be proud of your certificate – you worked hard to earn it. Familiarize yourself with the regulations discussed in this chapter.

For those of you who become ORCs or back-ups, also familiarize yourself with the system permit. Protect yourself and your certificate.

Other Regulations

In addition to state and federal regulations, there may be local regulations that apply to surface irrigation systems. Generally, local regulations deal with the zoning or location of surface irrigation systems rather than the actual operation of these facilities. It is beyond the scope of this manual to review local regulations and the legal issues pertinent to them.

Owners and operators of surface irrigation systems should research the pertinent local regulations to make sure they are in compliance with these, if any. Information on such regulations should be available from the county planning and zoning office, the county manager's office or the local county health department.

Permittees of surface irrigation systems are also subject to third-party lawsuits. A third-party lawsuit is a lawsuit brought by a person who is not responsible for enforcing a regulation. An example could be a lawsuit brought by a neighbor, as opposed to a lawsuit brought by a local, state, or federal government agency.

Third-party lawsuits are becoming more and more commonplace as subdivisions move into more rural settings. The best way to avoid such lawsuits is to keep accurate, detailed records and properly operate and maintain your surface irrigation system at all times.

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TROUBLESHOOTING THE AERATED AND FACULTATIVE WASTE TREATMENT LAGOON

by

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INTRODUCTION

Lagoon treatment is a simple, cost-effective method to handle disposal of domestic wastewater most often used by small communities. Today, approximately 7000 waste stabilization lagoons are in use in the U.S. Advantages of waste treatment lagoons are that they are relatively inexpensive, they are simple to operate (compared to other waste treatment methods), they withstand shock loadings better than other biological treatment processes (for example, wastes from a campground or resort), and they remove nitrogen and phosphorus in addition to BOD. However, many variables affect the quality of lagoon effluents and, at times, effluent quality is not suitable for discharge to the environment.

Waste stabilization lagoons involve a number of physical, chemical and microbiological processes. Wastewater is held in relatively shallow basins for a time period sufficient to permit stabilization of wastewater organics (biochemical oxygen demand or BOD), to cause die-away of pathogens (disinfection), and to allow percolation, evaporation or controlled discharge of the treated water. Lagoons duplicate in an accelerated fashion the natural purification processes that normally occur in natural waters. An additional function of lagoons, often ignored, is sludge storage for later removal and disposal. Lagoon systems in common use can be classified as aerated or non-aerated (facultative).

This paper will present a general overview of domestic waste treatment lagoons and a discussion of lagoon microbiology, cold weather operation, fate of conventional pollutants in lagoons, and a discussion of operational problems and their causes.

Facultative Lagoons

Facultative lagoons are usually 4-8 feet deep and have an upper aerobic layer overlying a deeper anaerobic layer. The aerobic layer is quite important in maintaining an oxidizing environment in which gases escaping the lower anaerobic layer are oxidized, preventing odors. Facultative lagoons rely on natural surface aeration and algal photosynthesis to supply the oxygen needed for aerobic bacterial stabilization of wastes. The organic loading rate, limited by natural aeration capacity, is ususally 15-50 lbs. BOD_5/acre/day. Hydraulic detention times vary from 5 to 30 days in temperate climates, and to 180 days in cold climates.

Aerobic stabilization of BOD by aerobic bacteria occurs in the upper oxygenated layer, supplied with oxygen at least partly by algal photosynthesis, while BOD is converted to methane in the lower anaerobic layer by methane bacteria. There is a symbiosis between bacteria and algae in this process and both microbial components are necessary for successful operation.

Facultative lagoons are the easiest type of lagoon system to operate, but there are limits to their performance. Effluent BOD_5 values range from 20 to 60 mg/L and suspended solids from 30 to 150 (mostly algae). A large surface area is required to keep organic loadings in a suitable range. Organic overloading leads to complete anaerobic conditions which cause odors and high effluent BOD_5 values.

Aerated Lagoons

Mechanical aeration supplements or replaces algal photosynthesis as the source of oxygen for waste stabilization in an aerated lagoon, which increases the cost of operation but decreases the size (and cost) of the system. Organic loading is higher than for facultative lagoons, usually in the range 50-200 lbs. BOD_5/acre/day. Aeration is provided by brush aerators, propeller pumps, or by rising air bubbles from a diffused air system. Many aerated lagoons evolved from overloaded facultative lagoons. Properly designed aerated lagoons are 8-12 feet deep which allows for sludge storage at the bottom of the lagoon below the influence of mixing. One problem with upgrading a facultative lagoon to an aerated one is the lack of sludge storage capacity in a shallow basin.

Algae may or may not play a major role in oxygenation of aerated lagoons, depending on the organic loading rate and mixing conditions. Continuous mixing disfavors algal growth due to blockage of light by the stirred solids. If algal photosynthesis is desired, then intermittent mixing should be used. Aerated lagoons operated at higher organic loading approach activated sludge in function, however, with less biomass present (100-300 mg/L dry weight biomass). True activated sludge units involve biomass (sludge) recycle, which increases the biomass concentration to 1000-4000 mg/L.

Dissolved oxygen concentrations in a facultative or aerated lagoon may vary significantly over a 24-hour period (Figure 1). Dissolved oxygen concentration can be 200-300 % of saturation at mid-afternoon due to algal photosynthesis. At night, dissolved oxygen concentration drops to a minimum, due to bacterial <u>and algal</u> respiration. Odor production would be most expected at night. A single dissolved oxygen measurement at midday is not reliable to judge whether aeration is sufficient. If supplemental mechanical aeration is used, it is most appropriate to run this at night during the lowest oxygen period.

The Microbiology of Waste Stabilization Lagoons

Microorganisms found in aerated and facultative lagoons are more diverse than observed in many other biological treatment processes. Both aerobic and anaerobic bacteria are involved as well as algae and some higher life forms such as rotifers, Daphnia and insect larvae.

The aerobic bacteria that occur are similar to those found in other treatment processes such as activated sludge. Freely dispersed, floc-forming and filamentous bacteria occur. All function similarly to oxidize organic carbon (BOD) to produce CO_2 and new bacteria (sludge).

Anaerobic bacteria that commonly occur are involved in methane formation (methane bacteria) and in sulfide oxidation (sulfur bacteria). Anaerobic methane formation involves two different groups of anaerobic bacteria that function together to convert organic materials to methane via a two step process:

acid-forming bacteria - this diverse group of bacteria converts organic materials under anaerobic conditions to simple alcohols and organic acids such as acetic, propionic and butyric acid. These bacteria are hardy and occur over a wide pH range.

methane-forming bacteria - this limited group of bacteria converts acetic acid under anaerobic conditions to methane. These bacteria are environmentally sensitive and have a narrow pH range of pH 6.8 - 7.4.

Note that the product of the acid formers (acetic acid) becomes the substrate for the methane producers. A problem at times exists where the acid formers overproduce, lowering the pH below where the methane bacteria can function. This can stop methane formation and lead to a build-up of sludge with a low pH. In an anaerobic fermentor, this is called a "stuck digester".

The anaerobic sulfur bacteria, represented by about 17 genera, oxidize reduced sulfur compounds (H_2S) using light energy to produce sulfur and sulfate. All are either strict anaerobes or microaerophillic. Most common are Chromatium, Thiocapsa and Chlorobium which can grow in profusion and give a lagoon a pink or red color. Their finding is most often an indication of organic overloading and anaerobic conditions. Conversion of odorous sulfides to sulfur or sulfate by these sulfur bacteria is a significant odor control mechanism in facultative and anaerobic lagoons, and is desirable. Occasionally, sulfur bacteria occur in a lagoon due to treatment of high sulfate groundwater, not related to organic loading.

Algae are aerobic organisms that are photosynthetic and grow with simple inorganic compounds (CO_2, NH_3, NO_3, PO_4) using light as an energy source. These are desirable in lagoons as they generate oxygen needed by bacteria for waste stabilization. Three major groups occur in lagoons, based on their chlorophyll type: brown algae (diatoms), green algae, and red algae. The predominant algal species at any given time in a lagoon is dependent on growth conditions, particularly temperature, organic loading, oxygen status, and nutrient availability.

A fourth type of "algae" common to lagoons is the cyanobacteria or blue-green bacteria. These organisms grow much as the true algae, with the exception that most species can fix atmospheric nitrogen. Blue-green bacteria often bloom in lagoons and some species produce odorous and toxic by-products.

Algae can bloom in lagoons at any time of the year (even under ice) however, a succession of algal types often is observed in lagoons over the season. A common pattern is.

Season	Growth Conditions		Main Organisms
winter	low light	low temperature	none
spring	high light	low temperature	diatoms
summer	high light	high temperature	green algae
fall	low light	high temperature	blue-green bacteria

Algae can grow to such an extent in lagoons (bloom) that they consume for photosynthesis all of the carbon dioxide and bicarbonate present, leaving only carbonate as the lagoon buffering species. This causes the pH of the lagoon to become alkaline. PH values of 9.5 or greater are common in lagoons during algal blooms which can lead to lagoon effluent pH violations (in most states this is pH = 9). It should be noted that an increase in the lagoon pH caused by algal growth can be beneficial. Phosphorus removal by natural chemical precipitation is greatly enhanced at pH values greater than pH = 8.5. In addition, ammonia stripping to the atmosphere is enhanced at higher pH values (NH_3 is stripable, not NH_4^+).

Cold Weather Operation

Temperature controls the growth and activity of microorganisms, both bacteria and algae, and the stabilization rate of organic wastes. Microbial growth and waste stabilization follow the Q10 rule: the reaction rate doubles or halves for each 10C temperature change. Necessary temperatures for important microorganisms in lagoons are:

heterotrophic bacterial oxidation of BOD	5-35C
algal growth and oxygen production	5-35C
anaerobic fermentation	> 14C

These conditions are not always met in colder climates, where lagoon surface freezing occurs. At lagoon temperatures of less than 5C, lagoons function merely to store wastewater organics. Due to this, discharge from lagoons in colder climates may need to be seasonal, with effluent being discharged once or twice per year when effluent quality is satisfactory. Optimum lagoon performance in colder climates occurs in the summer and fall, when lagoon temperatures are highest.

Lagoon organic loading rates have to be lower and hydraulic detention times longer in cold climates. Lagoon size is determined for the lower organic loading rate permissible in the winter, often 180 days detention time. Further, discharge of effluent should not occur from an ice-covered lagoon. Anaerobic conditions prevail in a lagoon that is ice-covered and effluent quality will be poor. Often, a mechanical aerator is operated in the wintertime to prevent complete freezing of a lagoon surface.

Seasonal temperature changes also cause thermal stratification in some lagoons. This can result in a sudden mixing of the upper and lower layers of a lagoon in the spring and fall (overturn periods). Significant odor production and a poor quality effluent may occur during these overturn periods.

Fate of Pollutants in Lagoon Systems

Organic wastes (BOD) are ultimately converted to CO_2, methane and inert sludge in a lagoon system. In time, the sludge may accumulate and need to be removed from the lagoon. Most waste treatment lagoons remove 85-95% of influent BOD_5, if given enough time and are not organically overloaded or limited by aeration. Typically, about 50% of the applied BOD is released as CO_2 gas by aerobic bacterial metabolism and 50% ends up as new bacteria (sludge). Anaerobic degradation, if it occurs, further reduces the remaining BOD by 50%, lost to the atmosphere as CH_4 gas. Overall, a net 75% BOD removal as gases (CO_2 and CH_4) occurs in lagoons. About 25% of the influent waste ends up as a sludge which may accumulate in the lagoon and which needs to be periodically removed and disposed of.

Nitrogen in wastewater is principally in the form of organic nitrogen (protein) and ammonia. Most of the organic nitrogen is rapidly converted to ammonia by ammonifying bacteria in the lagoon. Ammonia is removed from wastewater in lagoons through three processes: (1) stripping to the atmosphere, significant at pH values greater than pH=8 often induced by algal growth; (2) assimilation into microorganisms (bacteria and algae); and (3) bacterial nitrification followed by denitrification. Lagoons can remove 50 to 99% of influent nitrogen, depending on operation.

Phosphorus is also removed in lagoons by assimilation into microorganisms. However, the main phosphorus removal mechanism in lagoons appears to be chemical precipitation and phosphorus accumulation in the bottom sludge, enhanced by high pH values induced by algal growth (pH > 8.5). Lagoons can remove 30-95% of influent phosphorus.

Effluent Violations in Lagoon Systems

The most common problems leading to poor lagoon performance are: (1) low dissolved oxygen and poor BOD removal; (2) loss of wastewater solids to the final effluent by short-circuiting or sludge buildup; and (3) algal overgrowth.

BOD_5 violations in lagoon effluents are often accompanied by high effluent total suspended solids (TSS). A BOD_5/TSS ratio of >0.5 in a lagoon effluent is usually an indication of a solids loss problem. High solids in lagoon effluents have several causes.

1. solids overload with influent wastewater solids (sludge) being carried through the lagoon to the final effluent.

2. lagoon short-circuiting with sludge being carried through to the final effluent.

3. growth of waste treatment microorganisms that won't settle by gravity before effluent discharge. This is usually proliferation of filamentous bacteria (termed bulking sludge).

4. algal overgrowth (bloom) in the system and loss of these to the effluent.

A microscopic examination of the solids present in a lagoon effluent can usually identify the nature of the problem.

Troubleshooting the Aerated Lagoon

Many different problems can occur in aerated lagoon operation that can lead to effluent violations. Troubleshooting a problem should begin with a thorough engineering evaluation for proper organic loading rate and hydraulic detention time, adequate aeration and mixing, possible short-circuiting, and sludge buildup. Additional recommended procedures are a microscopic solids analysis, measurement of the diurnal dissolved oxygen concentration and pH, and performance of the filtered/unfiltered BOD_5 comparison.

One approach to the resolution of lagoon problems is the microscopic solids analysis, performed for each lagoon cell at the transfer point and for the final effluent before chlorination. This technique requires the microscopic examination of fresh lagoon samples using a phase contrast microscope capable of achieving a total magnification of 1000X. Solids types present and their relative abundance are measured by this technique. Solids type categories include: (1) raw wastewater or sludge solids; (2) treatment solids (bacterial flocs); (3) filamentous bacteria; (4) sulfur bacteria; and (5) algae. These solids types are easily recognized with a little experience.

It is recommended that a soluble/total BOD_5 analysis be performed on the lagoon final effluent, to be done in conjunction with the microscopic examination. Here, the lagoon effluent sample is analyzed for BOD_5 in two ways: (1) as normal for total BOD_5; and (2) first filtered through a 0.45 um pore size filter and the filtrate analyzed for BOD_5 (soluble BOD_5). The difference between these two values is the particulate BOD_5 present. A particulate BOD_5 value of >50% of the total BOD_5 indicates a solids loss problem in the lagoon effluent. The microscopic examination is then used to identify the types of solids being lost from the lagoon thus leading to the cause(s) of the problem.

The basic information needed for troubleshooting an aerated lagoon are:

1. the organic loading rate (lb. BOD /surface acre/day) and the type of waste being treated (domestic, industrial, or mixed domestic-industrial).

2. aeration type employed and lagoon dissolved oxygen measurements (each cell) and the dissolved oxygen diurnal fluctuation.

3. the lagoon pH (each cell) and any diurnal fluctuation.

4. a check, if needed, for lagoon hydraulic short-circuiting (dye or salt addition).

5. a solids analysis for the effluent, including both the unfiltered/filtered BOD_5 analysis and a microscopic examination.

An analysis of this information usually yields a pretty good picture of the problems occurring.

Algae growth in lagoons and loss to the final effluent (algae are BOD) is the single most common problem in lagoon operation in the summertime. One ton dry weight of algae can be produced for each million gallons of domestic wastewater treated under optimum conditions. It is not uncommon to see BOD values increase in the latter cells of a multicell lagoon system due to algal growth. Systems that control algae well have sufficient hydraulic detention time and number of cells (4-5) to allow algae to exhaust growth nutrients by the final cell and to settle naturally (algae settle when starved). Algal overgrowth is easy to diagnose -- green effluent and microscopically an abundance of algae. Algal counts above approximately 1-3 X 10^5 per ml generally contribute BOD above a 30 mg/L effluent limit. Algal counts above 10^6 per ml yield an effluent BOD above 100 mg/L. Algal control methods are varied and include:

1. alum coagulation and sedimentation.

2. effluent centrifugation.

3. variable depth effluent withdrawal from the final cell.

4. light shading in the final cell by a duckweed cover, a synthetic cover, or a chemical shading agent.

5. use of an algicide such as copper sulfate.

6. use of overland flow or a constructed wetlands after the final lagoon cell.

7. biological control using "algae eaters" such as Daphnia.

All of these algae prevention or control measures increase the cost and the complexity of lagoon operation, but may be necessary.

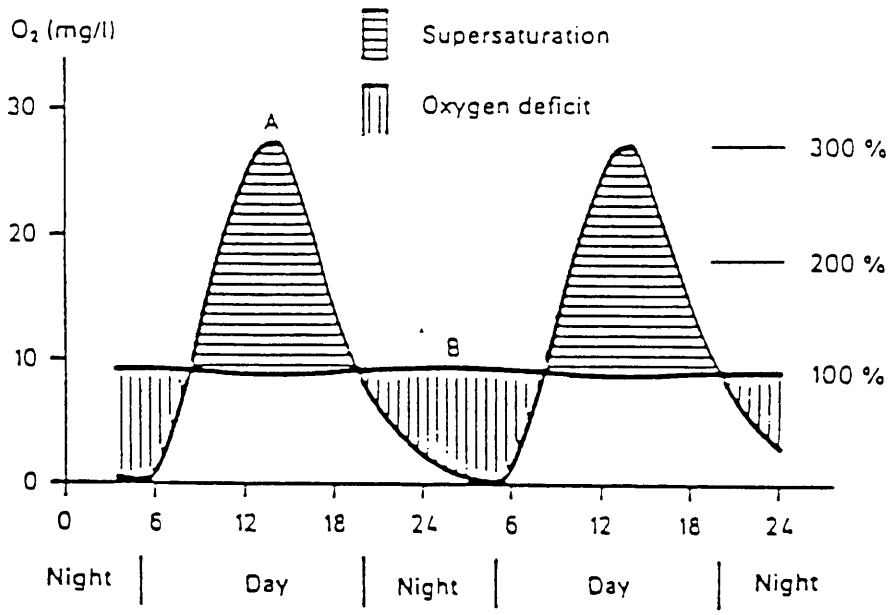


Fig. 1. — Daytime/night-time rhythm of the oxygen budget in a lagoon (from Uhlmann, 1982).

NOTE: The graph indicates that the lowest dissolved oxygen levels occur early in the morning due to the aerobic bacteria and algae utilizing oxygen during the night. The highest dissolved oxygen level is late in the afternoon due to algae photosynthesis. It is likely the aerators must run more at night to compensate for the algae metabolizing oxygen. It is important to insure proper aerator operation during the day for adequate mixing and to eliminate potential stratification conditions.

Troubleshooting guide for lagoons (Zickefoose and Hayes, 1977)

Indicators/observations	Probable cause	Solutions
Weeds	Poor circulation/maintenance, insufficient water depth	Pull weeds by hand if new growth
		Mow weeds with a sickle bar mower
		Lower water level to expose weeds, then burn with gas burner
		Allow the surface to freeze at a low water level, raise the water level and the floating ice will pull the weeds as it rises
		Increase water depth to above tops of weeds
		Use riprap; caution: if weeds get started in the riprap, they will be difficult to remove but can be sprayed with acceptable herbicides; get appropriate regulatory agencies' approval to use herbicides
		To control duckweed, use rakes or push a board with a boat, then physically remove duckweed from pond
Burrowing animals	Bank conditions that attract animals; high population in area adjacent to ponds	Remove food supply such as cattails and burr reed from ponds and adjacent areas
		Muskrats prefer a partially submerged tunnel; if the water level is raised, the tunnel will extend upward and if lowered sufficiently, the muskrat may abandon the tunnel completely; they may be discouraged by raising and lowering the level 0.15 to 0.20 m (6 to 8 in.) over several weeks; trapping or other methods of animal removal may be used if permitted by all appropriate regulatory agencies
High weed growth, brush, trees, and other vegetation	Poor maintenance	Periodic mowing is the best method
		Sow dikes with a mixture of fescue and blue grasses on the shore and short native grasses elsewhere; it is desirable to select a grass that will form a good sod, drive out tall weeds, bind the soil, and outcompete undesirable growth
		Spray with approved weed control chemicals
		Some small animals, such as sheep, have been used; may increase fecal coliform, especially to the discharge cell; some regulatory agencies advise against using animals for vegetation control due to concerns for liner and dike integrity
		Practice rotation grazing to prevent destroying individual species of grasses; an example schedule for rotation grazing in a three-pond system would be graze each pond area for 2 months over a 6-month grazing season
Undesirable scum formations	Pond bottom is turning over with sludge floating to the surface; poor circulation and wind action; high amounts of grease and oil in influent will also cause scum	Use rakes, a portable pump to get a water jet, or motor boats to break up scum formations; broken scum usually sinks
		Any remaining scum should be skimmed and disposed of by burial or hauled to landfill with approval of regulatory agency
Odors that are a nuisance	The odors are generally the result of overloading, long periods of cloudy weather, poor pond circulation, industrial wastes, or ice melt; use parallel feeding to primary cells to reduce loading; also, weeds and sometimes riprap will serve as areas for organic material accumulation resulting in odors	Apply chemicals such as sodium nitrate, or 1,2-dibromo-2,2-dichloroethyl dimethylphosphate to introduce oxygen; application rate: 5 to 15% of sodium nitrate/mil. gal (mil. gal $\times$ [3.785×10^3] = m^3); repeat at a reduced rate on succeeding days; use 100 lb sodium nitrate/ac (112 kg/ha) for first day, then 50 lb/ac/day (56 kg/ha·d) thereafter if odors persist; apply in the wake of a motorboat

Troubleshooting guide for lagoons (Zickefoose and Hayes, 1977) (continued)

Indicators/observations	Probable cause	Solutions
		Install supplementary aeration such as floating aerators, caged aerators, or diffused aeration to provide mixing and oxygen; daily trips over the lagoon area in a motorboat also help; note: stirring the pond may cause odors to be worse for short periods but will reduce total length of odorous period
		Recirculate pond effluent to the pond influent to provide additional oxygen and to distribute the solids concentration; recirculate on a 1:6 ratio
		Eliminate septic or high-strength industrial wastes
Blue-green algae	Blue-green algae is an indication of incomplete treatment, overloading, or poor nutrient balance	Use three applications of a solution of copper sulfate
		If the total alkalinity is above 50 mg/L, apply 10 lb of copper sulfate/mil. gal in cell (1 200 kg/m^3); if alkalinity is less than 50 mg/L, reduce the amount of copper sulfate to 5 lb/mil. gal (600 kg/m^3)
		Some states do not approve the use of copper sulfate because, in concentrations greater than 1 mg/L, it is toxic to certain organisms and fish; also, extensive use of copper sulfate may cause a buildup of copper in the sludge, making sludge disposal a problem
		Break up algal blooms by motorboat or a portable pump and hose; motorboat motors should be air cooled as algae may plug water-cooled motors
		Provide shading, increase dissolved oxygen (DO), add plankton and algae-eating fish
Mosquitoes, midges	Poor circulation and maintenance	Keep pond clear of weeds and allow wave action on bank to prevent mosquitoes from hatching
		Keep ponds free of scum
		Stock pond with *Gambusia* (mosquito fish)
		Spray with larvacide as a last resort; check with state regulatory officials for approved chemicals
High algal suspended solids in pond effluent	Weather or temperature conditions that favor particular population of algae	Draw off effluent from below the surface by use of a good baffling arrangement
		Use multiple ponds in series
		Intermittent sand filters and submerged rock filters may be used but will require modification and the services of a consulting engineer
		Provide shading, increase DO, add plankton and algae-eating fish
		In some cases, alum dosages of 20 mg/L have been used in final cells, used for intermittent discharge, to improve effluent quality; dosages at or less than this level are not toxic
Lightly loaded ponds that may produce filamentous algae and moss, which limit sunlight penetration	Overdesign, low seasonal flow	Increase the loading by reducing the number of cells in use
		Use series operation
A low, continued downward trend in DO	Poor light penetration, low detention time, high biochemical oxygen demand (BOD) loading, or toxic industrial wastes (daytime DO should not drop below 3.0 mg/L during warm months)	Remove weeds, such as duckweed, if covering greater than 40% of the pond
		Reduce organic loading to primary cells by going to parallel operation
		Add supplemental aeration (surface aerators, diffusers, or daily operation of a motorboat)
		Add recirculation by using a portable pump to return final effluent to the head works
		Apply sodium nitrate (see "Odors that are a nuisance" [above] for rate)
		Determine if overload is owing to industrial source and remove it

Troubleshooting guide for lagoons (Zickefoose and Hayes, 1977) (continued)

Indicators/observations	Probable cause	Solutions
Overloading, which results in incomplete treatment of the wastewater; overloading problems can be detected by offensive odors or a yellow, dull green, or gray color; laboratory tests showing low pH, DO, and excessive BOD loading per unit area should be considered	Short-circuiting, industrial wastes, poor design, infiltration, new construction (service area expansion), inadequate treatment, and weather conditions	Bypass the cell and let it rest Use parallel operation Apply recirculation of pond effluent Look at possible short-circuiting Install supplementary aeration equipment
Decreasing trend in pH; pH should be on the alkaline side, preferably about 8.0 to 8.4	A decreasing pH is followed by a drop in DO as the green algae die off; this is most often caused by overloading, long periods of adverse weather, or higher animals such as *Daphnia* feeding on the algae	Bypass the cell and let it rest Use parallel operation Apply recirculation of pond effluent Check for possible short-circuiting Install supplementary aeration equipment if problem is persistent and results from overloading Look for possible toxic or external causes of algae die off and correct at source
Odor problems, low DO in parts of the pond, anaerobic conditions, and low pH found by checking values from various parts of the pond and noting on a plan of the pond; differences of 100% to 200% may indicate short-circuiting; after recording the readings for each location, the areas not receiving good circulation are characterized by a low DO and pH	Poor wind action because of trees or poor arrangement of inlet and outlet locations; may also be due to shape of pond, weed growth, or irregular bottom	Cut trees and growth at least 500 ft (150 m) away from pond if in direction of prevailing wind Install baffling around inlet location to improve distribution Add recirculation to improve mixing; provide new inlet-outlet locations including multiple inlets Clean out weeds Fill in irregular bottoms; investigate potential for sludge accumulation in various parts of the pond
Facultative pond that turned anaerobic, resulting in high BOD, suspended solids, and scum in the effluent in continuous discharge ponds, unpleasant odors, the presence of filamentous bacteria, yellowish-green or gray color, and placid surface, indicating anaerobic conditions	Overloading, short-circuiting, poor operation, or toxic discharges	Change from series to parallel operation to divide load; helpful if conditions exist at a certain time each year and are not persistent Add supplemental aeration if pond is continuously overloaded Change inlets and outlets to eliminate short-circuiting Add recirculation (temporary-use portable pumps) to provide oxygen and mixing In some cases, temporary help can be obtained by adding sodium nitrate at rates suggested for odor control Eliminate sources of toxic discharge
High BOD concentrations that violate NPDES or other regulatory agency permit requirements; visible dead algae	Short detection times, poor inlet and outlet placement, high organic or hydraulic loads, and possible toxic compounds	Check for collection system infiltration and eliminate at source Use portable pumps to recirculate the water Add new inlet and outlet locations Reduce loads from industrial sources if greater than design level Prevent toxic discharges; convert to parallel operation
Fluctuating DO, fine pin floc in final cell effluent, and frothing or foaming	Shock loading, overaeration, industrial wastes, and floating ice	Control aeration system by using timeclock to allow operation during high-load periods; monitor DO to set up schedule for even operation, holding approximately 1 mg/L or more Vary operation of aeration system to obtain solids that flocculate or clump together in the secondary cell but are not torn apart by excessive aeration Locate industrial wastes that may cause foaming or frothing and eliminate or pretreat such wastes as slaughterhouse, milk, and some vegetable wastes
Ice interfering with the operation of aerated ponds	Floating ice	Operate units continuously during cold weather to prevent freezing damage or remove completely if not a type that will prevent freeze-up

Troubleshooting guide for lagoons (Zickefoose and Hayes, 1977) (continued)

Indicators/observations	Probable cause	Solutions
Odors in anaerobic ponds, caused by hydrogen sulfide (rotten egg) odors or other disagreeable conditions due to sludge in a septic condition	Lack of cover over water surface and insufficient load to have complete activity that eventually forms scum blanket	Use straw cast over the surface or polystyrene planks as a temporary cover until a good surface sludge blanket has formed
		Recirculate aerobic pond effluent to anaerobic pond
		Distribute over anaerobic pond by spraying to establish thin layer of aerobic water
Low pH in anaerobic ponds; a pH below 6.5 accompanied by odors, results from acid bacteria working in the anaerobic condition	Acid formers working faster than methane formers in an acid condition	The pH can be raised by adding a lime slurry of 100 lb of hydrated lime/50 gal (500 kg/200 L) of water at a dosage rate of 1 lb of lime/10 000 gal (120 g/10 000 L) in the pond; the slurry should be mixed while being added; the best place to put in the lime is at the entrance to the lagoon so that it is well mixed as it enters the pond
Groundwater contamination	Leakage through bottom or sides	Potential major capital improvements

Chapter 5

Inspecting Septic Tanks

5.1 Purpose of Inspection

Septage typically accumulates in a septic tank as shown in Figure 5-1. "Sludge," or heavy solids, grit, and sand, falls to the bottom of the tank. "Scum," or grease, fats, and floatable matter, collects on the surface, forming a mat. Between these zones of sludge and scum is a relatively clear liquid, called "effluent," which normally discharges into a soil absorption system (also referred to as a "leachfield" or "drainfield") each time wastewater is generated from the source.

The rate of accumulation of sludge and scum in a septic tank is highly variable and depends on many factors, including the number of family members, their personal hygiene and eating habits, the dimensions of the tank, the types of appliances used in the home (e.g., garbage disposals), and local climate. In some cases, natural digestion of organic matter significantly slows the accumulation rate, and pumping is required less frequently. If excessive buildup of sludge or scum occurs, however, solids may be carried with the effluent into the soil absorption system, where they accelerate soil clogging. Once soils are clogged, a new soil absorption system may be required, the construction of which is quite costly. Regular inspection and pumping of the septic tank is therefore essential.

Although a septic tank can be inspected to determine whether or not pumping is required, most inspections are performed as part of the pumping service to identify such items as broken baffles and cracked pipes. For older, established communities with septic tank access lids buried 6 to 24 in. (15 to 60 cm) below grade, locating and gaining access to the tanks for inspection can be time-consuming, which limits an inspection program's cost-effectiveness. For newer developments, in which septic tanks are equipped with surface risers that bring access ports flush with or above the existing grade (see Figure 5-1), inspection programs can be simple and therefore cost-effective.

5.2 Determining the Need for Pumping

Most older guidelines suggest that a septic tank serving a single family home should be pumped every 3 to 5 years. Depending on use, however, a modern septic tank may need less frequent pumping; some studies have shown that pumpout frequencies of 7 to 10 years are satisfactory. More frequent inspections, however, are prudent to identify such problems as cracked pipe joints and damaged or clogged baffles. Until local experience dictates otherwise, a pumpout frequency of 4 years is reasonable for most domestic septic tanks. Some states issue operating permits to homeowners that require regular septic tank inspections.

A relatively simple inspection of the septic tank can determine whether or not pumping is required. Inspection consists of measuring the depth of the scum and sludge layers, and assessing the physical condition of the tank and its components.

Scum layer depth can be measured using a stick with a hinged flap as shown in Figure 5-2. The stick is pushed through the scum layer until the flap falls into the horizontal position. The stick is raised until it meets resistance at the bottom of the mat. By marking the stick at the top of the scum layer, the thickness of the mat can be measured. The location of the bottom of the outlet baffle can be measured the same way. Instead of a hinged flap, some inspectors use a vertical stick with a small board attached horizontally at the bottom. If the bottom of the scum mat is less than 3 in. (8 cm) above the bottom of the baffle or outlet tee, or if the anticipated accumulation rate will result in this condition prior to the next inspection, the tank should be scheduled for pumping.

Sludge layer depth can be measured by wrapping a rough cloth strip or toweling around the lower 3 ft (1 m) of a measuring stick, fastening the cloth securely, and lowering the stick to the tank bottom. The measuring stick is lowered through a hole in the scum mat near the outlet baffle or through the outlet baffle itself to prevent scum from attaching to the toweling (see Figure 5-2). After at least 30 sec, the stick is slowly removed. Sludge depth can be estimated by the length of the cloth containing black sludge particles.

Another type of device for measuring sludge depth utilizes a hollow tube with a glass lens at the bottom. A small waterproof light source is attached a set distance from the glass lens, and liquid is allowed to enter the space between the light source and the lens. When the light can no longer be seen through the tube, the sludge layer has been

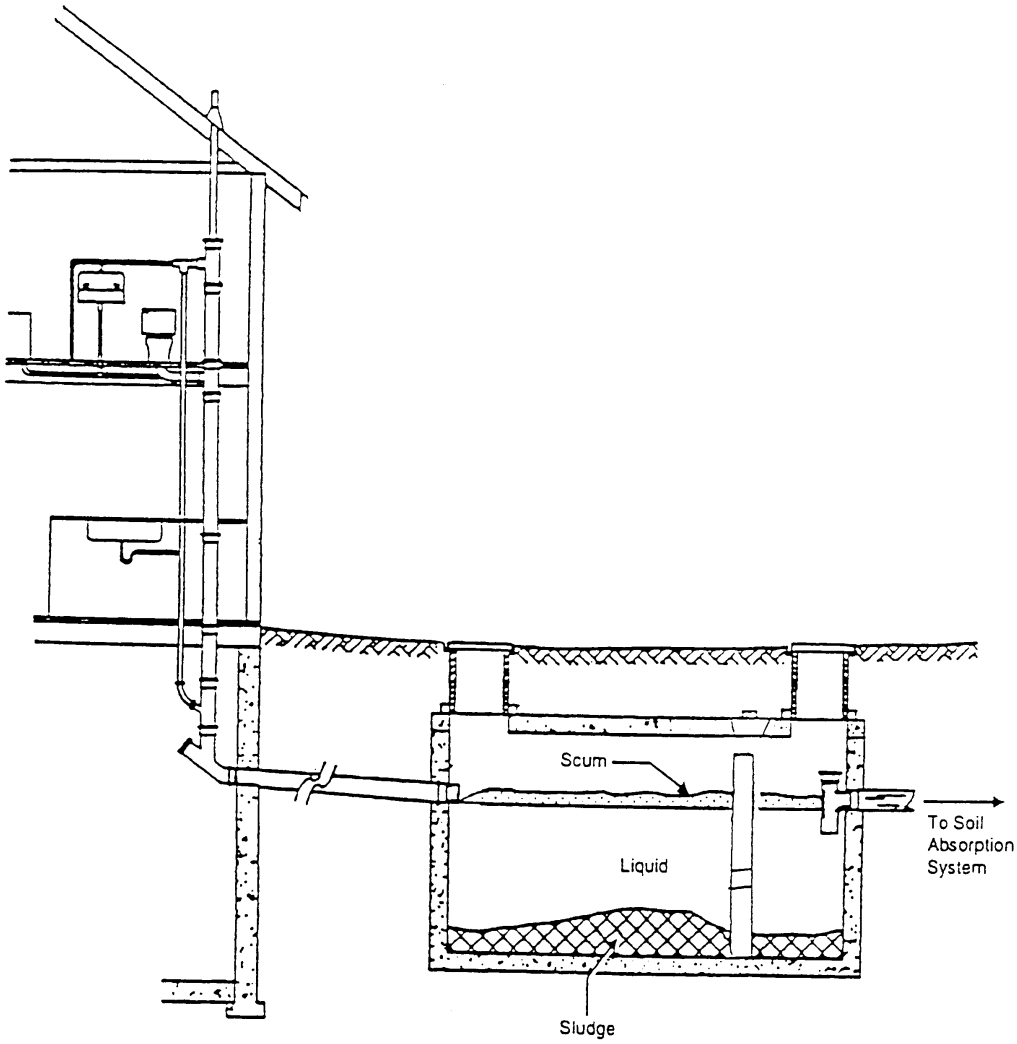


Figure 5-1. Typical residential septic tank.

reached. If the top of the sludge layer is closer than 12 in. to the bottom of the outlet baffle or tee or, more importantly, if the bottom of the scum layer is within 3 in. of the bottom of the outlet baffle or tee, the tank should be pumped.

Most commercial devices available to measure sludge depth are designed for use by operators of sewage treatment plants, and their accuracy for measuring sludge depth in a septic tank should first be demonstrated before purchasing such a device. Most of these instruments employ a light source and sight tube or photoelectric cell; other sludge blanket detectors use a transparent tube in which a "core" of the liquid profile is extracted and the sludge depth is directly measured. Yet another device employs a vertical rod that "floats" on the top of the sludge layer and extends through a hole in the septic tank cover to the surface. When the rod rises to a preset level, a sign becomes visible instructing the user to call a pumper.

Ideally, septic tanks should *initially* be inspected at least once every 2 years. A proper inspection of the septic tank includes observing the condition of the inlet and outlet baffles or tees; broken baffles or tees should be replaced.

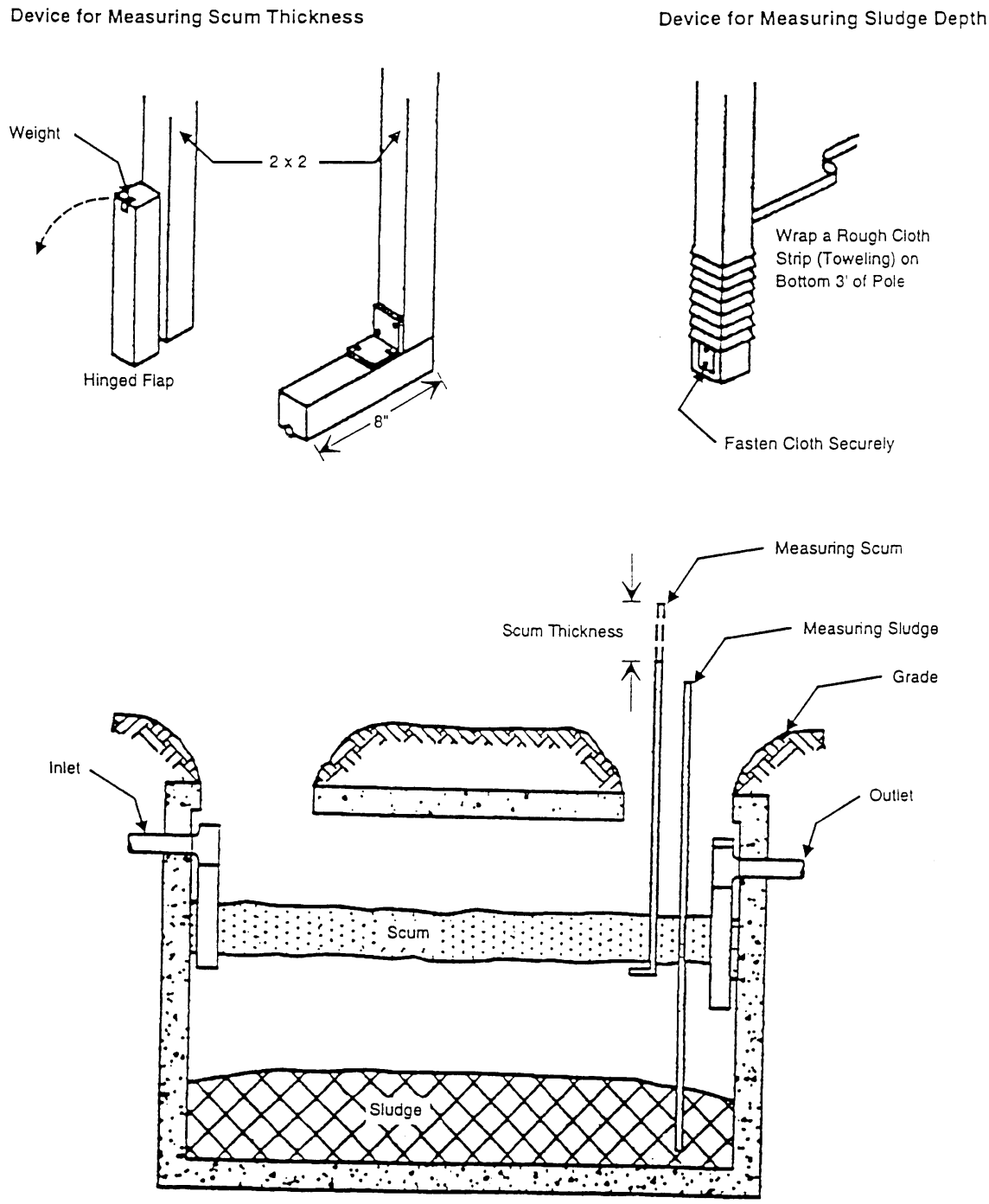


Figure 5-2. Measuring solids accumulation in a septic tank.

Inlet and outlet pipes should be sealed at the tank walls. Sludge and scum accumulation rates can be estimated based on measured levels and the time elapsed since the last pumping. The top level of water should also be compared with the outlet tee invert level (the bottom of the horizontal section) to see whether the tank is leaking.

Inspections of onsite sewage disposal systems generally are not limited to the septic tank. If present, distribution boxes should be inspected to determine if they are level and structurally sound and if solids have accumulated in them. Sludge in the distribution box indicates that solids have already been discharged into the drainfield, and the cause should be investigated and necessary action taken. Water levels in the box should also be noted; if levels are above the invert of the outlet pipe, the drainfield may malfunctioning, which might require a repair or additi The area of the drainfield should also be inspected for ev dence of surfacing or "daylighting" of septic tank effluent, such as waterlogged soils or ponded liquid, objectionable odors, dead grass from previous ponding episodes, presence of gray or black septic solids, and surface erosion due to runoff from accumulated liquid; these conditions might indicate a need for system improvements.

Chapter 6

Pumping Septic Tanks

6.1 Equipment

Pumper trucks typically range in capacity from 1,000 to 4,000 gal (3,800 to 15,000 L), although multiaxle trucks may have capacities over 6,000 gal (23,000 L). Most states require the business name, address, truck capacity, and other identifying information to be displayed on the side of the truck. Hose racks on the trucks store not only hoses but also devices used for breaking up the scum layer and other equipment.[1]

Pumps are typically either vacuum or centrifugal. Vacuum pumps, the most common system used by septage haulers, have the following advantages: liquid does not flow through the pump, which reduces wear; the pump is less likely to freeze; and the tank contents can be discharged under pressure. Vacuum pumps should be equipped with a water trap to prevent dispersion of aerosols. Because liquid moves through the pump, centrifugal pumps are more likely to clog and wear more readily from grit and debris. Centrifugal pumps are typically open-impeller or recessed-impeller for handling solids. Both types of centrifugal pumps have a maximum suction lift of about 27 ft (8 m). Some truck-mounted tanks are equipped with high-level automatic shutoff controls to prevent overfilling. Pump capacities are typically at least 400 gal/min (1,500 L/min).

Hoses should be of high-vacuum black rubber or synthetic material, with a minimum diameter of 3 in. (8 cm). Hoses should also be capable of being drained and capped to minimize spillage. Haulers typically carry at least 100 ft (30 m) of hose. Discharge valves on the hauler trucks should be drip tight, and a discharge nipple should accommodate a quick-disconnect coupling.

Other equipment includes a device for breaking up the scum layer (e.g., a long-handled fork), shovel, soil probe for locating the septic tank, and other tools to either measure accumulations or perform other tasks in the field. A squeegee and suction wand attachments should be carried to help clean up any spills. Lime should also be available to apply to areas where septage has been spilled.

Mobile septage dewatering systems, originally developed in Europe, are now available in the United States. With these systems, septage is pulled from the septic tank into one compartment on the truck; filtrate is returned to the septic tank. Polymer or lime is added to the septage during transfer to a dewatering tank, where solids are concentrated. A sludge solids content of 15 to 20 percent is reportedly achievable for polymer and lime systems, respectively. Mobile dewatering systems offer.

- Lower transportation costs due to fewer trips to the disposal site.
- Greater truck capacity.
- Lower volumes of material requiring further treatment and disposal.

These advantages are best suited to areas with many septic tanks and long travel distances to the discharge site. Disadvantages include more complex operational requirements and high equipment investment costs.

6.2 Procedures

After the septic tank has been located and the access hatches exposed, the inlet and outlet baffles or tees are examined for such problems as damage, loose connections, and plugging. Broken pipes or baffles should be replaced or repaired. If the liquid level in the tank is higher than the outlet pipe, this may indicate clogging in the outlet pipe or in the drainfield. Next, the scum mat is manually broken up to facilitate pumping. Before this is done, the liquid level in the septic tank first is lowered below the invert of the outlet, which prevents grease and scum from being washed into the drainfield. After the scum mat is broken up, the contents of the tank are removed. Normally, the vacuum/suction hose draws air at a point where 1 to 2 in. (2.5 to 5 cm) of sludge remains over the tank bottom; this material should be left in the tank. Washing down the inside of the tank is unnecessary unless leakage is suspected and the inside must be inspected for cracks. If internal inspection is warranted, fresh air should be continuously blown into the tank for at least 10 min to

[1] "The Pumper," a monthly publication aimed at the liquid waste hauler industry, produces an annual directory of equipment suppliers that is free with a subscription to "The Pumper." Contact Cole ublishing, P.O. Box 220, Three Lakes, WI 54562-0220, telephone 00) 257-7222.

displace toxic gases or oxygen-deficient air. The interior can then be inspected from the surface with a flashlight.

A septic tank should never be entered without first testing the air for oxygen content, lower explosive limit, and hydrogen sulfide. This is accomplished using electronic "triple gas detectors," available from suppliers of industrial safety equipment. Septic tanks are considered confined spaces and are subject to confined-space entry regulations published by the Occupational Safety and Health Administration (OSHA Standard 1910.146). Anyone entering a septic tank should wear a safety harness connected to an aboveground hoist. Two additional workers should be topside to assist the inspector in the event of problems. Your state or local agency responsible for occupational health and safety should be contacted regarding any additional regulations regarding confined-space entry in their jurisdiction.

In the event of a spill, septage should be immediately cleaned up. Hydrated lime should be sprinkled over the area of the spill, and a squeegee and a suction wand attached to the end of the vacuum hose are useful tools for cleanup. For large spills, a second pumper truck may be necessary; companies with one truck should reach an agreement with another company to assist in emergency spill cleanup.

Addition of any chemical or biochemical agents to the septic tank, such as disinfectants, microorganisms, and enzymes, is discouraged. Such formulations offer little or no benefit and may even be detrimental to the operation of the septic tank and drainfield. For instance, agents that emulsify grease allow its discharge to the soil absorption system, where the emulsion may break at the soil infiltrative surface and cause increased rates of clogging or pass through the soil to ground water. Other agents are formulated of strong alkaline compounds that can pass through a tank and destroy soil structure. The most detrimental formulations contain chlorinated hydrocarbons, which can pass through the tank and soil to contaminate ground water. Fortunately, many commercial products do little to affect performance of either tanks or soil systems. Although no known benefits have been demonstrated to date, the possibility of an effective formulation in the future cannot be ruled out.

Resources and Technical Assistance

There are a number of agencies that operators can turn to for help in operation and maintenance of surface irrigation systems. This appendix will explain the role of each relevant agency, as well as provide a resource list for your use should you have further questions or have the need to contact a representative from these agencies.

You are encouraged to use this material to develop a good working relationship with the individuals/agencies that may have involvement with your operation. Some agencies are strictly organized to deliver technical assistance, while others have a regulatory role. It is important to realize that the regulatory agencies are mandated to uphold the relevant laws and rules that have been dictated by the legislature and various state commissions. These laws are deemed necessary to protect the public health and the environment. Personnel with the regulatory agencies are also available to provide technical assistance, where possible, in addition to their regulatory role.

There may be instances where, due to circumstances that may or may not be beyond your control, you perceive that your facility has potential to cause a discharge of wastes (or has discharged wastes) that may affect the environment or the health of you, your employees, or the surrounding community. In such circumstances, your role as an environmental steward obligates you, as the operator in responsible charge, to contact the appropriate agencies to call attention to the situation. The regulatory agencies would much rather find out about a situation from the source than to wait until the consequences show up (such as a fish kill or contaminated water supply).

This is not to say that such an occurrence, when reported, is immune from regulatory action. However, regulatory action does take into consideration the willingness of the permittee or operator to report a waste spill and that individual's efforts to minimize the extent and impact of the spill. In short, you should keep a list of appropriate contacts available at all times, and notify all relevant agencies when situations arise (see the Emergency Action Plan in Chapter 5).

Below is a list of agencies (local, state, and federal) which have involvement in surface irrigation of wastewater in North Carolina. Each has a description of the major purpose of the agency, how each agency may be of benefit, and a list of contacts for the agencies' personnel.

North Carolina Division of Water Resources (DWR)

The North Carolina Division of Water Resources in the Department of Environment and Natural Resources is the agency reponsible for statewide regulatory programs in surface water and groundwater protection.

The Division, with central offices in Raleigh and seven regional offices located across the state, issues pollution control permits, monitors permit compliance, evaluates environmental quality and carries out enforcement actions for violations of environmental regulations. The link to the Division's home page is: http://portal.ncdenr.org/web/wq/.

DWR Non-Discharge Permitting Unit Central Office

The Division of Water Resources Non-Discharge Permitting Unit issues permits for and ensures compliance of non-discharge wastewater treatment systems, including land application of **wastewater (surface irrigation) and residuals.**

General Information	
Mailing Address: 1636 Mail Service Center Raleigh, NC 27699-1636	Physical Address: 512 N Salisbury St Raleigh, NC 27504
Telephone: (919) 807-6464	Fax Number: (919) 807-6496
Web Page: http://portal.ncdenr.org/web/wq/aps/lau	

Non-Discharge Permitting Unit :: Staff Directory

Name	Contact Information	Primary Contact	Secondary Contact
Vacant	Unit Supervisor	LAU Programs	Policies & Rules
Kristi Lynn Carpenter	Processing Assistant (919) 807-6332 kristilynn.carpenter@ncdenr.gov	Administrative Support	
Troy Doby, PE	Environmental Engineer (919) 807-6336 troy.doby@ncdenr.gov	Residuals Management	Wastewater Irrigation
David Goodrich, PG	Hydrogeologist (919) 807-6352 david.goodrich@ncdenr.gov	Hydrogeologic Issues	Closed-Loop Recycle
Ed Hardee	Environmental Specialist (919) 807-6319 ed.hardee@ncdenr.gov	Compliance Reporting	Residuals Management
Chonticha McDaniel	Environmental Engineer (919) 807-6337 chonticha.mcdaniel@ncdenr.gov	Reclaimed Water	Residuals Management
Nathaniel Thornburg	Environmental Engineer (919) 807-6453 nathaniel.thornburg@ncdenr.gov	High-Rate Infiltration & Reclaimed Water	Wastewater Irrigation & Rules
Alice Wessner	Environmental Engineer (919) 807-6425 alice.wessner@ncdenr.gov	Wastewater Irrigation	Closed-Loop Recycle

DWR Regional Offices

Regional office staff members are DWR's first line of response to environmental events that threaten or reveal problems with water quality, such as sewage system overflows or fish kills. Much of the work in the regions involves issuing permits, inspecting permitted activities and enforcing the rules that protect the environment.

DWR Regional Offices	Counties Served
Asheville Regional Office *Mailing and Physical Address:* 2090 U.S. 70 Highway, Swannanoa, NC 28778 *Phone:* 828-296-4500 *Fax:* 828-299-7043	Avery, Buncombe, Burke, Caldwell, Cherokee, Clay, Graham, Haywood, Henderson, Jackson, Macon, Madison, McDowell, Mitchell, Polk, Rutherford, Swain, Transylvania, Yancey
Fayetteville Regional Office *Mailing and Physical Address:* 225 Green Street, Suite 714, Fayetteville, NC 28301-5043 *Phone:* 910-433-3300 *Fax:* 910-486-0707	Anson, Bladen, Cumberland, Harnett, Hoke, Moore, Montgomery, Richmond, Robeson, Sampson, Scotland
Mooresville Regional Office *Mailing and Physical Address:* 610 East Center Avenue, Suite 301, Mooresville, NC 28115 *Phone:* 704-663-1699 *Fax:* 704-663-6040	Alexander, Cabarrus, Catawba, Cleveland, Gaston, Iredell, Lincoln, Mecklenburg, Rowan, Stanly, Union
Raleigh Regional Office *Mailing Address:* 1628 Mail Service Center, Raleigh, NC 27699-1628 *Physical Address:* 3800 Barrett Drive, Raleigh, NC 27609 *Phone:* 919-791-4200 *Fax:* 919-571-4718	Chatham, Durham, Edgecombe, Franklin, Granville, Halifax, Johnston, Lee, Nash, Northampton, Orange, Person, Vance, Wake, Warren, Wilson
Washington Regional Office *Mailing and Physical Address:* 943 Washington Square Mall, Washington, NC 27889 *Phone:* 252-946-6481 *Fax:* 252-975-3716	Beaufort, Bertie, Camden, Chowan, Craven, Currituck, Dare, Gates, Greene, Hertford, Hyde, Jones, Lenoir, Martin, Pamlico, Pasquotank, Perquimans, Pitt, Tyrrell, Washington, Wayne
Wilmington Regional Office *Mailing and Physical Address:* 127 Cardinal Drive Extension, Wilmington, NC 28405 *Phone:* 910-796-7215 *Fax:* 910-350-2004	Brunswick, Carteret, Columbus, Duplin, New Hanover, Onslow, Pender
Winston-Salem Regional Office *Mailing and Physical Address:* 585 Waughtown Street, Winston-Salem, NC 27107-2241 *Phone:* 336-771-5000 *Fax:* 336-771-4631	Alamance, Alleghany, Ashe, Caswell, Davidson, Davie, Forsyth, Guilford, Randolph, Rockingham, Stokes, Surry, Watauga, Wilkes, Yadkin

Emergency Response

During the normal workday - Monday - Friday, 8 a.m. through 5 p.m. - call the regional office closest to the environmental emergency. Do not leave a message. Make sure that you speak to an actual person so that you can share information that may be necessary to a fast response.

Outside of normal business hours, call the emergency hot line:

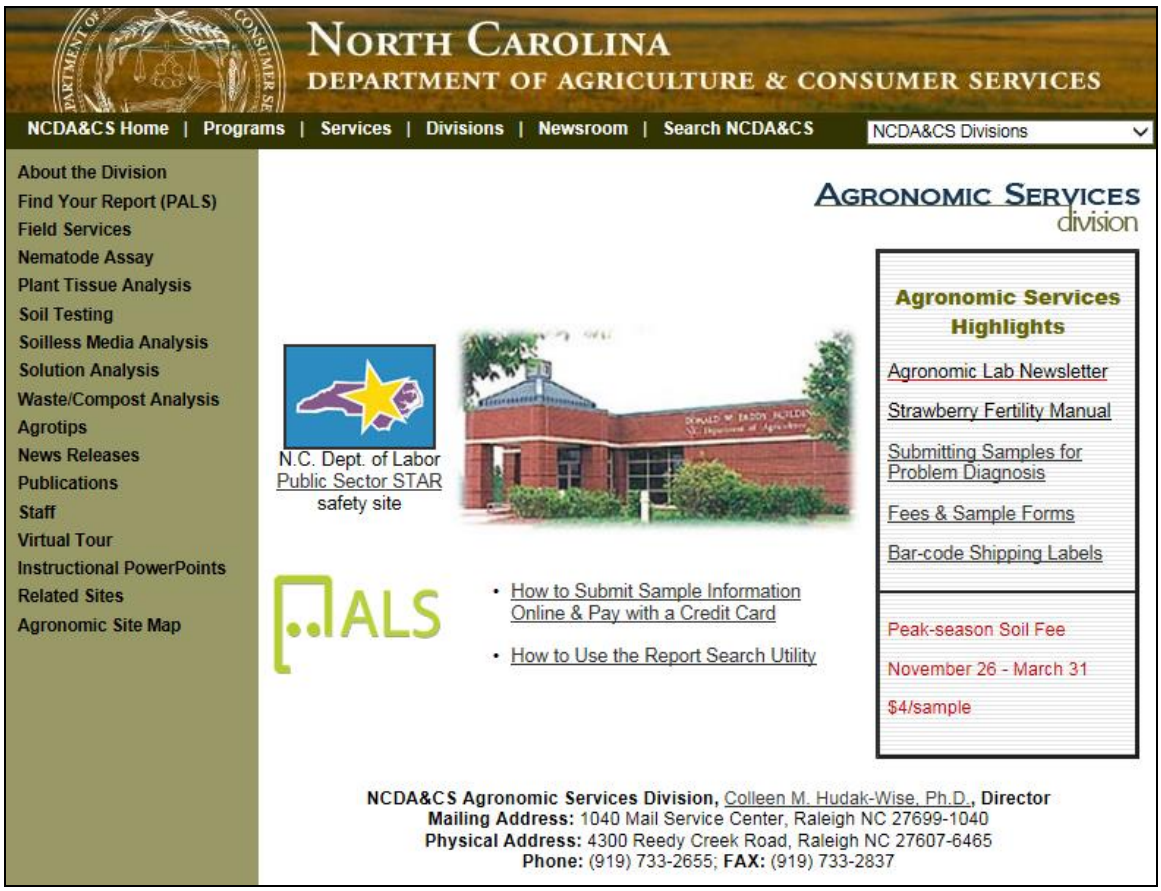
1-800-858-0368

and an appropriate regional staff member will be alerted.

Agronomic Services Division

NC Department of Agriculture & Consumer Services

http://www.ncagr.gov/agronomi/index.htm



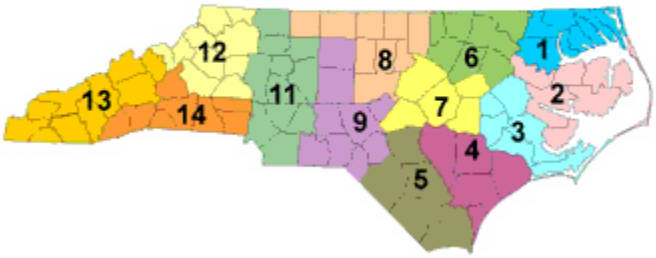
Agronomic Services — Field Services

Michelle McGinnis, Ph.D., section chief

Regional agronomists (RAs) provide on-site consulting services to help growers troubleshoot nutrient and nematode problems, establish appropriate agronomic sampling programs and implement management recommendations in a cost-effective and environmentally sound manner. Read RA success stories or the informational Field Services brochure!

By maintaining communications between growers and the Division's scientific and laboratory staff, RAs ensure that the Division remains responsive to current problems.

NCDA&CS Regional Agronomist Territories



Regional Agronomists

Name	Phone	Region/Counties
Adam Lassiter	(252) 326-1231	**Region 1:** Bertie, Camden, Chowan, Currituck, Gates, Hertford, Pasquotank, Perquimans
Jacob Searcy	(252) 503-8438	**Region 2:** Beaufort, Dare, Hyde, Martin, Pamlico, Tyrrell, Washington
Chris Jernigan	(252) 343-4760	**Region 3:** Craven, Carteret, Greene, Jones, Lenoir, Pitt
Tim Hall	(910) 324-9924	**Region 4:** Duplin, New Hanover, Onslow, Pender, Sampson
Georgia Love	(910) 690-0270	**Region 5:** Bladen, Brunswick, Columbus, Cumberland, Hoke, Robeson, Scotland
Mike Wilder	(919) 495-7495	**Region 6:** Edgecombe, Franklin, Halifax, Nash, Northampton, Vance, Warren
Don Nicholson	(919) 498-0504	**Region 7:** Harnett, Johnston, Wake, Wayne, Wilson
Robin Watson	(336) 570-6850	**Region 8:** Alamance, Caswell, Chatham, Durham, Granville, Orange, Person, Rockingham, Stokes
Colby Lambert	(919) 255-0514	**Region 9:** Anson, Guilford, Lee, Montgomery, Moore, Randolph, Richmond
		Region 10: no longer exists
Daniel Overcash	(704) 799-5070	**Region 11:** Cabarrus, Davidson, Davie, Forsyth, Iredell, Mecklenburg, Rowan, Stanly, Surry, Union, Yadkin
Dwayne Tate	(828) 443-5281	**Region 12:** Alexander, Alleghany, Ashe, Avery, Burke, Caldwell, McDowell, Mitchell, Watauga, Wilkes
Chris Leek	(828) 507-8671	**Region 13:** Buncombe, Cherokee, Clay, Graham, Haywood, Jackson, Macon, Madison, Swain, Yancey
Steve Dillon	(704) 276-1989	**Region 14:** Catawba, Cleveland, Gaston, Henderson, Lincoln, Polk, Rutherford, Transylvania

North Carolina Cooperative Extension Service (NCCES)

The North Carolina Cooperative Extension Service (NCCES) is a unique educational system with support from county, state, and federal governments and close ties to the state's two land grant universities–North Carolina State University and North Carolina A&T State University. The N.C. Cooperative Extension Service has educational centers located in every county and on the Cherokee Indian reservation. Each center has a staff with technical and programmatic responsibilities to serve the needs of their clients. Extension staff has expertise in crop and forage planting, harvesting, pest management, soil and plant science, animal and livestock husbandry, and some areas have regional water quality specialists.

Natural Resources Conservation Service (NRCS)

The Natural Resources Conservation Service (NRCS) is a branch of the U.S. Department of Agriculture. It provides technical assistance for the conservation of natural resources to all citizens who request such assistance. In the area of surface irrigation of wastewater, NRCS provides technical assistance with soil maps and soil interpretations, crop yield estimates, and erosion control and other best management practices. The link to the NC NRCS website is: http://www.nc.nrcs.usda.gov/.

North Carolina Division of Soil and Water Conservation (DSWC)

The Division of Soil and Water Conservation (DSWC) and the 96 soil and water conservation districts that serve North Carolina are dedicated to helping landowners reduce soil erosion and improve water quality through proper management of their natural resources. The Division works very closely with NRCS in the design and implementation of conservation measures, as well as policy decisions concerning the most effective means of natural resource conservation and use of available funds to meet conservation goals.

County Health Director

This individual supervises a department that oversees basic health services to each county. This includes drinking water, on-site sewage, restaurant sanitation, milk sanitation, and disease control. The health director has the authority to determine if a situation constitutes an "imminent health hazard," that is one that would place the general public in peril. Examples of such instances include closure of a restaurant, public swimming area, or school. In the event of a discharge of waste where a drinking water supply or public recreation area are subject to be impacted, the health director can declare a waste treatment operation to be such a hazard, and order the pollution eliminated immediately. This may include, in severe cases, complete closure of the operation so that no further discharge of wastes is possible.

You should be able to locate the phone number for your county's health director in the yellow pages of your phone book under the county government section.

County Emergency Management System (EMS)

The EMS system serves as a "hotline" number that can be used for emergencies of many types. It is necessary to know the local phone number for such occurrences as employee accidents. The EMS system may dispatch medical assistance to these types of emergencies. For other emergencies such as a large waste spill, EMS will contact other appropriate agencies as necessary.

CALIBRATING SOIL-WATER MEASURING DEVICES

Prepared by:
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Introduction

Measuring soil-water is important to effective irrigation scheduling. Most soil-water measuring devices do not measure soil-water content directly; instead, they measure a property that can be related to soil-water content by using a calibration curve.

Manufacturers of most soil-water measuring devices provide a calibration curvefor their equipment. However, manufacturer's calibration curves are developedfor general conditions and are not adequate for site-specific soil conditions.

For best results, soil-water measuring devices should be calibrated for the major soil types in each field being irrigated. This publication pro- vides a step-by-step description of how to use the gravimetric method to calibrate soil-water measuring equipment.

The purpose of calibration is to establish the specific relationship between the plant available water (PAW) on a soil site with the readings of the soil-water measuring device. It is important to calibrate each different type of equipment for each major soil where it will be used. Usually, it is not necessary to calibrate all of the devices of a similar type if the equipment comes from the same manufacturer, is used in the same field, and seems to be functioning properly.

Once a specific type of device is calibrated, all devices of the same type can be checked for uniformity of readings. For example, all tensiometers can be installed in one location in the field at the same depth. Any units that behave differently from the majority of units would then need to be examined carefully.

As seen in Table 1, the gravimetric method is the only method that measures soil-water content directly. Therefore, on-farm calibration requires matching water contents determined by the gravimetric method over a range of soil-water contents with the readings of the desired soil-water measuring device(s). Several weeks may be needed to develop a reliable calibration curve. This is

especially true for obtaining the relationship at low soil-water contents (dry range), because the soil may be wetted several times by rainfall during the calibration process. The best time to calibrate the devices is in the fall, preferably during October. In North Carolina, October is typically the driest month (least rainfall), and potential evapotranspiration (PET) is still fairly high. Performing the calibration during this period increases the probability of obtaining readings in the dry range, and the calibration data are then available at the start of the next irrigation season. The calibration can also be performed during the irrigation season, but it may not be completed in time to utilize the data during that season's irrigation.

The procedure for measuring soil-water by the gravimetric method is outlined below followed by an example tensiometer calibration using this procedure. This calibration procedure is similar for the other types of soil-water measuring devices.

Table 1. Soil-Water Property Measured by Different Soil-Water Measuring Devices

Soil-Water Measuring Device or Method	Soil-Water Property Actually Measured
Tensiometer (suction)	Soil-water tension
Electrical resistance block	Electrical resistance of the block
Feel method	Appearance and feel of the soil such as strength, stickiness, hardness, plasticity
Gravitational Method	**Soil-water content**
Neutron probe	Number (counts) of slow-moving neutrons over a fixed time interval
Phene cell	Heat conductance of the cell
Time domain reflectometer	Energy conductance

Determining Soil-Water by the Gravimetric Method

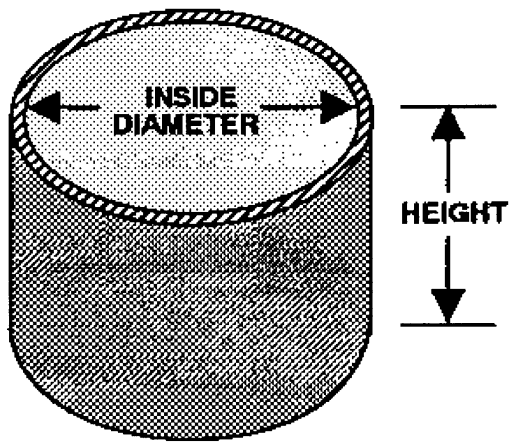
Soil-water content is determined by the gravimetric method by taking a soil sample, weighing it, drying it in an oven for 24 hours at 220 degrees F, and then weighing the dry sample to determine the mass of water removed. The difference between the moist weight and oven-dry weight is the mass of water contained by the soil at the time the sample was collected. For the purpose of irrigation scheduling, the soil-water content is then expressed on a volume basis (equivalent depth of water per unit depth of soil).

To determine water content on a volume basis, the bulk density of the soil is required. An undisturbed sample must be used to calculate bulk density because the exact volume of the sample must be known.

Bulk density, BD, of the soil is defined as the weight of oven-dry soil (Wds) divided by the volume of soil (Vs) before drying.

$$BD = Wds/Vs$$

The following is a step-by-step procedure for determining volumetric water content using the gravimetric method. The weighing device should be accurate to +/- 0.5 ounces.



$$\text{VOLUME}_{(\text{CORE})} = \frac{3.14 \times \text{INSIDE DIAMETER}^{(\text{SQUARED})} \times \text{HEIGHT}}{4}$$

$$V = \frac{3.14\ D^2\ H}{4}$$

Figure 1. Cylindrical tube for collecting an undisturbed soil sample.

Step 1

- Use a cylindrical tube about 2 to 3 inches in diameter by 2 to 3 inches long (see Figure 1).
- Measure the inside diameter and total length to the nearest 1/32 inch.
- Calculate the volume of the cylinder with the following equation:

  Volume of Core = 3.14(D)(D)(H)/4

Step 2

- Remove the soil above the zone to be sampled (see Figure 2).
- Take the soil sample from the center of the effective root zone. For example, if the effective root depth is 12 inches, the sample should be taken in the 5- to 8-inch depth range.

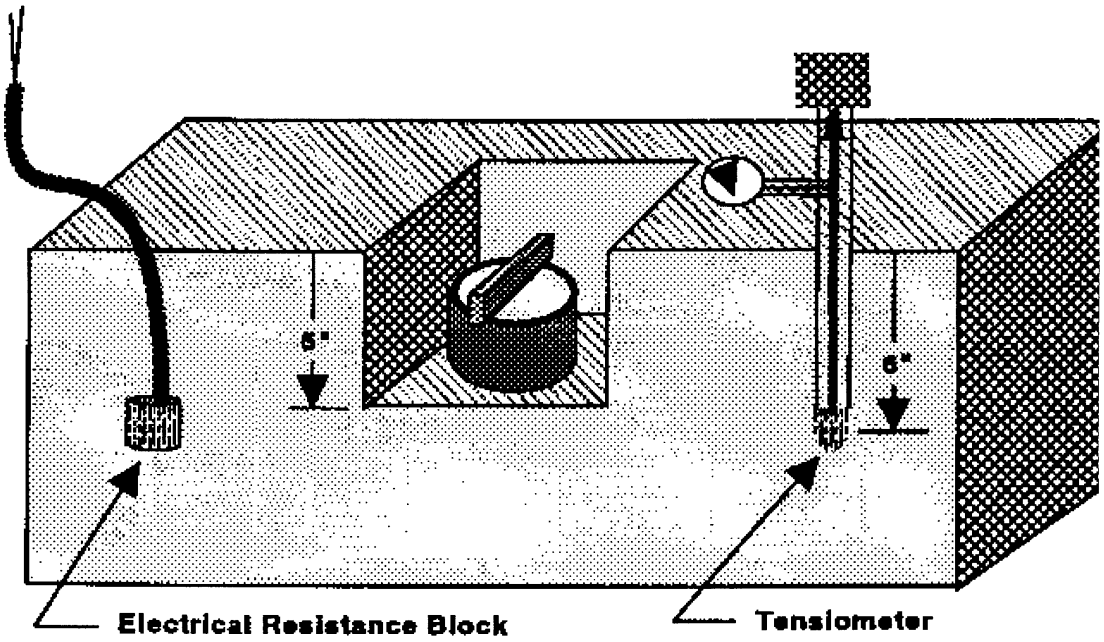


Figure 2. Location from which to take undisturbed soil core.

Step 3

- Use a hammer to tap the cylindrical tube into the soil (Figure 3) so that the top of the tube is flush with the excavated soil.
- Cut the soil 1/2 inch below the base of the tube with a knife or trowel.
- Remove the tube and soil without spilling any of the soil from inside the tube. (The soil should completely fill the tube).

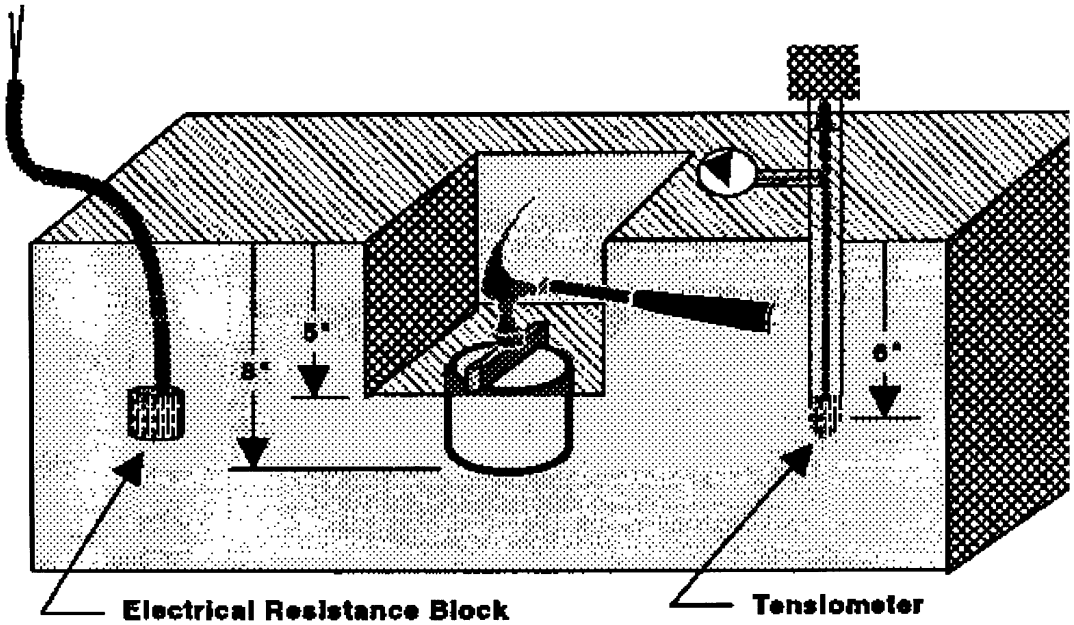


Figure 3. The core is tapped into the soil to take an undisturbed sample from the center of the effective root zone.

Step4

- Trim the soil at each end of the tube to the tube length (Figure 4) so that the soil occupies the exact tube volume.

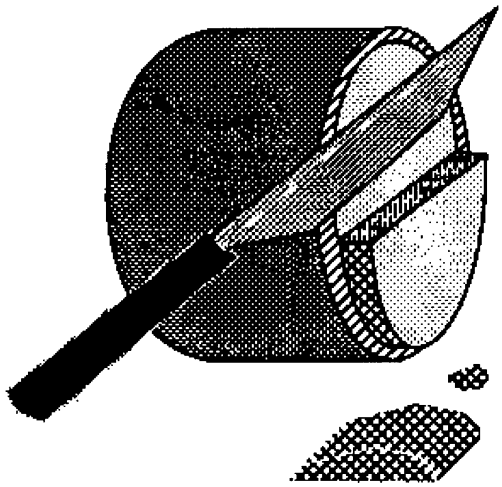


Figure 4. Trimming the soil core to the exact length of the cylindrical tube.

Step 5

- Immediately empty the soil from the tube into a plastic container (plastic bag) so the soil can be transported to the weig}ung location without drying. Be sure all of the soil is transferred from the tube to the plastic container.

Step 6

- Empty all of the soil from the plastic container to an oven-safe container and weigh it immediately. This is the wet weight of the soil plus the container

Step 7

- Place the sample now held in the oven-safe container into an oven and dry it for 24 hours at 220 degrees F.

Step 8

- Weigh the dried sample and oven container. This is the dry weight of the soil plus the container (Wds+c).

Step 9

- Discard the soil and weigh the empty oven container (Wc).

Step 10

- Use the following equation to determine the volumetric water content (Vw) of the sample:

Vw =

[(weight wet soil & container-weight dry soil & container)/ (weight dry soil & container - weight container)]X[bulk density soil/density water]

Vw =

[(Wws+c-Wds+c)/(Wds+c-Wc)]X[BD/DW]

The standard English unit for the density of water (DW) is 62.4 pounds per cubic foot. However, for working with small samples, a more convenient unit for DW is 0.578 ounces per cubic inch. An example calculation is given in the calibration example.

Example: Field Calibration of a Tensiometer

Step 1

- Prepare two tensiometers for field installation. (Preparation and installation procedures are discussed in Extension Publication AG 452-2, *Measuring Soil-Water for Irrigation Scheduling: Monitoring Methods and Devices.*)

Step 2

- Install each tensiometer at locations in the field that represent average field conditions. (Tensiometers should be placed in the row if the field is bedded or a crop is growing).
- Each tensiometer should be installed with the porous tip centered at one-half the effective root zone depth (typically 5 to 8 inches deep).

Step 3

- Check tensiometer readings immediately following a soaking rain (1 to 2 inches within 24 hours). They should read near zero (less than 3 centibars (cb) if their length is 12 inches).

Step 4

- Begin measurements for sandy to sandy loam soils approximately 24 hours after the rain ends. The soil should be near field capacity by this time.
- Record the tensiometer reading. The tensiometer will read around 5 to 10cb.

Step 5

- Collect a soil sample near each tensiometer at the depth of the porous tip. Each sample should be collected, weighed, and dried according to the procedure outlined in the previous section ("Determining Soil-Water by the Gravimetric Method").
- Take the gravimetric soil sample about 12 inches from the tensiometer so that the soil around the tensiometer is not disturbed. Replace unused soil.

Step 6

- Repeat steps four and five at least twice per day (around midday and late afternoon) until the tensiometer readings exceed 70 cb. (This sampling frequency is for calibration during periods of high evapotranspiration, May to October. Otherwise, measurements can be made once every 24 hours at any time of day).
- Take samples from an undisturbed area on either side of the row near the tensiometers (Figure 5). Replace unused soil after collecting each gravimetric soil sample. At least two samples near each tensiometer should be undisturbed so that bulk density can be computed. Tensions above 20 cb are not easily obtained in the field unless plants are growing or no rainfall occurs for several weeks.

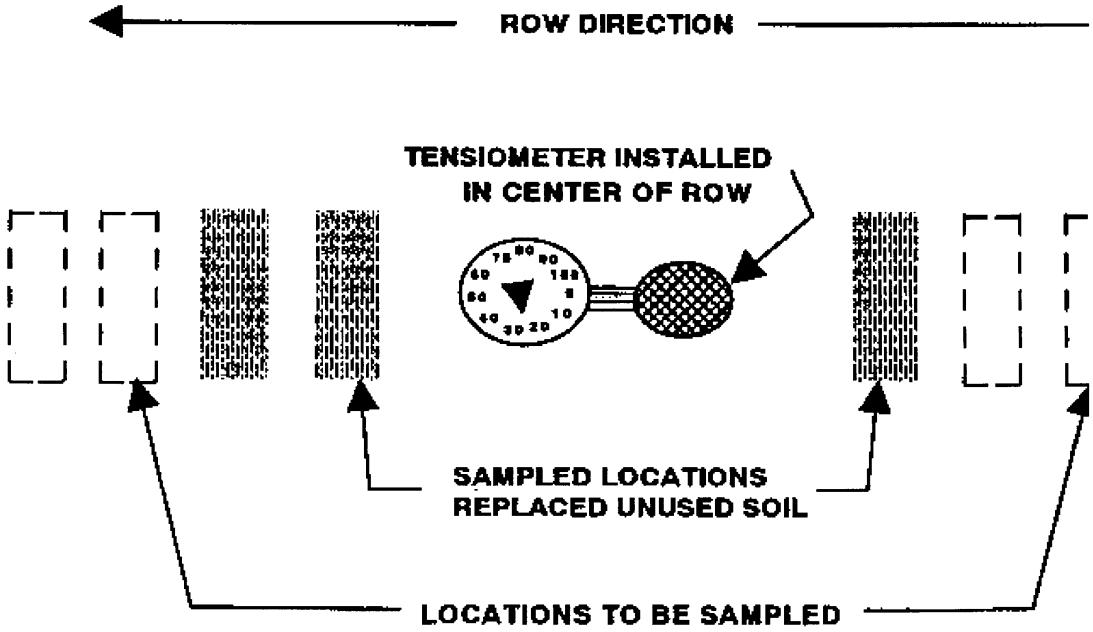


Figure 5. During the calibration process, gravimetric soil samples should be taken along the row at the same distance from the center of the row as the tensiometer or electrical resistance block. After collecting each sample, replace unused soil.

Step 7

- The above measurements will establish the moist range of the calibration curve. The permanent wilting point (POOP) water content is difficult to measure in the field. A gravimetric soil sample can be collected when a growing crop begins to remain continuously wilted for 24 hours. Otherwise, a soil sample should be sent to a laboratory so that the PWP water content can be determined by a laboratory procedure. If the PWP cannot be determined by one of the laboratory procedures, it may be estimated as one-half the water content at field capacity for most soil textures except soils with a clay content greater than about 35 percent.

Sample Calculations for the Calibration Procedure

Assume that the data in Table 2 were collected to calibrate a tensiometer as outlined above. Bulk density was determined on two undisturbed cylindrical core samples (3 inches in diameter by 3 inches in length). The bulk density can be computed from the volume of the core and the average weight of the undisturbed oven-dry samples.

Table 2. Field Data Collected During Tensiometer Calibration

Date	Time	Tensiometer Reading (centibars)	Sample Number	Weight of Moist Soil (ounces)	Weight of Oven-Dried Soil (ounces)	Comments
10/1	10 am	0	–			About 2 hours c fall stopped
10/2	12 pm		1	23.3	19.8	Undisturbed sar bulk density
10/3	12 pm	5	2	23.1	20.1	Undisturbed sar bulk density
10/3	6 pm	9	3	14.7	13.1	Disturbed samp in plastic bag
10/4	1 pm	17	4	16.2	14.7	Disturbed samp in plastic bag
10/4	7 pm	26	5	20.4	18.8	Disturbed samp in plastic bag
10/5	12 pm	37	6	13.9	12.9	Disturbed samp in plastic bag
10/5	6 pm	51	7	17.3	16.2	Disturbed samp in plastic bag
10/6	2 pm	68	8	19.6	18.4	Disturbed samp in plastic bag
10/6	7 pm	22	9	15.8	15.1	Tensiometer ha tension, sample laboratory dete of PWP

Volume of core = 3.14(3in.)(3in.)(3in.)/4 = 21.2 in3

Average dry weight of two undisturbed samples:
(19.8 oz + 20.1 oz)/2 = 19.95 oz

Bulk density of the soil:
=19.95 oz/21.2 in3 = 0.94 oz/in3.

Soil sampling basics

Agronomic News for North Carolina Growers — March 2009 www.ncagr.gov/agronomi/ (919) 733-2655

Useful Facts

- The sample you submit should be representative of the area.
- Sandy coastal plain soils should be tested every two to three years on average. Fine-textured soils from the piedmont or mountains should be tested every three to four years.
- Test results and recommendations can vary within short distances.
- A detailed map or an aerial photograph is useful for outlining fields and assigning permanent identification codes (five characters maximum).

Characteristics of Predictive (Routine) Soil Samples

- The grower is primarily interested in receiving lime and fertilizer recommendations.
- The area sampled has no known history of fertility problems.
- Samples are processed in the order received. It may take one to several weeks for analysis to be completed.

Charactistics of Diagnostic (Problem) Soil Samples

- Crops/plants have not responded as expected, and the grower suspects a nutrient problem.
- Diagnostic samples are analyzed like predictive ones except soluble salts are also measured.
- The best diagnostic samples are actually paired samples. Comparison of samples from both good and bad areas makes it easier to confirm a fertility problem.
- Problem samples have priority over predictive samples. They are moved to the head of the line and usually processed within one week or less. [Note: Don't try to get predictive samples processed more quickly by labelling them as diagnostic samples. It won't work.]
- Shipping packages containing diagnostic samples must be clearly marked so they will not end up mixed in with predictive samples.

Taking Samples

- For agricultural samples, take 15 to 20 cores from each area.
- For lawn and garden samples, take 6 to 8 samples per area (front, back, side, etc.).
- Use a clean, steel sampling instrument. A soil probe is best, but a shovel will work.
- Place each soil core into a clean plastic bucket. Avoid using metal buckets or containers.
- Walk a random pattern over the sampling area.
- Look for changes in soil color, texture, slope and history to establish separate sampling areas.

- Do not group together cores from areas that you know have received different treatments. These special areas should be sampled separately.
- Avoid field borders, ditch banks, old brush piles, burn sites, etc.
- If crop response has been different in an area and the area is large enough to manage separately, then sample it separately.
- The sampling depth for agricultural land where conventional tillage is practiced is 6 to 8 inches. In areas where a pasture or hay crop is to be established or a conservation tillage or no-till plan started, sample to a 6- to 8-inch depth. Where an existing sod is already established, such as pasture or hay, sampling depth is 4 inches. Where conservation or no-till is established, sampling depth is 4 inches.
- Samples from lawns should be taken to a depth of 4 inches. Samples from gardens, shrubs or any other homeowner site should be taken to a depth of 4 to 6 inches.
- Sampling areas should be units of manageable size. No sample should represent an area larger than 15 to 20 acres. Extremely small areas can also be difficult to treat.
- If soil is too wet to till, it is likely best to wait for dryer conditions before taking samples. Wet soils are difficult to mix thoroughly and may affect the quality of the subsample taken.
- After sampling an area, thoroughly mix the sample breaking up clumps and removing any large particles of trash. Fill the sample box to the fill line marked on the side of the box. Be sure the box is marked with the correct sample identification and the grower name.

Submitting Samples

- Put samples in NCDA&CS sample boxes, which are available at county Cooperative Extension offices and from the NCDA&CS Agronomic Division office in Raleigh.
- Use permanent ink to label each sample box and complete the appropriate sample information form. These forms are available online at www.ncagr.gov/agronomi/forms.htm. Do not use felt tip pens since most of them do not contain waterproof ink. Boxes labeled with a pencil can also be very difficult to read if the sample box becomes dirty.
- Select the appropriate crop code from the back of the sample information form, and write it in the appropriate column on the front of the form.
- Do not put soil in a plastic bag inside the sample box. Results and recommendations for samples received in plastic bags will be delayed.
- Do not tape sample box seams unless the sample is from a quarantined area.
- Do not place sample boxes inside a plastic bag before shipping. Moisture in samples may cause boxes to deteriorate.
- Do not put sample information forms inside soil sample boxes. Attach form(s) to the outside of the shipping box or put them inside the shipping box next to or on top of the samples.
- Do not use sample boxes as mailing containers.
- Do not send samples in manilla envelopes, padded or nonpadded. Samples should be shipped in a sturdy, corrugated cardboard box.
- To track your samples and receive e-mail notification when they arrive at the NCDA&CS lab, put a bar-code label on the outside of each shipping container. Visit www.ncagr.gov/agronomi/ and select the **Bar-code shipping labels** link.

Sample preparation and submission

- Use NCDA&CS soil sample boxes, label them completely and fill with soil to the red line.
- Complete the appropriate sample information form using permanent ink or pencil. You must list a crop or crop code in order to get lime and fertilizer recommendations. Forms are available from NCDA&CS regional agronomists, Cooperative Extension offices, the Agronomic Division office in Raleigh and online at www.ncagr.gov/agronomi/forms.htm.
- Package the sample appropriately. Do not tape the soil sample box or put soil in a plastic bag. If sending several sample boxes through the mail, pack them carefully in a sturdy container, and mail them to the address given on the back of this publication. Detailed packaging instructions are available at www.ncagr.gov/agronomi/pdffiles/packsoil.pdf.

The soil test report

As soon as analysis is complete, soil reports are posted online. Visit the Agronomic Division website www.ncagr.gov/agronomi, and click the link labelled "Find Your Report (PALS)" located in the left-column navigation bar. Reports remain online for about three fiscal years, and data can be downloaded into a spreadsheet.

If you have questions about sampling procedure or need help interpreting a report, consult your NCDA&CS regional agronomist or other agricultural advisor. Additional information about soil tests and their interpretation is also available online at www.ncagr.gov/agronomi/uyrst.htm.

North Carolina Department of Agriculture and Consumer Services

Steve Troxler, Commissioner of Agriculture

Agronomic Division

Colleen M. Hudak-Wise, Director

www.ncagr.gov/agronomi/

(919) 733-2655

Mailing Address
1040 Mail Service Center
Raleigh NC 27699-1040

Physical Address [DHL, FedEx, UPS]
4300 Reedy Creek Road
Raleigh NC 27607-6465

For more information on sampling, interpreting agronomic reports or implementing recommendations, contact your NCDA&CS regional agronomist or other agricultural advisor.

Agronomic Sampling
Folder No. 2

revised January 2013

Soil Sampling Large Areas: Agricultural Crops, Pastures, Parks or Athletic Turf

The goal of soil sampling a large area is to collect a sample that provides good representation for the entire area. These guidelines may help.

Before sampling a large area, it is a good idea to make a detailed map. Copies of aerial photographs from soil surveys may be helpful. Divide the map into individual sample areas of 20 acres or less. Each unique area should ideally have similar soil type, planting history and management history.

Assign a short, permanent sample identifier to each unique area using appropriate FARM ID and SAMPLE ID designations that will help you remember the location. Keep in mind that the SAMPLE ID space on the soil box is limited to five characters.

Always use clean, stainless-steel sampling equipment and a clean, plastic bucket. Brass, bronze or galvanized tools contaminate the sample with copper and/or zinc. If the sample-mixing bucket has been used for fertilizer or other chemicals, wash it thoroughly before use.

Timing of sampling

Whenever possible, sample three to six months before planting. For field crops, submitting soil samples right after harvest provides plenty of time to plan a liming and fertilization program before the busy growing season. In September and October, the laboratory workload is relatively light, and results can be returned within about two weeks.

The laboratory has its greatest workload from November through March due to the thousands of agricultural samples received at this time. Turn-around time can be six weeks or more. Anyone who can schedule their sampling at another time of year is urged to do so.

Problem samples should be taken from around actively growing plants whenever growth or plant discoloration occurs. To make sure these samples receive priority treatment when they arrive at the laboratory, label the outside of the shipping containers prominently with the words *PROBLEM SAMPLES*.

Frequency of sampling

For coastal plain soils, collect samples every two years or test one-half of your land every year. Sandy soils lose nutrients and become acidic more quickly than the fine-textured clay soils found in piedmont and mountain regions. In these two regions, collect samples every three years or test one-third of your land every year.

Depth of sampling

For cultivated crops, sample the plow layer, usually six to eight inches (Figure 1). Before establishing new lawns, pastures, orchards or other large no-till or minimum-tillage areas, sample to a depth of six to eight inches. For established no-till or minimum tillage areas, take cores to a depth of four inches.

Traditional sampling strategy

When a 5- to 15-acre field of similar soil type will be limed and fertilized uniformly, collect a soil sample of 15 to 20 cores using a zigzag pattern (Figure 2A). This approach will help ensure that overall field conditions and variability are taken into account. It is best to divide fields greater than 15 acres into smaller units (about 5 acres) until variability is known.

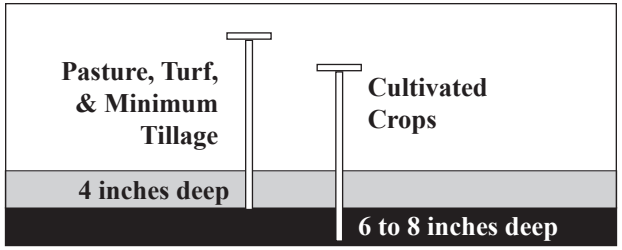


Figure 1. Proper sampling depth depends on tillage practices for the area sampled.

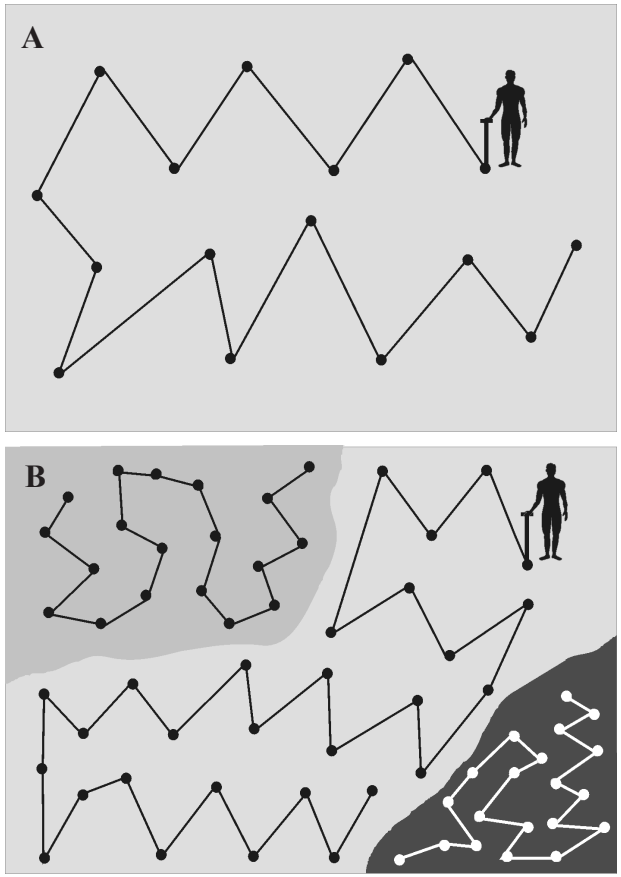


Figure 2. Sampling strategies. **A)** Use a zigzag pattern to collect cores randomly from a field with uniform soil. **B)** Subdivide fields that have distinct zones (soil type, cropping history, etc.) if it is feasible to lime and fertilize each area separately.

In any sampling, avoid small areas that differ markedly from the rest of the field—wet spots, severely eroded areas, old building sites, fence rows, spoil banks, burn row areas, old woodpile or fire sites and fertilizer application bands. Such samples can bias evaluations of a field's nutrient-supplying capacity.

Intensive sampling strategy

Over recent years, use of global positioning systems (GPS) has become increasingly used to document soil variability. This approach to soil testing is often coupled with variable nutrient application to match soil test needs. Information about precision sampling may be found at www.soil.ncsu.edu/publications/Soilfacts/AG-439-36/AG-439-36.pdf.

Grid sampling is a type of precision sampling whereby samples are collected in a field that has been overlaid with grids typically 2.5 acres in size. Within a grid, cores may be collected randomly (***cell sampling***) or at a certain distance from the center of the grid (***point sampling***).

Directed sampling is another technique that is also used to observe soil variability and fine-tune nutrient application. Sample areas are delineated using various spatial data (yield data, electrical conductivity, elevation, etc.). Samples are usually taken randomly within a zone. Directed sampling may be referred to as ***zone sampling*** (Figure 2B).

Packing soil samples for shipment

David H. Hardy, Ph.D., Soil Testing Section Chief

revised
January 2012

Agronomic News for North Carolina Growers www.ncagr.gov/agronomi/ (919) 733-2655

- Use sample boxes provided by NCDA&CS and fill about 2/3 full. Allow wet soil to air dry before placing in boxes. Wet soil can cause sample boxes to disintegrate.

- Use permanent black ink to label the sample box and fill out the information form. Pencil is not legible, and some pens have water-soluble ink that smears or bleaches when wet.

- Close box flaps securely to prevent spillage during shipment. Loose flaps allow soil to spill from the box and become mixed with other samples. Do not place tape or rubber bands around boxes. If you fold and close boxes properly, samples will arrive at the laboratory intact.

- Place individual sample boxes upright in a sturdy cardboard container for shipping. Package no more than 40 to 50 samples (less than 50 lb) per shipping container.

- Arrange samples in the shipping container in the same order that they are listed on the sample information form. Doing so helps ensure that you have placed all your samples in the container. It also helps the receiving clerk at the laboratory arrange your samples quickly and accurately for processing.

- Pack individual sample boxes firmly in the shipping container. Place newspaper or cardboard between layers to help keep samples intact and lessen problems with moisture. Do not stack samples more than three boxes high. If the boxes do not fill the shipping container, stuff newspaper around them. Do not use styrofoam "peanuts." They stick to boxes and make labels hard to read.

- Place the sample information forms that correspond to the samples in a plastic ziplock bag inside the shipping container with the samples.

- Label each shipping container with your name and address. If you are sending multiple shipping containers, write "Box 1 of 3," "Box 2 of 3," "Box 3 of 3," etc., to ensure that samples stay together when they arrive at the lab. Make sure each box contains the appropriate sample information form(s).

- When you send samples to the lab, be sure to indicate on the shipping container that the box contains soil samples. Samples sent via UPS or FedEx should be addressed to our physical address (see below). Samples sent through the U.S. Postal Service should be addressed to our mailing address (see below). Bar-code tracking is available. Visit www.ncagr.gov/agronomi/ for details.

NCDA&CS AGRONOMIC DIVISION, SOIL TESTING SECTION
Physical address: 4300 REEDY CREEK RD., RALEIGH NC 27607-6465
Mailing address: 1040 MAIL SERVICE CENTER, RALEIGH NC 27699-1040

- If you bring your samples to the lab, notify the soil receiving clerk that you are delivering soil samples.

Form AD-1 (November 2013)

SOIL SAMPLE INFORMATION — N.C. Soil Only

ROUTINE SAMPLES

April–November: no fee
December–March: $4 / sample

NCDA&CS Agronomic Division Soil Testing Section
Mailing Address: 1040 Mail Service Center, Raleigh NC 27699-1040
Physical Address (UPS/FedEx): 4300 Reedy Creek Road, Raleigh NC 27607
Phone: (919) 733-2655 Website: www.ncagr.gov/agronomi

SAMPLE INFORMATION	PAYMENT	GROWER INFORMATION *(please print legibly)*	CONSULTANT/OTHER RECIPIENT
FARM ID *(optional)*	FEE TOTAL _____ METHOD OF PAYMENT ESCROW ACCOUNT ONLY *(write account name below)* _____ To pay with credit card, you MUST use online sample submission.	LAST NAME FIRST NAME	LAST NAME FIRST NAME
SAMPLE DATE *(optional)*		ADDRESS (in N.C. where samples were collected)	ADDRESS
NC COUNTY *(where collected)*	***Reminders*** ***Use NCDA&CS sample boxes only. Fill to red line. Bags not accepted.*** ***Select crop code(s) from list on back of form.***	CITY STATE ZIP NC	CITY STATE ZIP
NUMBER OF SAMPLES		PHONE (___) ___ – ____	PHONE (___) ___ – ____
		E-MAIL ADDRESS ☐ **Do Not** notify me when report is available.	E-MAIL ADDRESS ☐ **Do Not** notify me when report is available.

By submitting this form to the NCDA&CS Agronomic Division, I attest that the accompanying samples were collected in North Carolina.

LAB NUMBER (Leave blank)	SAMPLE IDENTIFICATION	LIME APPLIED WITHIN PAST 12 MONTHS			You must specify a crop CODE to receive a recommendation (see reverse side of form)			
		Tons/Acre	Month	Year	FIRST CROP	CODE	SECOND CROP	CODE
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								

Thank you for using agronomic services to manage nutrients and safeguard environmental quality. — Steve Troxler, Commissioner of Agriculture

Taking a Soil Sample

A soil test is only as good as the soil sample!

Use iron or stainless steel tools. Sample dry soil in areas of 10 acres or fewer. Avoid combining soils of different types and/or treatment histories. Avoid fertilizer bands and corners or end-turn areas. For each sample, collect 15–20 cores at the appropriate depth (0–8" for plowed soils; 0–4" for no-till, sod & lawns). Mix cores in a plastic bucket, then fill the sample box.
DO NOT PUT SOIL IN PLASTIC BAGS.

Filling out the Sample Information Form

EXAMPLE

LAB NUMBER (Leave blank)	SAMPLE IDENTIFICATION	LIME APPLIED WITHIN PAST 12 MONTHS Tons/Acre	Month	Year	FIRST CROP	CODE	SECOND CROP	CODE
1	J1	1	9	2012	Corn	001	Small Grain	004
2	S1	2	9	2012	Clover / Grass, M	050	Clover / Grass, M	050
3	S2	0			Bermuda Hay, E	043	Bermuda Hay, M	044

REQUIRED INFORMATION
The lab **MUST** have this information.

SAMPLE & GROWER INFORMATION — Provide as much information as possible. Print neatly.
CONSULTANT/OTHER RECIPIENT — List name & contact information for anyone else who needs to know about the report.
SAMPLE IDENTIFICATION — Print an identifier (use numbers and/or letters) for each sample on a separate line. The identifier should help remind you where the sample came from (Example: J1, S1). Make sure the sample identifers on the boxes and on the information form are the same. **Use pencil or waterproof markers**.
FIRST CROP — List the crop for which you want lime and fertilizer recommendations. Be sure to include the appropriate **CODE** from the list below (*e.g.*, Bermuda hay or pasture establishment, 043).
A. Use **Lawn** (code 026) for all lawn grasses except **Centipede**. Use one of the **Fine Turf** codes only for golf and athletic field turf.
B. Use **Shrubs** (code 029) for all shrubs, except azalea, camellia, rhododendron and mountain laurel.
C. For all home garden vegetables, use code 024.

DESIRABLE INFORMATION
The lab can make better suggestions if this information is provided.

LIME APPLIED WITHIN PAST 12 MONTHS — Provide the amount of lime applied in tons/acre, as well as the year and month of the last application, if made during the past 12 months. **(50M = 50 lb/1000 ft^2, which is equivalent to one ton per acre.)**
SECOND CROP — List the name of the crop that will follow the one listed as **FIRST CROP**. Include its **CODE** from the list below. This will enable us to make suggestions for this crop, assuming that the field is treated as suggested the first year. List the second crop even if it will be grown the same year as **FIRST CROP**.

CROP CODES

E = establishment (1st year)
M = maintenance
SG = small grain

Field Crops
001 Corn, grain
002 Corn, silage
003 Cotton
004 Small Grain
005 Millet, pearl
006 Milo (Grain Sorghum)
007 Peanut
008 Rice
009 Sorghum, syrup
010 Soybean
011 Sunflower
012 Tobacco, burley
013 Tobacco, flue-cured
014 Tobacco, greenhouse
015 SG silage/ Soybean
016 SG silage/ Corn silage
017 Kenaf, fiber
018 SG/ Soybean (double crop)

Home Lawn & Garden
020 Azalea/ Camellia
022 Lawn, centipede
023 Flower garden
024 Vegetable garden
025 Mtn. Laurel/ Rhodod.
026 Lawn (not centipede)
028 Rose
029 Shrubs
030 Berries/Fruit/Nuts
031 Tree, shade
032 Blueberries, home

Christmas Trees
034 Leyland Cypress
035 Line-out/ Seed beds
036 Fir/N. Spruce/Hem, E
037 Fir/N. Spruce/Hem, M
038 Pine, white or Va.
039 Bl. Spruce/Red Cedar

Forage & Pasture
040 Alfalfa, E
041 Alfalfa, M
042 Com. Bermuda/Bahia

Forage & Pasture (cont.)
043 Bermuda hay/past., E
044 Bermuda hay/past., M
047 Bluegrass pasture
048 Bluegrass/Wh. Clover
049 Clover/Grass, E
050 Clover/Grass, M
051 Gamagrass
053 Legumes, misc.
054 Fescue/OGrass/Tim, E
055 Fescue/OGrass/Tim, M
056 Prairiegrass
057 Switchgrass
059 Sudan/Sorghum past.
060 Sudan/Sorghum silage

Roadside Areas
061 Critical area
062 Grass, roadside, E
063 Grass, roadside, M

Wildlife Areas / Food Plots
066 Deer/Turkey
067 Upland Game
068 Waterfowl
069 Fish Pond

Commercial Hort Crops ONLY
[024 = all Home Vegetables]
070 Asparagus, E
071 Asparagus, M
072 Beans/Peas
073 Beans, pole
074 Beet
075 Blueberry, E
076 Blueberry, M
077 Brocc/ BSprout/Caulif
079 Cabbage
080 Cantaloupe/Melons
084 Corn, sweet
085 Cucumber
088 Grape, E
089 Grape, M
090 Kale/ Mustard/ Spinach
093 Okra
095 Pea, southern
096 Pepper/Sage
097 Plant bed, vegetable
098 Potato, Irish
099 Sweetpotato
100 Radish
101 Canola/Rape

Commercial Hort Crops (cont.)
102 Black/Raspberry, E
103 Black/Raspberry, M
107 Squash/Pumpkin
108 Strawberry, E
109 Strawberry, M
110 Tomato
111 Tomato, greenhouse
115 Turnip
116 Vegetables, other
118 Strawberry, plastic
119 Hops

Commercial Nursery & Flowers
120 Dahlia
121 Gladiolus
122 Greenhouse
123 Gypsophila (baby's breath)
124 Flower, bulbs
125 Flower, roots
126 Container nursery
132 Rhod/Ginseng/Natives
136 Tree nursery

Orchard, Fruit & Nut
130 Apple, E
131 Apple, M
138 Peach, E
139 Peach, M
140 Pecan, E
141 Pecan, M

Forest Trees & Seed
133 Hardwood, E
134 Hardwood, M
137 Pine nursery
142 Pine, E
143 Pine, M
144 Hardwood, seed
145 Fir/Spruce, seed
146 Pine, seed

Fine Turf
150 Fairway/Athl. turf
151 Tee
152 Greens

Stormwater
200 Bioretention cell

Form AD-2 (August 2013)

DIAGNOSTIC SOIL SAMPLE INFORMATION

— N.C. Soil Only —

PROBLEM SAMPLES

April–November: no fee
December–March: $4 / sample

NCDA&CS Agronomic Division Soil Testing Section
Mailing Address: 1040 Mail Service Center, Raleigh NC 27699-1040
Physical Address (UPS/FedEx): 4300 Reedy Creek Road, Raleigh NC 27607
Phone: (919) 733-2655 Website: www.ncagr.gov/agronomi

SAMPLE INFORMATION

FARM ID ***(optional)***

SAMPLE DATE ***(optional)***

COUNTY ***(where collected)***

NUMBER OF SAMPLES

PAYMENT

FEE TOTAL _____

METHOD OF PAYMENT
ESCROW ACCOUNT ONLY
(write account name below)

_____

To pay w/ credit card, you must use online sample submission.

Reminders

Fill out back of form.

Do not ship w/routine samples.

Write PROBLEM SAMPLES on outside of shipping box.

GROWER INFORMATION ***(please print)***

LAST NAME FIRST NAME

ADDRESS **(in N.C. where samples were collected)**

CITY STATE ZIP
NC

PHONE
(_ _ _) _ _ _ – _ _ _ _

E-MAIL ADDRESS ☐ **Do Not** notify me when report is available.

CONSULTANT/OTHER RECIPIENT

LAST NAME FIRST NAME

ADDRESS

CITY STATE ZIP

PHONE
(_ _ _) _ _ _ – _ _ _ _

E-MAIL ADDRESS ☐ **Do Not** notify me when report is available.

LAB NUMBER (Leave blank)	SAMPLE IDENTIFICATION	LIME APPLIED WITHIN PAST 12 MONTHS Tons/Acre	Month	Year	PROBLEM CROP	NEXT CROP	CORRESPONDING SAMPLE IDS Plant Tissue	Nematode Assay	CROP CONDITION (check one) Poor	Fair	Good	DROUGHT STRESS Yes	No
1													
2													
3													
4													
5													
6													
7													
8													

By submitting this form to the NCDA&CS Agronomic Division, I attest that the accompanying samples were collected in North Carolina.

Diagnostic (problem) analysis requires that all relevant information requested on the front and back of this form be provided. If details regarding the problem are not provided, a predictive (routine) analysis will be conducted.

Thank you for using agronomic services to manage nutrients and safeguard environmental quality. — Steve Troxler, Commissioner of Agriculture

If signs or symptoms of insects or diseases are present, contact your Cooperative Extension office for information about collecting, preparing and shipping plant and insect specimens to the PLANT DISEASE & INSECT CLINIC, 100 Derieux Place, 1227 Gardner Hall, Campus Box 7211, North Carolina State University, Raleigh, NC 27695-7211. Phone 919-515-3619 about disease problems and 919-515-9530 about insect-related problems.

VISUAL SYMPTOMS of ABNORMAL PLANTS

Growth

General: Good _____ Fair_____ Poor _____ Dead_____

Specific: Brittle leaves/stems _____ Distorted leaves_____ Leaf rosette _____ Dwarfed _____

Roots: Good _____ Fair_____ Poor _____ Dead_____ If legumes, nodulated? Yes _____ No ____

Bud / New Growth: Good_____ Fair_____ Dead_____ Distorted _____

Color

Color Location: Younger leaves_____ Older leaves _____ Whole plant _____

Color of Leaves: Dark green _____ Light green_____ Yellow _____ Red ____ Reddish purple_____

Leaf Color Pattern: Whole leaf _____ Between veins_____ Veins & petiole _____ Margins_____ Tip _____ Spotted _____

Other pattern (describe) _____

CROP PRODUCTION INFORMATION

Method of Application	Fertilizer Applied to This Crop (lb/acre)							
	N	P_2O_5	K_2O	S	Mn	Zn	Cu	B
Broadcast								
Row / Band								
Topdress / Foliar								

Date of Planting _____

Was the previous crop affected?

Yes _____ No _____

Other Nutrient Materials (gypsum, sewage sludge, sawdust, etc.) _____

Crop Tillage: Conventional _____ No-till _____ Minimum Tillage _____

Field / Growing Conditions: Normal _____ Wet_____ Dry _____ Hot _____

Greenhouse Media Type: Peat-lite _____ Pine Bark _____ Sandy Loam_____ Silt-Clay Loam _____

COMMENTS — Please provide any other pertinent information, including whether or not you submitted matching samples to the NCSU Plant Disease & Insect Clinic.

Understanding the Soil Test Report

prepared by
David H. Hardy
M. Ray Tucker
Catherine Stokes

published by
N.C. Department of Agriculture
& Consumer Services
Agronomic Division

Miscellaneous Publication
revised October 2013

UNDERSTANDING THE SOIL TEST REPORT

WHAT IS A SOIL TEST?

A soil test chemically extracts and measures most of the elements essential to plant nutrition. It also measures soil acidity and pH. These factors are indicators of lime requirement, nutrient availability, and the potential of the soil to produce crops. This information enables growers to apply nutrients with environmental stewardship and profitability in mind.

The NCDA&CS Agronomic Division conducts two types of soil tests: predictive and diagnostic. The predictive is the standard soil test that provides the lime and fertilizer recommendations necessary to optimize yields. In contrast, the diagnostic soil test is used when samples are collected because of an observed problem situation. The purpose of a diagnostic test is to identify specific nutrient deficiencies or excesses that may be preventing optimal plant growth.

Predictive Soil Testing

NCDA&CS lime and fertilizer recommendations are based on field experiments conducted in North Carolina across a variety of soil types and cropping sequences. The rates suggested are designed to eliminate fertility constraints that may limit optimal crop production.

Other factors that have a strong impact on yield include environmental conditions during the growing season (rainfall, temperature, etc.), soil productivity, water-holding capacity, planting date, variety, pest and disease pressure, and soil compaction. If any of these factors are less than optimal, reduced yield results. Optimum production requires reasonable management of all factors involved in the overall crop production scheme.

Continuous field calibration research is essential to determine fertility requirements dictated by changes in farming practices and cropping sequences. These studies are conducted by N.C. State University researchers in conjunction with NCDA&CS agronomists.

The NCDA&CS soil test uses Mehlich-3 extractant for determining levels of phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulfur (S), manganese (Mn), copper (Cu), zinc (Zn) and sodium (Na). Results may or may not agree with those of other laboratories depending on method of extraction and other procedural variables. Growers are encouraged to use a laboratory whose recommendations are validated by field research within their own state.

Diagnostic Soil Testing

Problem soil samples are handled separately from routine predictive samples because, in these cases, results are needed for immediate management of a current crop-production issue. Samples for problem diagnosis must be submitted with a fully completed *Diagnostic Soil Sample Information* form that accurately describes crop history, symptoms and other relevant factors. In addition to the routine analyses, levels of soluble salts (**SS-I**) may also be determined. Test results for problem soil samples are reviewed by an agronomist, who provides appropriate comments regarding the cause of the problem and recommended treatment.

Plant tissue analysis, in conjunction with a diagnostic soil test, is the best way to troubleshoot a nutrient problem. Soil samples for nematode assay may also be warranted depending on the crop, soil type and pattern of poor growth. If you want to collect enough soil for both tests (soil test and nematode assay) at one time, be sure to collect samples from the crop root zone.

Collect soil and plant samples from both “good” and “bad” areas for comparison purposes.

When submitting matching samples, assign the same sample ID to both the soil sample and its corresponding plant sample: for example, GOOD1 could be the sample ID for both samples from the "good" area and BAD1 could be the ID for those from the "bad" area. This labeling system makes it easy to compare results.

ASSISTANCE AVAILABLE

The NCDA&CS Agronomic Division tries to present soil-test results and recommendations in a way that is easy to understand. Reports contain explanatory information, hyperlinks to relevant publications and, often, specific comments from an agronomist. If additional guidance is required, regional agronomists and county Cooperative Extension personnel are available to help clients interpret results and implement recommendations.

In essence, lime and fertilizer recommendations on a soil report are like a prescription to be filled. Without it, fertilizer suppliers are somewhat handicapped in their ability to advise farmers. If they make general fertilizer recommendations without a soil test, undue criticism may be levied toward their product if crop response is poor.

THE REPORT

The header contains the report number (e.g., FY13SL00001), relevant dates and the client's name and address. An advisor may be listed, if the client specified one. **Agronomist's Comments**, an advisory section, may or may not appear just below the header. Descriptive information for each sample includes **Sample ID** and **Lime History**. Report results for each sample include two types of information: **Recommendations** on the upper row and **Test Results** on the lower row. The last page of each soil report contains explanatory information and useful hyperlinks.

Lime History

This section contains any recent lime application information provided by the client on the sample information form. If lime was applied within 12 months prior to sampling, this information is used to determine the residual lime credit (RC). For an explanation of the residual credit calculation and its impact on lime recommendations, refer to the section titled **Lime** later in this document.

Recommendations

Details supplied by clients affect the quality of recommendations received. The codes selected to specify **FIRST CROP** and **SECOND CROP** on the sample information form determine the recommendations for **Crop 1** and **Crop 2** that appear on the soil report. Recommendations for **Crop 2** do not take into account fertilizer recommendations for **Crop 1**.

When recommendations for two crops with different target pHs are requested, the lime recommendation given will be for the crop that is least acid tolerant. This lime recommendation will be listed for **Crop 1**. Therefore, the higher of two possible lime recommendations will be given.

Soil-test calibration for the micronutrients Mn, Zn and Cu is not as well defined as it is for the macronutrients P, K, Ca, Mg and S. However, with the increased concern about maximizing yields through better management practices, research efforts to refine the calibration for micronutrient soil tests in relation to yields have increased. In addition, advances in laboratory instrumentation have led to more accurate determination of the critical soil-test levels at which a crop response can be expected.

Lime

Lime rates for crops grown on a large scale are expressed in units of tons/acre; recommendations for small areas, such as lawns and gardens, are given in units of lb/1000 ft^2. Rate calculation involves soil pH, exchangeable acidity (*Ac*), target pH and residual lime credit (*RC*). The lowest recommended rates are 0.3 ton/acre and 15 lb/1,000 ft^2. If the lime recommendation is 0, no lime should be applied. The formula is

$$\textit{tons lime / acre} = Ac\left[\frac{\textit{target pH} - \textit{current pH}}{6.6 - \textit{current pH}}\right] - RC$$

RC is the amount of lime applied in the last 12 months that has not reacted with soil acidity; it is reported in units of tons/acre. The *RC* calculation uses a reactivity rate that varies with soil type. The equation for determining *RC* is as follows:

$$RC = rate - (rate \times months \times reaction\ rate)$$

where

- *rate* is amount of lime applied in tons/acre,
- *months* is the number of months between lime application and the current soil test and
- *reaction rate* is 0.08 (8%) for mineral soils or 0.16 (16%) for mineral-organic and organic soils.

If *rate* = 1.2 tons/acre, *months* = 8, and *reaction rate* = 0.08, then $RC = 1.2 - (1.2 \times 8 \times 0.08) = 1.2 - 0.8 = 0.4$ ton/acre. If this lime application is not recorded on the *Soil Sample Information* form and the resulting soil-report lime recommendation is 0.9 ton/acre, then the adjusted recommendation after taking into account *RC* would be 0.5 ton/acre.

To convert ton/acre to lb/1000 ft^2, multiply by 46.
Example: 0.8 ton/acre × 46 = 36.8 lb/1000 ft^2.

To convert lb/1000 ft^2 to ton/acre, multiply by 0.0218.
Example: 20 lb/1,000 ft^2 × 0.0218 = 0.4 ton/acre

Nitrogen (N)

In most cases, soil tests do not measure nitrogen because N does not persist long in soil. Soil reports provide a **N** recommendation based on the known requirements of the crop(s) specified on the sample information form. Suggested application rates (lb/acre) are based on field research studies, but higher N rates may be justified under intensive management systems.

N applications must be timely to maximize yield and minimize potential environmental impact. Therefore, the total suggested N rate may not be applied all at once. Nitrogen is often put out in several applications: e.g., at or near planting followed later, as needed, by sidedress or topdress applications.

Supplemental N applications (more than the total suggested on a soil report) may be required under certain soil and climatic conditions, e.g., heavy rainfall with leaching. Soil reports for field crops contain a hyperlink to *Note 3*, which explains the conditions under which supplemental N may be needed. Use of plant tissue testing is also encouraged to justify supplemental N.

Phosphate (P_2O_5)

The application rate of P_2O_5 suggested on the soil report is based on **P-I** value, soil type and crop to be grown. Crop need for phosphorus is determined by rate studies on a number of different soils and cropping situations. Equations have been established to meet the majority of soil and crop conditions.

Potash (K_2O)

The suggested rate for potash is established in the same manner as for phosphate. Split applications may be beneficial on sandy soils with low cation exchange capacity that are prone to leaching.

Magnesium (Mg)

If the amount of magnesium in a soil sample is found to be below a pre-established critical level, then an application of 25 lb/acre will be recommended. If a rate is recommended for **Crop 1**, then a **$** will appear on the line for **Crop 2** to remind the grower that **Crop 2** may need Mg if it is not applied to **Crop 1**. Clients should review the *$ Note* via a hyperlink, located on the last page of the soil report. The note discusses options for applying Mg and micronutrients. Whenever lime is recommended, use of dolomitic lime will provide adequate Mg.

Sulfur (S)

When needed, as suggested by a sulfur index (**S-I**) of 25 or less, sulfur is recommended at rates of 15–20 or 20–25 lb/acre. Since sulfur leaches readily from sandy soils, split application as with N or K may be beneficial. Sulfur often helps optimize N use by the crop.

Manganese (Mn)

The Mn-availability index (**Mn-AI**) is calculated based on the soil-test Mn-index (**Mn-I**), crop sensitivity and soil pH. Of all the micronutrients, Mn is most closely correlated with soil pH: as pH increases, Mn availability decreases. The critical **Mn-AI** value is 25.

A zero (**0**) will appear in the **Mn** column if the soil level is considered adequate. When **Mn-AI** is 25 or below, an application rate of 10 lb/acre will be suggested for nearly all field crops because they are known to respond well to Mn. If a rate is recommended for **Crop 1**, then a **$** will appear on the line for **Crop 2** to remind the grower that **Crop 2** may need Mn if it is not applied to **Crop 1**.

When soil levels of Mn are low for crops without established response data (pastures, vegetables, etc.), a **$** appears on the soil report. This symbol refers to the *$ Note*, which provides further information on rates of application.

If soil pH is high enough to affect Mn availability, the **pH$** or **$pH** notations will appear in the **Mn** recommendations column. Refer to the *$ Note* provided via hyperlink for specific recommendations.

Zinc (Zn)

Zinc application is suggested for specific crops if the Zn-availability index (**Zn-AI**) is 25 or below and, the crop is known to respond to Zn. The **Zn-AI** is calculated based on soil levels of Zn and other factors affected by soil class. The current recommendation for Zn is 6.0 lb/acre broadcast or 3.0 lb/acre banded, regardless of soil type.

If a rate is recommended for **Crop 1**, a **$** symbol appears on the line for **Crop 2**. The **$** draws attention to this nutrient as a reminder that **Crop 2** may need Zn if it was not applied to **Crop 1**. Whenever insufficient data regarding crop response are available, the **$** symbol will appear when **Zn-AI** is 25 or below. The *$ Note* provides further information on rates of application.

Potential zinc toxicity is indicated whenever **Z** appears in the **Zn** column of the **Recommendations** section of a report. For most crops, the **Z** designation indicates that **Zn-AI** is greater than 2000 (the critical toxic level being 3000). However, in the case of peanut, which has a critical toxic level of 500, the **Z** notation indicates a **Zn-AI** value of 300 or more. Zn toxicity has occasionally been reported in peanut at a **Zn-AI** value as low as 250, especially under low pH situations. Management of pH is critical to reduce potential toxicity. Whenever **Z** appears on a soil report, check the **Agronomist's Comments** section for further information.

Copper (Cu)

An application rate for copper is provided if the **Cu-I** value is 25 or below for specific crops that have been shown to respond to fertilization. Uniform broadcasting and thorough incorporation contribute to optimum Cu response. If a rate is recommended for **Crop 1**, a **$** will appear on the line for **Crop 2**. The **$** draws attention to this nutrient as a reminder that **Crop 2** may need Cu if it was not applied to **Crop 1**. The **$** will appear when **Cu-I** is 25 or below and when Cu response data are limited or unavailable. The *$ Note* provides further information on rates of application.

A potential Cu toxicity is indicated whenever a **C** appears in the **Cu** column of the **Recommendations** section of a report. The **C** indicates that the **Cu-I** is greater than 2000. The critical toxic level is 3000. Whenever this notation appears on a soil report, check the **Agronomist's Comments** section for further information.

Boron (B)

Boron recommendations are made for crops that are known to respond to this micronutrient. Recommendations are based on field studies for specific crops. Actual levels of boron in soil are not measured due to the nutrient's high mobility in sandy soils, where many of the crops that require B are grown.

Test Results

The abbreviated headings that appear in the **Test Results** section of the soil report are explained briefly in Figure 1. Detailed explanations follow under the appropriate headings.

Many of the nutrients are reported as indices, which provide a relative scale of actual soil-test nutrient levels. Table 1 relates these index values to general nutrient availability and indicates the likelihood of crop response to fertilization. Table 2 shows micronutrient application rates by soil type, nutrient, and application method.

Table 1. Crop Response to Fertilization as Related to Soil Test Levels

Index	Nutrient Status	Response* to Applied P	K	Mn	Zn	Cu	S
0–10	Very Low	VH	VH	VH	VH	VH	VH
11–25	Low	H	H	H	H	H	H
26–50	Medium	M**	M**	N	N	N	M
51–100	High	N	L/N	N	N	N	L/N
100+	Very High	N	N	N	N	N	N

* Crop response to fertilizer is expected to be very high (VH), high (H), medium (M), low (L) or none (N).

** Response decreases as soil test index increases.

Table 2. Recommended Micronutrient Rates*

Soil Class	Banded Mn	Banded Zn	Broadcast Mn	Broadcast Zn	Broadcast Cu	Foliar Spray Mn	Foliar Spray Zn	Foliar Spray Cu
MIN	3	3	10	6	2	1/2	1/2	1/4
M-O	3	3	10	6	4	1/2	1/2	1/4
ORG	3	3	10	6	6	1/2	1/2	1/4

* Rates = lb element per acre.

Table 3. Soil Class Determinations as Based on Humic Matter and Weight per Volume

Soil Class	Humic Matter (HM%)	Weight/Volume (W/V) g/cc
Mineral	0–3.37	> 0.5
Mineral-Organic	3.4–5.2	> 0.5
Mineral-Organic	0–3.37	< 0.5
Organic	> 5.3	> 0.5
Organic	3.4–5.2	< 0.5

Soil Class

Each soil sample is classified as mineral, mineral organic or organic. These classifications are based primarily on humic matter percent (**HM%**), but in some cases, weight/volume ratio (**W/V**) is involved in class determination (Table 3). Each soil class has a different target pH: 6.0–6.5 for mineral soils, 5.5 for mineral-organic soils and 5.0 for organic soils. There are very few crops that have a target pH below 6.0 for mineral soils.

Mineral soils require a higher pH to neutralize exchangeable aluminum so that plant growth is not affected. Since mineral-organic and organic soils contain less exchangeable aluminum due to their lower mineral content or due to complexation with organic matter, a lower pH can be maintained without any detrimental effects to crop production. In addition, since mineral-organic and organic soils have much higher buffering capacity (resistance to change in pH in this case), it is not economically feasible or agronomically practical to apply lime at rates sufficient to raise the soil pH to 6.0.

Humic Matter (HM%)

Humic matter percent is a measurement of humic and fulvic acid components of soil organic matter, expressed on a volume basis. It represents the percentage of soil organic matter that is soluble in a dilute alkaline solution (NaOH). This portion represents the chemically active organic fraction used in determining lime rates.

Humic matter percent may or may not correlate with percent organic matter. For example, sandy soils have very low organic matter content and a correspondingly low **HM%**. In contrast, an organic soil could have in excess of 50% organic matter with a **HM%** of less than 0.10. In this case, such readings would imply that most of the organic matter has not yet decomposed to the humic and fulvic acid fractions. In general, as **W/V** increases, **HM%** usually decreases.

Figure 1. Explanation of Soil Test Results

Percent Humic Matter

Weight/Volume (g/cm^3)

Cation Exchange Capacity (meq/100 cm^3)

Base Saturation: percentage of CEC occupied by the basic cations calcium (Ca), magnesium (Mg) & potassium (K)

Exchangeable Acidity (meq/100 cm^3)

Soil pH: measure of the active acidity (H^+) in the soil solution

Phosphorus (P) Index

Test Results [units - W/V in g/cm^3; CEC and Na in meq/100 cm^3; NO_3-N in mg/dm^3]: Soil Class: Mineral

HM%	W/V	CEC	BS%	Ac	pH	P-I	K-I	Ca%	Mg%	S-I	Mn-I	Mn-AI1	Mn-AI2	Zn-I	Zn-AI	Cu-I	Na	ESP	SS-I	NO3-N
0.66	1.14	6.4	71	1.8	5.7	287	38	58	10	52	45	37	37	497	497	917	0.2	3		

Potassium Index

Percentage of CEC occupied by calcium

Percentage of CEC occupied by magnesium

Sulfur Index

Manganese Index

Manganese-availability index for the first crop

Manganese-availability index for the second crop

Zinc Index

Zinc-availability Index

Copper Index

Sodium

Exchangeable Sodium Percent

Soluble Salt Index

Nitrate (NO_3^-) Nitrogen, expressed in mg/dm^3

Weight/Volume Ratio (W/V)

Weight/volume ratio, expressed in g/cm^3, is used to classify the soil type of a sample. For example, a very sandy soil may have a **W/V** of 1.5 g/cm^3, whereas the **W/V** of an organic soil may be as low as 0.5 g/cm^3. Soils high in clay fall within these two extremes. **W/V** is generally inversely related to the cation exchange capacity (**CEC**) of the soil: that is, soils with a high **W/V** generally have a low **CEC**.

Cation Exchange Capacity (CEC)

CEC is a relative measure of the nutrient-holding capacity of a soil. It is expressed in units of meq/100 cm^3 and is determined by summation of extractable calcium, magnesium, potassium and exchangeable acidity (**Ac**). The **CEC** of North Carolina soils ranges from low (< 2.0 meq/100 cm^3) for sandy soils to as high as 25 meq/100 cm^3 for clay and organic soils.

A high **CEC** is desirable because nutrients are less subject to leaching and adequate quantities of nutrient reserves can be maintained. However, sandy soils, by nature, have low **CEC**, and little can be done to change it. The **CEC** will vary with changes in soil pH, organic matter and clay content.

Base Saturation (BS%)

Base saturation is expressed as a percentage of the **CEC** that is occupied by basic cations, principally calcium, magnesium and potassium. Base saturation and pH are directly correlated: as pH increases, so does **BS%**. A higher **BS%** also corresponds to a lower level of soil acidity.

Exchangeable Acidity (Ac)

Exchangeable acidity represents that portion of the **CEC** that is occupied by hydrogen (H^+) and aluminum (Al^{+++}) and is expressed as meq/100 cm^3. **Ac** is one of the measurements used in calculating the lime recommendation.

Current pH

The **pH** is a measure of the active acidity or the hydrogen ion (H+) activity in the soil solution. The **pH** value alone does not determine how much lime is required but is used in conjunction with exchangeable acidity (**Ac**) in determining lime rates. The **pH** determination is useful for indicating when too much lime has been applied and for evaluating micronutrient availability, particularly manganese.

Phosphorus (P-I) & Potassium (K-I) Indices

Levels of phosphorus and potassium are reported as indices. The index ranges are as follows: 0–10, very low; 11–25, low; 26–50, medium; 51–100, high; and 100$^+$, very high.

When levels are low, plants will respond to addition of these nutrients. At medium levels, response will depend on particular crop needs. With high soil nutrient levels, crop response to fertilization is not generally expected. When soil-test indices are above 100, no fertilization is recommended, except for especially high-value crops. Crop responses can occur when not expected if other stresses such as cold, wet soil conditions are factors.

The fertilizer recommendation is based on soil-test results and varies with the crop to be grown. Refer to Table 1 for P and K ratings and expected crop response to fertilizer at given soil-test levels.

Calcium (Ca%) & Magnesium (Mg%) Percents

Levels of calcium and magnesium are reported as percentages of the **CEC**. For example, if **Ca%** is 62, then 62% of the soil's capacity to hold nutrients (**CEC**) is occupied by Ca. Ca determination is essential to calculate **CEC** and to evaluate relationship among Ca, Mg and K. However, no specific **Ca%** or **Mg%** values have been associated with ideal fertility.

In general, Ca is the predominant cation in most soils. It is seldom low enough in soil to cause crop deficiency. Peanuts are an exception, and for this crop, landplaster ($CaSO_4$) is a good source of supplemental Ca.

The **Mg%** value determines whether Mg should be added to the soil. Dolomitic lime or a

Mg fertilizer are both good sources. Multiplying **Mg%** by **CEC** gives the amount of Mg present in units of meq/100 cm^3.

In general, Mg application *is not necessary* if

- **Mg%**×**CEC** is at least 0.5 meq/100 cm^3 *or*
- **Mg%**×**CEC** is between 0.25 and 0.5 meq/100 cm^3 and **Mg%** is greater than 10.

Mg application *is necessary* if

- **Mg%**×**CEC** is less than 0.5 meq/100 cm^3 and **Mg%** is less than 10 *or*
- **Mg%**×**CEC** is no more than 0.25 meq/100 cm^3.

When Mg is needed, the recommended rate is usually 25–30 lb/acre. The cheapest source is dolomitic lime since it contains 120 lb/ton. Additional information regarding Mg is provided in *$ Note*.

Sulfur Index (S-I)

Sulfur is a mobile element. Therefore, it is most likely to be low in sandy soils, which have low organic matter and are prone to leaching. Sulfur is more abundant and usually adequate in piedmont and mountain soils due to their high clay content.

Recommendations are made when the **S-I** is 25 or less, depending on soil class. These recommendations are based on N.C. field studies conducted in corn and small grains in the mid-2000s.

In sandy topsoils that have clay within 16 inches of the surface, there can be appreciable amounts of S. This factor should be considered when evaluating S status and crop needs even when topsoil S levels are low. Under normal growing conditions, S is usually sufficient in organic soils.

Manganese Index (Mn-I)

Mn-I is an indicator of Mn levels in the soil. Since Mn availability is closely associated with soil pH, a Mn-availability index (**Mn-AI**) is calculated, depending on crop sensitivity to this element.

Manganese-availability Index (Mn-AI)

Two manganese indices are given on a soil report when two crops are specified on the sample information form. **Mn-AI1** is the manganese-availability index for **Crop 1**; **Mn-AI2** applies to **Crop 2**. **Mn-AI** values decrease as soil pH increases. Values above 25 are considered sufficient for most crops if the pH is 6.0 or below.

If **Mn-AI** is 25 or below, the report provides a hyperlink to *$ Note* for fertilization suggestions.

Zinc Index (Zn-I)

Although **Zn-I** indicates the amount of Zn present in the soil, the actual availability of Zn is indirectly influenced by soil pH. It is the target pH of the soil class that dictates availability.

Zinc-availability Index (Zn-AI)

The **Zn-AI** is based on soil class as follows: 1.0×**Zn-I** for mineral soils, 1.25 ×**Zn-I** for mineral-organic soils, and 1.66×**Zn-I** for organic soils. The critical **Zn-AI** value is 25. When **Zn-AI** is above 25, zinc is considered sufficient for most crops.

Copper Index (Cu-I)

The **Cu-I** is a measure of plant-available copper in the soil. Adjustments in its availability are not made as they are for Mn and Zn. The **Cu-I** critical value is 25.

Sodium (Na)

Sodium is evaluated for all samples. Values less than 0.4 meq/100 cm^3 are inconsequential to plant nutrition. However, on sandy soils, values of 0.4 to 0.5 meq/100 cm^3 or greater may indicate that sodium accounts for 15 to 20% of the **CEC** as calculated by the exchangeable sodium percentage. Such levels could interfere with plant uptake of calcium, magnesium and potassium and also adversely affect soil structure. When **Na** is excessive, soluble salt levels may be high enough to cause root injury.

Exchangeable Sodium Percent (ESP)

Sodium (**Na**) levels may become too high in soils amended with industrial by-products, irrigation water high in sodium, or overspray of coastal waters during hurricanes. The acceptable limit for **Na** saturation of the **CEC**, also called exchangeable sodium percent (**ESP**), is generally 15%. **Na** levels higher than 15% of the **CEC** could result in soil dispersion, poor water infiltration and possible toxicity to plants. Note that the **CEC** value on the NCDA&CS soil report does not include **Na** in its calculation since **Na** levels are typically very low in N.C. soils.

Soluble Salt Index (SS-I)

SS-I indicates relative content of fertilizer salts within a soil after equilibrating for 4 hours in distilled/deinonized water. Results are expressed in 10^{-5} mho/cm, which is a measure of electrical conductivity. Units can be converted to ds/m by dividing by 100.

This measurement is provided on all diagnostic soil reports and on routine reports whenever a greenhouse crop code is specified. The explanatory Notes hyperlinked within the report explain the effect of soluble salts within specific greenhouse media. **Agronomist's Comments** are provided on diagnostic reports.

The submission of potting media (pine bark, perlite, vermiculite, etc.) as a soil sample is discouraged. The properties of such media are better evaluated through soilless media analysis, which uses saturated media extract (SME). This test is available from the NCDA&CS Agronomic Division for a fee of $4 per sample.

Nitrate Nitrogen (NO_3-N)

This test indicates the level of **NO_3-N** available at the time of sampling. Nitrate is a plant-available, water-soluble form of nitrogen. This test is conducted on a special-needs basis only. Since **NO_3-N** leaches very readily and fluctuates considerably with rainfall and soil texture, **NO_3-N** measurements have little predictive value. **NO_3-N** is reported in mg/dm^3, which is equivalent to parts/million on a volume basis.

Form AD-4 (October 2012)

PLANT SAMPLE INFORMATION

SAMPLE TYPE
[circle designation(s) / instructions on back]

Predictive	**Diagnostic**
Research	**Out of State**

NCDA&CS Agronomic Division Plant/Waste/Solution/Media Section
Mailing Address: 1040 Mail Service Center, Raleigh NC 27699-1040
Physical Address (UPS/FedEx): 4300 Reedy Creek Road, Raleigh NC 27607
Phone: (919) 733-2655 Web Address: www.ncagr.gov/agronomi

FOR OFFICE USE ONLY
REPORT #
DATE REC'D
INITIAL

SAMPLE INFORMATION	PAYMENT	GROWER INFORMATION *(please print)*	CONSULTANT/OTHER RECIPIENT
FARM ID	FEE TOTAL _____ AMT PAID _____	LAST NAME FIRST NAME	LAST NAME FIRST NAME
SAMPLED BY ☐Grower ☐NCDA&CS Agronomist ☐Advisor ☐Coop. Ext. Agent	METHOD OF PAYMENT ( ) CASH ( ) CHECK *(payable to NCDA&CS)* ( ) MONEY ORDER ( ) ESCROW *(provide account name below)*	ADDRESS	ADDRESS
SAMPLE DATE		CITY STATE ZIP	CITY STATE ZIP
COUNTY *(where collected)*		PHONE (___) ___ - ____	PHONE (___) ___ - ____
NUMBER OF SAMPLES		E-MAIL ADDRESS ☐ **Do Not** notify me when report is available.	E-MAIL ADDRESS ☐ **Do Not** notify me when report is available.

**** * * Instructions for completing this form are on back * * ****

LAB NUMBER (leave blank)	SAMPLE ID	CROP NAME	GROWTH STAGE	WEEK	PLANT PART	PLANT POSITION	CORRESPONDING SAMPLE(s) (if any) list type (soil, solution, etc.) & sample ID		PLANT APPEARANCE	SPECIAL TESTS ($2 EACH) Mo	Cl^-	NO_3
1												
2												
3												
4												
5												

GROWING CONDITIONS

Planting date:
How long have symptoms been present?
Are plants infected with disease? Yes No
Are plants infested with insects? Yes No
Environmental conditions in last three weeks:
Rainfall Below normal Normal Above normal
Temperature Below normal Normal Above normal

IRRIGATION (AMOUNT): **TYPE:**
FUNGICIDES USED: **DATE:**

PROBLEM SAMPLE COMMENTS

FERTILIZER HISTORY

	Date	Material	Rate	Comments
Preplant:				
Postplant:				
Micronutrient:				
Other:				

Thank you for using agronomic services to manage nutrients and safeguard environmental quality. — Steve Troxler, Commissioner of Agriculture

INSTRUCTIONS FOR COMPLETING THE PLANT SAMPLE INFORMATION FORM

SAMPLES WILL NOT BE ANALYZED UNLESS ALL INFORMATION REQUESTED IN THE SHADED AREAS ON THE FRONT OF THIS FORM IS PROVIDED.

SAMPLE TYPE

Predictive analysis checks nutrient content and provides interpretation and general recommendations.
Diagnostic analysis identifies nutritional problems and provides interpretation and specific recommendations.
Research is for samples submitted in connection with an approved research contract agreement.
Out of state is for samples submitted by non–North Carolina residents.

SAMPLE INFORMATION — Provide **FARM ID** (if applicable); details about sample collection (collector, date, number of samples and county where collected); and **PAYMENT** details: **Cost per sample = Base fee** [$5 for N.C. residents; $25 for out-of state samples; $12 for research samples] **+ $2 for each mandatory special test** [a petiole nitrate test is required for cotton and plasticulture strawberry; a molybdenum test is required for alfalfa, broccoli, all kinds of cabbage, cauliflower, collards, kale, poinsettia, spinach and turnip greens] **+ $2 for each optional test requested** [petiole nitrate, molybdenum and/or chloride). Be sure to indicate payment **TYPE**: cash, check, money order or escrow.

GROWER INFORMATION — Provide phone number with area code, mailing address and e-mail address (as an additional way for the lab to contact you, if necessary).

CONSULTANT/OTHER RECIPIENT — Provide indicated contact information for any partner/advisor who may need access to your test results.

SAMPLE ID — Provide sample identification (no more than six digits or letters). Put the same ID on the sample envelope.

CROP NAME — Enter the name of the crop sampled. You can use the common and/or botanical name.

GROWTH STAGE — Identify plant growth stage by one of these letter codes: **S = Seedling, E = Early growth, B = Bloom, F = Fruiting, M = Mature.**

WEEK — ***(necessary for cotton and strawberry only)*** Indicate the estimated number of weeks that the crop has been in the current growth stage.

PLANT PART — Identify the part of the plant that was sampled by one of these letter codes: **W = Whole plant** (from 1" above the soil line)**, T = Top three inches, E = Ear leaf, M = Most recent mature leaf** (including petioles for appropriate crops)**, H = Harvested leaf**, **P = Petiole only** (applies only to vinifera grapes at this time). For most plants, the most recent mature leaf (**M**) is the proper plant part to sample.

PLANT POSITION — Identify the position on the plant where the sample was taken by one of these letter codes: **U = Upper, M = Middle, L = Lower**. For most plants, the upper (**U**) position is the proper place to sample.

CORRESPONDING SAMPLE(S) — List sample type (soil, solution, media, etc.) and ID for one or two corresponding samples. Corresponding samples from the same general area or plant may be submitted in conjunction with plant tissue samples to provide additional information useful for problem diagnosis.

PLANT APPEARANCE — Describe the symptoms of the plant at sampling. **If this space is left blank, we assume growth is normal.**

SPECIAL TESTS — Indicate additional mandatory or desired tests. Read the information above under **SAMPLE INFORMATION** for details.

GROWING CONDITIONS — Provide all requested information.

IRRIGATION (AMOUNT) — Provide this information, if applicable.

FUNGICIDES USED — Provide this information, if applicable.

PROBLEM SAMPLE COMMENTS — Provide additional information needed to help diagnose specific problems.

FERTILIZER HISTORY — Provide all requested information.

Please do not place samples in plastic bags.
Leave ample air space in paper containers to promote drying and avoid sample deterioration.

Understanding the Plant Tissue Report

Healthy plants contain predictable concentrations of the elements (nutrients) required for normal growth and development. Plants need primary nutrients (N, P, K) in greatest quantities, secondary nutrients (Ca, Mg, S) in lesser quantities and micronutrients (Fe, Mn, Zn, Cu, B, Mo, Cl) in very small amounts. Plants get all these nutrients from fertilizer and/or the soil. Three other elements that plants need—hydrogen, oxygen and carbon—come from water and the atmosphere.

Standard plant analysis measures concentrations of 11 essential elements (N, P, K, Ca, Mg, S, Fe, Mn, Zn, Cu, B). Additional tests can be requested to measure Cl, Mo and/or NO3-N (petioles only). Concentrations of primary and secondary nutrients are reported as percentages; micronutrient concentrations are reported in parts per million (ppm). The plant analysis report also presents results as index values that make it easy to interpret results in terms of plant health and productivity. The concentration for each element is converted into an index value (0–124), which falls into one of five interpretative categories (Figure 1).

An index of 50–74 indicates that the nutrient concentration is sufficient for optimum growth and yield. Low (25–49) and deficient (0–24) index values indicate that the nutrient concentration is below the desired level and may be contributing to reduced growth, yield and/or quality. In such cases, supplying that nutrient to the crop at the optimum time and under optimum environmental conditions will result in an increase in growth and/or yield (Table 1).

Values in the high range (75–99) are not normally detrimental to growth or yield but, under some circumstances, may negatively impact crop quality. When values are in the excess (100+) range, growth problems may result due to nutrient imbalances or, in the case of micronutrients, toxic reactions. Values above 75 may indicate overfertilization and poor allocation of resources.

The critical value indicates the point at which a nutrient shortage causes a 5 to 10% loss in yield or growth; the point of mild toxicity indicates the same degree of loss due to nutrient excess. As the index decreases below the critical value or increases above the mild toxicity point, growth or yield will continue to decrease proportionately. The N:S, N:K and Fe:Mn ratios listed on the report indicate degree of balance among some essential elements.

Report Abbreviations

N	Nitrogen
P	Phosphorus
K	Potassium
Ca	Calcium
Mg	Magnesium
S	Sulfur
Fe	Iron
Mn	Manganese
Zn	Zinc
Cu	Copper
B	Boron
Mo	Molybdenum
Cl	Chloride
Na	Sodium
Ni	Nickel
Cd	Cadmium
Pb	Lead
NO_3-N	Nitrate N

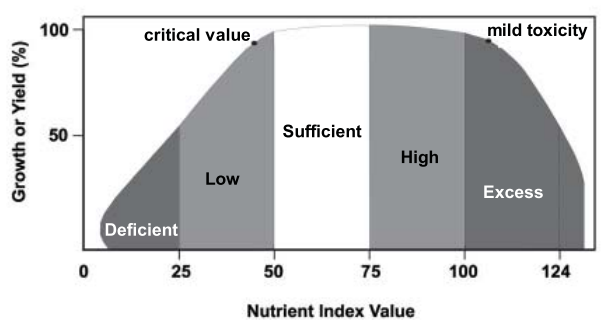


Figure 1. Nutrient index interpretation scale

Table 1. Response to nutrient applications *

Index	Interpretation	Crop Response
0–24	Deficient	High
25–49	Low	Medium
50–74	Sufficient	Low
75–99	High	None
100–124	Excess	None

* Fertilizer history, environmental conditions, stress factors and growth stage will affect ultimate response.

WASTEWATER AND GROUNDWATER SAMPLING

The purpose for collecting samples is to obtain a representative portion of that material or medium being evaluated. Since all sampling activities should be conducted in such a manner that the data could withstand a legal challenge, proper sampling procedures cannot be overemphasized. Valid results depend upon:

- insuring that the sample obtained is truly representative of the material or medium being evaluated;
- employing proper sampling, handling, and preservation techniques;
- properly identifying the collected samples and documenting their collection in permanent field records;
- maintaining sample chain-of-custody procedures;
- protecting the collected samples by properly packing and transporting (or shipping) them to the appropriate laboratory for analysis.

A. GENERAL CONSIDERATIONS

The following factors and procedures should be considered and/or implemented in planning and conducting surface irrigation system sampling operations. All of these factors and procedures should be considered with each sampling event.

1. Selection of parameters to be measured.

   The parameters to be measured are usually dictated by the purpose of the sampling and should be selected based upon permit requirements and, in the event of an investigation into a problem, knowledge of the problem.

2. Dissolved and particulate sample fractions.

   A sample is generally composed of dissolved and particulate fractions. When it is necessary to analyze samples for individual fractions, it may be necessary to filter the sample in the field at the time it is collected (e.g. dissolved phosphorus).

3. Required sample volumes.

   The volume of sample obtained should be sufficient to perform all of the required analyses with an additional amount collected to provide for any quality control needs such as split samples or repeat examinations.

4. Sample handling and mixing.

   Once a sample has been collected, it may be split into separate containers for multiple analyses. To split liquid samples, continually stir the sample contents with a clean pipette or Teflon rod and allow the contents to be siphoned into respective sample containers using Teflon or PVC (Tygon) tubing. Any device used for stirring, or tubing used for siphoning, must be cleaned in the same manner as the other equipment.

After collection, all samples should be handled as little as possible. All personnel should use extreme care to insure that samples are not contaminated. If samples are placed in an ice chest, personnel should insure that the ice does not submerge the sample containers which could result in cross-contamination of samples. The use of frozen water containers should prevent the possibility of cross-contamination that may result from the use of wet ice.

5. Special precautions for trace contaminant sampling.

   Since most compounds can be detected in the parts per billion or parts per trillion range, extreme care must be taken to prevent contamination of samples. The following precautions should be taken when trace contaminants are of concern:

   a. When sampling surface waters, the aqueous sample should always be collected prior to any sediment sample collection.

   b. Sample collection activities should proceed progressively from the least contaminated area to the most contaminated area (if this information is known).

   c. When sampling flowing streams, when possible, samples should be collected facing upstream to avoid contamination from sampling activities.

6. Procedures for identifying potentially hazardous samples.

   Any sample, either known or thought to be hazardous, should be so identified on both the sample tag and the field sample sheet. Information explaining the possible hazard (i.e. corrosive, flammable, poison etc.) must also be listed.

7. Collection of auxiliary data.

   All auxiliary data such as flow measurements, meteorological conditions, and other observations should be entered into field records at the time the samples are collected.

8. Time records.

   All records of time should be kept utilizing local time in the military 2400 hour time format and should be recorded to the nearest five (5) minutes.

9. Transporting and shipping of samples.

   Samples may be hand-delivered to the appropriate laboratory using available vehicles or they may be shipped by common carrier. All sampling personnel should be aware that certain samples could be classified as hazardous materials and, as such, could be regulated by the U.S. Department of Transportation under the Transportation Safety Act of 1974. These regulations are contained in Title 49, CFR, Parts 110-119.

B. WASTEWATER SAMPLING

1. General considerations.

   The wide variety of field conditions always requires judgment regarding the methodology and procedures for collection of wastewater samples. Important considerations for obtaining a representative wastewater sample include the following items.

   a. The sample should be collected where the wastewater is well-mixed. Therefore the sample should be collected near the center of the flow channel, at a depth of approximately half the total depth, where the turbulence is at a maximum and the possibility of solids settling is minimized. Skimming the water surface or dragging the bottom should be avoided.

   b. In sampling from a mixing zone, cross-sectional sampling should be considered. Dye may be use as an aid in determining the most representative sampling points.

   c. If manual compositing is employed, the individual sample bottles must be thoroughly mixed before pouring the individual aliquots into the composite container.

2. Site selection.

   Where applicable, wastewater samples should be collected at the location specified in the permit.

   a. Influent - Influent wastewaters are preferably sampled at points of highly turbulent flow in order to insure adequate mixing.

   b. Effluent - Effluent samples should be collected at the site specified in the permit, or if no site is specified, at the most representative site downstream from all discharges into the receiving waters.

   c. Pond and lagoon sampling - Generally, composite samples should be employed for the collection of wastewater samples from ponds and lagoons. Even if the ponds and lagoons have a long retention time, composite sampling is necessary because of the tendency of ponds and lagoons to short circuit. However, if dye studies or past experience indicate a homogenous discharge, a grab sample may be taken as representative of the waste stream. But in all cases, sampling should be consistent with all permit requirements.

C. USE OF AUTOMATIC SAMPLERS

1. General - Automatic samplers may be employed when several points are to be sampled at frequent intervals or when a continuous record is required.

    a. The sampling equipment must be properly cleaned to avoid cross-contamination which may be present from prior use.

    b. No plastic or metal parts of the sampler are to come in contact with the water or wastewater stream unless parameters to be analyzed preclude this requirement. Use of Teflon may be required for some parameters.

    c. The automatic sampler must be able to provide adequate refrigeration during the sampling period. This is accomplished in the field by using ice.

    d. The automatic sampler must be capable of collecting sufficient sample for all of the analyses of all needed parameters.

    e. A minimum of 100 mls should be collected each time the sampler is activated.

    f. The intake line leading to the pump must be purged before each sample is collected.

    g. The minimum intake line inside diameter should be 1/4 inch.

D. MANUAL SAMPLING

Manual sampling is usually employed when collecting grab samples and/or immediate in situ field analyses. However, it may also be used, in lieu of automatic equipment, over extended periods of time for composite sampling, especially when it is necessary to observe and/or note unusual waste stream conditions.

The best method to manually collect a sample is to use the actual sample container used to transport the sample to the laboratory. This eliminates the possibility of contaminating the sample with an intermediate collection container. The actual sample container must always be used for collecting oil and grease and bacterial samples.

If the water or wastewater stream cannot be physically reached by the sampling personnel, an approved intermediate sampling device can be used. The sample is then collected by lowering a properly cleaned Teflon, plastic, glass or stainless steel collection vessel (type of collection vessel used depends on the parameter being sampled for) into the material to be sampled. The collection vessel may be lowered by hand or attached to a pole or rope and the lowered into the stream.

In some cases, it may be best to use a pump, either power or hand operated, to withdraw a sample from the water or wastewater stream. If a pump is used, it is imperative that it be pre-purged and all components of the pump that come into contact with the liquid be properly cleaned to insure the integrity of the sample.

Samples are manually collected by tipping the collection container in the water or wastewater stream so the mouth of the container faces upstream. The container should be rinsed out via this procedure at least twice before the sample is collected (exceptions to this rinsing procedure may exist if preservatives are present in the sampling container and for certain analyses such as oil and grease).

A separate collection container can be used to collect the initial sample, from which the sample can be redistributed to other containers. If this is performed, however, the container employed to collect the initial sample must be properly cleaned and must be constructed of a material that meets requirements of the parameters being investigated.

E. SPECIAL SAMPLE COLLECTION PROCEDURES

1. Bacteria sample collection.

   Samples for bacterial analysis should always be collected directly into the prepared glass or plastic sample container. The sample container should be kept unopened until it is to be filled. When the cap is removed, care should be taken not to contaminate the stopper or the inside of the bottle. The bottle should be held near the base and filled to within one inch of the top without rinsing and recapped immediately. The bottle should be plunged, neck downward, below the surface and turned until the neck points slightly upward. The mouth should be directed toward the current.

   When the sample bottle must be lowered into the waste stream, either because of safety or impracticality of hand collection (manhole, slippery effluent area, etc.), care must be taken to avoid contamination.

2. Immiscible liquids/oil and grease

   Oil and grease may be present in wastewater as a surface film, an emulsion, a solution, or as a combination of these forms. As it is very difficult to collect a representative oil and grease sample, the inspector must carefully evaluate the location of the sampling point. The most desirable sampling location is at the point where greatest mixing occurs. Quiescent areas should be avoided. Because losses of oil and grease will occur onto the sampling equipment, the collection of a composite sample is impractical. Individual portions collected at prescribed time intervals must be analyzed separately to obtain the average concentrations over an extended period.

F. SAMPLE IDENTIFICATION

The method of sample identification utilized depends on the type of sample collected. Samples collected for in situ field analyses are those collected for specific field analyses for measurements where the data is recorded directly on a field sample collection record, with identifying information, while in the custody of the sampling team. Examples of such in situ field measurements and analyses include pH, temperature, conductivity, and flow measurements. Also included in this category are those field measurements or analyses such as the measurement of flow or dissolved oxygen that are made without actually collecting a sample.

Samples, other than those collected for in situ field measurements or analyses, are best identified by using some sort of identifying tag which can be attached to the sample container. In some cases, particularly with biological samples, the sample tag may be included with, or wrapped around, the sample. The following information should be included on the sample tag:

1. Site location;
2. Date(s) and time(s) of sampling;
3. Type of sample (grab, flow proportional composite, etc.);
4. Any relevant comments (such as readily detectable or identifiable odor, color, or known toxic properties);
5. The general types of analyses to be conducted;
6. The types of preservatives used in the sample, if any;
7. The name of the individual collecting the sample.

If a sample is split with a facility, state regulatory agency, or other party, sample tags with identical information should be attached to each of the sample containers. Also, all tags for blank or duplicate samples should be marked "blank" or "duplicate".

G. CHAIN-OF-CUSTODY PROCEDURES

The possession of samples must be traceable from the time the samples are collected until they are introduced as evidence at possible legal proceedings.

1. SAMPLE CUSTODY

A sample is under custody if:

A. it is in the sampler's actual possession or;
B. it is in the sampler's view, after being in his/her physical possession, or;
C. it is in the sampler's physical possession and then he/she secured it to prevent tampering, or;
D. it is placed in a designated secure area.

2. FIELD CUSTODY PROCEDURES

A. The minimum number of samples that provide a good representation of the media being sampled should be collected. The quantity and types of samples and sample locations should be determined before taking samples. To simplify the chain-of-custody record keeping and eliminate potential legal problems, as few people as possible should handle the samples.

B. The sampler must be responsible for the care and custody of the samples collected until they are properly transferred to another person or facility.

C. Sample tags must be completed for each sample. All samples should be sealed immediately on collection with some form of custody seal (tape). The sampler should write the date and his/her name on the seal (tape). Sealing of the samples is not necessary if the sampler keeps

the samples in his/her custody from the time of collection until the samples are delivered to a laboratory.

D. Documentation on all samples should be collected and maintained in a field log book and chain-of-custody forms must be used.

E. When transferring the possession of samples, the individuals receiving the samples must sign, date and note the time that they received the samples on the chain-of-custody form. A chain-of-custody form documents the transfer of custody of samples from the sampler to another person (e.g. to the laboratory).

F. Samples that are shipped to a laboratory must be properly packaged for shipment and promptly shipped to the laboratory. Shipping containers should be secured by using nylon-reinforced strapping tape and custody seals. The strapping tape should be placed on the container so that all joints of the tape are secured by a custody seal with the seal being placed under the joint and wrapped over the top of it. This prevents the strapping tape from being removed without breaking the custody seal or cutting the strapping tape. The custody seal must be signed, dated, and the time recorded.

G. Whenever samples are split, the agency receiving part of the sample must sign the chain-of-custody form in order to provide a chain-of-custody record of these samples.

H. All samples that are shipped to a laboratory must be accompanied by a chain-of-custody form which should be placed in a water-proof container (plastic bag) and placed inside of the shipping container with the samples. Since most laboratories have their own chain-of-custody forms that they require be used with samples that they receive and analyze, insure that the appropriate chain-of-custody form is submitted with the shipped samples.

I. Samples shipped by mail should be registered with a return receipt requested. If sent by common carrier, a bill of lading or air bill should be used. Receipts from post offices, copies of bills of lading, and air bills must be retained as part of the documentation of the chain-of-custody.

REFERENCE

Standard Operating Procedures Manual Physical and Chemical Monitoring, N.C. Department of Environment, Health and Natural Resources, Division of Environmental Management, Water Quality Section, December 1986.

COLLECTION AND ANALYSIS OF GROUNDWATER SAMPLES

1. Samples should be analyzed as soon as possible after collection. **SAMPLES WHICH ARE NOT ANALYZED WITHIN THE HOLDING TIME SPECIFIED FOR THE METHOD USED (SEE #4. BELOW) MUST BE DISCARDED AND NEW SAMPLES COLLECTED.**

2. Metals Analyses: Use Standard Method 3030C for sample preparation (mercury excluded). **DO NOT FILTER METALS SAMPLES IN THE FIELD!!!** When sampling from developed wells with high particulate levels, use low flow rate purging and sampling with a pump to improve data quality for groundwater samples. Unfiltered samples must be collected for metals, then field acidified with 5 milliliters of concentrated nitric acid per liter of sample, and should be submitted to the lab within 24 hours. Sample preparation in the laboratory (extraction and filtration) must be completed within 72 hours of collection.

3. **ANALYSES ARE TO BE MADE OF THE MOBILE CONSTITUENTS (DISSOLVED AS WELL AS COLLOIDAL) IN THE GROUNDWATER, NOT THOSE THAT ARE A PART OF SEDIMENT ASSOCIATED WITH WELL CONSTRUCTION OR SAMPLING PROCEDURES. CHECK WITH YOUR LABORATORY ON PROPER PROCEDURES FOR SAMPLE COLLECTION AND PRESERVATION.**

4. As per Title 15A, North Carolina Administrative Code, Subchapter 2L, analytical procedures will be in accordance with the methods described in one of the following publications, or by other methods approved beforehand by the Director, Division of Water Quality:

   (a) Standard Methods for the Examination of Water and Wastewater, the most recent version, published jointly by American Public Health Association, American Water Works Association, and Water Pollution Control Federation;

   (b) Methods for Chemical Analysis of Water and Waste, 1979, U.S. Environmental Protection Agency number EPA-600/4-79-020, as revised March, 1983;

   (c) Test Methods for Evaluating Solid Wastes: Physical/Chemical Methods, 3rd Edition, 1986, U.S. Environmental Protection Agency publication number SW-846;

   (d) Test Procedures for the Analysis of Pollutants Under the Clean Water Act, Federal Register Vol. 49, No. 209, 40 CFR Part 136, October 26, 1984.

5. Measure and record the depth of water in the well prior to pumping or bailing any water from the well.

6. At least 1 but not more than 3 volumes of water in the well should be pumped or bailed prior to collecting a sample for analysis. If the well is pumped/bailed dry before 3 well volumes are removed, samples can be collected as soon as the well recovers to the point where enough water is available to collect your sample.

7. Determination for specific conductance, pH, temperature, odor and appearance must be made in the field on unfiltered samples when the sample is collected.

8. Field equipment must be calibrated in accordance with recommendations by the manufacturer.

9. Samples must be filtered through a 0.45 micron filter immediately after collection when a dissolved analysis is required. (See #4 above)

10. The sample container should be labeled at the time of collection with the facility name, well identification number, and date and time collected.

11. An "authorized agent" is any corporate officer or public official authorized by the company, corporation, or governmental body to sign official documents.

RECOMMENDED SAMPLE CONTAINERS, PRESERVATION, AND HOLDING TIMES

The preservation, holding times, and materials associated with sampling depends upon the parameters to be analyzed. Once a sample is collected, it must be analyzed immediately or stored in a container with a preservative to maintain the integrity of the sample. Methods of preservation are intended to (1) retard biological activity (2) reduce volatility of constituents, and (3) retard hydrolysis of chemical compounds. Samples should be analyzed as soon as possible after collection. The times listed as holding times are the maximum times that samples may be held before analysis and still be considered valid.

Preservation techniques can only retard the processes that take place after a sample is removed from the source and are generally limited to chemical addition, pH control, refrigeration, and freezing. To maintain the integrity of the sample prior to sample collection, use the following general guidelines and consult with your laboratory about the appropriate selection of containers, pretreatment of containers, preservation, and holding times.

NOTE: Sample "HOLDING TIME" represents the MAXIMUM amount of time which can elapse between the time the sample is collected in the field and the time that sample analyses is begun in the laboratory.

Table II—Required Containers, Preservation Techniques, and Holding Times

Parameter number/name	Container [1]	Preservation [2,3]	Maximum holding time [4]
Table IA—Bacterial Tests:			
1–5. Coliform, total, fecal, and *E. coli*	PA, G	Cool, <10 °C, 0.0008% $Na_2S_2O_3$ [5].	8 hours.[22,23]
6. Fecal streptococci	PA, G	Cool, <10 °C, 0.0008% $Na_2S_2O_3$ [5].	8 hours.[22]
7. Enterococci	PA, G	Cool, <10 °C, 0.0008% $Na_2S_2O_3$ [5].	8 hours.[22]
8. *Salmonella*	PA, G	Cool, <10 °C, 0.0008% $Na_2S_2O_3$ [5].	8 hours.[22]
Table IA—Aquatic Toxicity Tests:			
9–12. Toxicity, acute and chronic	P, FP, G	Cool, ≤6 °C [16]	36 hours.
Table IB—Inorganic Tests:			
1. Acidity	P, FP, G	Cool, ≤6 °C [18]	14 days.
2. Alkalinity	P, FP, G	Cool, ≤6 °C [18]	14 days.
4. Ammonia	P, FP, G	Cool, ≤6 °C [18], H_2SO_4 to pH <2.	28 days.
9. Biochemical oxygen demand	P, FP, G	Cool, ≤6 °C [18]	48 hours.
10. Boron	P, FP, or Quartz	HNO_3 to pH <2	6 months.
11. Bromide	P, FP, G	None required	28 days.
14. Biochemical oxygen demand, carbonaceous	P, FP G	Cool, ≤6 °C [18]	48 hours.
15. Chemical oxygen demand	P, FP, G	Cool, ≤6 °C [18], H_2SO_4 to pH <2.	28 days.
16. Chloride	P, FP, G	None required	28 days.
17. Chlorine, total residual	P, G	None required	Analyze within 15 minutes.
21. Color	P, FP, G	Cool, ≤6 °C [18]	48 hours.
23–24. Cyanide, total or available (or CATC) and free.	P, FP, G	Cool, ≤6 °C [18], NaOH to pH >10 [5,6], reducing agent if oxidizer present.	14 days.
25. Fluoride	P	None required	28 days.
27. Hardness	P, FP, G	HNO_3 or H_2SO_4 to pH <2	6 months.
28. Hydrogen ion (pH)	P, FP, G	None required	Analyze within 15 minutes.
31, 43. Kjeldahl and organic N	P, FP, G	Cool, ≤6 °C[18], H_2SO_4 to pH <2.	28 days.
Table IB—Metals: [7]			
18. Chromium VI	P, FP, G	Cool, ≤6 °C[18], pH = 9.3–9.7 [20].	28 days.
35. Mercury (CVAA)	P, FP, G	HNO_3 to pH <2	28 days.
35. Mercury (CVAFS)	FP, G; and FP-lined cap [17]	5 mL/L 12N HCl or 5 mL/L BrCl [17].	90 days.[17]
3, 5–8, 12, 13, 19, 20, 22, 26, 29, 30, 32–34, 36, 37, 45, 47, 51, 52, 58–60, 62, 63, 70–72, 74, 75. Metals, except boron, chromium VI, and mercury.	P, FP, G	HNO_3 to pH <2, or at least 24 hours prior to analysis [19].	6 months.
38. Nitrate	P, FP, G	Cool, ≤6 °C [18]	48 hours.
39. Nitrate-nitrite	P, FP, G	Cool, ≤6 °C[18], H_2SO_4 to pH <2.	28 days.
40. Nitrite	P, FP, G	Cool, ≤6 °C [18]	48 hours.
41. Oil and grease	G	Cool to ≤6 °C[18], HCl or H_2SO_4 to pH <2.	28 days.
42. Organic Carbon	P, FP, G	Cool to ≤6 °C [18], HCl, H_2SO_4, or H_3PO_4 to pH <2.	28 days.
44. Orthophosphate	P, FP, G	Cool, to ≤6 °C [18,24]	Filter within 15 minutes; Analyze within 48 hours.
46. Oxygen, Dissolved Probe	G, Bottle and top	None required	Analyze within 15 minutes.
47. Winkler	G, Bottle and top	Fix on site and store in dark.	8 hours.
48. Phenols	G	Cool, ≤6 °C[18], H_2SO_4 to pH <2.	28 days.
49. Phosphorous (elemental)	G	Cool, ≤6 °C [18]	48 hours.
50. Phosphorous, total	P, FP, G	Cool, ≤6 °C [18], H_2SO_4 to pH <2.	28 days.
53. Residue, total	P, FP, G	Cool, ≤6 °C [18]	7 days.
54. Residue, Filterable	P, FP, G	Cool, ≤6 °C [18]	7 days.

TABLE II—REQUIRED CONTAINERS, PRESERVATION TECHNIQUES, AND HOLDING TIMES—Continued

Parameter number/name	Container [1]	Preservation [2,3]	Maximum holding time [4]
55. Residue, Nonfilterable (TSS)	P, FP, G	Cool, ≤6 °C [18]	7 days.
56. Residue, Settleable	P, FP, G	Cool, ≤6 °C [18]	48 hours.
57. Residue, Volatile	P, FP, G	Cool, ≤6 °C [18]	7 days.
61. Silica	P or Quartz	Cool, ≤6 °C [18]	28 days.
64. Specific conductance	P, FP, G	Cool, ≤6 °C [18]	28 days.
65. Sulfate	P, FP, G	Cool, ≤6 °C [18]	28 days.
66. Sulfide	P, FP, G	Cool, ≤6 °C [18], add zinc acetate plus sodium hydroxide to pH >9.	7 days.
67. Sulfite	P, FP, G	None required	Analyze within 15 minutes.
68. Surfactants	P, FP, G	Cool, ≤6 °C [18]	48 hours.
69. Temperature	P, FP, G	None required	Analyze.
73. Turbidity	P, FP, G	Cool, ≤6 °C [18]	48 hours.
Table IC—Organic Tests: [8]			
13, 18–20, 22, 24–28, 34–37, 39–43, 45–47, 56, 76, 104, 105, 108–111, 113. Purgeable Halocarbons.	G, FP-lined septum	Cool, ≤6 °C [18], 0.008% $Na_2S_2O_3$ [5].	14 days.
6, 57, 106. Purgeable aromatic hydrocarbons	G, FP-lined septum	Cool, ≤6 °C [18], 0.008% $Na_2S_2O_3$ [5], HCl to pH 2 [9].	14 days. [9]
3, 4. Acrolein and acrylonitrile	G, FP-lined septum	Cool, ≤6 °C [18], 0.008% $Na_2S_2O_3$, pH to 4–5 [10].	14 days. [10]
23, 30, 44, 49, 53, 77, 80, 81, 98, 100, 112. Phenols [11].	G, FP-lined cap	Cool, ≤6 °C [18], 0.008% $Na_2S_2O_3$.	7 days until extraction, 40 days after extraction.
7, 38. Benzidines [11,12]	G, FP-lined cap	Cool, ≤6 °C [18], 0.008% $Na_2S_2O_3$ [5].	7 days until extraction. [13]
14, 17, 48, 50–52. Phthalate esters [11]	G, FP-lined cap	Cool, ≤6 °C [18]	7 days until extraction, 40 days after extraction.
82–84. Nitrosamines [11,14]	G, FP-lined cap	Cool, ≤6 °C [18], store in dark, 0.008% $Na_2S_2O_3$ [5].	7 days until extraction, 40 days after extraction.
88–94. PCBs [11]	G, FP-lined cap	Cool, ≤6 °C [18]	1 year until extraction, 1 year after extraction.
54, 55, 75, 79. Nitroaromatics and isophorone [11]	G, FP-lined cap	Cool, ≤6 °C [18], store in dark, 0.008% $Na_2S_2O_3$ [5].	7 days until extraction, 40 days after extraction.
1, 2, 5, 8–12, 32, 33, 58, 59, 74, 78, 99, 101. Polynuclear aromatic hydrocarbons [11].	G, FP-lined cap	Cool, ≤6 °C [18], store in dark, 0.008% $Na_2S_2O_3$ [5].	7 days until extraction, 40 days after extraction.
15, 16, 21, 31, 87. Haloethers [11]	G, FP-lined cap	Cool, ≤6 °C [18], store in dark, 0.008% $Na_2S_2O_3$ [5].	7 days until extraction, 40 days after extraction.
29, 35–37, 63–65, 107. Chlorinated hydrocarbons [11].	G, FP-lined cap	Cool, ≤6 °C [18], 0.008% $Na_2S_2O_3$ [5].	7 days until extraction, 40 days after extraction.
60–62, 66–72, 85, 86, 95–97, 102, 103. CDDs/CDFs [11].		Cool, ≤6 °C [18]	
Aqueous Samples: Field and Lab Preservation	G		1 year.
Solids and Mixed-Phase Samples: Field Preservation.	G	Cool, ≤6 °C [18], 0.008% $Na_2S_2O_3$ [5], pH <9.	7 days.
Tissue Samples: Field Preservation	G		24 hours.
Solids, Mixed-Phase, and Tissue Samples: Lab Preservation.	G	Cool, ≤6 °C [18]	1 year.
114–118. Alkylated phenols	G	Cool, ≤6 °C [18]	28 days until extraction, 40 days after extraction.
119. Adsorbable Organic Halides (AOX)	G	Freeze, ≤ −10 °C	Hold *at least* 3 days, but not more than 6 months.
120. Chlorinated Phenolics		Cool, <6 °C, H_2SO_4 to pH <2.	30 days until acetylation, 30 days after acetylation.
		Cool, <6 °C, 0.008% $Na_2S_2O_3$ HNO_3 to pH <2.	
Table ID—Pesticides Tests:			
1–70. Pesticides [11]	G, FP-lined cap	Cool, <6 °C, 0.008% $Na_2S_2O_3$ H_2SO_4 to pH <2.	7 days until extraction, 40 days after extraction.
Table IE—Radiological Tests:			
1–5. Alpha, beta, and radium	P, FP, G	Cool, ≤6 °C [18], pH 5–9 [15]	6 months.
Table IH—Bacterial Tests:			
1. *E. coli*	PA, G	HNO_3 to pH <2	8 hours. [22]
2. Enterococci	PA, G	Cool, <10 °C, 0.0008% $Na_2S_2O_3$ [5].	8 hours. [22]
Table IH—Protozoan Tests:			
8. *Cryptosporidium*	LDPE; field filtration	Cool, <10 °C, 0.0008% $Na_2S_2O_3$ [5].	96 hours. [21]
9. *Giardia*	LDPE; field filtration		96 hours. [21]

[1] "P" is for polyethylene; "FP" is fluoropolymer (polytetrafluoroethylene (PTFE); Teflon®), or other fluoropolymer, unless stated otherwise in this Table II; "G" is glass; "PA" is any plastic that is made of a sterilizable material (polypropylene or other autoclavable plastic); "LDPE" is low density polyethylene.

[2] Except where noted in this Table II and the method for the parameter, preserve each grab sample within 15 minutes of collection. For a composite sample collected with an automated sample (*e.g.,* using a 24-hour composite sample; see 40 CFR 122.21(g)(7)(i) or 40 CFR Part 403, Appendix E), refrigerate the sample at ≤ 6 °C during collection unless specified otherwise in this Table II or in the method(s). For a composite sample to be split into separate aliquots for preservation and/or analysis, maintain the sample at ≤ 6 °C, unless specified otherwise in this Table II or in the method(s), until collection, splitting, and preservation is completed. Add the preservative to the sample container prior to sample collection when the preservative will not compromise the integrity of a grab sample, a composite sample, or aliquot split from a composite sample within 15 minutes of collection. If a composite measurement is required but a composite sample would compromise sample integrity, individual grab samples must be collected at prescribed time intervals (*e.g.,* 4 samples over the course of a day, at 6-hour intervals). Grab samples must be analyzed separately and the concentrations averaged. Alternatively, grab samples may be collected in the field and composited in the laboratory if the compositing procedure produces results equivalent to results produced by arithmetic averaging of results of analysis of individual grab samples. For examples of laboratory compositing procedures, see EPA Method 1664 Rev. A (oil and grease) and the procedures at 40 CFR 141.34(f)(14)(iv) and (v) (volatile organics).

[3] When any sample is to be shipped by common carrier or sent via the U.S. Postal Service, it must comply with the Department of Transportation Hazardous Materials Regulations (49 CFR part 172). The person offering such material for transportation is responsible for ensuring such compliance. For the preservation requirement of Table II, the Office of Hazardous Materials, Materials Transportation Bureau, Department of Transportation has determined that the Hazardous Materials Regulations do not apply to the following materials: Hydrochloric acid (HCl) in water solutions at concentrations of 0.04% by weight or less (pH about 1.96 or greater; Nitric acid (HNO_3) in water solutions at concentrations of 0.15% by weight or less (pH about 1.62 or greater); Sulfuric acid (H_2SO_4) in water solutions at concentrations of 0.35% by weight or less (pH about 1.15 or greater); and Sodium hydroxide (NaOH) in water solutions at concentrations of 0.080% by weight or less (pH about 12.30 or less).

[4] Samples should be analyzed as soon as possible after collection. The times listed are the maximum times that samples may be held before the start of analysis and still be considered valid. Samples may be held for longer periods only if the permittee or monitoring laboratory has data on file to show that, for the specific types of samples under study, the analytes are stable for the longer time, and has received a variance from the Regional Administrator under Sec. 136.3(e). For a grab sample, the holding time begins at the time of collection. For a composite sample collected with an automated sampler (*e.g.,* using a 24-hour composite sampler; see 40 CFR 122.21(g)(7)(i) or 40 CFR part 403, Appendix E), the holding time begins at the time of the end of collection of the composite sample. For a set of grab samples composited in the field or laboratory, the holding time begins at the time of collection of the last grab sample in the set. Some samples may not be stable for the maximum time period given in the table. A permittee or monitoring laboratory is obligated to hold the sample for a shorter time if it knows that a shorter time is necessary to maintain sample stability. See 136.3(e) for details. The date and time of collection of an individual grab sample is the date and time at which the sample is collected. For a set of grab samples to be composited, and that are all collected on the same calendar date, the date of collection is the date on which the samples are collected. For a set of grab samples to be composited, and that are collected across two calendar dates, the date of collection is the dates of the two days; *e.g.,* November 14–15. For a composite sample collected automatically on a given date, the date of collection is the date on which the sample is collected. For a composite sample collected automatically, and that is collected across two calendar dates, the date of collection is the dates of the two days; *e.g.,* November 14–15. For static-renewal toxicity tests, each grab or composite sample may also be used to prepare test solutions for renewal at 24 h, 48 h, and/or 72 h after first use, if stored at 0–6 °C, with minimum head space.

[5] ASTM D7365–09a specifies treatment options for samples containing oxidants (e.g., chlorine). Also, Section 9060A of Standard Methods for the Examination of Water and Wastewater (20th and 21st editions) addresses dechlorination procedures.

[6] Sampling, preservation and mitigating interferences in water samples for analysis of cyanide are described in ASTM D7365–09a. There may be interferences that are not mitigated by the analytical test methods or D7365–09a. Any technique for removal or suppression of interference may be employed, provided the laboratory demonstrates that it more accurately measures cyanide through quality control measures described in the analytical test method. Any removal or suppression technique not described in D7365–09a or the analytical test method must be documented along with supporting data.

[7] For dissolved metals, filter grab samples within 15 minutes of collection and before adding preservatives. For a composite sample collected with an automated sampler (*e.g.,* using a 24-hour composite sampler; see 40 CFR 122.21(g)(7)(i) or 40 CFR Part 403, Appendix E), filter the sample within 15 minutes after completion of collection and before adding preservatives. If it is known or suspected that dissolved sample integrity will be compromised during collection of a composite sample collected automatically over time (*e.g.,* by interchange of a metal between dissolved and suspended forms), collect and filter grab samples to be composited (footnote 2) in place of a composite sample collected automatically.

[8] Guidance applies to samples to be analyzed by GC, LC, or GC/MS for specific compounds.

[9] If the sample is not adjusted to pH 2, then the sample must be analyzed within seven days of sampling.

[10] The pH adjustment is not required if acrolein will not be measured. Samples for acrolein receiving no pH adjustment must be analyzed within 3 days of sampling.

[11] When the extractable analytes of concern fall within a single chemical category, the specified preservative and maximum holding times should be observed for optimum safeguard of sample integrity (*i.e.,* use all necessary preservatives and hold for the shortest time listed). When the analytes of concern fall within two or more chemical categories, the sample may be preserved by cooling to ≤ 6 °C, reducing residual chlorine with 0.008% sodium thiosulfate, storing in the dark, and adjusting the pH to 6–9; samples preserved in this manner may be held for seven days before extraction and for forty days after extraction. Exceptions to this optional preservation and holding time procedure are noted in footnote 5 (regarding the requirement for thiosulfate reduction), and footnotes 12, 13 (regarding the analysis of benzidine).

[12] If 1,2-diphenylhydrazine is likely to be present, adjust the pH of the sample to 4.0 ± 0.2 to prevent rearrangement to benzidine.

[13] Extracts may be stored up to 30 days at < 0 °C.

[14] For the analysis of diphenylnitrosamine, add 0.008% $Na_2S_2O_3$ and adjust pH to 7–10 with NaOH within 24 hours of sampling.

[15] The pH adjustment may be performed upon receipt at the laboratory and may be omitted if the samples are extracted within 72 hours of collection. For the analysis of aldrin, add 0.008% $Na_2S_2O_3$.

[16] Place sufficient ice with the samples in the shipping container to ensure that ice is still present when the samples arrive at the laboratory. However, even if ice is present when the samples arrive, immediately measure the temperature of the samples and confirm that the preservation temperature maximum has not been exceeded. In the isolated cases where it can be documented that this holding temperature cannot be met, the permittee can be given the option of on-site testing or can request a variance. The request for a variance should include supportive data which show that the toxicity of the effluent samples is not reduced because of the increased holding temperature. Aqueous samples must not be frozen. Hand-delivered samples used on the day of collection do not need to be cooled to 0 to 6 °C prior to test initiation.

[17] Samples collected for the determination of trace level mercury (<100 ng/L) using EPA Method 1631 must be collected in tightly-capped fluoropolymer or glass bottles and preserved with BrCl or HCl solution within 48 hours of sample collection. The time to preservation may be extended to 28 days if a sample is oxidized in the sample bottle. A sample collected for dissolved trace level mercury should be filtered in the laboratory within 24 hours of the time of collection. However, if circumstances preclude overnight shipment, the sample should be filtered in a designated clean area in the field in accordance with procedures given in Method 1669. If sample integrity will not be maintained by shipment to and filtration in the laboratory, the sample must be filtered in a designated clean area in the field within the time period necessary to maintain sample integrity. A sample that has been collected for determination of total or dissolved trace level mercury must be analyzed within 90 days of sample collection.

[18] Aqueous samples must be preserved at ≤ 6 °C, and should not be frozen unless data demonstrating that sample freezing does not adversely impact sample integrity is maintained on file and accepted as valid by the regulatory authority. Also, for purposes of NPDES monitoring, the specification of "≤ °C" is used in place of the "4 °C" and "< 4 °C" sample temperature requirements listed in some methods. It is not necessary to measure the sample temperature to three significant figures (1/100th of 1 degree); rather, three significant figures are specified so that rounding down to 6 °C may not be used to meet the ≤6 °C requirement. The preservation temperature does not apply to samples that are analyzed immediately (less than 15 minutes).

[19] An aqueous sample may be collected and shipped without acid preservation. However, acid must be added at least 24 hours before analysis to dissolve any metals that adsorb to the container walls. If the sample must be analyzed within 24 hours of collection, add the acid immediately (see footnote 2). Soil and sediment samples do not need to be preserved with acid. The allowances in this footnote supersede the preservation and holding time requirements in the approved metals methods.

[20] To achieve the 28-day holding time, use the ammonium sulfate buffer solution specified in EPA Method 218.6. The allowance in this footnote supersedes preservation and holding time requirements in the approved hexavalent chromium methods, unless this supersession would compromise the measurement, in which case requirements in the method must be followed.

[21] Holding time is calculated from time of sample collection to elution for samples shipped to the laboratory in bulk and calculated from the time of sample filtration to elution for samples filtered in the field.

[22] Sample analysis should begin as soon as possible after receipt; sample incubation must be started no later than 8 hours from time of collection.

[23] For fecal coliform samples for sewage sludge (biosolids) only, the holding time is extended to 24 hours for the following sample types using either EPA Method 1680 (LTB–EC) or 1681 (A–1): Class A composted, Class B aerobically digested, and Class B anaerobically digested.

[24] The immediate filtration requirement in orthophosphate measurement is to assess the dissolved or bio-available form of orthophosphorus (*i.e.*, that which passes through a 0.45-micron filter), hence the requirement to filter the sample immediately upon collection (*i.e.*, within 15 minutes of collection).

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Renovation of Municipal Wastewater and Biomass Production in Hardwood Tree Plantations

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Summary: Application of wastewater to hardwood tree plantations offers a viable opportunity to dispose of nutrients, water, and potentially some pollutants while producing large quantities of wood products. Hardwood plantations have numerous advantages over natural forests and other plant crops for wastewater treatment. This study was conducted at the Edenton Wastewater Facility in North Carolina. Wastewater was applied at a rate of 25.4 mm over a 4 hour time period for one day, every two weeks. Soils were described as State and Conetoe. Growth, yield, and nutrient data was collected for sycamore and sweetgum trees. Data indicated that hardwood trees are capable of assimilating nitrogen and phosphorus from the wastewater and producing large quantities of biomass that exceed biomass measurements of trees grown without wastewater irrigation.

Keywords: Wastewater, Land application, renovation

Introduction:

Application of wastewater to hardwood tree plantations offers a viable opportunity to dispose of nutrients and water and potentially some pollutants while producing large quantities of wood products. Forestland treatment has become commonplace in the U.S. with approximately 100 wastewater treatment systems less than 250 ha permitted each year (Morris and Nutter, 1997). In North Carolina, several dozen new forestland systems and systems converted from turf or agricultural receiver crops have been installed during the last 5 years. Additional systems are in various stages of planning and implementation.

Much of the interest in using forest systems for wastewater treatment has been related to a concern for improving water quality. One component of water quality protection is ecologically sound renovation of wastewater. Forestland treatment of wastewater can utilize the assimilative capacity of biological systems to remove and store nutrients and pollutants (Aschmann et al., 1990; Frederick et al., 1994; Red and Nutter, 1986; Stewart et al., 1990). These systems are much preferred over systems that discharge directly into surface waters. Combining this assimilative capacity for water and nutrients with woody crop production for fiber, solid wood products, energy or feedstock needs can have widespread application in the U.S. and international locations. There is an increasing national and international demand for hardwood wood products and revenue from the sale of these products can offset the cost of establishment and maintenance of hardwood plantations (Urie, 1986). These features of hardwood fiber production and wastewater assimilation and treatment have vast and immediate application to industry, municipalities and agriculture. Of the forest land application systems available, in many cases, hardwood plantations are the most effective and lowest cost alternative since large quantities of wood can concurrently be produced thereby offsetting wastewater treatment costs.

Extensive justification for using forests for wastewater treatment has been itemized by Cole, et al., (1983) including: 1. The large area of forestland available which is well-drained and not subject to flooding, 2. Forestland sites are nutrient deficient and are capable of assimilating large amounts of nutrients through microbial conversion and soil adsorption, 3. Forests are not considered food chain crops, 4. Forests have high potential for nutrient immobilization, 5. Tree cover minimizes surface runoff, and 6. Trees have perennial root systems, which allow year- round uptake of nutrients and enhance infiltration. Effects of wastewater on forests include dramatic growth increases, shortened rotations, decrease in insect and disease incidence and increased site stability.

Hardwood plantations have numerous advantages over natural forests and other plant crops for wastewater treatment. Species can be matched to site to ensure rapid growth. Growth response of hardwoods to irrigation and nutrients such as provided in wastewater is high and hardwoods rapidly concentrate nutrients in juvenile tissues. Under short rotations, trees can be whole-tree harvested removing the nutrients from the site in a non-food chain product. Under medium to longer rotations, high value, solid wood products such as lumber or veneer can be grown. Other crop possibilities include ornamental trees and shrubs (ball and burlap) grown for 3 to 6 years and removed as thinnings or as an entire crop. For harvested tree crops, a second rotation will result from coppice (sprouts) from the existing root systems. Coppicing will result in immediate tree cover and a continuance of vegetative cover on the site without replanting. Wastewater irrigation can provide an ideal source of low-cost irrigation and fertilizer needed to maximize growth in

short rotation hardwood plantations (Urie 1986). Many researchers studying forest land application of wastewater conclude that large-scale projects involving hardwood plantations are needed and that plantations can most effectively solve the wastewater disposal problem while providing large amounts of wood fiber more efficiently and with less maintenance compared to turf or agricultural systems.

Municipal sewage effluent has high concentrations of nutrients that have the potential to improve site productivity. Land application systems annually apply between 300-500kg nitrogen, 150-300kg phosphorous and 100-200kg potassium per hectare. Smaller quantities of calcium, magnesium, sodium and trace metals are also applied. Most of these nutrients are in a form readily available to plants. High nutrient levels combined with abundant moisture can result in very favorable conditions for high biomass growth; even greater than for conventional fertilizer and irrigation. However, there is very little quantitative growth information for wastewater irrigation systems using short rotation hardwood trees. Also, there is little performance data for comparing species under spray irrigation systems, renovation effectiveness or the costs associated with installing these systems.

Since the First Forest Alternatives Conference in 1986, several important limitations to forest land application identified by Cole and Henry (1986) have been addressed including 1. Public and regulatory acceptance, 2. Economics, 3. Design criteria for N application rates, 4. Improved application and management techniques and, 5. Risk assessment for metals, pathogens and organic compounds (Morris and Nutter, 1997).

Early concerns about nutrient cycling and storage capacity were cited by Mengel and Frederick, (1991). It is now accepted that a successful land application program must consider both the ability of the soils to store and process the residual products without unwanted losses as well as the ability of the vegetation to utilize, through accelerated uptake and storage, the available nutrients contained in the materials being added (Cole, 1997).

Results from existing studies have shown that forests can be used successfully to remove and store nutrients from municipal wastewater. Forest systems are typically deficient in nitrogen required for maximum yield due to past agricultural uses and respond to nitrogen amendments from wastewater application (Henry, 1997). Young plantations of poplar (*Populus nigra* L.) and Douglas fir (*Pseudotsuga menziesii* L.) removed over 50 percent of applied nitrogen (Schiess and Cole, 1981). Nitrogen renovation in older plantations of red pine (*Pinus resinosa* Ait.) in Michigan was near 70 percent when applied at a rate of 88 mm/week and exceeded 90 percent when applied at a rate of 22 mm/week (Urie, 1979). Wastewater loadings of 56 mm/week and annual nutrient loadings of 320 kg/ha (N) and 80 kg/ha (P) in commercial stands of radiata pine *(Pinus radiata)* in New Zealand resulted in meeting the limits of annual discharge to less than 24.5 tonnes of nitrogen and 2.5 tonnes of phosphorous (Tomer et al., 1997).

Phosphorous has the potential for groundwater pollution (Sopper and Kerr, 1979). Typically, forest soils are efficient at storing phosphorous in the profile particularly in soils with a high clay content. Trees typically require 5-15 Kg/ha/yr, but are capable of using much higher amounts under wastewater applications (Polglase, 1997). In one wastewater irrigation study, all phosphorous was retained in the soil profile (Stednick and

Woodridge, 1979) and on an upland Georgia site, phosphorous renovation was reported at an average of 98.7 percent (Nutter and Red, 1986).

With the exception of nitrogen and phosphorus, municipal wastewater typically has low concentrations of other nutrients. However, nutrient levels should be monitored closely to avoid imbalances. Maintaining well-balanced foliar nutrition where soil fertility has increased will improve overall productivity and stability in otherwise healthy forest ecosystems (Polglase, 1997). Ranges in nutrient content for municipal wastewater have been reported for coastal plain pine flatwoods (Red and Nutter, 1986), piedmont mixed pine/hardwood (Nutter, 1986), piedmont mixed hardwood plantation (Woody et al., 1996), and coastal plain hardwood plantation (Frederick, et al., 1994). Salt accumulation can become a restriction at wastewater sites and preventative or remedial measures may have to be taken. High levels of sodium, calcium, and magnesium can become an irrigation hazard and can result in soil deterioration (Nutter, 1986, Red and Nutter, 1986, and Woody et al., 1996). The sodium adsorption ratio (SAR) of irrigation water must be determined and monitored. Generally, an SAR of over 10 requires corrective measures such as gypsum addition.

Municipal wastewater is generally low in trace metals, but the land applied wastewater must be closely monitored to minimize loadings in the soil and the potential of leaching. Trace metals can be retained in the soil following wastewater application, but may leach into surface and groundwaters and may be a toxic threat to animal and plant life (Harrison et al., 1997).

Study Site:

The wastewater treatment facility used for this research is supplied with municipal wastewater from the City of Edenton, NC (population 5000). The 145 ha site was planted in 1987 with sycamore (*Platanus occidentalis*) 45 percent, sweetgum (*Liquidambar styraciflua*), 45 percent and loblolly pine (*Pinus taeda* L.), 10 percent. The sycamore was harvested in November 1997.

The site is dominated by two soil series: State and Conetoe. The State series is a fine loamy, mixed thermic, arenic Hapludult, and the Conetoe series is a fine loamy, mixed, thermic typic Hapludult. Both series have a clay B-horizon, which occurs at approximately 60 cm in the Conetoe and 30 cm in the State series. This layer restricts infiltration and provides for the majority of cation exchange sites for wastewater treatment. Wastewater is applied at a rate of 25.4 mm over a 4 hour time period, one day, every two weeks. Irrigation water is supplied via underground pipes to impact-type sprinklers on 1.2 m risers at 18.3 m x 24.4 m spacings. The operation pressure is 2.8 kg/cm^2. The wastewater is pumped to an 11.5 ha oxidation lagoon, with an influent rate of 4.8 x 10 –2 m^3/s. The wastewater is chlorinated for odor control before it enters the oxidation lagoon. The plantations are irrigated with water from the oxidation lagoon.

Study Design and Methods:

Separate plots have been installed to measure biomass production and nutrient assimilation. The wastewater renovation data are being collected on the nutrient assimilation plots. Biomass estimates for the sycamore harvest are based on weights of loaded chip vans weighed at the Weyerhaeuser Mill at Plymouth, NC.

Biomass

Eight 25-tree plots (4 each for sycamore and sweetgum) were installed for collection of biomass information. All trees were measured at the end of the growing season and unpublished biomass equations developed by the North Carolina State University Hardwood Research Cooperative were used to estimate biomass. Estimates represent all aboveground wood and bark biomass. Data have been collected at age 5 and age 10. In addition, approximately 20 ha of sycamore were harvested during the November 1997 and estimates of total tree, green biomass were estimated based on weighed chip vans.

Nutrient Assimilation and Wastewater Renovation

Eight 36-tree plots (4 irrigated and 4 nonirrigated) have been established to measure tree nutrient content in the sycamore and sweetgum plantations. Four trees for each species were destructively sampled for nutrient analyses. In addition, chip composite samples were taken from the chip vans for additional whole-tree nutrient determinations. Concentrations of nitrogen, phosphorous, calcium, potassium, magnesium and sodium were determined in the wood, bark foliage and total tree. Samples from plots were taken in October.

Results and Discussion:

Biomass:

Biomass, survival, and growth data for sweetgum and sycamore are presented in Tables 1 and 2. Both species have maintained excellent survival and growth through age ten. Sycamore height and diameter growth and biomass accumulation were significantly better than sweetgum. However, these differences are less between ages 5 and 10 which reflects an increase in the rate of growth and biomass production for sweetgum during the last 5 years. The trends in this study were noted by Mengel and Frederick, 1991. Early growth for sweetgum is typically low and maximum growth and biomass rate-of-increase will occur after age 10 compared to sycamore.

Intraspecific competition within the sycamore blocks during the past 5 years has been intense, resulting in growth slowdown and deteriorating crown ratios. Live crown ratios have become less than 30 percent (compared to 50 percent for sweetgum) and resulted in the decision to harvest the sycamore in the fall of 1997.

Biomass production for the sycamore exceeds the yields obtained in other biomass studies and in operational plantations (Wood et al., 1976 and Saucier et al., 1972). These yields are up to 50 percent greater than biomass yields from non-irrigated operational sycamore plantations (unpublished data) reported from the North Carolina State University Hardwood Research Cooperative.

Table 1: Stand and Biomass Data for Sycamore from the Edenton Wastewater Receiver Site

	Age 5	Age 10
Planted (trees/ha)	1788	1788
Percent Survival (%)	93	91
Height (m)	10.8	21.6
Diameter (DBH)(cm)	8.5	24.1
Green Biomass (Mg/ha)[a]	48.2	147.6
Dry Biomass (Mg/ha)	22.3	68.5

[a] Whole Tree Biomass

Table 2: Stand and Biomass Data for Sweetgum from the Edenton Wastewater Receiver Site

	Age 5	Age 10
Planted (trees/ha)	1650	1650
Percent Survival (%)	100	98
Height (m)	5.5	13.3
Diameter (DBH)(cm)	6.7	15.5
Green Biomass (Mg/ha)[a]	18.9	94.1
Dry Biomass (Mg/ha)	7.7	38.3

[a] Whole Tree Biomass

Both sycamore and sweetgum vigorously regenerate via coppicing. Biomass production and growth from coppice will exceed that of seedling-origin stands. Research coordinated by the North Carolina State University, Hardwood Research Cooperative found that 1-year-old coppice growth averages 5-6 times the green-weight biomass of 1-year-old seedling growth (North Carolina State University, 1985). Current measurements in harvested 7-year-old experimental clearcut blocks show coppice height growth after 1 year to average over 2 meters.

Results of sycamore biomass yields following clearcut, whole tree harvesting showed green and dry biomass yields of 135.5 and 63.7 Mg/ha respectively. These yields are slightly less than the data from destructively sampled trees (Table 1). However, the clearcut harvest included the entire range of sites occupied by sycamore including some wet off-site areas and areas with low survival.

Nutrients:

The primary function of any wastewater treatment system is to remove excess nutrients and other pollutants. Regulatory agencies are particularly concerned with discharges of nitrogen, phosphorous, BOD (biochemical oxygen demand), and fecal coliform. Fecal coliform is largely removed during the disinfection process and BOD is primarily removed during settling and facultative treatment in lagoons prior to land application. Forestland systems are particularly efficient at removing N and P since most forests are

deficient in these nutrients. In addition, hardwood plantation systems can be designed to include species that are tolerant of high hydraulic loads and exhibit high nutrient assimilation rates through rapid early growth.

Historically, land application facilities have relied on grass crops as the receiver vegetation for the system. A significant volume of literature has evolved concerning the assimilative capacity of grass and row crops (USEPA, 1980). Recent literature concerning nutrient assimilation capacity suggests that assimilative capacity is a function of crop yield: higher yields are generally associated with higher assimilative capacity (NCSU, 1996). Typical nutrient uptake for grass crops frequently utilized as receiver crops in land application systems are listed in Table 3.

Table 3: Annual accumulation of Nitrogen, Phosphorus, and Potassium in Grass Crops.

Crop	N (Kg/tonne/ha/yr)	P (Kg/tonne/ha/yr)	K (Kg/tonne/ha/yr)
Fescue	44	11	22-33
Coastal Bermuda	44-55	11-16.5	22-33
Coastal rye	55-66	16.5-22	33-44

Source: Nutrient Management Planning Guide, 1996

These nutrient uptake values are used to determine the amount of a specific nutrient which will be assimilated into a crop. For example, an anticipated yield of 4,536 Kg/ac of Fescue will utilize 91 Kg of nitrogen, 23 Kg of phosphorus, and 45 Kg of potassium per hectare per year. These values for nutrient uptake for row and grass crops are well established in the literature. The values for forest crops are not as well established and for that reason, forest crops are used less as a receiver for waste. Recent work with *Paulownia* sp. and a variety of hardwood crops (Green ash, Sycamore, Sweetgum, and others) indicate that the potential for nutrient uptake is significant. Bergman et al. (1997) indicate nutrient levels in Paulownia increase as the nutrient application through waste addition increases. Plant tissue sampling indicate nitrogen levels of up to 4.4% in Paulownia fertilized with the equivalent of 181 Kg of N/ac/yr.

Similar studies indicate that the potential for nutrient assimilation into woody biomass increases when hardwoods receive nutrient additions from swine waste (Bizic et al., 1996 and Frederick et al., 1998). These levels of nutrient assimilation into woody biomass are comparable to or higher than nutrient levels reported in Bermuda grass (Kelling and Matocha, 1990).

When the mass of woody forest product grown on waste receiver sites is coupled with nutrient content of that forest vegetation, the total uptake potential can be significant. The woody material raised on wastewater receiver sites has potential to exploit a large portion of the soil nutrient pool because of the extensive and well-established root system. The potential to exploit the soil nutrient pool is demonstrated at the Edenton site with comparison of nutrient levels in the control and the receiver site vegetation.

Nitrogen:
The level of nutrients in the woody material from the wastewater receiver site is significantly higher than that from control areas which received no wastewater

application (Table 4). Both the sycamore and the sweetgum show higher levels of nutrient than the control vegetation. The elevated nitrogen concentrations in the plant tissue of 2.2% to 3.6% compared to the 1.4% in control vegetation indicates that the nitrogen applied through the wastewater irrigation activity is assimilated into plant material. These elevated nutrient levels in plant tissue suggest that the plant material is assimilating nutrients at a rate consistent with the addition supplied in the wastewater. The stand of woody material was established on the Edenton site in 1987 and the green biomass accumulation to date averages 147.6 Mg/ha. Table 5 provides an estimate of the nutrient assimilation based on the plant tissue quality data provided and the yield data derived from the 1997 whole tree harvest.

Table 4: Nutrient Levels (ppm) in Woody Vegetation from Wastewater Receiver Sites and from Control Areas collected during 1996 and 1997 at Edenton, NC, 1997.

Type	TN %	TP %	K %	Ca%	Mg%	Zn ppm	Cu ppm	S%	NO3 ppm
Syc 96	3.55	0.32	1.48	0.58	0.23	31.9	12.7	0.28	200
Syc 97	3.22	0.36	1.43	0.62	0.17	28.8	11.9	0.25	180
SG 96	2.73	0.50	1.85	0.63	0.32	34.5	13.5	0.29	228
SG 97	2.28	0.41	1.63	0.74	0.28	41.2	13.7	0.30	132
Control									
Syc 97C	1.84	0.22	0.97	0.41	0.12	13.5	8.9	0.21	141
SG 97C	1.38	0.23	0.88	0.43	0.14	12.2	9.6	0.22	133

Phosphorus:

Many sites throughout the country are characterized by excess levels of soil phosphorus. The potential for hardwood vegetation to assimilate and subsequently store phosphorus is depicted by the increased levels of phosphorus in receiver site vegetation when compared to control vegetation. At Edenton, the levels of phosphorus in receiver site vegetation approach 0.5% compared to less than 0.25% on control sites (Table 4). As phosphorus becomes more critical as a limiting nutrient, the potential for woody biomass to assimilate and store this essential nutrient will become more critical in the process of vegetation selection and management.

The luxury consumption and accumulation of nutrients into plant tissue is a valuable attribute in a crop designated to receive wastewater or other by-products. Waste treatment and renovation is most efficient when plant material is able to assimilate large quantities of nutrients. Plant tissue sampling provides an indication of the efficiency of nutrient uptake. In addition to the tissue sampling, the wastewater irrigation activities resulted in increased levels of biomass production. The assimilation of nutrients into biomass is a function of the plant tissue quality and the measured yield. The accumulation of a spectrum of nutrients is addressed in Table 5.

application (Table 4). Both the sycamore and the sweetgum show higher levels of nutrient than the control vegetation. The elevated nitrogen concentrations in the plant tissue of 2.2% to 3.6% compared to the 1.4% in control vegetation indicates that the nitrogen applied through the wastewater irrigation activity is assimilated into plant material. These elevated nutrient levels in plant tissue suggest that the plant material is assimilating nutrients at a rate consistent with the addition supplied in the wastewater. The stand of woody material was established on the Edenton site in 1987 and the green biomass accumulation to date averages 147.6 Mg/ha. Table 5 provides an estimate of the nutrient assimilation based on the plant tissue quality data provided and the yield data derived from the 1997 whole tree harvest.

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Type	TN %	TP %	K %	Ca%	Mg%	Zn ppm	Cu ppm	S%	NO3 ppm
Syc 96	3.55	0.32	1.48	0.58	0.23	31.9	12.7	0.28	200
Syc 97	3.22	0.36	1.43	0.62	0.17	28.8	11.9	0.25	180
SG 96	2.73	0.50	1.85	0.63	0.32	34.5	13.5	0.29	228
SG 97	2.28	0.41	1.63	0.74	0.28	41.2	13.7	0.30	132
Control									
Syc 97C	1.84	0.22	0.97	0.41	0.12	13.5	8.9	0.21	141
SG 97C	1.38	0.23	0.88	0.43	0.14	12.2	9.6	0.22	133

Phosphorus:

Many sites throughout the country are characterized by excess levels of soil phosphorus. The potential for hardwood vegetation to assimilate and subsequently store phosphorus is depicted by the increased levels of phosphorus in receiver site vegetation when compared to control vegetation. At Edenton, the levels of phosphorus in receiver site vegetation approach 0.5% compared to less than 0.25% on control sites (Table 4). As phosphorus becomes more critical as a limiting nutrient, the potential for woody biomass to assimilate and store this essential nutrient will become more critical in the process of vegetation selection and management.

The luxury consumption and accumulation of nutrients into plant tissue is a valuable attribute in a crop designated to receive wastewater or other by-products. Waste treatment and renovation is most efficient when plant material is able to assimilate large quantities of nutrients. Plant tissue sampling provides an indication of the efficiency of nutrient uptake. In addition to the tissue sampling, the wastewater irrigation activities resulted in increased levels of biomass production. The assimilation of nutrients into biomass is a function of the plant tissue quality and the measured yield. The accumulation of a spectrum of nutrients is addressed in Table 5.

Table 5: Biomass and Nutrient Uptake of Ten-year-old Sycamore Whole-Tree Harvested in 1997 at Edenton, North Carolina

Green Biomass	(Mg/ha)	135.5
Dry Biomass	(Mg/ha)	63.7
Total Nitrogen	(Kg/ha)	4102.3
Total Phosphorus	(Kg/ha)	458.6
Potassium	(Kg/ha)	1821.8
Calcium	(Kg/ha)	942.8
Magnesium	(Kg/ha)	356.7
Zinc	(Kg/ha)	3.7
Copper	(Kg/ha)	1.5
Sulfur	(Kg/ha)	318.5

These data indicate that the annual uptake into plant material is highest in sycamore. These hardwood trees assimilated 179.6 and 20.1 Kg/ha of nitrogen and phosphorus respectively after 10 years. When compared to conventional crop systems used in wastewater application, these assimilative capacities compare favorably with high yield grass crops. Tree crops, however require harvest on a 10 to 12 year cycle as compared to the 4 or 5 cuttings required for the grass crops typically utilized in wastewater management operations.

Conclusions:

Land application of wastewater on hardwood plantations is a viable method of treating municipal wastewater while producing large quantities of biomass. Sycamore and sweetgum are two species of trees that respond well in a wastewater land application system. Sycamore produced significantly more biomass in the first five years while sweetgum increased biomass production in the last five years. Hardwood trees are capable of assimilating large quantities of nutrients and storing them in biomass. The large root systems of trees can exploit the surrounding soil and store nutrients in woody biomass equal to or greater than some Bermuda grass systems. Nitrogen is assimilated by trees equal to the rate being applied via the wastewater. This is significant since the primary reason to land-apply wastewater is to treat the waste and improve the quality of water entering surrounding receiving waters. Phosphorus is readily taken up by trees when it is not present in excess in the soil. Some receiving sites may have a history of agricultural use and may not be suitable for wastewaters with high concentrations of phosphorus. Also, special attention must be taken as to whether the phosphorus is plant available. Phosphorus uptake in tree plantations also compares favorably to high yield grass crops. Hardwood tree plantations are capable of nutrient assimilation and biomass production, and provide an alternative to traditional grass systems.

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Planting Guide for Forage Crops in North Carolina

This planting guide provides the best available information about planting rates, depths, and stand evaluation for forage crops commonly grown in North Carolina. The process of establishing a forage crop is very important because:

- *It is expensive—$100 to $250 per acre;*
- *Perennial crops can remain productive for several years without replanting, and thus poor stands can result in long-term low yields and increased production costs;*
- *Soil and water conservation and animal feeding depend upon rapid establishment of persistently good stands.*

Variety Selection

Variety selection can influence the productivity and persistence of a crop, but most of the information provided here applies to all varieties of the same species. Information on variety performance can be obtained from Extension Service publication AG-49, *Forage Crops Variety Testing*, or from *Forage Memos*, available from the Department of Crop Science. Remember, however, that poor stands can nullify the influence of even the best varieties.

Planting Region

The climate and soils of North Carolina vary considerably across the state. This variation makes it necessary to plant at different times in each area. The state can be divided into three major regions: mountains, piedmont, and coastal plain. The planting dates in this guide are listed for the major regions and are based on normal growing conditions.

A review of the average freezing dates in the spring (Figure 1) and fall (Figure 2) indicates significant differences in weather within and between the three major regions. Therefore, the planting dates suggested may be adjusted a few days on the basis of local experience and weather records. For example, the optimum planting dates for the mountains are 15 to 30 days earlier in the fall than those for the piedmont, but a review of the temperature records indicates that the best planting dates in the southern mountains may be similar to those in the piedmont.

Planting Time

Establishing a successful forage crop depends partly on weather conditions shortly before and after planting. Years of field research and experience under North Carolina's varied growing conditions have made it possible for researchers to recommend planting dates that will most likely lead to success or minimize risk. Delaying planting until the last possible dates indicated in the table may reduce the chance of a good stand by 30 to 50 percent.

Time of planting is important because the survival rate of developing seedlings is related to the time at which stress occurs from drought, freezing, or competition for light and nutrients. If no such stress

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occurs, or if it occurs after seedlings are well established, survival and production losses can be minimized.

Fall Plantings. In general, the perennial cool-season forages can best be established by planting in the fall in a disked or plowed seedbed that is firm and smooth. Seedbeds can best be prepared during favorable autumn weather when weeds are not as competitive. Furthermore, seedling root systems can become well established before hot, dry weather the following season. However, late fall plantings can result in winter injury from freezing and heaving.

A disadvantage to autumn planting is that there is often not enough moisture for good germination and seedling development. Planting in a hot, dry seedbed is a gamble because a light rain followed by continued drought can cause germination, then death of the seedlings. If planting is delayed beyond the possible seeding dates listed here, it is best to wait until the following spring or fall. Establishment costs are too high to risk winterkill unnecessarily.

Here are some points to remember about fall planting:

- Cool-season grass seedlings are more tolerant of freezing temperatures and heaving than legumes.
- In prepared seedbeds, alfalfa and ladino clover should have five to seven true leaves present before frequent freezing weather occurs.
- In prepared seedbeds, grasses should have three to four leaves before freezing weather occurs.

Spring Plantings. Spring plantings in the piedmont and mountains may be justified (1) if land or sod is prepared in the fall or winter, and plantings can be made early enough for the crop to become established before summer stress; (2) if seedling diseases on legumes have usually been a problem for fall plantings; and (3) if summer weeds can be controlled while the seedlings develop.

Sod Seeding

Fall plantings can be made later in sod than in prepared seedbeds because the existing sod provides protection for the developing seedlings during the winter.

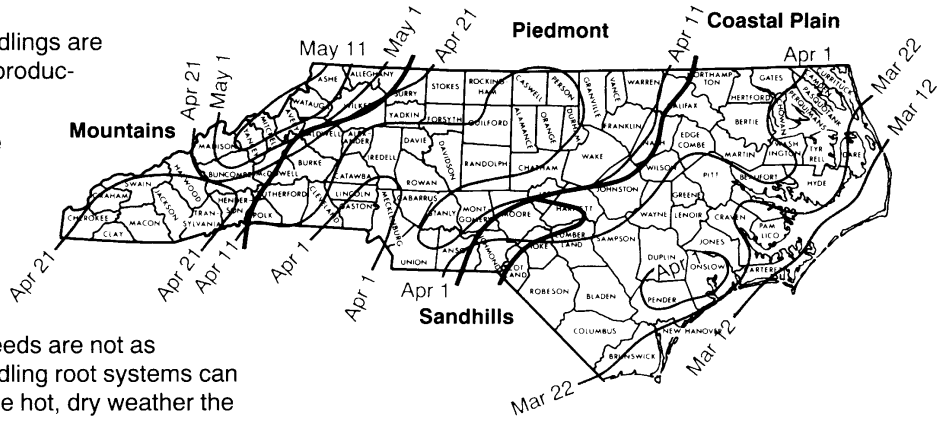

Figure 1. Average date of last freezing temperature (32°F) in spring.

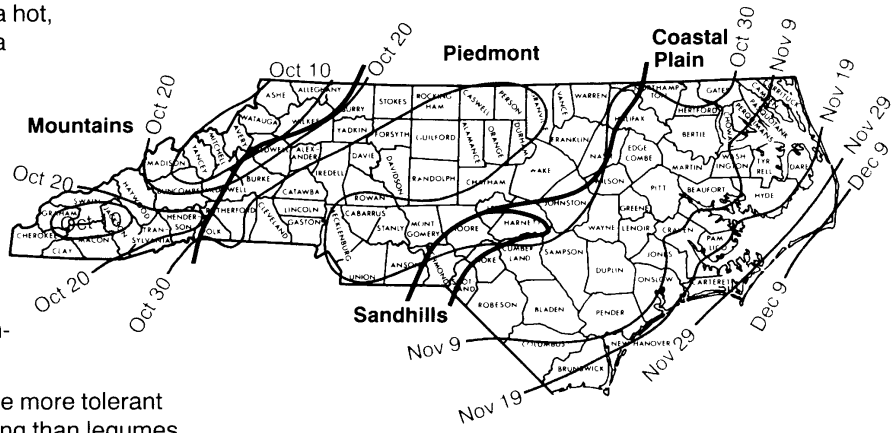

Figure 2. Average date of first freezing temperature (32°F) in fall.

When planting ladino clover in an established sod of tall fescue or other cool-season grass, late winter or early spring (February to March) plantings are often as effective as fall plantings. However, fall sod plantings of alfalfa in fescue have been more successful than late winter plantings in the piedmont and coastal plain, except for late winter plantings made in sod killed the previous fall. When planting low-endophyte fescue or orchardgrass in existing sod, it is best to plant in the fall. (See *Forage Memo 16* for details.)

Seeding Rates

Seeding rates vary because of seed size, purity, germination percentage, and seedling vigor. Under adverse conditions, only 10 to 50 percent of the seeds planted will establish successfully. Therefore, many seeds are needed to obtain a satisfactory stand.

Seed Size

Small seeds are not as vigorous as large ones. Therefore, emergence rates may vary with planting depth. The number of seeds per pound varies as follows: ladino clover, 800,000; orchardgrass, 650,000; fescue, 227,000; alfalfa, 200,000; and pearl millet, 88,000.

Germination Rate

The percentage of seeds that will germinate generally declines with age, but if seeds are stored in a cool, dry place, germination should not decline more than 10 percent the first year. In general, seeds that have low germination levels also produce seedlings with poor vigor.

Drill vs. Broadcast

Planting rates for drilling are 20 to 50 percent less than for broadcasting. Since drilling concentrates the seeds within a furrow, they occupy a smaller area of the ground and are better able to break through the soil crust. Seed placement, soil contact, and uniformity of stands are usually better with drilling than with broadcasting, especially when planting conditions are not optimum.

Table 1. Planting Depth Affects Grass and Legume Establishment

Crops	Planting Depth (inches) ¼	½	1	2
	Established Plants (sq ft)			
Alfalfa, ladino	47	22	9	0
Tall fescue, orchardgrass	48	39	31	9

Seeding rates per acre were 20 lb alfalfa, 5 lb ladino, 10 lb fescue, and 6 lb orchardgrass.

Planting Depth

Generally, small-seeded crops can be planted slightly deeper in sandy soils than in clay soils. Grasses can usually be planted deeper than legumes in similar soils. However, it is important to prepare a firm seed-

Table 2. Characteristics of Good Grass and Clover Stands

Plant Species	Seedlings (sq ft)
Mixtures[a]	
Ladino/fescue	20 to 35 of each living in November
Ladino/orchardgrass	20 to 35 ladino and 35 to 55 orchardgrass living in November
Cool Season Grasses[a]	
Fescue	40 to 60 living in November
Orchardgrass	70 to 100 living in November
Warm Season Grasses	
Pearlmillet	15 to 25 living after 1 month
Sorghum-sudan	15 to 25 living after 1 month

Alfalfa

Age of Stand (months)	Minimum Number of Plants to Keep Stand	Desirable Number of Plants for Good Production
	Plants (sq ft)	
3 to 6	10[b]	50 or more
12	10[b]	25 or more
24	10	15 or more
36	5 to 8	10 or more
48 or more	3 to 5	

[a] Assumes an autumn planting date.

[b] These figures will eventually result in satisfactory stands; however, yields will be low during the first season as weeds encroach.

bed before planting to conserve moisture and avoid variation in planting depth. Precision planting equipment is usually required to get proper depth control for small forage seeds. Table 1 shows how planting depth affects grass and legume stands.

What is a Good Stand?

Since plant characteristics change depending upon their density, age, grazing or cutting height, and other factors, it is difficult to say exactly how many plants it takes to make a good stand. In general, a *good stand* is one that provides 90 to 100 percent ground cover and will produce high yields when managed properly. The clover part of mixtures should make up at least 30 percent of the stand (on a weight basis) in order for it to significantly contribute to the mixture. One should walk fields several times each growing season in order to make a fair evaluation of stands. Table 2 presents some general characteristics of good stands for several forage crops.

When Using This Guide Remember:

The fact that information about a particular crop is given in this publication does not mean that the species is recommended for North Carolina. In fact, several crops have not performed satisfactorily in this state. Information about these varieties is included to increase the chance of success if the decision to plant them has already been made. Additional information on various forage varieties can be obtained by contacting your county Cooperative Extension Service agent.

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FORAGE PLANTING GUIDE FOR NORTH CAROLINA

Crop	Seeding Rate (lb/acre) B: broadcast D: drill (4- to 9-inch rows) R: row (30+ inches) PLS: pure live seeds	Planting Depth (inches)	Mountains (above 2,500 ft elevation)* See footnote for below 2,500 ft		Piedmont and Tidewater**		Coastal Plain**	
			Best Dates	Possible Dates	Best Dates	Possible Dates	Best Dates	Possible Dates
PERENNIAL GRASSES								
Bahiagrass	B:15-25; D:10-20	¼ - ½	Not adapted		Not well adapted		Feb 15-Mar 15	Feb 1-Mar 31
Bermudagrass (Hybrid) Sprigs - bu. = 1.25 ft^3	B:25-40; R:5-15 bushels	1 - 3	Not adapted		Mar 1-Mar 31	Feb 15-May 1 or thru Jul if irrigated	Mar 1-Mar 31	Feb 15-Apr 15 or thru Jul if irrigated
Bermudagrass (Common—seed only)	B:6-8; D:5-7	¼ - ½	Not adapted		Apr 15-May 15	Apr 1-Jun 15	Apr 1-May 15	Mar 15-Jun 7
Big Bluestem	D:8-10 PLS; B:10-12 PLS	½ - ¾	May 15-Jun 15	May 1-Jun 30	May 10-Jun 1	May 1-Jun 30	Apr 20-May 15	Apr 10-Jun 30
Bluegrass	B:10-15; D:8-12	¼	Jul 25-Aug 10	Jul 15-Aug 25	Not well adapted		Not well adapted	
Caucasian Bluestem	D:2 PLS; B:4 PLS	¼ - ½	May 15-Jun 15	May 1-Jun 30	May 10-Jun 1	May 1-Jun 30	Apr 20-May 15	Apr 10-Jun 30
Dallisgrass	B:20-30; D:15-20	¼ - ½	Not adapted		Not well adapted		Mar 1-Mar 30	Feb 15-Apr 15
Eastern Gammagrass	D:10-15 PLS; B: Do not broadcast	¾ - 1	May 15-Jun 15	May 1-Jun 30	May 10-Jun 1	May 1-Jun 30	Apr 20-May 15	Apr 10-Jun 30
Flaccidgrass	D:2-4; Precision plant: 1-2; Sprig: 3-4/ft in 18" rows; Tillers: 2-4/ft	¼ - ½ 2 - 3 root cover	Jun 1-Jun 15 Mar 1-Apr 7 May 15-Jun 15	May 15-Jul 1 Feb 15-Apr 15 May 1-Jul 15	May 15-Jun 7 Feb 20-Mar 20 Apr 25-Jun 1	Apr 15-Jul 1 Feb 1-Mar 30 Apr 15-Jul 15	May 7-Jun 1 Feb 15-Mar 15 Apr 25-May 20	Apr 15-Jun 15 Feb 1-Mar 30 Apr 15-Jul 10
Indiangrass	D:8-10 PLS; B:10-12 PLS	½ - ¾	May 15-Jun 15	May 1-Jun 30	May 10-Jun 1	May 1-Jun 30	Apr 20-May 15	Apr 10-Jun 30
Orchardgrass	B:12-15; D:8-12	¼ - ½	Jul 25-Aug 10 Mar 20-Apr 20	Jul 15-Aug 20 Mar 1-May 15	Aug 25-Sep 15	Aug 25-Oct 25 Feb 15-Mar 31	Not well adapted	
Reed Canarygrass	B:5-10; D:4-8	¼ - ½	Jul 25-Aug 10 Mar 20-Apr 20	Jul 15-Aug 20 Mar 1-May 15	Aug 25-Sep 15	Aug 25-Oct 25 Mar 1-Mar 31	Not well adapted	
Rescuegrass	D:20-25; B:25-35	½ - ¾	Aug 20-Sep 7 Mar 15-Mar 30	Aug 15-Oct 1 Mar 1-Apr 30	Sep 1-Sep 15 Mar 1-Mar 30	Aug 25-Oct 15 Feb 15-Apr 30	Sep 1-Sep 30	Aug 25-Oct 15
Smooth Bromegrass	B:10-20; D:8-15	¼ - ½	Jul 25-Aug 10 Mar 20-Apr 20	Jul 15-Aug 20 Mar 1-May 15	Not well adapted		Not adapted	
Switchgrass	D:8-12 PLS	½ - ¾	May 15-Jun 15	May 1-Jun 30	May 1-Jun 1	Apr 1-Jun 30	Apr 10-May 15	Apr 10-Jun 30
Tall Fescue	B:15-20; D:10-15	¼ - ½	Jul 25-Aug 10 Mar 20-Apr 20	Jul 15-Aug 20 Mar 1-May 15	Aug 25-Sep 15	Aug 25-Oct 25 Feb 15-Mar 31	Sep 1-Sep 30	Sep 1-Oct 31 Feb 15-Mar 20
Timothy	B:10-12; D:8-10	¼ - ½	Jul 25-Aug 10 Mar 20-Apr 20	Jul 15-Aug 20 Mar 1-May 15	Not well adapted		Not adapted	
MIXTURES								
Orchardgrass + Alfalfa	B:5 + 20; D:3 + 15	¼	Jul 25-Aug 10 Mar 20-Apr 20	Jul 15-Aug 20 Mar 1-May 15	Aug 25-Sep 15	Aug 25-Oct 15	Not well adapted	
Orchardgrass + Ladino Clover	B:12 + 4; D:9 + 3	¼	Jul 25-Aug 10 Mar 20-Apr 20	Jul 15-Aug 20 Mar 1-May 15	Aug 25-Sep 15	Aug 25-Oct 15 Feb 15-Mar 31	Not well adapted	
Orchardgrass + Red Clover	B:12 + 10; D:9 + 8	¼	Jul 25-Aug 10 Mar 20-Apr 20	Jul 15-Aug 20 Mar 1-May 15	Aug 25-Sep 15	Aug 25-Oct 15 Feb 15-Mar 31	Not adapted	
Tall Fescue + Ladino Clover	B:10 + 4; D:8 + 3	¼	Jul 25-Aug 10 Mar 20-Apr 20	Jul 15-Aug 20 Mar 1-May 15	Aug 25-Sep 15	Aug 25-Oct 15 Feb 15-Mar 31	Sep 1-Sep 30 (heavy soils only)	Sep 1-Oct 25 Feb 15-Mar 20
Tall Fescue + Red Clover	B:10 + 8; D:8 + 6	¼	Jul 25-Aug. 10 Mar 20-Apr 20	Jul 15-Aug 20 Mar 1-May 15	Aug 25-Sep 15	Aug 25-Oct 15 Feb 15-Mar 31	Sep 1-Sep 30 (heavy soils only)	Sep 1-Oct 25 Feb 15-Mar 20
ANNUAL GRASSES								
Barley	B:140; D:100	1 - 2	Aug 1-Aug 20	Aug 1-Oct 10	Aug 25-Sep 15	Aug 20-Oct 31	Not well adapted	
Millet, Pearl (Cattail)	B:20-25; D:15-20; R:6-10	½ - 1½	May 15-May 31	May 1-Jun 30	May 1-May 31	Apr 25-Jun 30	May 1-May 15	Apr 20-Jun 30
Millet, Foxtail, and Japanese (Not as productive as Pearl)	D:10-15; R:5-7	½ - 1½	May 15-May 31	May 1-Jun 30	May 1-May 31	May 1-Jun 30	May 1-May 15	Apr 20-Jun 30
Oats	B:130; D:100	1 - 2	Not well adapted		Aug 25-Sep 15	Aug 20-Oct 31	Sep 5-Sep 30	Sep 1-Nov 15
Rye	B:120; D:100	1 - 2	Aug 1-Aug 20	Aug 1-Oct 10	Aug 25-Sep 15	Aug 20-Oct 31	Sep 5-Sep 30	Sep 1- Nov 15
Ryegrass	B:30-40; D:20-30	¼ - ½	Jul 25-Aug 10	Jul 15-Aug 31	Aug 25-Sep 15	Aug 20-Oct 31	Sep 1-Sep 30	Sep 1-Oct 31

FORAGE PLANTING GUIDE FOR NORTH CAROLINA *(continued)*

Crop	Seeding Rate (lb/acre) B: broadcast D: drill (4- to 9-inch rows) R: row (30+ inches) PLS: pure live seeds	Planting Depth (inches)	Mountains (above 2,500 ft elevation)* See footnote for below 2,500 ft		Piedmont and Tidewater**		Coastal Plain**	
			Best Dates	Possible Dates	Best Dates	Possible Dates	Best Dates	Possible Dates
Ryegrass (With small grain or clover mixture)	Reduce ryegrass rate by 50%	See ryegrass, grain, or clover	See small grain or clover		See small grain or clover		See small grain or clover	
Sorghum (Sudan)	B:35-40; D:20-30; R:15-20	½ - 1	May 15-May 31	May 1-Jun 30	May 1-May 31	Apr 25-Jun 30	May 1-May 15	Apr 20-Jun 30
Sorghum, Forage (Silage)	R:4-6	1 - 1½	May 15-May 31	May 1-Jun 30	May 1-May 31	Apr 25-Jun 30	May 1-May 15	Apr 20-Jun 30
Sudangrass	B:30-40; D:20-25	1 - 2	May 15-May 31	May 1-Jun 30	May 1-May 31	Apr 25-Jun 30	May 1-May 15	Apr 20-Jun 30
Wheat	B:120; D:100	1 - 2	Aug 1-Aug 20	Aug 1-Oct 10	Aug 25-Sep 15	Aug 20-Oct 31	Sep 5-Sep 30	Sep 1-Nov 15
Small Grain Mix (2 Grains)	Reduce each selection by 50%	1 - 2	See dates for grains		See dates for grains		See dates for grains	
Small Grain Ryegrass Mix	Reduce each selection by 25%	½ - 1	See dates for grains and ryegrass		See dates for grains and ryegrass		See dates for grains and ryegrass	
PERENNIAL LEGUMES								
Alfalfa	B:20-25; D:15-20	¼	Jul 25-Aug 10 Mar 1-Apr 7	Jul 15-Aug 20 Mar 1-Apr 15	Aug 25-Sep 15	Aug 25-Oct 15 Mar 1-Mar 31	Sep 1-Sep 30	Sep 1-Oct 31
Alfalfa (For sod seeding into grass)	D:15-20	¼ - ½	Jul 25-Aug 10† Sep 15-Oct 1†	Jul 25-Oct 15	Aug 25-Sep 15† Oct 10-Oct 20†	Aug 25-Oct 20	Oct 15-Oct 25	Sep 1-Oct 31
Birdsfoot Trefoil	B:8-10; D:6-8	¼	Jul 25-Aug 10	Jul 15-Aug 30	Not well adapted		Not well adapted	
Crownvetch (For erosion control)	B:15-20; D:10-15	¼ - ½	Jul 25-Aug 10 Mar 20-Apr 20	Jul 15-Aug 20 Mar 1-Apr 15	Aug 25-Sep 15 Mar 1-Mar 30	Aug 15-Oct 25 Mar 1-Apr 15	Not well adapted	
Ladino or White Clover	B:5; D:3-5	¼	Jul 25-Aug 10 Mar 20-Apr 20	Jul 15-Aug 20 Mar 1-May 15	Aug 25-Sep 15	Aug 25-Oct 15 Mar 1-Mar 31	Sep 1-Sep 30	Sep 1-Oct 25 Feb 15-Mar 20
Ladino (For sod seeding into grass)	B:5; D:3-5	¼ - ½	Jul 25-Aug 10† Aug 1-Sep 1† Mar 1-Mar 20	Aug 1-Sep 15 Mar 1-May 15	Aug 25-Sep 15† Oct 7-Oct 15† Feb 20-Mar 10	Aug 25-Oct 25 Feb 15-Mar 20	Sep 1-Sep 30† Oct 7-Oct 15† Feb 15-Feb 28	Sep 1-Oct 31 Feb 10-Mar 15
Red Clover	B:10-15; D:8-10	¼ - ½	Jul 25-Aug 10	Jul 15-Aug 20 Mar 1-May 15	Aug 25-Sep 15	Aug 25-Sep 30 Feb 15-Mar 30	Sep 1-Sep 30	Sep 1-Oct 15 Feb 15-Mar 20
Red Clover (For sod seeding into grass)	B:10-15; D:8-10	¼ - ½	Jul 25-Aug 10† Aug 1-Sep 1† Mar 1-Mar 20	Aug 1-Sep 15 Mar 1-May 15	Aug 25-Sep 15† Oct 7-Oct 15† Feb 20-Mar 10	Aug 25-Oct 25 Feb 15-Mar 20	Sep 1-Sep 30† Oct 7-Oct 15† Feb 15-Feb 28	Sep 1-Oct 31 Feb 10-Mar 15
Sericea Lespedeza (Dehulled)	B:20-40; D:15-30	¼ - ½	Mar 15-Apr 15	Mar 1-Apr 30	Mar 1-Mar 20	Feb 15-Apr 30	Mar 1-Mar 20	Feb 15-Apr 30
Sweetclover (Dehulled)	B:20-30; D:10-15	¼ - ½	Jul 25-Aug 10 Mar 1-Apr 7	Jul 15-Aug 20 Mar 1-Apr 15	Aug 25-Oct 15 Aug 25-Sep 15	Mar 1-Mar 31	Sep 1-Sep 30	Sep 1-Oct 31
ANNUAL LEGUMES								
Crimson Clover	B:20-25; D:15-20	¼ - ½	Jul 25-Aug 10	Jul 15-Aug 20	Aug 25-Sep 15	Aug 25-Oct 25	Sep 1-Sep 30	Sep 1-Oct 30
Crimson Clover (Mixed with Ryegrass or Small Grain)	B:20; D:15 Reduce grain by 1/3	¼ - ½	Same as Crimson clover		Same as Crimson clover		Same as Crimson clover	
Lespedeza, Kobe **Korean**	B:30-40 B:20-30	¼ - ½	Mar 15-Mar 31	Mar 1-Apr 15	Feb 10-Feb 28	Feb 1-Mar 30	Feb 1-Feb 20	Feb 1-Mar 20
Subterranean Clover	B:10-20; D:8-15	¼ - ½	May not be adapted		Aug 25-Sep 15	Aug 15-Oct 25	Sep 1-Sep 30	Sep 1-Oct 31
Vetch (Common, Hairy)	B:25-40; D:20-30 B:20-30; D:15-20	½ - 1½	Jul 25-Aug 10	Jul 15-Aug 30	Aug 25-Sep 30	Aug 25-Oct 25	Sep 1-Sep 30	Sep 1-Oct 25
OTHER SPECIES								
Rape and Turnips	B:6-8; D:3-4	¼ - ½	Mar 1-Apr 30 Jul 15-Sep 1	Feb 15-May 10 Jul 1-Sep 15	Feb 15-Mar 15 Aug 15-Sep 15	Feb 1-Apr 15 Aug 1-Oct 1	Feb 15-Mar 1 Sep 1-Oct 1	Feb 1-Apr 1 Aug 15-Oct 30

* May extend the fall dates by 20 days, where elevation is below 2,500 feet, and seed 15 days earlier in spring.

** For the black, heavy-textured soils in the tidewater region, use dates for the piedmont.

†The best time to sod seed depends on the prevalence of insects in late August and early September and the drought prediction for September. If insects are not evident and moisture is adequate, plant on the early dates.

Alfalfa can be successfully seeded into a sod in mid- to late winter (same as ladino) provided that the grass sod is killed the previous fall (in October or November).

Winterization and Maintenance of Sprinkler Irrigation Equipment

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An irrigation system is an expensive investment. Regular maintenance and following recommended off-season storage procedures will help keep your system operating properly for many years. Following these procedures also reduces the risk of equipment failures that may lead to lost production time or crop loss. These procedures are particularly critical in wastewater application systems, where equipment failures could result in a discharge of liquid wastes and damage to the environment.

This publication provides general checklists for routine equipment inspections, regular maintenance schedules and winterization procedures for surface irrigation systems used for applying fresh water and those applying animal, industrial or municipal wastewater. Turf, landscape, surface drip, and subsurface drip irrigation systems are not covered.

The original operation and maintenance manual for a piece of irrigation equipment is your primary source of information regarding its required maintenance procedures. If the manual can not be located, ask your local dealer or equipment manufacturer for a replacement.

Solid Set Irrigation Systems

Stationary irrigation systems are usually permanent installations (lateral lines are PVC pipes permanently installed below ground). The stationary sprinkler systems is often used in irregularly shaped fields, making it difficult to give a standard layout, but there are some common features between systems. To provide proper overlap, sprinkler spacings are normally 50 to 65 percent of the sprinkler's wetted diameter. Sprinkler spacing is based on nozzle flow rate and desired application rate. Impact sprinkler spacings are typically in the range of 80 feet by 80 feet using single-nozzle sprinklers. Other spacings can be used and some systems are designed to use gun sprinklers (higher volume) on wider spacings. Most permanent systems use Class 160 PVC plastic pipe for mains, submains, and laterals, and either 1-inch galvanized steel or Schedule 40 or 80 PVC risers near the ground surface where an aluminum quick coupling riser valve is installed. In many wastewater application systems, ball valves are installed on sprinkler risers along buffers, hillsides, or other areas where runoff or ponding is a concern.

Table 1. Annual Maintenance Procedures for Sprinklers.

Type of Sprinkler	Procedures
Pressure Gauges	Check pressure gauge, pressure transducer, or flow meter for proper operation. Follow manufacturer's guidelines for calibrating transducers or flowmeters.
Big Guns	1) Check nozzle for wear. You may need to use machinist's calipers to check ring nozzles for appropriate diameter. Replace ring if worn. 2) Check reverse rotation of gun. The gun should travel in both directions (left to right, and right to left) at the same speed. Big guns operating in partial circles (less than 360°) tend to unevenly wear bearings, adversely affecting the speed of gun rotation. If bearings are worn, it may be necessary to replace the entire gun. 3) Cover the inlet of the gun to keep out of dirt or small animals.
Impact Sprinklers	1) Check nozzles for wear. Replace dented or worn brass nozzles. Check plastic nozzles for cracks, chips, or wear patterns. Replace if necessary. 2) Check rotation of each sprinkler. Swing the impact arm 4 inches to the right and release. The sprinkler head should freely and fluidly move several inches. Repeat. Ensure that the amount of rotation is consistent each time the impact arm is released. If the amount of rotation is not consistent or not fluid, replace the sprinkler head. 3) Tape over the sprinkler nozzle and pipe base to keep out foreign objects, such as insects, rodents, dust and dirt. Remove tape before operating.

Hard-Hose Travelers

Hard-hose travelers are the most popular pieces of irrigation equipment for applying animal wastes and lagoon effluent. Properly designed and installed hard-hose travelers are one of the most efficient and reliable methods of irrigating large areas. Hard-hose travelers are expensive and highly specialized pieces of equipment that cost $12,000 to $26,000. Maintenance will ensure that your equipment lasts for many years and operates properly. Proper maintenance of irrigators will also insure that waste can safely be applied, minimizing discharges or runoff events caused by malfunctioning equipment. Table 2 provides a schedule for lubricating and checking various necessary fluids on turbine-drive and engine-drive hard-hose travelers. Consult your equipment's operation and maintenance manual and follow the specific lubrication schedule that should be followed for your irrigator.

Table 2. Lubrication and Fluids Schedule for Hard-Hose Travelers.

LOCATION	TYPE OF LUBRICANT	DAILY	EVERY TWO WEEKS	MONTHLY	YEARLY
Inlet Spindle Thrust Washer	Multipurpose Grease			**X**	
Inlet Swivel	Multipurpose Grease		**X**		
PTO Shaft (if present)	Multipurpose Grease	**X**			
Traverse Assembly	Multipurpose Grease		**X**		
Drum Bearings	Multipurpose Grease			**X**	
Chains (except drum)	30 wt. Oil			**X**	
Wheel Bearings	Multipurpose Grease				**X**
Turntable Bearing Ring	Multipurpose Grease			**X**	
Gearbox (2)	90 wt. Oil				**X**
Gun Cart Wheel Bearings	Multipurpose Grease			**X**	
Drive Engine Oil	Follow Manufacturer's Specification	**X**			

Center-Pivot and Linear-Move Systems

Center-pivot and linear move systems are becoming more common in North Carolina. Center-pivots are available in both fixed-pivot point and towable machines. Linear-move systems are similar to pivots but instead of moving in a circular pattern they move only forward and reverse. Pivots and linears area powered electrically (480 V-AC or diesel generator) or by a diesel-powered hydraulic drives. They range from single tower machines that cover around 10 acres to multitower machines that can cover several hundred acres. Pivots and linears use either rotary sprinklers, small guns, or spray nozzles. Drop-type spray or rotary nozzles offer the advantage of applying water close to the ground at low pressure, which results in less evaporative losses and little drift due to wind. Depending on the type of sprinkler used, operating pressure ranges from 10 to 50 pound per square inch (psi). Low pressure systems (10 – 30 psi) reduce drift at the expense of higher application rates and greater potential for runoff.

DISCONNECT POWER WHEN PERFORMING MAINTENANCE. ALWAYS disconnect electrical power before servicing or performing maintenance to the machine. If you are going to perform maintenance to the machine, YOU shut off and lock the main power disconnect. Don't trust someone else to turn the power off for you. DO IT YOURSELF and take the key with you!

Table 3. Seasonal Maintenance Checklist for Center-Pivots and Linear-Move Systems.

LOCATION	ACTION
Tower	
Ground Cable	Ensure #6 bare copper wire is connected to main panel and ground rod.
Tie-downs & Turnbuckles	All tie-down bolts (turnbuckles on towable units) are drawn up tight.
Pivot Head/swivel	Grease pivot head and ensure that collector ring is in place.
Span	1. Check flanges for leaks and tighten as necessary. 2. Check pipe drains for proper drainage and rotate the seal each season. 3. Tighten all tower and span bolts and cables. 4. Check power cable for damage and proper banding to ensure proper attachment to span.
Wheels	1. Check tire pressure. Check maintenance manual for proper pressure. 2. Tighten wheel lug bolts. All wheel lugs should be torqued to 125 foot-pounds annually. 3. Check wheel gearbox oil level. Drain annually or every 1,000 hours, whichever occurs first.
Drive Motors	1. Check flex boots for leaks and tighten bands as necessary. 2. Check motor power and ground cables for damage and good connection. 3. Check gear motor lubricant. Replace lubricant after the first year of operation and then every 3 years or 3,000 hours, which ever occurs first. Consult manufacturer for appropriate gear lubricants.
Sprinklers	1. Check sprinklers, nozzles, pressure regulators for tightness. 2. Check sprinklers for free movement. 3. Check sprinkler nozzles for damage or wear. 4. Check pressure gauge or pressure transducer for proper operation.
End Gun & Booster Pump	1. Check overhang cables for damage and proper banding. 2. Clean and ensure proper operation of end gun drain. Flip drain annually. 3. Check end gun nozzle for wear. 4. Check end gun arc setting, bearings, and brake.

Pumps

A well maintained pumping system lasts longer and needs fewer repairs. This means less downtime that may limit your ability to apply animal wastes when environmental conditions are optimal.

Set up weekly, quarterly, and annual routine maintenance and inspection schedules for systems that are run more than twice a week (Table 4). If your pump is operated less often, inspect those items listed as weekly and quarterly every 2 months. Regardless of the amount of time a pump is used, a certified operator should conduct an annual inspection of the pumping and siphon system. As stated earlier, refer to the operation and maintenance manual provided with your pump for the lubrication and maintenance required for your pump.

Table 4. Weekly, Quarterly, and Annual Maintenance for Agricultural Pumps.

Weekly	
Stuffing Box	Pumps with packing rings should leak a small amount of water while the pump is in operation. If water is not dripping from the seal, loosen the gland nuts evenly until water is just running out of the snuff box in a DROPLET form. Water should not be streaming or spraying out. Approximately 20 drops per minute is recommended for most pumps. Adjust the gland nuts EVENLY as necessary to maintain this drop rate and provide necessary lubrication and cooling of the packing. If packing is tightened to the limit of the packing gland travel, additional packing is necessary.
Mechanical Seals	Pumps with mechanical seals, instead of packing rings and snuff boxes, should not leak. If leaks are detected, ensure that the pump housing bolts are tightened thoroughly. If leaks still continue, contact your pump provider or distributor.
Vibration	All rotating machines produce some amount of vibration. Excessive vibration, however, can reduce the life of your pumping and power unit. If a vibration seems excessive, stop operation, determine the cause, and correct.
Noise	When the unit is in operation, listen closely for unusual sounds that might indicate the unit is operating improperly. Determine the cause and correct.
Suction Line	Inspect line and screen for flow obstruction.
Quarterly	
Piping Connections	Inspect all system piping connections for leaks and misalignment. Misalignment of pipe connections will put excessive strain on the pump case and may cause damage to internal components of both the pump and motor. If stress on the pump case is suspected, adjust pipe supports to correct. For flange connections, shut down the pump, and remove the pipe flange bolts on the pump connections to check for misalignment. If the mating flanges come apart or shift, there is pressure at the connection(s) and adjustments should be made to the pipe supports until flanges mate without force.
Pump Foundation	Check foundation and for soundness and see that all securing bolts or lags are secure.
Lubrication	Complete all quarterly lubrications recommended in your operation and maintenance manual for you pump.
Snuff Box and Mechanical Seals	Inspect pump packing gland or mechanical seal for possible replacement. Examine shaft sleeve, if present, for wear and replace if necessary.
Pump and/or Motor Bearing	Inspect bearings for signs of wear. Repack or replace as required.
Annually	
Pumping System	Inspect the entire pump and pumping system for signs of wear.
Valves	Inspect system valves, screens, etc. Ensure that all valves are fully operational and not frozen. Lubricate or replace if necessary.
Impeller	Check pump impeller eye or proper clearance. Specific clearance specifications can be found in the pump's operation and maintenance manual or from the pump manufacturer or local distributor.
Pump Housing	Inspect pump impeller, volute case (housing), and seal chamber for signs of excessive wear or corrosion.
Hand Primer	Ensure the hand primer is operating properly. Disassemble and inspect the diaphragm for excessive wear or cracks. Replace if necessary.

Power Units

Both diesel engines and electric motors are used to power irrigation pumps. A well maintained engine system lasts longer and needs fewer repairs. The following tables provide a routine and annual maintenance and inspection schedule for pumps with electric motors (Table 5) or diesel engines (Table 6). The required maintenance and lubrication procedures should be followed daily, yearly, and for various intervals of engine operating time.

Table 5. Inspection and Maintenance Schedule for Electric Motors that Power Irrigation Pumps.

REQUIRED ACTION	SCHEDULE	PROCEDURE
Motor Bearings	Quarterly	Inspect motor bearings for signs of wear. Repack or replace as required.
Pump Foundation	Quarterly	Check the electric motor's foundation and for soundness. See that all securing bolts or lags are secure.
Lubrication	Quarterly	Complete all quarterly lubrications recommended in your operation and maintenance manual for your motor/pump.
Vibration	Quarterly	All rotating machines produce some amount of vibration. Excessive vibration, however, can reduce the life of your pumping and power unit. If a vibration seems excessive, stop operation, determine the cause, and correct.
Noise	Quarterly	When the unit is in operation, listen closely for unusual sounds that might indicate the unit is operating improperly. Determine the cause and correct.
Motor Windings	Annually	Check motor windings for degradation, rewind if necessary.
Terminal Connections	Annually	Check to ensure that terminal screws and wire connections are tight. After several years, normal heat and temperature fluctuations tend to loosen terminal screws and wire connections.

Winterization and Storage Procedures

To prevent damage, properly store your irrigator, engine, and pump anytime it will not be operating for several months. Preparing equipment for winter storage also allows you to conduct annual inspections and make necessary repairs. If possible, remove equipment from the field and store it in a clean, dry, covered storage area. The following tables (Tables 7 – 10) will help you minimize corrosion and deterioration of hard-hose travelers, irrigation pumps and diesel-powered pumping units.

Table 6. Inspection and Maintenance Schedule for Diesel Motors that Power Irrigation Pumps.

REQUIRED ACTION	SCHEDULE	NOTES
Check Engine Oil and Coolant Level	Daily	
Check Fuel Filter	Daily	
Lubricate PTO Release Bearing	Daily	DO NOT over-lubricate and avoid getting oil on clutch facings.
Check Dust Unloader Valve on Air Cleaner (if installed)	Daily	Check for air leaks and degraded rubber.
Lubricate PTO Clutch Shaft Bearings	Every 100 Hours	
Change Initial Engine Oil and Filter	Every 100 Hours	Initially change engine oil after 100 hours and then every 250 hours thereafter. Ensure that oil filter meets engine performance standards; refer to operation and maintenance manual.
Service Fire Extinguisher	Every 100 Hours	
Service Battery	Every 250 Hours	
Change Engine Oil and Filter	Every 250 Hours	Check operation and maintenance manual for recommended weight oil and approved filters.
Check Fan and Alternator Belt Tension.	Every 250 Hours	Do not pry against alternator rear frame. Once adjusted, recheck tightness of belts after operating 10 minutes.
Check PTO Clutch Adjustment	Every 250 Hours	Measure clutch engagement force at the handle grip using a spring scale. Force should be between 60 – 70 lbs.
Initial Engine Valve Clearance	400 Hours	Initially check valve clearance after 400 hours and then every 1,200 hours thereafter. Consult engine operation and maintenance manual or dealer.
Lubricate PTO Clutch Internal Levers and Linkage	Every 600 Hours or Annually	
Clean Crankcase Vent Tube	Every 600 Hours or Annually	
Check Air Intake Hoses and Connections	Every 600 Hours or Annually	The air intake system must not leak. Even the smallest leak may cause dame to the engine.
Replace Fuel Filter Element	Every 600 Hours or Annually	
Check Cooling System	Every 600 Hours or Annually	
Check Coolant Solution	Every 600 Hours or Annually	Add inhibitor as needed
Replace Air Cleaner Elements and Check Air Intake System	Every 600 Hours or Annually	
Perform Engine Tune-Up	Every 1,200 Hours or Every Other Year	
Check and Adjust Engine Speeds	Every 1,200 Hours or Every Other Year	Consult engine operation and maintenance manual or dealer.
Adjust Engine Valve Clearance	Every 1,200 Hours or Every Other Year	
Check Fuel Injection System	Every 1,200 Hours or Every Other Year	Consult your authorized engine repair station, servicing dealer, or distributor.
Inspect Turbocharger (if installed)	Every 1,200 Hours or Every Other Year	Check for excessive radial or axial play of compressor wheel and turbocharger boost pressure. Consult your servicing dealer or distributor.
Check Crankshaft Vibration Damper	Every 1,200 Hours or Every Other Year	Grasp vibration damper with both hands and attempt to turn in both directions. If rotation is felt, replace damper. Replace damper every 4,500 hours or every 5 years.
Flush Cooling System and Replace Thermostats	Every 1,200 Hours or Every Other Year	Flush with water before using a heavy duty cooling system cleaner. Fill system with only approved coolants.
Check Pressure Test Cooling System	Every 1,200 Hours or Every Other Year	Consult your authorized engine repair station, servicing dealer, or distributor.
Inspect and Service Air Cleaner Elements	As Required	When cleaning and washing primary element, remember to wash is a solution of warm water and filter element cleaner. NEVER use compressed air, gasoline, or other solvents. DO NOT oil element.

Table 7. Winterization and Storage Procedures for Hard-Hose Travelers.

REQUIRED ACTION	PROCEDURE
Purging Hose	The best method of removing water from a hard hose traveler is purging the hose with compressed air. If your irrigator is not equipped with an air-purging cap, ask your equipment distributor if one is available. Air purging will allow you to remove 85% of all of the water from your reel without risking damaging the hose when rolling up dry or from miswraping. 1. Retract hose from field and lower cart to the ground. Ensure that the cart/hose is pointed away from farm workers, vehicles, equipment, and structures. 2. Remove drain cap on cart or open drain valve. 3. Attach air-purging cap to the inlet of the irrigator. Attach hose from compressor to air-purging cap. 4. Start air compressor and build up at least 100 psi of pressure. When achieved, open valve and begin to purge the water from the irrigator. 5. DO NOT STAND near or in front of the cart during purging. Once pressure is built up in the hose, water will be blown from the irrigator at a great force. 6. Once water is blown from the reel, finish retracting the hose and cradle gun cart. Continue with off-season storage procedures.
Draining Hose	Follow this procedure only if your equipment cannot be purged with compressed air. 1. Tow the hose out to the full length and open plug or drain valve on cart. **NOTE: Leave at least ½ coil of hose on the drum to prevent pulling the hose off of the reel. 2. Rewind hose slowly with PTO or engine drive. This will allow water to drain from the reel and prevent damage from freezing. 3. DO NOT leave the reel unattended during the draining process. The hose will have a tendency to flatten slightly and miswrap. You may need to manually adjust the hose position on the drum using a wooden pole to pry the hose in place. 4. Check hose for any cracks, damage ,or loose connections. Replace or repair as necessary. 5. Replace/close drain plug or drain valve. 6. After removing the irrigator from storage, a full pull of the traveler should be made. This will ensure that no changes occur to the mechanical speed compensation devices on the equipment.
Drive Turbine	Open gate valve and drain plug or petcock on turbine assembly.
Fittings	Lubricate all fittings with multipurpose grease or appropriate weight oil.
Chassis	Touch up any scratched or chipped paint and repaint any rusted areas.
Big Gun	1) Check nozzle for wear. You may need to use machinist's calipers to check ring nozzles for appropriate diameter. Replace any worn rings. 2) Check reverse rotation of gun. The gun should travel left to right and right to left at the same speed. Big guns operating in partial circles tend to unevenly wear bearings, adversely affecting the speed of gun rotation. If bearings are worn, it may be necessary to replace the entire gun. 3) Cover the inlet of the gun to prevent the entrance of dirt or small animals.
Tires	1. Check tires for wear and cracks. 2. Reduce tire pressure to 15 psi for off-season storage. Inflate tires to 40 – 45 psi before operating.
Drive Engine	1. Change engine oil. 2. Clean/replace air filter as necessary.
Safety Shields	Check for the presence of all manufacturer's safety shields. Tighten and replace safety shields as necessary.
Chains	(Optional) Remove and store all chains in a lubricant, such as diesel fuel.
Storage	1. Store reel in a clean, dry place. 2. Block irrigator to remove the weight of the machine from the wheels. 3. If the reel is left outside, cover the entire machine with a waterproof canvas.

Table 8. Winterization and Storage Procedures for Center Pivot and Linear Move Systems.

REQUIRED ACTION	PROCEDURE
Flushing	Flush after pump repair, structural repair, winterization, season start-up, and as often as necessary to remove accumulated sand and debris. Excessive sprinkler clogging or wear can indicate high debris or sand content. 1. Turn main power off! Only water is required to flush the unit – the pivot/linear does not need to run. Ensure that the machine is not under water pressure. **REMOVING SAND TRAP PLUGS WHILE UNDER PRESSURE MAY CAUSE INJURY OR DEATH!** 2. Remove pipe drains at each tower. Clean sand and foreign particles from these drains. Flip rubber seals when reinstalling (step 6). 3. Remove the sand trap from the last regular drive tower. Clean sand and foreign particles from these drains and spray nozzles (if installed). 4. Remove the plugs in the overhang. 5. Start the engine/pump and allow the machine the flush thoroughly. 6. Turn off water supply. Reinstall all pipe drains, sand traps, and plugs. After flushing for winterization, be sure the water has drained completely from all drains before replacing drains and plugs to prevent freezing and splitting of the pipeline.
Booster Pump	Drain the booster pump. Ensure supply line is not plugged with sand or debris. Remove drain plug.
Valve or Sensor Strainers	Selenoid valve or sensor strainers should be cleaned at least once a year. Remove the strainer housing and wash strainer by running fresh water through the strainer. Avoid scrubbing the strainer to remove collected particles for this may damage the mesh.
Towable Hubs	Towable hubs should be greased thoroughly.
Parking the Machine	Steel will expand and contract with variation in temperature. When in operation this process posses no threat, but when equipment is parked, shrinkage could cause severe structural damage. The stress to contraction of the steel is more severe in longer machines. Irrigators 1,500 feet or longer are susceptible to these stresses and may exhibit shrinkage of 8-12 inches when wheel tracks are a problem. Refer to your manufacturer's or operator's manual or follow one of the following methods when parking the machine in the off-season: 1. Park the machine in an area where wheel tracks have been eliminated. 2. Place wooded planks, (2 x 12 inch), over the wheel tracks. Park the machine with the ties centered on the planks. 3. Remove all wheel tracks and run machine 100 - 200 yards. Only operate units (dry) if the temperature is above 40° F. 4. Disconnect machines with spans taller than 8 – 10 feet. Secure spans with chains to allow for contraction during cold weather.

See Table 6 for additional seasonal maintenance procedures.

Table 9. Winterization and Storage Procedures for Agricultural Pumps.

REQUIRED ACTION	PROCEDURE
Paint Pump Housing	Remove all exterior dirt and grime that may trap moisture. Prime and repaint any exposed metal to prevent corrosion.
Flush Suction and Discharge Lines	Flush suction and discharge lines. Check for leaks and replace worn gaskets.
Drain Pump Casing	Remove the lowest plug on pump and drain casing.
Lubricate Bearings	Lubricate bearings according to operation and maintenance manual.
Provide Storage	If possible, keep unit in clean, dry storage area to prevent corrosion.
Seal Open Ports	Seal all open ports to keep out foreign objects, such as insects, rodents, dust, and dirt.
Rotate Drive Shaft	Rotate dive shaft periodically to prevent freeze-up of internal components.

Table 10. Winterization and Storage Producers for Diesel Engines that Power Agricultural Pumps.

STEP	ACTION ITEM	PROCEDURE
1	**Engine Oil and Filter**	Change engine oil and oil filter.
2	**Air Filter**	Service air filter according to operation and maintenance manual.
3	**Cooling System**	Draining and flushing of cooling system is not required if engine will be store for several months. However, for longer than a year, drain the cooling system and refill according to operation and maintenance manual.
4	**Fuel Tank**	Drain the fuel tank and add 1 oz. Of inhibitor to the fuel tank for each 4 gallons of tank capacity.
5	**Crankcase Oil**	Add 1 oz. of inhibitor to the engine crankcase for each quart of crankcase oil.
6	**Air Intake**	Disconnect all air intake piping from the manifold. Pour 3 oz. of inhibitor into the intake system and replace piping.
7	**Start Engine**	Crank engine several revolutions with starter, while NOT allowing the engine to start.
8	**Belts**	Loosen fan and alternator belts to relieve tension. Remove belts if desired.
9	**Batteries**	Remove and clean batteries. Store in cool, dry placed and keep fully charged.
10	**PTO Clutch**	Disengage PTO clutch.
11	**Engine Openings**	Seal all openings on engine with plastic bags and tape. Contact engine dealer for specialized storage kits.
12	**Exposed Metal**	Coat all exposed metal surfaces with grease or corrosion inhibitor.
13	**Engine Exterior**	Clean the exterior of engine and touch-up any scratched or chipped painted surfaces.
14	**Engine Storage**	Store engine in a dry, protected area to prevent additional corrosion. If stored outside, cover with waterproof canvas or other suitable material, and seal ends with a strong waterproof tape.
	Removing Engine From Storage	
1	**Protective Coverings**	Remove all protective coverings from engine. Unseal all openings and remove covering from electrical system.
2	**Batteries**	Remove batteries from storage. Install batteries, and connect the cables.
3	**Belts**	Install new fan and alternator belts (if needed). Adjust belt tensions to appropriate specifications (refer to operation and maintenance manual).
4	**Fuel Tank**	Fill fuel tank.
5	**Start-up Checks**	Perform all start-up checks specified in operation and maintenance manual.
6	**Starting Engine**	1. Crank engine for 20 seconds, while not allowing the engine to start. Then start engine. DO NOT operate the starter more than 30 seconds at a time. Wait at least 2 minutes for starter to cool before trying again. 2. Operate engine at slow idle for several minutes. Warm up engine and check all gauges before initiating pump and placing the engine under load.

SUBCHAPTER 02T – WASTE NOT DISCHARGED TO SURFACE WATERS

SECTION .0100 – GENERAL REQUIREMENTS

15A NCAC 02T .0101 PURPOSE

The rules in this Subchapter set forth the requirements and procedures for application and issuance of permits for the following systems which do not discharge to surface waters of the state:

(1) sewer systems;
(2) disposal systems;
(3) treatment works;
(4) residual and residue disposal/utilization systems;
(5) animal waste management systems;
(6) treatment of contaminated soils; and
(7) stormwater management systems pursuant to 15A NCAC 2H .1000.

History Note: Authority G.S. 143-215.1; 143-215.3(a)(1);
Eff. September 1, 2006.

15A NCAC 02T .0102 SCOPE

The rules in this Subchapter apply to all persons proposing to construct, alter, extend, or operate any sewer system, treatment works, disposal system, contaminates soil treatment system, animal waste management system, stormwater management system or residual disposal/utilization system which does not discharge to surface waters of the state, including systems which discharge waste onto or below land surface. However, these Rules do not apply to sanitary sewage systems or solid waste management facilities which are permitted under the authority of the Commission for Health Services. The provisions for stormwater management systems can be found in 15A NCAC 02H .1000. The rules in this Section are general requirements that apply to all program rules (found in individual sections) in this Subchapter.

History Note: Authority G.S. 130A-335; 143-215.1; 143-215.3(a)(1);
Eff. September 1, 2006.

15A NCAC 02T .0103 DEFINITIONS

The terms used in this Subchapter shall be as defined in G.S. 143-212 and 143-213 except as provided in this Rule and in definitions provided in program specific rules in this Subchapter and as follows:

(1) "Agronomic rate" is defined as the amount of waste and other materials applied to meet the nitrogen needs of the crop, but does not overload the soil with nutrients or other constituents that cause or contribute to a contravention of surface water or groundwater standards, limit crop growth, or adversely impact soil quality. Nitrogen needs of the crop shall be based on realistic yield expectations (RYE) established for a soil series through published Cooperative Extension Service bulletins, Natural Resources Conservation Service publications, county soil surveys, or site specific agronomist reports.
(2) "Animal waste" means livestock or poultry excreta or a mixture of excreta with feed, bedding, litter or other materials generated at a feedlot.
(3) "Bedrock" is as defined in 15A NCAC 02L .0102.
(4) "Buffer" means a natural or vegetated area as defined in 15A NCAC 02B .0202.
(5) "CFR" means Code of Federal Regulations. All CFRs cited herein may be obtained at Government Institutes, Inc., 4 Research Place, Suite 200, Rockville, Md, 20850-1714 for a cost of thirty-six dollars ($36.00) each plus four dollars ($4.00) shipping and handling or at http://www.gpoaccess.gov/cfr/. Copies are also available for review at 512 North Salisbury Street, Raleigh, North Carolina 27604.
(6) "Commission" as defined in G.S. 143-212 or their delegate.
(7) "Compliance boundary" is as defined in 15A NCAC 02L .0102.
(8) "Deemed permitted" means that a facility is considered as having a needed permit and being compliant with the permitting requirements of G.S. 143-215.1(a) even though it has not received an individual permit for its construction or operation.
(9) "Department" as defined in G.S. 143-212.
(10) "Director" means the Director of the Division or its delegate.

(11) "Division" means the Division of Water Quality in the Department. All rules cited in this Section under the authority of the Division may be obtained at 512 North Salisbury Street, Raleigh, North Carolina 27604 or at the Division's web page at www.ncwaterquality.org at no charge.

(12) "Effluent" means wastewater discharged following all treatment processes from a water pollution control facility or other point source whether treated or untreated.

(13) "Engineer" is an individual who is currently licensed by the North Carolina Board of Examiners For Engineers and Land Surveyors or authorized to practice under G.S. 89C as an engineer.

(14) "EPA" means the United States Environmental Protection Agency.

(15) "Ephemeral (stormwater) stream" means a stream as defined in 15A NCAC 02B .0233.

(16) "Essential treatment unit" means any unit associated with the wastewater treatment process whose loss would likely render the facility incapable of meeting the required performance criteria including aeration units or other main treatment units, clarification equipment, filters, disinfection equipment, pumps and blowers.

(17) "General Permit" means a permit issued under G.S. 143-215.1(b)(3), 143-215.1(b)(4) or 143-215.10C.

(18) "Groundwaters" means those waters in the saturated zone of the earth as defined in 15A NCAC 02L .0102.

(19) "Groundwater standards" means groundwater standards as established in 15A NCAC 02L .0200.

(20) "Industrial wastewater" means all wastewater other than sewage or animal waste and includes:

(a) wastewater resulting from any process of industry or manufacture, or from the development of any natural resource;

(b) wastewater resulting from processes of trade or business, including wastewater from laundromats and vehicle/equipment washes, but not wastewater from restaurants;

(c) stormwater that is contaminated with an industrial wastewater;

(d) any combination of sewage and industrial wastewater;

(e) municipal wastewater unless it can be demonstrated to the satisfaction of the Division that the wastewater contains no industrial wastewater;

(f) contaminated groundwater extracted as part of an approved groundwater remediation system approved by the Division in accordance with 15A NCAC 02L .0100.

(21) "Intermittent stream" means a stream as defined in 15A NCAC 02B .0233.

(22) "NPDES" means National Pollutant Discharge Elimination System.

(23) "Perennial stream" means a stream as defined in 15A NCAC 02B .0233.

(24) "Perennial waterbody" means a waterbody as defined in 15A NCAC 02B .0233.

(25) "Pollutant" means waste as defined in G.S. 143-213.

(26) "Potable waters" means water as defined in 15A NCAC 02L .0102.

(27) "Private well" means any potable or irrigation well not directly controlled by a public authority or a public utility authorized by the North Carolina Public Utilities Commission. This may include a private individual or community well as defined in the public water supply rules contained in 15A NCAC 18C.

(28) "Professional engineer" means a person who is presently registered and licensed as a professional engineer by the North Carolina Board of Examiners For Engineers and Land Surveyors.

(29) "Public or community sewage system" means a single system of sewage collection, treatment, or disposal owned and operated by a sanitary district, a metropolitan sewage district, a water and sewer authority, a county, a municipality or a public utility authorized to operate by the North Carolina Utilities Commission.

(30) "Residuals" means any solid, semisolid, or liquid waste, other than effluent or residues from agricultural products and processing, generated from a wastewater treatment facility, water supply treatment facility or air pollution control facility permitted under the authority of the Commission.

(31) "Residues from agricultural products and processing" means solids, semi-solids or liquid residues from food and beverage processing and handling; silviculture; agriculture; and aquaculture operations permitted under the authority of the Commission that are non-toxic, non-hazardous and contain no domestic wastewater.

(32) "Restrictive horizon" is the layer in a soil profile that is capable of reducing the downward water movement to the minimum rate, as evidenced by lowest saturated hydraulic conductivity among all the soil layers. Restrictive horizon is often capable of perching ground water or wastewater effluent and is

characterized by accumulation of finer soil particles (such as aluminum, clay, iron, silica, organic matter, or other compounds) or compaction due to heavy equipments.

(33) "Review boundary" is as defined in 15A NCAC 02L .0102.

(34) "Seasonal High Water Table" or "SHWT" is the highest level to which the soil is saturated, as may be determined through the identification of redoximorphic features in the soil profile including low chroma mottling. This does not include temporary perched conditions. Alternatively, the SHWT can also be determined from water level measurements or via soil/groundwater modeling.

(35) "Secretary" as defined in G.S. 143-212 or its delegate.

(36) "Setback" means the minimum separation in linear feet, measured on a horizontal plane, required between a treatment works, disposal system, or utilization system and physical features such as building, roads, property lines, or water bodies.

(37) "Sewage" means the liquid and solid human waste, and liquid waste generated by domestic water-using fixtures and appliances, from any residence, place of business, or place of public assembly. Sewage does not include wastewater that is totally or partially industrial wastewater, or any other wastewater not considered to be domestic waste.

(38) "Soil scientist" means an individual who is currently licensed or authorized to practice soil science under G.S. 89F by the North Carolina Board for Licensing of Soil Scientists.

(39) "Staff" means the staff of the Division.

(40) "Surface waters" means all waters as defined in G.S. 143-212 except underground waters.

(41) "Surface water standards" means surface water standards as established in 15A NCAC 02B .0200.

(42) "Technical specialist" means an individual designated by the Soil and Water Conservation Commission, pursuant to rules adopted by that Commission, to certify animal waste management plans or specific parts of a certified animal waste management plan.

(43) "Toxicity test" means a test for toxicity conducted using the procedures contained in 40 CFR 261, Appendix II which is hereby incorporated by reference including any subsequent amendments and editions.

(44) "Treatment works or disposal system which does not discharge to surface waters" means any treatment works, facility, utilization system, or disposal system which is designed to:

(a) operate as closed system with no discharge to waters of the state, or

(b) dispose/utilize of wastes, including residuals, residues, contaminated soils and animal waste, to the surface of the land, or

(c) dispose of wastes through a subsurface disposal system pursuant to G.S. 143-215.1(b)(4).

(45) "Waste oil" means any used nonhazardous petroleum product other than crankcase oil. Crankcase oil mixed with other used nonhazardous petroleum products shall be considered as waste oil.

(46) "Wetlands" are "waters" as defined in G.S. 143-212 and are areas that are inundated or saturated by an accumulation of surface or ground water as defined in 15A NCAC 02B .0202.

History Note: *Authority G.S. 130A-335; 143-213; 143-215.3(a)(1);*
Eff. September 1, 2006.

15A NCAC 02T .0104 ACTIVITIES WHICH REQUIRE A PERMIT

No person shall do any of the things or carry out any of the activities contained in G.S. 143-215.1(a) until or unless the person shall have applied for and received a permit from the Division (or if appropriate a local program approved by the Division pursuant to this Subchapter) and shall have complied with the conditions prescribed in the permit or is deemed permitted by rules in this Subchapter.

History Note: *Authority G.S. 130A-335; 143-215.1; 143-215.3(a)(1);*
Eff. September 1, 2006.

15A NCAC 02T .0105 GENERAL REQUIREMENTS

(a) Jurisdiction. Applications for permits from the Division shall be made in accordance with this Rule. Applications for permits under the jurisdiction of a local program shall be made in accordance with the requirements of the Division approved program.

(b) Applications. Application for a permit must be made on Division forms completely filled out, where applicable, and fully executed in the manner set forth in Rule .0106 of this Section. A processing fee as described in G.S. 143-215.3D

must be submitted with each application in the form of a check or money order made payable to the Department. Applications shall be returned if incomplete. Sewer line extensions shall be applied for separately from treatment, utilization, and disposal systems. The applicant shall provide adequate documentation to the Division to ensure that the proposed system will meet all design and performance criteria as required under this Subchapter and other applicable rules, be operated as a non-discharge system, and protect surface water and groundwater standards. Variances to this Subchapter or adopted design criteria must be specifically requested in the application and, if approved pursuant to Paragraph (n) of this Rule, incorporated into the permit. The Division may accept certification from a licensed or certified professional (e.g. Professional Engineers, Licensed Soil Scientist, Licensed Geologist, Technical Specialist) that the design meets or exceeds minimum design criteria applicable to the project. Division acceptance of certifications by the applicant or by licensed or certified professionals preparing reports for the application shall not constitute approval of a variance to this Subchapter or applicable minimum design and performance criteria unless specifically requested in the application and approved in the permit.

(c) Application packages for new and expanding facilities shall include the following items:

(1) The number of executed copies shall include the number necessary for each review office and one additional copy. Additional copies shall be required if needed for federal and state grant and loan projects.

(2) Reports, engineering plans, specifications, and calculations as required by the applicable rules of this Subchapter. If prepared by licensed or certified professionals these reports shall be submitted in accordance with the respective statutes and rules governing that profession.

(3) Operational agreements as required by Rule .0115 of this Section.

(4) For projects that require environmental documentation pursuant to the North Carolina Environmental Policy Act, a final environmental document (Finding of No Significant Impact or Record of Decision).

(5) A general scaled location map, showing orientation of the facility with reference to at least two geographic references (e.g. numbered roads, named streams/rivers).

(6) Documentation that other directly related (i.e. needed to properly construct and operate the facilities permitted under this Subchapter) environmental permit or certification applications are being prepared, have been applied for, or have been obtained (e.g. 401 certifications, erosion and sedimentation control plans, stormwater management plans). The Division shall consider the application incomplete or issue the permit contingent on issuance of the dependent permits if issuance of other permits or certifications impact the system permitted under this Subchapter.

(7) A description of the project including the origin, type and flow of waste to be treated. For industrial processing facilities, a waste analysis extensive enough to allow a complete evaluation of the system's capability to treat the waste and any potential impacts on the waters of the state shall be included.

(8) Documentation of compliance with Article 21 Part 6 (Floodway Regulations) of Chapter 143 of the General Statutes.

(9) Documentation as required by other applicable rule(s) in this Subchapter.

(10) Documentation of the presence or absence of threatened or endangered aquatic species utilizing information provided by the Natural Heritage Program of the Department. This shall only apply to the area whose boundary is encompassed by and for the purpose of installation, operation, and maintenance of facilities permitted herein (wastewater collection, treatment, storage, utilization, or disposal). This documentation shall provide information on the need for permit conditions pursuant to Paragraph (i) of this Rule. The Natural Heritage Program can be contacted at http://www.ncnhp.org or write to Natural Heritage Program, 1601 Mail Service Center, Raleigh, NC 27699-1601.

(d) Application packages for renewals shall include updated site plans (if required as part of original submittal).

(e) Application and annual Fees.

(1) Application Fee. For every application for a new or major modification of a permit under this Section, a nonrefundable application processing fee in the amount provided in G.S. 143-215.3D shall be submitted to the Division by the applicant at the time of application. For a facility with multiple treatment units under a single permit, the application fee shall be set by the total design treatment capacity. Modification fees shall be based on the projected annual fee for the facility.

(2) Annual Fees. An annual fee for administering and compliance monitoring shall be charged in each year of the term of every renewable permit according to the schedule in G.S. 143-215.3D(a). Annual fees must be paid for any facility operating on an expired permit that has not been rescinded or revoked by the Division. Permittees shall be billed annually by the Division. A change in the facility

which changes the annual fee shall result in the revised annual fee being billed effective with the next anniversary date.

(3) Failure to pay an annual fee within 30 days after being billed shall be cause for the Division to revoke the permit.

(f) Designs for facilities permitted under this Section shall use the practicable waste treatment and disposal alternative with the least adverse impact on the environment in accordance with G.S. 143-215.1(b)(2).

(g) In order to protect Publicly Owned Treatment Works, the Division shall incorporate pretreatment requirements under 15A NCAC 2H .0900 into the permit.

(h) Setbacks and required separation distances shall be provided as required by individual rules in this Subchapter. Setbacks to streams (perennial and intermittent), perennial waterbodies, and wetlands shall be determined using the methodology set forth in 15A NCAC 02B .0233(4)(a). Setbacks to wells are for those wells outside the compliance boundary. Where wells would otherwise be inside the compliance boundary as established in 15A NCAC 02L .0107, the applicant may request the compliance boundary be established closer to the waste disposal area and this shall be granted provided the groundwater standards can be met at the newly established compliance boundary.

(i) Permits may provide specific conditions to address the protection of threatened or endangered aquatic species as provided in plans developed pursuant in 15A NCAC 02B .0110 if the construction and operation of the facility directly impacts such species.

(j) The permittee shall keep permits active until the waste treatment systems authorized by the permit are properly closed or subsequently permitted under another permit issued by the appropriate permitting authority for that activity.

(k) Monitoring of waste and surface waters shall be in accordance with 15A NCAC 02B .0505 except as otherwise provided by specific rules in this Subchapter.

(l) Reporting shall be in accordance with 15A NCAC 02B .0506 except as otherwise provided by specific rules in this Subchapter.

(m) Monitoring of groundwater shall be in accordance with Sections 15A NCAC 02L .0100 and 15A NCAC 02C .0100 except as otherwise provided by specific rules in this Subchapter.

(n) The Director shall approve alternative Design Criteria in cases where the applicant can demonstrate that the alternative design criteria will provide the following:

(1) equal or better treatment of the waste;

(2) equal or better protection of the waters of the state; and

(3) no increased potential for nuisance conditions from noise, odor or vermin.

History Note: Authority G.S. 143-215.1; 143-215.3(a);
Eff. September 1, 2006.

15A NCAC 02T .0106 SUBMISSION OF PERMIT APPLICATIONS

(a) Permit applications, supporting information, and processing fee for permits issued by the Division shall be filed with the Division. Applications for permits from a Division approved local permitting program shall be submitted directly to the local program director. Division permit processing fees are not required for permits issued by delegated local permitting programs.

(b) Permit applications shall be signed as follows:

(1) in the case of corporations, by a principal executive officer of at least the level of vice-president, or his authorized representative;

(2) in the case of a partnership or a limited partnership, by a general partner;

(3) in the case of a sole proprietorship, by the proprietor;

(4) in the case of a municipal, state, or other public entity by either an executive officer, elected official in the highest level of elected office, or other authorized employee.

(c) Delegation of other authorized employees or any employee in a specific position (i.e. signing officials) shall be provided in letter format to the Division signed by an authorized person pursuant to Paragraph (b) of this Rule. The delegation may be for a specific permit application or more general for certain or all types of water quality permits. The letter shall identify the extent of delegation.

History Note: Authority G.S. 143-215.3(a)(1); 143-215.1;
Eff. September 1, 2006.

15A NCAC 02T .0107 STAFF REVIEW AND PERMIT PREPARATION

(a) The staff of the Division shall conduct a review of plans, specifications and other project data accompanying the application and shall determine if the application and required information are complete. The staff shall acknowledge receipt of a complete application except for fast-track sewer applications. The local government unit or units having jurisdiction over specific residential projects shall be notified of permit applications in accordance with G.S. 143-215.1(d1).

(b) If the application is not complete with all required information and application fee, the application shall be returned to the applicant. The staff shall advise the applicant by mail:

(1) how the application or accompanying supporting information may be modified to make it acceptable or complete;

(2) that the 90 day processing period required in G.S. 143-215.1 and Rule .0108 of this Section begins upon receipt of corrected or complete application with required supporting information.

(c) Pursuant to G.S. 143-215.67(a), the staff of the Division shall determine for sewer system construction or sewer system extensions, whether the treatment works or the sewer system to which the proposed system will discharge is adequate to receive waste which will be discharged from the proposed system.

(d) For new and expanding treatment works and disposal systems, the staff shall make a site-specific evaluation to determine the potential impacts of the proposed project on surface and ground water quality. The applicant must make the site accessible to the Division.

(e) If an application is accepted and later found to be incomplete, the applicant shall be advised how the application or accompanying supporting information may be modified to make it acceptable or complete. The staff shall advise the applicant by mail:

(1) that the 90 day processing period required in G.S. 143-215.1(d) and Rule .0108 of this Section begins on the date the additional information is received;

(2) that if all required information is not submitted within 30 days, the project will be returned as incomplete. Any resubmittal of a returned application must be accompanied with a new application fee.

History Note: Authority G.S. 143-215.1(b); 143-215.1(d); 143-215.3(a)(1); 143-215.3(a)(4); Eff. September 1, 2006.

15A NCAC 02T .0108 FINAL ACTION ON PERMIT APPLICATIONS TO THE DIVISION

(a) The Director shall take final action on all applications not later than 90 days following receipt of a complete application and with required information. All permits or renewals of permits and decisions denying permits or renewals shall be in writing.

(b) The Director may:

(1) issue a permit containing such conditions as are necessary to effectuate the purposes of Article 21, Chapter 143 of the General Statutes;

(2) issue a permit containing time schedules for achieving compliance with applicable effluent standards and limitations, surface water or groundwater standards and other legally applicable requirements;

(3) deny a permit application where necessary to effectuate:

(A) the purposes of Article 21, Chapter 143;

(B) the purposes of G.S. 143-215.67(a);

(C) rules on coastal waste treatment, disposal, found in Section 15A NCAC 02H .0400;

(D) rules on groundwater quality standards found in Subchapter 02L of this Chapter.

(4) hold public meetings when necessary to obtain additional information needed to complete the review of the application. The application shall be considered as incomplete until the close of the meeting record.

(c) The Division may require any monitoring and reporting requirements, including groundwater, surface water or wetlands, waste, wastewater, sludge, soil, treatment process, lagoon/storage pond, and plant tissue, necessary to determine the source, quantity and quality of the waste and its effect upon the surface water, ground waters or wetlands. All reports must be submitted on Division supplied forms or forms approved by the Division as providing the same information as required by the Division's forms.

(d) If a permit is denied, the letter of denial shall state the reason(s) for denial and any reasonable measures which the applicant may take to make the application approvable.

(e) All permits requiring an annual fee shall be issued for a time period not to exceed five years.

History Note: *Authority G.S. 143-215.1(a); 143-215.1(b); 143-215.1(d); 143-215.3(a)(1);*
Eff. September 1, 2006.

15A NCAC 02T .0109 PERMIT RENEWALS

Requests for permit renewals shall be submitted to the Director at least 180 days prior to expiration unless the permit has been revoked by the Director in accordance with Rule .0110 of this Section or a request has been made to rescind the permit. Renewal requests shall be made in accordance with Rule .0105 and Rule .0106 of this Section.

History Note: *Authority G.S. 143-215.3(a)(1);*
Eff. September 1, 2006.

15A NCAC 02T .0110 MODIFICATION AND REVOCATION OF PERMITS

Any permit issued by the Division pursuant to this Subchapter is subject to revocation, or modification upon 60 days notice by the Director in whole or part for:

(1) violation of any terms or conditions of the permit;
(2) obtaining a permit by misrepresentation or failure to disclose fully all relevant facts;
(3) refusal of the permittee to allow authorized employees of the Department upon presentation of credentials:
    (a) to enter upon permittee's premises on which a system is located in which any records are required to be kept under terms and conditions of the permit;
    (b) to have access to any documents and records required to be kept under terms and conditions of the permit;
    (c) to inspect any monitoring equipment or method required in the permit; or
    (d) to sample any pollutants.
(4) failure to pay the annual fee for administering and compliance monitoring.

History Note: *Authority G.S. 143-215.1(b)(2.); 143-215.3(a)(1);*
Eff. September 1, 2006.

15A NCAC 02T .0111 CONDITIONS FOR ISSUING GENERAL PERMITS

(a) In accordance with the provisions of G.S. 143-215.1(b), (c) and (d), general permits may be developed by the Division and issued by the Director for categories of activities covered by this Subchapter. General permits may be written for categories of activities that involve the same or substantially similar operations, have similar treated waste characteristics, require the same limitations or operating conditions, and require the same or similar monitoring. After issuance of a general permit by the Director, persons operating facilities described by the general permit may request coverage under it, and the Director or his designee may grant appropriate certification. All individual operations which receive a "Certificate of Coverage" under a general permit are permitted under the specific general permit for which the coverage was issued. A Certificate of Coverage shall mean that approval is given to facilities that meet the requirements of coverage under the general permit. Persons operating facilities covered under general permits developed in accordance with this Rule shall be subject to the same limits, conditions, management practices, enforcement authorities, and rights and privileges as specified in the general permit.

(b) Upon development of a draft general permit, the Director shall publicly notice under G.S. 143-215.4 (b)(1) and (2), at least 30 days prior to final action, an intent to issue the general permit. A one time publication of the notice in a newspaper having general circulation in the geographic areas affected by the proposed permit shall be required. The notice shall provide the name, address and phone number of the Division, a brief description of the intended action, and a brief description of the procedures for the formulation of final determinations, including a 30-day comment period and other means by which interested persons may comment upon the determinations.

(c) No provisions in any general permit issued under this Rule shall be interpreted as allowing the permittee to violate state surface water standards, groundwater standards outside a Compliance Boundary established in accordance with 15A NCAC 02L .0107, or other applicable environmental Rules. Construction of new water supply wells for human consumption shall be prohibited within Compliance Boundaries for facilities covered under general permits issued under this Section. General permits issued pursuant to this Rule shall be considered individual permits for purposes of Compliance Boundaries established under 15A NCAC 02L .0107.

(d) To obtain an individual Certificate of Coverage, a Notice of Intent to be covered by the general permit must be given by the applicant to the Division using forms provided by the Division. Coverage under the general permit shall be granted unless the Director makes a determination under Paragraph (h) of this Rule that an individual permit is required. If all requirements are not met, an individual permit application and full application review procedure shall be required.
(e) General permits shall be effective for a term not to exceed five years at the end of which the Division may renew them. The Division shall satisfy public notice requirements specified in Paragraph (b) of this Rule prior to renewal of general permits. If the Division does not renew a general permit, all operations covered under that general permit shall be notified to submit applications for individual permits.
(f) Anyone engaged in activities covered by the general permit rules but not permitted in accordance with this Subchapter shall be in violation of G.S. 143-215.1.
(g) Any individual covered or considering coverage under a general permit may choose to pursue an individual permit for any operation covered by this Rule.
(h) The Director may require any person, otherwise eligible for coverage under a general permit, to apply for an individual permit by notifying that person that an application is required. Notification shall consist of a written description of the reason(s) for the decision, appropriate permit application forms and application instructions, a statement establishing the required date for submission of the application, and a statement informing the person that coverage by the general permit shall automatically terminate upon issuance of the individual permit. Reasons for requiring application for an individual permit include:

(1) the operation is a significant contributor of pollutants to the waters of the state;
(2) conditions at the permitted site change, altering the constituents or characteristics of the wastewater such that the operation no longer qualifies for coverage under a general permit;
(3) noncompliance with the general permit;
(4) noncompliance with the Commission rules in this Chapter;
(5) a change has occurred in the availability of demonstrated technology or practices for the control or abatement of pollutants applicable to the operation;
(6) a determination by the Division that there has been or is the potential to have a direct discharge of wastewater, sludge or residuals to waters of the state;
(7) the system has been allowed to deteriorate or leak such that it poses an immediate threat to the environment.

(i) General permits or individual Certificate of Coverages may be modified, terminated, or revoked and reissued in accordance with the authority and requirements of rules of this Subchapter.

History Note: *Authority G.S. 143-215.1; 143-215.3(a)(1); 143-215.10C;*
Eff. September 1, 2006.

15A NCAC 02T .0112 DELEGATION OF AUTHORITY

For permits issued by the Division, the Director is authorized to delegate any or all of the functions contained in the rules of this Subchapter except the following:

(1) denial of a permit application;
(2) revocation of a permit not requested by the permittee;
(3) modification of a permit not requested by the permittee.

History Note: *Authority G.S. 143-215.3(a)(1); 143-215.3(a)(4);*
Eff. September 1, 2006.

15A NCAC 02T .0113 PERMITTING BY REGULATION

(a) The following disposal systems as well as those in Permitting By Regulation rules in this Subchapter (i.e., Rules .0203, .0303, .0403, .0903, .1003, .1103, .1203, .1303, .1403, and .1503) are deemed to be permitted pursuant to G.S. 143-215.1(b) and it shall not be necessary for the Division to issue individual permits or coverage under a general permit for construction or operation of the following disposal systems provided the system does not result in any violations of surface water or groundwater standards, there is no direct discharge to surface waters, and all criteria required for the specific system is met:

(1) Swimming pool and spa filter backwash and drainage, filter backwash from aesthetic fountains, filter backwash from commercial or residential water features such as garden ponds or fish ponds that is discharged to the land surface.

(2) Backwash from raw water intake screening devices that is discharged to the land surface.
(3) Condensate from residential or commercial air conditioning units that is discharged to the land surface.
(4) Discharges to the land surface from individual non-commercial car washing operations.
(5) Discharges to the land surface from flushing and hydrostatic testing water associated with utility distribution systems, new sewer extensions or new reclaimed water distribution lines.
(6) Street wash water that is discharged to the land surface.
(7) Discharges to the land surface from fire fighting activities.
(8) Discharges to the land surface associated with emergency removal and treatment activities for spilled oil authorized by the federal or state on-scene coordinator when such removals are undertaken to minimize overall environmental damage due to an oil spill.
(9) Discharges to the land surface associated with biological or chemical decontamination activities performed as a result of an emergency declared by the Governor or the Director of the Division of Emergency Management and that are conducted by or under the direct supervision of the federal or state on-scene coordinator and that meet the following criteria:
    (A) the volume produced by the decontamination activity is too large to be contained onsite;
    (B) the Division is informed prior to commencement of the decontamination activity; and
    (C) the wastewater is not radiologically contaminated or classified as hazardous waste.
(10) Drilling muds, cuttings and well water from the development of wells or from other construction activities including directional boring.
(11) Purge water from groundwater monitoring wells.
(12) Composting facilities for dead animals, if the construction and operation of the facilities is approved by the North Carolina Department of Agriculture and Consumer Services; the facilities are constructed on an impervious, weight-bearing foundation, operated under a roof; and the facilities are approved by the State Veterinarian pursuant to G.S. 106-403.
(13) Overflow from elevated potable water storage facilities.
(14) Mobile carwashes if:
    (A) all detergents used are biodegradable;
    (B) no steam cleaning, engine or parts cleaning is being conducted;
    (C) notification is made prior to operation by the owner to the municipality or if not in a municipality then the county where the cleaning service is being provided; and
    (D) all non-recyclable washwater is collected and discharged into a sanitary sewer or wastewater treatment facility upon approval of the facility's owner.
(15) Mine tailings where no chemicals are used in the mining process.
(16) Mine dewatering where no chemicals are used in the mining process.
(17) Wastewater created from the washing of produce, with no further processing on-site, on farms where the wastewater is irrigated onto fields so as not to create runoff or cause a discharge.

(b) Nothing in this Rule shall be deemed to allow the violation of any assigned surface water, groundwater, or air quality standards, and in addition any such violation shall be considered a violation of a condition of a permit. Further, nothing in this Rule shall be deemed to apply to or permit disposal systems for which a state/NPDES permit is otherwise required.

(c) Any violation of this Rule or discharge to surface waters from the disposal systems listed in Paragraph (a) of this Rule or the activities listed in other Permitted By Regulation rules in this Subchapter shall be reported in accordance with 15A NCAC 02B .0506.

(d) Disposal systems deemed permitted under this Subchapter shall remain deemed permitted, notwithstanding any violations of surface water or groundwater standards or violations of this Rule or other Permitted By Regulation rules in this Subchapter, until such time as the Director determines that they should not be deemed permitted in accordance with the criteria established in this Rule.

(e) The Director may determine that a disposal system should not be deemed to be permitted in accordance with this Rule or other Permitted By Regulation rules in this Subchapter and require the disposal system to obtain an individual permit or a certificate of coverage under a general permit. This determination shall be made based on existing or projected environmental impacts, compliance with the provisions of this Rule or other Permitted By Regulation rules in this Subchapter, and the compliance history of the facility owner.

History Note: *Authority G.S. 130A-300; 143-215.1(a)(1); 143-215.1(b)(4)(e); 143-215.3(a),(d);*
Eff. September 1, 2006.

15A NCAC 02T .0114 WASTEWATER DESIGN FLOW RATES

(a) This Rule shall be used to determine wastewater flow rates for all systems covered by this Subchapter unless alternate criteria are provided by a program specific rule and for flow used for the purposes of 15A NCAC 02H .0105. These are minimum design daily flow rates for normal use and occupancy situations. Higher flow rates may be required where usage and occupancy are atypical, including, those in Paragraph (e) of this Rule. Wastewater flow calculations must take hours of operation and anticipated maximum occupancies/usage into account when calculating peak flows for design.

(b) In determining the volume of sewage from dwelling units, the flow rate shall be 120 gallons per day per bedroom. The minimum volume of sewage from each dwelling unit shall be 240 gallons per day and each additional bedroom above two bedrooms shall increase the volume by 120 gallons per day. Each bedroom or any other room or addition that can reasonably be expected to function as a bedroom shall be considered a bedroom for design purposes. When the occupancy of a dwelling unit exceeds two persons per bedroom, the volume of sewage shall be determined by the maximum occupancy at a rate of 60 gallons per person per day.

(c) The following table shall be used to determine the minimum allowable design daily flow of wastewater facilities. Design flow rates for establishments not identified below shall be determined using available flow data, water-using fixtures, occupancy or operation patterns, and other measured data.

Type of Establishments	Daily Flow For Design
Barber and beauty shops	
Barber Shops	50 gal/chair
Beauty Shops	125 gal/booth or bowl
Businesses, offices and factories	
General business and office facilities	25 gal/employee/shift
Factories, excluding industrial waste	25 gal/employee/shift
Factories or businesses with showers or food preparation	35 gal/employee/shift
Warehouse	100 gal/loading bay
Warehouse – self storage (not including caretaker residence)	1 gal/unit
Churches	
Churches without kitchens, day care or camps	3 gal/seat
Churches with kitchen	5 gal/seat
Churches providing day care or camps	25 gal/person (child & employee)
Fire, rescue and emergency response facilities	
Fire or rescue stations without on site staff	25 gal/person
Fire or rescue stations with on-site staff	50 gal/person/shift
Food and drink facilities	
Banquet, dining hall	30 gal/seat
Bars, cocktail lounges	20 gal/seat
Caterers	50 gal/100 sq ft floor space
Restaurant, full Service	40 gal/seat
Restaurant, single service articles	20 gal/seat
Restaurant, drive-in	50 gal/car space
Restaurant, carry out only	50 gal/100 sq ft floor space
Institutions, dining halls	5 gal/meal
Deli	40 gal/100 sq ft floor space
Bakery	10 gal/100 sq ft floor space
Meat department, butcher shop or fish market	75 gal/100 sq ft floor space
Specialty food stand or kiosk	50 gal/100 sq ft floor space
Hotels and Motels	
Hotels, motels and bed & breakfast facilities, without in-room cooking facilities	120 gal/room
Hotels and motels, with in-room cooking facilities	175 gal/room
Resort hotels	200 gal/room
Cottages, cabins	200 gal/unit
Self service laundry facilities	500 gal/machine
Medical, dental, veterinary facilities	
Medical or dental offices	250 gal/practitioner/shift

Veterinary offices (not including boarding)	250 gal/practitioner/shift
Veterinary hospitals, kennels, animal boarding facilities	20 gal/pen, cage, kennel or stall
Hospitals, medical	300 gal/bed
Hospitals, mental	150 gal/bed
Convalescent, nursing, rest homes without laundry facilities	60 gal/bed
Convalescent, nursing, rest homes with laundry facilities	120 gal/bed
Residential care facilities	60 gal/person
Parks, recreation, camp grounds, R-V parks and other outdoor activity facilities	
Campgrounds with comfort station, without water or sewer hookups	75 gal/campsite
Campgrounds with water and sewer hookups	100 gal/campsite
Campground dump station facility	50 gal/space
Construction, hunting or work camps with flush toilets	60 gal/person
Construction, hunting or work camps with chemical or portable toilets	40 gal/person
Parks with restroom facilities	250 gal/plumbing fixture
Summer camps without food preparation or laundry facilities	30 gal/person
Summer camps with food preparation and laundry facilities	60 gal/person
Swimming pools, bathhouses and spas	10 gal/person
Public access restrooms	325 gal/plumbing fixture
Schools, preschools and day care	
Day care and preschool facilities	25 gal/person (child & employee)
Schools with cafeteria, gym and showers	15 gal/student
Schools with cafeteria	12 gal/student
Schools without cafeteria, gym or showers	10 gal/student
Boarding schools	60 gal/person (student & employee)
Service stations, car wash facilities	
Service stations, gas stations	250 gal/plumbing fixture
Car wash facilities (if recycling water see Rule .0235)	1200 gal/bay
Sports centers	
Bowling center	50 gal/lane
Fitness, exercise, karate or dance center	50 gal/100 sq ft
Tennis, racquet ball	50 gal/court
Gymnasium	50 gal/100 sq ft
Golf course with only minimal food service	250 gal/plumbing fixture
Country clubs	60 gal/member or patron
Mini golf, putt-putt	250 gal/plumbing fixture
Go-kart, motocross	250 gal/plumbing fixture
Batting cages, driving ranges	250 gal/plumbing fixture
Marinas without bathhouse	10 gal/slip
Marinas with bathhouse	30 gal/slip
Video game arcades, pool halls	250 gal/plumbing fixture
Stadiums, auditoriums, theaters, community centers	5 gal/seat
Stores, shopping centers, malls and flea markets	
Auto, boat, recreational vehicle dealerships/showrooms with restrooms	125 gal/plumbing fixture
Convenience stores, with food preparation	60 gal/100 sq ft
Convenience stores, without food preparation	250 gal/plumbing fixture
Flea markets	30 gal/stall
Shopping centers and malls with food service	130 gal/1000 sq ft
Stores and shopping centers without food service	100 gal/1000 sq ft
Transportation terminals – air, bus, train, ferry, port and dock	5 gal/passenger

(d) Design daily flow rates for proposed non-residential developments where the types of use and occupancy are not known shall be designed for a minimum of 880 gallons per acre or the applicant shall specify an anticipated flow based upon anticipated or potential uses.

(e) Conditions applicable to the use of the above design daily flow rates:

(1) For restaurants, convenience stores, service stations and public access restroom facilities, higher design daily flow rates shall be required based on higher expected usage where use is increased because of its proximity to highways, malls, beaches, or other similar high use areas.

(2) Residential property on barrier islands and similar communities located south or east of the Atlantic Intracoastal Waterway used as vacation rental as defined in G.S. 42A-4 shall use 120 gallons per day per habitable room. Habitable room shall mean a room or enclosed floor space used or intended to be used for living or sleeping, excluding kitchens and dining areas, bathrooms, shower rooms, water closet compartments, laundries, pantries, foyers, connecting corridors, closets, and storage spaces.

(f) An adjusted daily sewage flow design rate shall be granted for permitted but not yet tributary connections and future connections tributary to the system upon showing that a sewage system is adequate to meet actual daily wastewater flows from a facility included in Paragraph (b) or (c) of this Rule without causing flow violations at the receiving wastewater treatment plant or capacity related sanitary sewer overflows within the collection system as follows:

(1) Documented, representative data from that facility or a comparable facility shall be submitted by an authorized signing official in accordance with Rule .0106 of this Section to the Division as follows for all flow reduction request:

(A) Dates of flow meter calibrations during the time frame evaluated and indication if any adjustments were necessary.

(B) A breakdown of the type of connections (e.g. two bedroom units, three bedroom units) and number of customers for each month of submitted data as applicable. Identification of any non-residential connections including subdivision clubhouses/pools, restaurants, schools, churches and businesses. For each non-residential connection, information as identified in Paragraph (c) of this Rule (e.g. 200 seat church, 40 seat restaurant, 35 person pool bathhouse).

(C) Owner of the collection system.

(D) Age of the collection system.

(E) Analysis of inflow and infiltration within the collection system or receiving treatment plant, as applicable.

(F) Where a dedicated wastewater treatment plant serves the specific area and is representative of the residential wastewater usage, at least the 12 most recent consecutive monthly average wastewater flow readings and the daily total wastewater flow readings for the highest average wastewater flow month per customers as reported to the Division.

(G) Where daily data from a wastewater treatment plant cannot be utilized or is not representative of the project area: at least 12 months worth of monthly average wastewater flows from the receiving treatment plant shall be evaluated to determine the peak sewage month. Daily wastewater flows shall then be taken from a flow meter installed at the most downstream point of the collection area for the peak month selected that is representative of the project area. Justification for the selected placement of the flow meter shall also be provided.

(H) An estimated minimum design daily sewage flow rate shall be taken by calculating the numerical average of the top three daily readings for the highest average flow month. The calculations shall also account for seasonal variations, excessive inflow and infiltration, age and suspected meter reading/recording errors.

(2) The Division shall evaluate all data submitted but shall also consider other factors in granting, with or without adjustment, or denying a flow reduction request including: applicable weather conditions during the data period (i.e. rainy or drought), other historical monitoring data for the particular facility or other similar facilities available to the Division, the general accuracy of monitoring reports and flow meter readings, and facility usage (i.e., resort area).

(3) Flow increases shall be required if the calculations in Subparagraph (f)(1) of this Rule yield design flows higher than that specified in Paragraphs (b) or (c) of this Rule.

(4) The applicant/owner shall retain the letter of any approved adjusted daily design flow rate for the life of the facility and shall transfer such letter to any new system owner.

History Note: *Authority G.S. 143-215.1; 143-215.3(a)(1);*
Eff. September 1, 2006.

15A NCAC 02T .0115 OPERATIONAL AGREEMENTS

(a) Prior to issuance or reissuance of a permit pursuant to this Subchapter for a wastewater facility or sewer extension as specified in G.S. 143-215.1(d1), a private applicant shall provide evidence with the permit application:

(1) To show that the applicant has been designated as a public utility by the North Carolina Utilities Commission and is authorized to provide service to the specific project area. This may be a Certificate of Public Convenience and Necessity or letter from the Public Staff; or

(2) Enter into and submit an executed Operational Agreement pursuant to G.S. 143-215.1(d1) with the Division.

(b) Where the applicant is not a Homeowner's or Property Owner's Association, an executed Operational Agreement must be submitted with the permit application. A copy of the Articles of Incorporation, Declarations and By-laws shall be submitted to the Division with the engineer's certification as required by 15A NCAC 02T .0116 and prior to operation of the permitted facilities.

(c) For permit applications where the applicant is a legally formed Homeowners' or Property Owner's Association, an executed Operational Agreement and a copy of the Articles of Incorporation, Declarations and By-laws shall be submitted to the Division with the permit application.

(d) An Operational Agreement is required prior to donation to a public utility or municipality unless the applicant is the respective municipality or public utility. The Operational Agreement shall become void upon transferring the permit to the public utility or municipality via a change of ownership request to the Division and permit issuance into the new owner name.

History Note: *Authority G.S. 143-215.1(d1);*
Eff. September 1, 2006.

15A NCAC 02T .0116 CERTIFICATION OF COMPLETION

(a) Prior to the operation of any sewer system, treatment works, utilization system, or disposal system for which an individual permit has been issued in accordance with this Subchapter and the application prepared by licensed professional, a certification must be received by the Division from a professional certifying that the sewer system, treatment works, utilization system, or disposal system has been installed in accordance with the rules, any minimum design criteria except as noted, and approved plans and specifications. The professional certification must be on official forms completely filled out, where applicable, and submitted to the Division. For facilities with phased construction or where there is a need to operate certain equipment under actual operating conditions prior to certification, additional certification may be needed as follow-ups to the initial, pre-operation certification. The Division may not acknowledge receipt of engineering certifications. The Permittee and the professional shall track the submittal of certifications.

(b) For sewer extensions involving developer donated projects where the developer is the original Permittee, a change of ownership request shall be submitted to the Division on Division forms upon certifying completion of the project.

(c) All deeds, easements and encroachment agreements necessary for installation and operation and maintenance of the system shall be obtained prior to operation of the system.

History Note: *Authority G.S. 143-215.1;*
Eff. September 1, 2006.

15A NCAC 02T .0117 TREATMENT FACILITY OPERATION AND MAINTENANCE

(a) For facilities permitted under this Subchapter, the permittee must designate an Operator in Responsible Charge and a back-up operator as required by the Water Pollution Control System Operators Certification Commission as established in 15A NCAC 08F .0200 and 15A NCAC 08G .0200. Copies of this Rule are available from the Division, Archdale Building, 512 N. Salisbury Street, Raleigh, North Carolina 27604 at no charge.

(b) In order to insure the proper operation and maintenance of facilities permitted under this Section, the Operator in Responsible Charge, or a back-up operator when appropriate must operate and visit the facility as required by the Water Pollution Control System Operators Certification Commission as established in 15A NCAC 08F .0200 and 15A NCAC 08G .0200. Copies of this Rule are available from the Division, Archdale Building, 512 N. Salisbury Street, Raleigh, North Carolina 27604 at no charge.

History Note: *Authority G.S. 143-215.3;*
Eff. September 1, 2006.

15A NCAC 02T .0118 DEMONSTRATION OF FUTURE WASTEWATER TREATMENT CAPACITIES

In order to insure that treatment, utilization, or disposal systems do not exceed their hydraulic treatment capacities, no permits for sewer line extensions shall be issued to wastewater treatment systems owned or operated by municipalities, counties, sanitary districts or public utilities unless they meet the following requirements:

(1) Prior to exceeding 80 percent of the wastewater treatment system's permitted hydraulic capacity (based on the average flow of the last calendar year), the permittee must submit an approvable engineering evaluation of their future wastewater treatment, utilization, and disposal needs. This evaluation must outline specific plans for meeting future wastewater treatment, utilization, or disposal needs by either expansion of the existing system, elimination or reduction of extraneous flows, or water conservation and must include the source(s) of funding for the improvements. If expansion is not proposed or is proposed for a later date, a detailed justification must be made to the satisfaction of the Director that wastewater treatment needs will be met based on past growth records and future growth projections and, as appropriate, shall include conservation plans or other specific measures to achieve waste flow reductions.

(2) Prior to exceeding 90 percent of the wastewater treatment, utilization, or disposal systems permitted hydraulic capacity, (based on the last calendar year), the permittee must obtain all permits needed for the expansion of the wastewater treatment, utilization, or disposal system and, if construction is needed, submit approvable final plans and specifications for expansion including a construction schedule. If expansion is not proposed or is proposed for a later date, a detailed justification must be made to the satisfaction of the Director that wastewater treatment needs will be met based on past growth records and future growth projections and, as appropriate, shall include conservation plans or other specific measures to achieve waste flow reductions.

(3) The Director shall allow permits to be issued to facilities that are exceeding the 80 percent or 90 percent loading rates if the additional flow is not projected to result in the facility exceeding its permitted hydraulic capacity, the facility is in compliance with all other permit limitations and requirements, and it is demonstrated to the satisfaction of the Director that adequate progress is being made in developing the needed engineering evaluations or plans and specifications. In determining the adequacy of the progress, the Director shall consider the projected flows, the complexity and scope of the work to be completed and any projected environmental impacts.

History Note: *Authority G.S. 143-215.3;*
Eff. September 1, 2006.

15A NCAC 02T .0119 RESERVED FOR FUTURE CODIFICATION

15A NCAC 02T .0120 HISTORICAL CONSIDERATION IN PERMIT APPROVAL

(a) The Division shall consider an applicant's compliance history in accordance with G.S. 143-215.1(b)(4)b.2. and with the requirements contained within this Rule for environmental permits and certifications issued under Article 21. Paragraph (b) of this Rule is a partial set of criteria for routine consideration under G.S. 143-215.1(b)(4)b.2. The Director may also consider other compliance information in determining compliance history.

(b) When any of the following apply, permits for new and expanding facilities shall not be granted, unless the Division determines that the permit is specifically and solely needed for the construction of facilities to resolve non-compliance with any environmental statute or rule:

(1) The applicant or any parent, subsidiary, or other affiliate of the applicant or parent has been convicted of environmental crimes under G.S. 143-215.6B or under Federal law that would otherwise be prosecuted under G.S. 143-215.6B where all appeals have been abandoned or exhausted.

(2) The applicant or any affiliation has previously abandoned a wastewater treatment facility without properly closing the facility in accordance with the permit or this Subchapter.

(3) The applicant or any affiliation has not paid a civil penalty where all appeals have been abandoned or exhausted.

(4) The applicant or any affiliation is currently not compliant with any compliance schedule in a permit, settlement agreement or order.

(5) The applicant or any affiliation has not paid an annual fee in accordance with Rule .0105(e)(2).

(c) Any variance to this Rule shall be approved by the Director and shall be based on the current compliance status of the permittee's facilities and the magnitude of previous violations. Variance approval shall not be delegated to subordinate staff.

History Note: *Authority G.S. 143-215.1(b); 143-215.3(a);*
Eff. September 1, 2006.

SECTION .0500 – WASTEWATER IRRIGATION SYSTEMS

15A NCAC 02T .0501 SCOPE

The rules in this Section apply to all surface irrigation of wastewater systems not otherwise specifically governed by other rules of this Subchapter. Surface irrigation of wastewater includes spray irrigation, drip irrigation, and any other application of wastewater to the ground surface.

History Note: Authority G.S. 143-215.1; 143-215.3(a);
Eff. September 1, 2006.

15A NCAC 02T .0502 RESERVED FOR FUTURE CODIFICATION

15A NCAC 02T .0503 RESERVED FOR FUTURE CODIFICATION

15A NCAC 02T .0504 APPLICATION SUBMITTAL

(a) The requirements in this Rule apply to all new and expanding facilities, as applicable.

(b) Soils Report. A soil evaluation of the disposal site shall be provided to the Division by the applicant in a report that includes the following. If required by G.S. 89F, a soil scientist shall prepare this evaluation:

[Note: The North Carolina Board for Licensing of Soil Scientists has determined, via letter dated December 1, 2005, that preparation of soils reports pursuant to this Paragraph constitutes practicing soil science under G.S. 89F.]

(1) Field description of soil profile, based on examinations of excavation pits or auger borings, within seven feet of land surface or to bedrock describing the following parameters by individual diagnostic horizons:
   - (A) thickness of the horizon;
   - (B) texture;
   - (C) color and other diagnostic features;
   - (D) structure;
   - (E) internal drainage;
   - (F) depth, thickness, and type of restrictive horizon(s); and
   - (G) presence or absence and depth of evidence of any seasonal high water table (SHWT).

   Applicants shall dig pits when necessary for evaluation of the soils at the site.

(2) Recommendations concerning loading rates of liquids, solids, other wastewater constituents and amendments. Annual hydraulic loading rates shall be based on in-situ measurement of saturated hydraulic conductivity in the most restrictive horizon for each soil mapping unit. Maximum irrigation precipitation rates shall be provided for each soil mapping unit.

(3) A field-delineated soil map delineating soil mapping units within each land application site and showing all physical features, location of pits and auger borings, legends, scale, and a north arrow. The legends shall also include dominant soil series name and family or higher taxonomic class for each soil mapping unit.

(4) A representative soils analysis (i.e., Standard Soil Fertility Analysis) conducted on each land application site. The Standard Soil Fertility Analysis shall include the following parameters:
   - (A) acidity,
   - (B) base saturation (by calculation),
   - (C) calcium,
   - (D) cation exchange capacity,
   - (E) copper,
   - (F) exchangeable sodium percentage (by calculation),
   - (G) magnesium,
   - (H) manganese,
   - (I) percent humic matter,
   - (J) pH,
   - (K) phosphorus,

(L) potassium,
(M) sodium, and
(N) zinc.

(c) Engineering design documents. If required by G.S. 89C, a professional engineer shall prepare these documents. The following documents shall be provided to the Division by the applicant:

[Note: The North Carolina Board of Examiners for Engineers and Surveyors has determined, via letter dated December 1, 2005, that preparation of engineering design documents pursuant to this Paragraph constitutes practicing engineering under G.S. 89C.]

(1) engineering plans for the entire system, including treatment, storage, application, and disposal facilities and equipment except those previously permitted unless those previously permitted are directly tied into the new units or are critical to the understanding of the complete process;
(2) specifications describing materials to be used, methods of construction, and means for ensuring quality and integrity of the finished product including leakage testing; and
(3) engineering calculations including hydraulic and pollutant loading for each treatment unit, treatment unit sizing criteria, hydraulic profile of the treatment system, total dynamic head and system curve analysis for each pump, buoyancy calculations, and irrigation design.

(d) Site plans. If required by G.S. 89C, a professional land surveyor shall provide location information on boundaries and physical features not under the purview of other licensed professions. Site plans or maps shall be provided to the Division by the applicant depicting the location, orientation and relationship of facility components including:

[Note: The North Carolina Board of Examiners for Engineers and Surveyors has determined, via letter dated December 1, 2005, that locating boundaries and physical features, not under the purview of other licensed professions, on maps pursuant to this Paragraph constitutes practicing surveying under G.S. 89C.]

(1) a scaled map of the site, with topographic contour intervals not exceeding 10 feet or 25 percent of total site relief and showing all facility-related structures and fences within the treatment, storage and disposal areas, and soil mapping units shown on all disposal sites;
(2) the location of all wells (including usage and construction details if available), streams (ephemeral, intermittent, and perennial), springs, lakes, ponds, and other surface drainage features within 500 feet of all waste treatment, storage, and disposal site(s) and delineation of the review and compliance boundaries;
(3) setbacks as required by Rule .0506 of this Section; and
(4) site property boundaries within 500 feet of all waste treatment, storage, and disposal site(s).

(e) A hydrogeologic description prepared by a Licensed Geologist, Licensed Soil Scientist, or Professional Engineer if required by Chapters 89E, 89F, or 89C respectively of the subsurface to a depth of 20 feet or bedrock, whichever is less, shall be provided to the Division by the applicant for systems treating industrial waste and any system with a design flow over 25,000 gallons per day. A greater depth of investigation is required if the respective depth is used in predictive calculations. This evaluation shall be based on borings for which the numbers, locations, and depths are sufficient to define the components of the hydrogeologic evaluation. In addition to borings, other techniques may be used to investigate the subsurface conditions at the site. These techniques may include geophysical well logs, surface geophysical surveys, and tracer studies. This evaluation shall be presented in a report that includes the following components:

[Note: The North Carolina Board for Licensing of Geologists, via letter dated April 6, 2006, North Carolina Board for Licensing of Soil Scientists, via letter dated December 1, 2005, and North Carolina Board of Examiners for Engineers and Surveyors, via letter dated December 1, 2005, have determined that preparation of hydrogeologic description documents pursuant to this Paragraph constitutes practicing geology under G.S. 89E, soil science under G.S. 89F, or engineering under G.S. 89C.]

(1) a description of the regional and local geology and hydrogeology;
(2) a description, based on field observations of the site, of the site topographic setting, streams, springs and other groundwater discharge features, drainage features, existing and abandoned wells, rock outcrops, and other features that may affect the movement of the contaminant plume and treated wastewater;
(3) changes in lithology underlying the site;
(4) depth to bedrock and occurrence of any rock outcrops;

(5) the hydraulic conductivity and transmissivity of the affected aquifer(s);
(6) depth to the seasonal high water table;
(7) a discussion of the relationship between the affected aquifers of the site to local and regional geologic and hydrogeologic features;
(8) a discussion of the groundwater flow regime of the site prior to operation of the proposed facility and post operation of the proposed facility focusing on the relationship of the system to groundwater receptors, groundwater discharge features, and groundwater flow media; and
(9) if the SHWT is within six feet of the surface, a mounding analysis to predict the level of the SHWT after wastewater application.

(f) Property Ownership Documentation shall be provided to the Division by the applicant consisting of:
(1) legal documentation of ownership (i.e., contract, deed or article of incorporation);
(2) written notarized intent to purchase agreement signed by both parties, accompanied by a plat or survey map; or
(3) written notarized lease agreement signed by both parties, specifically indicating the intended use of the property, as well as a plat or survey map. Lease agreements shall adhere to the requirements of 15A NCAC 02L .0107.

(g) Public utilities shall submit to the Division a Certificate of Public Conveyance and Necessity or a letter from the NC Utilities Commission stating that a franchise application has been received.

(h) A complete chemical analysis of the typical wastewater to be discharged shall be provided to the Division by the applicant for industrial waste, including Total Organic Carbon, 5-day Biochemical Oxygen Demand (BOD_5), Chemical Oxygen Demand (COD), Nitrate Nitrogen (NO_3-N), Ammonia Nitrogen (NH_3-N), Total Kjeldahl Nitrogen (TKN), pH, Chloride, Total Phosphorus, Phenol, Total Volatile Organic Compounds, Fecal Coliform, Calcium, Sodium, Magnesium, Sodium Adsorption Ratio (SAR), Total Trihalomethanes, Toxicity Test Parameters and Total Dissolved Solids.

(i) A project evaluation and a receiver site agronomic management plan (if applicable) and recommendations concerning cover crops and their ability to accept the proposed application rates of liquid, solids, minerals and other constituents of the wastewater shall be provided to the Division by the applicant.

(j) A residuals management plan as required by Rule .0508 of this Section shall be provided to the Division by the applicant. A written commitment is not required at the time of application; however, it must be provided to the Division prior to operation of the permitted system.

(k) A water balance shall be provided to the Division by the applicant that determines required effluent storage based upon the most limiting factor of the hydraulic loading based on either the most restrictive horizon or groundwater mounding analysis; or nutrient management based on either agronomic rates for the specified cover crop or crop management.

History Note: *Authority G.S. 143-215.1; 143-215.3(a);*
Eff. September 1, 2006.

15A NCAC 02T .0505 DESIGN CRITERIA

(a) The requirements in this Rule apply to all new and expanding facilities, as applicable.

(b) Minimum degree of treatment for new and expanding systems are as follows:
(1) For new municipal, domestic and commercial facilities, the minimum degree of treatment shall meet a monthly average of five-day Biochemical Oxygen Demand (BOD_5) $\leq$ 30 mg/L; Total Suspended Solids (TSS) $\leq$ 30 mg/L; Ammonia (NH_3) $\leq$ 15 mg/L; and Fecal Coliforms $\leq$ 200 colonies/100 ml.
(2) For expanding municipal, domestic, and commercial facilities except systems subject to Subparagraphs (b)(3) or (b)(4) of this Rule, facilities shall meet the limitation provided in Subparagraph (b)(1) of this Rule.
(3) For expanding municipal facilities, except those permitted as new under Subparagraph (b)(1) of this Rule, with lagoon treatment systems, the minimum degree of treatment shall meet a monthly average of five-day Biochemical Oxygen Demand (BOD_5) $\leq$ 60 mg/L; Total Suspended Solids (TSS) $\leq$ 90 mg/L; Fecal Coliforms $\leq$ 200 colonies/100 ml. No expanding facilities shall be permitted under this provision for any project whose application is received by the Division after December 31, 2011.

(4) For expanding municipal facilities whose application is received by the Division after December 31, 2011, except those permitted as new under Subparagraph (b)(1) of this Rule, with lagoon treatment systems, the minimum degree of treatment shall meet a monthly average of five-day Biochemical Oxygen Demand (BOD_5) ≤ 30 mg/L; Total Suspended Solids (TSS) ≤ 90 mg/L; Fecal Coliforms ≤ 200 colonies/100 ml.

(5) Treatment for other operations shall be based on producing the quality effluent used in documenting protection of surface water or groundwater standards.

(c) All wastes shall be applied at agronomic rates unless predictive calculations are provided that document State groundwater standards will be protected.

(d) All treatment/storage lagoons/ponds shall have at least two feet of freeboard.

(e) Waste, including treated waste, shall not be placed directly into, or in contact with, GA classified groundwater unless such placement will not result in a contravention of GA groundwater standards, as demonstrated by predictive calculations or modeling.

(f) Treatment works and disposal systems utilizing earthen basins, lagoons, ponds or trenches, excluding holding ponds containing non-industrial treated effluent prior to spray irrigation, for treatment, storage or disposal shall have either a liner of natural material at least one foot in thickness and having a hydraulic conductivity of no greater than 1×10^{-6} centimeters per second when compacted, or a synthetic liner of sufficient thickness to exhibit structural integrity and an effective hydraulic conductivity no greater than that of the natural material liner.

(g) The bottoms of earthen impoundments, trenches or other similar excavations shall be at least four feet above the bedrock surface, except that the bottom of excavations which are less than four feet above bedrock shall have a liner with a hydraulic conductivity no greater than 1×10^{-7} centimeters per second. Liner thickness shall be that thickness necessary to achieve a leakage rate consistent with the sensitivity of classified groundwaters. Liner requirements may be reduced if it can be demonstrated by the applicant through predictive calculations or modeling methods that construction and use of these treatment and disposal units will not result in contravention of surface water or groundwater standards.

(h) Impoundments, trenches or other excavations made for the purpose of storing or treating waste shall not be excavated into bedrock unless the placement of waste into such excavations will not result in a contravention of surface water or groundwater standards, as demonstrated by predictive calculations or modeling.

(i) Flow equalization of at least 25 percent of the facilities permitted hydraulic capacity must be provided for all seasonal or resort facilities and all other facilities with fluctuations in influent flow which may adversely affect the performance of the system.

(j) By-pass and overflow lines shall be prohibited.

(k) Multiple pumps shall be provided if pumps are used.

(l) Power reliability shall be provided consisting of:

(1) automatically activated standby power supply onsite, capable of powering all essential treatment units under design conditions; or

(2) approval by the Director that the facility:

(A) serves a private water distribution system which has automatic shut-off at power failure and no elevated water storage tanks,

(B) has sufficient storage capacity that no potential for overflow exists, and

(C) can tolerate septic wastewater due to prolonged detention.

(m) A water-tight seal on all treatment/storage units or minimum of two feet protection from 100-year flood shall be provided.

(n) Irrigation system design shall not exceed the recommended precipitation rates in the soils report prepared pursuant to Rule .0504 of this Section.

(o) A minimum of 30 days of residual storage shall be provided.

(p) Disposal areas shall be designed to maintain a one-foot vertical separation between the seasonal high water table and the ground surface.

(q) The public shall be prohibited access to the wetted irrigation area and treatment facilities.

(r) Influent pump stations shall meet the sewer minimum design criteria as provided in Section .0300 of this Subchapter.

(s) Septic tanks shall adhere to the standards established in 15A NCAC 18A .1900.

(t) The irrigation system shall be provided with a flow meter to allow accurate determination of the volume of treated wastewater applied to each field.

History Note: *Authority G.S. 143-215.1; 143-215.3(a);*
Eff. September 1, 2006.

15A NCAC 02T .0506 SETBACKS

(a) The setbacks for Irrigation sites shall be as follows:

	Spray	Drip
	(feet)	(feet)
Any habitable residence or place of public assembly under separate ownership or not to be maintained as part of the project site	400	100
Any habitable residence or place of public assembly owned by the permittee to be maintained as part of the project site	200	15
Any private or public water supply source	100	100
Surface waters (streams – intermittent and perennial, perennial waterbodies, and wetlands)	100	100
Groundwater lowering ditches (where the bottom of the ditch intersects the SHWT)	100	100
Surface water diversions (ephemeral streams, waterways, ditches)	25	25
Any well with exception of monitoring wells	100	100
Any property line	150	50
Top of slope of embankments or cuts of two feet or more in vertical height	15	15
Any water line from a disposal system	10	10
Subsurface groundwater lowering drainage systems	100	100
Any swimming pool	100	100
Public right of way	50	50
Nitrification field	20	20
Any building foundation or basement	15	15

(b) The setbacks for Treatment and storage units shall be as follows:

	(feet)
Any habitable residence or place of public assembly under separate ownership or not to be maintained as part of the project site	100
Any private or public water supply source	100
Surface waters (streams – intermittent and perennial, perennial waterbodies, and wetlands)	50
Any well with exception of monitoring wells	100
Any property line	50

(c) Achieving the reclaimed water effluent standards contained in 15A NCAC 02T .0906 shall permit the system to use the setbacks located in 15A NCAC 02T .0900 for property lines and the compliance boundary shall be at the irrigation area boundary.

(d) Setback waivers shall be written, notarized, signed by all parties involved and recorded with the County Register of Deeds. Waivers involving the compliance boundary shall be in accordance with 15A NCAC 02L .0107.

History Note: *Authority G.S. 143-215.1; 143-215.3(a);*
Eff. September 1, 2006.

15A NCAC 02T .0507 OPERATION AND MAINTENANCE PLAN

An operation and maintenance plan shall be maintained for all systems. The plan shall:

(1) describe the operation of the system in sufficient detail to show what operations are necessary for the system to function and by whom the functions are to be conducted;
(2) describe anticipated maintenance of the system;
(3) include provisions for safety measures including restriction of access to the site and equipment, as appropriate; and
(4) include spill control provisions including:
    (a) response to upsets and bypasses including control, containment, and remediation; and
    (b) contact information for plant personnel, emergency responders, and regulatory agencies.

History Note: *Authority G.S. 143-215.1; 143-215.3(a);*
Eff. September 1, 2006.

15A NCAC 02T .0508 RESIDUALS MANAGEMENT PLAN

A Residuals Management Plan shall be maintained for all systems that generate residuals. The plan must include the following:

(1) a detailed explanation as to how the residuals will be collected, handled, processed, stored and disposed;
(2) an evaluation of the residuals storage requirements for the treatment facility based upon the maximum anticipated residuals production rate and ability to remove residuals;
(3) a permit for residuals utilization, a written commitment to the Permittee of a Department approved residuals disposal/utilization program accepting the residuals which demonstrates that the approved program has adequate capacity to accept the residuals, or that an application for approval has been submitted; and
(4) if oil, grease, grit, or screenings removal and collection is a designed unit process, a detailed explanation as to how the oil/grease will be collected, handled, processed, stored and disposed.

History Note: *Authority G.S. 143-215.1; 143-215.3(a);*
Eff. September 1, 2006.

SUBCHAPTER 02U – RECLAIMED WATER

SECTION .0100 – GENERAL REQUIREMENTS

15A NCAC 02U .0101 PURPOSE

(a) The rules in this Subchapter apply to reclaimed water systems. This includes the generation and utilization of tertiary treated wastewater effluent meeting the standards in Rule .0301 of this Subchapter, used in a beneficial manner and for the purpose of conservation of the State's water resources by reducing the use of a water resource (potable water, surface water, groundwater).

(b) The disposal of treated wastewater effluent that does not serve in place of the use of a water resource is covered by Subchapter 02T of this Chapter.

(c) Reclaimed water utilization systems permitted pursuant to this Subchapter do not exempt any discharge to waters of the State from meeting the permitting requirements established by the National Pollutant Discharge Elimination System (NPDES) permitting program pursuant to G.S. 143-215.1 and 15A NCAC 02H .0100.

(c) Any use of reclaimed water for Aquifer Storage and Recovery shall be in accordance with G.S. 143-214.2.

(e) Requirements for closed-loop recycle systems are provided in Section .1000 of Subchapter 02T of this Chapter.

(f) The rules in this subchapter set forth the requirements and procedures for application and issuance of permits for the following reclaimed water systems:

(1) treatment works;
(2) utilization systems;
(3) bulk distribution programs; and
(4) local program approval.

History Note: Authority G.S. 143-215.1; 143-215.1(f); 143-215.3(a)(1); 143-355.5;
Eff. June 18, 2011.

15A NCAC 02U .0102 SCOPE

The rules in this Subchapter apply to all persons proposing to construct, alter, extend, or operate any reclaimed water treatment works or utilization system. The rules in this Section are general requirements that apply to all program rules (found in individual sections) in this Subchapter.

History Note: Authority G.S. 143-215.1; 143-215.3(a)(1);
Eff. June 18, 2011.

15A NCAC 02U .0103 DEFINITIONS

The terms used in this Subchapter are defined in G.S. 143-212 and 143-213, and 15A NCAC 02T .0103 except as provided in this Rule as follows:

(1) "Beneficial manner" means the use of water as a necessary part of an activity or process to which the water is being added.
(2) "Beneficial Reuse" means the utilization of reclaimed water in a beneficial manner and for the purpose of conservation of the State's water resources by reducing the use of other water resources (potable water, surface water, groundwater).
(3) "Conjunctive system" means a system where the reclaimed water option is not necessary to meet the wastewater disposal needs of the facility and where other wastewater utilization or disposal methods (e.g., NPDES permit) are available to the facility at all times.
(4) "Direct contact irrigation" means application methods that result in the direct contact of reclaimed water on the portion of the crop intended for human consumption.
(5) "Five-day side stream detention pond" means a basin capable of holding five days worth of treatment plant effluent (permitted flow capacity) in the event that the reclaimed water does not meet the required quality standards for the approved use.
(6) "Indirect contact irrigation" means application methods that will preclude direct contact of reclaimed water on the portion of the crop intended for human consumption.
(7) "Net environmental benefit" associated with wetlands augmentation sites is documented evidence supporting continued maintenance of natural conditions, and the protection of endangered species as required in Rule .0105(c)(10) of this Section. Wetland augmentation systems shall provide

documentation of the protection of existing wetland uses in accordance with 15A NCAC 02B .0201(f) and .0231 and shall not result in net degradation of the wetland.

(8) "Reclaimed Water" means treated wastewater effluent, meeting effluent standards established pursuant to Rule .0301 of this Subchapter, and used for beneficial reuse.

History Note: Authority G.S. 143-213; 143-215.3(a)(1);
Eff. June 18, 2011.

15A NCAC 02U .0104 ACTIVITIES WHICH REQUIRE A PERMIT

No person shall do any of the things or carry out any of the activities contained in G.S. 143-215.1(a) until or unless the person has applied for and received a permit from the Division (or if appropriate a local program approved by the Division pursuant to this Subchapter) and has complied with the conditions prescribed in the permit or is deemed permitted by rules in this Subchapter.

History Note: Authority G.S. 143-215.1; 143-215.3(a)(1);
Eff. June 18, 2011.

15A NCAC 02U .0105 GENERAL REQUIREMENTS

General requirements shall be in accordance with 15A NCAC 02T .0105.

History Note: Authority G.S. 143-215.1; 143-215.3(a);
Eff. June 18, 2011.

15A NCAC 02U .0106 SUBMISSION OF PERMIT APPLICATIONS

Submission of permit applications shall be in accordance with 15A NCAC 02T .0106.

History Note: Authority G.S. 143-215.3(a)(1); 143-215.1;
Eff. June 18, 2011.

15A NCAC 02U .0107 STAFF REVIEW AND PERMIT PREPARATION

Staff review and permit preparation shall be in accordance with 15A NCAC 02T .0107.

History Note: Authority G.S. 143-215.1(b); 143-215.1(d); 143-215.3(a)(1); 143-215.3(a)(4);
Eff. June 18, 2011.

15A NCAC 02U .0108 FINAL ACTION ON PERMIT APPLICATIONS TO THE DIVISION

Final action on permit applications to the Division shall be in accordance with 15A NCAC 02T .0108.

History Note: Authority G.S. 143-215.1(a); 143-215.1(b); 143-215.1(d); 143-215.3(a)(1);
Eff. June 18, 2011.

15A NCAC 02U .0109 PERMIT RENEWALS

Requests for permit renewals shall be submitted to the Director at least 180 days prior to expiration unless the permit has been revoked by the Director in accordance with Rule .0110 of this Section or a request has been made to rescind the permit. Renewal requests shall be made in accordance with Rule .0105 and Rule .0106 of this Section.

History Note: Authority G.S. 143-215.3(a)(1);
Eff. June 18, 2011.

15A NCAC 02U .0110 MODIFICATION AND REVOCATION OF PERMITS

Modification and revocation of permits shall be in accordance with 15A NCAC 02T .0110.

History Note: Authority G.S. 143-215.1(b)(2.); 143-215.3(a)(1);
Eff. June 18, 2011.

15A NCAC 02U .0111 CONDITIONS FOR ISSUING GENERAL PERMITS
Conditions for issuing general permits are established in 15A NCAC 02T .0111.

History Note: Authority G.S. 143-215.1; 143-215.3(a)(1); 143-215.10C; Eff. June 18, 2011.

15A NCAC 02U .0112 DELEGATION OF AUTHORITY
Delegation of authority shall be in accordance with 15A NCAC 02T .0112.

History Note: Authority G.S. 143-215.3(a)(1); 143-215.3(a)(4); Eff. June 18, 2011.

15A NCAC 02U .0113 PERMITTING BY REGULATION (SEE S.L. 2011-48)
(a) The following utilizations of reclaimed water are deemed to be permitted pursuant to G.S. 143-215.1(b) and it is not necessary for the Division to issue individual permits or coverage under a general permit for construction or operation of the following utilization systems provided the system does not result in any violations of surface water or groundwater standards, there is no unpermitted direct discharge to surface waters, and all criteria required for the specific system is met:

(1) Discharges to the land surface from flushing and hydrostatic testing water associated with utility distribution systems, new sewer extensions or new reclaimed water distribution lines;
(2) Overflow from elevated reclaimed water storage facilities where no viable alternative exists and all possible measures are taken to reduce the risk of overflow;
(3) Any de minimus runoff from reclaimed water used during fire fighting or extinguishing, dust control, soil compaction for construction purposes, street sweeping, overspray on yard inlets, overspray on golf cart paths, or vehicle washing provided the use is approved in a permit issued by the Division;
(4) Incidental discharge to a municipal separate storm sewer system (MS4) that occurs as a result of reclaimed water utilization activities provided the use is approved in a permit issued by the Division, and the discharge does not violate water quality standards. This does not exempt the reclaimed water user from complying with any applicable local ordinances that may prohibit such discharges;
(5) Rehabilitation, repair, or replacement of reclaimed water lines in kind (i.e., size) with the same horizontal and vertical alignment;
(6) In accordance with 15A NCAC 02H .0106(f)(5), flushing (including air release valve discharge) and hydrostatic testing water discharges associated with reclaimed water distribution systems provided that no water quality standards are violated;
(7) Utilization of reclaimed water received from a reclaimed water bulk distribution program permitted under Rule .0601 of this Subchapter;
(8) Irrigation of residential lots or commercial (non-residential) application areas less than one acre in size that are supplied with reclaimed water as part of a conjunctive use reclaimed water system meeting the requirements of Rules .0301, .0401, .0403, .0501, and .0701 of this Subchapter; Chapter 89G of the General Statutes; approved by the local building inspection department; and installed by a North Carolina Licensed Irrigation Contractor pursuant to G.S. 89G. A scaled site map showing the location of the reclaimed water irrigation system and all features necessary to show compliance with applicable setbacks in Rule .0701 of this Subchapter shall be submitted to the reclaimed water provider;
(9) Irrigation of agricultural crops supplied with reclaimed water as part of a conjunctive use reclaimed water system meeting the requirements of this Subchapter and approved by the reclaimed water provider; and
(10) Drip irrigation sites supplied with reclaimed water as part of a conjunctive use reclaimed water system generated from an onsite wastewater treatment facility meeting the criteria of this Subchapter and where the conjunctive system has been approved by the Department and is permitted under 18A .1900.

(b) Nothing in this Rule shall be deemed to allow the violation of any assigned surface water, groundwater, or air quality standards, and in addition any such violation is a violation of a condition of a permit.

(c) The reclaimed water user shall report any violation of this Rule or discharge to surface waters from the utilization systems listed in Paragraph (a) of this Rule.
(d) Utilization systems deemed permitted under this Subchapter shall remain deemed permitted, notwithstanding any violations of surface water or groundwater standards or violations of this Rule or other Permitted By Regulation rules in this Subchapter, until such time as the Director determines that they should not be deemed permitted in accordance with the criteria established in this Rule.
(e) The Director may determine that a utilization system should not be deemed to be permitted in accordance with this Rule and require the utilization system to obtain an individual permit or a certificate of coverage under a general permit. This determination shall be made based on existing or projected environmental impacts, compliance with the provisions of this Rule and the compliance history of the facility owner.

History Note: Authority G.S. 130A-300; 143-215.1(a)(1); 143-215.1(b)(4)(e); 143-215.3(a),(d);
Eff. June 18, 2011 (See S.L. 2011-48).

15A NCAC 02U .0114 WASTEWATER DESIGN FLOW RATES
Wastewater design flow rates shall be determined pursuant to 15A NCAC 02T .0114.

History Note: Authority G.S. 143-215.1; 143-215.3(a)(1);
Eff. June 18, 2011.

15A NCAC 02U .0115 OPERATIONAL AGREEMENTS
Operational agreements shall be completed pursuant to 15A NCAC 02T .0115.

History Note: Authority G.S. 143-215.1(d1);
Eff. June 18, 2011.

15A NCAC 02U .0116 CERTIFICATION OF COMPLETION
Certification of completion shall be completed pursuant to 15A NCAC 02T .0116.

History Note: Authority G.S. 143-215.1;
Eff. June 18, 2011.

15A NCAC 02U .0117 TREATMENT FACILITY OPERATION AND MAINTENANCE
Treatment facility operation and maintenance shall be completed pursuant to 15A NCAC 02T .0117.

History Note: Authority G.S. 143-215.3;
Eff. June 18, 2011.

15A NCAC 02U .0120 HISTORICAL CONSIDERATION IN PERMIT APPROVAL
Historical consideration in permit approval shall be in accordance with 15A NCAC 02T .0120.

History Note: Authority G.S. 143-215.1(b); 143-215.3(a);
Eff. June 18, 2011.

SECTION .0200 - APPLICATION REQUIREMENTS

15A NCAC 02U .0201 APPLICATION SUBMITTAL – CONJUNCTIVE SYSTEMS
(a) The requirements in this Rule apply to all new and expanding conjunctive facilities, as applicable.
(b) A soil evaluation of the utilization site where the reclaimed water is applied to the land surface or otherwise used in a ground absorption manner shall be provided to the Division by the applicant. Evaluations shall include recommended loading rates of liquids, solids, and other constituents. For systems that utilize reclaimed water through irrigation, the evaluation shall also include recommended maximum irrigation precipitation rates. If required by G.S. 89F, a soil scientist shall prepare this evaluation.
[Note: The North Carolina Board for Licensing of Soil Scientists has determined, via letter dated December 1, 2005, that preparation of soils reports pursuant to this Paragraph constitutes practicing soil science under G.S. 89F.]

(c) Engineering design documents. If required by G.S. 89C, a professional engineer shall prepare engineering design documents. The following documents shall be provided to the Division by the applicant:

(1) engineering plans for the entire system, including treatment, storage, application, and utilization facilities and equipment except those previously permitted unless those previously permitted are directly tied into the new units or are critical to the understanding of the complete process;

(2) specifications describing materials to be used, methods of construction, and means for ensuring quality and integrity of the finished product including leakage testing; and

(3) engineering calculations including hydraulic and pollutant loading for each treatment unit, treatment unit sizing criteria, hydraulic profile of the treatment system, total dynamic head and system curve analysis for each pump, buoyancy calculations, and irrigation design.

[Note: The North Carolina Board of Examiners for Engineers and Surveyors has determined, via letter dated December 1, 2005, that preparation of engineering design documents pursuant to this Paragraph constitutes practicing engineering under G.S. 89C. In addition, the North Carolina Board of Examiners for Engineers and Surveyors has determined that design of residential reclaimed irrigations systems owned by the property owner does not constitute engineering under G.S. 89C.]

(d) Site plans. If required by G.S. 89C, a professional land surveyor shall provide location information on boundaries and physical features not under the purview of other licensed professions. The applicant shall provide site plans or maps for treatment and storage facilities and where the reclaimed water is applied to the land surface or otherwise used in a ground absorption manner, except where reclaimed water is utilized for irrigation to single-family residential lots, showing the location, orientation and relationship of facility components including:

(1) a scaled map of the site showing all facility-related structures and fences within the treatment, storage, and utilization areas;

(2) for land application sites and other ground absorption uses, the site map shall include topography; and

(3) to the extent needed to determine compliance with setbacks, the location of all features included in Rule .0701 of this Subchapter.

[Note: The North Carolina Board of Examiners for Engineers and Surveyors has determined, via letter dated December 1, 2005, that locating boundaries and physical features, not under the purview of other licensed professions, on maps pursuant to this Paragraph constitutes practicing surveying under G.S. 89C.]

(e) The applicant shall provide property ownership documentation to the Division consisting of:

(1) legal documentation of ownership (e.g., contract, deed or article of incorporation);

(2) written notarized intent to purchase agreement signed by both parties, accompanied by a plat or survey map;

(3) an easement running with the land indicating the intended use of the property and meeting the condition of 15A NCAC 02L .0107(f); or

(4) written notarized lease agreement signed by both parties, indicating the intended use of the property, as well as a plat or survey map. When this Subparagraph is utilized to document property ownership, groundwater standards must be met across the entire site and a compliance boundary need not be provided.

(f) Public utilities shall submit a Certificate of Public Convenience and Necessity or a letter from the NC Utilities Commission to the Division stating that a franchise application has been received.

(g) The applicant shall provide a complete chemical analysis of the typical reclaimed water to be utilized for industrial waste. The analysis shall include:

(1) Total Organic Carbon;

(2) 5-day Biochemical Oxygen Demand (BOD5);

(3) Chemical Oxygen Demand (COD);

(4) Nitrate Nitrogen (NO3-N);

(5) Ammonia Nitrogen (NH3-N);

(6) Total Kjeldahl Nitrogen (TKN);

(7) pH;

(8) Chloride;

(9) Total Phosphorus;

(10) Phenol;

(11) Total Volatile Organic Compounds;

(12) Escherichia coli (E.coli) or Fecal Coliform;

(13) Coliphage (Type 2 reclaimed water only);

(14) Clostridium perfringens (Type 2 reclaimed water only);
(15) Calcium;
(16) Sodium;
(17) Magnesium;
(18) Sodium Adsorption Ratio (SAR);
(19) Total Trihalomethanes;
(20) Toxicity Test Parameters; and
(21) Total Dissolved Solids.

(h) For irrigation sites, the applicant shall provide to the Division a project evaluation and a receiver site agronomic management plan and recommendations concerning cover crops and their ability to accept the proposed application rates of liquid, solids, minerals and other constituents of the wastewater.

History Note: Authority G.S. 143-215.1; 143-215.3(a);
Eff. June 18, 2011.

15A NCAC 02U .0202 APPLICATION SUBMITTAL – NON-CONJUNCTIVE SYSTEMS

(a) The requirements in this Rule apply to all new and expanding non-conjunctive facilities, as applicable.

(b) Soils Report. A soil evaluation of the utilization site shall be provided to the Division by the applicant. If required by G.S. 89F, a soil scientist shall prepare this evaluation. This evaluation shall be presented in a report that includes the following:

(1) Field description of soil profile, based on examinations of excavation pits and auger borings, within seven feet of land surface or to bedrock describing the following parameters by individual diagnostic horizons:
   (A) thickness of the horizon;
   (B) texture;
   (C) color and other diagnostic features;
   (D) structure;
   (E) internal drainage;
   (F) depth, thickness, and type of restrictive horizon(s); and
   (G) presence or absence and depth of evidence of any seasonal high water table (SHWT);
   Applicants shall dig pits when necessary for proper evaluation of the soils at the site;
(2) Recommendations concerning loading rates of liquids, solids, other wastewater constituents and amendments; annual hydraulic loading rates shall be based on in-situ measurement of saturated hydraulic conductivity in the most restrictive horizon for each soil mapping unit; maximum irrigation precipitation rates shall be provided for each soil mapping unit;
(3) A soil map delineating soil mapping units within each land application site and showing all physical features, location of pits and auger borings, legends, scale, and a north arrow; and
(4) A representative soils analysis (i.e., Standard Soil Fertility Analysis) conducted on each land application site. The Standard Soil Fertility Analysis shall include the following parameters:
   (A) acidity;
   (B) base saturation (by calculation);
   (C) calcium;
   (D) cation exchange capacity;
   (E) copper:
   (F) exchangeable sodium percentage (by calculation);
   (G) magnesium;
   (H) manganese;
   (I) percent humic matter;
   (J) pH;
   (K) phosphorus;
   (L) potassium;
   (M) sodium; and
   (N) zinc.

[Note: The North Carolina Board for Licensing of Soil Scientists has determined, via letter dated December 1, 2005, that preparation of soils reports pursuant to this Paragraph constitutes practicing soil science under G.S. 89F.]

(c) Engineering design documents. If required by G.S. 89C, a professional engineer shall prepare these documents. The applicant shall provide the following documents to the Division:

(1) engineering plans for the entire system, including treatment, storage, application, and utilization facilities and equipment except those previously permitted unless those previously permitted are directly tied into the new units or are critical to the understanding of the complete process;

(2) specifications describing materials to be used, methods of construction, and means for ensuring quality and integrity of the finished product including leakage testing; and

(3) engineering calculations including hydraulic and pollutant loading for each treatment unit, treatment unit sizing criteria, hydraulic profile of the treatment system, total dynamic head and system curve analysis for each pump, buoyancy calculations, and irrigation design.

[Note: The North Carolina Board of Examiners for Engineers and Surveyors has determined, via letter dated December 1, 2005, that preparation of engineering design documents pursuant to this Paragraph constitutes practicing engineering under G.S. 89C. In addition, the North Carolina Board of Examiners for Engineers and Surveyors has determined that design of residential reclaimed irrigations systems owned by the property owner does not constitute engineering under G.S. 89C.]

(d) Site plans. If required by G.S. 89C, a professional land surveyor shall provide location information on boundaries and physical features not under the purview of other licensed professions. The applicant shall provide site plans or maps to the Division where the reclaimed water is applied to the land surface or otherwise used in a ground absorption manner depicting the location, orientation and relationship of facility components including:

(1) a scaled map of the site, with topographic contour intervals not exceeding 10 feet or 25 percent of total site relief and showing all facility-related structures and fences within the treatment, storage and utilization areas, soil mapping units shown on all utilization sites;

(2) the location of all wells (including usage and construction details if available), streams (ephemeral, intermittent, and perennial), springs, lakes, ponds, and other surface drainage features within 500 feet of all waste treatment, storage, and utilization site(s) and delineation of the review and compliance boundaries;

(3) setbacks as required by Rule .0701 of this Subchapter; and

(4) site property boundaries within 500 feet of all waste treatment, storage, and utilization site(s).

[Note: The North Carolina Board of Examiners for Engineers and Surveyors has determined, via letter dated December 1, 2005, that locating boundaries and physical features, not under the purview of other licensed professions, on maps pursuant to this Paragraph constitutes practicing surveying under G.S. 89C.]

(e) A hydrogeologic description prepared by a Licensed Geologist, License Soil Scientist, or Professional Engineer if required by Chapters 89E, 89F, or 89C respectively of the subsurface to a depth of 20 feet or bedrock, whichever is less, shall be provided to the Division by the applicant for systems treating industrial waste and any system with a design flow of over 25,000 gallons per day. A greater depth of investigation is required if the respective depth is used in predictive calculations. This evaluation shall be based on borings for which the numbers, locations, and depths are sufficient to define the components of the hydrogeologic evaluation. In addition to borings, other techniques may be used to investigate the subsurface conditions at the site. These techniques may include geophysical well logs, surface geophysical surveys, and tracer studies. This evaluation shall be presented in a report that includes the following components:

(1) a description of the regional and local geology and hydrogeology based on research of literature for the area;

(2) a description, based on field observations of the site, of the site topographic setting, streams, springs and other groundwater discharge features, drainage features, existing and abandoned wells, rock outcrops, and other features that may affect the movement of the contaminant plume and treated wastewater;

(3) changes in lithology underlying the site;

(4) depth to bedrock and occurrence of any rock outcrops;

(5) the hydraulic conductivity and transmissivity of the affected aquifer(s);

(6) depth to the seasonal high water table;

(7) a discussion of the relationship between the affected aquifers of the site to local and regional geologic and hydrogeologic features;

(8) a discussion of the groundwater flow regime of the site prior to operation of the proposed facility and post operation of the proposed facility focusing on the relationship of the system to groundwater receptors, groundwater discharge features, and groundwater flow media; and

(9) if the SHWT is within six feet of the surface, a mounding analysis to predict the level of the SHWT after wastewater application.

[Note: The North Carolina Board for Licensing of Geologists, via letter dated April 6, 2006, North Carolina Board for Licensing of Soil Scientists, via letter dated December 1, 2005, and North Carolina Board of Examiners for Engineers and Surveyors, via letter dated December 1, 2005, have determined that preparation of hydrogeologic description documents pursuant to this Paragraph constitutes practicing geology under G.S. 89E, soil science under G.S. 89F, or engineering under G.S. 89C.]

(f) The applicant shall provide property ownership documentation to the Division consisting of:

(1) legal documentation of ownership (i.e., contract, deed or article of incorporation);

(2) written notarized intent to purchase agreement signed by both parties, accompanied by a plat or survey map;

(3) an easement running with the land specifically indicating the intended use of the property and meeting the condition of 15A NCAC 02L .0107(f); or

(4) written notarized lease agreement signed by both parties, indicating the intended use of the property, as well as a plat or survey map. Groundwater standards shall be met across the entire site, and a compliance boundary shall not be provided.

(g) Public utilities shall submit a Certificate of Public Convenience and Necessity or a letter from the NC Utilities Commission stating that a franchise application has been received.

(h) The applicant shall provide to the Division a complete chemical analysis of the typical reclaimed water to be utilized for industrial waste. The analysis shall include:

(1) Total Organic Carbon;

(2) 5-day Biochemical Oxygen Demand (BOD5);

(3) Chemical Oxygen Demand (COD);

(4) Nitrate Nitrogen (NO3-N);

(5) Ammonia Nitrogen (NH3-N);

(6) Total Kjeldahl Nitrogen (TKN);

(7) pH;

(8) Chloride;

(9) Total Phosphorus;

(10) Phenol;

(11) Total Volatile Organic Compounds;

(12) Escherichia coli (E. coli) or Fecal Coliform;

(13) Coliphage (Type 2 reclaimed water only);

(14) Clostridium perfringens (Type 2 reclaimed water only);

(15) Calcium;

(16) Sodium;

(17) Magnesium;

(18) Sodium Adsorption Ratio (SAR);

(19) Total Trihalomethanes;

(20) Toxicity Test Parameters; and

(21) Total Dissolved Solids.

(i) For irrigation sites, the applicant shall provide to the Division a project evaluation and a receiver site agronomic management plan and recommendations concerning cover crops and their ability to accept the proposed application rates of liquid, solids, minerals and other constituents of the wastewater.

(j) The applicant shall provide to the Division a residuals management plan as required by Rule .0802 of this Subchapter. A written commitment is not required at the time of application; however, it shall be provided prior to operation of the permitted system.

(k) The applicant shall provide a water balance to the Division that determines required storage based upon the most limiting factor of the hydraulic loading based on either the most restrictive horizon or groundwater mounding analysis; or nutrient management based on either agronomic rates for a specified cover crop or crop management requirements.

History Note: *Authority G.S. 143-215.1; 143-215.3(a);*
Eff. June 18, 2011.

SECTION .0300 - EFFLUENT STANDARDS

15A NCAC 02U .0301 RECLAIMED WATER EFFLUENT STANDARDS

(a) Reclaimed water treatment processes classified as Type 2 by the rules in this Subchapter shall produce a tertiary quality effluent (filtered or equivalent) prior to storage, distribution, or utilization that meets the parameter limits listed below:

(1) monthly average BOD_5 of less than or equal to 5 mg/l and a daily maximum BOD_5 of less than or equal to 10 mg/l;

(2) monthly average TSS of less than or equal to 5 mg/l and a daily maximum TSS of less than or equal to 10 mg/l;

(3) monthly average NH_3 of less than or equal to 1 mg/l and a daily maximum NH_3 of less than or equal to 2 mg/l;

(4) monthly geometric mean Escherichia coli (E. coli) or fecal coliform level of less than or equal to 3/100 ml and a daily maximum E. coli or fecal coliform level of less than or equal to 25/100 ml;

(5) monthly geometric mean Coliphage level of less than or equal to 5/100 ml and a daily maximum Coliphage level of less than or equal to 25/100 ml;

(6) monthly geometric mean Clostridium perfringens level of less than or equal to 5/100 ml and a daily maximum Clostridium perfingen level of less than or equal to 25/100 ml; and

(7) maximum Turbidity of 5 Nephelometric Turbidity Units (NTUs).

(b) Reclaimed water treatment processes classified as Type 1 by the rules in this Subchapter shall produce a tertiary quality effluent (filtered or equivalent) prior to storage, distribution, or utilization that meets the parameter limits listed below:

(1) monthly average BOD_5 of less than or equal to 10 mg/l and a daily maximum BOD_5 of less than or equal to 15 mg/l;

(2) monthly average TSS of less than or equal to 5 mg/l and a daily maximum TSS of less than or equal to 10 mg/l;

(3) monthly average NH_3 of less than or equal to 4 mg/l and a daily maximum NH_3 of less than or equal to 6 mg/l;

(4) monthly geometric mean E. coli or fecal coliform level of less than or equal to 14/100 ml and a daily maximum E. coli or fecal coliform level of less than or equal to 25/100 ml; and

(5) maximum Turbidity of 10 NTUs.

(c) Reclaimed water produced by industrial facilities are not required to meet the criteria in this Rule if the reclaimed water is used at the facility in an industrial process and the area of use has no public access and does not result in employee exposure.

History Note: Authority G.S. 143-215.1; 143-215.3(a.);
Eff. June 18, 2011.

SECTION .0401 - DESIGN STANDARDS

15A NCAC 02U .0401 DESIGN CRITERIA FOR WASTEWATER TREATMENT FACILITIES - CONJUNCTIVE SYSTEMS

(a) The requirements in this Rule apply to all new and expanding conjunctive facilities, as applicable.

(b) Continuous on-line monitoring and recording for turbidity or particle count and flow shall be provided prior to storage, distribution or utilization.

(c) Effluent from the treatment facility shall not be discharged to the storage, distribution or utilization system if either the turbidity exceeds 10 NTUs or if the permitted pathogen levels cannot be met. The facility shall have the ability to utilize alternate wastewater management options when the effluent quality is not sufficient.

(d) An automatically activated standby power source or other means to prevent improperly treated wastewater from entering the storage, distribution or utilization system shall be provided.

(e) The permit shall require an operator certified by the Water Pollution Control System Operators Certification Commission (WPCSOCC) of a grade equivalent or greater than the facility classification to be on call 24 hours per day.

(f) No storage facilities are required as long as it can be demonstrated that other permitted means of disposal are available if 100 percent of the reclaimed water cannot be utilized. When provided, storage basins shall meet the design requirements in Rule .0402(g) of this Section.

(g) Reclaimed water irrigation system design shall not exceed the recommended precipitation rates in the soils report prepared pursuant to Rule .0201 of this Subchapter. Single family residential irrigation systems and commercial (non-residential) irrigation systems less than one acre in size that are permitted by regulation under Rule .0113(8) of this Subchapter do not require preparation of a soils report.
(h) Type 2 reclaimed water treatment facilities shall provide dual disinfection systems containing UV disinfection and chlorination or equivalent dual disinfection processes to meet pathogen control requirements.
(i) Type 2 reclaimed water treatment facilities shall provide documentation that the combined treatment and disinfection processes are capable of the following:

(1) log 6 or greater reduction of E. coli;
(2) log 5 or greater reduction of Coliphage; and
(3) log 4 or greater reduction of Clostridium perfringens.

History Note: Authority G.S. 143-215.1; 143-215.3(a);
Eff. June 18, 2011.

15A NCAC 02U .0402 DESIGN CRITERIA FOR WASTEWATER TREATMENT FACILITIES – NON-CONJUNCTIVE SYSTEMS

(a) The requirements in this Rule apply to all new and expanding non-conjunctive facilities, as applicable.
(b) Aerated flow equalization facilities shall be provided with a capacity based upon either a representative diurnal hydrograph or at least 25 percent of the daily system design flow.
(c) Dual facilities shall be provided for all essential treatment units.
(d) Continuous on-line monitoring and recording for turbidity or particle count and flow shall be provided prior to storage, distribution, or utilization.
(e) Effluent from the treatment facility shall be discharged to a five-day side-stream detention pond if either the turbidity exceeds 10 NTUs or if the permitted pathogen levels cannot be met. The facility shall have the ability to return the effluent in the five-day side-stream detention pond back to the head of the treatment facility.
(f) There shall be no public access to the wastewater treatment facility or the five-day side-stream detention pond. The five-day side-stream detention pond shall have either a liner of natural material at least one foot in thickness and having a hydraulic conductivity of no greater than 1×10^{-6} centimeters per second when compacted, or a synthetic liner of sufficient thickness to exhibit structural integrity and an effective hydraulic conductivity no greater than that required of the natural material liner. Liner requirements of the five-day side-stream detention pond or separation distances between the bottom of the five-day side-stream detention pond and the groundwater table may be reduced if it can be demonstrated by predictive calculations or modeling methods that satisfy the Director, that construction and use of the five-day side-stream detention pond will not result in contravention of assigned groundwater standards at the compliance boundary.
(g) The storage basin shall have either a liner of natural material at least one foot in thickness and having a hydraulic conductivity of no greater than 1×10^{-6} centimeters per second when compacted, or a synthetic liner of sufficient thickness to exhibit structural integrity and an effective hydraulic conductivity no greater than that required of the natural material liner. Liner requirements of the storage basin or separation distances between the bottom of storage basin and the groundwater table may be reduced if it can be demonstrated by predictive calculations or modeling methods that satisfy the Director, that construction and use of the storage basin will not result in contravention of assigned groundwater standards at the compliance boundary.
(h) Automatically activated standby power supply onsite, capable of powering all essential treatment units under design conditions shall be provided.
(i) The permit shall require an operator certified by the Water Pollution Control System Operators Certification Commission (WPCSOCC) of a grade equivalent or greater than the facility classification to be on call 24 hours per day.
(j) By-pass and overflow lines are prohibited.
(k) Multiple pumps shall be provided if pumps are used.
(l) A water-tight seal on all treatment/storage units or minimum of two feet protection from 100-year flood shall be provided.
(m) Reclaimed water irrigation system design shall not exceed the recommended precipitation rates in the soils report prepared pursuant to Rule .0202 of this Subchapter.
(n) A minimum of 30 days of residual storage shall be provided.
(o) Utilization areas shall be designed to maintain a one-foot vertical separation between the seasonal high water table and the ground surface.

(p) Influent pump stations shall meet the sewer minimum design criteria as provided in 15A NCAC 02T .0300.
(q) Type 2 reclaimed water treatment facilities shall provide dual disinfection systems containing UV disinfection or equivalent and chlorination or equivalent to provide pathogen control.
(r) Type 2 reclaimed water treatment facilities shall provide documentation that the combined treatment and disinfection processes are capable of the following:

(1) log 6 or greater reduction of E. coli;
(2) log 5 or greater reduction of Coliphage; and
(3) log 4 or greater reduction of Clostridium perfringens.

History Note: Authority G.S. 143-215.1; 143-215.3(a);
Eff. June 18, 2011.

15A NCAC 02U .0403 DESIGN CRITERIA FOR DISTRIBUTION LINES (SEE S.L. 2011-218)

(a) The requirements in this Rule apply to all new distribution lines.
(b) All reclaimed water valves, storage facilities and outlets shall be tagged or labeled to warn the public or employees that the water is not intended for drinking.
(c) All reclaimed water piping, valves, outlets and other appurtenances shall be color-coded, taped, or otherwise marked to identify the source of the water as being reclaimed water as follows:

(1) All reclaimed water piping and appurtenances shall be either colored purple (Pantone 522 or equivalent) and embossed or integrally stamped or marked "CAUTION: RECLAIMED WATER - DO NOT DRINK" or be installed with a purple (Pantone 522 or equivalent) identification tape or polyethylene vinyl wrap. The warning shall be stamped on opposite sides of the pipe and repeated every three feet or less;
(2) Identification tape shall be at least three inches wide and have white or black lettering on purple (Pantone 522 or equivalent) field stating "CAUTION: RECLAIMED WATER - DO NOT DRINK". Identification tape shall be installed on top of reclaimed water pipelines, fastened at least every 10 feet to each pipe length and run continuously the entire length of the pipe; and
(3) Existing underground distribution systems retrofitted for the purpose of utilizing reclaimed water shall be taped or otherwise identified as in Subparagraphs (1) or (2) of this Paragraph. This identification need not extend the entire length of the distribution system but shall be incorporated within 10 feet of crossing any potable water supply line or sanitary sewer line.

(d) All reclaimed water valves and outlets shall be of a type, or secured in a manner, that permits operation by personnel authorized by the entity that operates the reclaimed water system.
(e) Hose bibs shall be located in locked, below grade vaults that shall be labeled as being of nonpotable quality. As an alternative to the use of locked vaults with standard hose bib services, other locking mechanisms such as hose bibs which can only be operated by a tool may be placed above ground and labeled as nonpotable water.
(f) Cross-Connection Control

(1) There shall be no direct cross-connections between the reclaimed water and potable water systems;
(2) Where both reclaimed water and potable water are supplied to a reclaimed water use area in residential or commercial (irrigation) applications, a dual check valve device (or a device providing equal or better protection) shall be installed at the potable water service connection to the use area;
(3) Where both reclaimed water and potable water are supplied to a reclaimed water use area in industrial or commercial (non-irrigation) applications, a reduced pressure principle backflow prevention device or an approved air gap separation pursuant to 15A NCAC 18C shall be installed at the potable water service connection to the use area; and
(4) Where potable water is used to supplement a reclaimed water system, there shall be an air gap separation, approved and regularly inspected by the potable water supplier, between the potable water and reclaimed water systems.

(g) Irrigation system piping shall be considered part of the distribution system for the purposes of this Rule.
(h) Reclaimed water distribution lines shall be located 10 feet horizontally from and 18 inches below any water line where practicable. Where these separation distances can not be met, the piping and integrity testing procedures shall meet water main standards in accordance with 15A NCAC 18C.

(i) Reclaimed water distribution lines shall not be less than 50 feet from a well unless the piping and integrity testing procedures meet water main standards in accordance with 15A NCAC 18C, but in no case shall they be less than 25 feet from a private well.
(j) Reclaimed water distribution lines shall meet the separation distances to sewer lines in accordance with 15A NCAC 02T .0305.

History Note: Authority G.S. 143-215.1; 143-215.3(a.);
Eff. June 18, 2011 (S.L. 2011-218).

SECTION .0500 - GENERAL UTILIZATION REQUIREMENTS

15A NCAC 02U .0501 RECLAIMED WATER UTILIZATION (SEE S.L. 2011-48)

(a) Reclaimed water utilized in a manner that includes application to the land surface shall meet the following criteria:

(1) The reclaimed water shall meet requirements for Type 1 reclaimed water in Rule .0301(b) of this Subchapter;

(2) Notification shall be provided by the permittee or its representative to inform the public and employees of the use of reclaimed water (Non Potable Water) and that the reclaimed water is not intended for drinking. Notification material shall be provided to employees in a language they understand;

(3) The reclaimed water generator shall develop and maintain a record keeping program for distribution of reclaimed water;

(4) The reclaimed water generator shall develop and maintain an education and approval program for all use of reclaimed water. Educational material shall be provided to employees in a language they understand;

(5) The reclaimed water generator shall develop and maintain a routine review and inspection program for all uses of reclaimed water on property not owned by the generator;

(6) The compliance boundary and the review boundary for groundwater are established at the irrigation area boundaries. No deed restrictions or easements shall be required to be filed on adjacent properties. Land application of effluent shall be on property controlled by the generator unless an easement is provided in accordance with 15A NCAC 02L .0107 except in cases where a compliance boundary is not established; and

(7) Reclaimed water irrigated on designed soil matrix, such as artificial or natural turf athletic fields with subsurface drainage shall meet the following conditions:

(A) Annual hydraulic loading and maximum precipitation rates shall be designed to irrigate a volume not to exceed the design water capacity of the designed soil matrix above the drainage system; and

(B) Outlets of the drainage system shall not be allowed to discharge directly to surface waters (intermittent or perennial) or to storm water conveyance systems that do not allow for infiltration prior to discharging to surface waters.

(b) Reclaimed water used for activities other than land application (such as industrial and commercial uses) shall meet the criteria below:

(1) The reclaimed water shall meet requirements for Type 1 reclaimed water;

(2) Notification shall be provided by the permittee or its representative to inform the public and employees of the use of reclaimed water (Non Potable Water) and that the reclaimed water is not intended for drinking, and notification material shall be provided to employees in a language they understand;

(3) The reclaimed water generator shall develop and maintain an education and approval program for all reclaimed water users, and educational material shall be provided to employees in a language they understand;

(4) The reclaimed water generator shall develop and maintain a record keeping program for distribution of reclaimed water;

(5) The reclaimed water generator shall develop and maintain a routine review and inspection program for all reclaimed water users; and

(6) Reclaimed water used for activities other than land application shall not be used in a manner that causes exposure to aerosols.

(c) Reclaimed water used in commercial or industrial facilities for the purposes of urinal and toilet flushing or fire protection in sprinkler systems shall be approved by the Director if the applicant can demonstrate to the Division that public health and the environment will be protected.
(d) Reclaimed water shall not be used for swimming pools, hot-tubs, spas or similar uses.
(e) Reclaimed water shall not be used for direct reuse as a raw potable water supply.

History Note: Authority G.S. 143-215.1; 143-215.3(a);
Eff. June 18, 2011 (S.L. 2011-48).

SECTION .0600 - BULK DISTRIBUTION OF RECLAIMED WATER

15A NCAC 02U .0601 BULK DISTRIBUTION OF RECLAIMED WATER

(a) Tank trucks and other equipment used to distribute reclaimed water shall be identified with advisory signs.
(b) Tank trucks used to transport reclaimed water shall not be used to transport potable water that is used for drinking or other potable purposes.
(c) Tank trucks used to transport reclaimed water shall not be filled through on-board piping or removable hoses that may subsequently be used to fill potable water tanks.
(d) The reclaimed water generator shall develop and maintain an education and approval program for all reclaimed water users.
(e) The reclaimed water generator shall develop and maintain a record keeping program for bulk distribution of reclaimed water.
(f) The reclaimed water generator shall develop and maintain a routine review and inspection program for reclaimed water users.

History Note: Authority G.S. 143-215.1; 143-215.3(a);
Eff. June 18, 2011.

SECTION .0700 - SETBACKS

15A NCAC 02U .0701 SETBACKS

(a) Treatment and storage facilities associated with systems permitted under this Subchapter shall adhere to the setback requirements in 15A NCAC 02T .0500 except as provided in this Rule.
(b) Final effluent storage facilities shall meet all setback requirements for riparian buffer rules pursuant to 15A NCAC 02B as well as the following setbacks:

Any private or public water supply source	100 feet
Surface waters (streams – intermittent and perennial, perennial waterbodies, and wetlands)	50 feet
Any well with exception of monitoring wells	100 feet
Any property line	50 feet

Otherwise storage facilities shall meet the provisions of Paragraph (a) of this Rule.

(c) The setbacks for utilization areas where reclaimed water is discharged to the ground shall be as follows:

Surface waters (streams – intermittent and perennial, perennial waterbodies, and wetlands) not classified	25 feet
Surface waters (streams – intermittent and perennial, perennial waterbodies, and wetlands) classified	100 feet
Any well with exception t monitoring wells	100 feet

(d) No setback between the application area and property lines is required.

History Note: *Authority G.S. 143-215.1; 143-215.3(a);*
Eff. June 18, 2011.

SECTION .0800 - OPERATIONAL PLANS

15A NCAC 02U .0801 OPERATION AND MAINTENANCE PLAN

An Operation and Maintenance Plan shall be maintained by the permittee for all reclaimed water systems. The plan shall:

(1) describe the operation of the system in sufficient detail to show what operations are necessary for the system to function and by whom the functions are to be conducted;

(2) include a sampling and monitoring plan to evaluate quality of reclaimed water within the distribution system to provide quality assurance at the time of reuse, and specify actions to be taken in response to unsatisfactory monitoring results;

(3) provide a map of all distribution lines and record drawings of all utilization systems under the permittee's control;

(4) describe anticipated maintenance of the system;

(5) include provisions for safety measures including restriction of access to the site and equipment, as required in this Subchapter; and

(6) include spill control provisions including:

(a) response to upsets and bypasses including control, containment, and remediation; and

(b) contact information for plant personnel, emergency responders, and regulatory agencies.

History Note: *Authority G.S. 143-215.1; 143-215.3(a);*
Eff. June 18, 2011.

15A NCAC 02U .0802 RESIDUALS MANAGEMENT PLAN

A Residuals Management Plan shall be maintained for all reclaimed water systems that generate residuals. The plan shall include the following:

(1) an explanation as to how the residuals will be collected, handled, processed, stored and disposed;

(2) an evaluation of the residuals storage requirements for the treatment facility based upon the maximum anticipated residuals production rate and ability to remove residuals;

(3) a permit for residuals utilization, a written commitment to the Permittee of a Division approved residuals disposal/utilization program accepting the residuals which demonstrates that the program has adequate capacity to accept the residuals, or that an application for approval has been submitted; and

(4) if oil, grease, grit, or screenings removal and collection is a designed unit process, an explanation as to how the oil/grease will be collected, handled, processed, stored and disposed.

History Note: *Authority G.S. 143-215.1; 143-215.3(a);*
Eff. June 18, 2011.

SECTION .0900 - LOCAL PROGRAM APPROVAL

15A NCAC 02U .0901 LOCAL PROGRAM APPROVAL

(a) Municipalities, counties, local boards or commissions, water and sewer authorities, or groups of municipalities and counties may apply to the Division for approval of programs for permitting construction, modification, and operation of reclaimed water distribution lines and permitting users under their authority, unless prohibited by other rules in this Subchapter. Construction of and modifications to treatment works, including pump stations for reclaimed water distribution, require Division approval. Permits issued by approved local programs shall serve in place of permits issued by the Division. Local program approval shall not be granted for non-conjunctive reclaimed water uses.

(b) Applications. Applications for approval of local programs shall provide adequate information to assure compliance with the requirements of this Subchapter and the following:

(1) Include two copies of the permit application forms, intended permits including types of uses, minimum design criteria (specifications), flow chart of permitting, inspection and certification procedures, and other relevant documents to be used in administering the local program; and

(2) Certification that the local authority has procedures in place for processing permit applications, setting permit requirements, enforcement, and penalties that are compatible with those for permits issued by the Division.

(c) Any amendments to the requirements of this Subchapter shall be incorporated into the local program within 60 days of the effective date of the amendments.

(d) If required by G.S. 89C, a North Carolina registered Professional Engineer shall be on the staff of the local program or retained as a consultant to review unusual situations or designs and to answer questions that arise in the review of proposed projects. The local program shall also provide staff or retain a consultant to review all other non-engineering related program areas.

(e) Each project permitted by the local program shall be inspected for compliance with the requirements of the local program at least once during construction.

(f) Approval of Local Programs. The Division staff shall acknowledge receipt of an application for a local program in writing, review the application, notify the applicant of additional information that may be required, and make a recommendation to the Commission on the acceptability of the proposed local program.

(g) All permitting actions, bypasses from distribution lines, enforcement actions, and monitoring of the distribution system shall be summarized and submitted to the Division at a minimum on an annual basis on forms provided by the Division. The report shall also provide a listing and summary of all enforcement actions taken or pending during the year. The report shall be submitted within 30 days after the end of each year.

(h) A copy of all program documents such as specifications, permit applications, permit shells and shell certification forms shall be submitted to the Division on an annual basis along with a summary of any other program changes. Program changes to note include staffing, processing fees, and ordinance revisions.

(i) Modification of a Local Program. After a local program has been approved by the Commission, any modification of the program procedures or requirements specified in this Rule shall be approved by the Director to assure that the procedures and requirements remain at least as stringent as the state-wide requirements in this Subchapter.

(j) Appeal of Local Decisions. Appeal of individual permit denials or issuance with conditions the permit applicant finds unacceptable shall be made according to the approved local ordinance. The Commission shall not consider individual permit denials or issuance with conditions to which a permittee objects. This Paragraph does not alter the enforcement authority of the Commission as specified in G.S. 143-215.1(f).

History Note: Authority G.S. 143-215.1; 143-215.1(f); 143-215.3(a);
Eff. June 18, 2011.

SECTION .1100 - WETLANDS AUGMENTATION

15A NCAC 02U .1101 WETLANDS AUGMENTATION

(a) Wetland augmentation shall be limited as follows:

(1) Wetland augmentation shall be limited to pine flat and hardwood flat wetlands as defined in the most current version of the N.C. Wetland Assessment Method (NC WAM) User Manual developed by the N.C. Wetland Functional Assessment Team (NC WFAT), excluding riparian

zones. The NC WAM User Manual can be accessed at the following web address: http://portal.ncdenr.org/web/wq/swp/ws/pdu/ncwam;

(2) Reclaimed water discharge to Salt Water Wetlands (SWL) or Unique Wet Lands (UWL), as defined in 15A NCAC 02B .0101, is not permitted under the rules in this Subchapter; and

(3) Reclaimed water discharge to wetlands areas shall be limited to times when the depth to groundwater is greater than or equal to one foot.

(b) In addition to the requirements established in Rule .0201 or Rule .0202 of this Subchapter as applicable, all new and expanding wetlands augmentation facilities, as applicable, shall:

(1) Identify the classification of the existing wetlands according to the most current version of the N.C. Wetlands Assessment Method (NC WAM) User Manual and information provided by the North Carolina Natural Heritage Program (NC NHP);

(2) Identify the existing beneficial uses of the reclaimed water to the wetlands in accordance with 15A NCAC 02B .0231, and support any demonstration of net environmental benefit;

(3) Determine the hydrologic regime of the wetlands, including depth and duration of inundation, and average monthly water level fluctuations. An estimated monthly water budget shall be provided by the applicant and compared to actual conditions during operation;

(4) Identify class of reclaimed water to be discharged, associated parameter concentrations, and annual loading rates to the wetlands;

(5) Determine whether the wetland occurs in a ground water recharge or discharge area;

(6) Provide baseline monitoring information for wetlands sufficient to allow determination of reference conditions, to be performed for at least one representative year prior to initiation of discharge;

(7) Provide a project evaluation and receiver site agronomic plan that includes a hydraulic loading recommendation based on the soils report, hydrogeologic description, agronomic investigation, wetland type, local topography, aquatic life, wildlife, and all other investigative results to support that there will be no negative effects on the uses of the wetlands including the biological criteria and net environmental benefits will be gained. Hydraulic loading recommendations shall reflect seasonal changes to wetlands including restrictions during times of high water table levels;

(8) For non-conjunctive wetlands augmentation systems, provide 200 percent of the land requirements based on the recommended hydraulic loading rate. After five years of operation the Permittee may request and receive a reduction in the additional land requirement provided that operational data supports that sufficient utilization capacity exists for the reclaimed water generator;

(9) 10 percent of the land requirements shall remain in a natural state to be used as a basis of comparison to the wetlands receiving reclaimed water;

(10) For application of reclaimed water exhibiting parameter concentrations greater than 100 percent of the groundwater standards, provide a site-specific hydrogeologic investigation (i.e., evaluation of wetlands/groundwater interaction, groundwater recharge/discharge, gradient, project proximity to water supply wells) to show that hydrogeologic conditions are adequate to prevent degradation of groundwater quality and demonstrate through hydrogeological modeling that groundwater standards will not be exceeded at the compliance boundary; and

(11) Provide documentation that any applicable NPDES program requirements have been met, pursuant to 15A NCAC 02H .0100.

(c) All renewal applications for wetlands augmentation facilities, shall submit documentation that the project continues to function as designed and that the net environmental benefit aspects remain applicable.

(d) Reclaimed water utilized for wetlands augmentation shall meet the following reclaimed water effluent standards:

(1) Reclaimed water discharged to natural wetlands shall be treated to Type 1 reclaimed water standards;

(2) In addition to water quality requirements associated with Type 1 reclaimed water, reclaimed water discharged to wetlands shall not exceed the following concentrations, unless net environmental benefits are provided:

(A) Total Nitrogen (as Nitrogen) of 4.0 mg/l; and

(B) Total Phosphorus (as Phosphorus) of 1 mg/l;

(3) Metal concentrations in reclaimed water discharged to wetlands shall not exceed North Carolina surface water quality standards, unless acute whole effluent toxicity testing demonstrates absence of toxicity.

(e) Reclaimed water facilities utilizing wetlands augmentation, shall meet the criteria below:

(1) Notification shall be provided by the permittee or its representative to inform the public of the use of reclaimed water (Non Potable Water) and that the reclaimed water is not intended for drinking;

(2) The reclaimed water generator shall develop and maintain a wetlands monitoring program. This monitoring will be conducted during the first five growing seasons after initiation of the application of reclaimed water, after which the applicant may apply for and receive reduced monitoring. The monitoring requirements must include the following items:

(A) vegetation, macroinvertebrates, amphibians, fish, birds, and threatened or endangered species surveys;

(B) water chemistry;

(C) surface water and ground water depth readings; and

(D) groundwater monitoring plan except for those projects receiving reclaimed water characterized by average annual parameter concentrations less than or equal to 50 percent of ground water quality criteria, and less than 50 percent of required surface water discharge concentrations;

(3) The reclaimed water generator shall develop and maintain an education program for all users of reclaimed water on property not owned by the generator;

(4) The reclaimed water generator shall develop and maintain a routine review and inspection program for the wetlands augmentation system; and

(5) The compliance boundary and the review boundary for groundwater shall be established at the property line. No deed restrictions or easements are required to be filed on adjacent properties. Land application of reclaimed water shall be on property controlled by the generator unless a contractual agreement is provided in accordance with 15A NCAC 02L .0107 except in cases where a compliance boundary is not established.

(f) Permitting of wetlands augmentation uses shall not be delegated to local programs.

History Note: Authority G.S. 143-215.1; 143-215.3(a); S.L. 2006-250; Eff. June 18, 2011.

SECTION .1400 - IRRIGATION TO FOOD CHAIN CROPS

15A NCAC 02U .1401 IRRIGATION TO FOOD CHAIN CROPS

(a) Irrigation to food chain crops shall be limited as follows:

(1) Reclaimed water utilized for direct or indirect contact irrigation of food chain crops that will be peeled, skinned, cooked or thermally processed before consumption shall be treated to Type 1 reclaimed water standards;

(2) For the purposes of this Rule, tobacco is not considered a food chain crop;

(3) Reclaimed water shall not be utilized for direct contact irrigation of food chain crops that will not be peeled, skinned, cooked or thermally processed before consumption except as approved in Subparagraph (5) of this Paragraph;

(4) Reclaimed water utilized for indirect contact irrigation of food chain crops that will not be peeled, skinned, cooked or thermally processed before consumption shall be treated to Type 2 reclaimed water standards; and

(5) If requested, the Department shall authorize demonstration projects to collect and present data related to the direct application of reclaimed water on crops that are not peeled, skinned, cooked, or thermally processed before consumption. Crops produced during such demonstration projects may be used as animal feed or may be thermally processed, cooked, or otherwise prepared for human consumption in a manner approved by the North Carolina Department of Agriculture and Consumer Services. If the applicant, based on the data collected, demonstrates to the Department that public health will be protected if their reclaimed water is directly applied to crops which are not peeled, skinned, cooked, or thermally processed, the Department shall waive the prohibition described in Subparagraph (3) of this Paragraph for that project. When considering such

demonstration projects, the Department shall seek the advice of the North Carolina Department of Agriculture and Consumer Services.

(b) In addition to the requirements established in Rule .0201 or Rule .0202 of this Subchapter as applicable, all new and expanding irrigation to food chain crops systems shall submit a representative soil analysis for standard soil fertility for each field to be irrigated. A Standard Soil Fertility Analysis shall include the following parameters:

(1) Acidity;
(2) Base Saturation (by calculation);
(3) Calcium;
(4) Cation Exchange Capacity;
(5) Copper;
(6) Exchangeable Sodium Percentage (by calculation);
(7) Magnesium;
(8) Manganese;
(9) Percent Humic Matter;
(10) pH;
(11) Phosphorus;
(12) Potassium;
(13) Sodium; and
(14) Zinc.

(c) When a water balance is required by Rule .0202(k) of this Subchapter the water balance shall include seasonal water requirements for the crops.

(d) For irrigation sites not owned by the permittee, a notarized land owner agreement shall be provided to the Division. The land owner agreement shall include the following:

(1) a description of the approved uses and conditions for use of the reclaimed water consistent with the requirements of this Rule;
(2) a condition requiring the reclaimed water supplier shall provide the landowner with the results of sampling performed to document compliance with the reclaimed water effluent standards; and
(3) a condition requiring the landowner to report to the permittee any use of the reclaimed water inconsistent with the uses in the agreement.

(e) All renewal applicants for irrigation to food chain crop systems shall submit:

(1) A representative soil analysis for standard soil fertility for each field to be irrigated. A Standard Soil Fertility Analysis shall include the following parameters:
    (A) Acidity;
    (B) Base Saturation (by calculation);
    (C) Calcium;
    (D) Cation Exchange Capacity;
    (E) Copper;
    (F) Exchangeable Sodium Percentage (by calculation);
    (G) Magnesium;
    (H) Manganese;
    (I) Percent Humic Matter;
    (J) pH;
    (K) Phosphorus;
    (L) Potassium;
    (M) Sodium; and
    (N) Zinc;
(2) The inventory of commercial agricultural operations using reclaimed water to irrigate food chain crops required in Subparagraph (d)(7) of this Rule; and
(3) For irrigation sites not owned by the permittee, a notarized land owner agreement pursuant to Paragraph (d) of this Rule.

(f) Reclaimed water facilities providing reclaimed water for the irrigation of food chain crops shall meet the criteria below:

(1) Crops irrigated by direct contact with reclaimed water shall not be harvested within 24 hours of irrigation with reclaimed water;

(2) Notification at the utilization site shall be provided by the permittee or its representative to inform the public of the use of reclaimed water (Non Potable Water) and that the reclaimed water is not intended for drinking;

(3) The reclaimed water generator shall develop and maintain a record keeping program for distribution of reclaimed water;

(4) The permittee shall develop and maintain an education program for users of reclaimed water for irrigation to food chain crops;

(5) The reclaimed water generator shall provide all landowners receiving reclaimed water for irrigation of food chain crops a summary of all reclaimed water system performance as required in G.S. 143-215.1C;

(6) The reclaimed water generator shall develop and maintain a routine review and inspection program for all irrigation to food chain crop systems; and

(7) The permittee shall maintain an inventory of commercial agricultural operations using reclaimed water to irrigate food chain crops for each year of operation. The inventory shall be maintained for five years. The inventory of food chain crop irrigation shall include the following:

(A) name of the agricultural operation;

(B) name and telephone number of the owner or operator of the agricultural operation;

(C) address of the agricultural operation;

(D) food chain crops irrigated with reclaimed water;

(E) type of application (e.g., irrigation) method used; and

(F) approximate area under irrigation on which food chain crops are grown.

History Note: *Authority G.S. 143-215.1; 143-215.3(a); S.L. 2006-250; Eff. June 18, 2011.*

State of North Carolina
Department of Environment and Natural Resources
Division of Water Resources

15A NCAC 02T .0500 – WASTEWATER IRRIGATION SYSTEMS
INSTRUCTIONS FOR FORM: WWIS 11-13 & SUPPORTING DOCUMENTATION

Plans, specifications and supporting documents shall be prepared in accordance with 15A NCAC 02H .0400 (if necessary), 15A NCAC 02L .0100, 15A NCAC 02T .0100, 15A NCAC 02T .0500, Division Policies and good engineering practices. Failure to submit all required items will necessitate additional processing and review time.

For more information, visit the Water Quality Permitting Section's Non-Discharge Permitting Unit website at:
http://portal.ncdenr.org/web/wq/aps/lau

General – When submitting an application to the Water Quality Permitting Section's Non-Discharge Permitting Unit, please use the following instructions as a checklist in order to ensure all required items are submitted. Adherence to these instructions and checking the provided boxes will help produce a quicker review time and reduce the amount of requested additional information.

Unless otherwise noted, the Applicant shall submit one original and two copies of the application and supporting documentation.

A. **Cover Letter** (All Application Packages):
- ☐ List all items included in the application package, as well as a brief description of the requested permitting action.

B. **Application Fee** (All New and Major Modification Application Packages):
- ☐ Submit a check, money order or electronic funds transfer made payable to: North Carolina Department of Environment and Natural Resources (NCDENR). The appropriate fee amount for new and major modification applications may be found at: Standard Review Project Fees.

C. **Wastewater Irrigation Systems (FORM: WWIS 11-13) Application** (All Application Packages):
- ☐ Submit the completed and appropriately executed Wastewater Irrigation Systems (FORM: WWIS 11-13) application. Any unauthorized content changes to this form shall result in the application package being returned. If necessary for clarity or due to space restrictions, attachments to the application may be made, as long as the attachments are numbered to correspond to the section and item to which they refer.
- ☐ If the Applicant Type in Item I.2. is a corporation or company, provide documentation it is registered for business with the North Carolina Secretary of State.
- ☐ If the Applicant Type in Item I.2. is a partnership or d/b/a, enclose a copy of the certificate filed with the Register of Deeds in the county of business.
- ☐ The facility name in Item II.1. shall be consistent with the facility name on the plans, specifications, agreements, etc.
- ☐ The Professional Engineer's Certification on Page 12 of the application shall be signed, sealed and dated by a North Carolina licensed Professional Engineer.
- ☐ The Applicant's Certification on Page 12 of the application shall be signed in accordance with 15A NCAC 02T .0106(b). Per 15A NCAC 02T .0106(c), an alternate person may be designated as the signing official if a delegation letter is provided from a person who meets the criteria in 15A NCAC 02T .0106(b).
- ☐ If this project is for a renewal without modification, use the Non-Discharge System Renewal (FORM: NDSR) application.

D. **Property Ownership Documentation** (All Application Packages):
- ➢ Per 15A NCAC 02T .0504(f), the Applicant shall demonstrate they are the owner of all property containing the wastewater treatment, storage and irrigation facilities:
  - ☐ Legal documentation of ownership (i.e., GIS, deed or article of incorporation), or
  - ☐ Written notarized intent to purchase agreement signed by both parties with a plat or survey map, or
  - ☐ Written notarized lease agreement that specifically indicates the intended use of the property and has been signed by both parties, as well as a plat or survey map. Lease agreements shall adhere to the requirements of 15A NCAC 02L .0107.
- ☐ Provide all agreements, easements, setback waivers, etc. that have a direct impact on the wastewater treatment, conveyance, storage and irrigation facilities.

E. **Soil Evaluation** (All Application Packages that include new irrigation sites):

- ☐ Per 15A NCAC 02T .0504(b) and the Soil Scientist Evaluation Policy, submit a detailed soil evaluation that has been signed, sealed and dated by a North Carolina Licensed Soil Scientist and includes at a minimum:
  - ☐ The report shall identify all the sites/fields with project name, location, and include a statement that the sites/fields were recommended for the proposed land application activity.
  - ☐ Field delineated detailed soils map meeting all of the requirements of the Soil Scientist Evaluation Policy.
  - ☐ Soil profile descriptions meeting all of the requirements of the Soil Scientist Evaluation Policy.
  - ☐ Provide all soil boring logs performed at the site.
  - ☐ Standard soil fertility analysis conducted no more than one year prior to permit application for each map unit in the soil map legend for the following parameters:

☐ Acidity	☐ Exchangeable sodium percentage (by calculation)	☐ Phosphorus
☐ Base saturation (by calculation)	☐ Magnesium	☐ Potassium
☐ Calcium	☐ Manganese	☐ Sodium
☐ Cation exchange capacity	☐ Percent humic matter	☐ Zinc
☐ Copper	☐ pH	

  - ➢ Saturated hydraulic conductivity (K_{SAT}) data that shall include at a minimum:
    - ☐ A minimum of three K_{SAT} tests shall be conducted in the most restrictive horizon for each soil series in the soil map.
    - ☐ All K_{SAT} tests shall be conducted in areas representative of the site.
    - ☐ All K_{SAT} tests shall be run until steady-state equilibrium has been achieved.
    - ☐ All collected K_{SAT} data shall be submitted, including copies of field worksheets showing all collected readings.
    - ☐ Submit a soil profile description for each K_{SAT} data point that shall extend at least one foot below the tested horizon.
  - ➢ Soil evaluation recommendations shall include at a minimum:
    - ☐ A brief summary of each map unit and its composition and identification of minor contrasting soils.
    - ☐ Maximum irrigation precipitation rate (in/hr) for each soil/map unit within the proposed irrigation areas.
    - ☐ Seasonal irrigation restrictions, if appropriate.
    - ☐ Identification of areas not suitable for wastewater irrigation.
    - ☐ Recommended geometric mean K_{SAT} rate to be used in the water balance for each soil/map unit based upon in-situ measurement of the saturated hydraulic conductivity from the most restrictive horizon.
    - ☐ Recommended drainage coefficient to be used in the water balance based upon comprehensive site evaluation, review of collected onsite data, minor amounts of contrasting soils and the nature of the wastewater to be applied.
    - ☐ Recommended annual hydraulic loading rate (in/yr) for each soil/map unit within the proposed irrigation areas based upon in-situ K_{SAT} measurements form the most restrictive soil horizon.

NOTE – If the soil evaluation was performed more than one year prior to the submittal of this application package, a statement shall be included indicating that the site has not changed since the original investigation.

F. **Agronomist Evaluation** (All Application Packages that include new irrigation sites or new crops for existing irrigation sites):

- ☐ Per 15A NCAC 02T .0504(i), submit an agronomist evaluation that has been signed, sealed and dated by a qualified professional and includes at a minimum:
  - ☐ Proposed nutrient uptake values for each cover crop based upon each field's dominant soil series and percent slope.
  - ☐ Plant available nitrogen calculations for each cover crop using the designed effluent concentrations in Application Item V.1. and proposed mineralization and volatilization rates.
  - ☐ Historical site consideration, soil binding and plant uptake of phosphorus.
  - ☐ Seasonal irrigation restrictions, if appropriate.
  - ☐ A clear and reproducible map showing all areas investigated and their relation to proposed fields and crops.
  - ☐ Maintenance and management plan for all specified crops.

G. **Hydrogeologic Report** (All Application Packages treating industrial waste or having a design flow over 25,000 GPD):

- ☐ Per 15A NCAC 02T .0504(e), the Hydrogeologic Investigation and Reporting Policy, the Groundwater Modeling Policy and the Performance and Analysis of Aquifer Slug Tests and Pumping Tests Policy, submit a detailed hydrogeologic description that has been signed, sealed and dated by a qualified professional and includes at a minimum:
  - ☐ A hydrogeologic description to a depth of 20 feet below land surface or bedrock, whichever is less. A greater depth of investigation is required if the respective depth is used in predictive calculations.
  - ☐ Representative borings within the irrigation areas and all proposed earthen impoundments.
  - ☐ A description of the regional and local geology and hydrogeology.
  - ☐ A description, based on field observations of the site, of the site topographic setting, streams, springs and other groundwater discharge features, drainage features, existing and abandoned wells, rock outcrops, and other features that may affect the movement of the contaminant plume and treated wastewater.
  - ☐ Changes in lithology underlying the site.
  - ☐ Depth to bedrock and occurrence of any rock outcrops.
  - ☐ The hydraulic conductivity and transmissivity of the affected aquifer(s).
  - ☐ Depth to the seasonal high water table (SHWT).
  - ☐ A discussion of the relationship between the affected aquifers of the site to local and regional geologic and hydrogeologic features.
  - ☐ A discussion of the groundwater flow regime of the site prior to operation of the proposed facility and post operation of the proposed facility focusing on the relationship of the system to groundwater receptors, groundwater discharge features, and groundwater flow media.
  - ☐ If the SHWT is within six feet of the surface, a mounding analysis to predict the level of the SHWT after wastewater application.

H. **Water Balance** (All Application Packages that include new or modified irrigation sites, changes in flow or changes in storage):

- ☐ Per 15A NCAC 02T .0504(k) and the Water Balance Calculation Policy, submit a water balance that has been signed, sealed and dated by a qualified professional and includes at a minimum:
  - ☐ At least a two-year iteration of data computation that considers precipitation into and evaporation from all open atmosphere storage impoundments, and uses a variable number of days per month.
  - ☐ Precipitation based on the 80th percentile and a minimum of 30 years of observed data.
  - ☐ Potential Evapotranspiration (PET) using the Thornthwaite method, or another approved methodology, using a minimum of 30 years of observed temperature data.
  - ☐ Soil drainage based on the geometric mean of the in-situ K_{SAT} tests in the most restrictive horizon and a drainage coefficient ranging from 4 to 10% (unless otherwise technically documented).
  - ➢ Other factors that may restrict the hydraulic loading rate when determining a water balance include:
    - ☐ Depth to the SHWT and groundwater lateral movement that may result in groundwater mounding.
    - ☐ Nutrient limitations and seasonal application times to ensure wastewater irrigation does not exceed agronomic rates.
    - ☐ Crop management activities resulting in cessation of irrigation for crop removal.

NOTE – Wastewater Irrigation Systems serving residential facilities shall have a minimum of 14 days of wet weather storage.

I. **Engineering Plans** (All Application Packages):

- ☐ Per 15A NCAC 02T .0504(c)(1), submit standard size and 11 x 17-inch plan sets that have been signed, sealed and dated by a North Carolina licensed Professional Engineer, and shall include at a minimum:
  - ☐ Table of contents with each sheet numbered.
  - ☐ A general location map with at least two geographic references and a vicinity map.
  - ☐ A process and instrumentation diagram showing all flow, recycle/return, aeration, chemical, electrical and wasting paths.
  - ☐ Plan and profile views of all treatment and storage units, including their piping, valves, and equipment (i.e., pumps, blowers, mixers, diffusers, flow meters, etc.), as well as their dimensions and elevations.
  - ☐ Details of all piping, valves, pumps, blowers, mixers, diffusers, recording devices, fencing, auxiliary power, etc.
  - ☐ A hydraulic profile from the treatment plant headworks to the highest irrigation point.
  - ☐ The irrigation area with an overlay of the suitable irrigation areas depicted in the Soil Evaluation.
  - ☐ Each nozzle/emitter and their wetted area influence, and each irrigation zone labeled as it will be operated.
  - ☐ Locations within the irrigation system of air releases, drains, control valves, highest irrigation nozzle/emitter, etc.
  - ☐ For automated irrigation systems, provide the location and details of the precipitation/soil moisture sensor.
  - ☐ Plans shall represent a completed design and not be labeled with preliminary phrases (e.g., FOR REVIEW ONLY, NOT FOR CONSTRUCTION, etc.) that indicate they are anything other than final specifications. However, the plans may be labeled with the phrase: FINAL DESIGN - NOT RELEASED FOR CONSTRUCTION.

J. **Specifications** (All Application Packages):

- ☐ Per 15A NCAC 02T .0504(c)(2), submit specifications that have been signed, sealed and dated by a North Carolina licensed Professional Engineer, and shall include at a minimum:
  - ☐ Table of contents with each section/page numbered.
  - ☐ Detailed specifications for each treatment/storage/irrigation unit, as well as all piping, valves, equipment (i.e., pumps, blowers, mixers, diffusers, flow meters, etc.), nozzles/emitters, precipitation/soil moisture sensor (if applicable), audible/visual high water alarms, liner material, etc.
  - ☐ Site Work (i.e., earthwork, clearing, grubbing, excavation, trenching, backfilling, compacting, fencing, seeding, etc.)
  - ☐ Materials (i.e., concrete, masonry, steel, painting, method of construction, etc.)
  - ☐ Electrical (i.e., control panels, transfer switches, automatically activated standby power source, etc.)
  - ☐ Means for ensuring quality and integrity of the finished product, including leakage, pressure and liner testing.
  - ☐ Specifications shall represent a completed design and not be labeled with preliminary phrases (e.g., FOR REVIEW ONLY, NOT FOR CONSTRUCTION, etc.) that indicate they are anything other than final specifications. However, the specifications may be labeled with the phrase: FINAL DESIGN - NOT RELEASED FOR CONSTRUCTION.

K. **Engineering Calculations** (All Application Packages):

- ☐ Per 15A NCAC 02T .0504(c)(3), submit engineering calculations that have been signed, sealed and dated by a North Carolina licensed Professional Engineer, and shall include at a minimum:
  - ☐ Hydraulic and pollutant loading calculations for each treatment unit demonstrating how the designed effluent concentrations in Application Item V.1. were determined.
  - ☐ Sizing criteria for each treatment unit and associated equipment (i.e., blowers, mixers, flow meters, pumps, etc.).
  - ☐ Total and effective storage calculations for each storage unit.
  - ☐ Friction/total dynamic head calculations and system curve analysis for each pump used.
  - ☐ Manufacturer's information for all treatment units, pumps, blowers, mixers, diffusers, flow meters, irrigation system, etc.
  - ☐ Flotation calculations for all treatment and storage units constructed partially or entirely below grade.
  - ☐ A demonstration that the designed maximum precipitation and annual loading rates do not exceed the recommended rates.
  - ☐ A demonstration that the specified auxiliary power source is capable of powering all essential treatment units.

L. **Site Map** (All Application Packages):

- ☐ Per 15A NCAC 02T .0504(d), submit standard size and 11 x 17-inch site maps that have been signed, sealed and dated by a North Carolina licensed Professional Engineer and/or Professional Land Surveyor, and shall include at a minimum:
  - ☐ A scaled map of the site with topographic contour intervals not exceeding 10 feet or 25 percent of total site relief and showing all facility-related structures and fences within the wastewater treatment, storage and irrigation areas.
  - ☐ Soil mapping units shown on all irrigation sites.
  - ☐ The location of all wells (including usage and construction details if available), streams (ephemeral, intermittent, and perennial), springs, lakes, ponds, and other surface drainage features within 500 feet of all wastewater treatment, storage and irrigation sites.
  - ☐ Delineation of the compliance and review boundaries per 15A NCAC 02L .0107 and .0108, and 15A NCAC 02T .0506(c) if applicable.
  - ☐ Setbacks as required by 15A NCAC 02T .0506.
  - ☐ Site property boundaries within 500 feet of all wastewater treatment, storage and irrigation sites.
  - ☐ All habitable residences or places of public assembly within 500 feet of all treatment, storage and irrigation sites.

NOTE – For clarity, multiple site maps of the facility with cut sheet annotations may be submitted.

M. **Power Reliability Plan** (All Application Packages):

- ☐ Per 15A NCAC 02T .0505(l), submit documentation of power reliability that shall consist of at a minimum:
  - ☐ An automatically activated standby power supply onsite that is capable of powering all essential treatment units under design conditions, OR
  - ➢ Approval from the Director that the facility:
    - ☐ Serves a private water distribution system that has automatic shut-off during power failures and has no elevated water storage tanks,
    - ☐ Has sufficient storage capacity that no potential for overflow exists, and
    - ☐ Can tolerate septic wastewater due to prolonged detention.

N. **Operation and Maintenance Plan** (All Application Packages):

- ☐ Per 15A NCAC 02T .0507, submit an operation and maintenance (O&M) plan encompassing all wastewater treatment, storage and irrigation systems that shall include at a minimum a description of:
  - ☐ Operation of the wastewater treatment, storage and irrigation systems in sufficient detail to show what operations are necessary for the system to function and by whom the functions are to be conducted.
  - ☐ Anticipated maintenance of the wastewater treatment, storage and irrigation systems.
  - ☐ Safety measures, including restriction of access to the site and equipment.
  - ☐ Spill prevention provisions such as response to upsets and bypasses, including how to control, contain and remediate.
  - ☐ Contact information for plant personnel, emergency responders and regulatory agencies.

NOTE – A final O&M Plan shall be submitted with the partial and/or final Engineering Certification required under 15A NCAC 02T .0116, however, a preliminary O&M Plan shall be submitted with each application package.

O. **Residuals Management Plan** (All Application Packages with new, expanding or replacement wastewater treatment systems):

- ☐ Per 15A NCAC 02T .0504(j) and .0508, submit a Residuals Management Plan that shall include at a minimum:
  - ☐ A detailed explanation of how generated residuals (including trash, sediment and grit) will be collected, handled, processed, stored, treated, and disposed.
  - ☐ An evaluation of the treatment facility's residuals storage requirements based upon the maximum anticipated residuals production rate and ability to remove residuals.
  - ☐ A permit for residuals utilization or a written commitment to the Applicant from a Permittee of a Department approved residuals disposal/utilization program that has adequate permitted capacity to accept the residuals or has submitted a residuals/utilization program application.
  - ☐ If oil/grease removal and collection are a designed unit process, submit an oil/grease disposal plan detailing how the oil/grease will be collected, handled, processed, stored and disposed.

NOTE – Per 15A NCAC 02T .0505(o), a minimum of 30 days of residual storage shall be provided.

NOTE – Per 15A NCAC 02T .0504(j), a written commitment to the Applicant from a Permittee of a Department approved residuals disposal/utilization program is not required at the time of this application, however, it shall be provided prior to operation of any permitted facilities herein.

NOTE – If an on-site restaurant or other business with food preparation is contributing wastewater to this system, an oil/grease disposal plan shall be submitted.

P. **Additional Documentation:**

- ➢ **Certificate of Public Convenience and Necessity** (All Application Packages for Privately-Owned Public Utilities):
  - ☐ Per 15A NCAC 02T .0115(a)(1) and .0504(g), provide the Certificate of Public Convenience and Necessity from the North Carolina Utilities Commission demonstrating the Applicant is authorized to hold the utility franchise for the area to be served by the wastewater treatment and irrigation system, or
  - ☐ Provide a letter from the North Carolina Utilities Commission's Water and Sewer Division Public Staff stating an application for a franchise has been received and that the service area is contiguous to an existing franchised area or that franchise approval is expected.

- ➢ **Existing Permit** (All Modification Packages):
  - ☐ Submit the most recently issued existing permit.
  - ☐ Provide a list of any items within the permit the Applicant would like the Division to address during the permit modification (i.e., compliance schedules, permit description, monitoring, permit conditions, etc.).

- ➢ **Final Environmental Document** (All Application Packages using public monies or lands subject to the North Carolina Environmental Policy Act under 15A NCAC 01C .0100 to .0400):
  - ☐ Per 15A NCAC 02T .0105(c)(4), submit one copy of the environmental assessment and three copies of the final environmental document (i.e., Finding of No Significant Impact or Record of Decision).
  - ☐ Include information on any mitigating factors from the Environmental Assessment that impact the design and/or construction of the wastewater treatment and irrigation system.

- ➢ **Floodway Regulation Compliance** (All Application Packages where any portion of the wastewater treatment, storage and irrigation system is located within the 100-year floodplain):
  - ☐ Per 15A NCAC 02T .0105(c)(8), provide written documentation from all local governing entities that the facility is in compliance with all local ordinances regarding construction or operation of wastewater treatment and/or disposal facilities within the floodplain.

P. Additional Documentation (continued):

- **Operational Agreements** (All Application Packages for Home/Property Owners' Associations and Developers of lots to be sold):
  - Home/Property Owners' Associations
    - ☐ Per 15A NCAC 02T .0115(c), submit the properly executed Operational Agreement (FORM: HOA).
    - ☐ Per 15A NCAC 02T .0115(c), submit the proposed or approved Articles of Incorporation, Declarations and By-laws.
  - Developers of lots to be sold
    - ☐ Per 15A NCAC 02T .0115(b), submit the properly executed Operational Agreement (FORM: DEV).

- **Threatened or Endangered Aquatic Species Documentation** (All Application Packages):
  - ☐ Per 15A NCAC 02T .0105(c)(10), submit documentation from the Department's Natural Heritage Program demonstrating the presence or absence of threatened or endangered aquatic species within the boundary of the wastewater treatment, storage and irrigation facilities.
  - ☐ If the facility directly impacts such species, this documentation shall provide information on the need for permit conditions pursuant to 15A NCAC 02B .0110.

- **Wastewater Chemical Analysis** (All Application Packages treating Industrial Waste):
  - ☐ Per 15A NCAC 02T .0504(h), provide a complete Division certified laboratory chemical analysis of the effluent to be irrigated for the following parameters (For new facilities, an analysis from a similar facility's effluent is acceptable):

☐ Ammonia Nitrogen (NH_3-N)
☐ Calcium
☐ Chemical Oxygen Demand (COD)
☐ Chloride
☐ Fecal Coliform
☐ 5-day Biochemical Oxygen Demand (BOD_5)
☐ Magnesium
☐ Nitrate Nitrogen (NO_3-N)
☐ pH
☐ Phenol
☐ Sodium
☐ Sodium Adsorption Ratio (SAR)
☐ Total Dissolved Solids
☐ Total Kjeldahl Nitrogen (TKN)
☐ Total Organic Carbon
☐ Total Phosphorus
☐ Total Trihalomethanes
☐ Total Volatile Organic Compounds
☐ Toxicity Test Parameters

THE COMPLETED APPLICATION AND SUPPORTING DOCUMENTATION SHALL BE SUBMITTED TO:

NORTH CAROLINA DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES
DIVISION OF WATER RESOURCES
WATER QUALITY PERMITTING SECTION
NON-DISCHARGE PERMITTING UNIT

By U.S. Postal Service:
1636 MAIL SERVICE CENTER
RALEIGH, NORTH CAROLINA 27699-1636

By Courier/Special Delivery:
512 N. SALISBURY ST.
RALEIGH, NORTH CAROLINA 27604

TELEPHONE NUMBER: (919) 807-6464

FAX NUMBER: (919) 807-6496

I. APPLICANT INFORMATION:

1. Applicant's name: _____
2. Applicant type: ☐ Individual ☐ Corporation ☐ General Partnership ☐ Privately-Owned Public Utility
   ☐ Federal ☐ State ☐ Municipal ☐ County
3. Signature authority's name: _____ per 15A NCAC 02T .0106(b) Title: _____
4. Applicant's mailing address: _____
   City: _____ State: _____ Zip: _____-____
5. Applicant's contact information:
   Phone number: (___) ___-____ Email Address: _____

II. FACILITY INFORMATION:

1. Facility name: _____
2. Facility status: Select
3. Facility type: Select
4. Facility's physical address: _____
   City: _____ State: _____ Zip: _____-____ County: _____
5. Wastewater Treatment Facility Coordinates (Decimal Degrees): Latitude: __._____° Longitude: -__._____°
   Datum: Select Level of accuracy: Select Method of measurement: Select
6. USGS Map Name: _____

III. CONSULTANT INFORMATION:

1. Professional Engineer: _____ License Number: _____ Firm: _____
   Mailing address: _____
   City: _____ State: _____ Zip: _____-____
   Phone number: (___) ___-____ Email Address: _____
2. Soil Scientist: _____ License Number: _____ Firm: _____
   Mailing address: _____
   City: _____ State: _____ Zip: _____-____
   Phone number: (___) ___-____ Email Address: _____
3. Geologist: _____ License Number: _____ Firm: _____
   Mailing address: _____
   City: _____ State: _____ Zip: _____-____
   Phone number: (___) ___-____ Email Address: _____
4. Agronomist: _____ Firm: _____
   Mailing address: _____
   City: _____ State: _____ Zip: _____-____
   Phone number: (___) ___-____ Email Address: _____

IV. GENERAL REQUIREMENTS – 15A NCAC 02T .0100:

1. Application type: ☐ New ☐ Major Modification ☐ Minor Modification

   If a modification, provide the existing permit number: WQ00_____ and most recent issuance date: _____

2. Application fee: Select

3. Does this project utilize public monies or lands? ☐ Yes or ☐ No

   If yes, was an Environmental Assessment required under 15A NCAC 01C? ☐ Yes or ☐ No

   If yes, which final environmental document is submitted? ☐ Finding of No Significant Impact or ☐ Record of Decision

   Briefly describe any mitigating factors from the Environmental Assessment that may impact this facility: _____

4. What is the status of the following permits/certifications applicable to the subject facility?

Permit/Certification	Date Submitted	Date Approved	Permit/Certification Number	Agency Reviewer
Collection System (Q ≥ 200,000 GPD)				
Dam Safety				
Erosion & Sedimentation Control Plan				
Nationwide 12 / Section 404				
Pretreatment				
Sewer System				
Stormwater Management Plan				
Wetlands 401				
Other:				

5. What is the wastewater type? ☐ Domestic or ☐ Industrial (See 15A NCAC 02T .0103(20))

   → Is there a Pretreatment Program in effect? ☐ Yes or ☐ No

   → Has a wastewater chemical analysis been submitted? ☐ Yes or ☐ No

6. Wastewater flow: _____ GPD

   Limited by: ☐ Treatment, ☐ Storage, ☐ Field Hydraulics, ☐ Field Agronomics or ☐ Groundwater Mounding

7. Explain how the wastewater flow was determined: ☐ 15A NCAC 02T .0114 or ☐ Representative Data

   Has a flow reduction been approved under 15A NCAC 02T .0114(f)? ☐ Yes or ☐ No

Establishment Type	Daily Design Flow [a]	No. of Units	Flow
	gal/		GPD
	gal/		GPD
	gal/		GPD
	gal/		GPD
	gal/		GPD
	gal/		GPD
		Total	GPD

[a] See 15A NCAC 02T .0114(b), (d), (e)(1) and (e)(2) for caveats to wastewater design flow rates (i.e., minimum flow per dwelling; proposed unknown non-residential development uses; public access facilities located near high public use areas; and residential property located south or east of the Atlantic Intracoastal Waterway to be used as vacation rentals as defined in G.S. 42A-4).

IV. GENERAL REQUIREMENTS – 15A NCAC 02T .0100 (continued):

8. What is the nearest 100-year flood elevation to the facility? _____ feet mean sea level. Source: _____

   Are any treatment, storage or irrigation facilities located within the 100-year flood plain? ☐ Yes or ☐ No

   → If yes, which facilities are affected and what measures are being taken to protect them against flooding? _____

   → If yes, has the Applicant submitted written documentation of compliance with §143 Article 21 Part 6? ☐ Yes or ☐ No

9. Has the Applicant provided documentation of the presence or absence of threatened or endangered aquatic species utilizing information provided by the Department's Natural Heritage Program? ☐ Yes or ☐ No

10. Does the facility have a proposed or existing groundwater monitoring well network? ☐ Yes or ☐ No

    If no, provide an explanation as to why a groundwater monitoring well network is not proposed: _____

    If yes, complete the following table (NOTE – This table may be expanded for additional wells):

Well Name	Status	Latitude [a]	Longitude [a]	Gradient	Location
	Select	. °	- . °	Select	Select
	Select	. °	- . °	Select	Select
	Select	. °	- . °	Select	Select
	Select	. °	- . °	Select	Select
	Select	. °	- . °	Select	Select
	Select	. °	- . °	Select	Select
	Select	. °	- . °	Select	Select
	Select	. °	- . °	Select	Select
	Select	. °	- . °	Select	Select
	Select	. °	- . °	Select	Select

[a] Provide the following latitude and longitude coordinate determination information:

Datum: Select Level of accuracy: Select Method of measurement: Select

11. If the Applicant is a Privately-Owned Public Utility, has a Certificate of Public Convenience and Necessity been submitted? ☐ Yes, ☐No or ☐N/A

12. If the Applicant is a Developer of lots to be sold, has a Developer's Operational Agreement (FORM: DEV) been submitted? ☐ Yes, ☐No or ☐N/A

13. If the Applicant is a Home/Property Owners' Association, has an Association Operational Agreement (FORM: HOA) been submitted? ☐ Yes, ☐No or ☐N/A

14. Demonstration of historical consideration for permit approval – 15A NCAC 02T .0120:

    Has the Applicant or any parent, subsidiary or other affiliate exhibited the following?

    a. Has been convicted of environmental crimes under Federal law or G.S. 143-215.6B? ☐ Yes or ☐ No

    b. Has previously abandoned a wastewater treatment facility without properly closing that facility? ☐ Yes or ☐ No

    c. Has unpaid civil penalty where all appeals have been abandoned or exhausted? ☐ Yes or ☐ No

    d. Is non-compliant with an existing non-discharge permit, settlement agreement or order? ☐ Yes or ☐ No

    e. Has unpaid annual fees in accordance with 15A NCAC 02T .0105(e)(2)? ☐ Yes or ☐ No

V. WASTEWATER TREATMENT FACILITY DESIGN CRITERIA – 15A NCAC 02T .0505:

1. For the following parameters, provide the estimated influent concentrations and designed effluent concentrations as determined in the Engineering Calculations, and utilized in the Agronomic Evaluation and Groundwater Modeling (if applicable):

Parameter	Estimated Influent Concentration	Designed Effluent Concentration (monthly average)
Ammonia Nitrogen (NH_3-N)	mg/L	mg/L
Biochemical Oxygen Demand (BOD_5)	mg/L	mg/L
Fecal Coliforms		per 100 mL
Nitrate Nitrogen (NO_3-N)	mg/L	mg/L
Nitrite Nitrogen (NO_2-N)	mg/L	mg/L
Total Kjeldahl Nitrogen		mg/L
Total Nitrogen	mg/L	mg/L
Total Phosphorus	mg/L	mg/L
Total Suspended Solids (TSS)	mg/L	mg/L

2. Is flow equalization of at least 25% of the average daily flow provided? ☐ Yes or ☐ No
3. Does the treatment facility include any bypass or overflow lines? ☐ Yes or ☐ No

   If yes, describe what treatment units are bypassed, why this is necessary, and where the bypass discharges: _____
4. Are multiple pumps provided wherever pumps are used? ☐ Yes or ☐ No

   If no, how does the Applicant intend on complying with 15A NCAC 02T .0505(k)? _____
5. Check the appropriate box describing how power reliability will be provided in accordance with 15A NCAC 02T .0505(l):

   ☐ Automatically activated standby power supply onsite capable of powering all essential treatment units; or

   ☐ Approval from the Director that the facility:

   - Has a private water supply that automatically shuts off during power failures and does not contain elevated water storage tanks;
   - Has sufficient storage capacity that no potential for overflow exists; and
   - Can tolerate septic wastewater due to prolonged detention.
6. If the wastewater treatment system is located within the 100-year flood plain, are there water-tight seals on all treatment units or a minimum of two feet protection from the 100-year flood plain elevation? ☐ Yes, ☐ No or ☐ N/A
7. In accordance with 15A NCAC 02T .0505(o), how many days of residuals storage are provided? _____
8. How does the Applicant propose to prohibit public access to the wastewater treatment and storage facilities? _____
9. If an influent pump station is part of the proposed facility (i.e., within the wastewater treatment plant boundary), does the influent pump station meet the design criteria in 15A NCAC 02T .0305(h)? ☐ Yes, ☐ No, ☐ N/A – To be permitted separately, or ☐ N/A – Gravity fed
10. If septic tanks are part of the wastewater treatment facility, do the septic tanks adhere to the standards in 15A NCAC 18A .1900? ☐ Yes, ☐ No or ☐ N/A

V. WASTEWATER TREATMENT FACILITY DESIGN CRITERIA – 15A NCAC 02T .0505 (continued):

11. Provide the requested treatment unit and mechanical equipment information:

a. PRELIMINARY / PRIMARY TREATMENT (i.e., physical removal operations and flow equalization):

Treatment Unit	No. of Units	Manufacturer or Material	Dimensions (ft) / Spacings (in)	Volume (gallons)	Plan Sheet Reference	Specification Reference
Select						
Select						
Select						
Select						
Select						

b. SECONDARY / TERTIARY TREATMENT (i.e., biological and chemical processes to remove organics and nutrients)

Treatment Unit	No. of Units	Manufacturer or Material	Dimensions (ft)	Volume (gallons)	Plan Sheet Reference	Specification Reference
Select						
Select						
Select						
Select						
Select						
Select						
Select						
Select						

c. DISINFECTION

Treatment Unit	No. of Units	Manufacturer or Material	Dimensions (ft)	Volume (gallons)	Plan Sheet Reference	Specification Reference
Select						
Select						

- If chlorination is the proposed method of disinfection, specify detention time provided: _____ minutes (NOTE – 30 minutes minimum required), and indicate what treatment unit chlorine contact occurs: _____
- If ultraviolet (UV) light is the proposed method of disinfection, specify the number of banks: _____, number of lamps per bank: _____ and maximum disinfection capacity: _____ GPM.

d. RESIDUAL TREATMENT

Treatment Unit	No. of Units	Manufacturer or Material	Dimensions (ft)	Volume (gallons)	Plan Sheet Reference	Specification Reference
Select						
Select						

V. WASTEWATER TREATMENT FACILITY DESIGN CRITERIA – 15A NCAC 02T .0505 (continued):

e. PUMPS

Location	No. of Pumps	Purpose	Manufacturer / Type	Capacity		Plan Sheet Reference	Specification Reference
				GPM	TDH		

f. BLOWERS

Location	No. of Blowers	Units Served	Manufacturer / Type	Capacity (CFM)	Plan Sheet Reference	Specification Reference

g. MIXERS

Location	No. of Mixers	Units Served	Manufacturer / Type	Power (hp)	Plan Sheet Reference	Specification Reference

h. RECORDING DEVICES & RELIABILITY

Device	No. of Units	Location	Manufacturer	Maximum Capacity	Plan Sheet Reference	Specification Reference
Select						
Select						
Select						
Select						

i. EFFLUENT PUMP / FIELD DOSING TANK (IF APPLICABLE):

				Plan Sheet Reference	Specification Reference
Internal dimensions (L x W x H or φ x H)	ft	ft	ft		
Total volume	ft^3	gallons			
Dosing volume	ft^3	gallons			
Audible & visual alarms					
Equipment to prevent irrigation during rain events					

VI. EARTHEN IMPOUNDMENT DESIGN CRITERIA – 15A NCAC 02T .0505:

IF MORE THAN ONE IMPOUNDMENT, PROVIDE ADDITIONAL COPIES OF THIS PAGE AS NECESSARY.

1. What is the earthen impoundment type? Select
2. Storage Impoundment Coordinates (Decimal Degrees): Latitude: __.____° Longitude: -__.____°

   Datum: Select Level of accuracy: Select Method of measurement: Select
3. Do any impoundments include a discharge point (pipe, spillway, etc)? ☐ Yes or ☐ No
4. Are subsurface drains present beneath or around the impoundment to control groundwater elevation? ☐ Yes or ☐ No
5. Is the impoundment designed to receive surface runoff? ☐ Yes or ☐ No

   If yes, what is the drainage area? _____ ft^2, and was this runoff incorporated into the water balance? ☐ Yes or ☐ No
6. If a liner is present, how will it be protected from wind driven wave action?: _____
7. Will the earthen impoundment water be placed directly into or in contact with GA classified groundwater? ☐ Yes or ☐ No

   If yes, has the Applicant provided predictive calculations or modeling demonstrating that such placement will not result in a contravention of GA groundwater standards? ☐ Yes or ☐ No
8. What is the depth to bedrock from the earthen impoundment bottom elevation? _____ ft

   If the depth to bedrock is less than four feet, has the Applicant provided a liner with a hydraulic conductivity no greater than 1×10^{-7} cm/s? ☐ Yes, ☐ No or ☐ N/A

   → Has the Applicant provided predictive calculations or modeling demonstrating that surface water or groundwater standards will not be contravened? ☐ Yes or ☐ No

   If the earthen impoundment is excavated into bedrock, has the Applicant provided predictive calculations or modeling demonstrating that surface water or groundwater standards will not be contravened? ☐ Yes, ☐ No or ☐ N/A
9. If the earthen impoundment is lined and the mean seasonal high water table is higher than the impoundment bottom elevation, how will the liner be protected (e.g., bubbling, groundwater infiltration, etc.)? _____
10. If applicable, provide the specification page references for the liner installation and testing requirements: _____
11. If the earthen impoundment is located within the 100-year flood plain, has a minimum of two feet of protection (i.e., top of embankment elevation to 100-year flood plain elevation) been provided? ☐ Yes or ☐ No
12. Provide the requested earthen impoundment design elements and dimensions:

Earthen Impoundment Design Elements			Earthen Impoundment Dimensions	
Liner type:	☐ Clay ☐ Other	☐ Synthetic ☐ Unlined	Top of embankment elevation:	ft
Liner hydraulic conductivity:	x - cm/s		Freeboard elevation:	ft
Hazard class:	Select		Toe of slope elevation:	ft
Designed freeboard:	ft		Impoundment bottom elevation:	ft
Total volume:	ft^3	gallons	Mean seasonal high water table depth:	ft
Effective volume:	ft^3	gallons	Embankment slope:	:
Effective storage time:	days		Top of dam water surface area:	ft^2
Plan Sheet Reference:			Freeboard elevation water surface area:	ft^2
Specification Section:			Bottom of impoundment surface area:	ft^2

NOTE – The effective volume shall be the volume between the two foot freeboard elevation and the: (1) pump intake pipe elevation; (2) impoundment bottom elevation or (3) mean seasonal high water table, whichever is closest to the two foot freeboard elevation.

VII. IRRIGATION SYSTEM DESIGN CRITERIA – 15A NCAC 02T .0505:

1. Provide the minimum depth to the seasonal high water table within the irrigation area: _____

   NOTE – The vertical separation between the seasonal high water table and the ground surface shall be at least one foot.

2. Are there any artificial drainage or water movement structures (e.g., surface water or groundwater) within 200 feet of the irrigation area? ☐ Yes or ☐ No

   If yes, were these structures addressed in the Soil Evaluation and/or Hydrogeologic Report, and are these structures to be maintained or modified? _____

3. Soil Evaluation recommended loading rates (NOTE – This table may be expanded for additional soil series):

Soil Series	Fields within Soil Series	Recommended Loading Rate (in/hr)	Recommended Loading Rate (in/yr)	Annual / Seasonal Loading	If Seasonal, list appropriate months
				Select	
				Select	
				Select	
				Select	
				Select	
				Select	

4. Are the designed loading rates less than or equal to Soil Evaluation recommended loading rates? ☐ Yes or ☐ No

   If no, how does the Applicant intend on complying with 15A NCAC 02T .0505(n)? _____

5. How does the Applicant propose to prohibit public access to the irrigation system? _____

6. Has the irrigation system been equipped with a flow meter to accurately determine the volume of effluent applied to each field as listed in VII.8.? ☐ Yes or ☐ No

   If no, how does the Applicant intend on complying with 15A NCAC 02T .0505(t)? _____

7. Provide the required cover crop information and demonstrate the effluent will be applied at or below agronomic rates:

Cover Crop	Soil Series	% Slope	Nitrogen Uptake Rate (lbs/ac·yr)	Phosphorus Uptake Rate (lbs/ac·yr)

   a. Specify where the nitrogen and phosphorus uptake rates for each cover crop were obtained: _____

   b. Proposed nitrogen mineralization rate: _____

   c. Proposed nitrogen volatilization rate: _____

   d. Minimum irrigation area from the Agronomist Evaluation's nitrogen balance: _____ ft^2

   e. Minimum irrigation area from the Agronomist Evaluation's phosphorus balance: _____ ft^2

   f. Minimum irrigation area from the water balance: _____ ft^2

VII. IRRIGATION SYSTEM DESIGN CRITERIA – 15A NCAC 02T .0505 (continued):

8. Field Information (NOTE – This table may be expanded for additional fields):

Field	Area (acres)	Dominant Soil Series	Designed Loading Rate (in/hr)	Designed Loading Rate (in/yr)	Latitude [a]	Longitude [a]	Waterbody Stream Index No. [b]	Classification
					. °	- . °		
					. °	- . °		
					. °	- . °		
					. °	- . °		
					. °	- . °		
					. °	- . °		
					. °	- . °		
					. °	- . °		
					. °	- . °		
					. °	- . °		
					. °	- . °		
					. °	- . °		
					. °	- . °		
					. °	- . °		
					. °	- . °		
					. °	- . °		
					. °	- . °		
					. °	- . °		
					. °	- . °		
Total								

[a] Provide the following latitude and longitude coordinate determination information:

Datum: Select Level of accuracy: Select Method of measurement: Select

[b] For assistance determining the waterbody stream index number and its associated classification, instructions may be downloaded at: http://portal.ncdenr.org/web/wq/aps/lau/applications#Agreements

Spray Irrigation Design Elements		Drip Irrigation Design Elements	
Nozzle wetted diameter:	ft	Emitter wetted area:	ft^2
Nozzle wetted area:	ft^2	Distance between laterals:	ft
Nozzle capacity:	GPM	Distance between emitters:	ft
Nozzle manufacturer/model:	/	Emitter capacity:	GPH
Elevation of highest nozzle:	ft	Emitter manufacturer/model:	/
Specification Section:		Elevation of highest emitter:	ft
		Specification Section:	

VIII. SETBACKS – 15A NCAC 02T .0506:

1. Does the project comply with all setbacks found in the river basin rules (15A NCAC 02B .0200)? ☐ Yes or ☐ No

   If no, list non-compliant setbacks: _____

2. Have any setback waivers been obtained in order to comply with 15A NCAC 02T .506(a) and .0506(b)? ☐ Yes or ☐ No

   If yes, have these waivers been written, notarized and signed by all parties involved and recorded with the County Register of Deeds? ☐ Yes or ☐ No

3. Provide the minimum field observed distances (ft) for each setback parameter to the irrigation system and treatment/storage units (NOTE – Distances greater than 500 feet may be marked N/A):

Setback Parameter	Irrigation System	Treatment / Storage Units
Any habitable residence or place of assembly under separate ownership or not to be maintained as part of the project site		
Any habitable residence or place of assembly owned by the Permittee to be maintained as part of the project site		
Any private or public water supply source		
Surface waters (streams – intermittent and perennial, perennial waterbodies, and wetlands)		
Groundwater lowering ditches (where the bottom of the ditch intersects the SHWT)		
Subsurface groundwater lowering drainage systems		
Surface water diversions (ephemeral streams, waterways, ditches)		
Any well with exception of monitoring wells		
Any property line		
Top of slope of embankments or cuts of two feet or more in vertical height		
Any water line from a disposal system		
Any swimming pool		
Public right of way		
Nitrification field		
Any building foundation or basement		
Impounded public water supplies		
Public shallow groundwater supply (less than 50 feet deep)		

4. Does the Applicant intend on complying with 15A NCAC 02T .0506(c) in order to have reduced irrigation setbacks to property lines? ☐ Yes or ☐ No

   If yes, complete the following table by providing the required concentrations as determined in the Engineering Calculations:

Parameter	Estimated Influent Concentration	Designed Effluent Concentration (monthly average)	Designed Effluent Concentration (daily maximum)
Ammonia Nitrogen (NH_3-N)	mg/L	mg/L	mg/L
Biochemical Oxygen Demand (BOD_5)	mg/L	mg/L	mg/L
Fecal Coliforms		per 100 mL	per 100 mL
Total Suspended Solids (TSS)	mg/L	mg/L	mg/L
Turbidity			NTU

IX. COASTAL WASTE TREATMENT DISPOSAL REQUIREMENTS – 15A NCAC 02H .0400:

1. Is this facility located in a Coastal Area as defined per 15A NCAC 02H .0403? ☐ Yes or ☐ No

   For assistance determining if the facility is located within the Coastal Area, a reference map may be downloaded at: http://portal.ncdenr.org/web/wq/aps/lau/applications#Agreements.

2. Is this an Interim Treatment and Disposal Facility per 15A NCAC 02H .0404(g)? ☐ Yes or ☐ No

   NOTE – Interim facilities do not include County and Municipal area-wide collection and treatment systems.

IF ANSWERED YES TO ITEMS IX.1. AND IX.2., THEN COMPLETE ITEMS IX.3. THROUGH IX.17.

3. Is equalization of at least 25% of the average daily flow provided? ☐ Yes or ☐ No
4. How will noise and odor be controlled? _____
5. Is an automatically activated standby power source provided? ☐ Yes or ☐ No
6. Are all essential treatment units provided in duplicate? ☐ Yes or ☐ No

   NOTE – Per 15A NCAC 02T .0103(16), essential treatment units are defined as any unit associated with the wastewater treatment process whose loss would likely render the facility incapable of meeting the required performance criteria, including aeration units or other main treatment units, clarification equipment, filters, disinfection equipment, pumps and blowers.

7. Are the disposal units (i.e., irrigation fields) provided in duplicate (e.g., more than one field)? ☐ Yes or ☐ No
8. Is there an impounded public surface water supply within 500 feet of the wetted area? ☐ Yes or ☐ No
9. Is there a public shallow groundwater supply (less than 50 feet deep) within 500 feet of the wetted area? ☐ Yes or ☐ No
10. Is there a private groundwater supply within 100 feet of the wetted area? ☐ Yes or ☐ No
11. Are there any SA classified waters within 100 feet of the wetted area? ☐ Yes or ☐ No
12. Are there any non-SA classified waters within 50 feet of the wetted area? ☐ Yes or ☐ No
13. Are there any surface water diversions (i.e., drainage ditches) within 25 feet of the wetted area? ☐ Yes or ☐ No
14. Per the requirements in 15A NCAC 02H .0404(g)(7), how much green area is provided? _____ ft^2
15. Is the green area clearly delineated on the plans? ☐ Yes or ☐ No
16. Is the spray irrigation wetted area within 200 feet of any adjoining properties? ☐ Yes, ☐ No or ☐ N/A (i.e., drip irrigation)
17. Does the designed annual loading rate exceed 91 inches? ☐ Yes or ☐ No

Professional Engineer's Certification:

I, _____attest that this application for
(Professional Engineer's name from Application Item III.1.)

_____
(Facility name from Application Item II.1.)

has been reviewed by me and is accurate, complete and consistent with the information supplied in the plans, specifications, engineering calculations, and all other supporting documentation to the best of my knowledge. I further attest that to the best of my knowledge the proposed design has been prepared in accordance with this application package and its instructions, as well as all applicable regulations and statutes. Although other professionals may have developed certain portions of this submittal package, inclusion of these materials under my signature and seal signifies that I have reviewed this material and have judged it to be consistent with the proposed design.

NOTE – In accordance with General Statutes 143-215.6A and 143-215.6B, any person who knowingly makes any false statement, representation, or certification in any application package shall be guilty of a Class 2 misdemeanor, which may include a fine not to exceed $10,000, as well as civil penalties up to $25,000 per violation.

North Carolina Professional Engineer's seal, signature, and date:

Applicant's Certification per 15A NCAC 02T .0106(b):

I, _____attest that this application for
(Signature Authority's name & title from Application Item I.3.)

_____
(Facility name from Application Item II.1.)

has been reviewed by me and is accurate and complete to the best of my knowledge. I understand that any discharge of wastewater from this non-discharge system to surface waters or the land will result in an immediate enforcement action that may include civil penalties, injunctive relief, and/or criminal prosecution. I will make no claim against the Division of Water Resources should a condition of this permit be violated. I also understand that if all required parts of this application package are not completed and that if all required supporting information and attachments are not included, this application package will be returned to me as incomplete. I further certify that the Applicant or any affiliate has not been convicted of an environmental crime, has not abandoned a wastewater facility without proper closure, does not have an outstanding civil penalty where all appeals have been exhausted or abandoned, are compliant with any active compliance schedule, and do not have any overdue annual fees per 15A NCAC 02T .0105(e).

NOTE – In accordance with General Statutes 143-215.6A and 143-215.6B, any person who knowingly makes any false statement, representation, or certification in any application package shall be guilty of a Class 2 misdemeanor, which may include a fine not to exceed $10,000 as well as civil penalties up to $25,000 per violation.

Signature: _____ Date: _____

State of North Carolina
Department of Environment and Natural Resources
Division of Water Resources

NON-DISCHARGE SYSTEM RENEWAL
INSTRUCTIONS FOR FORM: NDSR 11-13 & SUPPORTING DOCUMENTATION

This form is for renewal without modification for all non-discharge system permits, except Residuals Management permits.

For more information, visit the Water Quality Permitting Section's Non-Discharge Permitting Unit website at:
http://portal.ncdenr.org/web/wq/aps/lau

A. **Non-Discharge System Renewal (FORM: NDSR 11-13) Application** (All Application Packages):
- ☐ Submit one original and one copy of the completed and appropriately executed Non-Discharge System Renewal (FORM: NDSR 11-13) application.
- ☐ The Applicant's Certification shall be signed in accordance with 15A NCAC 02T .0106(b). Per 15A NCAC 02T .0106(c), an alternate person may be designated as the signing official if a delegation letter is provided from a person who meets the criteria in 15A NCAC 02T .0106(b).

B. **Existing Permit** (All Application Packages):
- ☐ Submit two copies of the most recently issued permit.

C. **Certificate of Public Convenience and Necessity** (All Application Packages for Privately-Owned Public Utilities):
- ☐ Per 15A NCAC 02T .0115(a)(1), provide two copies of the Certificate of Public Convenience and Necessity from the North Carolina Utilities Commission demonstrating the Applicant is authorized to hold the utility franchise for the area to be served by the non-discharge system.

D. **Operation and Maintenance Agreement** (All Application Packages for Single-Family Residences):
- ☐ Submit one original and one copy of the signed Operation and Maintenance Agreement (FORM: SFRWWIS O&M).

E. **Operational Agreements** (All Application Packages for Home/Property Owners' Associations and Developers of lots to be sold):
- ➢ Home/Property Owners' Associations
  - ☐ Per 15A NCAC 02T .0115(c), submit an original and one copy of the properly executed Operational Agreement (FORM: HOA).
  - ☐ Per 15A NCAC 02T .0115(c), submit an original and one copy of the proposed or approved Articles of Incorporation, Declarations and By-laws.
- ➢ Developers of lots to be sold
  - ☐ Per 15A NCAC 02T .0115(b), submit an original and one copy of the properly executed Operational Agreement (FORM: DEV).

F. **Site Map** (All Application Packages for permits originally issued or modified after September 1, 2006):
- ☐ Submit two copies of an updated site map in accordance with 15A NCAC 02T .0105(d).

THE COMPLETED APPLICATION AND SUPPORTING DOCUMENTATION SHALL BE SUBMITTED TO:

NORTH CAROLINA DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES
DIVISION OF WATER RESOURCES
WATER QUALITY PERMITTING SECTION
NON-DISCHARGE PERMITTING UNIT

By U.S. Postal Service:
1636 MAIL SERVICE CENTER
RALEIGH, NORTH CAROLINA 27699-1636

TELEPHONE NUMBER: (919) 807-6464

By Courier/Special Delivery:
512 N. SALISBURY ST.
RALEIGH, NORTH CAROLINA 27604

FAX NUMBER: (919) 807-6496

State of North Carolina
Department of Environment and Natural Resources
Division of Water Resources

NON-DISCHARGE SYSTEM RENEWAL
FORM: NDSR 11-13

I. PERMITTEE INFORMATION:

1. Permittee's name: _____
2. Signature authority's name: _____ per 15A NCAC 02T .0106(b) Title: _____
3. Permittee's mailing address: _____

   City: _____ State: _____ Zip: _____-____
4. Permittee's contact information: Phone number: (___) ___-____ Email Address: _____

II. FACILITY INFORMATION:

1. Facility name: _____
2. Facility's physical address: _____

   City: _____ State: _____ Zip: _____-____ County: _____

III. PERMIT INFORMATION:

1. Existing permit number: WQ00_____ and most recent issuance date: _____
2. Existing permit type: Select
3. Has the facility been constructed? ☐ Yes or ☐ No
4. Demonstration of historical consideration for permit approval – 15A NCAC 02T .0120:

   Has the Applicant or any parent, subsidiary or other affiliate exhibited the following?

   a. Has been convicted of environmental crimes under Federal law or G.S. 143-215.6B? ☐ Yes or ☐ No
   b. Has previously abandoned a wastewater treatment facility without properly closing that facility? ☐ Yes or ☐ No
   c. Has unpaid civil penalty where all appeals have been abandoned or exhausted? ☐ Yes or ☐ No
   d. Is non-compliant with an existing non-discharge permit, settlement agreement or order? ☐ Yes or ☐ No
   e. Has unpaid annual fees in accordance with 15A NCAC 02T .0105(e)(2)? ☐ Yes or ☐ No

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Applicant's Certification per 15A NCAC 02T .0106(b):

I, _____attest that this application for
(Signature Authority's name & title from Application Item I.2.)

_____
(Facility name from Application Item II.1.)

has been reviewed by me and is accurate and complete to the best of my knowledge. I understand that any discharge of wastewater from this non-discharge system to surface waters or the land will result in an immediate enforcement action that may include civil penalties, injunctive relief, and/or criminal prosecution. I will make no claim against the Division of Water Resources should a condition of this permit be violated. I also understand that if all required parts of this application package are not completed and that if all required supporting information and attachments are not included, this application package will be returned to me as incomplete. I further certify that the Applicant or any affiliate has not been convicted of an environmental crime, has not abandoned a wastewater facility without proper closure, does not have an outstanding civil penalty where all appeals have been exhausted or abandoned, are compliant with any active compliance schedule, and do not have any overdue annual fees per 15A NCAC 02T .0105(e).

NOTE – In accordance with General Statutes 143-215.6A and 143-215.6B, any person who knowingly makes any false statement, representation, or certification in any application package shall be guilty of a Class 2 misdemeanor, which may include a fine not to exceed $10,000 as well as civil penalties up to $25,000 per violation.

Signature: _____ Date: _____

North Carolina Department of Environment and Natural Resources

Pat McCrory
Governor

Donald R. van der Vaart
Secretary

February 18, 2015

Subject: Permit No. WQ0015010
Wastewater Surface Irrigation
Sampson County

Dear Mr.

In accordance with your permit renewal request and minor modification received September 19, 2014, we are forwarding herewith Permit No. WQ0015010 to dated February 18, 2015, for the continued operation of the subject wastewater treatment and irrigation facilities.

The minor modification to the subject permit is as follows: the WWTF effluent limit is Attachment A was changed from 1,440 gallons per day to 525,600 gallons per year. In addition changes to this permit were made to make it consistent with other permitted truck wash facilities.

Condition III. 15 requires a gauge to monitor waste levels in the settling basin and the lagoon. This gauge shall have readily visible permanent markings, at inch or tenth of a foot increments, indicating the following elevations: maximum liquid level at the top of the temporary liquid storage volume; minimum liquid level at the bottom of the temporary liquid storage volume; and the lowest point on top of the dam.

Please note that per the Division of Water Resources' Non-Discharge Permitting Unit Wastewater Monitoring Policy, all non-discharge systems are having their effluent monitoring schedules reevaluated based on the type of system as well as the flow in gallons per day. Accordingly, the sampling frequency for pH (00400) is now weekly unless Pemittee documents that the facility irrigates at a rate less than once per week. In addition, the monitoring requirements for BOD (00310), Fecal Coliform (31616), Total Nitrogen (00600), Chloride (00940), Total Dissolved Solids (70300) and Total Suspended Solids (00530) have been added.

This permit shall be effective from the date of issuance until January 31, 2020, shall void Permit No. WQ0015010 issued October 22, 2008, and shall be subject to the conditions and limitations as specified therein. Please read your permit in full, as conditions have changed since the last permit. Please pay particular attention to the monitoring requirements listed in Attachments A, B & C. Failure to establish an adequate system for collecting and maintaining the required operational information shall result in future compliance problems.

For your convenience, customized electronic copies of your facility's NDMR, NDMLR, and NDAR-1 reporting forms are available for download at:

http://portal.ncdenr.org/web/wq/aps/lau/reporting.

If any parts, requirements or limitations contained in this permit are unacceptable, the Permittee has the right to request an adjudicatory hearing upon written request within 30 days following receipt of this permit. This request shall be in the form of a written petition, conforming to Chapter 150B of the North Carolina General Statutes, and filed with the Office of Administrative Hearings at 6714 Mail Service Center, Raleigh, NC 27699-6714. Unless such demands are made, this permit shall be final and binding.

If you need additional information concerning this permit, please contact Alice M. Wessner at (919) 807-6425 or at alice.wessner@ncdenr.gov.

Sincerely,

S. Jay Zimmerman, Acting Director
Division of Water Resources

cc: Fayetteville Regional Office, Water Quality Regional Operations Section (Electronic Copy)
Beth Buffington, Public Water Supply Section – Protection and Enforcement Branch (Electronic Copy)
Central Files
Digital Permit Archive (Electronic Copy)

NORTH CAROLINA

ENVIRONMENTAL MANAGEMENT COMMISSION

DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES

RALEIGH

WASTEWATER IRRIGATION SYSTEM PERMIT

In accordance with the provisions of Article 21 of Chapter 143, General Statutes of North Carolina as amended, and other applicable Laws, Rules and Regulations

PERMISSION IS HEREBY GRANTED TO

Sampson County

FOR THE

continued operation of a 525,600 gallons per year (1,440 GPD average) spray irrigation treatment and disposal facility consisting of:

a 250,000 gallon lagoon and a 2.0 acre spray irrigation field irrigated by a honey wagon to serve the with no discharge of wastes to the surface waters, pursuant to the application received September 19, 2014, by the Division of Water Resources (Division), and in conformity with the project plan, specifications, and other supporting data subsequently filed and approved by the Department of Environment and Natural Resources and considered a part of this permit.

This permit shall be effective from the date of issuance until January 31, 2020, shall void Permit No. WQ0012630 issued September 11, 2008, and shall be subject to the following specified conditions and limitations:

I. SCHEDULES

1. A monitoring well (MW-1) as required in condition IV.10 shall be installed prior to January 1, 2016.

2. The Fayetteville Regional Office, telephone number (910)796-7215, shall approve the monitoring well prior to installation. At least one monitoring well shall be placed between the wetted perimeter of sprayfield #1 and the Beaverdam Swamp as deemed appropriate by the Fayetteville Regional Office. The regional office shall be notified at least 48 hours prior to the construction of any monitoring well and such notification to the regional supervisor shall be made from 8:00 a.m. until 5:00 p.m. on Monday through Friday, excluding State Holidays. The monitoring well shall be constructed such that the water level in the well is never above or below the screened (open) portion of the well at any time during the year, and in accordance with 15A NCAC 02C .0108. The Fayetteville Regional office can provide assistance with the general location of the monitoring well.

3. Within 60 days of completion of the monitoring wells, the Permittee shall submit two original copies of a site map with a scale no greater than 1-inch equals 100 feet; however, special provisions may be granted upon prior approval for large properties. At a minimum, the map shall include the following information:

   a. The location and identity of each monitoring well.
   b. The location of major components of the waste disposal system.
   c. The location of property boundaries within 500 feet of the disposal areas.
   d. The latitude and longitude of the established horizontal control monument.
   e. The elevation of the top of the well casing (i.e., measuring point) relative to a common datum.
   f. The depth of water below the measuring point at the time the measuring point is established.
   g. The location of compliance and review boundaries.
   h. The date the map is prepared and/or revised.

   Control monuments shall be installed in such a manner and made of such materials that the monument will not be destroyed due to activities taking place on the property. The map and any supporting documentation shall be sent to the Division of Water Resources, Water Quality Permitting Section, 1636 Mail Service Center, Raleigh, NC 27699-1636.

5. No later than six months prior to the expiration of this permit, the Permittee shall request renewal of this permit on official Division forms. Upon receipt of the request, the Division will review the adequacy of the facilities described therein, and if warranted, will renew the permit for such period of time and under such conditions and limitations as it may deem appropriate. Please note Rule 15A NCAC 02T .0105(d) requires an updated site map to be submitted with the permit renewal application.

II. PERFORMANCE STANDARDS

1. The subject non-discharge facilities shall be effectively maintained and operated at all times so there is no discharge to surface waters, nor any contravention of groundwater or surface water standards. In the event the facilities fail to perform satisfactorily, including the creation of nuisance conditions due to improper operation and maintenance, or failure of the irrigation areas to adequately assimilate the effluent, the Permittee shall take immediate corrective actions including Division required actions, such as the construction of additional or replacement wastewater treatment or irrigation facilities.

2. This permit shall not relieve the Permittee of their responsibility for damages to groundwater or surface water resulting from the operation of this facility.

3. All wells constructed for purposes of groundwater monitoring shall be constructed in accordance with 15A NCAC 02C .0108 (Standards of Construction for Wells Other than Water Supply), and any other jurisdictional laws and regulations pertaining to well construction.

4. Effluent limitations shall not exceed those specified in Attachment A. The flow limit shall be based on a 12-month floating total.

5. Application rates, whether hydraulic, nutrient or other pollutant, shall not exceed those specified in Attachment B.

6. The compliance boundary for the disposal system shall be specified in accordance with 15A NCAC 02L .0107(b). This disposal system was individually permitted on or after December 30, 1983; therefore, the compliance boundary is established at either 250 feet from the effluent disposal area, or 50 feet within the property boundary, whichever is closest to the effluent disposal area. An exceedance of groundwater standards at or beyond the compliance boundary is subject to remediation action according to 15A NCAC 02L .0106(d)(2) as well as enforcement actions in accordance with North Carolina General Statute 143-215.6A through 143-215.6C.

7. In accordance with 15A NCAC 02L .0108, the review boundary is established midway between the compliance boundary and the effluent disposal area. Any exceedance of groundwater standards at the review boundary shall require action in accordance with 15A NCAC 02L .0106.

8. The Permittee shall apply for a permit modification to establish a new compliance boundary prior to any sale or transfer of property affecting a compliance boundary.

9. In accordance with 15A NCAC 02L .0107(d), no wells, excluding Division approved monitoring wells, shall be constructed within the compliance boundary except as provided for in 15A NCAC 02L .0107(g).

10. Except as provided for in 15A NCAC 02L .0107(g), the Permittee shall ensure any landowner who is not the Permittee and owns land within the compliance boundary shall execute and file with the Bladen County Register of Deeds an easement running with the land containing the following items:

    a. A notice of the permit and number or other description as allowed in 15A NCAC 02L .0107(f)(1);

    b. Prohibits construction and operation of water supply wells within the compliance boundary; and

    c. Reserves the right of the Permittee or the State to enter the property within the compliance boundary for purposes related to the permit.

    The Director may terminate the easement when its purpose has been fulfilled or is no longer needed.

11. The facilities permitted herein shall be constructed according to the following setbacks:

    a. The setbacks for irrigation sites permitted under 15A NCAC 02H .0200 shall be as follows (all distances in feet):

i.	Any habitable residence or place of public assembly under separate ownership:	400
ii.	Surface waters:	100
iii.	Any well with exception of monitoring wells:	100
iv.	Any property line:	150
v.	Public right of way:	50

    b. The setbacks for storage and treatment units permitted under 15A NCAC 02H .0200 shall be as follows (all distances in feet):

i.	Any well with exception of monitoring wells:	100
ii.	Any property line:	50

III. OPERATION AND MAINTENANCE REQUIREMENTS

1. The facilities shall be properly maintained and operated at all times. The facilities shall be effectively maintained and operated as a non-discharge system to prevent the discharge of any wastewater resulting from the operation of this facility. The Permittee shall maintain an Operation and Maintenance Plan pursuant to 15A NCAC 02T .0507, which at a minimum shall include operational functions, maintenance schedules, safety measures and a spill response plan.

2. Upon the Water Pollution Control System Operators Certification Commission's (WPCSOCC) classification of the subject non-discharge facilities, in accordance with 15A NCAC 08G .0200 the Permittee shall designate and employ a certified operator in responsible charge (ORC) and one or more certified operator(s) as back-up ORC(s). The ORC or their back-up shall visit the facilities in accordance with 15A NCAC 08G .0200, and shall comply with all other conditions specified in the previously cited rules.

3. A suitable year round vegetative cover shall be maintained at all times, such that crop health is optimized, allows for even distribution of effluent and allows inspection of the irrigation system.

4. Adequate measures shall be taken to prevent effluent ponding in or runoff from the irrigation sites listed in Attachment B.

5. Irrigation shall not be performed during inclement weather or when the ground is in a condition that will cause ponding or runoff.

6. All irrigation equipment shall be tested and calibrated at least once per permit cycle. Calibration records shall be maintained at the facility for a period of no less than five years, and shall be made available to the Division upon request.

7. Only effluent from [redacted] facility shall be irrigated on the sites listed in Attachment B.

8. Soil pH on all land application fields must be maintained in the optimum range for crop production.

9. The attached Waste Utilization Plan (WUP) is hereby incorporated by reference into this permit. Any modification of the WUP, including changes to the cropping plan, shall require submittal of the revised WUP to the Fayetteville Regional Office and the Central Office but may not require permit modification.

10. No automobiles or machinery shall be allowed on the irrigation sites except during equipment installation or while maintenance is being performed.

11. Public access to the irrigation sites and wastewater treatment facilities shall be prohibited.

12. The residuals generated from the wastewater treatment facilities shall be disposed or utilized in accordance with 15A NCAC 02T .1100. The Permittee shall maintain a residual management plan pursuant to 15A NCAC 02T .0508.

13. Diversion or bypassing of untreated or partially treated wastewater from the treatment facilities is prohibited.

14. Freeboard in the settling basin or lagoon shall not be less than two feet at any time.

15. A gauge to monitor waste levels in the settling basin and the lagoon shall be provided. This gauge shall have readily visible permanent markings, at inch or tenth of a foot increments, indicating the following elevations: maximum liquid level at the top of the temporary liquid storage volume; minimum liquid level at the bottom of the temporary liquid storage volume; and the lowest point on top of the dam.

16. Only those cleaning agents and soaps that are EPA approved, will not harm the cover crop, and will not contravene the groundwater standards listed in 15A NCAC 2L may be utilized in the subject facility. Instruction labels are to be followed when using cleaning agents and soaps.

17. Results from the soils analysis required in Condition IV.10. shall be utilized to determine the appropriate amount of lime and/or gypsum to be incorporated into the irrigation field to neutralize potential salts buildup from the cleaning agents and disinfectants. Salts accumulation shall not be allowed to build to a point that inhibits the soil's ability to absorb the irrigated wastewater.

18. Results of The North Carolina Department of Agriculture, Agronomic Division's Waste Analysis Report shall be used in the monitoring and the proper management of the cover crops of the permitted application sites. The analysis shall also be used as an indicator to prevent any damage to the soil's ability to absorb the subject wastewater or nutrients.

19. Engine and engine parts shall not be washed or rinsed in the wastewater system. Oil drained from the engine crankcases, antifreeze, or degreasing solvent wastes shall not be discharged into the wastewater system.

20. A protective vegetative cover shall be established and maintained on all earthen embankments (i.e., outside toe of embankment to maximum allowable temporary storage elevation on the inside of the embankment), berms, pipe runs, erosion control areas, and surface water diversions. Trees, shrubs, and other woody vegetation shall not be allowed to grow on the earthen dikes or embankments. Earthen embankment areas shall be kept mowed or otherwise controlled and accessible.

21. Only those cleaning agents and soaps that are EPA approved, will not harm the cover crop, and will not contravene the groundwater standards listed in 15A NCAC 2L may be utilized in the subject facility. Instruction labels are to be followed when using cleaning agents and soaps.

22. Soil pH on all irrigation fields must be maintained in the optimum range for crop production.

IV. MONITORING AND REPORTING REQUIREMENTS

1. Any Division required monitoring (including groundwater, plant tissue, soil and surface water analyses) necessary to ensure groundwater and surface water protection shall be established, and an acceptable sampling reporting schedule shall be followed.

2. Per 15A NCAC 02H .0800, a Division certified laboratory shall conduct all laboratory analyses for the required effluent, groundwater or surface water parameters. Results for ammonia and nitrate that are part of the North Carolina Department of Agriculture, Agronomic Division's Waste Analysis may also be submitted.

3. Flow through the treatment facility shall be continuously monitored, and daily average flow values shall be reported on Form NDMR. Flow may be estimated from water use records, provided the Permittee's water use is metered. This flow may also be determined by using irrigation records. Daily average flow values shall be calculated by dividing the monthly metered water usage by the number of days in the month.

4. The Permittee shall monitor the effluent from the subject facilities at the frequencies and locations for the parameters specified in Attachment A.

5. The Permittee shall maintain adequate records tracking the amount of effluent irrigated. At a minimum, these records shall include the following information for each irrigation site listed in Attachment B:

   a. Date of irrigation;
   b. Volume of effluent irrigated;
   c. Site irrigated;
   d. Length of time site is irrigated;
   e. Continuous weekly, monthly, and year-to-date hydraulic (inches/acre) loadings;
   f. Continuous monthly and year-to-date loadings for any non-hydraulic parameter specifically limited in Attachment B;
   g. Weather conditions; and
   h. Maintenance of cover crops.

6. Freeboard (i.e., waste level to the lowest embankment elevation) in the lagoon shall be measured to the nearest inch or tenth of a foot, and recorded weekly. Weekly freeboard records shall be maintained at the facility for a period of no less than five years, and shall be made available to the Division upon request.

7. Three copies of all monitoring data (as specified in Conditions IV.3. and IV.4.) on Form NDMR for each PPI and three copies of all operation and disposal records (as specified in Conditions IV.5. and IV.6.) on Form NDAR-1, and NDMLR for every site in Attachment B shall be submitted on or before the last day of the following month. NDMLR data shall include cover crop type and PAN loading for each month as well as cumulative PAN loading for the year. If no activities occurred during the monitoring month, monitoring reports are still required documenting the absence of the activity. All

information shall be submitted to the following address:

Division of Water Resources
Information Processing Unit
1617 Mail Service Center
Raleigh, North Carolina 27699-1617

8. A maintenance log shall be maintained at this facility. This log shall be maintained at the facility for a period of no less than five years, and shall be made available to the Division upon request. At a minimum, this log shall include:

   a. Date of calibration of flow measurement device;
   b. Visual observations of the plant and plant site; and
   c. Record of preventative maintenance (e.g., changing of equipment, adjustments, testing, inspections and cleanings, etc.).

9. A record shall be maintained of all residuals removed from this facility. This record shall be maintained at the facility for a period of no less than five years, and shall be made available to the Division upon request. At a minimum, this record shall include:

   a. Name of the residuals hauler;
   b. Non-Discharge permit number authorizing the residuals disposal, or a letter from a municipality agreeing to accept the residuals;
   c. Date the residuals were hauled; and
   d. Volume of residuals removed.

10. Monitoring wells shall be sampled after construction and within 3 months prior to initiating non-discharge disposal operations. Monitoring wells shall be sampled thereafter at the frequencies and for the parameters specified in Attachment C. <u>All mapping, well construction forms, well abandonment forms and monitoring data shall refer to the permit number and the well nomenclature.</u>

11. For initial sampling of monitoring wells, the Permittee shall submit a Compliance Monitoring Form (GW-59) and a Well Construction Record Form (GW-1) listing this permit number and the appropriate monitoring well identification number. Initial Compliance Monitoring Forms (GW-59) without copies of the Well Construction Record Forms (GW-1) are deemed incomplete, and may be returned to the Permittee without being processed.

12. Two copies of the monitoring well sampling and analysis results shall be submitted on a Compliance Monitoring Form (GW-59), along with attached copies of laboratory analyses, on or before the last working day of the month following the sampling month. The Compliance Monitoring Form (GW-59) shall include this permit number, the appropriate well identification number, and one GW-59a certification form shall be submitted with each set of sampling results. All information shall be submitted to the following address:

    Division of Water Resources
    Information Processing Unit
    1636 Mail Service Center
    Raleigh, North Carolina 27699-1636

13. A representative soils analysis (i.e., Standard Soil Fertility Analysis) shall be conducted on each irrigation site listed in Attachment B at a minimum of every three years. These results shall be maintained at the facility for a period of no less than five years, and shall be made available to the Division upon request. At a minimum, the Standard Soil Fertility Analysis shall include the following parameters:

Acidity	Exchangeable Sodium Percentage	Phosphorus
Base Saturation (by calculation)	Magnesium	Potassium
Calcium	Manganese	Sodium
Cation Exchange Capacity	Percent Humic Matter	Zinc
Copper	pH	

14. Monitoring wells shall be sampled after construction and within 3 months prior to initiating non-discharge disposal operations. Monitoring wells shall be sampled thereafter at the frequencies and for the parameters specified in Attachment C. <u>All mapping, well construction forms, well abandonment forms and monitoring data shall refer to the permit number and the well nomenclature as provided in Attachment C.</u>

15. **Noncompliance Notification:**

    The Permittee shall report by telephone to the Wilmington Regional Office, telephone number (910) 791-7215, <u>as soon as possible</u>, but in no case more than 24 hours, or on the next working day following the occurrence or first knowledge of the occurrence of any of the following:

    a. Any occurrence at the facility resulting in the treatment of significant amounts of wastes that is abnormal in quantity or characteristic, including the known passage of a hazardous substance.

    b. Any process unit failure (e.g., mechanical, electrical, etc.), due to known or unknown reasons, rendering the facility incapable of adequate wastewater treatment.

    c. Any facility failure resulting in a by-pass directly to receiving surface waters.

    d. Any time self-monitoring indicates the facility has gone out of compliance with its permit limitations.

    e. Ponding in or runoff from the irrigation sites.

    Any emergency requiring immediate reporting (e.g., discharges to surface waters, imminent failure of a storage structure, etc.) outside normal business hours shall be reported to the Division's Emergency Response personnel at telephone number (800) 662-7956, (800) 858-0368, or (919) 733-3300. Persons reporting such occurrences by telephone shall also file a written report in letter form within five days following first knowledge of the occurrence. This report shall outline the actions taken or proposed to be taken to ensure the problem does not recur.

V. INSPECTIONS

1. The Permittee shall provide adequate inspection and maintenance to ensure proper operation of the wastewater treatment and irrigation facilities.

2. The Permittee or their designee shall inspect the wastewater treatment and irrigation facilities to prevent malfunctions, facility deterioration and operator errors resulting in discharges, which may cause the release of wastes to the environment, a threat to human health or a public nuisance. The Permittee shall maintain an inspection log that includes, at a minimum, the date and time of inspection, observations made, and any maintenance, repairs, or corrective actions taken. The Permittee shall maintain this inspection log for a period of five years from the date of the inspection, and this log shall be made available to the Division upon request.

3. Any duly authorized Division representative may, upon presentation of credentials, enter and inspect any property, premises or place on or related to the wastewater treatment and irrigation facilities permitted herein at any reasonable time for the purpose of determining compliance with this permit; may inspect or copy any records required to be maintained under the terms and conditions of this permit, and may collect groundwater, surface water or leachate samples.

VI. GENERAL CONDITIONS

1. Failure to comply with the conditions and limitations contained herein may subject the Permittee to an enforcement action by the Division in accordance with North Carolina General Statutes 143-215.6A to 143-215.6C.

2. This permit shall become voidable if the permitted facilities are not constructed in accordance with the conditions of this permit, the Division approved plans and specifications, and other supporting documentation.

3. This permit is effective only with respect to the nature and volume of wastes described in the permit application; Division approved plans and specifications, and other supporting documentation. No variances to applicable rules governing the construction or operation of the permitted facilities are granted, unless specifically requested and approved in this permit pursuant to 15A NCAC 02T .0105(n).

4. The issuance of this permit does not exempt the Permittee from complying with any and all statutes, rules, regulations, or ordinances, which may be imposed by other jurisdictional government agencies (e.g., local, state, and federal). Of particular concern to the Division are applicable river buffer rules in 15A NCAC 02B .0200; erosion and sedimentation control requirements in 15A NCAC Chapter 4 and under the Division's General Permit NCG010000; any requirements pertaining to wetlands under 15A NCAC 02B .0200 and 02H .0500; and documentation of compliance with Article 21 Part 6 of Chapter 143 of the General Statutes.

5. In the event the permitted facilities change ownership or the Permittee changes their name, a formal permit modification request shall be submitted to the Division. This request shall be made on official Division forms, and shall include appropriate property ownership documentation and other supporting documentation as necessary. The Permittee of record shall remain fully responsible for maintaining and operating the facilities permitted herein until a permit is issued to the new owner.

6. The Permittee shall retain a set of Division approved plans and specifications for the life of the facilities permitted herein.

7. The Permittee shall maintain this permit until all permitted facilities herein are properly closed or permitted under another permit issued by the appropriate permitting authority pursuant to 15A NCAC 02T .0105(j).

8. This permit is subject to revocation or unilateral modification upon 60 days notice from the Division Director, in whole or part for the requirements listed in 15A NCAC 02T .0110.

9. Unless the Division Director grants a variance, expansion of the permitted facilities contained herein shall not be granted if the Permittee exemplifies any of the criteria in 15A NCAC 02T .0120(b).

10. The Permittee shall pay the annual fee within 30 days after being billed by the Division. Failure to pay the annual fee accordingly shall be cause for the Division to revoke this permit pursuant to 15A NCAC 02T .0105(e) (3).

Permit issued this the 18th day of February 2015

NORTH CAROLINA ENVIRONMENTAL MANAGEMENT COMMISSION

_____

S. Jay Zimmerman, Acting Director
Division of Water Resources
By Authority of the Environmental Management Commission

Permit Number WQ0015010

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PPI 001 – WWTF Effluent

EFFLUENT CHARACTERISTICS		EFFLUENT LIMITS					MONITORING REQUIREMENTS	
PCS Code	**Parameter Description**	**Units of Measure**	**12 Month Total**	**Monthly Geometric Mean**	**Daily Minimum**	**Daily Maximum**	**Measurement Frequency**	**Sample Type**
50050	Flow, in Conduit or thru Treatment Plant	Gallons	525,600[2]				Monthly	Estimate
00310	BOD, 5-Day (20 degrees C)	mg/L					3 x year[1]	Grab
31616	Coliform, Fecal MF, M-FC, Broth, 44.5 ºC	#/100 mL					3 x year[1]	Grab
00610	Nitrogen, Ammonia Total (as N)	mg/L					3 x year[1]	Grab
00625	Nitrogen, Kjeldahl, Total (as N)	mg/L					3 x year[1]	Grab
00620	Nitrogen, Nitrate Total (as N)	mg/L					3 x year[1]	Grab
00600	Nitrogen, Total (as N)	mg/L					3 x year[1]	Grab
00400	pH	su					Weekly[3]	Grab
00530	Solids, Total Suspended	mg/L					3 x year[1]	Grab
70300	Solids, Total Dissolved – 180 degrees C	mg/L					3 x year[1]	Grab
00940	Chloride (as Cl)	mg/L					3 x year[1]	Grab
00665	Phosphorus, Total (as P)	mg/L					3 x year[1]	Grab
	North Carolina Department of Agriculture, Agronomic Division's Waste Analysis Report [3]	Various					3 x year[1]	Grab

1. 3 x Year sampling shall be conducted in March, July and November.
2. Flow shall not exceed 525,600 gallons over any consecutive 12 months.
3. pH monitoring can be "per event" if the Permittee documents that the facility irrigates at a rate less than once per week.
4. North Carolina Department of Agriculture, Agronomic Division's Waste Analysis Report information can be found at: http://www.ncagr.gov/agronomi/uyrwaste.htm. Only results for parameters specifically listed in this attachment need be reported on Form NDMR per condition IV.7.

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IRRIGATION AREA INFORMATION							APPLICATION LIMITATIONS		
Field	**Owner**	**County**	**Latitude**	**Longitude**	**Net Acreage**	**Dominant Soil Series**	**Parameter**	**Application Rate**	**Units**
1	TDM Farms, Inc.	Sampson	35°13’26”	78°21’29”	3.0	MaC - Marvyn loamy sand	01284 – Non Discharge Application	67.6	inches/year
							WQ09C - Plant Available Nitrogen - Loading	275	lbs/acre
Totals					**3.0**				

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Monitoring wells: MW-1

GROUNDWATER CHARACTERISTICS		GROUNDWATER STANDARDS		MONITORING REQUIREMENTS		
PCS Code	**Parameter Description**	**Daily Maximum**		**Frequency Measurement**	**Sample Type**	**Footnotes**
00680	Carbon, Tot Organic (TOC)		mg/L	3 x Year	Grab	1, 6
00940	Chloride (as Cl)	250	mg/L	3 x Year	Grab	1
31616	Coliform, Fecal MF, M-FC Broth, 44.5 ºC		#/100 mL	3 x Year	Grab	1
00610	Nitrogen, Ammonia Total (as N)	1.5	mg/L	3 x Year	Grab	1
00620	Nitrogen, Nitrate Total (as N)	10	mg/L	3 x Year	Grab	1
00400	pH	6.5-8.5	su	3 x Year	Grab	1, 2
00665	Phosphorus, Total (as P)		mg/L	3 x Year	Grab	1
70300	Solids, Total Dissolved - 180 ºC	500	mg/L	3 x Year	Grab	1
GWVOC	Volatile Compounds (GC/MS)		Present: Yes/No	Once per Permit Cycle	Grab	1, 4, 5
82546	Water Level, Distance from measuring point		feet	3 x Year	Calculated	1, 2, 3

1. 3 x Year monitoring shall be conducted in March, July & November; Once per permit cycle monitoring shall be conducted in November.
2. The measurement of water levels shall be made prior to purging the wells. The depth to water in each well shall be measured from the surveyed point on the top of the casing. The measurement of pH shall be made after purging and prior to sampling for the remaining parameters.
3. The measuring points (top of well casing) of all monitoring wells shall be surveyed to provide the relative elevation of the measuring point for each monitoring well. The measuring points (top of casing) of all monitoring wells shall be surveyed relative to a common datum.
4. Volatile Organic Compounds (VOC) - In November only, analyze by one of the following methods:
   a. Standard Method 6230D, PQL at 0.5 µg/L or less
   b. Standard Method 6210D, PQL at 0.5 µg/L or less
   c. EPA Method 8021, Low Concentration, PQL at 0.5 µg/L or less
   d. EPA Method 8260, Low Concentration, PQL at 0.5 µg/L or less
   e. Another method with prior approval by the Water Quality Permitting Section Chief

   Any method used must meet the following qualifications:
   a. A laboratory must be DWR certified to run any method used.
   b. The method used must, at a minimum, include all the constituents listed in Table VIII of Standard Method 6230D.
   c. The method used must provide a PQL of 0.5 µg/L or less that must be supported by laboratory proficiency studies as required by DWR. Any constituents detected above the MDL but below the PQL of 0.5 µg/L must be qualified (estimated) and reported.
5. If any volatile organic compounds (VOC) are detected as a result of monitoring as provided in Attachment C, then the Fayetteville Regional Office supervisor, telephone number (910) 433-3300, must be contacted immediately for further instructions regarding any additional follow-up analyses required.
6. Monitoring wells shall be reported consistent with the nomenclature and location information provided in this attachment.

NON-DISCHARGE APPLICATION REPORT (NDAR-1)

Permit No.:	Facility Name:	County:	Month:	Year:

Did irrigation occur at this facility?

☐ YES ☐ NO

					Field Name:				Field Name:				Field Name:				Field Name:				Field Name:			
					Area (acres):				Area (acres):				Area (acres):				Area (acres):				Area (acres):			
					Cover Crop:				Cover Crop:				Cover Crop:				Cover Crop:				Cover Crop:			
					Hourly Rate (in):				Hourly Rate (in):				Hourly Rate (in):				Hourly Rate (in):				Hourly Rate (in):			
					Annual Rate (in):				Annual Rate (in):				Annual Rate (in):				Annual Rate (in):				Annual Rate (in):			
	Weather		Freeboard		Field Irrigated?	☐ YES		☐ NO	Field Irrigated?	☐ YES		☐ NO	Field Irrigated?	☐ YES		☐ NO	Field Irrigated?	☐ YES		☐ NO	Field Irrigated?	☐ YES		☐ NO
Day	Weather Code	Temperature	Precipitation	Storage	5-Day Upset (if applicable)	Volume Applied	Time Irrigated	Daily Loading	Maximum Hourly Loading	Volume Applied	Time Irrigated	Daily Loading	Maximum Hourly Loading	Volume Applied	Time Irrigated	Daily Loading	Maximum Hourly Loading	Volume Applied	Time Irrigated	Daily Loading	Maximum Hourly Loading
		°F	in	ft	ft	gal	min	in	in	gal	min	in	in	gal	min	in	in	gal	min	in	in
1																					
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31																					
Monthly Loading:																					
12 Month Floating Total (in):																					

NON-DISCHARGE APPLICATION REPORT (NDAR-2)

Permit No.:	Facility Name:	County:	Month:	Year:

Did infiltration occur at this facility?

☐ YES ☐ NO

					Site Name:				Site Name:				Site Name:				Site Name:				Site Name:			
					Area (acres):				Area (acres):				Area (acres):				Area (acres):				Area (acres):			
					Rate (GPD/ft^2):				Rate (GPD/ft^2):				Rate (GPD/ft^2):				Rate (GPD/ft^2):				Rate (GPD/ft^2):			
	Weather			Freeboard	Site Infiltrated?		☐ YES	☐ NO	Site Infiltrated?		☐ YES	☐ NO	Site Infiltrated?		☐ YES	☐ NO	Site Infiltrated?		☐ YES	☐ NO	Site Infiltrated?		☐ YES	☐ NO
Day	Weather Code	Temperature	Precipitation	Storage (if applicable)	5-Day Upset (if applicable)	Volume Applied	Time Infiltrated	Daily Loading	Freeboard (Basins Only)	Volume Applied	Time Infiltrated	Daily Loading	Freeboard (Basins Only)	Volume Applied	Time Infiltrated	Daily Loading	Freeboard (Basins Only)	Volume Applied	Time Infiltrated	Daily Loading	Freeboard (Basins Only)	Volume Applied	Time Infiltrated	Daily Loading	Freeboard (Basins Only)
		°F	in	ft	ft	gal	min	GPD/ft^2	ft	gal	min	GPD/ft^2	ft	gal	min	GPD/ft^2	ft	gal	min	GPD/ft^2	ft	gal	min	GPD/ft^2	ft
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Monthly Loading (GPD/ft^2):																									
Year to Date Loading (GPD/ft^2):																									

FORM: NDAR-3 10-13

NON-DISCHARGE APPLICATION REPORT (NDAR-3)

Permit No.:	Facility Name:	County:	Month:	Year:

Did conjunctive utilization occur at this facility? ☐ YES ☐ NO	Field Name:		Field Name:		Field Name:		Field Name:	
	Area (acres):		Area (acres):		Area (acres):		Area (acres):	
	Field Irrigated?	☐ YES ☐ NO	Field Irrigated?	☐ YES ☐ NO	Field Irrigated?	☐ YES ☐ NO	Field Irrigated?	☐ YES ☐ NO

Day	Weather			Freeboard		Volume Applied	Time Irrigated	Daily Loading	Maximum Hourly Loading	Volume Applied	Time Irrigated	Daily Loading	Maximum Hourly Loading	Volume Applied	Time Irrigated	Daily Loading	Maximum Hourly Loading	Volume Applied	Time Irrigated	Daily Loading	Maximum Hourly Loading
	Weather Code	Temperature	Precipitation	Storage (if applicable)	5-Day Upset (if applicable)																
		°F	in	ft	ft	gal	min	in	in	gal	min	in	in	gal	min	in	in	gal	min	in	in
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Monthly Loading (gallons):																					

FORM: NDMR 10-13

NON-DISCHARGE MONITORING REPORT (NDMR)

Permit No.:	Facility Name:	County:	Month:	Year:

PPI:	Flow Measuring Point: ☐ Influent ☐ Effluent ☐ No flow generated	Parameter Monitoring Point: ☐ Influent ☐ Effluent ☐ Groundwater Lowering ☐ Surface Water

Parameter Code →			50050															
Day	ORC Arrival Time	ORC Time On Site	Flow															
	24-hr	hrs	GPD															
1																		
2																		
3																		
4																		
5																		
6																		
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28																		
29																		
30																		
31																		
Average:																		
Daily Maximum:																		
Daily Minimum:																		
Sampling Type:																		
Monthly Avg. Limit:																		
Daily Limit:																		
Sample Frequency:																		

FORM: NDMLR 10-13

NON-DISCHARGE MASS LOADING REPORT (NDMLR)

Permit No.:	Facility Name:	County:	Month:	Year:

	Field Name:				Field Name:				Field Name:				Field Name:				Field Name:				Field Name:			
	Area (acres):				Area (acres):				Area (acres):				Area (acres):				Area (acres):				Area (acres):			
	Cover Crop:				Cover Crop:				Cover Crop:				Cover Crop:				Cover Crop:				Cover Crop:			
	Load Type:				Load Type:				Load Type:				Load Type:				Load Type:				Load Type:			
	Field Loaded?	☐ YES	☐ NO		Field Loaded?	☐ YES	☐ NO		Field Loaded?	☐ YES	☐ NO		Field Loaded?	☐ YES	☐ NO		Field Loaded?	☐ YES	☐ NO		Field Loaded?	☐ YES	☐ NO	
Date	Volume Applied	Average Concentration	Monthly Load	Cumulative Load	Volume Applied	Average Concentration	Monthly Load	Cumulative Load	Volume Applied	Average Concentration	Monthly Load	Cumulative Load	Volume Applied	Average Concentration	Monthly Load	Cumulative Load	Volume Applied	Average Concentration	Monthly Load	Cumulative Load
Month	gal	mg/L	lbs/ac	lbs/ac	gal	mg/L	lbs/ac	lbs/ac	gal	mg/L	lbs/ac	lbs/ac	gal	mg/L	lbs/ac	lbs/ac	gal	mg/L	lbs/ac	lbs/ac
12 Month Floating Load (lbs/ac/yr):																				
Annual Load Limit (lbs/ac/yr):																				

SUBMIT FORM ON YELLOW PAPER ONLY

GROUNDWATER QUALITY MONITORING: COMPLIANCE REPORT FORM

Mail original and 1 copy to:

DEPARTMENT OF ENVIRONMENT & NATURAL RESOURCES
DIVISION OF WATER RESOURCES - INFORMATION PROCESSING UNIT
1617 MAIL SERVICE CENTER, RALEIGH, NC 27699-1617 Phone: 919-807-6306

FACILITY INFORMATION

Please Print Clearly or Type

Facility Name: _____

Permit Name (if different): _____

Facility Address: _____
(Street)

_____ County _____
(City) (State) (Zip)

Contact Person: _____ Telephone#: _____

Well Location/Site Name: _____ No. of wells to be sampled: _____ (from Permit)

PERMIT Number: Expiration Date: _____

Non-Discharge _____ UIC _____

NPDES _____ Other _____

TYPE OF PERMITTED OPERATION BEING MONITORED

- ☐ Lagoon
- ☐ Spray Field
- ☐ Rotary Distributor
- ☐ Water Source Heat Pump
- ☐ Remediation: Infiltration Gallery
- ☐ Remediation: _____
- ☐ Land Application of Sludge
- ☐ Other: _____

SAMPLING INFORMATION

WELL ID NUMBER (from Permit): _____ Date sample collected: _____

Well Depth: ____ ft. Well Diameter: ____ in.

Depth to Water Level 82546: _____ ft. below measuring point Screened Interval: ____ ft. to ____ ft.

Measuring Point is _____ ft. above land surface Relative M.P. Elevation: _____ ft.

Volume of water pumped/bailed before sampling: _____ gallons

Samples for **metals** were collected **unfiltered**: ☐ YES ☐ NO and field acidified: ☐ YES ☐ NO

FIELD ANALYSES:

pH 00400: ____ units Temp. 00010: _____ °C

Spec. Cond. 00094: _____ µMhos

Odor 00085: _____

Appearance _____

If **WELL WAS DRY** at time of sampling, check here: ☐

LABORATORY INFORMATION

Date sample analyzed: _____ Laboratory Name: _____ Certification No. _____

PARAMETERS NOTE: Values should reflect dissolved and colloidal concentrations.

COD 00335		mg/L	Nitrite (NO_2) as N 00615		mg/L	Pb - Lead 01051	**ug/L**
Coliform: MF Fecal 31616		/100mL	Nitrate (NO_3) as N 00620		mg/L	Zn - Zinc 01092	mg/L
Coliform: MF Total 31504		/100mL	Phosphorus: Total as P 00665		mg/L		
(Note: Use MPN method for highly turbid samples)			Orthophosphate 70507		mg/L	Other (Specify Compounds and Concentration Units):	
Dissolved Solids:Total 70300		mg/L	Al - Aluminum 01105		mg/L		
pH (Lab) 00403		units	Ba - Barium 01007		**ug/L**		
TOC 00680		mg/L	Ca - Calcium 00916		mg/L		
Chloride 00940		mg/L	Cd - Cadmium 01027		**ug/L**		
Arsenic 01002		**ug/L**	Chromium: Total 01034		**ug/L**		
Grease and Oils 00552		mg/L	Cu - Copper 01042		mg/L	**ORGANICS:** (by GC, GC/MS, HPLC)	
Phenol 32730		**ug/L**	Fe - Iron 01045		**ug/L**	**(Specify test and method #. ATTACH LAB REPORT.)**	
Sulfate 00945		mg/L	Hg - Mercury 71900		**ug/L**	**Lab Report Attached?** ☐ Yes (1) ☐ No (0)	
Specific Conductance 00095		µMhos	K - Potassium 00937		mg/L	VOC 7873	, method #
Total Ammonia 00610		mg/L	Mg - Magnesium 00927		mg/L		, method #
(Ammonia Nitrogen; NH_3 as N; Ammonia Nitrogen, Total)			Mn - Manganese 01055		**ug/L**		, method #
TKN as N 00625		mg/L	Ni - Nickel 01067		**ug/L**		, method #

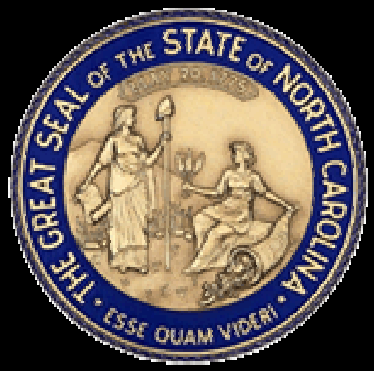
For Remediation Systems Only (Attach Lab Reports): Influent Total VOCs: _____ mg/L Effluent Total VOCs: _____ mg/L **VOC Removal%** _____

I certify that, to the best of my knowledge and belief, the information submitted in this report is true, accurate, and complete, and that the laboratory analytical data was produced using approved methods of analysis by a DWR-certified laboratory. I am aware that there are significant penalties for submitting false information, including the possibility of fines and imprisonment for knowing violations.

_____ _____
Permittee (or Authorized Agent) Name and Title - Please print or type Signature of Permittee (or Authorized Agent) (Date)

North Carolina Administrative Code

Title 15A
Department of Environment and Natural Resources
Division of Water Quality



Subchapter 8G
Section .0100 through Section .1100

WATER POLLUTION CONTROL SYSTEM OPERATORS RULES

Last Amended on December 1, 2006

Water Pollution Control System Operators Certification Commission
Raleigh, North Carolina

SUBCHAPTER 8G - AUTHORITY: ORGANIZATION: STRUCTURE: DEFINITIONS

SECTION .0100 - GENERAL PURPOSE AND DEFINITIONS

15A NCAC 08G .0101 PURPOSE

The purpose of these Rules is to:

(1) protect the public health of the citizens of the State; and

(2) conserve, protect, and maintain the quality of the water resources of the State as assigned by the North Carolina Environmental Management Commission; and

(3) protect the public investment in water pollution control systems; and

(4) provide for the classification of water pollution control systems; and

(5) establish the procedures for the examination and certification of operators of water pollution control systems.

History Note: *Authority G.S. 90A-35;*
Eff. April 1, 1999.

15A NCAC 08G .0102 DEFINITIONS

(a) "Activated sludge" means a biological wastewater treatment process in which predominantly biodegradable pollutants in wastewater are absorbed, or adsorbed, by living aerobic organisms and bacteria in an aerated suspension which is separated from the treated wastewater gravimetrically.

(b) "Actual experience" means the time working as a water pollution control system operator or operator in responsible charge. An operator is an individual whose principal job responsibility is the actual physical operation of process equipment and systems at a water pollution control system. Primary job responsibilities such as laboratory testing, facility and equipment maintenance, administrative support, or direct or indirect supervision do not qualify as actual experience.

(c) "Approved training" means any training, required in order to be eligible for an examination or to meet continuing education requirements as established in accordance with 15A NCAC 08G .0400 and 15A NCAC 08G .0701. The standards for approved training shall be developed by a committee consisting of representatives for training sponsors, DWQ staff, instructors and certified operators. The standards must be approved by the Commission and shall be known as "Water Pollution Control System Operator Certification Commission Training Course Standards" or "Needs to Know". These standards can be found at http://h20.enr.state.nc.us/tacu.

(d) "Back-up ORC" means Back-up Operator in Responsible Charge and refers to the operator who is designated to act as surrogate for the Operator in Responsible Charge (ORC) when the ORC is absent from his or her professional duties as set forth in G.S. 90A-44.

(e) "Basic sciences" means courses in agronomy, biology, botany, chemistry, engineering, environmental health and sciences, geology, math, physics, soil science, and zoology offered by an accredited college or university.

(f) "Chemical process" means a water pollution control system process consisting exclusively of the addition of chemicals to treat wastewaters.

(g) "Collection system" means a continuous connection of pipelines, conduits, pumping stations and other related constructions or devices used to conduct wastewater to a water pollution control system.

(h) "Commission" means the Water Pollution Control System Operators Certification Commission created by G.S. 143B-300.

(i) "Contact Hour" means one hour of Commission approved operator instruction in accordance with 15A NCAC 08G .0701.

(j) "Contract operations firm" means any commercial water pollution control system operations firm which contracts with the owner of a water pollution control system to provide operational services for the system pursuant to G.S. 90A-45(a).

(k) "Contract operator" means any certified water pollution control system operator who contracts with the owner of a water pollution control system to provide operational and other services for the system pursuant to G.S. 90A-45(a).

(l) "Electrodialysis system" means a system utilizing a selective separation of dissolved solids process that is based on electrical charge and diffusion through a semipermeable membrane.

(m) "Fixed growth" means a biological wastewater treatment system in which the wastewater is treated by contact with a biological growth that is affixed to support media and includes systems such as trickling filters, rotating biological contactors, and biological tower treatment systems.

(n) "GED" means general educational development in reference to a high school diploma equivalency.

(o) "Nutrient Reduction" means the reduction of total nitrogen or total phosphorous by an activated sludge or fixed growth process.
(p) "Operator in Training (OIT)" means the certificate issued with Commission approval to an individual prior to the completion of the experience requirements for that level of certification.
(q) "Operator in Responsible Charge (ORC)" means the individual designated by a person, firm, or corporation (municipal or private) owning or having control of a water pollution control system as the operator of record of the water pollution control system and who has primary responsibility for the operation of such system as defined in G.S. 90A-46.
(r) "Owner" means the person, firm, or corporation (municipal or private) owning or having control of a water pollution control system as described in G.S. 90A-44.
(s) "Passing score" means earning 70 percent of the available points on an examination administered by the Commission.
(t) "Permanent certificate" means the certificate of competency issued by the Commission to an individual as the result of the individual obtaining a passing score on an examination administered by the Commission, or a certificate issued by reciprocity agreement by the Commission, and is subject to the provisions of G.S. 90A-40(a).
(u) "Physical/Chemical system" means any water pollution control system which utilizes a physical or a chemical process or both.
(v) "Physical process" means any water pollution control system process consisting of electrodialysis, adsorption, absorption, air stripping, gravimetric sedimentation, flotation or filtration as the means of treatment.
(w) "Reciprocity certificate" means a certificate issued of the appropriate type and grade without examination to any person who is properly registered on the "National Association of Boards of Certification" Reciprocity Register and who meets all other requirements of these Rules as set forth in G.S. 90A-40(b).
(x) "Regional office" means one of the seven local offices of the Division of Water Quality located across the State.
(y) "Residuals" means any solid or semisolid byproduct that is produced by the treatment of wastewater in a water pollution control system.
(z) "Reverse osmosis system" means a system which utilizes solutions and semipermeable membranes to separate and treat wastewaters.
(aa) "Successful completion" means the attendance of at least 80 percent of the approved training for examination eligibility and 100 percent of training for continuing education.
(bb) "Temporary certificate" means a certificate issued of an appropriate type and grade, without examination, to any person employed as a water pollution control system operator when the Commission finds that the supply of certified operators, or persons with the training and experience necessary for certification, is inadequate and the situation meets the requirements set forth in G.S. 90A-40(e).
(cc) "Ultrafiltration system" means a system which utilizes a membrane filter process to remove pollutants from wastewater.
(dd) "Valid certificate" means the certificate of an operator that has all required renewal fees paid, all required continuing education training completed, and has not been revoked relinquished, invalidated, or suspended.
(ee) "Water pollution control system" means any system for the collection, treatment, or disposal of wastewater and is classified under the provisions of G.S. 90A-37.

History Note: *Authority G.S. 143B-300;*
Eff. April 1, 1999;
Amended Eff. December 1, 2006.

SECTION .0200 - DUTIES AND RESPONSIBILITIES

15A NCAC 08G .0201 RESPONSIBILITY OF SYSTEM OWNERS TO DESIGNATE CERTIFIED OPERATORS

Owners of classified water pollution control systems must designate operators, certified by the Water Pollution Control System Operators Certification Commission (WPCSOCC), of the appropriate type and grade for the system, and, for each classification must:

(1) designate one Operator In Responsible Charge (ORC) who possesses a valid certificate of the type and grade at least equivalent to the type and grade of the system;
(2) designate one or more Back-up Operator(s) in Responsible Charge (Back-up ORCs) who possesses a valid certificate of the type of the system and no more than one grade less than the grade of the system, with the exception of no backup operator in responsible charge is required for systems whose minimum visitation requirements are twice per year; and
(3) submit a signed completed "Water Pollution Control System Operator Designation Form" to the Commission (or to the local health department for owners of subsurface systems) countersigned by the

designated certified operators, designating the Operator in Responsible Charge (ORC) and the Back-up Operator in Responsible Charge (Back-up ORC):

(a) 60 calendar days prior to wastewater or residuals being introduced into a new system; or

(b) within 120 calendar days following:

(i) receiving notification of a change in the classification of the system requiring the designation of a new Operator in Responsible Charge (ORC) and Back-up Operator in Responsible Charge (Back-up ORC) of the proper type and grade; or

(ii) a vacancy in the position of Operator in Responsible Charge (ORC) or Back-up Operator in Responsible Charge (Back-up ORC).

(c) within seven calendar days of vacancies in both ORC and Back-up ORC positions replacing or designating at least one of the responsibilities.

History Note: Authority G.S. 90A-37; 90A-38; 90A-39; 90A-40; 90A-41; 90A-42; 90A-43; 90A-44; 90A-45;
Eff. April 1, 1999;
Amended Eff. December 1, 2006.

15A NCAC 08G .0202 RESPONSIBILITIES OF SYSTEM OWNERS

History Note: Authority G.S. 90A-37 through 90A-45;
Eff. April 1, 1999;
Repealed Eff. December 1, 2006.

15A NCAC 08G .0203 RESPONSIBILITIES OF ALL CERTIFIED OPERATORS

Certified operators must:

(1) comply with all terms and conditions of their certification as set forth in these Rules;

(2) notify the Commission, in writing, within 30 calendar days of any changes in their mailing address;

(3) be responsible for the renewal of their certification(s) as specified in Section .0700 of this Subchapter; and

(4) comply with all statutes and rules regarding the operation of water pollution control systems.

History Note: Authority G.S. 90A-40; 90A-41; 90A-42; 90A-44;
Eff. April 1, 1999;
Amended Eff. December 1, 2006.

15A NCAC 08G .0204 RESPONSIBILITIES OF AN OPERATOR IN RESPONSIBLE CHARGE (ORC)

An Operator in Responsible Charge (ORC) of a water pollution control system must:

(1) possess a valid certificate of the appropriate type and grade for the system;

(2) visit the system as often as is necessary to insure the proper operation of the system but in no case less frequently than specified in the following schedule, unless otherwise specified in permit:

(a) biological grade I systems with the exception of Sub-item (2)(e) of this Rule; weekly;

(b) biological grade II, III, and IV systems, other than those systems specified in Sub-item(2)(f) of this Rule; five days per week, excluding holidays;

(c) surface irrigation systems with the exception of Sub-item (2)(e) of this Rule; weekly;

(d) collection systems; within 24 hours of knowledge of a bypass, spill, or overflow of wastewater from the system unless visited by a collection system Back-up Operator in Responsible Charge;

(e) domestic wastewater systems with a treatment capacity of 1500 gallons per day or less; twice per year with a six month interval between visits;

(f) domestic wastewater aerobic treatment units (ATUs) with a treatment capacity of 1500 gallons per day or less; weekly;

(g) systems permitted under rules adopted by the Commission for Health Services; as required by 15A NCAC 18A .1961;

(h) physical/chemical systems:

(i) grade I systems, including groundwater remediation systems; weekly;

(ii) grade II systems; five days per week, excluding holidays

(i) land application systems during or within 48 hours after application of residuals;

(j) systems not otherwise classified; as specified by the Commission based on the complexity of the system;

(3) operate and maintain the system efficiently and attempt to insure the compliance of the system with any permit(s) issued for the system as well as any other applicable local, state, and federal environmental permitting and regulatory requirements;

(4) certify, by signature, as to the validity of all monitoring and reporting information performed on the system as prescribed in any permit issued for the system and provide the owner a copy;

(5) document the operation, maintenance, and all visitation of the system in a daily log that must be maintained at the system;

(6) notify the owner of the system as soon as possible, and in writing within five calendar days of first knowledge, of any:

(a) overflows from the system or any treatment process unit;

(b) bypasses of the system or any treatment process unit; or

(c) violations of any limits or conditions of the permit.

(7) notify the owner, in writing, of the need for any system repairs and modifications that may be necessary to insure the compliance of the system with all local, state, and federal environmental permitting and regulatory requirements;

(8) be available:

(a) for consultations with the system owner and regulatory officials;

(b) to handle emergency situations; and

(c) to provide access to the facility by regulatory agencies; and

(9) upon vacating an ORC position, notify the Commission and the appropriate regional office of the Division of Water Quality (or the local health department for owners of subsurface systems) of the vacancy, in writing within 14 calendar days.

History Note: *Authority G.S. 90A-37 through 90A-40; 90A-44;*
Eff. April 1, 1999;
Amended Eff. December 1, 2006.

15A NCAC 08G .0205 RESPONSIBILITIES OF A BACK-UP OPERATOR IN RESPONSIBLE CHARGE (BACK-UP ORC)

The Back-up Operator in Responsible Charge (Back-up ORC):

(1) may act as surrogate for the Operator in Responsible Charge (ORC), if he/she possesses a valid certificate of the appropriate type and grade for the system, for a period:

(a) not to exceed 40 percent of the system visitations required per calendar year under Rule .0204(2) of this Section; or

(b) not to exceed 120 consecutive calendar days when the Operator in Responsible Charge (ORC) is absent due to:

(i) the vacancy of the Operator in Responsible Charge (ORC) position; or

(ii) personal or familial illness; and

(2) must fulfill all of the requirements of Rule .0204 of this Section when acting as surrogate for the Operator in Responsible Charge (ORC); and

(3) upon vacating a Backup ORC position, notify, in writing, the Commission and the appropriate regional office of the Division of Water Quality (or the local health department for owners of subsurface systems) of the vacancy within 14 calendar days.

History Note: *Authority G.S. 90A-37; 90A-44;*
Eff. April 1, 1999;
Amended Eff. December 1, 2006.

SECTION .0300 - CLASSIFICATION OF WATER POLLUTION CONTROL SYSTEMS

15A NCAC 08G .0301 APPLICABILITY

(a) The purpose of this Section is to establish procedures for the classification of water pollution control systems.

(b) Not withstanding the requirements in Rules .0302 through .0307 of this Section, the Commission may modify the classification of a water pollution control system when:

(1) conditions created by system design features, or inherent operational requirements, exist which make normal operation of the system more or less complex;
(2) upgrades or other modifications to a system are completed; or
(3) changes in Commission classification rules are made.

(c) In-plant processes and related water pollution control equipment which are integral parts of direct industrial production, are not considered water pollution control systems for the purpose of this Section.
(d) Water Pollution Control Systems permitted under rules adopted by the Commission for Health Services shall be classified pursuant to Rule .0307 of this Section.
(e) Water Pollution Control Systems permitted under rules adopted by the Environmental Management Commission shall be classified pursuant to Rules .0302 through .0308 of this Section.
(f) Reservoirs, settling ponds and associated pumps and piping which are an integral part of closed-loop water recycle systems for the non-biological and non-toxic treatment of process water at sand, gravel, crushed stone and similar operations shall not be subject to the requirements of these Rules unless the Commission determines that the system is not being properly operated or maintained in accordance with permit conditions.
(g) Any water pollution control system, regardless of type or ownership, may be classified and required to designate an Operator in Responsible Charge (ORC) and a Back-up Operator in Responsible Charge (Back-up ORC), in the event that the Commission determines that the system is not being properly operated or maintained.

History Note: *Authority G.S. 90A-37;*
Eff. April 1, 1999;
Amended Eff. December 1, 2006.

15A NCAC 08G .0302 CLASSIFICATION OF BIOLOGICAL WATER POLLUTION CONTROL TREATMENT SYSTEMS

(a) The following discharging systems are assigned a classification of Grade I Biological Water Pollution Control System unless the permitted flow, or operational complexity of the system requires a higher classification:

(1) septic tank/sand filter systems;
(2) biological lagoon systems; and
(3) constructed wetlands and associated appurtenances.

(b) Systems that utilize an activated sludge or fixed growth process with a permitted flow less than or equal to 0.5 million gallons per day (mgd) are assigned the classification of Grade II Biological Water Pollution Control System.
(c) Systems utilizing an activated sludge or fixed growth process with permitted flows of greater than 0.5 through 2.5 million gallons per day (mgd) are assigned the classification of Grade III Biological Water Pollution Control System.
(d) Systems utilizing an activated sludge or fixed growth process with a permitted flow greater than 2.5 million gallons per day (mgd) are assigned a classification of Grade IV Biological Water Pollution Control System.
(e) Any system receiving a classification of Grade II Biological Water Pollution Control System that is required to achieve nutrient reduction is assigned the classification of Grade III Biological Water Pollution Control System.
(f) Any system receiving a classification of Grade III Biological Water Pollution Control System that is required to achieve nutrient reduction is assigned the classification of Grade IV Biological Water Pollution Control System.

History Note: *Authority G.S. 90A-37;*
Eff. April 1, 1999;
Amended Eff. December 1, 2006.

15A NCAC 08G .0303 CLASSIFICATION OF WATER POLLUTION CONTROL COLLECTION SYSTEMS

(a) Water pollution control collection systems operated to convey wastewater to water pollution control systems which are permitted or tributary to municipalities, regional water pollution control systems, water and sewer authorities, public utilities, or are a Grade II, III or IV state or federally owned system, are subject to classification in accordance with Rule .0303(b) of this Section. Any collection system, regardless of ownership, is classified pursuant to this Rule and required to designate an Operator in Responsible Charge (ORC) and a Back-up Operator in Responsible Charge (Back-up ORC) if the Commission determines that the system is not being operated and maintained in a manner which prevents the escape of wastewater from the system into the environment.
(b) Collection systems are assigned the lower grade classification that is either:

(1) the same as the grade of the biological water pollution control system to which the collection system is tributary; or

(2) based on the population served by the collection system in accordance with the following chart:

(A)	1,500 or less	Grade I;
(B)	1,501 to 15,000	Grade II;
(C)	15,001 to 50,000	Grade III;
(D)	50,001 or more	Grade IV.

In the event that the population served cannot be determined, the equivalent population served shall be calculated by using the design flow of the system divided by a flow of 60 gallons per day per person.

History Note: *Authority G.S. 90A-37;*
Eff. April 1, 1999;
Amended Eff. December 1, 2006.

15A NCAC 08G .0304 CLASSIFICATION OF SURFACE IRRIGATION WATER POLLUTION CONTROL SYSTEMS

(a) Systems which utilize surface irrigation for the treatment, reuse or disposal of wastewater are classified as surface irrigation water pollution control systems. Those systems which contain only preliminary treatment processes such as septic tanks, sand filters, oil/water separators, lagoons, storage basins, physical screening, or sedimentation processes are not subject to additional operator requirements as specified in Rule .0302 or .0306 of this Section.

(b) Any surface irrigation system that has, as part of its treatment process, systems other than those specified in Paragraph (a) of this Rule, is subject to additional classification pursuant to these Rules.

History Note: *Authority G.S. 90A-37;*
Eff. April 1, 1999;
Amended Eff. December 1, 2006.

15A NCAC 08G .0305 CLASSIFICATION OF LAND APPLICATION OF RESIDUALS SYSTEMS

Systems permitted for the land application of:

(1) residuals that are produced by a water pollution control system; or

(2) contaminated soils;

are classified as a land application of residuals system.

History Note: *Authority G.S. 90A-3;*
Eff. April 1, 1999;
Amended Eff. December 1, 2006.

15A NCAC 08G .0306 CLASSIFICATION OF PHYSICAL/CHEMICAL WATER POLLUTION CONTROL TREATMENT SYSTEMS

(a) Any water pollution control system, including systems designed for the remediation of contaminated groundwater, that utilizes a primarily physical process to treat wastewaters is classified as a Grade I Physical/Chemical Water Pollution Control System.

(b) Any water pollution control system that utilizes a primarily chemical process to treat wastewaters, including those systems whose treatment processes are augmented by physical processes, is classified as a Grade II Physical/Chemical Water Pollution Control System. Any reverse osmosis, electrodialysis, and ultrafiltration system is classified as a Grade II Physical/Chemical Water Pollution Control System.

(c) Any water pollution control system that has, as part of its treatment process, a biological water pollution control system is subject to additional classification as a biological water pollution control system.

(d) Any water pollution control system subject to classification under Rule .0302 of this Section, utilizing a physical or chemical process to enhance an activated sludge or fixed growth process, is not subject to additional classification under this Rule.

History Note: *Authority G.S. 90A-37;*
Eff. April 1, 1999;
Amended Eff. December 1, 2006.

15A NCAC 08G .0307 CLASSIFICATION OF SUBSURFACE WATER POLLUTION CONTROL SYSTEMS

(a) Systems permitted under rules adopted by the Environmental Management Commission which utilize the soil for the subsurface treatment and disposal of wastewater shall be classified as subsurface water pollution control systems.

(b) Any subsurface water pollution control system that is required to have a certified operator under 15A NCAC 18A .1961 shall be deemed classified as a subsurface water pollution control system.

(c) Any subsurface water pollution control system that has as part of its treatment process a water pollution control system that may be classified under Rules .0302 through .0307 of this Section shall be subject to additional classification. If the subsurface system consists only of septic tanks, pump tanks, siphon or pump dosing systems, sand filters, grease traps or grease interceptors, or oil/water separators, and subsurface disposal of the wastewater, no additional classification will be required.

History Note: Authority G.S. 90A-37;
Eff. April 1, 1999.

15A NCAC 08G .0308 SYSTEMS NOT OTHERWISE CLASSIFIED

The Commission may classify any water pollution control system which is not otherwise classified when that system is receiving wastewater that has distinctly different characteristics from typical domestic wastewater or is a water pollution control system which contains treatment processes that are sufficiently different from the conventional treatment processes classified in Rules .0302 through .0306 of this Section.

History Note: Authority G.S. 90A-37;
Eff. April 1, 1999.

SECTION .0400 - ELIGIBILITY REQUIREMENTS FOR EXAMINATIONS

15A NCAC 08G .0401 GENERAL REQUIREMENTS

(a) An applicant for certification as an operator of a water pollution control system must meet the following criteria and possess the knowledge and abilities listed as they relate to the specific type of system for which certification is being sought and shall, at a minimum, include:

(1) possess a high school diploma or a general educational development (GED) equivalent;
(2) be at least 18 years of age;
(3) have a general knowledge of typical wastewater characteristics and treatment processes; and
(4) have the ability to:
  (A) read and understand the statutes and rules which govern water pollution control system operators and the operation of the type of system for which certification is being sought;
  (B) perform mathematical calculations required to operate the system for which certification is being sought;
  (C) complete and maintain logs and regulatory reporting forms required to document the proper operation of the system; and
  (D) safely and effectively operate the equipment employed in the type of system for which certification is being sought; and
  (E) describe the general maintenance requirements for such equipment.

(b) An applicant who has failed to achieve a passing score on a specific type and grade of examination after three consecutive attempts must:

(1) attend and successfully complete approved training for the same type and grade as the certification being sought; and

(2) provide verification, in the form of a certificate of completion or other such documentation, of the successful completion of the required training with any subsequent application made to the Commission to sit for the examination.

(c) An applicant for certification must not have had any certification revoked by the Commission within the two - year period prior to the date of the application for certification.

(d) An applicant for certification is not allowed to sit for any examination offered by the Commission during the period of a suspension of any certification held by the applicant with the Commission.

(e) An applicant who holds a valid biological or collection certification of any level on April 1, 1999, may progress to the highest level of certification of the same type without meeting the requirements of Subparagraph (a)(1) of this Rule.

History Note: *Authority G.S. 90A-37;*
Eff. April 1, 1999;
Amended Eff. December 1, 2006.

15A NCAC 08G .0402 ELIGIBILITY REQUIREMENTS FOR BIOLOGICAL WATER POLLUTION CONTROL SYSTEM OPERATORS

Eligibility for certification as a Biological Water Pollution Control System Operator is based on the following qualifications:

(1) for Grade I certification, the applicant must:
  (a) have successfully completed approved training for Grade I Biological Water Pollution Control System operators.

(2) for Grade II certification, the applicant must:
  (a) hold a valid North Carolina Grade I Biological Water Pollution Control System Operator certificate;
  (b) have 6 months of actual experience at a Grade II or higher biological water pollution control system; and
  (c) have successfully completed approved training for Grade II Biological Water Pollution Control System operators.

(3) for Grade III certification, the applicant must:
  (a) hold a valid North Carolina Grade II Biological Water Pollution Control System Operator certificate;
  (b) have successfully completed approved training for Grade III Biological Water Pollution Control System operators; and
  (c) either:
    (i) have two years of actual experience at a Grade II, or higher, biological water pollution control system, or
    (ii) be a graduate of two or four year college or university and have taken, and passed, a minimum of six courses in the basic sciences and have 18 months of actual experience at a Grade II, or higher, biological water pollution control system.

(4) for Grade IV certification, the applicant must:
  (a) hold a valid North Carolina Grade III Biological Water Pollution Control System Operator certificate;
  (b) have successfully completed approved training for Grade IV Biological Water Pollution Control System operators; and
  (c) either:
    (i) have three years of actual experience at a Grade III, or higher, biological water pollution control system, or
    (ii) be a graduate of a two or four year college or university and have taken, and passed, a minimum of six courses in the basic sciences and have two years of actual experience at a Grade III, or higher, biological water pollution control system.

History Note: *Authority G.S. 90A-39.*
Eff. April 1, 1999;
Amended Eff. December 1, 2006.

15A NCAC 08G .0403 ELIGIBILITY REQUIREMENTS FOR WATER POLLUTION CONTROL COLLECTION SYSTEM OPERATORS

Eligibility for certification as a Water Pollution Control Collection System Operator is based on the following qualifications:

(1) for Grade I certification, the applicant must: have successfully completed approved training for Grade I water pollution control collection system operators.

(2) for Grade II certification, the applicant must:
- (a) hold a valid North Carolina Grade I Water Pollution Control Collection System Operator certificate;
- (b) have six months of actual experience in water pollution control collection system operations; and
- (c) have successfully completed approved training for Grade II water pollution control collection system operators.

(3) for Grade III certification, the applicant must:
- (a) hold a valid North Carolina Grade II Water Pollution Control Collection System Operator certificate;
- (b) have successfully completed approved training for Grade III water pollution control collection system operators; and
- (c) either:
  - (i) have two years of actual experience in water pollution control collection system operations, or
  - (ii) be a graduate of a two or four year college or university and have taken and passed, a minimum of six courses in a field directly related to the operation and maintenance of a collection system, e.g. civil, mechanical, or environmental engineering, and have one year of actual experience in the operation of a water pollution control collection system.

(4) for Grade IV certification, the applicant must:
- (a) hold a valid North Carolina Grade III Water Pollution Control Collection System Operator certificate;
- (b) have successfully completed approved training for Grade IV water pollution control collection system operators; and
- (c) either:
  - (i) have three years of actual experience in water pollution control collection system operations, or
  - (ii) be a graduate of a two or four year college or university and have taken and passed, a minimum of six courses in a field directly related to the operation and maintenance of a collection system, e.g. civil, mechanical, or environmental engineering, and have two years of actual experience in the operation of a water pollution control collection system.

History Note: *Authority G.S. 90A-39;*
Eff. April 1, 1999;
Amended Eff. December 1, 2006.

15A NCAC 08G .0404 ELIGIBILITY REQUIREMENTS FOR LAND APPLICATION OF RESIDUALS OPERATORS

An applicant for certification as a Land Application of Residuals Operator must have successfully completed approved training for land application of residuals operators and:

(1) have one year of actual experience in the land application of residuals;

(2) be a graduate of a two or four year college or university and have taken and passed a minimum of six courses in the basic sciences; or

(3) hold a valid grade III or higher biological water pollution control system operator certification.

History Note: *Authority G.S. 90A-39;*
Eff. April 1, 1999;
Amended Eff. December 1, 2006.

15A NCAC 08G .0405 ELIGIBILITY REQUIREMENTS FOR PHYSICAL/CHEMICAL WATER POLLUTION CONTROL SYSTEM OPERATORS

Eligibility for certification as a Physical/Chemical Water Pollution Control System Operator is based on the following qualifications:

(1) for the Grade I have successfully completed approved training for Grade I Physical/Chemical Water Pollution Control System Operators.

(2) for the Grade II:

(a) possess a valid Grade I Physical/Chemical Water Pollution Control System Operator certificate;

(b) have one year of actual experience at a Grade II Physical/Chemical Water Pollution Control System; and

(c) have successfully completed approved training for Grade II Physical/Chemical Water Pollution Control System Operators.

History Note: *Authority G.S. 90A-39;*
Eff. April 1, 1999;
Amended Eff. December 1, 2006.

15A NCAC 08G .0406 ELIGIBILITY REQUIREMENTS FOR SURFACE IRRIGATION WATER POLLUTION CONTROL SYSTEM OPERATORS

An applicant for certification as a Surface Irrigation Water Pollution Control System Operator must have successfully completed approved training for surface irrigation water pollution control system operators and:

(1) have one year of actual experience in the operation of a surface irrigation water pollution control system;

(2) be a graduate of a two or four year college or university and have taken and passed a minimum of six courses in the basic sciences;

(3) be a private homeowner who intends to operate only his/her own domestic spray irrigation water pollution control system; or

(4) hold a valid grade III or higher biological water pollution control system operator certification.

History Note: *Authority G.S. 90A-39;*
Eff. April 1, 1999;
Amended Eff. December 1, 2006.

15A NCAC 08G .0407 ELIGIBILITY REQUIREMENTS FOR SUBSURFACE WATER POLLUTION CONTROL SYSTEM OPERATORS

An applicant for certification as a Subsurface Water Pollution Control System Operator must have successfully completed approved training for subsurface water pollution controls system operator and:

(1) have one year of actual experience in the operation of a subsurface water pollution control system;

(2) be a graduate of a two or four year college or university and have taken and passed a minimum of six courses in the basic sciences;

(3) be a private homeowner who intends to operate only his/her own domestic subsurface water pollution control system; or

(4) hold a valid grade III or higher biological water pollution control system operator certification.

History Note: *Authority G.S. 90A-39;*
Eff. April 1, 1999;
Amended Eff. December 1, 2006.

15A NCAC 08G .0408 ELIGIBILITY REQUIREMENTS FOR OPERATOR IN TRAINING (OIT) CERTIFICATION

(a) The Commission may allow an applicant for any water pollution control system operator certificate to take the examination if the individual has met all of the prerequisite education and certification requirements but is unable to meet the actual experience requirement.

(b) Upon achieving a passing score on the examination, the applicant shall be issued an Operator In Training (OIT) certificate of the same type and grade as the examination.

(c) The Operator In Training (OIT) must not be designated as the Operator in Responsible Charge (ORC) or Back-up Operator In Responsible Charge (Back-Up ORC) of a system.

(d) Operator In Training (OIT) certificates must be renewed annually as stipulated in 15A NCAC 08G .0701.

(e) When the holder of an Operator in Training (OIT) certificate completes the prerequisite experience for the permanent certificate at that type and level, the holder must submit an application documenting the experience, with the appropriate fee for a replacement certificate in order to receive the permanent certificate at that level.

History Note: *Authority G.S. 90A-39;*
Eff. April 1, 1999;
Amended Eff. December 1, 2006.

15A NCAC 08G .0409 ELIGIBILITY REQUIREMENTS FOR CONDITIONAL WATER POLLUTION CONTROL SYSTEM OPERATORS

Conditional Certificates shall remain valid contingent upon the individuals holding the certificates meeting renewal requirements as found in Section .0700 of this Subchapter.

History Note: *Authority G.S. 90A-39;*
Eff. April 1, 1999;
Amended Eff. December 1, 2006.

15A NCAC 08G .0410 RECIPROCITY CERTIFICATION

(a) The Commission shall issue certification(s) to individuals certified in other States or legal jurisdictions if the individuals:

(1) meet or exceed all eligibility requirements or the equivalent thereof as determined by the Commission as found in Rules .0302 to .0308 of the Section, with the exception of completion of approved training,
(2) complete Application for Reciprocity Form and submit it with the appropriate non-refundable fee as specified in G.S. 90A-42,
(3) provide a letter of verification from certifying State agency that applicant is certified at stated level and that no disciplinary actions are outstanding against the applicant, and
(4) apply for and achieve a passing score on a Commission-administered examination of the same type and grade as that for which reciprocity certification is being requested. The requirement for completion of approved training is waived in the case of applicants pursuant to this Rule.

(b) Applicants pursuant to this Rule must not have taken and failed to achieve a passing score on a Commission – administered examination of the same type and grade as that for which reciprocity certification is being requested, within the previous two year period prior to the date of application for reciprocity.

(c) Applicants failing to achieve a passing score on three or more examinations of the same type and grade as that for which certification is being requested, must successfully complete approved training for that certification before being eligible for that examination.

(d) Applicants who obtain certification by providing false information to the Commission shall be subject to disciplinary actions as set forth in Section .0800 of this Subchapter.

History Note: *Authority G.S. 90A-4; 90A-40;*
Eff. December 1, 2006.

SECTION .0500 - CERTIFICATION BY EXAMINATION

15A NCAC 08G .0501 APPLYING FOR EXAMINATION

(a) All applications for examination submitted to the Commission must be:

(1) submitted on an a WPCSOCC Examination Application;
(2) accompanied by the appropriate non-refundable application fee per G.S. 90A-42;
(3) completed in entirety with all required information, documentation, and signatures provided; and
(4) postmarked at least 30 days prior to the scheduled date of the examination if an examination is scheduled.

(b) Upon receipt of an application by the Commission, the application shall be reviewed for completeness and a determination as to the eligibility of the applicant to sit for the requested examination shall be made. Incomplete applications shall be returned to the applicant.

(c) Each applicant shall be notified, in writing, of the applicant's eligibility to sit for the requested examination. Individuals determined to be eligible for an examination shall be sent written notification containing information concerning the date, time and location of the examination. This written notification shall be considered a receipt from the Commission to the applicant

for the examination fee. Applicants found to be ineligible for an examination shall be sent written notification of the ineligibility determination.
(d) Any applicant who obtains certification by supplying false information to the Commission shall be subject to disciplinary action(s) as set forth in Section .0800 of this Subchapter.

History Note: *Authority G.S. 90A-39; 90A-41; 90A-42;*
Eff. April 1, 1999;
Amended Eff. December 1, 2006.

15A NCAC 08G .0502 INELIGIBLE APPLICANTS

History Note: *Authority G.S. 90A-39;*
Eff. April 1, 1999;
Repealed Eff. December 1, 2006.

15A NCAC 08G .0503 EXAMINATION ADMINISTRATION
(a) The Commission shall set the dates, times, and locations for all examinations.
(b) Examinations may be administered by the Commission at any time, or at any location, when a sufficient number of applications have been received to warrant such an examination.
(c) Before each applicant receives an examination paper, an applicant shall display a valid driver's license, photo identification or other form of identification satisfactory to the proctor.

History Note: *Authority G.S. 90A-39;*
Eff. April 1, 1999;
Amended Eff. December 1, 2006.

15A NCAC 08G .0504 EXAMINATION GRADING
(a) A passing score on any examination administered by the Commission is 70 percent of the available points on the examination.
(b) Each applicant, and only the applicant, shall be notified, in writing, of the results on an examination.
(c) If a passing score is attained by an applicant on an examination, the written notification to the applicant shall constitute the certification of the applicant as an operator or operator in training of a water pollution control system of the same type and grade as the examination.

History Note: *Authority G.S. 90A-39; 90A-40;*
Eff. April 1, 1999;
Amended Eff. December 1, 2006.

15A NCAC 08G .0505 EXAMINATION REVIEWS
(a) Any applicant who fails to make a passing score on an examination may request to review the examination. All requests to review an examination must be received by the Commission in writing within 15 calendar days of receiving notification of failing to make a passing score on an examination.
(b) Applicants who submit a written request to review an examination shall be notified of a date, time, and location at which the applicant shall be given the opportunity to review the examination. This shall be the only opportunity the applicant will be allowed for reviewing the examination.
(c) An applicant shall not be allowed to review the examination within 30 calendar days of an upcoming examination date.

History Note: *Authority G.S. 90A-39;*
Eff. April 1, 1999;
Amended Eff. December 1, 2006.

SECTION .0600 - CERTIFICATION WITHOUT EXAMINATION

15A NCAC 08G .0601 RECIPROCITY CERTIFICATION

History Note: *Authority G.S. 90A-40; 90A-42;*
Eff. April 1, 1999;
Repealed Eff. December 1, 2006.

15A NCAC 08G .0602 TEMPORARY CERTIFICATES

(a) Temporary certificates, of any type and grade, may be issued by the Commission to the operator of a water pollution control system, for a period not to exceed one year, due to:

(1) the vacancy of the Operator in Responsible Charge (ORC) or the Back-up Operator in Responsible Charge (Back-up ORC);
(2) the suspension or revocation of the certification of the Operator in Responsible Charge (ORC) or the Back-up Operator in Responsible Charge (Back-up ORC);
(3) a change in the classification of the system due to a permit modification or the completion of an upgrade or expansion; or
(4) a modification to Commission rules.

(b) Temporary Certificates shall only be issued for the Operator in Responsible Charge (ORC) or the Back-up Operator in Responsible Charge (Back-up ORC) of the system specified on the application.

(c) All applications for a temporary certificate must:

(1) be submitted by the owner of the system for the applicant;
(2) be accompanied by the required fee; and
(3) include a letter from the owner that contains:
    (A) an explanation for the need of a temporary certificate for the applicant;
    (B) an explanation of all of the efforts that were made to employ an operator who possessed the required certification;
    (C) a statement designating the applicant as either the Operator in Responsible Charge (ORC) or Back-up Operator in Responsible Charge (Back-up ORC) of the system; and
    (D) a plan that describes the actions that:
        (i) the applicant will pursue in order to attempt to obtain permanent certification during the effective period of the temporary certificate; and
        (ii) the owner of the system will be pursuing in the event that the applicant fails to obtain permanent certification during the effective period of the temporary certificate.

(d) Applicants for a temporary certificate must:

(1) Either:
    (A) for biological or collection system grade II or higher operator certification, possess a valid certificate of the same type as the system and that is no more than one grade lower than the classification of the system when applying as an Operator in Responsible Charge (ORC) and no more than two grades lower than the classification of the system when applying as a Back-up Operator in Responsible Charge (Back-up ORC); or
    (B) for a Grade I biological, Grade I Physical/Chemical, Grade I Collection, Surface Irrigation, Land Application, or Subsurface Water Pollution Control System; have a minimum of three months of actual experience in the operation of the type of system for which a temporary certificate is being applied if the temporary certificate is requested.
(2) be eligible for permanent certification prior to the expiration date of the temporary certificate;
(3) not have made three previous unsuccessful attempts to make a passing score on the same type and grade examination as the temporary certificate; and
(4) have never relinquished, nor had revoked, any water pollution control operator certificate issued by the Commission.

(e) Applicants who obtain a temporary certificate by providing false information to the Commission shall be subject to disciplinary action(s) as set forth in Section .0800 of this Subchapter.

History Note: *Authority G.S. 90A-40; 90A-42;*
Eff. April 1, 1999;
Amended Eff. December 1, 2006.

15A NCAC 08G .0603 TEMPORARY CERTIFICATE RENEWAL

(a) All applications for renewal of a temporary certificate must:

(1) be submitted by the owner of the system 60 calendar days prior to the expiration date of the original temporary certificate;
(2) be accompanied by the required fee; and
(3) include a letter from the owner that explains:
(A) the need for renewal of the temporary certificate;
(B) the reasons for the failure of the applicant to obtain permanent certification during the original effective period of the temporary certificate;
(C) the efforts that have been made by the owner to employ a properly certified operator during the effective period of the original temporary certificate; and
(D) the actions that will be taken by:
(i) the applicant in order to obtain permanent certification during the effective period of the renewed temporary certificate; and
(ii) the owner if the applicant does not obtain permanent certification during the effective period of the renewed temporary certificate.

(b) The renewal request shall be denied if the applicant has failed:
(1) to seek permanent certification by examination during the original effective period of the temporary certificate; or
(2) to obtain permanent certification after four examination attempts during the original effective period of the temporary certificate.

(c) A temporary certificate may be renewed only once for the same operator.

(d) Applicants who obtain a temporary certificate renewal by providing false information to the Commission shall be subject to disciplinary action(s) as set forth in Section .0800 of this Subchapter.

History Note: *Authority G.S. 90A-40; 90A-42;*
Eff. April 1, 1999;
Amended Eff. December 1, 2006.

15A NCAC 08G .0604 CONVERSION OF VOLUNTARY CERTIFICATION TO MANDATORY CERTIFICATION

History Note: *Authority G.S. 90A-39; 90A-40; 90A-42;*
Eff. April 1, 1999;
Repealed Eff. December 1, 2006.

SECTION .0700 - RENEWAL OF CERTIFICATION

15A NCAC 08G .0701 REQUIREMENTS

(a) In order to maintain a valid certificate, the certificate must be renewed annually by:
(1) Submitting payment of the appropriate required annual renewal fee, as set forth in G.S. 90A-42, by the end of the effective year; and
(2) Each operator must provide documentation of a minimum of six contact hours of Commission approved training during each year following the year of initial certification.

(b) Certificate(s) that are not renewed when due shall be considered invalid. In order to renew a certificate that has been invalid for up to two years, all outstanding renewal fees and supplemental processing fees and penalties that have accrued since the certificate was last renewed must be paid and all accrued continuing education requirements must be met. In order to renew a certificate that has been invalid for two or more consecutive years the operator shall be required to take and make a passing score on an examination of the same type and grade as the former certificate. In order to qualify for the examination, all relevant requirements of Section .0400 of this Subchapter must be met. Any requirements in Section .0400 of this Subchapter for Commission approved training must have been met within the previous 12 month period. Invalid Conditional Certificates are not renewable.

(c) Renewal notices shall be mailed to each certified operator, at the last known address for the operator on file with the Commission, 60 calendar days prior to the renewal due date. Failure to receive a renewal notice does not relieve a certified operator of the responsibility to renew the certificate by the renewal due date.

History Note: *Authority G.S. 90A-40; 90A-42; 90A-44; 90A-46.1;*

Eff. April 1, 1999;
Amended Eff. December 1, 2006.

SECTION .0800 - DISCIPLINARY ACTIONS

15A NCAC 08G .0801 GROUNDS FOR DISCIPLINARY ACTIONS

The Commission may take disciplinary actions, in accordance with Rule .0802 of this Section, against a certified operator for:

(1) practicing fraud or deception in the performance of duties;
(2) failure to use reasonable care or judgment in the performance of duties;
(3) failure to apply their knowledge or ability in the performance of duties;
(4) incompetence or the inability to perform duties;
(5) supplying false information in order to obtain or maintain certification; or
(6) cheating on a certification examination.

History Note: *Authority G.S. 90A-41;*
Eff. April 1, 1999;
Amended Eff. December 1, 2006.

15A NCAC 08G .0802 DISCIPLINARY ACTIONS

(a) The Commission shall revoke or suspend the certification of an operator or issue a letter of reprimand to an operator in accordance with the provisions of G.S. 90A-41, 150B-3 and this Rule.

(b) The Chairman of the Commission may issue notification of summary suspension, the intention to revoke or suspend the certification of an operator or the intent to issue a letter of reprimand.

(c) The Chairman shall convene an advisory committee to review the circumstances of the proposed disciplinary action(s).

(1) The advisory committee shall include at least:
  (A) the Chairman of the Commission;
  (B) the Vice Chairman of the Commission;
  (C) the member of the Commission who represents the type of system at which the operator is employed or another member of the Commission appointed by the Chairman of the Commission; and
  (D) a certified operator appointed by the Chairman.
(2) The members of the advisory committee shall offer guidance to the Commission chairman in regards to the actions that should be taken against an operator.

(d) Notification of the advisory committee meeting shall be sent by certified mail at least 15 calendar days prior to the date of the meeting, to the last known address of the operator. This notification shall contain the alleged facts or conduct upon which the proposed revocation or suspension of the certification or letter of reprimand is based.

(e) The operator shall have an opportunity to submit a written response to the Chairman prior to the date of the advisory committee meeting. The operator shall also be given the opportunity to make an oral statement before the advisory committee.

(f) Within 10 working days of the conclusion of the advisory committee meeting, the Chairman shall issue a decision. If this decision is to issue a revocation or suspension or a letter of reprimand, the Chairman shall advise the operator of the effective date of the action and the facts or conduct upon which the action is based. The revocation or suspension of a certification or the letter of reprimand shall be delivered to the affected operator and the owner of the system(s) at which the operator works by certified mail, at the last known address for the operator and owner on file with the Commission, at least 20 calendar days prior to the effective date of the revocation or suspension or letter of reprimand.

(g) The revocation, suspension or letter of reprimand becomes a final Commission action if the operator does not file a petition for a contested case hearing in the Office of Administrative Hearings as provided in the Administrative Procedure Act, G.S. 150B.

(h) If an applicant is caught cheating on an examination by a proctor of the examination, the applicant shall be excused from the examination, the examination shall not be graded, the fee for the examination shall be forfeited by the applicant and any other certification(s) held by the applicant with the Commission shall be subject to revocation as set forth in G.S. 90A-41 and in this Rule.

(i) If the Commission determines, after the examination has been graded, that an applicant cheated on an examination and certification has been conveyed to the applicant, the certification obtained through the examination shall be revoked and any

other certification(s) held by the applicant with the Commission shall be subject to revocation as set forth in G.S. 90A-41 and in this Rule.

History Note: *Authority G.S. 90A-40; 90A-41; 143B-300; 150B-23;*
Eff. April 1, 1999;
Amended Eff. December 1, 2006.

15A NCAC 08G .0803 CERTIFICATION FOLLOWING DISCIPLINARY ACTIONS

(a) An individual who has had certification revoked by the Commission shall petition the Commission for any new certification sought and may not petition the Commission for such new certification sooner than two years after the effective date of the revocation. Following the denial of eligibility for re-certification after relinquishment or revocation, an operator must wait one year before reapplying for certification.

(b) The following information must be included in the petition for certification:

(1) a written statement explaining the actions that the individual has taken to correct those problems that lead to the revocation of the certification previously held with the Commission; and

(2) a statement that attests to the Commission that, upon obtaining certification, the individual shall comply with all laws governing the proper operation of water pollution control systems.

(c) After submittal of the petition for certification, the petitioner may be required to appear before the Commission at a regularly scheduled meeting. The petitioner shall be notified, by certified mail, of the date, time and location of the meeting at least 15 calendar days prior to the meeting.

(d) Within 120 calendar days following receipt of a petition for certification, the Commission shall notify the individual, in writing, of its decision to deny or grant examination eligibility in accordance with the procedures set forth in Section .0500 of this Subchapter. Eligibility for certification shall be granted only if there is substantial evidence that those conditions that lead to the revocation of previous certification held by the petitioner have been corrected.

(e) Certification of an individual whose previous certification has been revoked shall occur only after the individual sits for, and obtains a passing score on, an examination. Once approval is granted by the Commission for certification after reviewing the petition for certification, the individual must submit an application, accompanied by the appropriate examination fee, and meet the examination eligibility requirements for the type of certification being sought as set forth in Section .0400 of this Subchapter. The individual must begin the certification process at the lowest grade level offered for the type of certification sought. Operational experience accrued by the individual prior to the revocation of any previously held certification(s) shall not be considered when determining the eligibility of the individual for the examination.

(f) Applicants for certification who were previously determined to be ineligible for certification due to supplying false information to the Commission must follow the procedures set forth in Paragraphs (a) through (e) of this Rule in order to obtain certification.

History Note: *Authority G.S. 90A-39; 90A-41; 150B-23;*
Eff. April 1, 1999;
Amended Eff. December 1, 2006.

15A NCAC 08G .0804 CONTESTED CASE PROCEDURES

(a) Administrative hearings shall be held in accordance with G.S. 150B and the administrative hearing procedures codified at 15A NCAC 01B .0200 et seq., are hereby incorporated by reference including any subsequent amendments and additions.

(b) For information on obtaining a copy of 15A NCAC 01B .0200, you may contact the Rules Division of the NC Office of Administrative Hearings at (919) 733-2678.

History Note: *Authority G.S. 143B-300; 150B-23;*
Eff. April 1, 1999;
Amended Eff. December 1, 2006.

SECTION .0900 - CONTRACT OPERATION OF WATER POLLUTION CONTROL SYSTEMS

15A NCAC 08G .0901 RESPONSIBILITIES OF CONTRACT OPERATORS AND CONTRACT OPERATIONS FIRMS

Each contract operator, or contract operations firm, that enters into a contract with the owner of a water pollution control system to operate the system must notify the owner, in writing, within five calendar days of:

(1) any change in the designation of the Operator in Responsible Charge (ORC) or the Back-up Operator in Responsible Charge (Back-up ORC) of the system; or

(2) becoming aware of any situation or problem (preexisting, anticipated, or otherwise) which may interfere with the proper operation of the system and necessitate corrective action by the owner. This notice shall include the comments and recommendations of the operator in regards to actions or measures that should be taken to correct the noted situation or problem.

History Note: *Authority G.S. 90A-44; 90A-45;*
Eff. April 1, 1999.

15A NCAC 08G .0902 ANNUAL REPORT

History Note: *Authority G.S. 90A-45;*
Eff. April 1, 1999;
Repealed Eff. December 1, 2006.

SECTION .1000 - RULE MAKING PROCEDURES AND PETITIONS FOR REGULATORY ACTIVITY

15A NCAC 08G .1001 PETITIONS FOR REGULATORY ACTIVITY

(a) Any person(s) desiring to request the adoption, amendment, or repeal of a rule may make such request in a petition filed pursuant to G.S. 150B-20, addressed to the Water Pollution Control System Operators Certification Commission and mailed to the Chairman at 1618 Mail Service Center, Raleigh, NC 27699-1618. Such petitions must contain:

(1) a draft of the proposed rule or a summary of its intent;

(2) reasons for adoption of the proposed rule(s) and the effect it will have on existing rules and practices; and

(3) the name(s) and address(es) of the petitioner(s).

(b) Petitions shall be placed on the agenda of the next regularly scheduled meeting of the Commission if received at least four weeks prior to the meeting. The Chairman shall prepare recommended responses to petitions for the Commission's consideration. Petitions shall be considered in accordance with the requirements of G.S. 150B-20.

History Note: *Authority G.S. 143B-300; 150B-20;*
Eff. April 1, 1999;
Amended Eff. December 1, 2006.

SECTION .1100 - ADMINISTRATIVE DUTIES

15A NCAC 08G .1101 REFUNDING OF FEES

History Note: *Authority G.S. 90A-42;*
Eff. April 1, 1999;
Repealed Eff. December 1, 2006.

Water Pollution Control System Operator Designation Form

WPCSOCC

NCAC 15A 8G .0201

Permittee Owner/Officer Name: _____

Mailing Address: _____

City: _____ State: _____ Zip: _____- _____ Phone #: (____) _____

Email address: _____

Signature: _____ Date: _____

Facility Name: _____ **Permit #:** _____

SUBMIT A SEPARATE FORM FOR EACH TYPE SYSTEM!

Facility Type/Grade:

Biological WWTP	_____	Surface Irrigation	_____
Physical/Chemical	_____	Land Application	_____
Collection System	_____		

Operator in Responsible Charge (ORC)

Print Full Name: _____

Certificate Type / Grade / Number: _____ Work Phone #: (____) _____

Signature: _____ Date:_____

"I certify that I agree to my designation as the Operator in Responsible Charge for the facility noted. I understand and will abide by the rules and regulations pertaining to the responsibilities of the ORC as set forth in 15A NCAC 08G .0204 and failing to do so can result in Disciplinary Actions by the Water Pollution Control System Operators Certification Commission."

Back-Up Operator in Responsible Charge (BU ORC)

Print Full Name: _____

Certificate Type / Grade / Number: _____ Work Phone #: (____) _____

Signature: _____ Date: _____

"I certify that I agree to my designation as a Back-up Operator in Responsible Charge for the facility noted. I understand and will abide by the rules and regulations pertaining to the responsibilities of the BU ORC as set forth in 15A NCAC 08G .0205 and failing to do so can result in Disciplinary Actions by the Water Pollution Control System Operators Certification Commission."

Mail, fax or email the original to: **WPCSOCC, 1618 Mail Service Center, Raleigh, NC 27699-1618 Fax: 919.715.2726**
Email: certadmin@ncdenr.gov

Mail or fax a copy to the appropriate Regional Office:

Asheville
2090 US Hwy 70
Swannanoa 28778
Fax: 828.299.7043
Phone: 828.296.4500

Fayetteville
225 Green St
Suite 714
Fayetteville 28301-5043
Fax: 910.486.0707
Phone: 910.433.3300

Mooresville
610 E Center Ave
Suite 301
Mooresville 28115
Fax: 704.663.6040
Phone: 704.663.1699

Raleigh
3800 Barrett Dr
Raleigh 27609
Fax: 919.571.4718
Phone:919.791.4200

Washington
943 Washington Sq Mall
Washington 27889
Fax: 252.946.9215
Phone: 252.946.6481

Wilmington
127 Cardinal Dr
Wilmington 28405-2845
Fax: 910.350.2004
Phone: 910.796.7215

Winston-Salem
585 Waughtown St
Winston-Salem 27107
Fax: 336.771.4631
Phone: 336.771.5000

Facility Name: _____ **Permit #:** _____

Back-Up Operator in Responsible Charge (BU ORC)

Print Full Name: _____

Certificate Type / Grade / Number: _____ Work Phone #: (____) _____

Signature: _____ Date: _____

"I certify that I agree to my designation as a Back-up Operator in Responsible Charge for the facility noted. I understand and will abide by the rules and regulations pertaining to the responsibilities of the BU ORC as set forth in 15A NCAC 08G .0205 and failing to do so can result in Disciplinary Actions by the Water Pollution Control System Operators Certification Commission."

Back-Up Operator in Responsible Charge (BU ORC)

Print Full Name: _____

Certificate Type / Grade / Number: _____ Work Phone #: (____) _____

Signature: _____ Date: _____

"I certify that I agree to my designation as a Back-up Operator in Responsible Charge for the facility noted. I understand and will abide by the rules and regulations pertaining to the responsibilities of the BU ORC as set forth in 15A NCAC 08G .0205 and failing to do so can result in Disciplinary Actions by the Water Pollution Control System Operators Certification Commission."

Back-Up Operator in Responsible Charge (BU ORC)

Print Full Name: _____

Certificate Type / Grade / Number: _____ Work Phone #: (____) _____

Signature: _____ Date: _____

"I certify that I agree to my designation as a Back-up Operator in Responsible Charge for the facility noted. I understand and will abide by the rules and regulations pertaining to the responsibilities of the BU ORC as set forth in 15A NCAC 08G .0205 and failing to do so can result in Disciplinary Actions by the Water Pollution Control System Operators Certification Commission."

Back-Up Operator in Responsible Charge (BU ORC)

Print Full Name: _____

Certificate Type / Grade / Number: _____ Work Phone #: (____) _____

Signature: _____ Date: _____

"I certify that I agree to my designation as a Back-up Operator in Responsible Charge for the facility noted. I understand and will abide by the rules and regulations pertaining to the responsibilities of the BU ORC as set forth in 15A NCAC 08G .0205 and failing to do so can result in Disciplinary Actions by the Water Pollution Control System Operators Certification Commission."

Request for Listing as a North Carolina
Water Pollution Control System Contract Operator

Effective December 1, 2006, North Carolina regulations no longer require water pollution control system contract operators or contract operations firms to submit annual reports.

Submission of this form is considered a request to list your or your company's name and information on a list of contract operators that is available to the public. To remain on the list, you must submit this form at least every twelve months.

Contract Operator or Operation Firm Name		
Owner's Name	Contact Person	
Street Address or PO Box		
City	State	Zip
Phone #	Phone #	
Fax #	Email / Website	

I am interested in offering my/my company's services for the types of systems checked below:

Biological Wastewater (WW)		Surface Irrigation (SI)	
Collections (CS)		Subsurface (SS)	
Physical/Chemical (PC)		Type A Animal Waste (AWA)	
Land Application (LA)		Type B Animal Waste (AWB)	

I am interested in offering my/my company's services in the counties listed below:

Signature of Owner *Date*

Submit to:

WPCSOCC
Division of Water Resources
1618 Mail Service Center
Raleigh NC 27699 -1618

Phone: (919) 807-6334
Fax: (919) 807-6498
Email: Beth.Buffington@ncdenr.gov

8-2013

DIMENSIONS AND WEIGHTS

PVC and CPVC Schedule 40 Pipe

Nominal Pipe Size (in.)	Outside Diameter	Min. Wall	Approximate Wt. (lbs / 100 ft)	
			PVC	CPVC
1/2	.840	.109	15.7	17.3
3/4	1.050	.113	21.0	23.0
1	1.315	.133	31.0	34.2
1 1/4	1.660	.140	42.0	46.3
1 1/2	1.900	.145	50.4	55.3
2	2.375	.154	67.6	74.3
2 1/2	2.875	.203	107.0	117.9
3	3.500	.216	141.0	154.2
4	4.500	.237	200.0	219.6
5	5.563	.258	275.3	—
6	6.625	.280	352.0	396.3
8	8.625	.322	539.0	581.1
10	10.750	.365	755.0	850.8
12	12.750	.406	1001.0	1119.6
14	14.000	.438	1181.0	—
16	16.000	.500	1527.8	—

PVC and CPVC Schedule 80 Pipe

Nominal Pipe Size (in.)	Outside Diameter	Min. Wall	Approximate Wt. (lbs / 100 ft)	
			PVC	CPVC
1/4	.540	.119	10.0	—
3/8	.675	.126	13.8	—
1/2	.840	.147	20.5	22.1
3/4	1.050	.154	27.5	30.0
1	1.315	.179	40.9	44.2
1 1/4	1.660	.191	55.7	61.0
1 1/2	1.900	.200	68.6	73.9
2	2.375	.218	94.9	102.2
2 1/2	2.875	.276	142.1	155.9
3	3.500	.300	193.8	208.6
4	4.500	.337	283.3	304.9
5	5.563	.375	391.0	—
6	6.625	.432	541.1	581.5
8	8.625	.500	805.2	882.9
10	10.750	.593	1200.0	1309.1
12	12.750	.687	1650.0	1801.2
14	14.000	.750	2010.0	—
16	16.000	.843	2549.0	—

Note: All dimensions are in inches.

CHARLOTTE
PIPE AND FOUNDRY COMPANY

DIMENSIONS AND WEIGHTS

SDR Pressure Pipe

Nominal Pipe Size (in.)	Outside Diameter	SDR 13.5 (PR 315)		SDR 21 (PR 200)		SDR 26 (PR 160)	
		Min. Wall	Approx. Wt. (lbs/100 ft)	Min. Wall	Approx. Wt. (lbs/100 ft)	Min. Wall	Approx. Wt. (lbs/100 ft)
1/2	.840	.062	9.5				
3/4	1.050			.060	11.8		
1	1.315			.063	15.9		
1 1/4	1.660			.079	24.8	.064	21.6
1 1/2	1.900			.090	32.2	.073	27.7
2	2.375			.113	50.8	.091	42.8
2 1/2	2.875			.137	75.8	.110	63.9
3	3.500			.167	111.8	.135	92.2
4	4.500			.214	184.8	.173	152.0
5	5.563			.265	282.3	.214	230.9
6	6.625			.316	417.5	.255	329.7
8	8.625			.410	676.5	.332	553.4
10	10.750			.511	1051.6	.413	858.9
12	12.750					.490	1208.5
14	14.000					.538	1472.0
16	16.000					.615	1919.0

Pipe Inside Diameters

Nominal Pipe Size (in.)	Type of Pipe			
	Schedule 80	Schedule 40	SDR 21 (PR 200)	SDR 26 (PR 160)
1/4	.302	—	—	—
3/8	.423	—	—	—
1/2	.546	.622	.716 (PR 315)	—
3/4	.742	.824	.930	—
1	.957	1.049	1.189	—
1 1/4	1.278	1.380	1.502	1.532
1 1/2	1.500	1.610	1.720	1.754
2	1.939	2.067	2.149	2.193
2 1/2	2.323	2.469	2.601	2.655
3	2.900	3.068	3.166	3.230
4	3.826	4.026	4.072	4.154
5	4.813	5.047	5.033	5.135
6	5.761	6.065	5.993	6.115
8	7.625	7.981	7.803	7.961
10	9.564	10.020	—	9.924
12	11.376	11.938	—	11.770
14	12.500	13.124	—	12.924
16	14.314	15.000	—	14.770

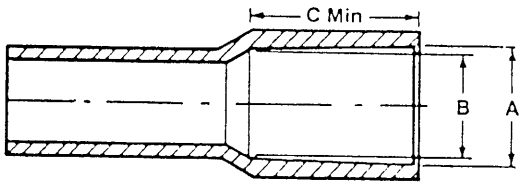
Note: All dimensions are in inches.

DIMENSIONS AND WEIGHTS

Socket Dimensions For Belled-End Pipe

Nom. Pipe Size	SOCKET ENTRANCE (A)		SOCKET BOTTOM (B)		SOCKET LENGTH (C)		
	I.D. Min.	I.D. Max.	I.D. Min.	I.D. Max.	SDR	Schedule 40	Schedule 80
½	0.844	0.852	0.832	0.840	2.000	2.000	—
¾	1.054	1.062	1.042	1.050	2.250	2.250	—
1	1.320	1.330	1.305	1.315	2.500	2.500	—
1¼	1.665	1.675	1.650	1.660	2.750	2.750	—
1½	1.906	1.918	1.888	1.900	3.000	3.000	—
2	2.381	2.393	2.363	2.375	4.000	4.000	3.750
2½	2.882	2.896	2.861	2.875	4.000	4.000	—
3	3.508	3.524	3.484	3.500	4.000	4.000	4.000
4	4.509	4.527	4.482	4.500	5.000	5.000	5.000
6	6.636	6.658	6.603	6.625	6.500	6.500	6.500
8	8.640	8.670	8.595	8.625	—	7.000	7.000
10	10.761	10.791	10.722	10.752	—	9.000	9.000
12	12.763	12.793	12.721	12.751	—	10.000	10.000
14	14.020	14.050	13.955	13.985	—	10.000	10.000
16	16.030	16.060	15.955	15.985	—	10.000	—

Note: All dimensions are in inches.



PRESSURE RATINGS

MAXIMUM OPERATING PRESSURE (PSI) AT 73° F

Nominal Pipe Size	Schedule 80 PVC and CPVC		Schedule 40 PVC and CPVC (2)	SDR 26 PVC (2)	SDR 21 PVC (2)	SDR 13.5 PVC (2)
	Plain End	Threaded				
1/4	1130	570	780	—	—	—
3/8	920	460	620	—	—	—
1/2	850	420	600	—	—	315
3/4	690	340	480	—	200	—
1	630	320	450	—	200	—
1¼	520	260	370	160	200	—
1½	470	240	330	160	200	—
2	400	200	280	160	200	—
2½	420	210	300	160	200	—
3	370	190	260	160	200	—
4	320	160	220	160	200	—
5	290	Threading pipe above 4" is not recommended	190	160	200	—
6	280		180	160	200	—
8	250		160	160	200	—
10	230		140	160	200	—
12	230		130	160	200	—
14	220 (1)		130 (1)	160	—	—
16	220 (1)		130 (1)	160	—	—

The operating pressures listed above are based on the hydrostatic design of the pipe using water at 73° F as the test medium.

The PVC pipe shown is for PVC 1120 with a cell class of 12454-B. The CPVC pipe shown is for CPVC 4120 with a cell class of 23447-A.

The pressure ratings for the SDR pipe shown were derived by using the following equation:

$$P = \frac{2ST}{D - T}$$

Where: P = pressure (psi)
D = average outside diameter
T = minimum wall thickness
S = hydrostatic design stress (HDS)*

*The HDS for Charlotte Pipe and Foundry's PVC and CPVC compounds is 2,000 psi.
(1) PVC only.
(2) Threading is not recommended.

PVC AND CPVC PIPE ARE NOT RECOMMENDED FOR USE IN COMPRESSED AIR OR GAS SERVICE.

CHARLOTTE
PIPE AND FOUNDRY COMPANY

INSTALLATION PROCEDURES

Solvent Cementing PVC and CPVC Pipe and Fittings

BASIC PRINCIPLES OF SOLVENT CEMENTING

To make consistently good joints the following should be clearly understood:

1. The joining surfaces must be softened and made semi-fluid.
2. Sufficient cement must be applied to fill the gap between pipe and fitting.
3. Assembly of pipe and fittings must be made while the surfaces are still wet and fluid.
4. Joint strength develops as the cement dries. In the tight part of the joint the surfaces will tend to fuse together, in the loose part the cement will bond to both surfaces.

Penetrating and softening can be achieved by the use of both primer and cement. A suitable primer will usually penetrate and soften the surfaces more quickly than the cement alone. Additionally, the use of a primer can provide a safety factor for the installer, for he can know, under various temperature conditions, when he has achieved sufficient softening. For example, in cold weather more time and additional applications are required.

PRIMERS AND CEMENTS

Primer

It is recommended that Tetrahydrofuran (THF) be used to prepare the surfaces of pipe and fittings for solvent welding. Do not use water, rags, gasoline, or any other substitutes for cleaning PVC or CPVC surfaces. A chemical cleaner such as MEK may be used.

Cement

Make sure the solvent cement used is suitable for the type and size of the pipes being installed. PVC cement must be used with PVC pipe and fittings. CPVC cement must be used with CPVC pipe and fittings. Also, cement with the proper viscosity for the type and size of pipe, must be used. Contact the supplier of the cement if there are any questions on the suitability of the cement for the intended application.

Solvent cements are formulated to be used "as received" in original containers. Adding of thinners to change viscosity is not recommended. If the cement is found to be jelly-like and is not free-flowing, it should not be used. Containers should be kept covered when not in actual use.

Solvent cements should be stored at temperatures between 40°F and 110°F and away from heat or open flame. The cements should be used within one year of the date stamped on the container. Stocks should be constantly rotated to prevent build-up of old cement inventories. If new cement is subjected to freezing it may become extremely thick or gelled. This cement can be placed in a warm area where, after a period of time, it will return to its original, useable condition. But such is not the case when gellation has taken place because of actual solvent loss; for example, when container was left open too long during use or not sealed properly after use. Cement in this condition has lost its formulation and should be discarded.

Solvent cements and primers are extremely flammable and should not be used or stored near heat or open flame. They should be used only with adequate ventilation. In confined or partially enclosed areas, a ventilating device should be used to remove vapors and minimize their inhalation. Containers should be kept tightly closed when not in use and covered as much as possible when in use. Avoid frequent contact with the skin. In case of eye contact, flush repeatedly with water. Keep out of reach of children.

Applicators

To properly apply the primer and cement, the correct size and type of applicator must be used. There are three basic types of applicators:

Daubers—should only be used on pipe sizes 2" and below.

Brushes—can be used on any diameter pipe, should always have natural bristles, and should have a width equal to at least 1/2 the diameter of the pipe.

Rollers—can be used on 4" and larger diameter pipe and should have a length equal to at least 1/2 the diameter of the pipe.

SOLVENT CEMENTING

The chart below shows the recommended applicator sizes

Nominal pipe size (in.)	Applicator Type		
	Dauber	Brush Width (in.)	Roller Length (in.)
1/4	A	1/2	NR
3/8	A	1/2	NR
1/2	A	1/2	NR
3/4	A	1	NR
1	A	1	NR
1 1/4	A	1	NR
1 1/2	A	1 - 1 1/2	NR
2	A	1 - 1 1/2	NR
2 1/2	NR	1 1/2 - 2	NR
3	NR	1 1/2 - 2 1/2	NR
4	NR	2 - 3	3
5	NR	3 - 5	3
6	NR	3 - 5	3
8	NR	4 - 6	7
10	NR	6 - 8	7
12	NR	6 - 8	7
14	NR	7 - 8	7
16	NR	8 +	8

A = Acceptable NR = Not Recommended

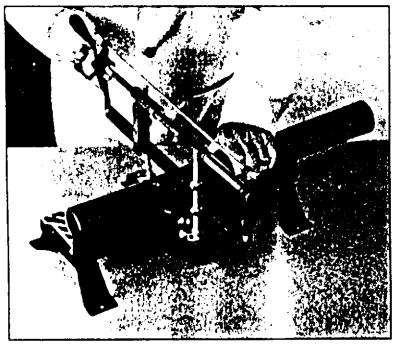
MAKING THE JOINTS

1. Preparation

Before starting to make any joints, the pipe and fittings should be visually inspected for any damage or defects. The fittings should be exposed to the same temperature conditions as the pipe, for at least one hour prior to installation, so that the pipe and fittings are basically at the same temperature when joined.

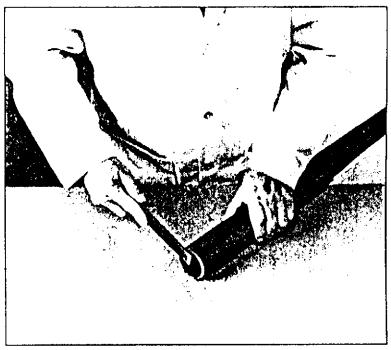
2. Cutting

Cut pipe square using a miter box or a plastic pipe cutting tool which DOES NOT flare up diameter at end of pipe.



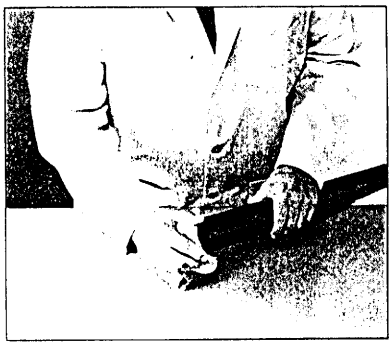
3. Deburring and Chamfering

Remove all burrs from end of pipe with a knife, file, or plastic pipe deburring tool. Chamfer (bevel) the end of the pipe 10°-15° as shown to the right.



4. Cleaning

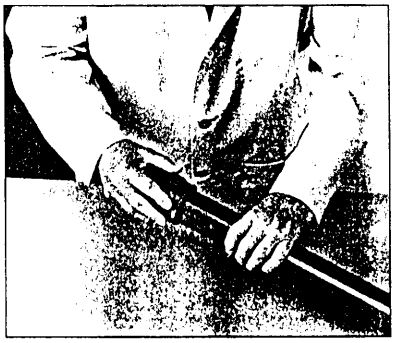
Remove any dirt, moisture, or grease from pipe end and fitting sockets with a clean dry rag. A chemical cleaner must be used if the wiping fails to clean the surfaces.



SOLVENT CEMENTING

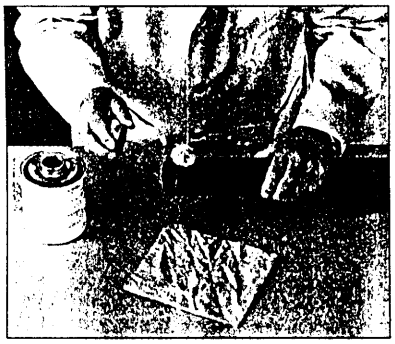
5. Dry Fitting

Check dry fit of pipe and fitting by inserting pipe into fitting. With light pressure, pipe should easily go at least 1/3 of the way in. If it bottoms, it should be snug.



6. Priming

Using the correct applicator (as shown in chart), apply primer freely to fitting socket, keeping the surface and applicator wet until the surface has been softened. This will usually require 5-15 seconds. More time is needed for hard surfaces and in cold weather conditions. Redip the applicator in primer as required. When the surface is primed, remove any puddles of primer from the socket.

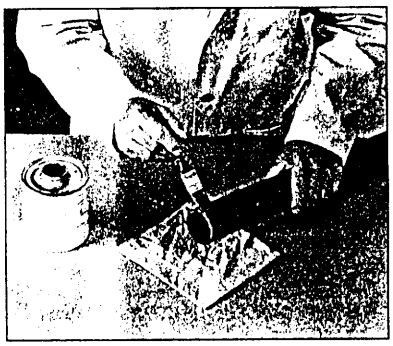


A second application in the socket is recommended if it has unusually hard surfaces. These hard surfaces are often found in belled-ends and in fittings made from pipe stock.

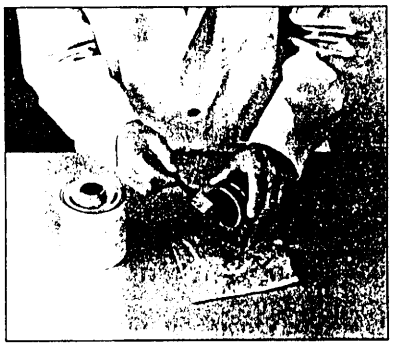
Apply the primer to the end of the pipe equal to the depth of the fitting socket. Application should be made in the same manner as was done on the fitting socket.

7. Cementing

While the surfaces of the pipe and fitting are still wet with primer, immediately apply a full even layer of cement to the pipe (using the proper size applicator shown in chart) equal to the depth of the socket.



Apply a medium layer of cement to the fitting socket. Do not let the cement puddle. Also, when joining belled-end pipe, do not coat beyond the bell depth or allow the cement to run down the inside of the pipe.



Apply a second full even layer of cement to the pipe. Assemble parts QUICKLY! Parts must be assembled while cement is still fluid. If assembly is interruped, recoat parts and assemble. Push pipe FULLY into fitting, using a turning motion, if possible, of 1/8 to 1/4 turn, until it bottoms. Hold them together for 15 - 30 seconds to offset tendency of pipe to move out of fittings. With a rag, wipe off excess bead of cement from juncture of pipe and fitting.

Note: For pipe sizes 6" and larger, two people will be required, a mechanical forcing device should be used, and the joint should be held together for up to 3 minutes.

PVC Schedule 40 Gray Pressure Fittings

Some items may have been discontinued. Consult current price list.

45° ELLS

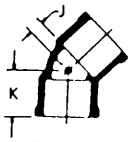


FIG. 417
S x S

Size	Size Code	K	J	Weight (lb.) 417
½	005	1	¼	.04
¾	007	1 5/16	5/16	.06
1	010	1 7/16	5/16	.10
1¼	012	1⅝	⅜	.17
1½	015	1¾	7/16	.23
2	020	2	⅝	.34
2½	025	2¾	¾	.71
3	030	2 13/16	13/16	.97
4	040	3	1	1.46
5	050	4⅜	1⅜	2.82
6	060	5¼	1¾	4.47

COUPLINGS

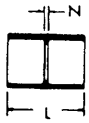


FIG. 429
S x S

Size	Size Code	L Slip	N	Weight (lb.) 429
½	005	1 19/32	3/32	.02
¾	007	2 3/32	3/32	.05
1	010	2 11/32	3/32	.10
1¼	012	2 19/32	3/32	.14
1½	015	2 23/32	3/32	.18
2	020	2 27/32	3/32	.25
2½	025	4 3/16	3/16	.59
3	030	5 3/16	3/16	.90
4	040	5¼	¼	1.28
5	050	6¼	¼	2.02
6	060	7¼	¼	3.12

REDUCING TEES

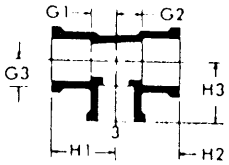


FIG. 401
S x S x S

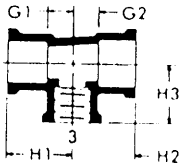


FIG. 402
S x S x T

Size	Size Code	H1	H2	H3	G1	G2	G3	Weight (lb.) 401	Weight (lb.) 402
¾ x ¾ x ½	101	1½	1⅛	1 5/16	½	½	9/16	.11	.09
1 x ¾ x ¾	125	1 29/32	1 9/16	1 27/32	23/32	9/16	23/32	.16	N.A.
1 x 1 x ½	130	1⅝	1¼	1 15/32	½	½	11/16	.13	.14
1 x 1 x ¾	131	1 11/16	1 17/64	1 23/32	9/16	9/16	11/16	.17	.19
1¼ x 1¼ x ½	166	1¾	1¾	1 21/32	½	½	29/32	N.A.	.22
1¼ x 1¼ x ¾	167	1 13/16	1 13/16	1 29/32	9/16	9/16	29/32	.23	.24
1¼ x 1¼ x 1	168	1 31/32	1 31/32	2 1/32	23/32	23/32	29/32	.26	N.A.
1½ x 1½ x ½	209	1 13/16	1 13/16	1 25/32	½	½	1 1/32	N.A.	.25
1½ x 1½ x ¾	210	1⅞	1⅞	2 1/32	9/16	9/16	1 1/32	.27	.29
1½ x 1½ x 1	211	2 1/32	2 1/32	2 5/32	23/32	23/32	1 1/32	.31	.33
2 x 2 x ½	247	1⅞	1⅞	2	½	½	1¼	N.A.	.41
2 x 2 x ¾	248	1 15/16	1 15/16	2¼	9/16	9/16	1¼	.37	.37
2 x 2 x 1	249	2 3/32	2 3/32	2⅜	23/32	23/32	1¼	.41	.43
2 x 2 x 1½	251	2 13/32	2 13/32	2 9/16	1 1/32	1 1/32	1¼	.49	.53
2½ x 2½ x 1	289	2 23/32	2 23/32	2 11/16	23/32	23/32	1 9/16	N.A.	.79
3 x 3 x ¾	334	2 9/16	2 9/16	2⅞	9/16	9/16	1⅞	.91	N.A.
3 x 3 x 1	335	2 23/32	2 23/32	3	23/32	23/32	1⅞	.99	N.A.
3 x 3 x 1½	337	3 1/32	3 1/32	3 3/16	1 1/32	1 1/32	1⅞	1.16	N.A.
3 x 3 x 2	338	3¼	3¼	3¼	1¼	1¼	1⅞	1.22	N.A.
4 x 4 x ¾	416	2 9/16	2 9/16	3⅜	9/16	9/16	2⅜	1.36	N.A.
4 x 4 x 2	420	3¼	3¼	3¾	1¼	1¼	2⅜	1.73	N.A.
4 x 4 x 3	422	3⅞	3⅞	4⅜	1⅞	1⅞	2⅜	2.18	N.A.

REDUCING BUSHINGS

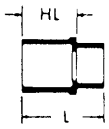


FIG. 437
Style 1
SPG x S

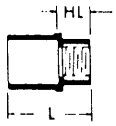


FIG. 438
Style 1
SPG x T

FIG. 437
Style 2
SPG x S

FIG. 438
Style 2
SPG x T

Size	Size Code	Style	L		HL		N	Weight (lb.)	
			Slip	Thread	Slip	Thread		437	438
1/2 x 3/8	073	2	15/16	15/16	—	—	3/16	.01	.01
1/2 x 1/4	072	2	15/16	15/16	—	—	5/16	.01	.01
3/4 x 1/2	101	2	1 3/16	1 3/16	—	—	7/16	.02	.02
3/4 x 3/8	099	2	1 3/16	1 3/16	—	—	—	.03	—
1 x 3/4	131	2	1 3/8	1 3/8	—	—	3/8	.04	.04
1 x 1/2	130	1	2 1/8	2 1/8	1 3/8	1	—	.06	.06
1 1/4 x 1	168	2	1 1/2	1 17/32	—	—	3/8	.06	.07
1 1/4 x 3/4	167	1	2 17/32	2 11/32	1 17/32	1 3/32	—	.10	.09
1 1/4 x 1/2	166	1	2 9/32	2 9/32	1 17/32	1 1/32	—	.09	.09
1 1/2 x 1 1/4	212	2	1 9/16	1 9/16	—	—	5/16	.06	.07
1 1/2 x 1	211	1	2 3/4	2 5/8	1 5/8	1 5/16	—	.13	.13
1 1/2 x 3/4	210	1	2 9/16	2 11/32	1 9/16	1 3/32	—	.12	.11
1 1/2 x 1/2	209	1	2 3/8	2 3/8	1 9/16	1 1/16	—	.10	.11
2 x 1 1/2	251	2	1 3/4	1 3/4	—	—	7/16	.16	.15
2 x 1 1/4	250	1	3	2 3/4	1 3/4	1 3/8	—	.18	.18
2 x 1	249	1	2 7/8	2 3/4	1 3/4	1 3/8	—	.18	.18
2 x 3/4	248	1	2 3/4	2 17/32	1 3/4	1 5/32	—	.16	.17
2 x 1/2	247	1	2 1/2	2 3/16	1 3/4	1 1/8	—	.15	.15
2 1/2 x 2	292	2 & 1	2 3/8	2 3/8	—	—	1	.27 (2)	.33 (1)
2 1/2 x 1 1/2	291	1 & 2	3 11/16	3 13/32	2 3/8	1 13/32	—	.34 (1)	.34 (2)
2 1/2 x 1 1/4	290	1	3 5/8	3 3/8	2 3/8	1 3/8	—	.34	N.A.
2 1/2 x 3/4	288	1	3 3/8	3 5/32	2 3/8	1 5/32	—	N.A.	.31
2 1/2 x 1/2	287	1	3 1/8	3 1/8	2 3/8	1 1/8	—	.30	N.A.
3 x 2 1/2	339	2	2 3/8	2 3/8	—	—	3/8	.42	N.A.
3 x 2	338	1	3 3/4	3 7/16	2 3/8	1 7/16	—	.49	.48
3 x 1 1/2	337	1	3 11/16	3 13/32	2 3/8	1 13/32	—	.46	N.A.
3 x 1 1/4	336	1	3 5/8	3 3/8	2 3/8	1 3/8	—	.44	.44
3 x 1	335	1	3 1/2	3 3/8	2 3/8	1 3/8	—	.44	.44
3 x 3/4	334	1	3 3/8	3 5/32	2 3/8	1 5/32	—	.43	N.A.
4 x 3	422	1	4 3/8	4	2 3/8	2	—	.85	.84
4 x 2 1/2	421	1	4 3/8	3 61/64	2 3/8	1 15/16	—	.84	N.A.
4 x 2	420	1	3 3/4	3 7/16	2 3/8	1 7/16	—	.70	.70
5 x 4	490	1	5 7/16	5 3/16	3 7/16	2 5/32	—	1.35	N.A.
6 x 4	532	1	5 15/16	5 11/16	3 15/16	2 3/16	—	2.07	2.11

THREAD ADAPTERS

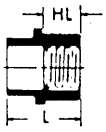


FIG. 478
SPG x T

Size	Size Code	HL	L	Weight (lb.)
1/2	005	15/16	1 11/16	.03
3/4	007	1	2	.05
1	010	1 1/4	2 3/8	.09
1 1/4	012	1 9/32	2 17/32	.13
1 1/2	015	1 11/32	2 21/32	.16
2	020	1 7/16	2 13/16	.24
2 1/2	025	1 15/16	3 15/16	.52
3	030	2	4	.68
4	040	2 1/8	4 1/8	.96

PLUGS

FIG. 449
SPG

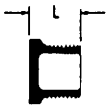


FIG. 450
Thread

Size	Size Code	R		L		Weight (lb.)	
		Slip	Thread	Slip	Thread	449	450
3/8	003	N.A.	N.A.	N.A.	25/32	N.A.	.01
1/2	005	3/16	N.A.	15/16	15/16	.01	.01
3/4	007	7/32	N.A.	1 7/32	1	.02	.02
1	010	1/4	N.A.	1 3/8	1 1/4	.04	.04
1 1/4	012	9/32	N.A.	1 17/32	1 9/32	.07	.07
1 1/2	015	5/16	N.A.	1 5/8	1 11/32	.10	.10
2	020	3/8	N.A.	1 3/4	1 7/16	.16	.16
2 1/2	025	N.A.	N.A.	N.A.	1 15/16	N.A.	.28

PVC Schedule 40 Gray Pressure Fittings (continued)

TEES

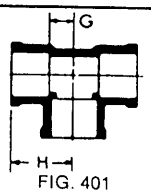


FIG. 401
S x S x S

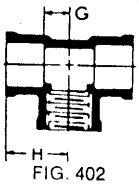


FIG. 402
S x S x T

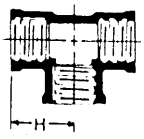


FIG. 405
T x T x T

Size	Size Code	H			G		Weight (lb.)		
		401	402	405	401	402	401	402	405
3/8	003	1 1/8	N.A.	N.A.	3/8	N.A.	.05	N.A.	N.A.
1/2	005	1 1/4	1 1/16	N.A.	1/2	1/2	.07	.07	N.A.
3/4	007	1 9/16	1 9/64	N.A.	9/16	9/16	.10	.13	N.A.
1	010	1 11/16	1 25/64	1 27/32	23/32	23/32	.21	.23	.25
1 1/4	012	7/8	2 5/32	N.A.	29/32	29/32	.29	.33	N.A.
1 1/2	015	1	2 11/32	N.A.	1 1/32	1 1/32	.39	.43	N.A.
2	020	2 5/8	2 5/8	N.A.	1 1/4	1 1/4	.55	.60	N.A.
2 1/2	025	3 9/16	N.A.	N.A.	1 9/16	N.A.	1.27	N.A.	N.A.
3	030	3 7/8	N.A.	N.A.	1 7/8	N.A.	1.77	N.A.	N.A.
4	040	4 3/8	N.A.	N.A.	2 3/8	N.A.	2.59	N.A.	N.A.
6	060	7	N.A.	N.A.	3 1/2	N.A.	6.97	N.A.	N.A.

90° ELLS

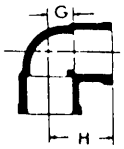


FIG. 406
S x S

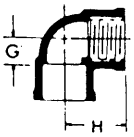


FIG. 407
S x T

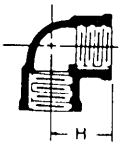


FIG. 408
T x T

Size	Size Code	H			G		Weight (lb.)		
		406	407	408	406	407	406	407	408
1/2	005	1 1/4	1 1/16	1 1/16	1/2	1/2	.05	.06	.05
3/4	007	1 9/16	1 9/64	1 1/4	9/16	9/16	.07	.09	.06
1	010	1 27/32	1 25/64	1 9/16	11/16	23/32	.12	.14	.10
1 1/4	012	2 5/32	2 5/32	—	7/8	29/32	.22	.24	—
1 1/2	015	2 11/32	2 11/32	—	1	1 1/32	.29	.31	—
2	020	2 5/8	2 5/8	—	1 1/4	1 1/4	.42	.47	—
2 1/2	025	3 9/16	—	—	1 9/16	—	.89	—	—
3	030	3 7/8	—	—	1 7/8	—	1.24	—	—
4	040	4 3/8	—	—	2 3/8	—	1.89	—	—
5	050	5 15/16	—	—	2 15/16	—	3.42	—	—
6	060	7	—	—	3 1/2	—	5.18	—	—

90° STREET ELLS

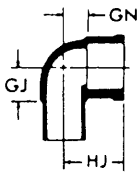


FIG. 409
SPG x S

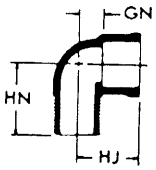


FIG. 410
MT x S

FIG. 412
MT x T

Size	Size Code	HJ			GN		HN		GJ	Weight (lb.)		
		409	410	412	409	410	410	412	409	409	410	412
3/8	003	N.A.	N.A.	1 1/8	N.A.	N.A.	N.A.	1 5/32	N.A.	N.A.	N.A.	.04
1/2	005	1 1/4	1 1/4	1 1/4	1/2	1/2	1 3/8	1 3/8	5/8	.05	.05	.05
3/4	007	1 9/16	N.A.	1 9/16	9/16	N.A.	N.A.	1 17/32	3/4	.08	N.A.	.09
1	010	1 27/32	1 27/32	1 27/32	23/32	23/32	1 7/8	1 7/8	7/8	.14	.14	.16
1 1/4	012	N.A.	2 5/32	2 5/32	N.A.	1 29/32	2 3/32	2 3/32	N.A.	N.A.	.20	.22
1 1/2	015	2 11/32	2 11/32	2 11/32	1 1/32	1 1/32	2 1/4	2 1/4	1 7/32	.28	.28	.30
2	020	2 5/8	2 5/8	N.A.	1 1/4	1 1/4	2 1/2	N.A.	1 7/16	.39	.41	N.A.

FEMALE ADAPTERS

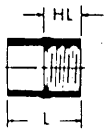


FIG. 435
S x T

Size	Size Code	HL	L	Weight (lb.)
1/2	005	27/32	1 19/32	.04
3/4	007	7/8	1 7/8	.06
1	010	1 3/32	2 7/32	.10
1 1/4	012	1 3/32	2 11/32	.14
1 1/2	015	1 1/8	2 7/16	.18
2	020	1 5/32	2 17/32	.24
2 1/2	025	1 3/4	3 3/4	.57
3	030	1 13/16	3 13/16	.74
4	040	1 31/32	3 31/32	1.07
5	050	2 3/32	5 3/32	1.78
6	060	2 3/16	5 11/16	2.64

CAPS

FIG. 447
Slip

FIG. 448
Thread

Size	Size Code	W		HL	Weight (lb.)	
		Slip	Thread		447	448
3/8	003	N.A.	27/32	N.A.	N.A.	.01
1/2	005	1 5/64	1 5/64	21/64	.02	.03
3/4	007	1 3/8	1 5/32	3/8	.04	.04
1	010	1 35/64	1 13/32	27/64	.06	.07
1 1/4	012	1 3/4	1 1/2	1/2	.10	.10
1 1/2	015	1 59/64	1 39/64	39/64	.13	.13
2	020	2 3/64	1 47/64	43/64	.18	.19
2 1/2	025	2 55/64	2 37/64	55/64	.40	.41
3	030	2 31/32	2 39/64	31/32	.55	.56
4	040	3 3/16	2 59/64	1 3/16	.86	.88
5	050	4 25/64	3 15/64	1 25/64	1.56	1.35
6	060	5 11/64	3 19/32	1 43/64	2.24	1.96

MALE ADAPTERS

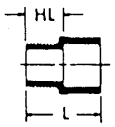
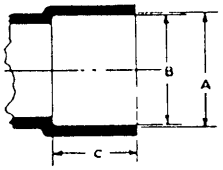


FIG. 436
T x S

Size	Size Code	HL	L	Weight (lb.)
3/8	003	25/32	1 17/32	.02
1/2	005	29/32	1 21/32	.03
3/4	007	31/32	1 31/32	.05
1	010	1 3/16	2 5/16	.07
1 1/4	012	1 7/32	2 15/32	.12
1 1/2	015	1 1/4	2 9/16	.15
2	020	1 9/32	2 21/32	.22
2 1/2	025	1 27/32	3 27/32	.46
3	030	1 29/32	3 29/32	.66
4	040	2 3/64	4 3/64	.97
5	050	2 7/32	5 7/32	1.70
6	060	2 3/8	5 7/8	3.28
REDUCING SIZES				
1/2 x 3/4	074	29/32	1 29/32	.05
3/4 x 1/2	101	15/16	1 11/16	.03
1 x 3/4	131	1 5/32	2 5/32	.05
1 1/4 x 1 1/2	169	1 7/32	2 17/32	.15
1 1/4 x 1	168	1 5/32	2 9/32	.09
1 1/2 x 1 1/4	212	1 1/4	2 1/2	.12

PVC — IPS SCHEDULE 40 SOCKET DIMENSIONS



Size	Pipe O.D.	Entrance (A)		Bottom (B)		Max. Out of Round	Socket Depth (C)
		Max.	Min.	Max.	Min.		
1/4	.540	.556	.548	.540	.532	.016	.500
3/8	.675	.691	.683	.675	.667	.016	.594
1/2	.840	.852	.844	.840	.832	.016	.688
3/4	1.050	1.062	1.054	1.050	1.042	.020	.719
1	1.315	1.330	1.320	1.315	1.305	.020	.875
1 1/4	1.660	1.675	1.665	1.660	1.650	.024	.938
1 1/2	1.900	1.918	1.906	1.900	1.888	.024	1.094
2	2.375	2.393	2.381	2.375	2.363	.024	1.156
2 1/2	2.875	2.896	2.882	2.875	2.861	.030	1.750
3	3.500	3.524	3.508	3.500	3.484	.030	1.875
4	4.500	4.527	4.509	4.500	4.482	.030	2.000
5	5.563	5.593	5.573	5.563	5.543	.060	3.000
6	6.625	6.658	6.636	6.625	6.603	.060	3.000

Complies with ASTM D-2466.
There is no specification for threaded fittings in Schedule 40.

TO SPECIFY OR PLACE AN ORDER
USE THE FIGURE NUMBER AND SIZE CODE
EXAMPLE: 401-020 = 2" TEE S x S x S

GLOSSARY

S = Slip Socket
T = Female Thread
SPG = Spigot End
MT = Male Thread

DRIP IRRIGATION

COURSE CONTENTS

I. INTRODUCTION
II. HYDRAULIC THEORY
III. DESIGN OF DISTRIBUTION SYSTEM
IV. IRRIGATION SCHEDULING
V. OPERATION & MAINTENANCE

I. INTRODUCTION:

A. Basic Concepts:

Drip, or trickle, or micro-irrigation are terms used to describe a method of irrigation which is characterized by the following features:

* water is delivered at a very low rate of discharge
* water is delivered over a very long period of time
* water is delivered at a point ideally suited for use by the crop
* water is delivered over the applied area with great uniformity

The water is usually applied via emitter tubing installed as "laterals" generally along contours of equal elevation. Spacing of the laterals are usually a function of the desired instantaneous application rate or to accommodate the crop being grown. A standard emitter tubing incorporates a 0.61 gal/hr. emitter spaced at 24"/hr., if spaced 3' apart the laterals are spaced 2' apart the application rate is 0.24"/hr., if spaced 3' apart 0.167"/hr., or if installed 6' apart 0.09"/hr. By keeping the instantaneous application rate low the risk of runoff is minimized, and the total flow rate to each zone is minimized. The benefit of this will be the ability to service large areas of application with a smaller supply line size, smaller valving, smaller horsepower pumps, downsizing of electrical components and power requirements.

A drip irrigation system delivers water to the area under application by way of a network of supply mains, manifold line, and the emitter laterals. The laterals contain emission devices the deliver a constant rate of flow with pin-point accuracy to the root zone of the cover crop. In this manner, the cover crop is never damaged by impacts of trajectory spray

application, or mis-application to parts of the plant where no real benefit is derived. Because plants take in moisture and nutrients only from the root zone, the drip irrigation method of application is well suited to replenishing the essential elements at a slow and constant rate.

B. Benefits of Drip Irrigation (Taken from Hardee Irrigation Design Manual):

-Low Application Rate: A truly distinctive feature of micro-irrigation is the very low application rate used. Many micro-irrigation systems are designed to supply an individual plant's water requirement by a daily application of 12 hours duration or longer. When compared to a high-volume sprinkler which may apply a week's water requirement in one hour, this is a low application rate indeed. A low application rate often means a less expensive irrigation system, and more efficient utilization of pumps, filters, and pipelines, because these system components may be sized for lower flow rates and used for longer periods of time. In short, a lower water application rate often means lower capital costs, lower operating costs, and lower replacement costs.

-Uniformity of Water Application: Another highly desirable feature of micro-irrigation is the excellent uniformity of water application which is achieved. Uniform water application means that all plants receive the same amount of water. In some systems having poor uniformity, it is necessary to under-irrigate in order to ensure that those areas receiving too much effluent applied do not runoff, leaving some areas under utilized. Therefore, good uniformity, results in the maximum utilization of power, applied effluent, and performance of the growth of the crop.

-Water Placement: A major advantage of micro-irrigation is the fact that water and nutrients are virtually "hand-fed" directly to the roots of the crop. This means that roads and the rows between plants or other designated areas can remain dry, and has major advantages in harvesting and other in-field operations which may be hampered by wet ground. It also means that the damage and soil losses caused by erosion can be reduced or eliminated.

-Difficult Terrain: Irregular or rolling terrain poses far fewer problems for a micro-irrigation system than for conventional methods. In some areas micro-irrigation systems are installed on very steep slopes which would be difficult or impossible to irrigate by other methods.

-Problem Soils: Micro-irrigation systems are often ideally suited to "problem" soils. The low application rate that micro-irrigation systems provide is ideal for tight clay soils with low infiltration, as the water can be applied slowly enough for the soil to absorb

it without surface runoff occurring. On the other hand, very sandy soils frequently cannot store large amounts of water, and under conventional irrigation systems much of the applied water is lost to deep percolation. Micro-irrigation is ideal for these soils because of its ability to frequently provide small amounts of water to the cover crop.

C. Components of the Drip Irrigation System:

-Float Control Switches: Indicate water level in the storage reservoir, signals the system micro-processor or operator of the status of the level condition. "Low Water" activation will de-activate the application operation. "High Water" activation will energize an audible and visual alarm, and perhaps telemetry communication equipment.

-Microprocessor: Controls the system operations, functions, flow measurements, data logging, alarm activation, filter backwashing, field flushing and status indicators. Receives input from soil moisture probes, temperature probes, and float switches, and makes "go", or "no-go" decisions about system operation. Sequences the alternation of irrigation zones, their operation dose volumes, and field flushing schedules.

-Filters: Usually disk filters, providing screening out of particulate matter to a 115 micron level. The filter should be capable of automatically backwashing itself and returning to normal operation without operator participation. Filers should backwash either manually, or automatically upon reaching a pre-set pressure differential.

-Meter: Sends flow measured pulses to the processor which will indicate when pre-set dose volumes have been delivered. Provides irrigation flow rates.

-Field Control Valves: Normally closed until the micro-processor sends a 24 volt output to the selected valve causing that valve to open and allow zone to operate.

-Field Flush Valves: Normally closed except during selected times of zone flushing operations. Can be manually or automatically actuated.

-Motors and Pumps: Used for generating the flow rates and pressures required to supply the irrigation and flushing needs of the system.

-Emitter Tubing: The effluent application component that incorporates either pressure compensating or turbulent flow (non pressure-compensating) emitters. The discharge rate from the emitter tubing is at a very low and constant rate. The spacing of the emitter lines are determined by the crop being grown, topography, or soils. The tubing is usually 1/2" diameter poly-ethylene tubing with U.V. inhibitors added. It is usually laid directly on the ground surface and covered with mulch, or can be installed sub-surfacely.

II. HYDRAULIC THEORY

A. Characteristic of Emission Devices:

For any application or distribution system its components should possess the following qualities:

1. Inexpensive
2. Ease and Simplicity of Installation
3. Resistance to Clogging
4. Uniform Discharge (Emission) Rate
5. Consistent Performance Over Time & Long Life
6. Ease of Repair or Replacement

B. Types of Emission Devices:

Several types of emission devices are available for drip irrigation systems. The basic two types are: pressure compensating, and; turbulent flow emitters. The two types are available either in the form of pre-fabricated into the dripper tubing at the time of manufacture, or installed at the site for customized applications. The difference between the two types are that the pressure compensating emitters will provide uniform and unchanging emission rates over a wide range of system pressures, while the turbulent flow emitters will produce fluctuating discharges over a given pressure range. For most wastewater applications, the pressure compensating emitters present the most practical choice in emitter types, providing uniform discharge rates over the application area regardless of elevation changes or varying system working pressures.

C. Lateral and Zone Flushing

Because, in the general case, the irrigating flows into each lateral is low (normally 0.5 to 2.0 gal/min.) the velocity of the wastewater approaching the distal ends of each lateral becomes very slow. Consequently, they become subject to sedimentation and slime formation at low flow velocities. Proper system design provides for sufficient flow to be developed by the pumps and the locating of flush control valves (automatic or manual) to facilitate lateral flushing operations by whole zones, and capable of achieving a minimum of 2.0 feet per second of flow at the distal ends of each lateral. For pressure compensating emitters with a constant irrigating loss the calculations for the extra required flow for flushing is simplified, and more complicated for emitter systems whose discharge rates vary with changing system flows and system pressures.

III. DESIGN OF DISTRIBUTION SYSTEMS

A. Irrigation Rates:

The flow rate to each zone is usually governed by the number and discharge rates of emitters operating in the zone under application. If, for example, a 60,000 sq. ft. zone having laterals on 3 ft. spacings utilizing 0.61 gal/hr. pressure compensating emitters (24" spacing along tubing), the irrigating flow would be estimated as follows:

Total tubing length: 60,000 sq.ft./3' o.c. = 20,000 1.f.
Total number of emitters: 20,000 1.f./2' o.c. = 10,000 emitters
Irrigation Rate: 10,000 emitters x 0.61 gph = 6,100 gal/hr. or 101 g.p.m.

B. Instantaneous Application Rate:

The instantaneous application rate being delivered by the system is usually expressed in terms of inches of water per hour. A common amount might be 0.2 "/hr for Piedmont clays, less for tighter clays, greater for sand or sandy loams. The value is used by the designer is a limit not to be exceeded or surface runoff will occur. Most manufacturers of irrigation application equipment specify this value for certain delivery flows applied to certain coverage areas. With drip irrigation systems, the discharge rate is relatively small but constant, so by varying either the emitter spacing or the lateral spacing, an ideal instantaneous application rate can be achieved. For example, laterals on 2' spacing utilizing 0.61 gph p-c emitters on 24" spacings, will have an application rate of 0.24 "/hr. A lesser application rate can be achieved by increasing the distance between laterals, or between emitters, or a combination of both.

C. Areas Under Application:

Unlike surface sprinkler systems, which are restricted to circular patterns, drip tubing systems can be fitted to most any application are configuration. Because wastewater is being applied at the ground surface and not in a wind driven aerosol, the system setback buffers from streams and property lines are normally reduced. These features enable the facility to maximize all practical areas available.

IV. IRRIGATION SCHEDULING

A. Water Balance Method:

As with other types of surface irrigation, the water balance method is often employed to determine the time and duration of the proper irrigation event. The details of the water balance method or explanation of its derivation is not covered here, but elsewhere in the seminar session. The more advanced drip irrigation systems can be programmed to automatically deliver operator-determined volumes to pre-selected zones.

B. Soil Moisture or Temperature Probes:

Many automated drip irrigation systems that are operated by a CPU, or data processor, can incorporate soil moisture or temperature probes that will prevent or interrupt automatic irrigation operation if the soil becomes too wet or the environment too cold to operate. The operating limits of the probes can be selected by the system operator for its "go", or "no-go" operating decision.

C. Zone Rotation:

If soil moisture or temperature problems are used in the automated operation of the irrigation equipment, a preset routine can be established that loads a zone with its desired application volume and then return to it after a pre-set drying time (i.e. 6 days). The operation would be suspended or deactivated by the soil or temperature probes, and resume upon the probes signaling a "go" condition.

V. OPERATION AND MAINTENANCE

A. System Flushing:

One of the most important maintenance functions is the periodic flushing of the supply line and laterals. Regardless of the type and degree of pretreatment, the water will contain sufficient organics, solids, and other impurities that will tend to grow slimes on the tubing walls or deposit within the supply lines. A CPU controller incorporated with electronic solenoid field valves can automate the frequency and execution of this function. If flushing of the entire zone to a central surface discharge point is not permitted, or the installation of a return flush main back to the treatment facility is too expensive, consideration can be given for each lateral distal end have a simple automatic flush valve (+/-$7) that will flush the lateral at the beginning of each irrigation cycle (12 second

duration) and stay sealed until system pressure is relieved (<7 psi). Proper lateral flushing velocity should exceed 2.0 feet per second (but less than 5 fps) and occur at least every 30 days.

B. Meter Readings:

Normally, a flow meter is incorporated as an essential element of every irrigation system. This provides several vital pieces of system operation and performance. The flow meter accumulated the total flow out of the system. These amounts are recorded periodically to determine the wastewater applied over certain periods (per day, per month, per year). The flow meter should also feature a sweep hand so that the flow rate delivered to any zone, or flush rate can be determined by the number of gallons pumped per minute. The irrigation flow rates to each zone should be carefully measured every 6 months and recorded in the System Operations log. Any irrigation flow rates that show a decreasing discharge trend might indicate some emitter clogging taking place. Any zones so identified should be targeted for closer examination and chemical treatment if required.

C. Filtration Equipment:

During routine system operation the filtration equipment performs automatic backwashing events to keep them in optimum working condition. As needed, usually twice a year the filter media elements should be inspected for deeply impacted filtered detritus not being removed by normal backwashing operation. The filter disk elements should be removed and soaked over night in a solution of muriatic acid or intense cleaning with high-pressure water spray wand. Any filter disk elements that are cracked or showing excessive abrasive wear should be replaced and noted in the operation and maintenance log.

D. Suction Intake:

At least once a year the suction intake and screen/strainer should be examined for accumulated trash or debris that might be restricting the supply of water to the pumps. In case of the necessity of examining the intake assembly during periods of high water storage stages, the suction supply line should be capable of dis-assembly from a point above the high water level. Generally, problems associated with pumps occur on the suction side of the pump.

E. Cover Crop Management

Ideally, drip irrigation systems are located in forested area that require little or no mowing operations because grasses and weeds are shaded out. When the laterals are located on the ground surface in grass meadow-like applications they are ideally covered and protected by a mulch mound along the length of tubing. Spacing between laterals should accommodate the width of mowing equipment. When the installation of mulch mounds are not feasible, temporary tubing removal is possible, or raising the height of the mowing deck to avoid cutting the tubing is also feasible. The field should be clearly marked with tall stakes and brightly colored identifiers to alert the mower operator of areas of caution or sensitive areas of concern.