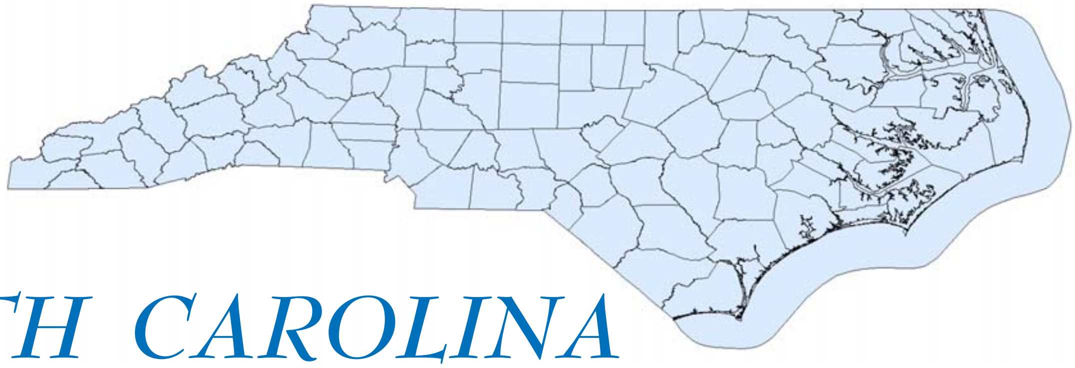


NORTH CAROLINA IRRIGATION GUIDE

April, 2010

United States Department of Agriculture

NRCS Natural Resources Conservation Service

North Carolina

Acknowledgements

This North Carolina Irrigation Guide was originally prepared in 1976 by NRCS (authors undocumented). This version was prepared by Sherman Biggerstaff under the guidance of Thomas Cutts, State Conservation Engineer. Kim Kroeger provided interpretations of Mountain irrigation soil management groups. Sherman Biggerstaff provided interpretations of Piedmont/Coastal Plain irrigation soil management groups with reviews from John Gagnon. Terri Ruch provided document reviews. Special thanks to Dr. Ronald Snead who provided document reviews and his irrigation insightfulness.

Front Cover photograph: A North Carolina application of the University of Georgia UGA EASY (Evaporation-based Accumulator for Sprinkler-enhanced Yield) Pan Irrigation Scheduler can provide in-field monitoring of crop water needs in humid areas for a fraction of the management time and cost associated with other irrigation scheduling methods (Cooperative Extension Service/The University of Georgia College of Agricultural and Environmental Sciences, "UGA EASY Pan Irrigation Scheduler", D.L. Thomas, K.A. Harrison, J.E. Hook, and T.W. Whitley, Bulletin 1201, January, 2002). See page 48 (Irrigation Scheduling) for further information on this device. Photograph by Andy Smith.

North Carolina IRRIGATION GUIDE

Contents:

<u>Comments Welcome and Updates</u>: Contact the North Carolina Natural Resources Conservation Service (NRCS) at any one of the field offices located throughout the state, or the state office in Raleigh, with suggestions or comments in regards to this document. It may be updated periodically, and all comments and suggestions are welcome.

Chapter 1 (NEH 652.0106) North Carolina NRCS Irrigation Guide Supplement - Introduction

1a - General Information for North Carolina

The North Carolina supplement to the Natural Resources Conservation Service (NRCS) National Engineering Handbook (NEH) Part 652, Irrigation Guide, has been adapted from the original 1976 NRCS North Carolina Irrigation Guide. The material was developed to assist North Carolina NRCS field personnel and others working with North Carolina irrigators to provide general planning, design, and management guidance on various methods of irrigation commonly used in the State.

The NRCS in North Carolina has a long history of assisting the agriculture community with resource issues, which include the planning, design and operation of irrigation systems. North Carolina is a state with abundant resources that should be maintained and enhanced to ensure they will be available for future generations to come. This document will attempt to provide a holistic approach which considers all benefits as well as the associated impacts, while maximizing the utilization of resources without causing any degradation. “Leave it better than you found it”.

Conservation of water and nutrient resources is a prominent issue in the forefront of today’s irrigation designer. Conservation makes dollars and sense for the long-term operation and maintenance of an irrigation system. The irrigation system should allow for efficient application quantities and quality of water, with a minimum of waste, and have a good cost/benefit ratio. An additional benefit from an irrigation system should be a more consistent crop output of higher quality. Land resources, soil fertility, and water quality should not be negatively impacted by a properly designed irrigation system.

North Carolina has six unique physiographic regions, as shown in Figure NC1-1. Each of the regions will have their own specific challenges to the design and operation of an irrigation system. Those regions are the Mountains (Blue Ridge), Piedmont, Sandhills, Inner Coastal Plains, Outer Coastal Plains and Coastal (Barrier) Islands. Each of these regions have resource issues that should be considered in the design of an irrigation system. Groundwater quality and quantity, surficial aquifers, nutrient sensitive watersheds, coastal sound areas, and impacts to fisheries or shellfish beds must all be considered, as well as any other resource issues not specifically discussed here.

State and local laws/guidelines must be addressed by any irrigation system designer, and are not generally covered in this document. Check with state and local government representatives to insure compliance with any associated regulations/requirements. This NRCS North Carolina supplement is not intended to stand completely on its own, and is intended to be used as a supplement to the NRCS NEH Part 652, Irrigation Guide. Some important points from the NRCS NEH Part 652, Irrigation Guide, will be reiterated in this supplement, but the irrigation designer should use both in an irrigation system design.

The North Carolina Irrigation Guide Supplement contains information and experience about soils, climate, water supplies, crops, cultural practices, and farming conditions in North Carolina. These factors can be used to improve the planning and design of an irrigation system located in this state. Adjoining states were consulted during this revision process to allow for as much consistency with these states as possible.

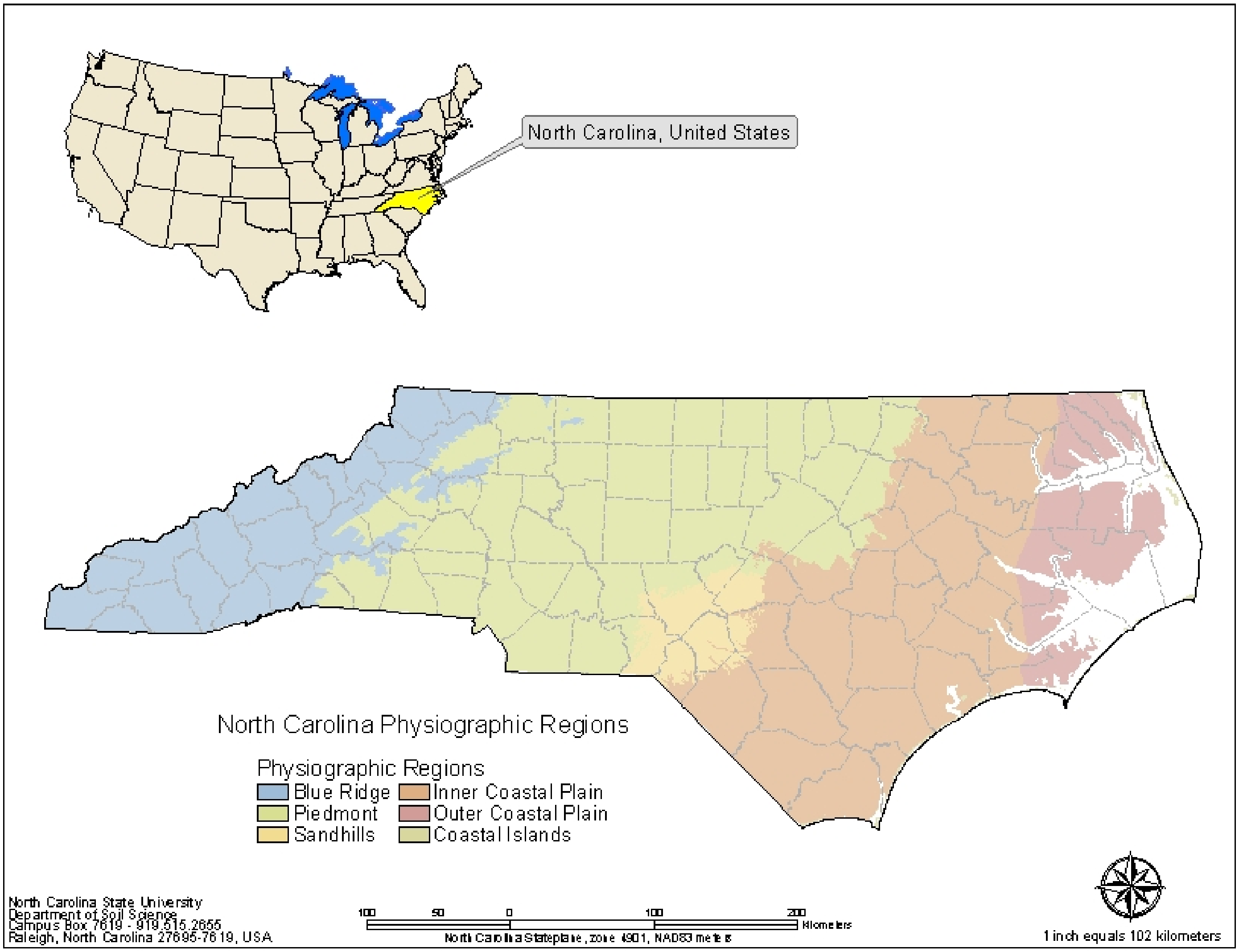


Figure NC1-1: Physiographic Regions of North Carolina.

In general, the climate of North Carolina is affected by latitude, variations in elevation, proximity to the ocean, and location with respect to principle path of storms. The ocean generally provides a moderating effect for the land adjacent to it, but the influences do not extend very far inland due to the predominantly west-to-east wind currents. North Carolina lies between 33.5 and 37 degrees north latitude, with an average annual temperature variation of about 2^{o} F from south to north. The state varies in elevation from sea level at the coast to 6684 feet at Mount Mitchell, the highest peak in the eastern United States. The average annual temperature decreases by about 3.5^{o} F for each 1000 feet increase in elevation, for a range of about 20 degrees from the coast to the higher mountains. (“Climate of North Carolina Research Stations”, Agricultural Experiment Station, North Carolina State Univ. at Raleigh, Bulletin #433, July 1967)

The locations of daily pan evaporation weather stations are shown in Figure NC1-2 for North Carolina and surrounding states. Expected first and last frost dates are shown in Figure NC1-3 for North Carolina. The frost-free period between the last spring frost and the first fall frost is considered the length of the growing season for the regions of North Carolina.

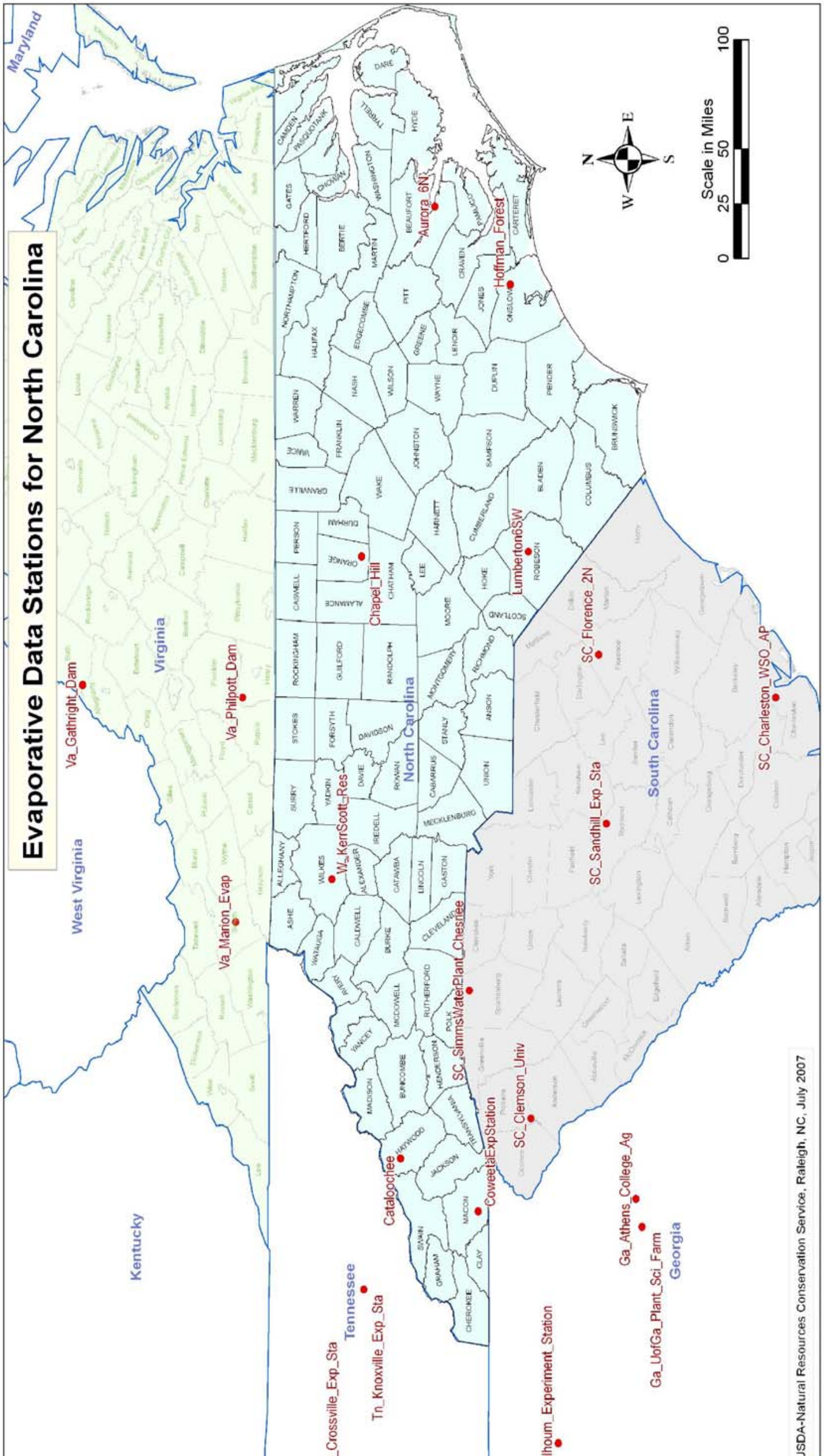
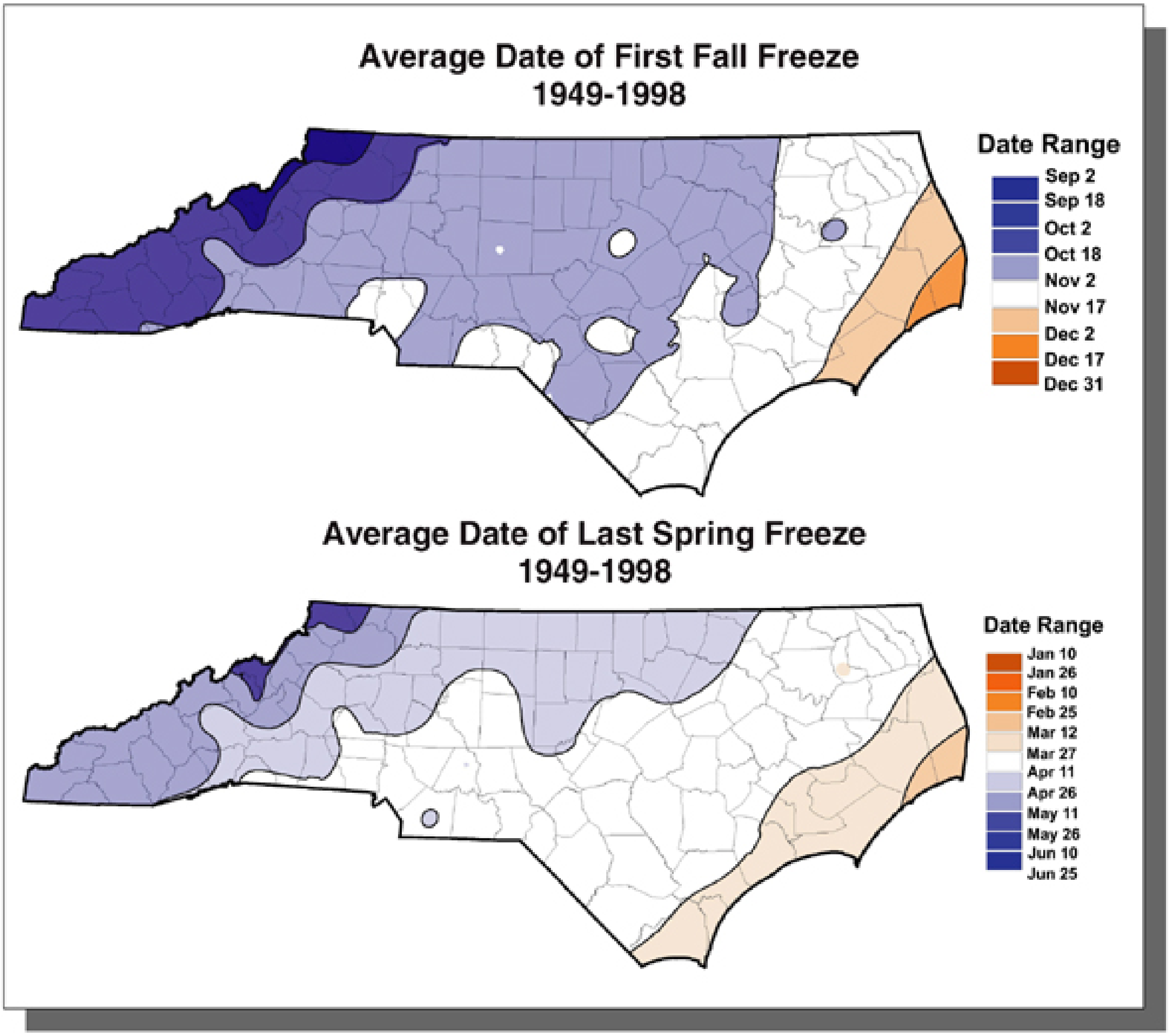


Figure NC1-2: Evaporation weather stations in and around North Carolina



Over the past 50 years, the dates of the first and last freeze have shifted. In the 1990s, the length of the warm season, measured as the difference between the last spring freeze and first fall freeze, was longer than in the previous 40 years. The SCO is developing a variety of products that focus on agricultural needs.

Figure NC1-3: Average spring and fall freeze dates ("North Carolina Climate. A Summary of Climate Normals and Averages at 18 Agricultural Research Stations", North Carolina Agricultural Research Service, Tech. Bull. No. 322, 2004). In the above figure, SCO refers to the State Climate Office which is located at the North Carolina State University campus.

1b - Rainfall and Drought in North Carolina

North Carolina has abundant yearly rainfall that is well distributed throughout the year. However, drought is not an uncommon occurrence during the North Carolina growing season. Extended periods of no rain (< 0.1”/day) that exceed 30 days have been noted in most North Carolina rain gage stations that have at least 50 years of data. It is recognized that estimates of drought conditions rely on not only rainfall (or lack thereof), but other factors such as temperature, solar radiation, wind, crop type, rooting depth, drainage, and soil moisture storage capacity that is available to the crop.

An agricultural drought condition is usually defined as a period when the moisture needs of the crop are not met by the available soil moisture and is often manifest by reduced crop growth and/or wilting. One study estimated that 1 in 5 years will have from 55 to more than 80 days that meet drought conditions within North Carolina (“Agricultural Drought in North Carolina”, North Carolina Agricultural Experiment Station, Tech. Bul. No. 122, June 1956).

The grower will probably be aware of how often and to what extent his crop production has been affected by drought conditions. An estimate of direct monetary losses to drought conditions can probably be estimated from this data if there is sufficient detail to determine drought years. Crop quality and consistency are generally improved by an irrigation system and therefore must also be considered a monetary benefit. Lack of rain and/or drought

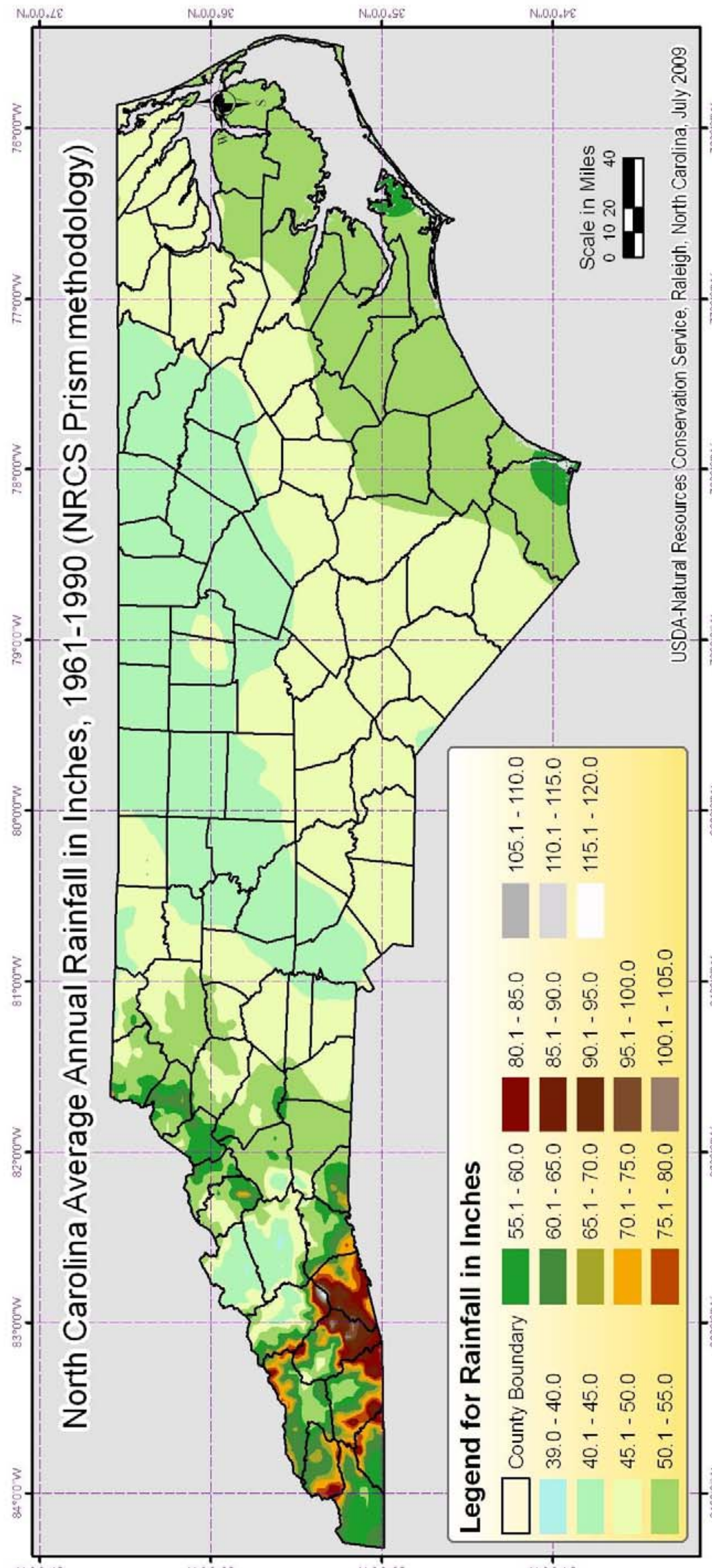


Figure NC1-4: Average Annual Rainfall

in North Carolina during critical crop growing stages is often one of the driving factors in the acquisition of irrigation systems for a farmer/grower.

Following is a general description of North Carolina precipitation from the State Climate Office (web address: http://www.nc-climate.ncsu.edu/climate/ncclimate.html). Some of the rainfall amounts were updated with NRCS PRISM rainfall data which is shown in Figure NC1-4.

While there are no distinct wet and dry seasons in North Carolina, average rainfall does vary around the year. Summer precipitation is normally the greatest, and July is the wettest month. Summer rainfall is also the most variable, occurring mostly in connection with showers and thunderstorms. Daily showers are not uncommon, nor are periods of one to two weeks without rain. Autumn is the driest season, and November the driest month. Precipitation during winter and spring occurs mostly in connection with migratory low pressure storms, which appear with greater regularity and in a more even distribution than summer showers. In southwestern North Carolina, where moist southerly winds are forced upward in passing over the mountain barrier, the average annual precipitation can go as high as 119 inches. This region has the highest annual precipitation in the eastern United States. Less than 50 miles to the north, in the valley of the French Broad River, sheltered by mountain ranges on all sides, is the driest point south of Virginia and east of the Mississippi River. Here the average annual precipitation is only 39 inches. East of the Mountains, average annual rainfall ranges mostly between 40 and 57 inches.

Winter-type precipitation usually occurs with southerly through easterly winds, and is seldom associated with very cold weather. Snow and sleet occur on an average once or twice a year near the coast, and not much more often over the southeastern half of the State. Such occurrences are nearly always connected with northeasterly winds, generated when a high pressure system over the interior, or northeastern United States, causes a southward flow of cold dry air down the coastline, while offshore a low pressure system brings in warmer, moist air from the North Atlantic. Farther inland, over the Mountains and western Piedmont, frozen precipitation sometimes occurs in connection with low pressure storms, and in the extreme west with cold front passages from the northwest. Average winter snowfall over the State ranges from about (one) inch per year on the outer banks and along the lower coast to about 10 inches in the northern Piedmont and 16 inches in the southern Mountains. Some of the higher mountain peaks and upper slopes receive an average of nearly 50 inches a year.

1c - Irrigation in North Carolina

North Carolina is a diverse state for irrigation system types and crops to be irrigated. Rainfall, although abundant, often does not occur during critical stages of plant growth, and sometimes does not occur for extended periods that can exceed 30 to 60 days. Some crops are very susceptible to production losses or reduced quality related to drought. North Carolina is in a humid region where irrigation applications should be adjusted by some method of irrigation scheduling, for the prevailing rainfall conditions. Irrigation scheduling is the use of water management strategies to prevent over-application of water while minimizing yield loss due to drought stress. Irrigation scheduling computer programs are available both from NRCS and others.

North Carolina has about 343 thousand acres of agricultural land under irrigation according to the 1997 NRCS National Resource Inventory (NRI) data. Statewide, approximately 28 percent of tobacco, 10.5 percent of peanuts, 2 percent of cotton, and 11 percent of corn is irrigated (1994 memo from Dr. Robert Evans, NC State University-Department of Biological and

Agricultural Engineering). More than 87 percent of the agriculture related irrigation water comes from surface waters, such as streams, canals, and ponds (1997 NRCS NRI). However, a U.S. Geological Survey (USGS) study (Open-File Report 97-599, Walters, 1997) indicated that in 1995, 76 percent of irrigation water was derived from surface waters. This is probably not a change in the amount of surface water used for irrigation, but indicative of the amount of error in the estimates. The amount of irrigation acreage increased between 1982 and 1992 by about 70.8 thousand acres (about 21%), but only increased by 3 thousand acres (about 1%) between 1992 and 1997 (NRCS NRI).

Changes in commodity prices often drive the percent of a crop and the amount of land that is irrigated. Corn and soybeans are seeing potential increased production in North Carolina driven by a developing biofuels market and associated price increases. This may help to increase the percentage of corn (current preferred input for ethanol based biofuel production) that will be under irrigation in the future. Soybeans are the preferred crop for biodiesel fuels and could also see an increased future demand as this market develops. Many other North Carolina crops, such as sweet potatoes, also have the potential for use in the developing biofuels market.

1d - Water Supply for Irrigation in North Carolina

Water rights have not been a large issue in the past for North Carolina. However, it is still an issue that should be considered by the irrigation designer. Over-drafting of groundwater, salt water intrusion, interbasin transfer, and aquifer water quality degradation can also be issues that deserve consideration. The North Carolina Water Use Act of 1967 allows the Environmental Management Commission to designate an area as a Capacity Use Area (CUA) if it finds that the long-term sustainability of the water resource is threatened or that water use in an area requires coordination to protect the public interest. Within a designated CUA, all persons withdrawing more than 100,000 gallons of water per day (about 69 gpm, which many irrigation systems will exceed) may need to obtain a permit from the NC Department of Environment and Natural Resources (DENR) Division of Water Resources (DWR). In 1998, 15 counties in the central coastal plain region of North Carolina were declared a CUA due to significant dewatering of the Black Creek and Upper Cape Fear aquifers (Jennifer Adams and Ronald Cummings, North Georgia Water Planning and Policy Center, Water Policy Working Paper # 2004-002). Water use permits for irrigation withdrawal wells may be required in these areas. The irrigation system designer is advised to check with local and state officials for any local requirements or permits.

Concerns in North Carolina about withdrawals from subsurface aquifers are generally focused on the coastal plains region. The USGS has found that ground-water levels throughout the North Carolina coastal plains are declining (USGS Fact sheet FS-033-95), with an area near Lumberton declining more than 12 feet from 1988 to 1992. Many North Carolina communities rely on groundwater for public water supplies for large municipal systems. There are also many smaller community well-water systems serving small subdivisions, mobile home parks, schools, and churches. Irrigation systems often compete with these other uses when well water is used as the irrigation water supply.

Wells supply the drinking water needs of more than 50 percent of the North Carolina population and in some areas represents the only practical source of water for domestic use (Dan Bius, draft North Carolina Groundwater Implementation Plan- A Comprehensive Groundwater Decision Support System, 05/16/03). Some groundwater sources have naturally high levels of phosphorus that are considered pollutants to nutrient sensitive waters in North Carolina (Pixie A. Hamilton and Timothy L. Miller, “Managing the Water Above and Below”, Geotimes, May 2002). Saltwater intrusion may also be a concern when a well site is in near proximity to coastal waters. There are also indications that neighboring states (see proposed South Carolina Bill H 3486, Apr 2007) of North Carolina are looking at ways to control and monitor water use in this state. Interbasin water transfers have also been an issue in North Carolina and the surrounding states, and should be avoided if possible. Water usage requirements could change in the future as the population and competition for water resources increase.

The first requirement for irrigation is an adequate supply of good quality water during those periods when the need for irrigation is greatest. The number of acres that can be properly irrigated at such times is dependent on the available water supply. The water supply should be adequate to irrigate the intended area of crops during a prolonged dry period before serious crop damage occurs. “Irrigating less land better will generally yield more benefits than inadequate irrigation of a larger area.”

Wells, ponds, streamflow, and even cisterns may be found supplying water to irrigation systems in North Carolina. Streams can become unreliable sources during extreme drought conditions when the irrigation system most needs the water supply. Some systems use tailwater recovery, and many use a sophisticated management and control system. Losses are an inherent part of every irrigation system. Careful management, well designed systems, and methods of water recovery, can help reduce the water needs and cost of an irrigation system. Water control structures have been effectively used in flat coastal areas to maintain a higher water table in the effective rooting depth of the plants and thus reducing the irrigation demand.

Issues associated with artificially elevated groundwater levels can stem from either an increased rate of groundwater recharge (from surface irrigation water, for example), water table management where drainage release is controlled, or a disruption in groundwater discharge to surficial waters (recent construction for example). Irrigation impacts to groundwater are generally localized to the field, as in the case of water table management, and should not extend much beyond the intended area. Common effects of elevated groundwater levels include mineralized soils, increased runoff from rainfall, slowness of soil to dry out, new wet spots, basement flooding, and foundation saturation.

Recharge areas for aquifers may also be a concern in the future to the irrigator since there is the potential for significant deep percolation to an underlying aquifer. However, aquifer recharge areas are not well defined, and a properly designed/managed irrigation system should not present an increase in adverse impacts when compared to non-irrigated farmland. Deep soaking rainfalls occur in North Carolina and can translocate farming associated plant nutrients, whether irrigated or not, down below the rooting zone.

Chapter 2 (NEH 652.0204) North Carolina NRCS Irrigation Guide Supplement-Soils

North Carolina has six general regions as discussed in the Introduction (NEH 652.0106) section. They are the Mountains, Piedmont, Sandhills, Inner Coastal Plains, Outer Coastal Plains and Coastal (Barrier) Islands. Each region has its own irrigation resource challenges associated with the soil-crop systems that are indigenous. For example, the Sandhills region of North Carolina can be found to support a multitude of cactus not found in the other regions. Cactus would not be irrigated of course, but it does illustrate how different this region is, because of its hot almost desert-like climate and light colored sandy soils. North Carolina has a wide variety of soil types and these cannot be irrigated alike. An accurate, detailed soil survey of the area to be irrigated is necessary. On-site testing of soil properties may also be justified.

Instrumentation to measure soil moisture contents at multiple depths that represent the crop rooting zone is essential to any good irrigation management system. Moisture measurements should be taken at multiple locations in the irrigated area to accurately give an indication of the field moisture condition for irrigation scheduling. Field soil moisture should be managed to ensure most of the irrigated water is used by the crop and not lost from the rooting zone.

2a - Soil Surveys

Knowledge of soils is essential for the efficient use of water for crop production. Soil survey maps and data for most of the state are now available online through the NRCS Web Soil Survey (WSS), http://websoilsurvey.nrcs.usda.gov/app/. See Exhibit NC2-1 for instructions on how to use and access the NRCS WSS. The WSS is replacing the familiar, traditional paper copies of soil survey reports that were previously available at the NRCS County office. As new and updated soil surveys are completed, NRCS is distributing the results of these surveys by means of the WSS instead of published reports. The WSS allows NRCS to update the information more rapidly and ensures a single source for official data. Those without computer access can still acquire soil survey information from an NRCS field office (look under Government listing in local Phone Book) or local library via WSS.

Important physical and chemical characteristics of each kind of soil are recorded in soils handbooks or soil survey publications. This soils information is available for download through the NRCS Soil Data Mart, http://soildatamart.nrcs.usda.gov/, or online at the WSS. See Exhibit NC2-2 for instructions on how to access and use the NRCS Soil Data Mart. Some physical characteristics of these soils that are important to understanding soil-moisture plant relationships are discussed in this guide. They include available water capacity, permeability, intake rate, slope, wetness (drainage and depth to water table), and surface texture. Note that in the Soil Survey, most of these physical soil characteristic terms are estimated and have a wide range of values. In most cases the estimated Soil Survey physical soil characteristic data should be verified with actual on-site testing.

Exhibit NC2-1: Instructions on how to use and access the NRCS Web Soil Survey (WSS). Go to a computer that has web access and start an Internet Explorer application. Type in the following web address "http://websoilsurvey.nrcs.usda.gov" on the open line as illustrated (see red arrow). There are 3 basic steps; Define, View/Explore, and Checkout. You must first select the button "Start WSS" to begin the process. Follow the on-line instructions to define and view data and/or maps for your area of interest.

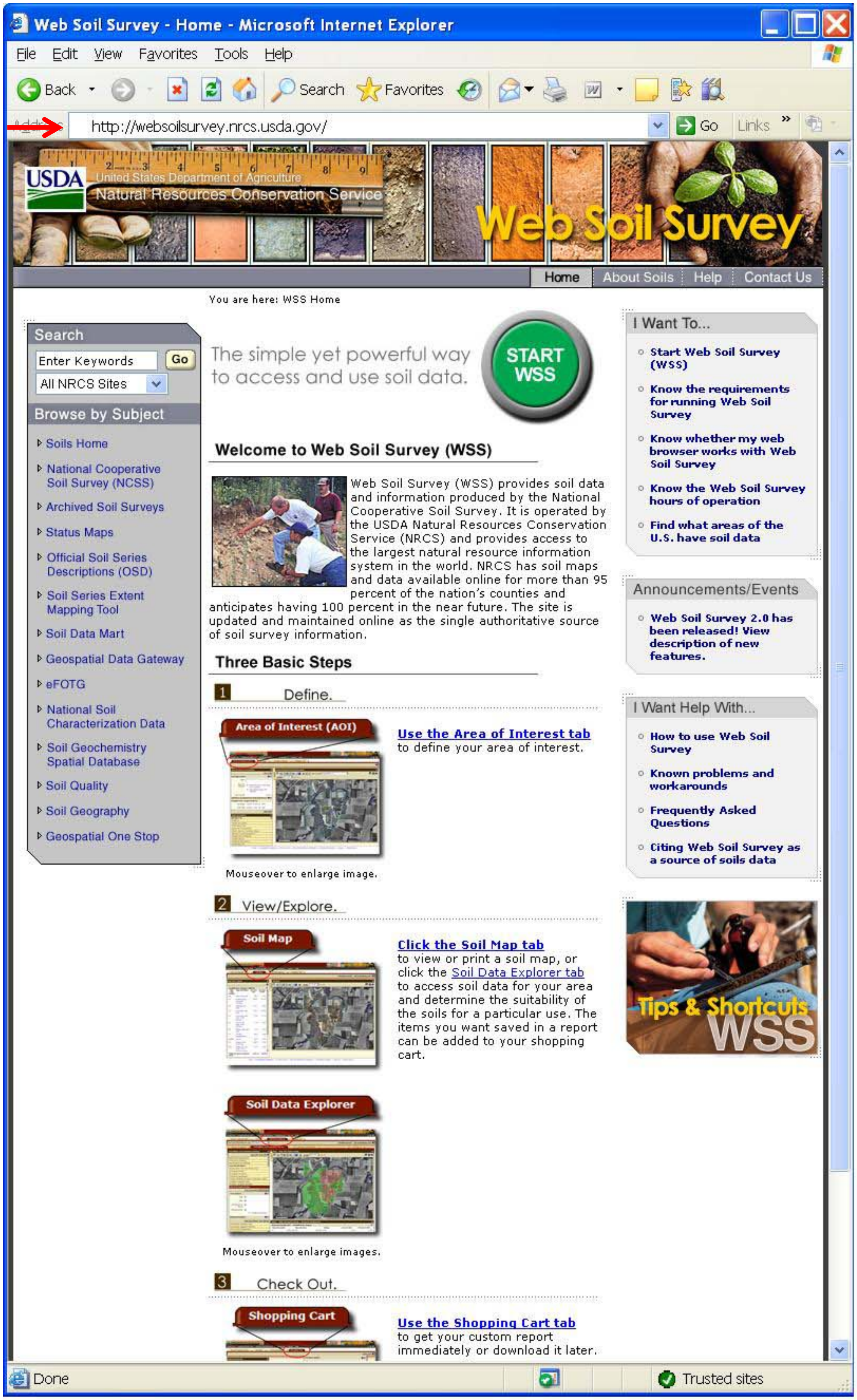
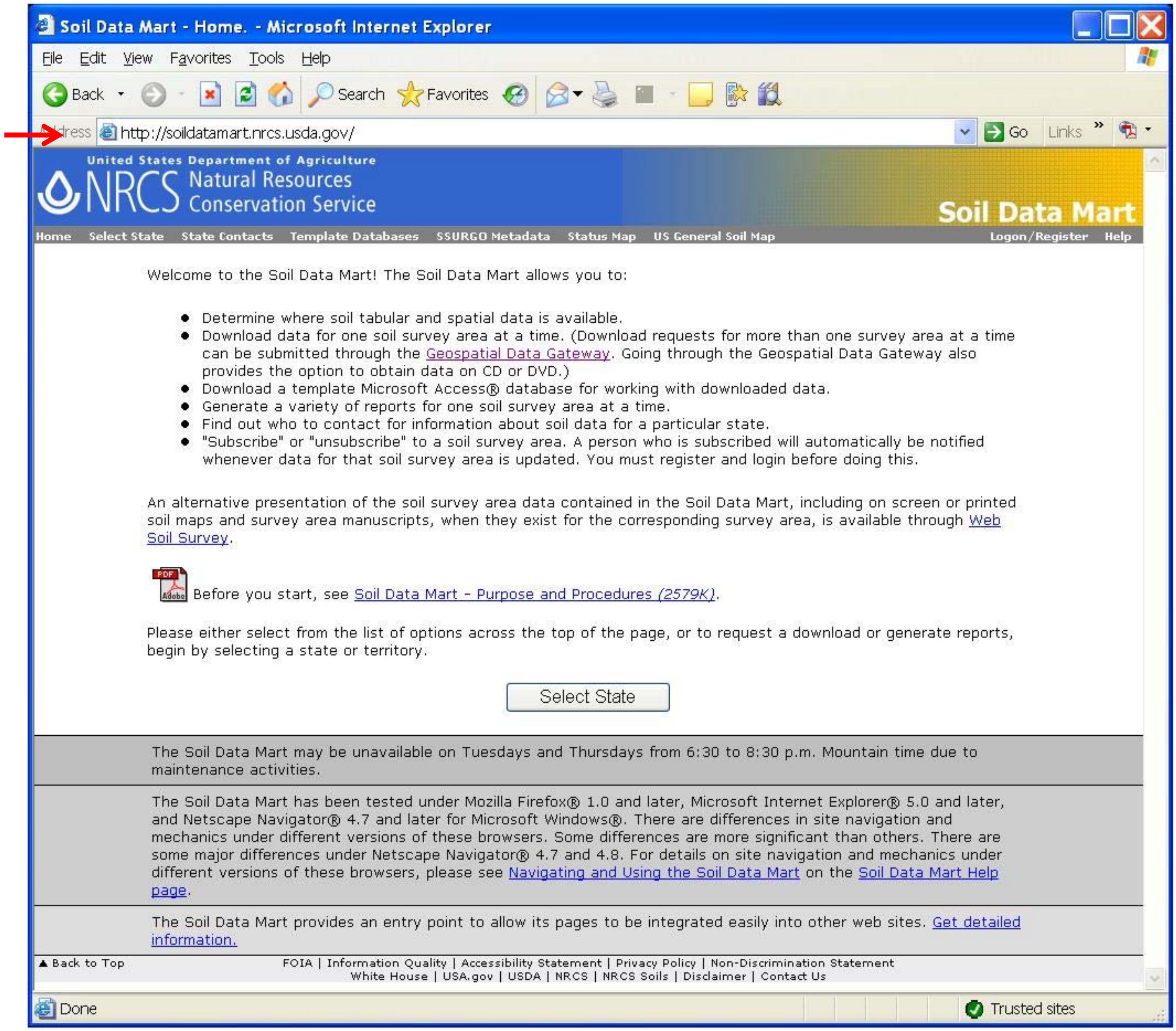


Exhibit NC2-2: Instructions on how to use and access the NRCS Soil Data Mart.

Go to a computer that has web access and start an Internet Explorer application. Type in the following web address “http://soildatamart.nrcs.usda.gov“ on the open line as illustrated below (see red arrow). You must first select the button “Select State” to begin the process. Follow the on-line instructions to download the data and/or maps for your area of interest.



2b - Available Water Capacity

The available water capacity (AWC) of a soil is a measure of its ability to make water available for plant growth within the rooting zone. The AWC of a soil is primarily related to the soil texture, organic matter content, and bulk density. A simple analogy would be that of a sponge, where it adsorbs water and then releases it when squeezed. For irrigation, the AWC is defined as the amount of water held between field capacity (FC) and the permanent wilting point (WP) as shown in Figure NC2-1. AWC is a simple and useful concept for irrigation, but it must be stressed that soils vary spatially and with depth over most fields, as do the AWC, FC and WP. It is recognized that plants can withdraw water from a soil that is above FC or is below WP. Also, FC and WP are hard to measure and define for a field and generally involves some lab work. For simplicity, AWC is commonly expressed as the water retained between 0.33 bar (FC) and 15 bar tension (WP) for fine to medium textured soils and between 0.10 bar and 15 bar for moderately coarse to very coarse textured soils. A formula for the computation of available water capacity is

Available water capacity in inches = $AWC = \frac{(d_b * T * P_w)}{(d_w * 100)}$

Where:

d_b = Bulk density = (Weight of ovendry soil sample in grams) / (Field volume of sample in cm^3)
T = Thickness of soil horizon under consideration in inches
P_w = Moisture content between field capacity and wilting point in percentage by weight
d_w = Density of water taken as 1 gm/cm^3

There are two methods to consider in the determination of AWC and when to irrigate. One method is based on the percentage of AWC within the root zone and the other is based on soil moisture tension. This difference in concept is shown in Figure NC2-2 which shows moisture release curves for three soils. In this figure moisture content is expressed as a percentage of AWC rather than a percentage by weight. FC is 100 percent of AWC and the WP is 0 percent of AWC (15 bars). Tension at any moisture level is different for the three soils. At the 50 percent level, for example, moisture tension for the clay is 4.3 bars; for the loam, 2 bars; and for the sand, 0.60 bars. Often, soil moisture gauges report their reading in tension (bars) and AWC must then be calculated from a moisture release curve.

Moisture is more readily available to plants at low soil moisture tension (near field capacity). Since tension values are so different in the three soils shown in Figure NC2-2, it is possible that crop response would be different if the soils were irrigated when available moisture depletes to the 50 percent level. However, for most soils, irrigation should be started when the soil moisture content is no lower than the 50 percent level.

The NRCS Soil Data Mart can be used to generate reports on physical soil properties for North Carolina soils, including AWC. For example, water holding capacity for 24 inches of rooting depth on an Norfolk (NrB) soil in Pitt County is:

0”-9”, 0.125 in./in. × 9 in. = 1.125 in.
9”-15”, 0.085 in./in. × 6 in. = 0.51 in.
15”-19”, 0.120 in./in. × 4 in. = 0.48 in.
19”-24”, 0.125 in./in. × 5 in. = 0.625 in.

Total AWC for 24 in. depth = 2.74 in.

The weighted AWC for the rooting depth is obtained by dividing the total AWC by the rooting depth. For the above example, the weighted AWC is:

2.74 in./24 in. = 0.114 in./in.

Note that the median Soil Survey AWC was used for each soil layer in the above example. For example, in the 0”-9” layer, the range for AWC was 0.10 in/in to 0.15 in/in. This is a difference of about 50 percent and illustrates the need for on-site testing to determine the actual soil characteristics.

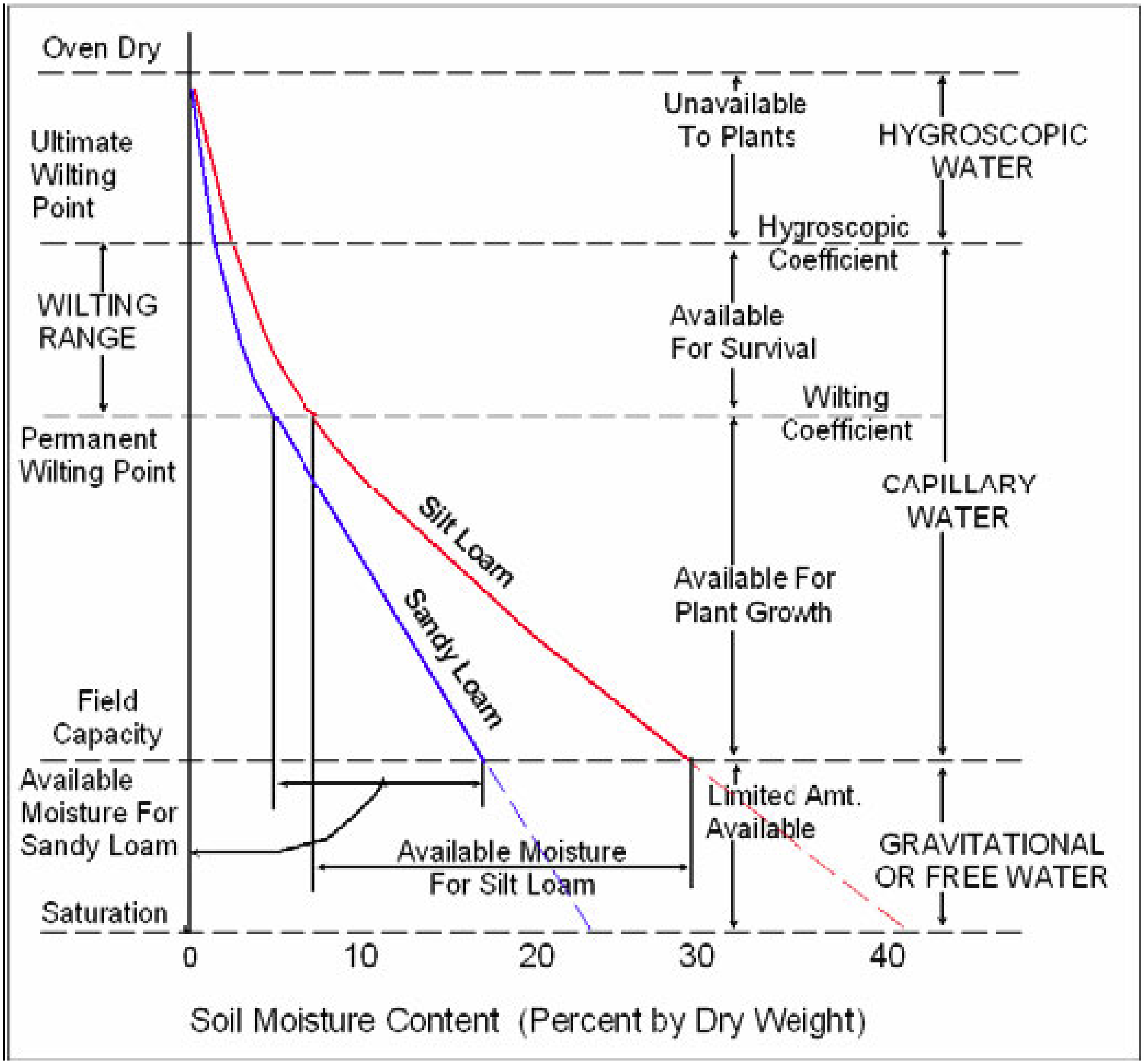


Figure NC2-1 Representative Soil moisture release curves for two soil groups

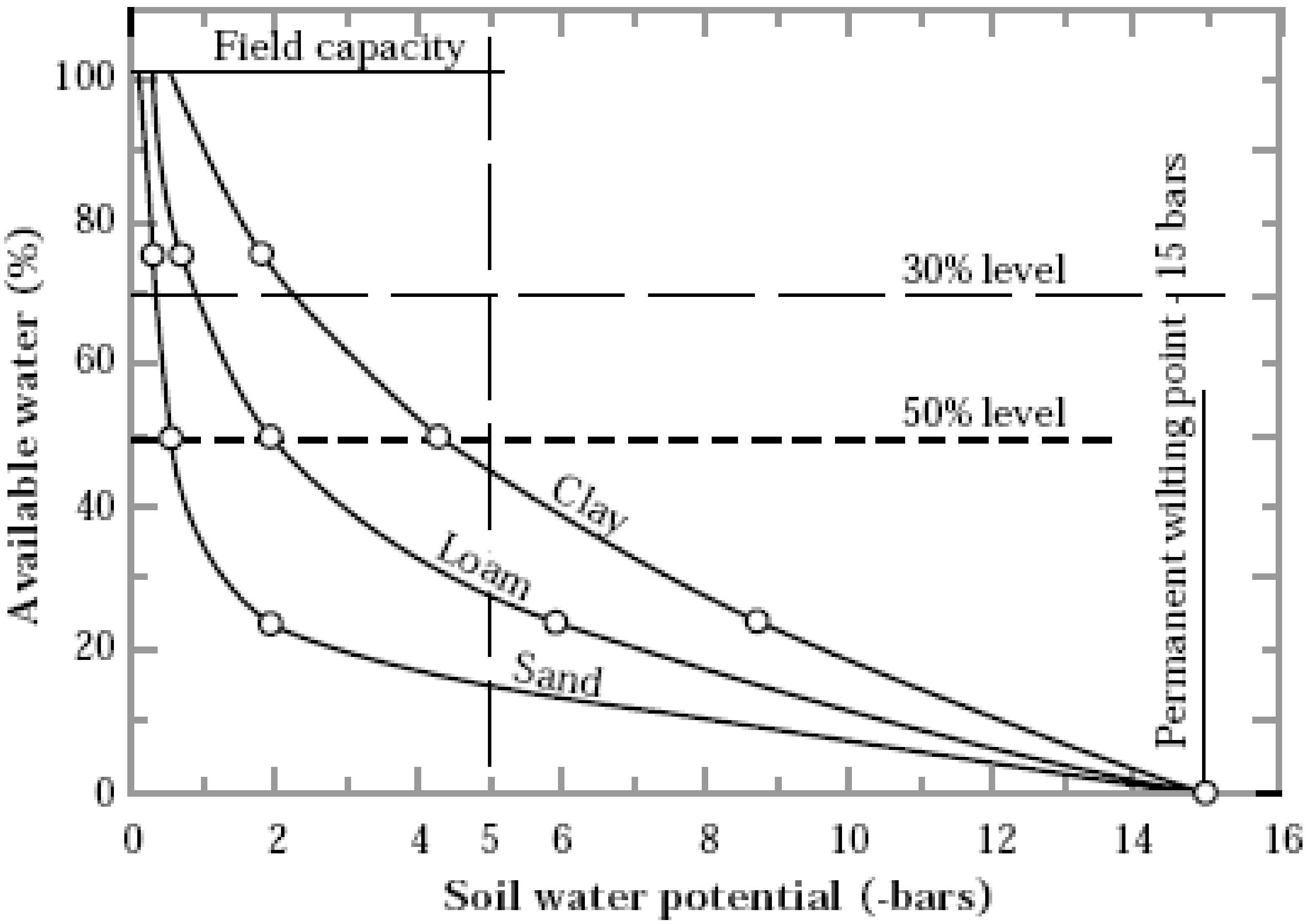


Figure NC2-2 Representative Soil moisture release curves for three soil groups

2c - Permeability

Soils can be viewed as a permeable medium in which air and water can move within and through the medium. Permeability is the quality of the soil that enables it to transmit gases and liquids within and through the medium. Generally, there is a concern for the rate at which water can move into or out of the soil. It should be noted that other liquids, such as oil or gasoline, may also move through a permeable medium such as soil. Often, saturated hydraulic conductivity will be confused with or used interchangeably with permeability. They are similar, but different terms. Permeability is a characteristic of a permeable medium that is based on mean grain diameter of the particle, grain shape, packing order, and other factors. Permeability affects the rate of movement of all gasses and liquids in that porous medium and is generally given as a length squared term, such as ft^2 or cm^2. (Warren Wessman Jr., John W. Knapp, Gary L. Lewis, and Terence E. Harbaugh, Introduction to Hydrology, 1977, pg 300)

Hydraulic conductivity is generally used in reference to the movement of water in a porous medium such as soil. It is the rate at which water will move through a soil under a driving head. Hydraulic conductivity is related to soil permeability, but also considers the properties of the liquid being transmitted through the soil or porous medium, and the state of saturation.

Generally, the saturated hydraulic conductivity, of water in a soil at a specific depth, is the property most often measured during the investigation of a specific field site or location. This term, saturated hydraulic conductivity, is a specific state within the soil where it is saturated and the hydraulic conductivity is determined for that state. Hydraulic conductivity is a term that applies to both saturated and unsaturated water movements within the soil. For example, there will be unsaturated movement of water from a subsurface water table upward into the drier soil above. This movement upward can supply plant available water to a plant root system above the water table and is therefore important in sub-irrigation systems.

The saturated hydraulic conductivity of a soil, shown in NRCS soils reports, is based on the most restrictive layer in the soil. The saturated hydraulic conductivity of soils may be separated into water movement rate classes as described by the terms listed in Table NC2-1.

Table NC2-1: Relative Water Movement Rate Class for Soils

Rate Term	**Saturated Hydraulic Conductivity (in/hr)**	**Saturated Hydraulic Conductivity (µm/sec)**
Very slow	<0.06	<0.42
Slow	0.06 - 0.2	0.42 – 1.41
Moderately slow	0.2 - 0.6	1.41 – 4.23
Moderate	0.6 - 2.0	4.23 – 14.1
Moderately rapid	2.0 - 6.0	14.1 – 42.3
Rapid	6.0 - 20.0	42.3 – 141.1
Very rapid	>20	>141.1

The saturated hydraulic conductivity, K_{sat} (µm/sec) for North Carolina soils are shown in the Physical Soil Properties report at the NRCS Soil Data Mart. These values can be converted to in./hr. if desired. The conversion equation would be 1 in/hr = 25400 µm/3600 sec = 7.0555 µm/sec.

2d - Intake Rate

Intake rate is a measure of soil's capacity to absorb irrigation water (or rainfall) from the surface, and move it into and through the soil profile. It is an expression of several factors, including infiltration and percolation. The term, “basic intake rate” is the rate at which water moves into soil after infiltration has decreased to a low and nearly constant value.

Infiltration is the downward flow of water from the surface through the soil. Water enters the soil through pores, cracks, worm and decayed root holes, and cavities introduced by tillage. Surface sealing and crusting can restrict or reduce infiltration. This surface sealing effect can be reduced by vegetative or mechanical (usually mulch) covers which protect the soil surface from raindrop impact energy.

Percolation is the movement of water through the soil profile. In order for irrigation water to be effective in replenishing the soils water supply, it must be able to move through the profile, or percolate, to a predetermined irrigation depth. The crop rooting zone generally sets the irrigation depth that is targeted for moisture replenishment. The percolation rate is governed by the permeability of the soil or its hydraulic conductivity. Both terms (see previous section on permeability) are used to indicate the ease with which water can move within a soil medium.

The amount of moisture already in the soil greatly influences the rate at which water enters the soil. The soil takes in and absorbs irrigation water or rainfall rapidly when water is first applied to the field surface and the soil is at less than saturation. As the irrigation application or rainfall continues, the rooting zone gradually becomes saturated and the intake rate decreases until it reaches a nearly constant value.

The intake of any soil is limited by any restriction to the flow of water into or through the soil profile. The soil layer with the lowest transmission rate, either at the surface or in the rooting zone below it, usually determines intake rate. The most important general factors that influence intake rate are the physical properties of the soil and, in sprinkler irrigation, the plant cover. But for any given soil, other factors may affect the intake rate, such as surface sealing, hard pans, frosting, very hot temperatures, salts, organic matter, dispersiveness, worm activity, and so on.

Since so many factors affect the water intake, it is not surprising that it varies so much among soils. Furthermore, the intake characteristics of a given field vary from place to place within the field, from irrigation to irrigation, and from season to season. The intake characteristics that must be considered in sprinkler irrigation design differ from those for other surface irrigation methods.

Actual measured intake rates are unavailable for North Carolina soils. Intake rates are estimates based on the characteristics of the top two feet of the soil. If the soil has a water table within two feet of the surface, the intake rate is assigned as if the soil is drained. Typically, for a well-drained soil with good cover and no clayey or restrictive subsoil, the intake rate is estimated at 2.0 in./hr (14 µm/sec). Note that this soil intake rate is not the same as the irrigation application rate, which is discussed in the following section. For other soil types, consult with a soil scientist to determine an intake rate value.

2e - Irrigation Water Application Rates

The Irrigation Water Application Rate (IAR) is the rate at which water is applied to a field by an irrigation system in inches per hour (in/hr) or micro meters per second (µm/sec). The IAR will be less than the soil intake rate and should not cause runoff to occur at any time during the irrigation cycle. Generally a dry soil will begin the irrigation cycle with a high surface infiltration rate and can easily adsorb irrigation water, but later when a soil is at or near field capacity, surface infiltration rates will decline and runoff may occur. The IAR is an average rate with areas that are above it and a portion of the field below this average. Slope also increases the likelihood of runoff from a field for a given soil intake rate under irrigation.

The rate at which irrigation water can be applied to a field soil depends on many factors, including, but not limited to the following:

a. The time required for the soil to absorb the calculated depth of application without runoff for the given conditions of soil, slope, and cover. The depth of application divided by this required time is the maximum application rate. The depth of application varies with crop type and associated soil rooting zone with consideration given to the soil and any restrictions therein.

b. The minimum application rate that will result in reasonably uniform distribution and satisfactory efficiency under prevalent climatic conditions.

c. The desirable time for applying the required depth of water considering efficient use of available labor and the other operations on the farm.

d. The application rate adjusted to the number of operating sprinklers using the most practical layout of lateral and main lines.

In general, the selected irrigation water application rate should fall somewhere between a minimum value of 0.2 in./hr (1.4 μm/sec) and a maximum of 1.0 in./hr (7 μm/sec). Irrigation application rates less than 0.2 in./hr (1.4 μm/sec) may have distribution uniformity issues. Irrigation application rates greater than 1.0 in./hr (7 μm/sec) may have excessive runoff issues. Maximum irrigation water application rates are given for most North Carolina soil/crop combinations in Tables NC6-1 through NC6-4 and additional discussion can be found accompanying these tables in Chapter 6.

2f - Slope

Slope refers to the incline of the surface of the soil area. A simple, or single slope is defined by its gradient, shape, and length. Slopes may also be defined as single or complex depending on the nature of the area. Soil slope is expressed in terms of a percentage. It is the difference in elevation in feet for each 100-feet horizontal. A soil inclined at 45 degrees has a slope of 100 percent since the difference in elevation of two points 100 feet apart horizontally is 100 feet.

Soil slope and intake rate are important factors in determining runoff rates. However, runoff should not be allowed during an irrigation event. Adjustments should be made to the irrigation equipment or management strategy so that there is little to no runoff. Extreme slopes should not be irrigated since there is such a high potential for substantial runoff losses. If a tractor cannot safely maneuver on a slope, it probably should not be irrigated. Any slope greater than 3% (3 feet of drop in 100 feet of run) may require special measures to address the increased runoff potential, sprinkler pressure drops, and any other negative effects. If irrigation is necessary on steeper slopes (>5%), great care should be exercised by the designer to control runoff and other negative impacts to the irrigation system.

2g - Wetness

Wetness problems are generally found to cause equipment passage issues for a farmer and/or poor crop growth. Wetness is expressed as a function of soil drainage and depth to water table. Internal soil drainage is a natural condition of the soil that refers to the frequency and duration of periods when the soil is free of saturation. For example, in well drained soils the water is removed readily but not rapidly; in poorly drained soils the root zone is waterlogged for long periods unless artificially drained. In excessively drained soils, water is removed so completely that most plants suffer from lack of water.

Table NC2-2. Drainage Classes of Soils

Drainage Class	Abbreviation
Very poorly drained	VP
Poorly drained	P
Somewhat poorly drained	SP
Moderately well drained	MW
Well drained	W
Somewhat excessively drained	SE
Excessively drained	E

Except for very young soils, the natural soil drainage conditions are reflected in soil morphology. The drainage class shown for the various soils is the drainage that existed during the development of the soil as opposed to altered drainage as the result of artificial drainage. Table NC2-2 lists classes (with their abbreviations) to define natural soil drainage in broad terms.

High water table is defined as the top of the zone of saturation at the highest average depth elevation during the wettest season. It persists in the soil for more than a few days. The depth to water table is given for each soil in the Water Features report in the NRCS Soil Data Mart. Refer to a soil scientist or engineer, who can usually determine the seasonal high water table for a given farm field or location.

The presence of a saturated zone (water table) is a prime factor in determining soils adaptability for irrigation. If a saturated zone is at a shallow depth, a hazard always exists that heavy rains can raise the saturated zone to depths shallow enough to slow or inhibit plant growth. Thus, soils with wetness limitations are given different considerations than other similar soils that do not have a wetness limitation.

2h - Surface Texture, Drainage, and Restrictive Feature

Table NC2-3: Soil Texture Abbreviations

Soil Texture	Abbreviation
Sand	S
Coarse sand	COS
Fine sand	FS
Loamy coarse sand	LCOS
Loamy sand	LS
Loamy fine sand	LFS
Coarse sandy loam	COSL
Sandy loam	SL
Fine sandy loam	FSL
Very fine sandy loam	VFSL
Loam	L
Silt loam	SIL
Clay loam	CL
Sandy clay loam	SCL
Silty clay loam	SICL
Silty clay	SIC
Sandy clay	SC
Clay	C
Muck or peat	MK or PT
Additional Textural Modifiers	
Channery	CN
Gravelly	GR
Shaley	SH

Surface Texture

Surface texture is displayed in the Engineering Properties report in the NRCS Soil Data Mart, for all soil series. The abbreviations in Table NC2-3 are used to describe soil texture.

Drainage

Land to be irrigated should be well drained. If the land is not naturally well drained, adequate surface and subsurface drainage should be provided. Otherwise, a large rainfall event following an irrigation cycle may cause crop damage.

Restrictive Features

Certain soil features affect design, layout, construction, management or performance of an irrigation system. Those features important in design and management of most irrigation systems are wetness or ponding and the need for drainage, flooding, available water capacity, intake rate, permeability, susceptibility to wind or water erosion, and slope. Soil features that influence construction are large stones and depth to bedrock or cemented pan. The features that affect performance of the system are rooting depth, amount of salts or sodium, and soil acidity. These properties, limits, and restrictive features are shown in Table NC2-4. Particular soils with restrictive features are displayed in the Engineering Properties, Physical Properties, and Irrigation reports in the NRCS Soil Data Mart or the NRCS Web Soil Survey (both are discussed in a previous section on internet access to Soil Surveys).

Table NC2-4. Irrigation Restrictive Features		
Property	**Limits**	**Restrictive Factors**
Fraction >3 in. (wt. %)[1/]	>25	Large Stones
Depth to High Water Table (ft)	<3	Wetness Ponding
Available Water Capacity (in./in.)[1/]	<0.10	Droughty
USDA Texture (Surface Layer)	S, FS, VFS, LS, LFS, VFSL	Fast Intake
USDA Texture (Surface Layer)	SIC, C, SC	Slow Intake
Wind Erodibility Group	1, 2, 3	Soil Blowing
Permeability (in./hr.) - (0-60")	<0.2	Percs Slowly
Depth to Bedrock (in.)	<40	Depth to Rock
Depth to Cemented Pan (in.)	<40	Cemented Pan
Fragipan (Great Group)	All Fragi	Rooting Depth
Bulk Density (g/cc) - (0-40")	>1.7	Rooting Depth
Slope (%)	>3	Slope
Erosion Factor (K) - (Surface Layer)	>0.35	Erodes Easily
Flooding	Occasional or Frequent	Floods
Sodium Absorption Ratio (Great Group)	>12 (Natric, Halic)	Excess Sodium
Salinity (mmho/cm)	>8	Excess Salt
Soil Reaction (pH)	<5	Too Acidic
-------------	None of Above	Favorable
1/ Weighted average to 40 inches (101.6 cm).		

Chapter 3 (NEH 652.0308) North Carolina NRCS Irrigation Guide Supplement - Crops (in North Carolina)

The primary crops irrigated in North Carolina are horticulture crops, corn, cotton, pastures, peanuts, small grains, sorghum, soybeans, strawberries, tobacco, turfgrasses, and vegetables. Low fertility, low or high pH, and/or an imbalance of nutrients are often the limiting production factors on irrigated land. A well-fed plant uses water more efficiently than a plant deprived of nutrients. The irrigator should monitor soil moisture, control weeds and pests, plant high quality seed of adapted varieties, and use timely operations. Weeds, insects, and diseases can be a greater problem for irrigated land than for non-irrigated farm land.

Small grains are best suited to medium texture soils. Peanuts and most pasture plants are best suited to moderately coarse texture soils. Most vegetables do well on coarse textured soils. Alfalfa, tobacco, corn, cotton and soybeans will perform well on most deep, well drained, medium, and coarse textured soils when irrigated and fertilized properly.

Computer modeling with irrigation management software has shown that a winter cover crop should be used with a waste water irrigation system in order to increase crop utilization of fall, winter, and spring irrigation applications. Irrigated waste water is often applied in the fall/winter/spring periods which generally last four to five months in North Carolina, and sometimes longer in the mountain regions. This fall/winter/spring period is outside of the normal growing season of most harvested crops. A cover or winter crop can grow later into the fall and starts growing earlier in the spring. Irrigation applied waste water must be consumed by growing plants and is not allowed to be lost in runoff or deep percolation below the rooting zone. Soils are often at maximum plant available water in the spring, which limits the irrigation potential. Use of Irrigation Scheduling accounting methods (computer models or spreadsheets) is needed to properly schedule waste water irrigation applications during the spring time.

Crop residue or vegetative cover should be maintained on the surface to keep soil loss within the allowable limits for irrigated soils. At the outer portions of some center pivot irrigation systems, the application rate may exceed the soil water intake rate. Leaving crop residue on the surface can minimize this condition. Also minimum tillage will improve or maintain soil water intake rates. Cover crops (usually small grains) are essential to control wind and water erosion on many soils, especially in the southeastern Coastal Plains and Sandhills regions of North Carolina.

3a - Critical Crop Growth Periods

For optimum production and the most efficient use of water, plants must have ample moisture throughout the growing season. For most crops there are critical periods in the growing season when a high moisture level must be maintained for high yields. The critical period can best be defined as that time when soil moisture stress can most reduce yield in an otherwise healthy crop. This is not to say that it is the only time in the life of the crop that moisture stress reduces yield. It is the time when moisture stress has the greatest effect. If there is enough moisture for germination and for the development of an adequate stand, the critical moisture period is almost always in the latter part of the growing season during the reproductive growth stage. Although plants indicate moisture stress by various symptoms, yields will usually be reduced by the time the plant shows stress. Time and duration of irrigation should be determined by an accurate estimation of the soil moisture content and the remaining plant available water in the rooting zone. Critical moisture periods for North Carolina crops are shown in Table NC3-1.

3b - Crop Rooting Depth and Moisture Extraction

The effective root zone depth is the depth of soil used by the main body of the plant roots to obtain most of the stored moisture and plant food under proper irrigation. It is not the same as the maximum root zone depth. Application of irrigation water should be limited to an amount that will penetrate only the effective root zone depth. Applications in excess of this amount will result in waste of water and added pumping cost. Also, in the lighter textured soils, heavy applications may cause leaching of plant food beyond reach of the plant feeder roots.

It should be noted that some irrigators in North Carolina define the effective root zone as being the surface 12 to 18 inches of a soil for most crops. The NRCS uses a more national approach in the determination of the effective root zone, and thus may have larger values for crops as shown in Table NC3-1. It is recognized that managing the surface 12 to 18 inches will be very effective at scheduling and applying the proper amounts of irrigation water. However, using less effective root depth may cause a reduction in the irrigation application amount and an increase in the irrigation frequency. Therefore it is left to the irrigation designer and grower/user to determine the effective root zone that will be managed with a specific field and crop that are to be irrigated.

In uniform soils with ample available moisture, plants use water rapidly from the upper part of the root zone and slowly from the lower part. Most plants have similar moisture extraction patterns. The usual crop moisture extraction pattern for soils with a uniform texture is as follows: about 40% from the upper quarter of the root zone, 30% from the second quarter of the root zone, 20% from the third quarter, and 10% from the bottom quarter. Therefore, it follows that most crops will meet 70 percent of their moisture needs from the upper half of the effective root zone. Because of this pattern of water extraction, if 50% of the available water capacity (AWC) has been used, the upper portion of the root zone is most affected by the lack of moisture. This will make the upper 12 to 18 inches the most critical zone for a given crop and soil combination from an irrigation management view point.

The effective rooting depth of the crop determines the volume of the soil moisture reservoir to be managed by the irrigator. The effective rooting depth depends on the crop being grown and soil conditions. Table NC3-1 gives the normal effective rooting depth of common crops grown in deep soils. Shallow soils can limit the rooting depth of crops. This rooting depth restriction can be due to shallow depths to bedrock, gravel, acidity, soil with a hardpan, high water table, or any other restriction to root development. A minimum effective rooting depth as shown in Table NC3-1 should be available to support the crop. There may be occasions where field conditions indicate that effective root zone depth other than those listed may be more appropriate. The proper effective root zone depth can be determined in the field by observation and measurement. If moisture conditions and growth period have been sufficient to develop normal rooting characteristics, the effective root zone depth may be determined by digging a hole alongside the plant and carefully tunneling back underneath the plant to expose the hair like moisture feeder roots. The depth to which two or more rootlets are noted per six square inches of exposure indicates effective moisture utilization. Determination of the moisture content of each layer encountered can also indicate the moisture extraction pattern.

3c - Plant Moisture Stress and Limited Irrigation

Many factors contribute to the need to limit irrigation. These factors include declining ground water supplies, salt-water intrusion, increases in pumping cost and disease control. For any crop, there is a point where further application of irrigation water cannot be justified economically. Profit may be maximized by limiting irrigations to the particular crop's critical moisture characteristics in lieu of trying for maximum yields by maintaining a high soil-moisture level throughout the growing season.

Plant growth is a very complex process that can be impacted by many external factors such as pests, disease, soil alkalinity or acidity, plant available water, plant nutrient availability, and soil toxicity levels (salts, heavy metals, etc.). However, some generalities can be made in regards to plant response to water related stresses. It should be noted that this does not hold true for every year due to the complex interactions that govern plant growth. Plant moisture stress is any period during the plant's growing season when its water needs are not met. Plants are generally most sensitive to soil plant-available moisture deficits during the flowering and fruiting or grain filling stages of its growth cycle. Critical plant moisture stress periods for some of the major crops of North Carolina are discussed in the following list and are shown in Table NC3-1.

Alfalfa

Alfalfa needs adequate soil moisture for high production. The most critical need for moisture is at the start of flowering and after cutting. Irrigations should be scheduled 3 to 5 days after each cutting, if possible. The soil should be brought to field capacity 2 to 3 feet deep depending upon soil type. The spring, before cutting, and in the fall are the most critical periods of growth in the maintenance of a highly productive stand. Fall growth should be sufficient to permit the production and storage of large quantities of reserve food in the crown and roots to reduce winter kill of plants. Irrigation scheduling computer programs or spreadsheet scheduling type methods is recommended for irrigated alfalfa crops since water stress results in reduced ET and usually reduced yields. Irrigation scheduling should also reduce over-application of water, which increase costs and will not increase yields or make up for a previous stress period.

Blueberries

Irrigation water should be applied according to the water needs of the blueberry. The root system on a blueberry plant will begin to grow before the top. Therefore, if the winter has been dry, it is important to irrigate thoroughly 3 to 4 weeks before the top starts to grow. From bloom until harvest is a critical moisture period for blueberries. After harvest the blueberry continues to make new growth to support the next season's crop. Water and adequate fertility are critical during this stage of growth.

Corn

The use of irrigation for growing corn in North Carolina has increased steadily over the past 30 years. The major advantages of irrigation in corn production come from an increase in yield potential and more consistent yields over time. Comparisons of commercial fields over a seven year period found that irrigated corn fields yielded over 215 bushels per acre on average; while non-irrigated fields on the same farm over the same period averaged only 140 bushels per acre. Furthermore, the irrigated yields during the seven years ranged from 194 to 245 bushels per acre; while non-irrigated yields ranged from 13 to 204 bushels per acre. (R. W. Heiniger, NC Corn Production Guide-Ch 4-Irrigation and Drought Management, NC State Crop Science Department, 7/26/00)

Corn is a shallow rooted plant until it nears tasseling. Water requirements for corn, whether from rain or irrigation are as follows:

(1) about 1 inch of water every 12 days for the first 40 days of growth,
(2) about 1 inch every 5 to 7 days between 40 days and tasseling, and
(3) 1 inch every 3 to 4 days from tasseling to maturity.

Total irrigation and/or rainfall requirement for corn during the first 60 days is about 7.7 inches. Demand for water from 60 days to maturity is high, totaling about 13.0 inches, and is especially high and important during the tasseling and grain filling period. The grain filling period is the 3 weeks following tasseling.

Corn should never be allowed to wilt since yield losses will probably have already occurred once the wilting is evident. A drought period of a few days can significantly reduce yields, especially if occurring during critical growth stages. Under limited irrigation the critical period for irrigation is from the tassel stage through grain filling.

Cotton

Cotton is a drought tolerant plant. However, timely irrigation increases yields considerably. Quite often, preplant irrigation will supply adequate moisture up to the blooming period. The next irrigation should be at the early bloom stage. The first bloom through boll maturing stage is the most critical period for cotton. Adequate moisture is needed at this time to maintain high yields. An additional irrigation may be needed during the boll forming stage. High moisture levels after the boll forming stage will delay the crop and increase the amount of immature fibers.

Grapes

Adequate soil moisture is critical for grapes during the first year after planting. Many first-year plants die from moisture stress when there is no irrigation system. The most critical moisture period is during the sizing of the fruit. Applications of 1 inch of water every week during late April, May and early June should be sufficient for both old and young vines when rains do not occur. Extended periods of drought are common in North Carolina during the summer and will also benefit from irrigation. Competition with weeds may also stress grapes and must be controlled.

Pasture Grasses

Irrigation of pastures in eastern North Carolina is often associated with the disposal of animal wastes. Animal waste irrigation is not addressed specifically in this guide. There are nutrient concerns, state permits, and other waste-specific issues that must be addressed with a waste irrigation system design in North Carolina.

In droughty locations and during dry years inadequate soil moisture may limit production of warm season grasses during the late spring and early summer. Where economically feasible apply 0.6 to 1 inch of irrigation water per week during this period to improve forage production.

Cool season grass in the coastal plains may fail to establish in some years due to poor soil moisture conditions in November and December. Where economically feasible, apply 0.6 inches of water per week, when rains do not occur. Cool season forages are generally not recommended in eastern North Carolina, especially without supplemental irrigation during the establishment period.

To reduce opportunity of soil compaction on irrigated pastures, livestock should be excluded during and after irrigation until adequate soil surface dry-out occurs.

Peaches

The fruit growth pattern of peaches is referred to as a double sigmoid growth curve that brings fruit to maturity in 70 to 120 days. Depending upon the variety, there is an initial period of rather rapid fruit enlargement followed by a pit hardening period during which fruit enlargement is slight. Finally the flesh of the fruit thickens and total enlargement is very rapid immediately prior to maturity. It is during this final swell that moisture stress can reduce yield the most. During the last 30 days before harvest, about two-thirds of the final volume is attained.

Researchers have not agreed on the proper Management Allowable soil-water Depletion (MAD) to maintain for peaches, but data on cling peaches show that the growth rate is reduced when the MAD in the upper two feet root depth was less than 50%, especially during final swell. See chapter 4 for a discussion of MAD and its use in irrigation system management.

Several agricultural water-related precautions should be considered. Practically all peach production locations require irrigation. Water may be applied through micro-sprinklers under the tree, or by overhead systems. Drip irrigation is generally not used with peaches. Compared to any other form of irrigation, overhead irrigation is more likely to spread pathogens into the tree canopy. Water used as a means of frost protection must be potable (safe for drinking).

The quality of source water is a key concern. Surface waters, such as lakes, ponds, streams, etc., should be tested. The presence of the bacterium Escherichia coli (*E. coli)* is an indicator of fecal contamination. Do not irrigate from a pond or lake if animals were grazing nearby or had access to the water.

Underground (well) water is less likely to have fecal contamination, although such situations have been documented. Pesticide residues and heavy metals are generally of more concern in underground sources of water.

Peanuts

Only a small percentage (less than 20 percent) of North Carolina peanuts is grown under irrigation. The majority of the peanuts grown in North Carolina is the Virginia-type and is targeted primarily for the in-shell market. (Rick L. Brandenburg, David L. Jordan, Barbara B. Shew, John W. Wilcut, and Stephen J. Toth, Jr. (ed.), Crop Profile for Peanuts in North Carolina, North Carolina State Univ., 2005)

Peanuts respond well to irrigation with the greatest increases in yields on light textured sandy soils. During the growing season, peanuts will require from four to eight inches of supplemental irrigation. Usually, irrigation commenced at no more than 50 percent MAD during the peak growing season will result in maximum yields. This will require an application every 4 to 5 days on light sandy soils and every 6 to 8 days on heavier soils. Do not exceed 1 inch per application for light sandy soils whereas 1.5 inches may be necessary for heavy soils.

If water supplies are limited or restricted, probably the most important irrigation is preplant if moisture is not adequate at planting time. One-half to three-fourths inch of water applied just before planting has proven to be very effective in producing good plant population. Growers should also irrigate during the main fruiting period.

Pecans

Irrigation is strongly encouraged to maximize pecan production in North Carolina. Low-volume irrigation systems, such as drip or micro-sprinkler systems have been very effective at maintaining tree growth and productivity. (Micael L. Parker and Kenneth A. Sorensen, Growing Pecans in North Carolina, AG-81, NC Cooperative Extension Service)

Irrigation is very important on newly planted pecan trees. A water ring should be maintained around the tree for at least a year and water applied every 7-10 days during the growing season in the absence of suitable rainfall. Microsprinklers work well for this application. Under no circumstance, should the young trees be allowed to wilt. Critical moisture periods for older trees are during nut forming and nut filling.

Small Grains

Moderate to high small grain yields can be obtained with limited quantities of irrigation water. One method of achieving this goal is to delete the preplant irrigation when a good stand can be obtained without it. Spring irrigation can be delayed until the boot stage unless the small grains begin to show moderate soil moisture stress. Usually the most economical irrigations are at preplant and boot stage.

Sorghum

Grain sorghum is a drought tolerant plant that responds well to limited irrigation. Probably the most important irrigation is preplant if soil moisture is not adequate. In addition to preplant irrigation, be sure to irrigate at boot to early heading stage of growth.

Soybeans

Inadequate moisture during germination and early seedling growth can prevent establishment of a uniform stand. If there is not sufficient moisture in the surface layer to stimulate the germination of the seeds, it is desirable to apply a preplant or pre-emergence irrigation. Once a good stand is established soybeans can tolerate short droughts up until bloom with minimum adverse effects. The soybean uses water most in the reproductive phase. Particularly during pod growth and seed fill, lack of water will significantly reduce final soybean yields. Water stress in the early reproductive stage (flowering) may result in higher than normal levels of flower abortion, leading to reduced numbers of pods per plant. Moisture deficiencies during the seed filling stage will result in smaller than normal seeds, tending to lower overall yields. If irrigation is limited, then supplemental water at mid to late flowering will help produce the greatest increase in yield per unit of water applied.

Strawberries

The strawberry plant is shallow-rooted with 80 to 90 percent of its roots in the top 12 inches of soil. In the plastic mulch cultural system, adequate moisture is necessary in the surface soil to permit transplants to set and make maximum growth. Irrigation is needed at transplanting, during fruit bud formation and fruit enlargement. Usually, irrigation commenced at no more than 50 percent MAD or less appears to be adequate.

Tobacco

Irrigation of tobacco at transplanting will improve plant survival and early growth and enable weaker plants to initiate growth similar to the stronger plants. An analysis of moisture uptake by tobacco during the first three weeks after transplanting has shown the main moisture supply to be in the top 6 inches of soil and during the next two weeks it is in the top 12 inches. The top 18 inches of soil supplies most of the water for the plants for the remainder of the growing period. This being so, it is suggested that the soil be irrigated to a depth of 6 inches during the first three weeks, 12 inches during the next two weeks, and 18 inches during the remaining period of growth. Under limited irrigation, the critical time other than at transplanting is when the tobacco is from the knee-high stage until the top leaves are filled out.

Turfgrass

Many turfgrass species can be grown in North Carolina. Determining which one is best for a particular situation is based on several factors. Many soils in eastern North Carolina are sandy in nature which makes a deep-rooted grass desirable. If properly maintained, bahia grass and St. Augustine grass provide deep rooting and therefore increased drought resistance. Bahia grass can survive on natural rainfall whereas St. Augustine requires supplemental irrigation even during the winter months.

If the purchaser is willing to allot more time, energy and economic resources to turf maintenance, a finer-texture species is suggested such as one of the Bermuda grass or zoysia grass cultivars. In addition, centipede grass is available for those regions with heavier, acidic soils, such as the piedmont area of North Carolina, and for those with less resources and time available for upkeep.

Supplemental irrigation is necessary to maintain a desirable turfgrass. For North Carolina's sandy soils, in the absence of rain, irrigation will be necessary a minimum of one to two times weekly during summer to prevent stress on the turf. In most North Carolina areas, 0.75 inch of water should be applied per irrigation. Irrigation with 0.75 inch will wet the entire root zone without leaching nutrients from the soil profile. Do not irrigate frequently (i.e. daily) with light rates of water as this encourages shallow turf rooting as well as increased pest activity. Irrigation with 0.75 inch should be applied when the turf shows signs of drought stress (i.e. wilting or bluish-grey color). Once applied, wait until drought symptoms reappear before watering again.

Irrigate in early spring when day temperatures are warm but night temperatures are still cool. Turfgrass crowns coming out of winter dormancy are especially susceptible to dehydration at time of 'green-up'. Higher mowing heights and adequate soil potassium will increase the drought tolerance of turfgrasses.

Irrigation is required for turfgrass to produce quality sod for resell. Ample water of good quality should be a priority during the planting stage.

Vegetables

Vegetables are 80-95 percent water. Since they contain so much water, their yield and quality suffer very quickly from drought. Thus for good yields and high quality, irrigation is essential to the production of most vegetables. If water shortages occur early in the crop's development, maturity may be delayed and yields are often reduced. If a moisture shortage occurs later in the growing season, quality is often reduced even though total yield is not affected. Most vegetables are rather shallow rooted and even short periods of two to three days of stress can hurt marketable yield.

Most vegetables have small seeds which are planted 0.75 inches deep or less. When seeds are planted shallow, the upper layer of soil can dry rapidly leaving the seed without sufficient moisture to complete germination. When this happens, no stand or at best a poor stand will result. An irrigation of 0.5 inch immediately after planting should be applied to settle the soil and to start germinating seeds. For larger seeded crops, irrigation a few days prior to seeding is desired. If seed is slow to emerge, then irrigations of 0.50 inch should be applied as needed. This should keep the area around the seed moist until seedlings emerge. Irrigation is a valuable tool in getting good, uniform stands which ensure high yields. Good uniform stands also mean uniform harvest dates and more efficient production.

Vegetable transplants also require irrigation and adequate water cannot be applied to dry soil with a transplanter. A light irrigation of 0.5 to 0.75 inch will help transplants get firmly set in the soil and will provide a ready supply of water to young broken roots in the small root system of the transplants.

Irrigation at planting time can hasten seedling emergence. If 0.5 inch of irrigation is slowly applied, either with low rates or by turning the irrigation system off long enough to allow the water to soak in, crusting can be reduced and the stand improved.

Most vegetables that are fruits, such as tomatoes and peppers, are injured by wide fluctuations in soil moisture. These contain large amounts of water and depend on this water for expansion and growth. When soil moisture is allowed to drop below the proper level, the fruit does not expand to produce maximum size before it ripens, thus reducing yield. If moisture is allowed to fluctuate too much, blossom end rot can occur and fruit is no longer useable.

If moisture fluctuation occurs during the fruit expansion stage, fruit cracking will occur. Fruit cracking usually occurs when inadequate water has been applied and then heavy rains bring too much water. The best way to prevent fruit cracking is a steady moisture supply. Second growth or knobs in potatoes are also caused by soil moisture fluctuations.

Additional information for crops, including some specialty crops, may be found on the internet at the website for North Carolina Cooperative Extension "http://www.ces.ncsu.edu/depts/".

Table NC3-1: Critical crop moisture periods and effective rooting depths

Crop	Critical Cropping Period	Normal Effective Rooting Depth Unrestricted-Inches	Min Effective Rooting Depth restricted-Inches
Apples	During final swell prior to harvest	Tree - variable	
Alfalfa	Early spring and immediately after cuttings	36	24
Blueberries	Transplanting and from bloom until harvest	24	18
Corn, grain	15 days prior to and 15 days after silking	36	24
Corn, silage	15 days prior to and 15 days after silking	36	24
Corn, sweet	From silking through ear formation	30	18
Cotton	During and immediately after bloom stage	36	24
Flowers, annual	Throughout growing season	6	6
Grain, small	Planting and 2 weeks before pollination through head formation	24	18
Grapes	Transplanting, and during fruit enlargement	60	36
Hay	Planting and just prior to harvest and for perennials, immediately after harvest		
Lespedeza Seed	Planting and during seed formation		
Pasture Grass	At planting and throughout summer	36	30
Peaches	During final swell prior to harvest	60	36
Peanuts	Nut enlargement stage	24	18
Pears	During final swell prior to harvest	tree	
Pecans	During nut set (Apr-May) and nut fill (Aug-Sept)	60	48
Sorghum, grain	From boot to flowering stage	36	24
Soybeans	Pod filling stage	30	24
Strawberries	Transplanting, prior to and during harvest and during fruit bud formation	12	10
Tobacco	Transplanting, knee high to bloom, during harvest	18	18
Turfgrass	Planting and throughout growing season	6	6

Table NC3-1: Critical crop moisture periods and effective rooting depths (continued)

Vegetables			
Asparagus	Crown set and transplanting	24	18
Beans, Dry-Snap	During and Immediately following bloom	24	18
Beans, Lima	During and Immediately following bloom	30	24
Beans, Pole-Green	During and Immediately following bloom	24	18
Beans, Soy	During and Immediately following bloom	24	18
Beets	During rapid root expansion	24	18
Beets, Sugar	During early growth and Root expansion	36	24
Brussels Sprout	Sprout formation	18	12
Cabbage	Last 3-4 weeks prior to harvest	18	12
Cabbage, Chinese	Throughout growing season	18	12
Carrot	Seed germination, root expansion	18	12
Cantaloupe	Flowering & fruit development	18	12
Cauliflower	Throughout growing season	18	12
Celery	Throughout growing season	18	12
Collards	Throughout growing season	18	12
Cucumber, Pickling-Slicing	Flowering & fruiting	18	12
Eggplant	Flowering & fruiting	18	12
Endive	Throughout growing season	6	6
Greens	From just prior to maturation and during harvest	18	12
Leeks	Throughout growing season	18	12
Lettuce	Throughout growing season	24	18
Melons, Water-others	At pollination and 2-3 weeks afterwards	36	24
Nursery Stock	Throughout growing season	varies	
Okra	From bloom through harvest	24	18
Onion	Throughout growing season to just prior to harvest	18	12
Parsnip	Root Expansion	24	18
Peas, Green-Southern	From bloom through harvest season	18	12
Peppers	1-2 weeks prior to bloom to 2-3 weeks prior to end of harvest	18	12
Potato, Irish	4 weeks prior to harvest	18	12
Potato, Sweet	During rapid root expansion	24	18
Pumpkin	During Fruiting	24	18
Radish	Continuous	12	6
Rhubarb	Leaf emergence	24	18
Rutabagas	Root expansion	18	12
Spinach	From just prior to maturation through harvest	24	18
Squash, Summer	From bloom through harvest season	24	18
Squash, Winter	From bloom through harvest season	24	18
Tomatoes	1-2 weeks prior to bloom to 2-3 weeks prior to end of harvest	24	18

3d - Salinity Tolerance

Salts originate from mineral weathering, inorganic fertilizers, soil amendments (e.g., gypsum, composts and manures), and irrigation waters. An additional source of salts in many landscape soils comes from ice melters used on roads and sidewalks. It is only when salts are present in relatively high amounts that plant growth is adversely affected.

North Carolina has a humid climate with coastal yearly rainfalls of 40 to 60 inches. The rainfall is somewhat evenly distributed with October through December receiving the smallest amounts. The fall to early winter is the period where limited rainfall availability may be an issue. Spring and summer often have drenching rains which can offset or reduce the impacts of salinity in irrigation water. Salinity is generally not an issue for North Carolina irrigators, but should be a consideration in some situations.

High levels of salt accumulation in the root zone of the soil may affect plant growth in several ways.

First, it decreases the availability of nutrients and water for easy and rapid uptake by plant roots. This could lead to the need for more frequent irrigation on "salty" soils even though less than 50 percent of the normally available water has been used in the root zone. Such plants are usually stunted and have a bluish-green color.

Second, plants may be affected by a direct toxicity of one or more of the constituents of the salt in the irrigation water. This is more likely to affect tree fruit than field or vegetable crops.

Third, after a certain amount of sodium has been absorbed on the clay particles, the soil tends to puddle very easily, becomes less permeable to air and water, and forms into hard lumps and crusts when dry. When and if this happens, the grower should consult Rutgers Cooperative Extension for powdered gypsum application rates, to counteract the excess sodium in the soil.

In Table NC3-2, vegetable, fruit, and field crops are grouped according to their salt tolerances. Table NC3-3 shows the number of permissible irrigations with salt (brackish) water between leaching rains for crops of different salt tolerances. The number of irrigations permitted should be decreased on heavier soils (silt and clay loams). If there is any evidence of severe leaf burning after one or two irrigations owing to excessive salt accumulation on the plant leaves, no more irrigations should be applied unless the failure to irrigate would result in greater loss than that due to burning of the crop.

TABLE NC3-2 SALT TOLERANCE OF PLANTS 1/		
Plants that can tolerate 2/		
Up to 8-16 Millimhos 3/, 5120 to 10,240 ppm (Good Resistance)	Only up to 4-8 millimhos 3/, 2560 to 5120 ppm (Moderate Resistance)	No more than 1-4 millimhos 3/, 640 to 2560 ppm (Poor Resistance)
FIELD CROPS		
Barley and rape	Rye, wheat, oats, sorghum, corn, soybeans, and sorghum (grain)	Field beans
FORAGE CROPS		
Bermudagrass and barley hay	Sweet clover, sorghum, sudangrass, alfalfa, tall fescue, wheat and oat hays, orchardgrass perennial ryegrass, vetch, smooth brome, soybeans, Proso millet, pearl millet, and Alsike clover	White clover, Ladino clover, and red clover
VEGETABLE CROPS		
Garden beets, kale, asparagus, and spinach	Tomatoes, broccoli, cabbage, peppers, cauliflower, lettuce, sweet corn, potatoes, carrots, onions, peas, squash, cucumbers, collards, radishes, and rhubarb	Radishes, celery, and green beans
FRUIT CROPS		
	Grapes, cantaloupe	Pears, apples, plums, peaches
OTHER CROPS		
Bermudagrass, Zoysia, creeping bentgrass American beachgrass (production of)		Red fescue, Ky. bluegrass, colonial bentgrass

1/ The information in this table were obtained from USDA Agricultural Research Service Publication ARS41-29, "Brackish Water for Irrigation in Humid Regions" 1960.
2/ Crops, plants, or trees are listed in order of increasing sensitivity.
3/ These figures represent the electrical conductivity (ECe) of the soil saturation extract, where 1 millimho equals approx. 640 ppm of salts.

TABLE NC3-3 PERMISSIBLE NUMBER OF IRRIGATIONS WITH BRACKISH WATER BETWEEN LEACHING RAINS FOR CROPS OF DIFFERENT SALT TOLERANCES 1/

Irrigation Water		Irrigations allowed between Leaching (heavy) Rainfalls		
Total Salts (ppm)	**Electrical Conductivity (millimhos per cm at 25° C)**	**Good Salt Tolerance**	**Moderate Salt Tolerance**	**Poor Salt Tolerance**
640	1		15	7
1280	2	11	7	4
1920	3	7	5	2
2560	4	5	3	2
3200	5	4	2-3	1
3840	6	3	2	1
4480	7	2-3	1-2	
5120	8	2	1	

1/ The information in this table was obtained from USDA Agriculture Information Bulletins Nos. 213 and 283.

Chapter 4 (NEH 652.0408) North Carolina NRCS Irrigation Guide Supplement - Water Requirements (for North Carolina)

General Issues for Water Supply Requirements

The first requirement for irrigation is an adequate supply of good quality water during those periods when the need for irrigation water is greatest. The number of acres which can be properly irrigated at such times is dependent on the available water supply. The water supply should be adequate to irrigate the intended area of crops during a prolonged dry period before serious crop damage occurs. When water supply capacity is limited, it is often better to irrigate fewer acres well than to irrigate more acres poorly.

In North Carolina the following recommendations (shown in Table NC4-1) are made with respect to the minimum water supply that should be available for each acre to be irrigated.

Table NC4-1: Recommended minimum irrigation water supply

Crop to be Irrigated	Wells or Streams	Ponds
Improved Pasture and Mixed Hay	5 – 7 GPM / ac	1.0 ac-ft / ac
Most Vegetable Crops and Tobacco	6 – 10 GPM / ac	1.0 ac-ft / ac
Most Field Crops and Clean Tilled Orchards	7 – 13 GPM / ac	1.3 ac-ft / ac
Orchards with Cover	9 – 16 GPM / ac	1.6 ac-ft / ac
Note: GPM is gallons-per-minute flow rate, and ac-ft is the storage volume in acre-feet of water		

In Table NC4-1 above, for the “Wells or Streams” column, the value of GPM has a range that is related to the number of hours per day that the irrigation system is operated. The lower GPM flow rate is for a system that is operated daily for 18 hours. Whereas, the larger GPM flow rate is for an irrigation system that is operated daily for 10 hours. Container grown nursery plants are not covered in the Table NC4-1 above. They require the greatest amount of water, up to 0.5 inches per day, and therefore would require a larger water supply.

The capacity, Q, of a system may be computed by the formula:

$$Q = \frac{(453 * A * d)}{FH}$$

Where: Q = discharge capacity in GPM
A = size of the irrigated area in acres
d = gross depth of application in inches
F = the days allowed for completion of one irrigation cycle
H = the actual hours of operation per day

Note that gross application depth, d, must take irrigation efficiencies into account by the following formula:

$$d = \frac{d_n}{E_a}$$

Where: d_n = net application in inches
Ea = application efficiency of the system in decimal form

In some areas of North Carolina deep wells are the most dependable source of irrigation water. Information concerning such wells can be obtained from local well drillers or the state geologist.

Ponds and reservoirs, used as sources of irrigation water, can have losses as high as 50 percent of the total capacity. Losses are generally in the form of seepage and evaporation. The pond or reservoir must be large enough to meet the irrigation demands and overcome the storage losses. It can be helpful to run a reservoir water balance model for a period of about 10 years of recent weather data to evaluate the storage capacity. Computer models such as the NRCS Technical Release 19 (TR19), Reservoir Operation (RESOP) computer program are suited for this type of analysis. A water supply should be able to meet maximum crop irrigation demands for at least 8 out of 10 years.

Upward flow of water from a water table can be used to meet part of or the entire seasonal crop water requirement. Reasonable estimates need to be made of the water supplied by a water table. Methods to predict upward soil-water flow rates (upflux) from a water table are given in the water table management software program DRAINMOD. Soil parameters required for this procedure may require field data to evaluate specific sites.

Determination of irrigation water needs requires a measurement or estimate for the rate of crop water use. Daily and weekly crop water use estimates are needed to schedule irrigation applications and determine minimum system capacities. Seasonal or annual water use estimates can be used to size irrigation reservoirs and to determine consumptive use permits. Therefore, a procedure to determine both short- and long-term rates of water use may be necessary. NRCS NEH, Chapter 2, Irrigation Water Requirements, describes the processes needed to determine crop evapotranspiration and irrigation water requirements for a crop, field, farm, and project.

Crops grown in North Carolina generally need about 6 to 10 inches of irrigation per year to supplement the natural rainfall during a growing season (NC Cooperative Extension Service, Pub. No. AG 452-4, Irrigation Scheduling to Improve Water- and Energy-Use Efficiencies, June 1996; NC State University, Tobacco Irrigation Costs for the Piedmont and Coastal Plains of NC, updated 2007; NC Cooperative Extension Service, Animal Waste Management Systems, Chapter 5: Proper Application of Liquid Animal Waste-Type A, Draft Copy, 1997). The amount of irrigation needed will vary with the crop, management goals, weather conditions, soil and location within the state. There will be wet years when little to no irrigation is needed. There will also be drought years when lower than normal rainfalls occur and more irrigation is needed.

Crop evapotranspiration (ET_c), sometimes called crop consumptive use, is the amount of water that plants use in transpiration and building cell tissue plus water evaporated from the adjacent soil surface. Crop evapotranspiration is influenced by several major factors: plant temperature, ambient air temperature, solar radiation (sunshine duration/intensity), wind speed/movement, relative humidity/vapor pressure, plant growth stage, canopy coverage, and soil-water availability. Daily, weekly, monthly, and seasonal local crop water use requirements may need to be determined. These data can be used for planning, designing, and operating irrigation systems and for making irrigation management decisions, such as determining when and how much to irrigate. Irrigation operating expenses can be very large and are generally associated with the amount of irrigation water that is applied. Irrigation scheduling will generally reduce the amount of over-applications and insure soil moisture is available when and where it is needed. The irrigator can easily recoup the small amount of time/cost needed to input data into an irrigation scheduling program or method by the increased water-use efficiencies and associated cost savings.

Seasonal water requirements, in addition to crop water needs, may also include water used for preplant irrigation, agricultural waste application, leaching for salt control, temperature control (for frost protection, bud delay, and cooling for product quality), chemigation, facilitation of crop harvest, seed germination, and dust control.

The NC Agriculture Cost Share Program and the federal USDA Environmental Quality Incentives Program (EQIP) offer financial assistance for water conservation and for water saving technology. These programs offer over forty approved best management practices for producers that contribute to water use reduction and efficiency. Improved water management often results in improved water quality as well as water savings. State and federal agricultural cost share and technical assistance programs recognize this connection and are giving more attention to water use efficiency and conservation.

4a - Direct Measurement of Crop Evapotranspiration

Direct measurement of crop evapotranspiration is generally used by research or regional weather stations, and is not often used by a single farm entity. Direct measurement methods generally use a lot of costly equipment to directly measure or determine crop evapotranspiration (ET_c). Direct measurement methods for ET_c include:

Aerodynamic method
Detailed soil moisture monitoring
Lysimetry
Plant porometers
Regional inflow-outflow measurements

All these methods require localized and detailed measurements of plant water use. Detailed soil moisture monitoring in controlled and self contained devices (lysimeters) is probably the most commonly used. Little long term historical data outside of a few ARS and university research stations are available. Use of lysimetry is discussed in more detail in NRCS NEH, Chapter 2, Irrigation Water Requirements. The use of soil moisture monitoring devices to monitor ET_c is described in NRCS NEH Section 15, Chapter 1, Plant-Soil-Water Relationships.

4b - Methods for Estimating Crop Evapotranspiration

More than 20 methods have been developed to estimate the rate of ET_c based on local climate factors. The simplest methods are equations that generally use only mean air temperature. The more complex methods are described as energy equations. They require real time measurements of solar radiation, ambient air temperature, wind speed/movement, relative humidity/vapor pressure, and crop parameters. The concept of a reference crop/surface was introduced to obviate the need to define unique evaporation parameters for each crop and stage of growth. These ET equations have been adjusted for reference crop ET with lysimeter data. Selection of the method used for determining local ET_c depends on:

Location, type, reliability, timeliness, and duration of climatic data;
Natural pattern of evapotranspiration during the year; and
Intended use of crop evapotranspiration estimates.

In the past, an open water surface has been proposed as a reference surface. However, the differences in aerodynamic, vegetation control and radiation characteristics present a strong challenge in relating ET_c to measurements of free water evaporation. Relating reference evapotranspiration (ET_0) to a specific crop has the advantage of incorporating the biological and physical processes involved in the evapotranspiration (ET) from a cropped surface.

Grass, together with alfalfa, is a well-studied crop regarding its aerodynamic and surface characteristics and is accepted worldwide as a reference surface. Because the resistance to diffusion of vapor strongly depends on crop height, ground cover, leaf area index (LAI) and soil moisture conditions, the characteristics of the reference crop should be well defined and fixed. To avoid problems of local calibration which would require demanding and expensive studies, a hypothetical grass reference can be selected. Difficulties with a living grass reference result from the fact that the grass variety and morphology can significantly affect the evapotranspiration rate, especially during peak water use. Large differences may exist between warm-season and cool-season grass types. Cool-season grasses have a lower degree of stomatal control and hence higher rates of evapotranspiration. It also may be difficult to grow cool-season grasses in some arid, hot, or tropical climates.

The NC State Climate Office (a source of climate data in North Carolina) and others have accepted the following definition for the reference crop surface: "A hypothetical reference crop with an assumed crop height of 0.12 m (4.7”), a fixed surface resistance of 70 s m-1 and an albedo of 0.23 (from Food and Agriculture Organization of the United Nations [FAO], Irrigation and Drainage Paper No. 56, Crop Evapotranspiration, by Richard G Allen, Luis S Pereira, Dirk Raes, Martin Smith)”. This reference surface closely resembles an extensive surface of green grass of uniform height, actively growing, completely shading the ground and with adequate water. The requirements that the grass surface should be extensive and uniform result from the assumption that all fluxes are one-dimensional upwards.

With grass reference crop ET_0 known, ET estimates for any crop at any stage of growth can be calculated by multiplying ET_0 by the appropriate crop growth stage coefficient (K_c), usually displayed as a curve or table. The resulting value is called crop evapotranspiration (ET_c). The following methods and equations can be used to estimate reference crop evapotranspiration, ET_0. The methods are described in detail in NRCS NEH, Section 15, Chapter 2, Irrigation Water Requirements (1990). The crop coefficients should be based on local or regional growth characteristics. The following methods are recommended by the Natural Resources Conservation Service (NRCS).

(1) Temperature method:
- Food and Agricultural Organization of the United Nations (FAO) Modified Blaney-Criddle (FAO Paper 24)
- Modified Blaney-Criddle (SCS TR 21). See NRCS NEH, Section 15, Chapter 2, “Irrigation Water Requirements”, for more information on this method.

(2) Energy method:
- Penman-Monteith method (used by the NC State Climate Office)

(3) Radiation method:
- FAO Radiation method (FAO Paper 24)

(4) Evaporation pan method

The FAO Modified Blaney-Criddle, Penman-Monteith, and FAO Radiation equations represent the most accurate equations for these specific methods. They are the most accurately transferable over a wide range of climate conditions. These methods and equations are also widely accepted in the irrigation profession today (American Society of Civil Engineers, “Evapotranspiration and irrigation water requirements”, Manuals & Reports on Engineering Practice, No. 70, 1990).

The intended use, reliability, and availability of local climatic data may be the deciding factor as to which equation or method is used. For irrigation scheduling on a daily basis, an energy method, such as the Penman-Monteith equation, is probably the most accurate method available today, but complete and reliable local real time climatic data must be available. Normal year (historical) monthly averages of ET_0 for four cities in NC are shown in Table NC4-2.

For irrigation scheduling information on a 10+ day average basis, use of a radiation method, such as FAO Radiation, or use of a local evaporation pan, may be quite satisfactory. For estimation of monthly and seasonal crop water needs, a temperature based method generally proves to be quite satisfactory. The FAO Modified Blaney-Criddle equation uses long term mean temperature data with input of estimates of relative humidity, wind movement, and sunlight duration. This method also includes an adjustment for elevation. The FAO Radiation method uses locally measured solar radiation and air temperature.

Table NC4-2: Normal Evapotranspiration Data For North Carolina (Inches)

MONTH	Asheville	Charlotte	Raleigh	Wilmington
January	0.50	1.95	2.01	2.10
February	0.63	2.44	2.44	2.64
March	1.35	4.07	4.00	4.21
April	2.65	6.04	5.81	6.35
May	4.33	7.16	6.38	7.31
June	5.83	7.63	6.87	7.24
July	6.36	7.64	6.89	7.53
August	5.76	7.06	6.25	6.40
September	4.11	5.45	4.88	5.34
October	2.40	3.87	3.56	4.00
November	1.03	2.70	2.71	2.86
December	0.56	2.07	2.15	2.39

Data from: website “http://www.ces.ncsu.edu/depts/hort/nursery/short/2003_short_course/irrigation-needs.html”

4c - Estimating Crop Evapotranspiration (ET_c) in North Carolina

Daily reference crop ET_0 data for North Carolina using the Penman-Monteith method in near real-time (one day lag) is available from the the NC State Climate Office. This ET_0 data can be obtained from the following website: "http://www.nc-climate.ncsu.edu/ ".

With grass reference crop ET_0 known, ET estimates for any crop at any stage of growth can be calculated by multiplying ET_0 by the appropriate crop growth stage coefficient (K_c). K_c is usually displayed as a curve or table. Table NC4-3 (source: New Jersey Irrigation Guide, June 2005, Table NJ 4.3) or any other reliable source should be used to determine the appropriate crop coefficient (K_c) for a given crop growth stage. The resulting value is called crop evapotranspiration (ET_c) and is estimated on a daily basis by the equation:

$$ET_c = ET_0 \times K_c$$

Crop growth coefficients will need to be defined if you are using a hand-entry type worksheet or a spreadsheet computer program to estimate crop evapotranspiration (ET_c). A spreadsheet type program or worksheets can usually be obtained from your local extension agent or NRCS office. There are also computer programs available that often include the crop growth stage coefficients (K_c) for your selected crop. One of the Irrigation Scheduling computer programs that show promise for ease of use, work with available weather data, and requiring low time inputs would be KanSched2 (http://www.oznet.ksu.edu/mil/).

There are other more complex, and thus harder to use, Irrigation Scheduling computer programs such as SPAW and CropFlex that have more capabilities. One of the above methods should be used for irrigation scheduling to reduce losses and insure adequate moisture is available when the crop needs it.

Irrigation Climatic Zones

"Climate is what you expect, weather is what you get" - Robert A. Heinlein. There are several climatic factors (rainfall, sunshine, wind, and temperature, for example) that affect the consumptive water requirements of crops and the evaporative losses from the soil beneath. The effects and variation of climate within North Carolina generally coincide with the six physiographic regions discussed previously in Figure NC1-1. This can be considered as a residual effect of some of the physiographic features of each region such as proximity to the coast, elevation (mountains, piedmont, and coastal plains), reflectivity of sands (desert effect in the sandhills region), and aspect (especially to prevailing winds and approaching rainfall systems). Generally, climatic data from the closest weather station within the same physiographic region (Figure NC1-1) can be used for irrigation scheduling inputs at a specific farm site. However, aspect in the mountain region should also be considered, since it can have a dramatic impact on the local weather. The westerly facing slopes of the Blue Ridge mountains in North Carolina generally have dramatically different weather conditions than the easterly facing slopes of the same mountain system. Weather data and estimated reference evapotranspiration (ET_0) is available for most locations within North Carolina from the following website: "http://www.nc-climate.ncsu.edu/ ".

TABLE NC4-3: CROP GROWING SEASON AND CROP COEFFICIENT VALUES (K_c)												
CROP NAME	GROWING SEASON		% GROWING SEASON K_c FACTORS									
	Begin Growth	End Growth	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
VEGETABLES												
Asparagus	1-Apr	10-Jun	0.25	0.43	0.69	0.95	1.00	1.00	1.00	1.00	0.93	0.25
Azalea	15-May	1-Oct	0.25	0.43	0.69	0.95	1.00	1.00	1.00	1.00	0.93	0.25
Beets	1-Apr	30-Jun	0.25	0.25	0.36	0.57	0.79	1.00	1.00	1.00	0.98	0.90
Broccoli	20-Jun	30-Sep	0.25	0.28	0.44	0.59	0.75	0.90	0.95	0.95	0.94	0.80
Bunch Onion	1-Apr	20-Jun	0.25	0.25	0.28	0.43	0.58	0.74	0.89	0.95	0.95	0.95
Cabbage	1-Apr	30-Aug	0.25	0.28	0.44	0.59	0.75	0.90	0.95	0.95	0.94	0.80
Carrots	1-May	15-Sep	0.25	0.25	0.50	0.75	1.00	1.00	1.00	1.00	0.88	0.70
Cauliflower	20-Jun	30-Sep	0.25	0.28	0.44	0.59	0.75	0.90	0.95	0.95	0.94	0.80
Celery	1-May	30-Oct	0.25	0.40	0.70	1.00	1.00	1.00	1.00	1.00	0.99	0.90
Collards	1-May	30-Aug	0.25	0.25	0.48	0.72	0.95	0.95	0.95	0.95	0.95	0.90
Cucumbers	30-Apr	5-Sep	0.25	0.27	0.51	0.74	0.90	0.90	0.90	0.90	0.83	0.70
Dandelion	1-Mar	15-Jun	0.25	0.25	0.33	0.51	0.70	0.89	0.95	0.95	0.95	0.90
Dry Onion	25-Mar	15-Sep	0.25	0.69	0.95	0.95	0.95	0.95	0.95	0.91	0.83	0.75
Egg Plant	15-May	30-Sep	0.25	0.25	0.43	0.64	0.86	0.95	0.95	0.95	0.89	0.80
Endive	15-May	15-Sep	0.25	0.25	0.33	0.51	0.70	0.89	0.95	0.95	0.95	0.90
Escarole	15-May	15-Sep	0.25	0.25	0.33	0.51	0.70	0.89	0.95	0.95	0.95	0.90
Fennel	15-May	15-Sep	0.25	0.25	0.33	0.51	0.70	0.89	0.95	0.95	0.95	0.90
Lettuce	1-May	5-Sep	0.25	0.25	0.33	0.51	0.70	0.89	0.95	0.95	0.95	0.90
Lima Beans	10-Apr	10-Jul	0.25	0.25	0.41	0.62	0.83	0.95	0.95	0.95	0.94	0.85
Muskmelons	1-May	30-Sep	0.25	0.25	0.53	0.82	1.10	1.10	1.10	1.10	0.95	0.65
Peas	10-Apr	10-Sep	0.25	0.25	0.55	0.84	1.05	1.05	1.05	1.05	1.02	0.95
Peppers	1-May	30-Aug	0.25	0.25	0.48	0.72	0.95	0.95	0.95	0.95	0.90	0.80
Potatoes	30-Mar	1-Oct	0.25	0.25	0.57	0.89	1.05	1.05	1.05	1.05	0.88	0.70
Pumpkins	20-Jun	20-Oct	0.25	0.25	0.47	0.68	0.90	0.90	0.90	0.90	0.80	0.70
Radish	1-Apr	15-May	0.25	0.25	0.43	0.62	0.80	0.80	0.80	0.80	0.79	0.75
Snap Beans	10-May	30-Sep	0.25	0.25	0.41	0.62	0.83	0.95	0.95	0.95	0.94	0.85
Spinach	30-Mar	30-May	0.25	0.25	0.48	0.72	0.95	0.95	0.95	0.95	0.95	0.90
Squash	15-May	1-Sep	0.25	0.25	0.47	0.68	0.90	0.90	0.90	0.90	0.80	0.70
Sweet Corn	1-May	30-Sep	0.25	0.25	0.43	0.66	0.89	1.03	1.03	1.03	1.02	0.95
Sweet Potatoes	15-May	1-Nov	0.25	0.25	0.57	0.89	1.05	1.05	1.05	1.05	0.88	0.70
Tomatoes	1-May	30-Sep	0.25	0.25	0.52	0.78	1.05	1.05	1.05	1.05	0.95	0.85
Watermelons	15-May	30-Sep	0.25	0.25	0.53	0.82	1.10	1.10	1.10	1.10	0.93	0.60
SMALL FRUIT and ORCHARDS												
Apples	10-Apr	30-Oct	0.50	0.75	1.00	1.00	1.00	1.10	1.10	1.10	0.85	0.85
Blueberries	15-Apr	15-Oct	0.46	1.10	1.10	1.10	1.04	0.97	0.87	0.82	0.75	0.67
Cranberries	1-Apr	1-Nov	0.40	0.40	1.05	1.10	1.10	1.10	0.85	0.50	0.40	0.40
Grapes	1-May	30-Oct	0.50	0.50	0.60	0.65	0.75	0.80	0.80	0.75	0.65	0.65
Peaches	1-Apr	30-Oct	0.50	0.70	0.70	0.90	1.00	1.00	1.00	0.95	0.75	0.75
Pears	1-Apr	30-Oct	0.50	0.70	0.70	0.90	1.00	1.00	1.00	0.95	0.75	0.75
Raspberries	15-Apr	15-Oct	0.40	1.05	1.05	1.05	1.05	1.05	.85	0.75	0.50	0.50
Strawberries	30-Aug	20-Feb	0.25	0.40	0.55	0.70	0.70	0.70	0.70	0.70	0.70	0.70
FIELD CROPS or HAY LAND												
Alfalfa	30-Mar	15-Oct	0.25	0.44	0.72	0.99	1.05	1.05	1.05	1.05	0.98	0.25
Barley	1-Mar	1-Jul	0.25	0.53	0.93	1.05	1.05	1.05	1.05	0.89	0.57	0.25
Corn	10-May	15-Oct	0.25	0.35	0.69	1.03	1.20	1.20	1.20	1.15	0.87	0.60
Oats	1-Apr	31-Jul	0.25	0.53	0.93	1.05	1.05	1.05	1.05	0.89	0.57	0.25
Sorghum	30-May	10-Nov	0.25	0.37	0.65	0.94	1.00	1.00	1.00	0.90	0.70	0.50
Soybeans	30-May	10-Nov	0.25	0.42	0.76	1.00	1.00	1.00	1.00	1.00	0.74	0.45
Wheat	1-Mar	15-Jul	0.25	0.53	0.93	1.05	1.05	1.05	1.05	0.89	0.57	0.25

Daily Crop ET Rate for System Design

Irrigation system designs generally use a maximum peak moisture use rate (often a 10 to 14 day period average) of transpiration by the crop plus evaporation from the soil surface, which combined equal ET_c. For most plants, the maximum rate of transpiration occurs when the daylight hours are longest, air temperature is greatest, wind movement is high, humidity is lowest, and the plant has developed a good rooting system and is in the rapid growth stage.

Estimates of daily or weekly crop ET_c rates are necessary to adequately size distribution systems. They are used to determine the minimum capacity requirements of canals, pipelines, water control structures, and irrigation application systems. Daily ET rates also influence the administration of wells, streams, and reservoirs from which irrigation water is diverted or pumped. A daily (or several day average) peak crop ET_c rate can be used in order to insure the crop's consumptive needs are met during the highest use periods.

Estimated daily crop ET_c is not the average daily use for longer time periods (monthly crop ET_c use estimates are common). Daily crop ET_c is best estimated using real time day-specific information and the appropriate ET method or equation. Daily crop ET_c can then be determined using the computed daily ET_0 times the appropriate crop coefficient (K_c) from Table NC4-3 or any other reliable source, using the equation previously given ($ET_c = ET_0 \times K_c$). Crop coefficients (K_c) are highest during the peak crop growth period. Local knowledge about crop consumptive use may also be used to determine the maximum rate for crop evapotranspiration for an irrigation design. The maximum use rate for ET_c should be equal to or greater than the values given in Tables NC6-3 and NC6-4 for the crop and soil conditions.

4d - Net Irrigation Water Requirements

The net irrigation water requirement is defined as the water required by irrigation to satisfy crop evapotransipiration and auxiliary water needs that are not provided by water stored in the soil profile or precipitation. The net irrigation water requirement is defined as (all values are depths, in inches):

$$Fn = ET_c + Aw - R_e - GW - \Delta SW$$

where:

Fn = net irrigation requirement for period considered
ET_c = crop evapotranspiration for period considered
Aw = auxiliary water-leaching, temperature modification, crop quality
Re = effective precipitation during period considered
GW = ground water contribution
ΔSW = change in soil-water content for period considered

Along with meeting the seasonal irrigation water requirement, irrigation systems must be able to supply enough water during shorter periods. The water supply rate generally is expressed in acre inches per hour or acre inches per day and can be easily converted to cubic feet per second or gallons per minute (1 ft^3/s = 1 ac-in/hr = 449 gpm, approximate). The simplified equation can be used:

$$QT = DA$$

where:

Q = flow rate, acre-inch per hour
T = time, hours
D = depth, inches (water applied or crop ET)
A = area, acres

The irrigation system must be able to supply net water requirements plus expected losses of deep percolation, runoff, wind drift, and evaporation. It must account for the efficiency of the irrigation decision-maker to schedule the right amount of water at the right time and the ability of an irrigation system to uniformly apply that water across a field. Net and gross water application and system capacity are related by an estimated or measured application efficiency:

$$Fg = \frac{Fn}{Ea} \quad \text{and} \quad Cg = \frac{Cn}{Ea}$$

where:

Fg = gross application, inches
Fn = net application, inches
Ea = application efficiency, expressed as decimal
Cg = gross system capacity, gallons per minute
Cn = net system capacity, gallons per minute

4e - Management Allowable Soil-Water Depletion

Management Allowable Soil-Water Depletion (MAD) is generally defined for each local crop. It is a grower’s management decision whether or not to fine tune generalized MAD values based on yield and product quality objectives. MAD is the greatest amount of water to be removed by plants from the soil rooting zone when scheduling an irrigation cycle, so that undesirable crop water stress does not occur. Historically, an allowable depletion of between 30 and 60 percent of the soil’s Available Water Capacity (AWC) has been used for management purposes. Most crops should be irrigated before more than half of the available moisture in the crop root zone has been used. Some crops, however, are thought to do better at higher moisture levels (less moisture deficiency at time of irrigation), while some require higher depletion levels at different growth stages (deficit irrigation in wine grapes). Refer to Table NC4-4 for a summary of some recommended MAD levels for various crops in a loamy soil. Irrigation must begin so that the entire area to be covered can be irrigated before the available moisture level in the last portion of the field reaches a point to cause unfavorable moisture stress to the crop. This aspect of management is crucial for systems that may need several days to irrigate the entire field area, such as traveling guns and hand move laterals.

Estimated irrigation frequency, in days, is based on the MAD level for the AWC in the total crop root zone and the estimated crop ET.

Irrigation frequency, in days, can be determined by:

$$\text{Irrigation Frequency (days)} = \frac{\text{MAD x (Total AWC for crop root zone in inches)}}{\text{Daily ETc rate in inches/day}}$$

Table NC4-4: Recommended Management Allowable Depletion (MAD) for crop growth stages (% of AWC) growing in loamy soils **1/**,**2/**

Crop	---------Crop growth stage----------			
	Establishment	**Vegetative**	**Flowering yield formation**	**Ripening maturity**
Alfalfa hay	50	50	50	50
Alfalfa seed	50	60	50	80
Beans, green	40	40	40	40
Beans, dry	40	40	40	40
Citrus	50	50	50	50
Corn, grain	50	50	50	50
Corn, seed	50	50	50	50
Corn, sweet	50	40	40	40
Cotton	50	50	50	50
Cranberries	40	50	40	40
Garlic	30	30	30	30
Grains, small	50	50	40 **3/**	60
Grapes	40	40	40	50
Grass pasture/hay	40	50	50	50
Grass seed	50	50	50	50
Lettuce	40	50	40	20
Milo	50	50	50	50
Mint	40	40	40	50
Nursery stock	50	50	50	50
Onions	40	30	30	30
Orchard, fruit	50	50	50	50
Peas	50	50	50	50
Peanuts	40	50	50	50
Potatoes	35	35	35	50 **4/**
Safflower	50	50	50	50
Sorghum, grain	50	50	50	50
Spinach	25	25	25	25
Sugar beets	50	50	50	50
Sunflower	50	50	50	50
Tobacco	40	40	40	50
Vegetables				
1 to 2 ft root depth	35	30	30	35
3 to 4 ft root depth	35	40	40	40

For medium to fine textured soils:
1/ (Most restrictive MAD) Some crops are typically not grown on these soils.
2/ Check soil moisture for crop stress point approximately one third of the depth of the crop root zone.
3/ From boot stage through flowering.
4/ At vine kill.

4f - Auxiliary Water Requirements (special needs and other uses)

In addition to crop evapotranspiration water requirements, irrigation systems can also meet special needs of crops and soils. These other uses need to be considered when determining the seasonal water requirements and minimum system capacities. Auxiliary uses include the following and are described in more detail in NRCS NEH Part 652, Chapter 2, Irrigation Water Requirements:

- Leaching requirement for salinity and sodicity management
- Frost protection (fruits, citrus, berries, vegetables)
- Bud delay
- Crop and soil cooling
- Wind erosion and dust control
- Chemigation
- Plant disease control
- Seed germination

Frost Control

For frost control, the irrigation system must have enough capacity to cover the entire area with a fine mist of water, (application rates 0.17 in/hr or less). Experience has shown that strawberries need 0.11-0.13 in/hr, berries need 0.13-0.15 in/hr, and tree fruit needed 0.15-0.17 in/hr. Irrigation for frost control utilizes the latent heat of fusion released when water changes from the liquid form to ice. The water is applied as a fine spray and the latent heat of fusion is released when the water freezes on the plant surface. The heat thus released maintains ice temperature around 32^o F. The ice acts as a buffer against cooling of plant surfaces by radiation or contact with cold air. The principle is valid and the process is effective only so long as the water application and subsequent ice formation continues. Not all of the heat is retained by the ice. Some is lost to cold air in contact with the ice, and some is lost to evaporation and sublimation at the water-ice surface. Each gallon of water at 32^o F., changing into ice at 32^o F gives off 1,200 BTU's of heat. Properly designed and operated systems can provide protection for certain crops to temperatures as low as 22^o F. See NRCS NEH , Section 15, Chapter 2, Irrigation Water Requirements, for a complete discussion of this issue and recommendations.

Fertilizer and Chemical Application

Using irrigation water as the carrier for fertilizers, herbicides, and other chemicals used in crop production is a practice that is increasing in popularity and acceptance. Savings in labor and time, and in many instances a more efficient fertilization program can be achieved through fertigation. Fertilizers can be applied with irrigation water, regardless of the methods used for water distribution. Equipment designed to inject fertilizer solutions into the water system is considered an integral part of practically all microirrigation designs offered on today's market. Likewise, injector pumps and metering devices are frequently considered as a standard component of any newly installed microirrigation and sprinkler system. Field tests and research projects have established that nitrogen mechanically applied before planting is often lost to the plant through leaching by rains or early irrigations that carry the nutrient to depths below the root feeder zone. This possibility shores up the arguments for the concept of "spoon feeding" a growing crop by applying smaller amounts of fertilizer at regular irrigation intervals throughout the season than with one or two applications. These same tests have further established that applying nitrogen with irrigation water is more effective on sandy soils and just as beneficial on fine-textured soils as when using mechanical applicators.

There is a danger of agricultural fertilizers polluting underground aquifers or surface streams with leached or runoff water laden with nitrates, phosphorus, or other plant nutrients. Offsite losses can be minimized when fertilizer is applied in amounts that can be readily absorbed by the growing crop while the fertilizer is still in the upper part of the root zone. This danger is more likely in coarse textured, sandy soils than in soils having fine textures, but can be of significant concern on any farm. See NRCS NEH , Section 15, Chapter 2, Irrigation Water Requirements, for a complete discussion of this issue and recommendations.

4g - Water Table Contribution, Drainage, and Irrigation Scheduling

Upward flow of water from a water table can be used to meet part or all of the seasonal crop water requirement. Reasonable estimates need to be made of the water supplied by a water table. See Figure 2-6 in NRCS NEH Part 652, Chapter 2, Irrigation Guide. Methods to predict upward soil-water flow rates (upflux) from a water table are discussed in both NRCS NEH , Section 15, Chapter 2, Irrigation Water Requirements, and in DRAINMOD (water table management computer software program developed by Wayne Skaggs at North Carolina State University). Soil parameters required for these procedures are quite variable and may require field data to evaluate specific sites.

Drainage System for Optimized Irrigation

North Carolina is located in the humid east climate environment where it is often too wet in the winter/spring and too dry in the summer/fall periods. During the wetter winter/spring period, rainfall generally exceeds the soil losses to evapotranspiration and drainage, and the ground is often too wet to work. During the dryer summer/fall period, rainfall is generally less than the soil losses to evapotranspiration and drainage, and the ground is generally very dry. A complete water management system would include both irrigation and drainage components. Drainage can improve plant growth by increasing soil temperatures in early spring permitting more rapid germination and establishment of a crop, and by increasing the rate at which organic matter is mineralized to nitrate nitrogen. Drainage also indirectly affects plant growth and crop production by permitting more timely field operations. Typically, the earlier most crops can be planted, the greater the yield. Drainage may enable planting a crop one to two weeks earlier. However, excessive drainage can increase the risk of water deficiencies during times of drought. A water-level controlled drainage system can limit the amount of water lost in a drainage system by blocking the outlet. Therefore, controlled drainage can be helpful to reduce the risk of over-drainage during the summer period or times of drought. In all, a drainage system should be seriously considered during the irrigation system design if it is not already installed. (Some exerpts in the above paragraph were from "Design and Operation of Farm Irrigation Systems", M.E. Jenson, American Society of Agricultural Engineers, p27, 1981.)

Water-Flow Measurement

Water-flow measurement devices, for both on- and off-farm conveyance, include weirs, flumes, and in-canal flow meters for open ditches, internal/external meters for pipe delivery systems, and flow meters in wells to monitor groundwater pumping. Of the 380,000 wells in the US that were used in 2003 to pump ground water for agriculture, only 61,000 (16 percent) used flow meters. While this is a 32-percent increase since 1994, flow meters on wells account for just 1 in 5 acres irrigated with ground water. (The above paragraph contains excerpts from

"*Agricultural Resources and Environmental Indicators,* Ch 4-6, *2006 Edition, EIB-16,* Economic Research Service, USDA".)

Increases or decreases in irrigation system flow rates can be indicative of distribution systems problems that will need correction. Worn or clogged sprinkler nozzles, pump wear, and pipe flow restrictions can affect efficiency, distribution uniformity, pressure, wind drift, evaporation, and application rates. Water-flow measurement devices can be used to identify problems such as these, especially if they are kept for many years.

Irrigation Scheduling

Proper irrigation scheduling and precise measurement of water flow help producers match water applied to crop needs. Most irrigated farms continue to use a combination of less sophisticated methods to schedule irrigations (USDA National Agriculture Statistics Service, Farm and Ranch Irrigation Survey {2003}, *Vol. 3,* Special Studies Part 1, AC-02-SS-1, Nov. 2004). Nearly 80 percent of irrigated farms use visual observation to evaluate the "condition of the crop", while some farms (ranging from 6 to 35 percent) simply feel-the-soil, irrigate "when their neighbor irrigates", use a "personal calendar schedule", use "media daily weather/crop evapotranspiration (ET) reports", or irrigate consistent with "scheduled water deliveries". Most irrigated farms do not use the more advanced, information-intensive methods to schedule irrigation; less than 8 percent of irrigated farms use soil and/or plant moisture sensing devices, commercial or government-sponsored irrigation scheduling services, or computer simulation models. These current national statistics suggest a significant potential for greater agricultural water conservation through public policy that promotes broader understanding and more extensive application of such scheduling techniques.

Irrigation scheduling based on soil-water balance is a simple procedure that can be operated either manually or using computer programs. Adoption of the procedure is still low due to lack of soil water parameters and availability of climatic information. Furthermore, potential users are often deterred by both the time and paper work required to carry out the calculations.

Many different techniques have been suggested to allow farmers to better manage water in soil. Some techniques are complicated, others are simple. The evaporation from a pan has been shown to correlate reasonably well with the crop water removal from soil, especially in humid climates. A simple irrigation scheduling method was developed based on the direct relationship between pan evaporation and soil water removal.

The University of Georgia UGA EASY (Evaporation-based Accumulator for Sprinkler-enhanced Yield) Pan Irrigation Scheduler can provide in-field monitoring of crop water needs in humid areas for a fraction of the management time and cost associated with other irrigation scheduling methods (Cooperative Extension Service/The University of Georgia College of Agricultural and Environmental Sciences, "UGA EASY Pan Irrigation Scheduler", D.L. Thomas, K.A. Harrison, J.E. Hook, and T.W. Whitley, Bulletin 1201, January, 2002). If a farmer is not currently using a more sophisticated irrigation scheduling method, this unit is a simplified, low cost alternative. This system can be homemade and has a visible indicator attached to a float that monitors the water level in a wash tub pan. When a predetermined amount of water evaporates from the tub, then it is time to irrigate. The UGA EASY Pan Irrigation Scheduler is designed to help keep track of when the next application is needed, so as to avoid applying too much or too little water. The overall goal is to be more efficient in the use of irrigation water. A North Carolina application of this device is shown on the front cover photograph for this guide.

The system operates under the basic principal of *Potential Evapotranspiration* (PET). Potential evapotranspiration is the maximum potential rate of water removal from a full canopy with no limitations on water availability in the soil. A properly irrigated field will generally approach PET. Placing screen materials over the tub allows this device to more accurately reflect the PET of a full canopy crop. The EASY Pan Irrigation Scheduler responds to both water removal (evaporation) and water addition (rainfall and sprinkler type irrigation).

4h - Soil-Water Budget/Balance Analysis

The components of a soil-water budget/balance analysis must include all water going *in* and all water going *out* of an area for the period of consideration. The basic purpose for such an analysis is to determine the location of all water applied. Generally a soil-water budget analysis is determined for a period involving a month, an irrigation season, a year, or maybe even for an average over several years. Availability of climatic data may also dictate the time period for the analysis. For example, if long-term mean temperature is the only reliable data available, determining monthly and seasonal water requirements may be the most accurate analysis that can be done. This would dictate a reasonably accurate analysis period of a month or longer.

If complete and reliable daily climatic data (temperature, solar radiation, wind movement, and relative humidity) are available nearby, then a daily soil-water accounting or balance can be developed because accurate daily water requirements can be estimated. The soil-water budget/balance analysis process is a tool that can be used for determining gross water applied and contributions of irrigation water and precipitation to downstream surface water and ground water.

The soil-water budget/balance can be displayed in equation form as follows:

$$F_g = ET_c + A_w + D_P + RO + SDL - P - GW - \Delta SW$$

where:

F_g = Gross irrigation water applied during the period considered
ET_c = Crop evapotranspiration during the period considered
A_w = Water applied for auxiliary purposes during the period considered
D_P = Deep percolation below the root zone from irrigation and precipitation
RO = Surface runoff that leaves the site from irrigation and precipitation
SDL = Spray, drift losses, and canopy intercept evaporation from sprinkler irrigation system during the period considered
P = Total precipitation during the period considered
GW = Ground water contribution to the crop root zone during the period
ΔSW = Change in soil-water content within the crop root zone during the period

Note: Only those factors that apply to the site under consideration need to be used. Typically all factors would not be used for an analysis of one site.

Generally the soil-water budget analysis can be thought of as supporting a planning process where the soil-water balance analysis can be thought of as supporting an operational process. With appropriate soil-water content monitoring, accurate estimated daily crop ET and measurement of system inflow and surface outflow, a reliable daily soil-water balance can be developed. These daily values can be summarized for any desirable longer period that data are available.

The period of reliable climatic data is key to the soil-water budget/balance analysis. For development of a soil-water balance, only immediate past events are evaluated. It is not an irrigation scheduling tool. For example, a soil-water balance is an analysis process of what water went where for the last year, last month, last week, last event, or from some specific date up to the present time. Each rainfall and irrigation event versus daily crop ET and soil-water content change can be evaluated. It requires appropriate and current monitoring of soil-water content, irrigation water applied, onsite rainfall measurement, runoff, and full climatic data for daily crop ET determination.

For development of a soil-water budget, historic climate data along with estimated or measured soil water content, irrigation flows, and losses would be used. The time period for an analysis for an average condition is whatever is necessary to provide reliable data. As an example, a site with fairly consistent climate from year to year, but with a rather short number of years record, might provide satisfactory results. A site with wide ranging climate from year to year might require a much longer period of record. An analysis showing the average for the last 5 years, or for a specific year of importance, could use climate data for that specific period only.

Table NC4–5 displays a simple and basic soil-water budget using assumed and estimated values. The input data can be refined to whatever degree is necessary with field observations or measurements, or both. In this table, a water surplus of 1.7 inches for the season is indicated, and the water will go into deep percolation below the root zone.

A soil-water budget can be developed for planning purposes or as an evaluation tool. As the example shows, the consultant can use any level of accuracy desired or necessary. Also refer to NRCS NEH Part 652, Irrigation Guide, Chapter 4 for more discussion of the soil-water budget.

Example soil-water budget

A simplified soil-water budget (example from the Midwest) would be displayed using the following assumptions:

- Crop is grain corn.
- Mature rooting depth = 48 inches. (Note: 24” may be more appropriate for NC)
- Total AWC = 8.0 inches. (Note: 3” to 4” may be more appropriate for NC)
- MAD = 50%.
- Soil profile is at field capacity at start of season.
- Sprinkler irrigation system with gross application for each irrigation = 6.0 inches.
- Application efficiency of 67% providing a net application = 4.0 inches.
- DU = (Distribution Uniformity) 100% with no surface runoff. Note: DU is always less than 100%, but for simplicity, is assumed to be 100 for this example.
- Precipitation infiltration for all season = 70% of total.
- No contribution from a shallow water table.

All crop ET, irrigation, and precipitation units are in inches. Note that a some of the values in this example would be changed for the North Carolina climate, soils, and irrigation system. But the concept and techniques that are illustrated in Table NC4–5 can be easily adapted to a specific irrigation field.

Table NC4–5: Example soil-water budget in inches								
Month	Crop ET	Soil water used	Precipitation		Irrigation		Water	
			Total (in)	Effective (in) **1/**	Number of Cycles	Net water applied	Deficit (-)	Surplus (+) **2/**
May	2.3	2.3	3.0	2.1	0	0	0.2	
June	4.8	5.0	2.0	1.4	1	4.0		0.4
July	8.1	8.1	0	0	2	8.0	0.1	
Aug	6.6	6.7	0	0	2	8.0		1.3
Sept	2.0	2.0	1.5	1.0	0	0	1.0	
Total	23.8	24.1		4.5	5	20		1.7

1/ Assuming all effective precipitation infiltrated into the soil.
2/ Typically lost to deep percolation. The total is in inches.

Additional and more detailed examples of a soil-water budget and a soil-water balance are in NRCS NEH Part 652, Irrigation Guide, Chapter 8, Project and Farm Irrigation Water Requirements.

Chapter 5 (NEH 652.0505) North Carolina NRCS Irrigation Guide Supplement - Selecting an Irrigation Method

5a - General

The purpose of this chapter is to provide necessary planning considerations for selecting an irrigation method and system. This chapter describes the most widely used irrigation methods and systems in North Carolina along with their adaptability and limitations. The grower should consider what yield increases (per acre) can be expected over several years. This should be compared to the projected annual cost (per acre irrigated) of the proposed irrigation system to insure this is a good business decision. Additionally, the grower will need to have the financial ability, cash flow, time, resources, and management to install and operate an irrigation system effectively so as to realize the potential production gains both in quantity and quality.

The NRCS Field Office Technical Guide (FOTG), section V, displays the conservation effects of irrigation methods and systems and their related components. These should be referenced during the planning and design process. They will provide insight as to the effects of surface irrigation on ground and surface water quantity and quality, and on wildlife.

The recommended irrigation method and system should consider available water supply, field size/shape/slope, the adaptability to what crops are grown, cost effectiveness of the system, level of management, labor requirements, environmental impacts/concerns, grower preferences/concerns, and local regulations.

Refer to NRCS NEH Part 652, National Irrigation Guide, Chapter 5, and NRCS NEH, Section 15, chapters 3-9, and 11 for additional information. Also, see NRCS NEH Part 652 Chapter 11 for additional information on developing and comparing typical capital and operating costs for selected irrigation systems.

5b - Methods and Systems to Apply Irrigation Water

The four basic irrigation methods, along with the many systems to apply irrigation water, include: sprinkler, surface, micro, and subirrigation.

Sprinkler - A majority of the irrigation in North Carolina consists of the sprinkler type. This method applies water through a system of nozzles (impact and gear driven sprinkler, or spray heads) with water distributed to the sprinkler under pressure through a system of surface or buried pipelines. Sprinkler heads and nozzles are available in a wide variety of sizes, and can apply water at rates near 0.1 inch per hour to more than 2 inches per hour. Sprinkler irrigation systems include the following: Solid Set, Handmove Laterals, Sideroll (wheel) Laterals, Center Pivot, Linear Move, and Traveling and Stationary Guns. Low Energy Precision Application (LEPA) and Low Pressure in Canopy (LPIC) systems are included with sprinkler systems because they use center pivot and linear move irrigation systems.

Surface - Water is applied by gravity across the soil surface by flooding or small channels (i.e., basins, borders, paddies, furrows, rills, corrugations)

Micro – Water is applied through low pressure, low volume discharge devices (drip emitters, line source emitters, micro spray and sprinkler heads, bubblers etc.). These are supplied by small diameter surface or buried pipe, tubing, hose or tape. There is an emitter close to the base of each plant. Water trickles or drips out the emitter and soaks into the ground. Several emitters may be placed around the base of the tree for orchard use. It is a highly efficient system, because water is applied directly to the root zone. Micro irrigation is adaptable to many specialty fruits and vegetables grown in North Carolina and is increasing in acreage each year, replacing many lower efficiency sprinkler systems such as the hand move laterals and traveling gun systems. This is resulting in a water and energy savings along with improved yield quality and quantity.

Subirrigation - Water is made available to the crop root system by upward capillary flow through the soil profile from a controlled water table. In North Carolina this is done through a system of ditches or tile drains. To be successful, the topography must be nearly level and smooth. The upper soil layers must be permeable to permit free and rapid water movement laterally and vertically. The permeable soil must be underlain by relatively impervious soil on which an artificial water table can be built up or it must have a natural high water table. Controlled drainage of organic soils has been the most common use of subsurface irrigation. A series of ditches and water control structures are used to maintain the water table level. If necessary, well water is also pumped into the ditches to fill and maintain the water table during the growing season. This method can also be supplemented with sprinkler or micro irrigation.

Each irrigation method and system has specific site applicability, capability, and limitations. Broad factors that should be considered are:

- crops to be grown
- topography or physical site conditions
- water supply
- climate
- energy available
- chemigation
- operation and management skills
- local support for repairs and parts
- environmental concerns
- soils
- farming equipment
- costs

5c - Site Conditions

Refer to Table NC5-1, Site Conditions to Consider in Selecting an Irrigation Method and System. Additional factors to consider are environmental impacts, Local and State Laws, Water-Use permits, energy for pumping plant, skill level of operators, availability of parts/supplies, and local use or knowledge of the irrigation system.

Table NC5-1: Site conditions to consider in selecting an irrigation method and system

Crop	Soil	Water	Climate
Crops grown & rotation	AWC	Quality	Wind
Water requirement	Infiltration rate	salts, toxic elements	Rainfall
Height	Depth	sediment	Frost conditions
Cultural practices	to water table	organic materials	Humidity
Pests	to impervious layer	fish, aquatic creatures	Temperature extremes
Tolerance to spray	Drainage	Quantity	Rainfall frequency
Toxicity limitations	surface	Reliability	Evaporation from:
Allowable MAD level	subsurface	Source	plant leaves and stems
Climate Control	Condition	stream	soil surface
frost protection	Uniformity	reservoir	Solar radiation
cooling	Stoniness	well	
Diseases & Control	Slope (s)	delivery point	
Crop quality	Surface texture	Delivery schedule	
Planned yield	Profile textures	frequency	
	Structure	duration	
	Fertility	rate	
	Temporal properties		

5d - Selection of Irrigation Method and System

The grower will often have in mind a system which has particular interest for their location. This would be a starting point, but the designer must keep an open mind and inform the grower of other suitable irrigation systems. It is the responsibility of the designer to advise the grower of the associated pros and cons of systems which could be adapted to the grower's specific site. The final decision is usually made by the grower in consultation with the designer. There are various factors that must be considered when selecting an irrigation method and system. Primary concerns in North Carolina include available water supply, field size/shape/slope, adaptability to the crops grown, cost effectiveness of the system, level of management, and labor requirements.

Local water-use restrictions, regulatory standards and criteria for irrigation efficiency, or maximum water losses may strongly influence the selection of one or two specific irrigation systems so that water is applied without excessive negative impacts on local water quantity and quality. The fact that the best planned, designed, and installed system can still be grossly mismanaged must also be recognized. Availability of irrigation equipment replacement parts, repair service, skilled labor for system operation, and irrigation water availability and timing must be considered. A system commonly used by neighboring farms can have an advantage due to the local store of knowledge in the use, setup, and maintenance of an irrigation system.

Minimizing total annual operating energy requirements should be a basic part of the decision-making process. Any over-applications of irrigation water will have an associated pumping cost as well as the lost nutrients that can be leached from the soil. Irrigation scheduling methods and soil moisture monitoring are crucial to keeping irrigation water losses to a minimum with most irrigation systems.

Table NC5-2 displays the estimated typical life and annual maintenance for irrigation system components. See NRCS NEH Part 652, Irrigation Guide, Chapter 11, Economic Evaluations, for additional information on developing and comparing typical capital and operating costs for selected irrigation systems.

In some circumstances, it could be advantageous and cost effective to have two different irrigation systems for the same fields. Where ample water is available during the early part of the growing season, but becomes deficient during the peak water use period, either a surface flood (i.e. borders) or subirrigation system could be used in the spring and a sprinkler system used during peak water use. Several benefits can be realized with both irrigation methods:

- Reduced energy use compared to pumping the full flow for the full season
- Maximized water use efficiency during the peak water use period
- Reduced drainage losses for the sprinkler irrigation system when combined with controlled drainage in porous sandy type soils

Sprinkler irrigation systems are adaptable for use on most crops and on nearly all irrigable soils. Particular care is needed in the design and operation of a sprinkler system with low application rates (0.15 to 0.25 in/hr) and on soils (generally fine textured) with low infiltration rates. Principal concerns with low application rates are time of set, increased system cost, acceptable distribution uniformity, wind drift, evaporation, and system operational requirements.

For example, with an application rate of 0.15 inch per hour, time of set would have to be nearly 10 hours to apply a net irrigation application of 1 inch. It is recommended that sprinkler systems apply water at a rate greater than 0.15 inch per hour for improved wind resistance. In areas of high temperature, wind, or both, minimum application rate and volume should be higher because of potential losses from evaporation and wind drift. For frost control, where evaporation and wind drift potential are low, an application rate of 0.10 to 0.15 inch per hour is common. See NRCS NEH, Section 15, Chapter 11, Sprinkle Irrigation for more information.

Most irrigation application methods and systems can be automated to some degree. The amount of automation may be an important factor to some growers. More easily automated are micro systems, center pivot sprinkler systems, solid set sprinkler systems, level furrow and basin systems, graded border systems, subsurface systems, and graded furrow systems using automated ditch turnouts, cutback, cablegation, and surge techniques.

Table NC5-3 shows recommended slope limitations for surface and sprinkler irrigation systems. Note that these slope recommendations are guidelines, but no irrigation system should have any surface runoff. Surface runoff can become an issue on long slopes and/or tight soils even on shallow grades of less than five percent. The irrigation system designer will insure that no or very minimal surface runoff occurs.

Table NC5-2: Typical life and annual maintenance cost percentage for irrigation system components

System and components	Life (yr)	Annual maint. (% of cost)	System and components	Life (yr)	Annual maint. (% of cost)
Sprinkler systems	10 - 15	2 - 6	**Surface & subsurface systems**	15	5
Handmove	15 +	2			
Side or wheel roll	15 +	2	**Related components**		
End tow	10 +	3	Pipelines		
Side move w/drag lines	15 +	4	buried thermoplastic	25 +	1
Stationary gun type	15 +	2	buried steel	25	1
Center pivot—standard	15 +	5	surface aluminum	20 +	2
Linear move	15 +	6	surface thermoplastic	5 +	4
Cable tow	10 +	6	buried nonreinforced concrete	25 +	1
Hose pull	15 +	6	buried galv. steel	25 +	1
Traveling gun type	10 +	6	buried corrugated metal	25 +	1
Fixed or solid set			buried reinforced PMP	25 +	1
permanent	20 +	1	gated pipe, rigid, surface	10 +	2
portable	15 +	2	surge valves	10 +	6
Sprinkler gear driven, impact & spray heads	5 - 10	6			
			Pumps		
Valves	10 - 25	3	pump only	15 +	3
			w/electric motors	10 +	3
Micro systems 1/	1 - 20	2 - 10	w/internal combustion engine	10 +	6
Drip	5 - 10	3			
Spray	5 - 10	3	Wells	25 +	1
Bubbler	15 +	2	Linings		
Semi-rigid, buried	10 - 20	2	nonreinforced concrete	15 +	5
Semi-rigid, surface	10	2	flexible membrane	10	5
Flexible, thin wall, buried	10	2	reinforced concrete	20 +	1
Flexible, thin wall, surface	1 - 5	10			
Drip Tape, surface	1 - 2				
Emitters & heads	5 - 10	6	Land grading, leveling	2/	
Filters, injectors, valves	10 +	7	Reservoirs	3/	

1/ With no disturbance from tillage and harvest equipment.
2/ Indefinite with adequate maintenance.
3/ Indefinite with adequate maintenance of structures, watershed.

Table NC5-3: Slope limitations for sprinkler irrigation systems

Type	Max Slope (%) 1/	Comments
Periodic move/set		Laterals should be laid cross slope to minimize and control pressure variation. Consider using pressure or flow control regulators in the mainline, lateral, or individual sprinkler spray heads, when pressure differential causes an increase of > 20 % of design operating pressure.
portable handmove	20+/-	
sideroll - wheel mounted	10	
gun type	20+/-	
end tow	5-10	
Fixed (solid) set		
permanent laterals	no limit	
portable laterals	no limit	
gun type	no-limit	
Continuous move		
center pivot	15	
linear move	15	
gun type	20+/-	
LEPA		
center pivot	1.0	
linear	1.0	
LPIC		
center pivot	2.5	
linear	2.5	

1/ Regardless of type of sprinkler irrigation system used, runoff and resulting soil erosion becomes more hazardous on steeper slopes. Proper conservation measures should be used; i.e., conservation tillage, crop residue use, filter strips, pitting, damming-diking, terraces, or permanent vegetation.

5e - Adaptability and Limitations of Irrigation Methods and Systems

A properly designed irrigation system will be well adapted to the specific field/farm for the planned crops, cropping system, local weather, and the on-farm resources that are available to the grower. Each irrigation system has its strengths and weaknesses. When the right system is selected, it performs as the grower would expect and satisfies the intended irrigation duties with a minimum of repairs and low maintenance. A very important aspect to most growers is that it also have a positive cost versus benefits ratio, as it will probably be viewed as a business investment. Also refer to NRCS NEH Part 652, Irrigation Guide, Chapter 5, Selecting an Irrigation Method, for more information on the adaptability and limitations of irrigation systems. Following is a listing of generalized characteristics for some of the irrigation systems that may be encountered in North Carolina.

Sprinkler Systems

Solid Set, Permanent

- Adaptable to irregular fields and rolling terrain
- Low labor requirement
- Allows for light applications at frequent intervals
- Adaptable to irrigating blueberries, brambles, container nursery, orchards, and trees
- Entire system can be operated at one time for frost control and crop cooling at low application rates < 0.15 in/hr
- Easily automated
- High initial cost versus hand move laterals systems
- Wind drift and evaporation problems with low application rates < 0.15 in/hr

Solid Set, Portable

- Somewhat low labor requirement when the pipe is not moved while in the field
- Adaptable to irregular fields and rolling terrain
- Allows for light applications at frequent intervals
- Adaptable for high value crops such as strawberries, tomatoes, vegetables, and nursery stock
- Can be used to germinate crops that will later be drip irrigated
- Entire system can be operated at one time for frost control and crop cooling at low application rates < 0.15 in/hr
- High initial cost of needing sufficient lateral pipe and sprinklers to cover the entire field
- Wind drift and evaporation problems with low application rates < 0.15 in/hr
- Not easily automated
- Efficiency is lower than permanently installed solid set due to leaky pipe connections and runoff
- Caution must be taken during tillage and harvest operations to prevent damage to pipeline, risers and sprinkler heads

Hand Move Lateral

- Adaptable to irrigating vegetable, orchard, berries, and potatoes
- Lowest initial cost
- Adaptable to irregular fields and rolling terrain
- Lower efficiency than solid set.
- Highest labor requirement

Side or Wheel Roll

- Adaptable to irrigating cotton, peanuts, soybeans, potatoes, vegetables, field crops, and alfalfa hay
- Low labor requirement
- Higher initial costs and maintenance costs then hand move laterals
- Field must be rectangular
- Not adapted to tall crops
- Topography must be flat or gently rolling

Center Pivot

- High uniformity and high efficiency with low volume and low pressure nozzles on drops
- Adaptable for irrigating corn, cotton, peanuts, soybeans, potatoes, vegetables, field crops, and alfalfa hay
- Easily automated
- Low labor requirement
- High initial cost
- Irrigates circular area and corners with end guns or corner arms
- High application rates at the outer end may cause runoff and erosion problems
- Drive wheels may cause ruts in some soils
- Requires uniform topography with slopes <10%

Linear Move

- Adaptable for irrigating corn, cotton, peanuts, soybeans, potatoes, vegetables, field crops, and alfalfa hay
- Easily automated
- Can irrigate an entire field
- Uniform water application
- Requires rectangular fields
- Higher labor then a center pivot but less then a hand move system
- Requires uniform topography with slopes <10%.

Traveling Gun

- Adaptable for irrigating corn, cotton, peanuts, soybeans, potatoes, vegetables, alfalfa and field crops
- Adaptable to irregular shaped fields
- Moderate costs
- Less labor than hand move laterals
- Require high operating pressures and high power pumping units
- Towpaths are required in the crop
- Wind seriously affects the distribution pattern, causing non-cropped areas to be wetted
- Low efficiency due to high evaporation and runoff potential

Microirrigation

- Highest potential application efficiency-low runoff and evaporation losses
- Highest design distribution uniformity
- Spoon feeding directly to root zone
- High yields and excellent quality
- Low water use enables small water supplies to be utilized. However, higher production capacity of Microirrigation may reduce or negate any water supply reductions.

- Requires 50% of the water needed for an overhead system
- Low pumping costs due to low pressure and flow requirements
- Pipe network can be smaller than high pressure/flow systems and therefore less costly
- Disease control is high since leaves are not wetted
- Ability to fertigate through system resulting in less fertilizer applied
- Extensive automation is possible
- Field operations can continue while irrigating
- Adaptable to irregular shaped fields
- Entire system can be operated at one time
- High degree of filtration and pressure regulation required
- High maintenance requirement
- High management input
- Requires good quality water supply and properly designed filtration system to prevent emitter clogging
- May require water treatment through chlorination to kill algae, bacteria, or precipitate iron out of water supply
- Rodent and insect damage to plastic tape/hose can be a problem
- Not adaptable to frost protection
- Initial investment and annual costs are higher than some other methods

<u>Point Source Drip Emitter</u>

- Adaptable for irrigating orchards, berries, and vineyards
- With pressure compensation, can be operated on undulating topography and odd shaped fields
- Application uniformity not affected by wind

<u>Line Source Tape</u>

- Best adaptable to irrigating fresh vegetables and row crops
- Application uniformity not affected by wind
- Not suitable on steep or undulating topography
- Tape life is usually 1-2 years

<u>Micro Spray/Sprinkler</u>

- Adaptable for irrigating orchards, nursery trees and container stock
- Provides frost control in orchards with new applications in vineyard and small fruit
- Application uniformity can be affected by wind
- Higher evaporation losses

<u>Subsurface Irrigation</u>

<u>Open Ditches and/or Drainlines with Water-Level Control Structures</u>

- Topography must be level or slopes very gentle and uniform
- Adaptable to soils with low available water holding capacity and high intake rates
- Soil must have either a natural high water table or impermeable layer in the substratum
- Low installation and operating costs, especially if a drainage system is already present
- Easily integrated with other irrigation systems
- Low labor and management inputs
- Sudden heavy rains during the irrigation mode may flood the crop root zone
- Problems with creating and maintaining a level water table throughout the field

Chapter 6 (NEH 652.0605) North Carolina NRCS Irrigation Guide Supplement - Irrigation System Design

6a - General

A properly designed irrigation system should have uniform irrigation application in a timely manner while minimizing losses and damage to soil, water, air, plant, and animal resources. The design of a conservation irrigation system matches soil and water characteristics with water application rates to assure that water is applied in the amount needed at the right time and at a rate at which the soil can absorb the water without runoff. Physical characteristics of the area to be irrigated must be considered in locating the lines and spacing the sprinklers or emitters, and in selecting the type of irrigation system. The location of the water supply, capacity, and the source of water will affect the size of the pipelines, irrigation system flow rates, and the size and type of pumping plant to be used. The power unit selected will be determined by the overall pumping requirements and the energy source available.

Key points in designing an irrigation system include:

- The irrigation system must be able to deliver and apply the amount of water needed to meet the crop-water requirement.
- Application rates must not exceed the maximum allowable infiltration rate for the soil type. Excess application rates will result in water loss, soil erosion, and possible surface sealing. As a result, there may be inadequate moisture in the root zone after irrigation, and the crop could be damaged. Application rates for many traveler, center pivot, and linear move irrigation systems exceed soil intake rates and is an ongoing concern for North Carolina irrigators. This should be addressed in the irrigation system design so as to reduce or eliminate impacts from using one of these irrigation systems
- Flow rates must be known for proper design and management.
- Soil textures, available soil water holding capacity, and crop rooting depth must be known for planning and designing system application rates, irrigation water management, and scheduling irrigations so that water applied is beneficially used by the crop.
- The water supply, capacity, and quality need to be determined and recorded.
- Climatic data addressed - precipitation, wind velocity, temperature, and humidity.
- Applied irrigation water should always be considered supplemental to rainfall events.
- Topography and field layout must be recorded.
- Farmer's preferences in irrigation methods, available operation time, farm labor, cultural practices, and management skills must be noted for selecting and planning the type and method of irrigation.
- Irrigate at night if possible, to reduce evaporative losses with sprinkler type systems.
- The irrigation applications should be managed so as to reduce conditions that are favorable to crop disease.

The most opportune time to discuss and review problems and revise management plans that affect design and operation of the irrigation system is during the planning and design phase. Minimum requirements for the design, installation, and performance of irrigation systems should be in accordance with the standards of the Natural Resources Conservation Service (NRCS), the American Society of Agricultural and Biological Engineers (ASABE), and the Irrigation Association. Design standards for irrigation practices are contained in the NRCS National Handbook of Conservation Practices, and Section IV of the Field Office Technical Guide.

Material and equipment used should conform to the standards of the American Society for Testing Materials (ASTM) and the Irrigation Association.

There are many types of irrigation systems used in North Carolina which were not covered in this supplement. The reader is referred to the NRCS NEH Part 652, National Irrigation Guide, Chapter 6, Irrigation System Design, and NRCS NEH, Section 15, chapters 3-9, and 11 for additional information on many types of irrigation systems, including sprinkler.

6b - Sprinkler Irrigation Systems

The preceding Chapter (5) should be used along with this chapter to help the irrigation designer select the sprinkler irrigation system. The three main types of sprinkler systems are classified as fixed, periodic move, and continuous/self move systems.

Fixed Systems include solid set (portable or permanent pipeline). There are enough laterals and sprinklers that none have to be moved to complete an irrigation.

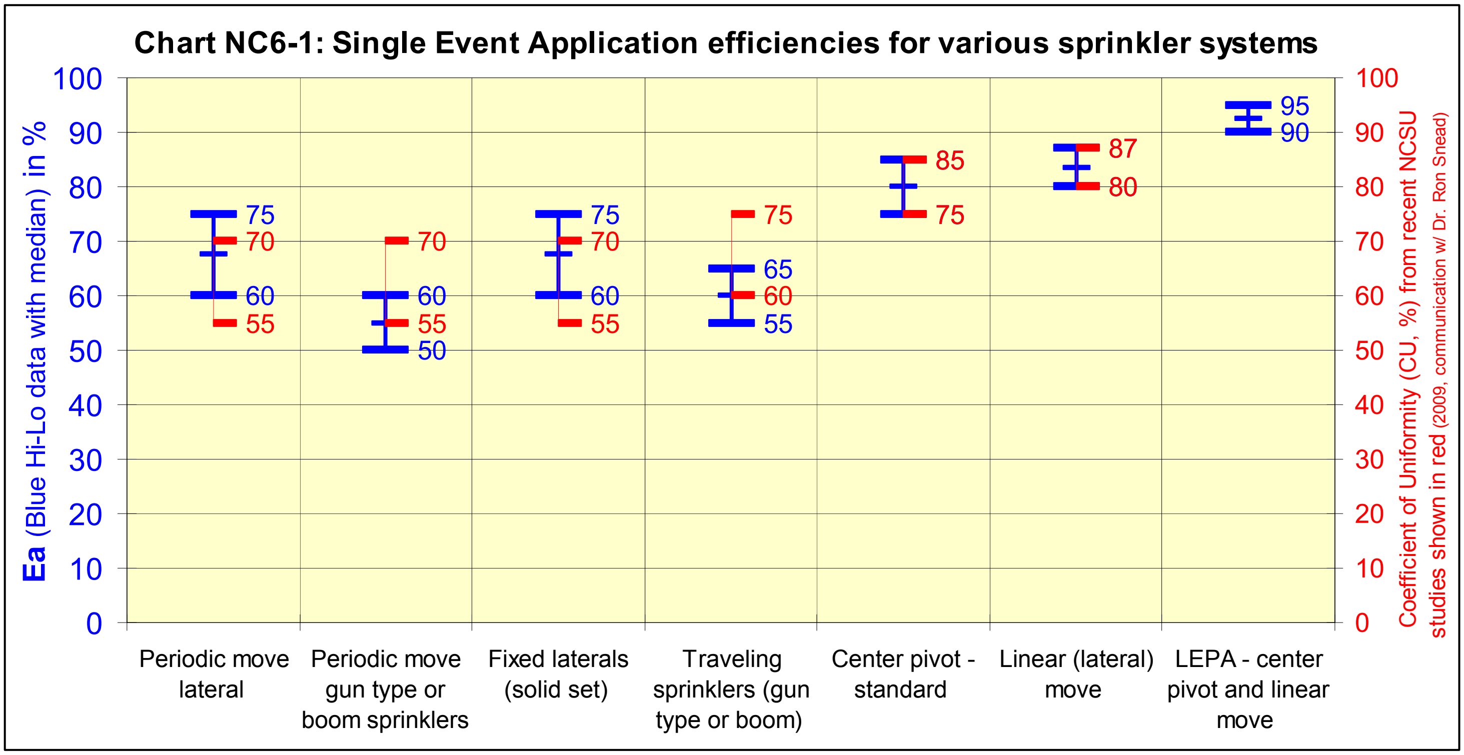
Periodic Move Systems include handmove laterals, side roll laterals, end tow laterals, hose fed (pull) laterals, gun type sprinklers, boom sprinklers, and perforated pipe. Continuous Move/Self Move Systems include center pivots, linear move laterals, and traveling gun sprinklers.

Pressure for sprinkler systems is generally provided by pumping powered mainly by diesel or electric and some gasoline engines. If the system is properly designed and operated, application efficiencies of 50 to 95 percent can be obtained. Application efficiency (Ea) is the percentage of applied irrigation water that is actually stored in the soil rooting zone and is available for transpiration and evaporation. See the NRCS National Engineering Handbook (NEH), Section 15 Irrigation, Chapter 11 Sprinkle Irrigation, for a more complete discussion of Application efficiency (Ea) or the Coefficient of Uniformity (CU). Ea depends on the type of system, cultural practices, and management. Poor management (i.e. irrigating too soon or applying too much water) is the greatest cause of reduced water application efficiency. Refer to Chart NC6-1 (from NEH, Irrigation Guide, Part 652, Table 6-4) for single event Ea values (shown in blue) for various types of sprinkler systems. Season long irrigation application efficiencies typically are lower because of early season plant water requirements and soil intake rate changes. Also shown in Chart NC6-1 (in red) are some observed Christiansen CU (Coefficient of Uniformity) from North Carolina State University irrigation research studies (2009, communication with Dr. Ronald Snead). CU is a parameter that is easily measured in the field and used to evaluate sprinkle irrigation application uniformity

System losses are caused by the following:

- Direct evaporation in the air from the spray, from the soil surface, and from plant leaves that intercept spray water
- Wind drift (normally 5-10 percent losses, depending on temperature, wind speed, and droplet size)
- Leaks and system drainage
- Surface runoff and deep percolation resulting from nonuniform or over application within the sprinkler pattern

If the system is designed to apply water at less than the maximum soil infiltration rate, no runoff losses should occur. With some systems where water is applied below or within the crop canopy, wind drift and most evaporation losses are reduced.



On sloping sites where soils have a low to medium intake rate, runoff often occurs under center pivot systems, especially at the outer end of the sprinkler lateral.

Planning and design considerations and guidelines should be referenced to NRCS NEH, Section 15, Chapter 11, Sprinkle Irrigation. Operating pressures for these guidelines are grouped as follows:

- Low Pressure 2-35 psi
- Moderate Pressure 35-50 psi
- Medium Pressure 50-75 psi
- High Pressure 75+ psi

Some design generalizations and considerations for the three main types of sprinkler systems (1-fixed, 2-periodic move, and 3-continuous/self move) are as follows:

6b1 - Fixed - Solid Set Sprinkler Systems

Solid set sprinkler systems consist of either an above ground portable pipe system (aluminum pipe) or a permanently buried system (plastic pipe). Solid set systems are placed in the field at the start of the irrigation season and left in place throughout the entire crop season. A portable solid set system can be moved to a different field at the end of a particular crop season. A permanent solid set system consists of mainlines and laterals (mostly plastic pipe) buried below the depth of normal field operations. Only the sprinklers and a portion of the risers are above the ground surface.

To irrigate the field, one or more zones of sprinklers are cycled on or off with a control valve at the mainline. Opening and closing of valves can be manual, programmed electronically, or timer clock controlled. Solid set systems can be easily automated. Application efficiencies can be 60 - 85 percent (60 -75% is typical, Chart NC6-1), depending on design and management.

In addition to applying irrigation water, these systems are used to apply water for environmental control, such as frost protection, crop cooling, humidity control, bud delay, crop quality improvement, dust control, and chemical application.

A diamond or triangular pattern for sprinkler head layout is recommended for solid set systems, thereby improving application uniformity.

6b2 - Periodic Move Sprinkler Systems

A periodic move sprinkler system is set in a fixed location for a specified length of time to apply a required depth of water. This is known as the irrigation set time. After an irrigation set, the lateral or sprinkler is moved to the next set position. Application efficiencies can range from 50 - 75 percent.

Hand Move Lateral Systems

Hand move portable aluminum lateral systems are common for vegetable, orchard, and field crops. Aluminum laterals are moved by hand between irrigation sets. Lateral sections are typically 20, 30, or 40 feet long. The mains may be portable above ground or permanent buried mains. Riser height must be based on the maximum height of the crop to be grown. Minimum height is generally 6 inches, and risers over 4 feet in height must be anchored or stabilized. Lateral size is generally either 3 inch or 4 inch. Due to the ease of carrying from one set to the next, 3 inch is often preferred. However for long lateral lines, 4 inch aluminum should be used to keep velocity under 5 feet per second and maintain pressure losses below 20 percent of the design pressure. Hand move lateral systems have the lowest initial cost, have the highest labor requirement, and are easily adapted to irregular fields. Application efficiencies are generally 60 - 75 percent with proper management.

Side Roll System

A side roll system is similar to a hand move system except that the wheels are mounted on the lateral. The lateral pipe serves as an axle to assist in moving the system sideways by rotation to the next set. Each pipe section is supported by a large diameter wheel (at least 3 ft) generally located at the center, but can be at the end. Wheel diameters should be selected so that the lateral clears the crop. A flexible hose or telescoping section of pipe is required at the beginning of each lateral to connect on to the mainline outlet valves. Rigid couplers permit the entire lateral, up to 1/4 mile long, to be rolled forward by applying power at the center or the end while the lateral pipe remains in a nearly straight line. Normally, the drive unit contains a gasoline engine and a transmission with a reverse gear. Self righting or vertical self aligning sprinkler heads are used because the sprinkler head is always upright. Without the self aligning heads, extra care must be taken so that the pipe rotation is fully complete for the full length of the lateral, and all sprinkler heads are upright. Poor distribution uniformity results if the sprinkler heads are not upright. Lateral diameters of 4 or 5 inches are most common and sprinkler head spacing 30 or 40 feet. Laterals can be up to 1600 feet long with one power unit. Quick drain valves are installed at several locations on each lateral to assist line drainage before it is moved since the lateral moves much easier when it is empty. Minimum operating pressure must not drop below 24 psi for drains to properly close and seal. Empty laterals must be anchored to prevent movement by wind. Side roll systems have a low labor requirement, but they have higher initial and maintenance costs than hand move lateral systems. They irrigate a rectangular area. They are not adapted to tall crops. Topography must be flat or gently rolling. With proper management, application efficiencies can be 60 - 75 percent.

Gun Type Sprinkler (Stationary)

Large, periodic move, gun type sprinklers are operated as a large single impact type sprinkler head. The sprinkler is moved from one set to the next either by hand or a small tractor depending on the size or whether they are towable. Generally only one sprinkler is operated per lateral. Lateral lines are usually aluminum pipe with quick-coupled joints. Nozzle sizes are large and generally 0.5 to 1.75 inches. Operating pressures can range from 50 to 120 psi with flow rates at 50 to 500 gallons per minute or more. When irrigating, the sprinkler is allowed to remain at one location (set) until the desired amount of water is applied. Application rates can be very high and uniformity of application can be adversely affected with wind speed greater then 4 mph. Droplet size will be large beyond 50 feet of the sprinkler, resulting in soil puddling and damage to sensitive crops. With proper management application efficiency can be 50 - 60 percent.

6b3 - Continuous (Self) Move Sprinkler System

Center-Pivot Systems

Center pivot systems consist of a single lateral supported by towers with one end anchored to a fixed pivot structure and the other end continuously moving around the pivot point while applying water. This system irrigates a circular field unless end guns and swing lines are cycled on in corner areas to irrigate more of a square field. The water is supplied from the source to the lateral through the pivot. The lateral pipe with sprinklers is supported on drive units. The drive units are normally powered by hydraulic water drives or electric motors. Various operating pressures and configurations of sprinkler heads or nozzles (types and spacing) are located along the lateral. Sprinkler heads with nozzles may be high or low pressure impact, gear driven, or one of many low pressure spray heads. A higher discharge, part circle gun is generally used at the extreme end (end gun), of the lateral to irrigate the outer fringe of the lateral. Each tower, which is generally mounted on rubber tires, has a power device designed to propel the system around the pivot point. The most common power units include electric motor and hydraulic oil drive. Towers are spaced from 80 to 250 feet apart, with lateral lengths up to one half mile. Long spans require a substantial truss or cable to support the lateral pipe in place.

When feasible, agricultural operators are converting from portable sprinkler systems and travelers to install center pivot systems. Many improvements have been made over the years. This includes the corner arm system. Some models contain an added swing lateral unit that expands to reach the corners of a field and retracts to a trailing position when the system is along the field edge. When the corner unit starts, discharge flow in all other heads is reduced. Overall field distribution uniformity is affected with the corner arm. Typically 85% of maintenance is spent maintaining the corner arm unit itself. Due to less than adequate maintenance in corner systems operating all the time, total field application uniformity is reduced even further. Many techniques have been developed to reduce energy used, lower system flow capacities, and maximize water use efficiency. These include using Low Energy Precision Application (LEPA) and Low Pressure In-Canopy (LPIC) systems. LEPA systems (precision application) require adequate (implemented) soil, water and plant management. LPIC systems are used on lower value crops where localized water translocation is acceptable, (30 feet ahead of or behind the lateral position). Water is applied within the crop canopy through drop tubes fitted with low pressure 5 - 10 psi application devices near the ground surface. Good soil and water management are required to obtain application efficiencies in the high 80's. LPIC systems are not suitable for use on low intake soils. With proper management, application efficiencies for center pivot systems can be 75 - 95 percent depending on wind speed/direction, sprinkler type, operating pressure, and tillage practices.

Linear Move Sprinkler System

A linear move sprinkle system is a continuous, self moving, straight lateral that irrigates a rectangular field. It is similar to the center pivot in that the lateral is supported by trusses, cables, and towers mounted on wheels. Most linear move systems are driven by electric motors located in each tower, but some use hydraulic drive. A self aligning system is used to maintain near straight line uniform travel. One tower is the master control tower for the lateral where the speed is set, and all other towers operate in start-stop mode to maintain alignment. A small cable mounted 12 to 18 inches above the ground surface along one edge or the center of the field guides the master control tower across the field. Other methods of guidance are below ground buried cable or furrow.

Linear move systems can be equipped with a variety of sprinkle or spray heads. Drop tubes and low pressure spray heads located a few inches above the ground surface or crop canopy can be used instead of sprinkler heads attached directly to the lateral. The low pressure sprinkle heads on drop tubes conserve water and energy. Linear move systems are similar to center pivot as they are also used as LEPA and LPIC. With these methods surface storage (residue or small basins) must be available throughout the irrigation season to prevent runoff due to the high application rates.

With proper management, application efficiencies are similar to the center pivot system. Linear move systems are high cost and are generally used on medium to high value crops and multiple crop production areas.

Traveling Gun Sprinkler

The traveling gun sprinkler system uses a gun-type high capacity, single-nozzle sprinkler that is fed with water from a flexible hose which is either dragged on the soil surface or wound on a reel. The gun is mounted on wheels and travels along a straight line while operating. The flexible hose is usually 2.5 to 5 inches in diameter and up to 1320 feet long. Smaller traveling guns with 1 to 1.25 inch hoses that are up to 200 feet long are being used for small areas such as sporting fields or landscaping. The self-propelled traveling gun is most popular in the eastern US where fields tend to be smaller and growers need labor saving, mechanical-move portable irrigation systems

There are two general types of self-propelled traveling gun sprinklers. These are: 1) cable-tow traveler and 2) the hose-drag traveler sometimes referred to as the hose-pull or drum traveler. The cable-tow traveler was very popular for a few years, but it has been largely replaced by the hose-drag traveler. (excerpts in the above two paragraphs from: Robert Evans and R. E. Snead, 1996, NC Coop Ext Pub #:EBAE-91-150, "Selection and Management of Efficient Self-Propelled Gun Traveler Irrigation Systems", Note: see this publication for more information).

With a traveling gun system, the gun is mounted on a 2 to 4-wheel chassis and is pulled along selected travel lanes by a cable or the hose wrapping on a rotating reel. The reel or winch can be powered by a water turbine, water piston, or engine drive and reels in the anchored cable or hose through the field in a straight line.

Application depth is regulated by the speed at which the hose or cable reel is operated or by the speed of the self-contained power unit. As the traveler moves along its path, the sprinkler wets a strip of land that is generally 200 to 400 feet wide. After the unit reaches the end of the travel path, it is moved and set to water an adjacent strip of land. The overlap of adjacent strips depends on the distance between the travel paths, wetted diameter of sprinkler, average wind speed, and application pattern of the sprinkler. After one travel path (towpath) is completed, the sprinkler is reset by towing it to the edge of the field. Refer to Figure NC6-1 for typical traveling gun system layout.

Sprinkler discharge flows can range from 50 to more then 1,000 gallons per minute (gpm) for the USA. However, it would be rare to find a system in North Carolina that is near the 1,000 gpm discharge rate given the smaller cropping field sizes found in North Carolina (as compared to field sizes found in the Midwest). The nozzles generally range from 0.5 to 1.75 inches in diameter with operating pressure from 60 to 120 psi.

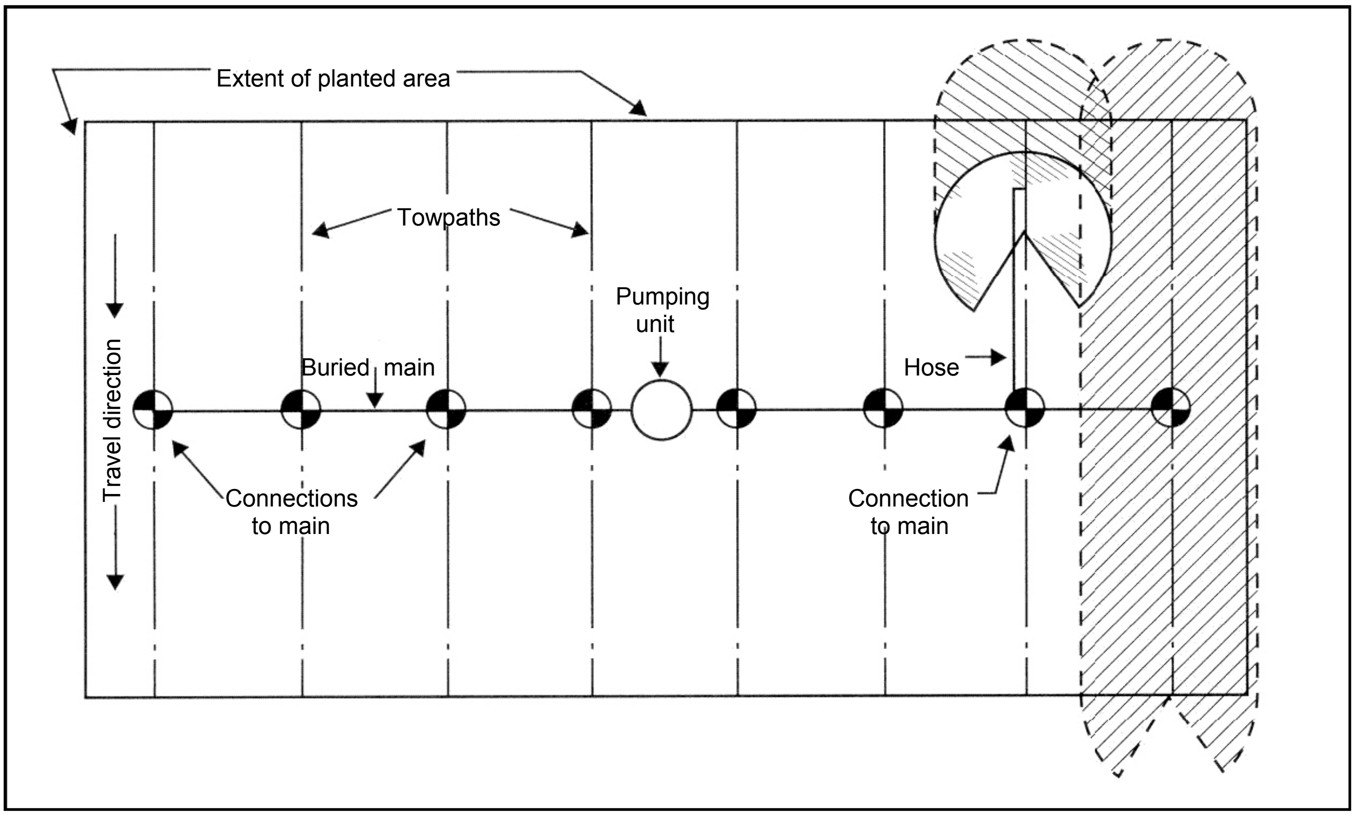


Figure NC6-1 Traveling gun type sprinkler system layout

Traveling Boom Sprinkler Systems

A traveling boom system is similar to a traveling gun except several nozzles are used. These systems have higher distribution uniformity than traveling guns for the same diameter of coverage. They do provide options when a grower prefers a lower volume and pressure systems to reduce the high energy costs associated with a traveling gun system. The boom can be designed with low pressure and low flow nozzles that operate at higher efficiency and uniformity.

The traveling boom usually is rotated by back pressure from fixed nozzles, or may be fixed. It is typically moved by a self-contained continuously moving power unit by dragging or coiling the water feed hose on a reel. A boom can be nearly 100 feet long with uniformly spaced nozzles that overlap (similar to a linear move lateral).

6c - Sprinkler Irrigation System Capacity

The sprinkler irrigation system capacity is generally defined as the peak or maximum flow rates that will be sustained in the main supply line to the irrigation system that will meet the maximum crop demand period. A pump of some sort is usually driving the water into the main supply line at a given flow rate which will meet sprinkler design pressure and flow needs. The sprinkler irrigation system capacity shall be sufficient to supply the peak flows and volume of water required to meet the peak-period consumptive use of the crop or crops to be irrigated. There should be adequate well flow capacity, stream flow, or pond storage to supply both the peak flow and total volume needs of the growing crop to be irrigated in a timely manor.

The required capacity of a sprinkle irrigation system depends on the size of the area irrigated, gross depth of water to be applied at each irrigation, and the operating time allowed to apply the water. See NRCS NEH, Section 15, Chapter 2, Irrigation Water Requirements, for further details regarding crop water needs. The required capacity of a sprinkle system can be computed by:

$$Q = \frac{453\ A\ d}{f\ T} \qquad \text{or} \qquad Q = \frac{453\ A\ d'}{T}$$

where:
Q = system capacity (gpm)
A = area irrigated (acres)
d = gross depth of application (inches)
f = time allowed for completion of one irrigation (days)
T = actual operating time per day (hours per day) to cover entire area
d' = gross daily water use rate (inches per day) - may be peak or average, depending on need and risks to be taken.

Note: This equation represents the basic irrigation equation QT = DA with conversion factors for sprinkler irrigation design. Typically, tables readily available by NRCS and manufacturers pertaining to sprinkler heads, pipe friction losses, and pump curves are in units of gallons per minute (gpm) rather than cubic feet per second, cubic meters per second, or liters per minute.

6d - Sprinkler Irrigation System Design

The irrigation system designer is urged to contact NRCS Field Office personnel, and consult the reference NRCS Field Office Technical Guide, for information and guidance on the desired irrigation system. Chapter 4, Water Requirements, and Table NC4-1, should be reviewed to insure an adequate irrigation water supply is available. Uniformity coefficients should be used in selecting sprinkler spacing, nozzle sizes, and operating pressures. Lateral lines should be designed so that variation in sprinkler head pressures does not exceed 20 percent of the design operating pressure or 10 percent of the design flow of the sprinklers, respectively.

There are wastewater irrigation design parameter worksheets which were distributed (1995) for North Carolina that may be helpful to communicate specific irrigation information between NRCS Field Office personnel and the irrigation system designer/supplier. These worksheets are given in Appendix B and can also be used with non-wastewater irrigation systems.

Irrigation designs are very field specific, but generalities can be made by region to help in simplifying the design process. For example, soils and landscape position can be used to form Irrigation Soil Management Groups (ISMG). Each ISMG can then be represented by one general soil profile which can then be used to make good approximations for soil moisture storage in the irrigation system planning process. Additionally, it was noted that the mountains region is very different in soils and weather from that of the other regions in North Carolina.

The state was divided into two sprinkler irrigation management areas for general design purposes as follows:

1. Coastal Plain and Piedmont regions (includes Sandhills and Barrier Islands)
2. Mountain region

The recommended peak moisture use rate was adjusted to 0.02 inches per day less for all crops in the Mountain region as compared to the same crop in the Coastal Plain and Piedmont regions. The two sprinkler irrigation management regions will each have a set of ISMG's and design tables that are specific to that region. Table NC6-1 contains Mountain ISMG's and Table NC6-2 contains Piedmont and Coastal Plain Soil ISMG's. Tables NC6-1 and NC6-2 also contain the Hydrologic Soil Group (HSG) and the Sprinkler Irrigation use limitations for each Soil Series. Determination of the Soil Series name for the irrigated field is discussed earlier in Chapter 2 of this document. Hydrologic Soil Groups are based on the most restrictive soil layer in the rooting zone with regards to infiltration water transmission in a downward direction. HSG's range from A to D, with A having a high infiltration capacity (ex. sand or gravel soil texture), and D having a low infiltration capacity (ex. clay soil texture, hardpans or swamp). Please refer to other NRCS documents (NRCS NEH Part 630, Chapter 7, Hydrology) if a more complete definition of HSG's are needed. Soil Series limitations for use with a Sprinkler Irrigation System is also given. Soil Series limitations noted here are general in nature and not site specific. They are taken from the NRCS soil series descriptions and are an indicator of possible issues for a specific site. The limitations shown are generally the most restrictive, but are not considered to be complete, due to table space limitations. See Table NC2-4 for a listing of Irrigation Restrictive Feature limits that are used in assigning Soil Series limitations. An on-site visit must be made to assess these, and any other site-specific limitations, which should be addressed in the Irrigation System design process. Additionally, the most current NRCS county soil survey data should be reviewed for a complete listing of soil properties and limitations. Note that the NRCS Soil Survey should not be used in lieu of on-site soil testing for soil properties. The irrigation system designer is responsible for the determination of all soil limitations through on-site evaluations and testing. The information provided here and elsewhere (Web Soil Survey, etc.) is to be viewed only as supplemental to actual on-site or in-field data.

Table NC6-1: Mountain Soils with Irrigation Soil Management Groups (ISMG)			
Series Name	**Hydrologic Soil Group**	**Limitations / Notes for use with Sprinkler Irrigation System**	**Group Index No.**
Alarka	D	Mostly Forested, organic surface mat	3
Anakeesta	B	Slope, Erosion, Soil Creep, Mostly Forested	NR
Arkaqua	C	Moderate permeability in subsoil	3
Ashe	B	Slope, Erosion, Soil Creep, Mostly Forested	NR
Balsam	A	Slope, Erosion, Mostly Forested	NR
Bandana	B	Moderately Rapid Permeability in A and B horizons	3
Biltmore	A	Slope, Erosion, Mostly Forested	1
Braddock	B	Slope, Erosion, slow permeability in subsoil	8
Bradson	B	Slope, Erosion	8
Brasstown	B	Slope, Erosion, Soil Creep, Mostly Forested	NR
Breakneck	B	Slope, Erosion, Soil Creep, Mostly Forested	NR
Brevard	B	Slope, Erosion, Mostly Forested	8
Brownwood	B	Slope, Erosion, Mostly Forested	NR
Buladean	B	Slope, Erosion, Soil Creep, Mostly Forested	NR
Burton	B	Slope, Erosion, Soil Creep, Mostly Forested	NR
Calvin	C	Slope, erosion on steeper land	2
Cashiers	B	Slope, Erosion, Soil Creep, Mostly Forested	NR
Cataloochee	B	Slope, Erosion, Soil Creep, Mostly Forested	NR
Cataska	D	Slope, Erosion, Soil Creep, Mostly Forested	NR
Chandler	A	Slope, Erosion, Soil Creep, Mostly Forested	NR
Cheoah	B	Slope, Erosion, Soil Creep, Mostly Forested	NR
Chester	B	Medium runoff, high saturated hydraulic conductivity	2
Chestnut	B	Slope, Erosion, Soil Creep, Mostly Forested	NR
Chestoa	B	Slope, Erosion, Soil Creep, Mostly Forested	NR
Chiltoskie	B	Slope, Erosion, Mostly Forested	2
Chute	D	Rapid Permeability	5
Cleveland	C	Slope, Erosion, Soil Creep, Mostly Forested	NR
Cliffield	B	Slope, Erosion, Soil Creep, Mostly Forested	8
Clifton	B	Slope, Erosion, slow permeability in subsoil	7
Clingman	D	Organic deposits, Forested, Saturated short periods	NR
Colvard	A	Occasional flooding, moderately rapid permeability	1
Cowee	B	Slope, Erosion, Soil Creep, Mostly Forested	NR
Craggey	D	Slope, Erosion, Soil Creep, Mostly Forested	NR
Crossnore	B	Slope, Erosion, Soil Creep, Mostly Forested	NR
Cruso	A	Mostly Forested, Rapid Ksat	12
Cullasaja	A	Slope, Erosion, Forested	NR
Cullowhee	B/D	Moderately Rapid Permeability in A and B horizons	3
Dellwood	A	Flooding, Moderately Rapid Permeability in A	1
Dillard	C	Slope, erosion, high water table in Winter & Spring	8
Dillsboro	B	Slope, Erosion, Seeps	8
Ditney	C	Slope, Erosion, Mostly Forested	NR
Edneytown	B	Slope, Erosion, Soil Creep, Mostly Forested	7
Edneyville	A	Slope, Erosion, Soil Creep, Mostly Forested	2
Ela	B/D	Occasional flooding, ponding, water table	12
Ellijay	B	Slope, Erosion, Mostly Forested	8
Elsinboro	B	Moderate permeability	5
Eutrochrepts	B		1
Evard	B	Slope, Erosion, Soil Creep, Mostly Forested	7

Table NC6-1: Mountain Soils with Irrigation Soil Management Groups (ISMG)			
Series Name	**Hydrologic Soil Group**	**Limitations / Notes for use with Sprinkler Irrigation System**	**Group Index No.**
Fannin	B	Slope, Erosion, Soil Creep, Mostly Forested	7
Fletcher	B	Medium runoff, Moderate Permeability	7
Fluvaquents	D		1
Fontaflora	A	Flooding	1
French	C	High water table, flooding	3
Greenlee	A	Slope, Erosion, Mostly Forested	NR
Guyot	B	Slope, Erosion, Soil Creep, Mostly Forested	NR
Harmiller	B	Slope, Erosion, Soil Creep, Mostly Forested	NR
Hayesville	B	Slope, Erosion	8
Heintooga	A	Slope, Erosion, Mostly Forested	8
Hemphill	D	Rare Flooding, high WT, slow permeability	9
Horsetrough	-	Narrow units next to drainageways, Forested	12
Huntdale	B	Slope, Erosion, Soil Creep, Mostly Forested	NR
Iotla	B	Flooding, Moderately rapid permeability	3
Jeffrey	B	Slope, Erosion, Soil Creep, Mostly Forested	NR
Junaluska	B	Slope, Erosion, Soil Creep, Mostly Forested	7
Kanuga	B	Moderately slow permeability	8
Keener	B	Slope, Erosion, Mostly Forested	NR
Kinkora	D	Drainage, high water table, low saturated hydraulic cond.	9
Lauada	B	Slope, Erosion, Soil Creep, Mostly Forested	7
Leatherwood	B	Slope, Erosion, Soil Creep, Mostly Forested	7
Longhope	D	Organic Soil, Drainage, High Water table,	11
Lonon	B	Slope, Erosion >60% Wooded(Pasture, Christmas Trees)	8
Lostcove	B	Slope, Erosion, Mostly Forested	8
Luftee	B	Slope, Erosion, Soil Creep, Mostly Forested	NR
Mars Hill	B	Slope, Erosion, Most acreage in pasture	2
Maymead	A	Slope, Erosion, Mostly Forested	2
Micaville	B	Slope, Erosion, Soil Creep, Mostly Forested	NR
Nantahala	B	Slope, Erosion, Mostly Forested	7
Nikwasi	B/D	Ponding, Wetness, Flooding, Need drainage	12
Northcove	A	Slope, Erosion, Cobbles, Low AWC	2
Nowhere	B	Slope, Erosion, Mostly Forested	12
Oconaluftee	A	Slope, Erosion, Soil Creep, Mostly Forested	NR
Ostin	A	Flooding	6
Oteen	C	Slope, Erosion, Mostly pasture, Depth to Bedrock, Low AWC	7
Peregrine	Not rated		
Pigeonroost	B	Slope, Erosion, Soil Creep, Mostly Forested	2
Pilot Mountain	B	Slope, Erosion, Mostly Forested, Cobbly	8
Pineola		Slope, Erosion, Mostly Forested	2
Pits	Not rated		NR
Plott	A	Slope, Erosion, Soil Creep, Mostly Forested	NR
Porters	B	Slope, Erosion, Soil Creep, Mostly Forested	10
Potomac		Mod to rapid permeability, Boulders, Low AWC, Freq Flooding	1
Pullback	D	Slope, Erosion, Soil Creep, Mostly Forested	2
Rabun		Slope, erosion, rapid runoff	8
Reddies	B	Flooding, moderately rapid permeability in A and B horizons	1
Rock outcrop	D		

Table NC6-1: Mountain Soils with Irrigation Soil Management Groups (ISMG)			
Series Name	**Hydrologic Soil Group**	**Limitations / Notes for use with Sprinkler Irrigation System**	**Group Index No.**
Rosman	A	Flooding, moderately rapid permeability	10
Rubble land	A		
Saluda	C	Slope, Erosion, Mostly Forested	7
Santeetlah	A	Slope, Erosion, Mostly Forested	5
Saunook	B	Slope, High saturated conductivity, seeps and springs	8
Sauratown	B	Slope, Erosion, Runoff, Mostly Forested	2
Shinbone	B	Slope, Erosion, Mostly Forested	2
Smokemont	A	Flooding, moderately to rapid permeability	1
Snowbird	B	Slope, Erosion, Soil Creep, Mostly Forested	NR
Soco	B	Slope, Erosion, Soil Creep, Mostly Forested	NR
Spivey	A	Slope, Erosion, Mostly Forested	NR
Statler	B	Slow to medium runoff	8
Stecoah	B	Slope, Erosion, Soil Creep, Mostly Forested	NR
Suches	B	Moderate permeability	6
Swannanoa	C	Drainage, SHWT spring, surface runoff	9
Sylco	C	Slope, Erosion, Soil Creep, Mostly Forested	NR
Sylva	A/D	Drainage, moderately rapid permeability	9
Tanasee	A	Slope, Erosion, Mostly Forested	5
Tate	B	Slope, erosion, moderate permeability in subsoil	10
Thunder	B	Slope, erosion, some areas in pasture	8
Thurmont	B	Slope, erosion, Runoff, moderate permeability in subsoil	5
Toecane	A	Slope, Erosion, Mostly Forested	5
Toxaway	B/D	Drainage, Frequent Flooding	11
Transylvania	B	Common flooding	10
Trimont	B	Slope, Erosion, Soil Creep, Mostly Forested	NR
Tsali	C	Slope, Erosion, Soil Creep, Mostly Forested	7
Tuckasegee	A	Slope, Erosion	8
Tusquitee	B	Slope, Erosion	10
Udifluvents	A		1
Udorthents	B		1
Unaka	B	Slope, Erosion, Mostly Forested	2
Unicoi	C	Slope, Erosion, Soil Creep, Mostly Forested	7
Unison	B	Slope, Erosion, Rapid Runoff	5
Walnut	B	Slope, Erosion, Mostly Pasture	2
Watauga	B	Slope, Erosion	7
Wayah	B	Slope, Erosion, Mostly Forested	2
Wesser	B/D	Drainage, High water table	11
Whiteoak	B	Slope, Moderate permeability	8
Whiteside	B	Slope, Moderate permeability	4
Zillicoa	C	Runoff, Erosion, Primarily Hay Production	8
NR – this soil was not rated and may not be suitable for irrigation			

Table NC6-2: Piedmont and Coastal Plain Soils with Irrigation Soil Management Groups (ISMG)			
Soil Series Name	**Hydrologic Soil Group**	**Limitations / Notes for use with Sprinkler Irrigation System**	**Group Index No.**
Acredale	C/D	Depth to Sat zone, Drained, Seepage, Slow water Mvmt	19
Ailey	B	Low AWC, Slow water Mvmt	7
Alaga	A	Low AWC, Seepage, Slope	16
Alamance	B	Depth to soft bedrock, Depth to Sat zone, Slope	NR
Alpin	A	Low AWC, Seepage, Slope	16
Altavista	C	Depth to Sat zone, Seepage	6
Appling	B	Slope, Too acid	4
Arapahoe	B/D	Drained, Depth to Sat zone, Too acid	22
Argent	D	Drained, Depth to Sat zone, Slow water Mvmt	23
Armenia	D	Freq flooded, Slow water mvmt, Depth to Sat zone	NR
Ashlar	B	Slope, Depth to bedrock, Low AWC	15
Augusta	C	Depth to Sat zone, Seepage	10
Autryville	A	Seepage, Low AWC	7
Aycock	B	Slope	13
Ayersville	B	Slope, Depth to restrictive layer, Low AWC	NR
Backbay	D	Tidal Marshes, Freq flooded	NR
Badin	B	Slope, Depth to restrictive layer, Low AWC	NR
Ballahack	B/D	Drained, Depth to Sat zone, Flooding	22
Banister	C	Slope, Slow water mvmt, Too acid	11
Bannertown	B	Slope, Depth to bedrock, Low AWC	15
Barclay	C	Depth to Sat zone, Drainage	10
Bayboro	D	Drained, Depth to Sat zone, Slow water Mvmt	24
Baymeade	A	Low AWC, Seepage, Slope	7
Beaches	D	Low AWC, Freq flooded, Excess Sodium	NR
Belhaven	D	Drained, Depth to Sat zone, Too acid	25
Bertie	C	Depth to Sat zone, Seepage, Too acid	10
Bethera	D	Drained, Depth to Sat zone, Slow water Mvmt	23
Bethlehem	B	Slope, Low AWC, Depth to restrictive layer	NR
Bibb	D	Depth to Sat zone, Freq flooded, Seepage	19
Bladen	D	Drained, Depth to Sat zone, Slow water Mvmt	23
Blaney	B	Low AWC, Seepage, Slope	7
Blanton	A	Low AWC, Seepage, Slope	16
Bohicket	D	Excess Sodium, Freq flooded, Low AWC	NR
Bojac	A	Low AWC, Seepage	6
Bolling	C	Depth to Sat zone, Seepage	6
Bonneau	A	Seepage, Slope	7
Bragg	C	Modified soil, Cut and Fill	NR
Brickhaven	C	Slope, Low AWC, Depth to restrictive layer	NR
Brookman	D	Drained, Depth to Sat zone, Slow water Mvmt	24
Buncombe	A	Freq flooded, Low AWC, Slope	16
Butters	B	Low AWC, Seepage	16
Byars	D	Drained, Depth to Sat zone, Slow water Mvmt	24
Cainhoy	A	Low AWC, Seepage, Slope	16
Callison	C	Slope, Depth to Sat zone, Depth to restrictive layer	11
Candor	A	Slope, Low AWC, Seepage	7

Table NC6-2: Piedmont and Coastal Plain Soils with Irrigation Soil Management Groups (ISMG)			
Soil Series Name	**Hydrologic Soil Group**	**Limitations / Notes for use with Sprinkler Irrigation System**	**Group Index No.**
Cape Fear	C/D	Drained, Depth to Sat zone, Slow water Mvmt	24
Cape Lookout	C/D	Drained, Depth to Sat zone, Slow water Mvmt, Too acid	24
Carbonton	C	Slope, Low AWC, Depth to restrictive layer	NR
Caroline	C	Seepage, Too acid, Slope	8
Carteret	D	Depth to Sat zone, Excess Sodium, Low AWC & Freq flooding	NR
Cecil	B	Slope	3
Centenary	A	Low AWC, Seepage	16
Chapanoke	C/D	Drained	10
Charleston	B	Low AWC, Seepage	7
Chastain	D	Depth to Sat zone, Ponding & Freq flooding, Seepage	21
Chenneby	C	Freq flooded, Depth to Sat zone, Too acid	21
Chesapeake	B	Too Acid, Seepage, Low AWC	6
Chewacla	C	Freq flooded, Depth to Sat zone, Too acid	21
Chipley	B	Depth to Sat zone, Low AWC, Seepage	16
Chowan	D	Depth to Sat zone, Freq flooding, Seepage	NR
Cid	C	Depth to Sat zone, Depth to restrictive layer, Low AWC	NR
Claycreek	C	Slow Water Mvmt, Depth to Sat zone, Slope	11
Clifford	B	Slope, Too acid	3
Cliffside	B	Slope	NR
Codorus	C	Freq flooded, Depth to Sat zone	21
Colfax	C	Freq flooded, Depth to Sat zone, Slope	21
Conaby	B/D	Drained, Depth to Sat zone, Too acid	25
Conetoe	A	Too Acid, Seepage	7
Congaree	C	Freq flooded, Too acid	1
Corolla	A/D	Low AWC, Excess salt and sodium, Depth to Sat zone	NR
Coronaca	B	Slope, Water Erosion	2
Cowarts	C	Seepage, Slope	5
Coxville	D	Drained, Depth to Sat zone, Seepage	23
Craven	C	Slope, Depth to Sat zone, Too acid & Slow water mvmt	14
Creedmoor	C	Slope, Depth to Sat zone, Slow Water Mvmt	11
Croatan	C/D	Depth to Sat zone, Too acid, Drained	25
Cullen	C	Slope, Slow Water Mvmt	3
Currituck	D	Freq flooded, Depth to Sat zone, Too acid	NR
Dare	D	Drained, Too acid	25
Davidson	B	Slope, Water Erosion	2
Deloss	B/D	Depth to Sat zone, Drainage	20
Delway	D	Freq Flooding, Depth to Sat zone, Excess salt and sodium	NR
Devotion	C	Slope, Depth to restrictive layer, Low AWC	5
Dogue	C	Slow Water Mvmt, Too acid, Depth to Sat zone	14
Dorovan	D	Drained, Too acid, Depth to Sat zone	NR
Dothan	B	Seepage, Slope	6
Dragston	C	Drained, Depth to Sat zone, Seepage	17
Duckston	A/D	Low AWC, Excess salt and sodium, Depth to Sat zone	NR
Dumps	Not rated	Variable site conditions, Generally unsuitable for crops and Irr.	NR
Dunbar	C/D	Drained, Depth to Sat zone, Seepage	9

Table NC6-2: Piedmont and Coastal Plain Soils with Irrigation Soil Management Groups (ISMG)			
Soil Series Name	**Hydrologic Soil Group**	**Limitations / Notes for use with Sprinkler Irrigation System**	**Group Index No.**
Dune land	A	Low AWC, Seepage	NR
Duplin	C	Depth to Sat zone, Seepage	8
Durham	B	Seepage, Slope	5
Echaw	A	Low AWC, Seepage, Too acid	16
Emporia	C	Low AWC, Too acid	6
Engelhard	B/D	Drained, Depth to Sat zone, Frequently Flooded	19
Enon	C	Slope, Water Erosion	12
Exum	C	Depth to Sat zone, Too acid	13
Exway	B	Slope, Low AWC	12
Faceville	B	Slope, Seepage	8
Fairview	B	Slope	3
Foreston	B	Seepage, Low AWC	17
Fork	C	Occasional Flooding, Depth to Sat zone	10
Fortescue	C/D	Depth to Sat zone, Too acid, Drained	20
Fripp	A	Low AWC, Seepage, Slope	NR
Fuquay	B	Low AWC, Seepage, Slow water Mvmt	7
Gaston	B	Slope	3
Georgeville	B	Slope, Water Erosion	2
Gertie	D	Drained, Depth to Sat zone, Slow water Mvmt	23
Gilead	C	Slope, Depth to Sat zone, Seepage	14
Goldsboro	B	Depth to Sat zone, Seepage, Too acid	6
Goldston	C	Depth to bedrock, Low AWC, Slope	15
Grantham	D	Drained, Depth to Sat zone, Too acid	19
Granville	B	Slope, Seepage	5
Green Level	D	Slope, Slow water Mvmt	11
Grifton	D	Depth to Sat zone, Frequently Flooded	19
Gritney	C	Slope, Slow water Mvmt	14
Grover	B	Slope	NR
Gullied land	D	Slope, Eroded topsoil, Water Erosion issue must be addressed	NR
Gullrock	C/D	Drained, Depth to Sat zone, Too acid	25
Gwinnett	B	Slope	3
Hallison	C	Slope	11
Hatboro	B/D	Drained, Frequently Flooded, Depth to Sat Zone	21
Helena	C	Depth to Sat zone, Slow water Mvmt, Slope	11
Herndon	B	Slope, Slow water Mvmt, Too acid	2
Hibriten	B	Slope, Cobbles	NR
Hiwassee	B	Slope, Water Erosion	2
Hobonny	D	Frequently Flooded, Depth to Sat Zone, Too acid	NR
Hobucken	D	Frequently Flooded, Depth to Sat Zone, Excess salt and sodium	NR
Hornsboro	D	Drainage, Excess salt and sodium, Depth to Sat zone	14
Hulett	B	Slope	4
Hyde	C/D	Drained, Depth to Sat zone, Too acid	20
Hydeland	C/D	Drained, Depth to Sat zone, Slow water Mvmt	20
Icaria	B/D	Drained, Depth to Sat zone, Seepage	20
Invershiel	C	Depth to Sat zone, Slow water Mvmt	6

Table NC6-2: Piedmont and Coastal Plain Soils with Irrigation Soil Management Groups (ISMG)			
Soil Series Name	**Hydrologic Soil Group**	**Limitations / Notes for use with Sprinkler Irrigation System**	**Group Index No.**
Iredell	C/D	Drained, Depth to Sat zone, Slow water Mvmt	12
Johns	C	Depth to Sat zone, Seepage	9
Johnston	D	Drained, Depth to Sat zone, Frequently Flooded	21
Kalmia	B	Low AWC, Seepage, Too acid	6
Kenansville	A	Low AWC, Seepage	7
Kinston	B/D	Drained, Depth to Sat zone	21
Kirksey	C	Slope, Too acid, Depth to bedrock	11
Kureb	A	Slope, Low AWC, Seepage	16
Lakeland	A	Low AWC, Seepage, Slope	16
Leaf	D	Drained, Depth to Sat zone, Slow water Mvmt	23
Leaksville	D	Depth to Sat zone, Depth to bedrock, Low AWC	21
Lenoir	D	Drained, Depth to Sat zone, Slow water Mvmt	14
Leon	B/D	Depth to Sat zone, Low AWC, Drainage, Seepage	18
Liddell	B/D	Drained, Depth to Sat zone, Too acid	19
Lignum	C	Slope, Depth to Sat zone, Slow water Mvmt	12
Lillington	B	Slope, Low AWC	7
Lloyd	B	Slope, Too acid, Depth to bedrock	3
Longshoal	D	Frequently Flooded, Depth to Sat Zone, Excess salt and sodium	NR
Louisa	B	Slope, Depth to bedrock, Low AWC	NR
Louisburg	B	Slope, Depth to bedrock, Low AWC	15
Lucy	A	Seepage, Slope, Low AWC	7
Lumbee	B/D	Depth to Sat zone, Low AWC, Drained	19
Lynchburg	C	Depth to Sat zone, Seepage	10
Lynn Haven	B/D	Depth to Sat zone, Too acid, Drained	18
Madison	B	Slope, Too acid	3
Mandarin	B	Low AWC, Depth to Sat zone, Too acid	18
Mantachie	B/D	Frequently Flooded, Depth to Sat zone, Drained	19
Marlboro	B	Seepage, Slope, Too acid	8
Marvyn	B	Slope, Seepage	6
Masada	C	Slope, Too acid	4
Masontown	D	Drained, Depth to Sat zone, Flooding	22
Mattaponi	C	Slope, Too acid	11
Maxton	B	Seepage, Low AWC	6
Mayodan	B	Slope, Water Erosion, Seepage	4
McColl	D	Depth to Sat zone, Low AWC, Drained	23
McQueen	C	Slope, Slow water Mvmt	3
Meadowfield	B	Slope, Gravelly, Depth to bedrock	NR
Mecklenburg	C	Slope, Slow water Mvmt	2
Meggett	D	Drained, Depth to Sat zone, Slow water Mvmt	23
Merry Oaks	D	Depth to Sat zone, Too acid	21
Misenheimer	C	Slope, Depth to bedrock, Low AWC	15
Mocksville	B	Slope	5
Monacan	C	Freq flooded, Depth to Sat zone	21
Moncure	D	Freq flooded, Depth to Sat zone, Slow water Mvmt	21
Montonia	B	Slope, Depth to bedrock	NR

Table NC6-2: Piedmont and Coastal Plain Soils with Irrigation Soil Management Groups (ISMG)			
Soil Series Name	**Hydrologic Soil Group**	**Limitations / Notes for use with Sprinkler Irrigation System**	**Group Index No.**
Mooshaunee	C	Slope, Too acid	11
Muckalee	D	Depth to Sat zone, Frequently Flooded, Low AWC	NR
Munden	B	Slope, Too acid, Seepage	6
Murville	A/D	Depth to Sat zone, Drained, Seepage, Freq ponded	18
Myatt	B/D	Depth to Sat zone, Too acid, Drained	19
Nahunta	C	Drained, Depth to Sat zone, Too acid	10
Nakina	B/D	Drained, Depth to Sat zone, Seepage	20
Nanford	B	Slope, Too acid	3
Nankin	C	Slope, Too acid, Slow water Mvmt	8
Nason	B	Slope, Water Erosion, Depth to bedrock	3
Nawney	D	Freq flooded, Depth to Sat zone, Too acid	21
Neeses	C	Slope, Too acid	NR
Newhan	A	Low AWC, Seepage, Slope	NR
Newholland	B/D	Drained, Depth to Sat zone, Too acid	22
Nimmo	B/D	Drained, Depth to Sat zone, Too acid	19
Nixonton	C	Seepage, Too acid	13
Noboco	B	Seepage, Too acid, Low AWC	6
Norfolk	B	Seepage, Too acid	6
Oakboro	C	Depth to bedrock, Frequently Flooded	21
Ocilla	C	Depth to Sat zone, Low AWC, Seepage	17
Onslow	B	Depth to Sat zone, Seepage	6
Orange	D	Slope, Depth to Sat zone, Depth to bedrock	11
Orangeburg	B	Slope, Low AWC, Seepage	6
Osier	A/D	Drained, Frequently Flooded, Low AWC	16
Ousley	B	Depth to Sat zone, Low AWC, Too acid	16
Pacolet	B	Slope, Seepage, Water Erosion	3
Pactolus	B	Low AWC, Depth to Sat zone, Seepage	16
Pamlico	D	Drained, Depth to Sat zone, Too acid	25
Pantego	B/D	Drained, Depth to Sat zone	20
Pasquotank	B/D	Drained	19
Paxville	B/D	Drained, Depth to Sat zone, Too acid	20
Peakin	B	Slope, Too acid	4
Peawick	D	Slope, Slow water Mvmt, Too acid	11
Pelion	B/D	Slope, Drained, Slow water Mvmt, Too acid	8
Pender	C	Low AWC, Seepage, Too acid	17
Perquimans	C/D	Drained, Depth to Sat zone, Reduced Application rate	19
Pettigrew	D	Drained, Depth to Sat zone, Root zone restriction	25
Picture	D	Ponding, Slow water Mvmt, Depth to bedrock	21
Pinkston	B	Slope, Depth to bedrock, Low AWC	15
Pinoka	B	Slope, Depth to bedrock, Low AWC	15
Pittsboro	D	Slope, Depth to Sat zone, Depth to bedrock	11
Plummer	A/D	Drained, Depth to Sat zone, Low AWC	18
Pocalla	A	Seepage, Too acid, Low AWC	7
Poindexter	B	Slope, Depth to bedrock	5
Polawana	A/D	Drained, Depth to Sat zone, Ponding	20

Table NC6-2: Piedmont and Coastal Plain Soils with Irrigation Soil Management Groups (ISMG)			
Soil Series Name	**Hydrologic Soil Group**	**Limitations / Notes for use with Sprinkler Irrigation System**	**Group Index No.**
Polkton	D	Slope, Slow water Mvmt, Depth to bedrock	11
Ponzer	D	Drained, Depth to Sat zone, Too acid	25
Portsmouth	B/D	Drained, Depth to Sat zone, Root zone restriction	20
Pungo	D	Drained, Depth to Sat zone, Too acid	25
Rains	B/D	Drained, Depth to Sat zone	19
Redbrush	C	Slope, Depth to bedrock, Low AWC	12
Rhodhiss	B	Slope	5
Rimini	A	Low AWC, Too acid	NR
Rion	B	Slope, Too acid	5
Riverview	B	Frequently Flooded	1
Roanoke	C/D	Depth to Sat zone, Occasional flooding, Too acid, Drained	23
Roper	C/D	Drained, Depth to Sat zone, Too acid	25
Rumford	B	Low AWC, Too acid, Slope	6
Ruston	B	Slope, Low AWC, Seepage	6
Rutlege	B/D	Drained, Depth to Sat zone, Low AWC	18
Saw	B	Slope, Slow water Mvmt	3
Scuppernong	D	Drained, Depth to Sat zone, Too acid	25
Seabrook	B	Seepage, Low AWC, Depth to Sat zone	16
Seagate	B	Seepage, Low AWC, Depth to Sat zone	18
Secrest	C	Slope, Slow water Mvmt	11
Sedgefield	C	Depth to Sat zone, Slow water Mvmt, Slope	11
Seewee	B	Seepage, Low AWC, Depth to Sat zone	18
Shellbluff	B	Occasional flooding	1
Siloam	D	Slope, Depth to bedrock	12
Skyuka	B	Slope	2
Spray	B	Too Acid, Depth to bedrock	2
Stallings	C	Drained, Depth to Sat zone, Too acid	17
Starr	B	Slope, Water Erosion, Seepage	1
State	B	Too Acid, Seepage	6
Stockade	B/D	Drained, Depth to Sat zone, Frequently Flooded	20
Stoneville	B	Slope, Slow water Mvmt, Too acid	2
Stott Knob	B	Slope, Depth to bedrock, Too acid	5
Suffolk	B	Slope, Seepage	6
Tallapoosa	C	Slope, Depth to bedrock, Low AWC	15
Tarboro	A	Low AWC, Seepage, Slope	16
Tarrus	B	Slope, Depth to bedrock, Too acid	2
Tatum	B	Slope, Low AWC, Depth to bedrock	3
Tetotum	C	Depth to Sat zone, Too acid, Seepage	13
Thursa	B	Seepage, Slope, Low AWC	6
Toast	B	Slope, Depth to bedrock, Too acid	3
Toccoa	B	Occasional flooding	1
Toisnot	D	Occasional flooding, Depth to Sat zone, Fragipan	18
Tomahawk	B	Depth to Sat zone, Low AWC	7
Tomotley	B/D	Drained, Depth to Sat zone, Too acid	19
Torhunta	C	Depth to Sat zone, Low AWC	20

Table NC6-2: Piedmont and Coastal Plain Soils with Irrigation Soil Management Groups (ISMG)			
Soil Series Name	**Hydrologic Soil Group**	**Limitations / Notes for use with Sprinkler Irrigation System**	**Group Index No.**
Troup	A	Low AWC, Seepage	16
Turbeville	C	Slope, Seepage, Water Erosion	8
Uchee	A	Seepage, Slope, Low AWC	7
Uwharrie	B	Slope, Large boulders, Too acid	3
Valhalla	A	Seepage, Low AWC	7
Vance	C	Slow Water Mvmt, Seepage, Slope	11
Varina	C	Slow Water Mvmt, Seepage, Low AWC	8
Vaucluse	C	Seepage, Slope, Low AWC	7
Wadesboro	B	Slope, Depth to bedrock, Excess salt and sodium	3
Wagram	A	Low AWC, Slope, Seepage	7
Wahee	C/D	Drained, Depth to Sat zone, Slow water Mvmt	14
Wake	D	Slope, Depth to bedrock, Low AWC	15
Wakulla	A	Seepage, Low AWC, Slope	16
Wando	A	Seepage, Low AWC, Slope	16
Wasda	B/D	Drained, Depth to Sat zone, Too acid	25
Wateree	B	Slope, Low AWC, Seepage	15
Wedowee	B	Slope, Seepage, Water Erosion	4
Weeksville	B/D	Drained, Depth to Sat zone	20
Wehadkee	D	Drained, Depth to Sat zone, Frequently Flooded	21
Westfield	B	Slope, Gravel	3
White Store	D	Depth to Sat zone, Slow water Mvmt, Slope	12
Wickham	B	Seepage, Slope	6
Wilbanks	D	Depth to Sat zone, Frequently Flooded, Slow water Mvmt	24
Wilkes	D	Depth to bedrock, Slope, Low AWC	15
Winnsboro	C	Slope, Slow water Mvmt	2
Winton	C	Slope, Depth to Sat zone, Too acid	NR
Woodington	B/D	Drained, Depth to Sat zone	19
Woolwine	B	Slope, Gravel & Cobbles, Depth to bedrock	3
Worsham	D	Drained, Depth to Sat zone, Slow water Mvmt	21
Wrightsboro	C	Depth to Sat zone, Seepage, Too Acid	6
Wynott	C	Depth to bedrock, Slope, Slow water Mvmt	12
Wysocking	B/D	Drained, Depth to Sat zone, Too acid	19
Yaupon	D	Slow Water Mvmt, Excess salt and sodium	NR
Yeopim	C	Depth to Sat zone, Too acid	13
Yonges	C/D	Drained, Depth to Sat zone, Some Flooding	19
Zion	C	Depth to bedrock, Slope, Slow water Mvmt	12

NR – this soil was not rated and may not be suitable for irrigation

Tables NC6-3 and NC6-4 present irrigation system General Design Parameters, given the Irrigation Soil Management Group (ISMG) and Crop, for the Mountain and Piedmont/Coastal Plains regions of North Carolina. These tables use average expected conditions to estimate the irrigation system needs for planning purposes. Assumptions are stated and should be adjusted to actual system parameters and on-site data for a final design. For example, the ISMG uses a representative soil profile to stand for the entire group with similar soils and landscape position. The irrigation system designer should use an actual field soil profile to determine the AWC in the final design. Note that there will be variations within a field of both soil types and soil layer thicknesses. The challenge to the designer is to identify the most restrictive features in each facet of the design so that crop needs are met without exceeding inflow and storage capacities of the field soils under irrigation. The columns presented in tables NC6-3 and NC6-4 are defined as follows:

Column 1 – Irrigation Soil Management Group (ISMG) Number: Soils having similar physical characteristics for irrigation are grouped together to simplify design and management. This grouping takes into account relevant soil irrigation properties such as depth, texture, water holding capacity, intakes rate, surface condition, and general landscape position. These data are of a general nature for this Soil Management Group. Therefore, data gathered during a site visit should be used to revise and refine the irrigation design.

Column 2 – Soil Type and Description: A brief description of the general soil profile in this group and some representative soil series names.

Column 3 – Average Soil Depth: The average soil depth through which plant roots can penetrate readily in search of sustaining nutrients and moisture. In cases where this depth is less than normal root zone depth for a crop, it becomes a limiting factor in determining the amount of available moisture that can be stored in the soil profile.

Column 4 – Available Water Capacity (AWC): The capacity of the soil profile to hold and store moisture for plant use in inches of water per depth of soil profile. The AWC is expressed as the total amount available at multiple depths in the soil profile beginning at 12 inches and then progressing in six inch increments (i.e. 12", 18", 24" …). Heavier clay soils may hold up to three times the amount of soil moisture per equal depth as compared to a light textured sandy soil. It is important to know the available moisture holding capacity within the rooting zone to determine the correct irrigation application amount. Irrigation efficiency is directly related to both over application and improper timing of irrigation applications. The AWC values used in the table are for a representative soil and are not field specific. Field specific AWC should be determined by soils testing for each irrigated field using a minimum of three sampling areas within the field. More samples would be required for larger fields or fields with multiple soil types and soil properties that vary by a large amount.

Columns 5 and 6 – Recommended Maximum Application Rate: Maximum recommended irrigation application rates are set to insure no surface runoff occurs during irrigation. This amount is based upon the soils group, field tests and observations. Runoff is usually a concern during the last portion of the irrigation cycle when soils are nearing saturation and intake rates are lowest, and thereby control maximum application rates.

Column 7 – Crop: Contains the crops that are most often associated with the soils group which includes landscape position. These crops are not being recommended for irrigation, since this decision should be based on many factors. These are crops that have been found to be economically feasible to irrigate under certain favorable conditions.

Column 8 – Depth of Moisture Replacement: The depth of soil which contains the majority of plant roots that will consume moisture for plant use. This is the soil zone that will be recharged by irrigation and managed to insure the plant available water is adequate to meet the cropping demands.

Column 9 – Moisture to be Replaced by Each Irrigation Cycle: The moisture, in inches of water, which should be replaced into the crop root zone during each irrigation cycle. This amount is used for general planning purposes and is one half of the Plant Available Water (PAW). However, in practice, irrigation is often started at moisture levels different from one half PAW. Therefore, the actual application amount should be adjusted for field soil moisture levels to reduce under- and over-watering situations. Irrigation scheduling software can be used to determine the most appropriate amount of soil moisture to be replaced for any given day. Accuracy for PAW determinations can be improved by field specific soils testing data to determine AWC, as noted above.

Column 10 – Design Moisture Use Rate: The average maximum peak moisture use rate (10 to 14 day period, in inches per day) of transpiration by the crop plus evaporation from the soil surface. For most plants the maximum rate of transpiration occurs when the daylight hours are the longest, air temperature is greatest, wind movement is high, humidity is lowest, and the plant has developed a good root system and is in the rapid growth stage.

Column 11 – Irrigation Frequency for the Peak Use Period: The frequency, in days, between planned irrigation cycles for a specific location. This frequency period is derived from the Moisture to be Replaced by each Irrigation (column 9) divided by the Crop Design Moisture Use Rate (column 10). This would be the number of days the designer can allow for completion of one irrigation cycle over the entire design area.

Column 12 – Application Amount: The actual amount of water, in inches, applied by the irrigation system during each irrigation cycle. Sprinkler irrigation systems involve some unavoidable losses due to evaporation from the spray, unequal distribution, and deep percolation. Therefore, more water must be applied than actually becomes available for plant use. The efficiency of a sprinkler irrigation system can vary considerably depending on local conditions, but is considered to be 75 percent for planning purposes in this table. This application amount is derived from the Moisture to be Replaced by each Irrigation (column 9) divided by the irrigation efficiency of 0.75. This amount should be adjusted by the designer if the actual irrigation efficiency is significantly different from this 75 percent value.

Table NC6-3: Mountain Region of North Carolina – General Design Parameters

SOILS						CROPS			IRRIGATION PARAMETERS		
Irr. Soil Mgmt Group #	Soil Type and Description	Average Soil Depth (ft)	Available Water Capacity (in) [1]	Recommended maximum application rate		Crop [2]	Depth of moisture replace-ment (ft)	Moisture to be replaced by each Irrigation (in)	Design peak moisture use rate for crop (in/day)	Irrigation frequency for peak use period (days)	Applica-tion amount (in) [3]
				Bare (in/hr)	Cover (in/hr)						
Col 1	Column 2	Col 3	Column 4	Col 5	Col 6	Column 7	Column 8	Column 9	Col 10	Column 11	Column 12
1	Well drained, first bottom soils with sandy surface layers and loose sandy subsoils.	3.0+	0.8	0.75	0.75	Corn	2.5	1.05	0.20	5	1.40
			1.3			Small Grain or Soybeans	2.0	0.85	0.16	5	1.13
			1.7								
			2.1								
			2.8								
2	Well drained upland soils with loamy surface layers and friable loamy subsoils	2.5	1.0	0.40	0.60	Corn	2.5	1.35	0.20	6	1.80
			1.5			Improved pasture or mixed hay	1.5	0.75	0.22	3	1.00
			2.2			Nursery Crops, 1^{st} year	1.0	0.50	0.14	3	0.67
			2.7			Nursery Crops, 2^{nd} year	2.0	1.10	0.16	7	1.47
						Small Grain or Soybeans	2.0	1.10	0.16	7	1.47
						Orchards, bare	2.5	1.35	0.18	7	1.80
						Orchards, cover	2.5	1.35	0.22	6	1.80
						Tobacco	1.5	0.75	0.16	4	1.00
						Vineyards, cultivated	2.5	1.35	0.16	8	1.80
						Vegetables, Group 1	1.0	0.50	0.12	4	0.67
						Vegetables, Group 2	1.5	0.75	0.12	6	1.00
						Vegetables, Group 3	1.5	0.75	0.16	4	1.00
						Vegetables, Group 4	2.0	1.10	0.16	7	1.47
3	Somewhat poorly drained first bottom soils with loamy surface layers and friable loamy subsoils	3.0+	1.3	0.35	0.45	Corn	2.5	1.65	0.20	8	2.20
			2.0			Gladioli	1.0	0.65	0.12	5	0.87
			2.7			Improved Pasture or mixed hay	1.5	1.00	0.22	4	1.33
			3.3			Small Grain or Soybeans	2.0	1.35	0.16	8	1.80
			4.0			Tobacco	1.5	1.00	0.16	6	1.33
						Vegetables, Group 1	1.0	0.65	0.12	5	0.87
						Vegetables, Group 2	1.5	1.00	0.12	8	1.33
						Vegetables, Group 3	1.5	1.00	0.16	6	1.33
						Vegetables, Group 4	2.0	1.35	0.16	8	1.80
4	Moderately well drained terrace soils with loamy surface layers and firm loamy subsoils.	3.0+	1.3	0.30	0.35	Corn	2.5	2.20	0.20	11	2.93
			2.4			Improved Pasture or mixed hay	1.5	1.20	0.22	5	1.60
			3.4			Small Grain or Soybeans	2.0	1.70	0.16	10	2.27
			4.4			Tobacco	1.5	1.20	0.16	7	1.60
			5.2			Vegetables, Group, 1	1.0	0.65	0.12	5	0.87
						Vegetables, Group, 2	1.5	1.20	0.12	10	1.60
						Vegetables, Group, 3	1.5	1.20	0.16	7	1.60
						Vegetables, Group, 4	2.0	1.70	0.16	10	2.27

Table NC6-3: Mountain Region of North Carolina – General Design Parameters

5	Well drained terrace soils with loamy surface layers and friable loamy subsoils	3.0+	1.3	0.30	0.35	Alfalfa	2.5	2.20	0.22	10	2.93
			2.4			Corn	2.5	2.20	0.20	11	2.93
			3.4			Improved Pasture or mixed hay	1.5	1.20	0.22	5	1.60
			4.4			Small Grain or Soybeans	2.0	1.70	0.16	10	2.27
			5.2			Tobacco	1.5	1.20	0.16	7	1.60
						Vegetables, Group 1	1.0	0.65	0.12	5	0.87
						Vegetables, Group 2	1.5	1.20	0.12	10	1.60
						Vegetables, Group 3	1.5	1.20	0.16	7	1.60
						Vegetables, Group 4	2.0	1.70	0.16	10	2.27
6	Well drained first bottom soils with loamy surface layers and friable loamy subsoils	3.0+	1.3	0.35	0.45	Alfalfa	2.5	1.65	0.22	7	2.20
			2.0			Corn	2.5	1.65	0.20	8	2.20
			2.7			Gladioli	1.0	0.65	0.12	5	0.87
			3.3			Improved Pasture or mixed hay	1.5	1.00	0.22	4	1.33
			4.0			Small Grain or Soybeans	2.0	1.35	0.16	8	1.80
						Tobacco	1.5	1.00	0.16	6	1.33
						Vegetables, Group1	1.0	0.65	0.12	5	0.87
						Vegetables, Group 2	1.5	1.00	0.12	8	1.33
						Vegetables, Group 3	1.5	1.00	0.16	6	1.33
						Vegetables, Group 4	2.0	1.35	0.16	8	1.80
7	Well drained upland soils, with loamy surface layers and friable loamy subsoils.	2.0	1.5	0.40	0.60	Alfalfa	2.0	1.45	0.22	6	1.93
			2.2			Corn	2.0	1.45	0.20	7	1.93
			2.9			Improved Pasture or mixed hay	1.5	1.10	0.22	5	1.47
						Nursery Crops, 1st yr.	1.0	0.75	0.14	5	1.00
						Nursery Crops, 2nd yr.	2.0	1.45	0.16	9	1.93
						Orchards (bare)	2.0	1.45	0.18	8	1.93
						Orchards (cover)	2.0	1.45	0.22	6	1.93
						Irish Potatoes	1.5	1.10	0.18	6	1.47
						Small Grain or Soybeans	2.0	1.45	0.16	9	1.93
						Tobacco	1.5	1.10	0.16	7	1.47
						Vineyards, cultivated	2.0	1.45	0.16	9	1.93
						Vegetables, Group 1	1.0	0.75	0.12	6	1.00
						Vegetables, Group 2	1.5	1.10	0.12	9	1.47
						Vegetables, Group 3	1.5	1.10	0.16	7	1.47
						Vegetables, Group 4	2.0	1.45	0.16	9	1.93
8	Well drained upland and terrace soils, with loamy surface layers and friable to firm clayey subsoils	2.5	1.5	0.40	0.60	Alfalfa	2.5	1.75	0.22	8	2.33
			2.2			Corn	2.5	1.75	0.20	9	2.33
			2.9			Improved Pasture or mixed hay	1.5	1.10	0.22	5	1.47
			3.5			Nursery Crops, 1st yr.	1.0	0.75	0.14	5	1.00
						Nursery Crops, 2nd yr.	2.0	1.45	0.16	9	1.93
						Orchards (bare)	2.5	1.75	0.18	10	2.33
						Orchards (cover)	2.5	1.75	0.22	8	2.33
						Irish Potatoes	1.5	1.10	0.18	6	1.47
						Small Grain or Soybeans	2.0	1.45	0.16	9	1.93
						Tobacco	1.5	1.10	0.16	7	1.47
						Vineyards, cultivated	2.5	1.75	0.16	11	2.33
						Vegetables, Group 1	1.0	0.75	0.12	6	1.00
						Vegetables, Group 2	1.5	1.10	0.12	9	1.47
						Vegetables, Group 3	1.5	1.10	0.16	7	1.47
						Vegetables, Group 4	2.0	1.45	0.16	9	1.93

Table NC6-3: Mountain Region of North Carolina – General Design Parameters

9 [4]	Poorly drained terrace soils with loamy surface layers and firm plastic clayey subsoils.	3.0+	1.6 2.5 3.3 4.2 5.0	0.30	0.35	Improved Pasture or mixed hay Small Grain or Soybeans	1.5 2.0	1.25 1.65	0.22 0.16	6 10	1.67 2.20
10	Well drained upland and terrace soils with loamy surface layers and friable subsoil.	3.0+	1.8 2.6 3.4 4.2 5.0	0.50	0.60	Alfalfa Corn Improved Pasture or mixed hay Nursery Crops, 1st yr. Nursery Crops, 2nd yr. Orchards (bare) Orchards (cover) Irish Potatoes Small Grain or Soybeans Tobacco Vegetables, Group 1 Vegetables, Group 2 Vegetables. Group 3 Vegetables. Group 4	2.5 2.5 1.5 1.0 2.0 3.0 3.0 1.5 2.0 1.5 1.0 1.5 1.5 2.0	2.10 2.10 1.30 0.90 1.70 2.50 2.50 1.30 1.70 1.30 0.90 1.30 1.30 1.70	0.22 0.20 0.22 0.14 0.16 0.18 0.22 0.18 0.16 0.16 0.12 0.12 0.16 0.16	9 10 6 6 10 14 11 7 10 8 7 11 8 10	2.80 2.80 1.73 1.20 2.27 3.33 3.33 1.73 2.27 1.73 1.20 1.73 1.73 2.27
11 [4]	Very poorly drained first bottom soils with loamy surface layers and friable loamy subsoils	3.0+	1.8 2.6 3.4 4.2 5.0	0.50	0.60	Corn Gladioli Improved Pasture or mixed hay Small Grain or Soybeans Vegetables, Group1 Vegetables, Group 2 Vegetables, Group 3 Vegetables, Group 4	2.5 1.0 1.5 2.0 1.0 1.5 1.5 2.0	2.10 0.90 1.30 1.70 0.90 1.30 1.30 1.70	0.20 0.12 0.22 0.16 0.12 0.12 0.16 0.16	10 7 6 10 7 10 8 10	2.80 1.20 1.73 2.27 1.20 1.73 1.73 2.27
12 [4]	Poorly drained first bottom soils with loamy surface layers and friable loamy subsoils.	3.0+	1.5 2.2 2.9 3.6 4.5	0.30	0.35	Improved Pasture or mixed hay	1.5	1.10	0.22	5	1.47

[1] Top figure indicates the available moisture (in inches) for the upper 12 inches of the soil profile. Each additional figure indicates the available moisture for the upper 18, 24, 30, and 36 inches of the soil profile.

[2] Crops are as shown. Vegetable groups are as follows: **Group 1** – kale, lettuce, mustard, onions, spinach, and strawberries; **Group 2** – Beans (snap), beets, broccoli, cabbage, cauliflower, carrots, collard, peas (garden), peppers, turnips, rutabagas**; Group 3** – Beans (lima), cucumbers, tomatoes; **Group 4** – asparagus, cantaloupes, corn (sweet), eggplant, okra, watermelon.

[3] Using a 75 percent irrigation efficiency

[4] For these soils adequate surface and subsurface drainage should be provided. Otherwise a heavy rainfall following an irrigation may cause crop damage.

Table NC6-4: Piedmont and Coastal Plain Regions of North Carolina – General Design Parameters

SOILS						CROPS			IRRIGATION PARAMETERS		
Irr. Soil Mgmt Group #	Soil Type and Description	Average Soil Depth (ft)	Available Water Capacity (in) [1]	Recommended maximum application rate Bare (in/hr)	Recommended maximum application rate Cover (in/hr)	Crop [2]	Depth of moisture replace-ment (ft)	Moisture to be replaced by each Irrigation (in)	Design peak moisture use rate for crop (in/day)	Irrigation frequency for Peak use period (days)	Applica-tion amount (in) [3]
Col 1	Column 2	Col 3	Column 4	Col 5	Col 6	Column 7	Column 8	Column 9	Col 10	Column 11	Col 12
1	Well drained, loamy, alluvial or colluvial soils on first bottoms and upland depressions.	3.0+	1.5	0.30	0.35	Alfalfa	2.5	1.80	0.24	7	2.40
			2.2			Cotton	2.5	1.80	0.20	9	2.40
			2.9			Corn, field	2.5	1.80	0.22	8	2.40
			3.6			Gladioli	1.0	0.75	0.14	5	1.00
			4.5			Ladino clover and grass, Summer perennials or Mixed Hay	1.5	1.10	0.24	4	1.47
						Nursery Crops, 1st year	1.0	0.75	0.16	5	1.00
						Nursery Crops, 2nd year	2.0	1.45	0.18	8	1.93
						Peanuts	2.0	1.45	0.18	8	1.93
						Peas, field	1.5	1.10	0.18	6	1.47
						Irish Potatoes	1.5	1.10	0.20	5	1.47
						Small Grain or Soybeans	2.0	1.45	0.18	8	1.93
						Tobacco	1.5	1.10	0.18	6	1.47
						Vegetables, Group 1	1.0	0.75	0.14	5	1.00
						Vegetables, Group 2	1.5	1.10	0.14	8	1.47
						Vegetables, Group 3	1.5	1.10	0.18	6	1.47
						Vegetables, Group 4	2.0	1.45	0.18	8	1.93
2	Well drained soils of the Piedmont uplands that have loamy surface layers and clayey subsoils.	3.0+	1.7	0.25	0.30	Alfalfa	2.5	2.35	0.24	10	3.13
			2.7			Cotton	2.5	2.35	0.20	12	3.13
			3.7			Corn, field	2.5	2.35	0.22	11	3.13
			4.7			Ladino Clover & Grass, Summer					
			5.5			perennials or Mixed Hay	1.5	1.35	0.24	6	1.80
						Nursery Crops, 1st yr.	1.0	0.85	0.16	5	1.13
						Nursery Crops, 2nd yr.	2.0	1.85	0.18	10	2.47
						Orchards (bare)	3.0	2.75	0.20	14	3.67
						Orchards (cover)	3.0	2.75	0.24	11	3.67
						Peas, field	1.5	1.35	0.18	7	1.80
						Small Grain or Soybeans	2.0	1.85	0.18	10	2.47
						Tobacco	1.5	1.35	0.18	7	1.80

Table NC6-4: Piedmont and Coastal Plain Regions of North Carolina – General Design Parameters

3	Well drained soils of the Piedmont uplands with loamy surface layers and firm clayey subsoils.	3.0	1.4	0.30	0.40	Alfalfa	2.5	2.10	0.24	9	2.80
			2.3			Cotton	2.5	2.10	0.20	10	2.80
			3.3			Corn, field	2.5	2.10	0.22	9	2.80
			4.2			Gladioli	1.0	0.70	0.14	5	0.93
			5.0			Ladino Clover & Grass, Summer perennials or Mixed Hay	1.5	1.15	0.24	5	1.53
						Nursery Crops, 1st yr.	1.0	0.70	0.16	4	0.93
						Nursery Crops, 2nd yr.	2.0	1.65	0.18	9	2.20
						Orchards (bare)	3.0	2.50	0.20	12	3.33
						Orchards (cover)	3.0	2.50	0.24	10	3.33
						Peas, field	1.5	1.15	0.18	6	1.53
						Small Grain or Soybeans	2.0	1.65	0.18	9	2.20
						Vegetables, Group 1	1.0	0.70	0.14	5	0.93
						Tobacco	1.5	1.15	0.18	6	1.53
4	Well drained soils of the Piedmont uplands with sandy surface layers and firm clayey subsoils.	3.0	1.2	0.35	0.45	Alfalfa	2.5	2.00	0.24	8	2.67
			2.1			Cotton	2.5	2.00	0.20	10	2.67
			3.1			Corn, field	2.5	2.00	0.22	9	2.67
			4.0			Gladioli	1.0	0.60	0.14	4	0.80
			4.7			Ladino Clover & Grass, Summer perennials or Mixed Hay	1.5	1.05	0.24	4	1.40
						Nursery Crops, 1st yr.	1.0	0.60	0.16	4	0.80
						Nursery Crops, 2nd yr.	2.0	1.55	0.18	9	2.07
						Orchards (bare)	3.0	2.35	0.20	12	3.13
						Orchards (cover)	3.0	2.35	0.24	10	3.13
						Peanuts	2.0	1.55	0.18	9	2.07
						Peas, field	1.5	1.05	0.18	6	1.40
						Sweet Potatoes	2.0	1.55	0.22	7	2.07
						Small Grain or Soybeans	2.0	1.55	0.18	9	2.07
						Tobacco	1.5	1.05	0.18	6	1.40
						Vegetables, Group 1	1.0	0.60	0.14	4	0.80
						Vegetables, Group 2	1.5	1.05	0.14	7	1.40
						Vegetables, Group 3	1.5	1.05	0.18	6	1.40
						Vegetables, Group 4	2.0	1.55	0.18	9	2.07
5	Well drained soils of the Piedmont uplands with sandy surface layers and friable loamy subsoils.	3.0	1.3	0.40	0.45	Alfalfa	2.5	1.85	0.24	8	2.47
			2.1			Cotton	2.5	1.85	0.20	9	2.47
			2.9			Corn, field	2.5	1.85	0.22	8	2.47
			3.7			Ladino Clover & Grass, Summer perennials or Mixed Hay	1.5	1.05	0.24	4	1.40
			4.4			Nursery Crops, 1st yr.	1.0	0.65	0.16	4	0.87
						Nursery Crops, 2nd yr.	2.0	1.45	0.18	8	1.93
						Orchards (bare)	3.0	2.20	0.20	11	2.93
						Orchards (cover)	3.0	2.20	0.24	9	2.93
						Peas, field	1.5	1.05	0.18	6	1.40
						Small Grain or Soybeans	2.0	1.45	0.18	8	1.93
						Tobacco	1.5	1.05	0.18	6	1.40

Table NC6-4: Piedmont and Coastal Plain Regions of North Carolina – General Design Parameters

6	Well to moderately well drained Coastal Plain and terrace soils with sandy surface layers and friable loamy subsoils.	3.0+	1.1	0.40	0.50	Alfalfa	2.5	1.55	0.24	6	2.07
			1.7			Annual & Perennial Flowers	1.0	0.55	0.14	4	0.73
			2.4			Cotton	2.5	1.55	0.20	8	2.07
			3.1			Gladioli	1.0	0.55	0.14	4	0.73
			3.8			Ladino Clover & Grass, Summer perennials or Mixed Hay	1.5	0.85	0.24	4	1.13
						Nursery Crops, 1st yr.	1.0	0.55	0.16	3	0.73
						Nursery Crops, 2nd yr.	2.0	1.20	0.18	7	1.60
						Orchards (bare)	3.0	1.90	0.20	9	2.53
						Orchards (cover)	3.0	1.90	0.24	8	2.53
						Peanuts	2.0	1.20	0.18	7	1.60
						Peas, field	1.5	0.85	0.18	5	1.13
						Sweet Potatoes	2.0	1.20	0.22	5	1.60
						Small Grain or Soybeans	2.0	1.20	0.18	7	1.60
						Tobacco	1.5	0.85	0.18	5	1.13
						Vineyards, cultivated	3.0	1.90	0.18	10	2.53
						Vegetables, Group 1	1.0	0.55	0.14	4	0.73
						Vegetables, Group 2	1.5	0.85	0.14	6	1.13
						Vegetables, Group 3	1.5	0.85	0.18	5	1.13
						Vegetables, Group 4	2.0	1.20	0.18	7	1.60
7	Well drained Coastal Plain and terrace soils, with thick sandy surface layers and friable loamy subsoils.	3.0+	0.9	0.50	0.60	Alfalfa	2.5	1.20	0.24	5	1.60
			1.3			Annual & Perennial Flowers	1.0	0.45	0.14	3	0.60
			1.8			Cotton	2.5	1.20	0.20	6	1.60
			2.4			Corn, field	2.5	1.20	0.22	5	1.60
			3.0			Gladioli	1.0	0.45	0.14	3	0.60
						Summer Perennials	1.5	0.65	0.24	3	0.87
						Nursery Crops, 1st yr.	1.0	0.45	0.16	3	0.60
						Nursery Crops, 2nd yr.	2.0	0.90	0.18	5	1.20
						Orchards (bare)	3.0	1.50	0.20	7	2.00
						Orchards (cover)	3.0	1.50	0.24	6	2.00
						Peanuts	2.0	0.90	0.18	5	1.20
						Peas, field	1.5	0.65	0.18	4	0.87
						Sweet Potatoes	2.0	0.90	0.22	4	1.20
						Small Grain or Soybeans	2.0	0.90	0.18	5	1.20
						Tobacco	1.5	0.65	0.18	4	0.87
						Vineyards, cultivated	3.0	1.50	0.18	8	2.00
						Vegetables, Group 1	1.0	0.45	0.14	3	0.60
						Vegetables, Group 2	1.5	0.65	0.14	5	0.87
						Vegetables, Group 3	1.5	0.65	0.18	4	0.87
						Vegetables, Group 4	2.0	0.90	0.18	5	1.20

Table NC6-4: Piedmont and Coastal Plain Regions of North Carolina – General Design Parameters

8	Well to moderately well drained Coastal Plain soils, with sandy surface layers and firm clayey subsoils.	3.0+	1.2	0.35	0.40	Alfalfa	2.5	1.80	0.24	7	2.40
			2.0			Cotton	2.5	1.80	0.20	9	2.40
			2.8			Corn, field	2.5	1.80	0.22	8	2.40
			3.6			Gladioli	1.0	0.60	0.14	4	0.80
			4.3			Ladino Clover & Grass, Summer perennials or Mixed Hay	1.5	1.00	0.24	4	1.33
						Nursery Crops, 1st yr.	1.0	0.60	0.16	4	0.80
						Nursery Crops, 2nd yr.	2.0	1.40	0.18	8	1.87
						Peanuts	2.0	1.40	0.18	8	1.87
						Peas, field	1.5	1.00	0.18	6	1.33
						Irish Potatoes	1.5	1.00	0.20	5	1.33
						Sweet Potatoes	2.0	1.40	0.22	6	1.87
						Small Grain or Soybeans	2.0	1.40	0.18	8	1.87
						Tobacco	1.5	1.00	0.18	6	1.33
						Vegetables, Group 1	1.0	0.60	0.14	4	0.80
						Vegetables, Group 2	1.5	1.00	0.14	7	1.33
						Vegetables, Group 3	1.5	1.00	0.18	6	1.33
						Vegetables, Group 4	2.0	1.40	0.18	8	1.87
9[4]	Somewhat poorly drained Coastal Plain and terrace soils with sandy surface layers and friable loamy or firm clayey subsoils.	3.0+	1.1	0.40	0.50	Annual & Perennial Flowers	1.0	0.55	0.14	4	0.73
			1.9			Azaleas & Camellias	2.0	1.35	0.18	7	1.80
			2.7			Cotton	2.5	1.75	0.20	9	2.33
			3.5			Corn, field	2.5	1.75	0.22	8	2.33
			4.3			Gladioli	1.0	0.55	0.14	4	0.73
						Ladino Clover & Grass, Summer perennials or Mixed Hay	1.5	0.95	0.24	4	1.27
						Nursery Crops, 1st yr.	1.0	0.55	0.16	3	0.73
						Nursery Crops, 2nd yr.	2.0	1.35	0.18	7	1.80
						Peanuts	2.0	1.35	0.18	7	1.80
						Peas, field	1.5	0.95	0.18	5	1.27
						Irish Potatoes	1.5	0.95	0.20	5	1.27
						Sweet Potatoes	2.0	1.35	0.22	6	1.80
						Small Grain or Soybeans	2.0	1.35	0.18	7	1.80
						Tobacco	1.5	0.95	0.18	5	1.27
						Vegetables, Group 1	1.0	0.55	0.14	4	0.73
						Vegetables, Group 2	1.5	0.95	0.14	7	1.27
						Vegetables, Group 3	1.5	0.95	0.18	5	1.27
						Vegetables, Group 4	2.0	1.35	0.18	7	1.80

Table NC6-4: Piedmont and Coastal Plain Regions of North Carolina – General Design Parameters

10 [4]	Somewhat poorly drained Coastal Plain soils with loamy surface layers and friable loamy subsoils		1.5	0.35	0.40	Azaleas & Camellias	2.0	1.65	0.18	9	2.20
			2.4			Cotton	2.5	2.10	0.20	10	2.80
		3.0+	3.3			Corn, field	2.5	2.10	0.22	10	2.80
			4.2			Gladioli	1.0	0.75	0.14	5	1.00
			4.9			Ladino Clover & Grass, Summer					
						perennials or Mixed Hay	1.5	1.20	0.24	5	1.60
						Nursery Crops, 1st yr.	1.0	0.75	0.16	5	1.00
						Nursery Crops, 2nd yr.	2.0	1.65	0.18	9	2.20
						Peas, field	1.5	1.20	0.18	7	1.60
						Irish Potatoes	1.5	1.20	0.20	6	1.60
						Small Grain or Soybeans	2.0	1.65	0.18	9	2.20
						Vegetables, Group 1	1.0	0.75	0.14	5	1.00
						Vegetables, Group 2	1.5	1.20	0.14	8	1.60
						Vegetables, Group 3	1.5	1.20	0.18	7	1.60
						Vegetables, Group 4	2.0	1.65	0.18	9	2.20
11	Well to moderately well drained soils of the Piedmont uplands with loamy surface layers and firm plastic clayey subsoils.		1.3	0.30	0.35	Cotton	2.5	2.30	0.20	11	3.07
			2.4			Corn, field	2.5	2.30	0.22	10	3.07
		3.0+	3.6			Ladino Clover & Grass,					
			4.6			Summer perennials or Mixed Hay	1.5	1.20	0.24	5	1.60
			5.3			Peas, field	1.5	1.20	0.18	7	1.60
						Small Grain or Soybeans	2.0	1.80	0.18	10	2.40
						Tobacco	1.5	1.20	0.18	7	1.60
						Vegetables, Group 1	1.0	0.65	0.14	5	0.87
						Vegetables, Group 2	1.5	1.20	0.14	8	1.60
						Vegetables, Group 3	1.5	1.20	0.18	7	1.60
						Vegetables, Group 4	2.0	1.80	0.18	10	2.40
12	Well to moderately well drained soils of the Piedmont uplands with loamy surface layers and plastic, sticky clayey subsoils.	1.5	1.5	0.20	0.20	Cotton	1.5	1.25	0.20	6	1.67
			2.5			Corn, field	1.5	1.25	0.22	6	1.67
						Ladino Clover & Grass,					
						Summer perennials or Mixed Hay	1.5	1.25	0.24	5	1.67
						Peas, field	1.5	1.25	0.18	7	1.67
						Small Grain or Soybeans	1.5	1.25	0.18	7	1.67
						Tobacco	1.5	1.25	0.18	7	1.67
13	Well to moderately well drained Coastal Plain soils, with silty surface layers and friable loamy subsoils.		1.5	0.30	0.35	Alfalfa	2.5	2.20	0.24	9	2.93
			2.4			Cotton	2.5	2.20	0.20	11	2.93
		3.0+	3.4			Corn, field	2.5	2.20	0.22	10	2.93
			4.4			Gladioli	1.0	0.75	0.14	5	1.00
			5.2			Ladino Clover & Grass,					
						Summer perennials or Mixed Hay	1.5	1.20	0.24	5	1.60
						Nursery Crops, 1st yr.	1.0	0.75	0.16	5	1.00
						Nursery Crops, 2nd yr.	2.0	1.70	0.18	9	2.27
						Peanuts	2.0	1.70	0.18	9	2.27
						Peas, field	1.5	1.20	0.18	7	1.60
						Small Grain or Soybeans	2.0	1.70	0.18	9	2.27
						Tobacco	1.5	1.20	0.18	7	1.60
						Vegetables, Group 1	1.0	0.75	0.14	5	1.00
						Vegetables, Group 2	1.5	1.20	0.14	8	1.60
						Vegetables, Group 3	1.5	1.20	0.18	7	1.60
						Vegetables, Group 4	2.0	1.70	0.18	9	2.27

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	Moderately well to		1.5	0.30	0.35	Cotton	2.5	2.20	0.20	11	2.93
	somewhat poorly		2.7			Corn, field	2.5	2.20	0.22	10	2.93
	drained Coastal Plain	3.0	3.5			Gladioli	1.0	0.75	0.14	5	1.00
	and terrace soils, with		4.4			Ladino Clover & Grass, Summer					
	loamy surface layers		5.3			perennials or Mixed Hay	1.5	1.35	0.24	6	1.80
14	and firm clayey					Peas, field	1.5	1.35	0.18	7	1.80
	subsoils.					Irish Potatoes	1.5	1.35	0.20	7	1.80
						Small Grain or Soybeans	2.0	1.75	0.18	10	2.33
						Vegetables, Group 1	1.0	0.75	0.14	5	1.00
						Vegetables, Group 2	1.5	1.35	0.14	9	1.80
						Vegetables, Group 3	1.5	1.35	0.18	7	1.80
						Vegetables, Group 4	2.0	1.75	0.18	10	2.33
	Well drained shallow	1.5	0.8	0.30	0.35	Ladino Clover & Grass, Summer					
	soils of the Piedmont		1.3			perennials or Mixed Hay	1.5	0.65	0.24	4	0.87
	Uplands with thin					Orchards (bare)	1.5	0.65	0.20	4	0.87
15	discontinuous					Orchards (cover)	1.5	0.65	0.24	4	0.87
	subsoils.					Peas, field	1.5	0.65	0.18	5	0.87
						Small Grain or Soybeans	1.5	0.65	0.18	5	0.87
						Tobacco	1.5	0.65	0.18	5	0.87
	Well drained to		0.7	0.75	0.75	Cotton	2.5	0.90	0.20	4	1.20
	moderately well		1.0			Corn, field	2.5	0.90	0.22	4	1.20
	drained Coastal Plain	3.0+	1.4			Summer Perennials	1.5	0.50	0.24	2	0.67
	and terrace soils with		1.8			Orchards (bare)	3.0	1.10	0.20	5	1.47
16	sandy surface layers		2.2			Orchards (cover)	3.0	1.10	0.24	5	1.47
	and loose sandy					Peanuts	2.0	0.70	0.18	4	0.93
	subsoils.					Peas, field	1.5	0.50	0.18	3	0.67
						Small Grain	2.0	0.70	0.18	4	0.93
						Tobacco	1.5	0.50	0.18	3	0.67
						Vineyards, cultivated	3.0	1.10	0.18	6	1.47
	Moderately well		0.8	0.50	0.50	Alfalfa	2.5	1.05	0.24	4	1.40
	drained to somewhat		1.3			Annual & Perennial Flowers	1.0	0.40	0.14	3	0.53
	poorly drained Coastal	3.0+	1.7			Azaleas & Camellias	2.0	0.85	0.18	5	1.13
	Plain and terrace soils		2.1			Cotton	2.5	1.05	0.20	5	1.40
	with sandy surface		2.8			Corn, field	2.5	1.05	0.22	5	1.40
	layers and friable					Gladioli	1.0	0.40	0.14	3	0.53
	loamy subsoils.					Summer Perennials or	1.5	0.65	0.24	3	0.87
						Nursery Crops, 1st yr.	1.0	0.40	0.16	3	0.53
						Nursery Crops, 2nd yr.	2.0	0.85	0.18	5	1.13
						Orchards (bare)	3.0	1.40	0.20	7	1.87
17						Orchards (cover)	3.0	1.40	0.24	6	1.87
						Peanuts	2.0	0.85	0.18	5	1.13
						Peas, field	1.5	0.65	0.18	4	0.87
						Sweet Potatoes	2.0	0,85	0.22	4	1.13
						Small Grain or Soybeans	2.0	0.85	0.18	5	1.13
						Tobacco	1.5	0.65	0.18	4	0.87
						Vineyards, cultivated	3.0	1.40	0.18	8	1.87
						Vegetables, Group 1	1.0	0.40	0.14	3	0.53
						Vegetables, Group 2	1.5	0.65	0.14	5	0.87
						Vegetables, Group 3	1.5	0.65	0.18	4	0.87
						Vegetables, Group 4	2.0	0.85	0.18	5	1.13

Table NC6-4: Piedmont and Coastal Plain Regions of North Carolina – General Design Parameters

18 [4]	Poorly drained to very poorly drained Coastal Plain and terrace soils with organic hardpans, fragipans or loose sandy subsoils.	2.0	0.7	0.60	0.65	Annual & Perennial Flowers	1.0	0.35	0.14	3	0.47
			1.2			Azaleas & Camellias	2.0	0.85	0.18	5	1.13
			1.7			Corn, field	2.0	0.85	0.22	4	1.13
						Gladioli	1.0	0.35	0.14	3	0.47
						Ladino clover & grass or mixed hay	1.5	0.60	0.24	2	0.80
						Nursery Crops, 1st yr.	1.0	0,35	0.16	2	0.47
						Nursery Crops, 2nd yr.	2.0	0.85	0.18	5	1.13
						Irish Potatoes	1.5	0.60	0.20	3	0.80
						Small Grain or Soybeans	2.0	0.85	0.18	5	1.13
						Vegetables, Group 1	1.0	0.35	0.14	2	0.47
						Vegetables, Group 2	1.5	0.60	0.14	4	0.80
						Vegetables, Group 3	1.5	0.60	0.18	3	0.80
						Vegetables, Group 4	2.0	0.85	0.18	5	1.13
19 [4]	Poorly drained Coastal Plain and terrace soils with loamy surface layers and friable loamy subsoils.	3.0+	1.2	0.35	0.40	Annual & Perennial Flowers	1.0	0.60	0.14	4	0.80
			2.0			Azaleas & Camellias	2.0	1.45	0.18	8	1.93
			2.9			Corn, field	2.5	1.75	0.22	8	2.33
			3.5			Gladioli	1.0	0.60	0.14	4	0.80
			4.3			Ladino clover & grass or mixed hay	1.5	1.00	0.24	4	1.33
						Nursery Crops, 1st yr.	1.0	0.60	0.16	4	0.80
						Nursery Crops, 2nd yr.	2.0	1.45	0.18	8	1.93
						Peanuts	2.0	1.45	0.18	8	1.93
						Peas, field	1.5	1.00	0.18	6	1.33
						Irish Potatoes	1.5	1.00	0.18	6	1.33
						Small Grain or Soybeans	2.0	1.45	0.18	8	1.93
						Vegetables, Group 1	1.0	0.60	0.14	4	0.80
						Vegetables, Group 2	1.5	1.00	0.14	7	1.33
						Vegetables, Group 3	1.5	1.00	0.18	6	1.33
						Vegetables, Group 4	2.0	1.45	0.18	8	1.93
20 [4]	Very poorly drained Coastal Plain and terrace soils with loamy surface layers and friable loamy subsoils.	3.0+	1.5	0.40	0.45	Annual & Perennial Flowers	1.0	0.75	0.14	5	1.00
			2.4			Azaleas & Camellias	2.0	1.60	0.18	9	2.13
			3.2			Cotton	2.5	2.00	0.20	10	2.67
			4.0			Corn, field	2.5	2.00	0.22	9	2.67
			4.8			Gladioli	1.0	0.75	0.14	5	1.00
						Ladino clover & grass or mixed hay	1.5	1.20	0.24	5	1.60
						Nursery Crops, 1st yr.	1.0	0.75	0.16	5	1.00
						Nursery Crops, 2nd yr.	2.0	1.60	0.18	9	2.13
						Peas, field	1.5	1.20	0.18	7	1.60
						Irish Potatoes	1.5	1.20	0.20	6	1.60
						Small Grain or Soybeans	2.0	1.60	0.18	9	2.13
						Vegetables, Group 1	1.0	0.75	0.14	5	1.00
						Vegetables, Group 2	1.5	1.20	0.14	8	1.60
						Vegetables, Group 3	1.5	1.20	0.18	7	1.60
						Vegetables, Group 4	2.0	1.6	0.18	9	2.13
21 [4]	Somewhat poorly and poorly drained loamy alluvial soils on first bottoms and upland Piedmont depressions	3.0+	1.5	0.30	0.35	Corn, field	2.5	1.80	0.22	8	2.40
			2.2			Ladino clover & grass or mixed hay	1.5	1.10	0.24	5	1.47
			2.9			Peas, field	1.5	1.10	0.18	6	1.47
			3.6			Small Grain or Soybeans	2.0	1.45	0.18	8	1.93
			4.5								

Table NC6-4: Piedmont and Coastal Plain Regions of North Carolina – General Design Parameters

22 [4]	Very poorly drained Coastal Plain soils with loamy surface layers and friable loamy subsoils.	3.0+	1.3	0.40	0.45	Annual & Perennial Flowers	1.0	0.65	0.14	5	0.87
			2.2			Azaleas & Camellias	2.0	1.50	0.18	8	2.00
			3.0			Corn, field	2.5	1.85	0.22	8	2.47
			3.7			Gladioli	1.0	0.65	0.14	5	0.87
			4.5			Ladino clover & grass or mixed hay	1.5	1.10	0.24	5	1.47
						Nursery Crops, 1st yr.	1.0	0.65	0.16	4	0.87
						Nursery Crops, 2nd yr.	2.0	1.50	0.18	8	2.00
						Peas, field	1.5	1.10	0.18	6	1.47
						Irish Potatoes	1.5	1.10	0.20	5	1.47
						Small Grain or Soybeans	2.0	1.50	0.18	8	2.00
						Vegetables, Group 1	1.0	0.65	0.14	5	0.87
						Vegetables, Group 2	1.5	1.10	0.14	8	1.47
						Vegetables, Group 3	1.5	1.10	0.18	6	1.47
						Vegetables, Group 4	2.0	1.50	0.18	8	2.00
23 [4]	Poorly drained Coastal Plain and terrace soils with loamy surface layers and firm plastic clayey subsoils.	3.0+	1.6	0.30	0.35	Annual & Perennial Flowers	1.0	0.80	0.14	6	1.07
			2.5			Azaleas & Camellias	2.0	1.65	0.18	9	2.20
			3.3			Cotton	2.5	2.10	0.20	10	2.80
			4.2			Corn, field	2.5	2.10	0.22	10	2.80
			5.0			Gladioli	1.0	0.80	0.14	6	1.07
						Ladino Clover & Grass	1.5	1.25	0.24	5	1.67
						Nursery Crops, 1st yr.	1.0	0.80	0.16	5	1.07
						Nursery Crops, 2nd yr.	2.0	1.65	0.18	9	2.20
						Peas, field	1.5	1.25	0.18	7	1.67
						Small Grain or Soybeans	2.0	1.65	0.18	9	2.20
						Vegetables, Group 1	1.0	0.80	0.14	6	1.07
						Vegetables, Group 2	1.5	1.25	0.14	9	1.67
						Vegetables, Group 3	1.5	1.25	0.18	7	1.67
						Vegetables, Group 4	2.0	1.65	0.18	9	2.20
24 [4]	Very poorly drained Coastal Plain and terrace soils with loamy surface layers and firm plastic clay subsoils.	3.0+	1.6	0.35	0.40	Annual & Perennial Flowers	1.0	0.80	0.16	5	1.07
			2.5			Azaleas & Camellias	2.0	1.60	0.18	9	2.13
			3.2			Cotton	2.5	2.00	0.21	9	2.67
			4.0			Corn, field	2.5	2.00	0.23	9	2.67
			5.0			Gladioli	1.0	0.80	0.15	5	1.07
						Ladino Clover & Grass	1.5	1.25	0.23	5	1.67
						Nursery Crops, 1st yr.	1.0	0.80	0.17	5	1.07
						Nursery Crops, 2nd yr.	2.0	1.60	0.18	9	2.13
						Irish Potatoes	1.5	1.25	0.20	6	1.67
						Small Grain or Soybeans	2.0	1.60	0.18	9	2.13
						Vegetables, Group 1	1.0	0.80	0.15	5	1.07
						Vegetables, Group 2	1.5	1.25	0.15	8	1.67
						Vegetables, Group 3	1.5	1.25	0.18	7	1.67
						Vegetables, Group 4	2.0	1.60	0.18	9	2.13
25 [4]	Poorly drained Coastal Plain, flats, and terrace soils with organic materials over clayey, loamy, or sandy marine deposits.	3.0+	2.3	0.30	0.35	Corn, field	2.5	2.20	0.23	9	2.93
			3.0			Small Grain or Soybeans	2.0	1.85	0.18	10	2.47
			3.7			Vegetables, Group 1	1.0	1.15	0.15	8	1.53
			4.4			Vegetables, Group 2	1.5	1.50	0.15	10	2.00
			5.1			Vegetables, Group 3	1.5	1.50	0.18	8	2.00
						Vegetables, Group 4	2.0	1.85	0.18	10	2.47

Following is an example of how Tables NC6-1 through NC6-4 can be used to obtain general irrigation design data for each region.

Sample Irrigation System Planning Calculations for Mountain Area:

Soil:	Rosman - The Table NC6-1 lists this soil in Group 10
Crop:	Tobacco – See this crop listing in Table NC6-3, column 7
Column 8:	Depth of Moisture Replacement is 1.5 feet
Column 9:	Moisture Replacement by each Irrigation cycle is 1.3 inches
Column 10:	Design Moisture Use Rate is 0.16 inches per day
Column 11:	Irrigation Frequency for Peak Use Rate is 8 days
Column 12:	Planned Irrigation Application Amount is 1.73 inches (75 % Irr. Efficiency)
Column 5:	The maximum irrigation application rate that cannot be exceeded is 0.5 inches per hour (bare soil condition)

<u>Sample Irrigation System Planning Calculations for Piedmont and Coastal Area:</u>

Soil:	Appling – The Table NC6-2 lists this soil in Group 4
Crop:	Tobacco – See this crop listing in Table NC6-4, column 7
Column 8:	Depth of Moisture Replacement is 1.5 feet
Column 9:	Moisture Replacement by each Irrigation cycle is 1.05 inches
Column 10:	Design Moisture Use Rate is 0.18 inches per day
Column 11:	Irrigation Frequency for Peak Use Rate is 6 days
Column 12:	Planned Irrigation Application Amount is 1.4 inches (75 % Irr. Efficiency)
Column 5:	The maximum irrigation application rate that cannot be exceeded is 0.35 inches per hour (bare soil condition)

Note that the above data is very generalized and are for planning purposes. All assumptions, such as irrigation efficiencies, soil AWC, and crop rooting depths, should be verified as correct for this site design. The input data should be verified with site-specific data which may require field measurements or lab testing. The irrigation designer is responsible to see that all calculations are correct for the design, even those taken from tables and charts included here or elsewhere. The irrigator and designer are encouraged to use Irrigation Scheduling computer software to more accurately define when and how much to irrigate. More accurate determinations of water use (evapotranspiration), deep percolation (deep losses from rooting zone), and soil moisture recharge (from rainfall or irrigation) can be made using the Irrigation Scheduling computer software or spreadsheets.

The soil and its irrigation limitations were discussed earlier in this section and are given in Table NC6-1 and NC6-2. If a field contains more than one soil, the most restrictive soil must be determined. Also, the crop, AWC, MAD, maximum allowable application rates, usable rooting depth, net and gross application amount, and irrigation frequency were discussed and determined in the above examples. Assumptions, such as crop rooting depth, should be verified with the grower and any other knowledgeable sources for local irrigation systems. A field investigation is strongly recommended to the designer/ planner to insure all design assumptions are valid.

Identify potential alternative irrigation systems suitable to the site and determine the recommended system. Discuss the recommended and alternative irrigation systems with the grower/user. Once the irrigation system is determined, specifics to that system must then be determined.

Irrigation efficiency for different types of irrigation systems vary, but generally run between 50 and 95 percent. Determine gross irrigation water requirements with the expected irrigation efficiency of the selected irrigation system (Tables NC6-1 and NC6-2 assume 75%). Computer programs such as the NRCS SPAW model can be used to assess historic weather data to determine estimated daily/weekly/monthly/yearly irrigation water consumption that would have been expected with this irrigation system and planned crop. Calculation of design sprinkler irrigation system capacity (generally in gpm) can be computed using an equation presented and discussed earlier in this chapter.

See Table NC4-1 for the minimum irrigation water supply capacity per acre that is recommended. A water supply should be able to meet maximum crop irrigation demands for at least 8 out of 10 years. Crops grown in North Carolina generally need about 6 to 10 inches of irrigation per year to supplement the natural rainfall during a growing season (NC Cooperative Extension Service, Pub. No. AG 452-4, Irrigation Scheduling to Improve Water- and Energy-Use Efficiencies, June 1996; NC State University, Tobacco Irrigation Costs for the Piedmont and Coastal Plains of NC, updated 2007; NC Cooperative Extension Service, Animal Waste Management Systems, Chapter 5: Proper Application of Liquid Animal Waste-Type A, Draft Copy, 1997).

Determine sprinkler spacing, nozzle size(s), head type, discharge, operating pressure, wetted diameter, average application rate, and performance characteristics. For some systems, the manufacturer may be utilized for determining the best layouts for their irrigation system.

Determine number of sprinklers in an irrigation set (zone) required to meet system capacity requirements; number of laterals needed for a selected time of set; set spacing; and moves per day (if applicable). Center pivot systems are generally designed by the equipment dealer using a computer program supplied by each center pivot system manufacturer. These designs should be reviewed to assure the proposed application provides adequate water to satisfy the needs of the crop(s), match the available water capacity of the soil, and that it does not have negative impacts on field or farm resources such as soil erosion, offsite sedimentation, and pollution of surface and ground water.

Evaluate design. Does it meet the objective and purpose(s) identified by the grower/user.

Make necessary adjustments to meet layout conditions so the system fits the field, soils, crops, water supply, environmental concerns, and the desires of the irrigation decision-maker. Consider a buffer between the irrigation system spray area and any flowing water such as streams or grassed waterways. Direct access of cropping field runoff to any perennial stream should be avoided and may violate state laws.

Finalize sprinkler irrigation system design and layout. Determine lateral size(s) based on number of heads, flow rate, pipeline length, and allowable pressure loss differential between the first and last sprinkler head. Determine if pressure or flow regulators are needed. Determine minimum operating pressure required in mainline(s) at various critical locations on the terrain.

Determine mainline sizes required to meet pressure and flow requirements according to the number of operating laterals. This includes diameter, pipe material, mainline location, and type of valves and fittings. It involves hydraulic calculations, basic cost-benefit relationships, and potential pressure surge evaluations for pipe sizes and velocities selected. Thrust blocks should be considered at any change in flow direction or pipe size. Mainline operating pressure measured at the discharge side of each lateral outlet valve, should be within 10 percent of the design lateral operating pressure. It is recommended that velocity be no greater than five feet per second (1.52 m/s) in mainline and lateral pipes to help prevent pipe damage from water hammer during flow changes such as valve operation or pump drive power failure. Check main line pipe sizes for power economy. Compare pumping cost versus pipe size initial cost on annual basis.

Total Dynamic Head (TDH) is the sum of all the heads (static, pressure, friction, etc.) that a pump must operate against at a given flow rate. Determine maximum and minimum TDH required for critical lateral location conditions. Determine total accumulated friction loss in mainline, elevation rise from pump to extreme point in the fields, water surface to pump impeller (lift), column loss with vertical turbine pumps, and miscellaneous losses (fittings, valves, elbows) at the pump and throughout the system. Add 10% more to TDH and increase flow rates somewhat for system wear.

Determine maximum and minimum pumping plant capacity using required flow rate and TDH. Estimate brake horsepower for the motor or engine to be used. Insure irrigation system has a method of filling and draining mainlines and laterals. Filling and draining should be done so that a water hammer does not occur. A water hammer can be very damaging to the system. Fill and drain velocities over one foot per second should be avoided. Long runs of pipe can experience water hammers, especially when run on a slope, and may require flow restrictors to slow flow.

Select pump and power unit for maximum operating efficiency within range of operating conditions. Use pump performance curves prepared for each make and model of pump. Every pump has a different set of performance (characteristic) curves relating to operating head (pressure) output and discharge capacity. Select pumps and power units for maximum operating efficiency within the full range of expected operating conditions. Only pump capacity and TDH requirements are recommended to be provided to the user. Never select a pump based on horsepower alone. Let a pump dealer select the appropriate motor or engine and pump to fit the conditions. Availability of a pump dealer for providing maintenance and repair should be considered by the operator. Buying a used pump without first checking pump characteristic curves for that specific pump is seldom satisfactory. A pump needs to match the required capacity and TDH for efficient and economic performance. An inefficient operating pump increases operating costs by using needless excess energy.

Prepare final layout and operation, maintenance, and irrigation water management plans. Include methods of determining when and how much to irrigate (irrigation scheduling) which should reduce irrigation waste from over-application and better meet the crop water needs. A method or plan to measure and track field moisture levels (useful with irrigation scheduling) should be recommended to the grower/user. Provide recommendations and plans for at least one water measuring device to be installed in the system for water management purposes. Record keeping is recommended and should include date, rainfall, irrigation amount, flow meter reading (start and finish), soil moisture level/deficit, and hours of operation for each field/set, as a minimum.

Design procedures and examples are provided in more detail in NRCS NEH, Section 15, Chapter 11, Sprinkle Irrigation. Manufacturer literature is readily available and most useful in selection of sprinkler head models, nozzle sizes, and discharge at various pressures. North

Carolina Wastewater Irrigation Design Parameters Worksheets (see Appendix B) can be used to identify and document site specific information for any irrigation system.

The following details of design and materials should accompany all irrigation designs:

1. A scale drawing of the proposed irrigation system which includes hydrant locations, travel lanes, pipeline routes, thrust block locations and buffer areas where applicable.
2. Assumptions and computations for determining total dynamic head and horsepower requirements.
3. Computations used to determine all mainline and lateral pipe sizes.
4. Sources and/or calculations for determining application rates.
5. Computations used to determine the size of thrust blocks and illustrations of all thrust block configurations required in the irrigation system.
6. Manufacturer's specifications for the irrigation pump, traveler, and sprinkler(s).
7. Manufacturer's specifications for the irrigation pipe and/or USDA-NRCS standard for Irrigation Water Conveyance, NC Field Office Technical Guide, Section IV, Practice Code 430-DD.
8. Operation and Maintenance Plan, including procedures such as start-up, shutdown, winterization, and regular maintenance of all equipment.

The final drawings, design details, and assumptions should be discussed with the grower/user to insure they are familiar with the design features and limitations of the irrigation system. The Operation and Maintenance Plan should be covered item by item with the grower/user, especially if they have limited irrigation experience.

A post-installation field calibration should be discussed with the grower/user. The post-installation field calibration is used to assess distribution uniformity and application rates to verify they are consistent with the design and manufacturer's specifications. See NRCS NEH Part 652, Irrigation Guide, Chapter 9, Irrigation Water Management, for more information on post-installation evaluations for water use and efficiency of the irrigation system. Also discuss visual observations that are to be noted and system adjustments that may be required. This can be situations such as ponding, runoff, or erosion occurring in the irrigated field during, and often at the end of an irrigation cycle. Application rate and/or set time should probably be adjusted since ponding and runoff are to be avoided. Pipe vibrations or movements, under- or over-powered sprinklers, varying speeds of movement, excessive leaking, outflow in subsurface drains, and any other unusual observations should be noted and discussed with the manufacturer and/or the system designer.

The above gives a general approach for designing a sprinkler irrigation system. The reader should also review the NRCS NEH Part 652, Irrigation Guide, Chapter 6, Irrigation System Design, for additional information and Design Worksheets. Specific design steps for each irrigation system type can be found in this reference, as well as design charts and tables which may be useful. Other chapters from the NRCS NEH Part 652, Irrigation Guide, may also be helpful for more information on specific tasks, such as Chapter 11, Economic Evaluations.

APPENDIX A

Following are some excerpts from the 2007 Fact Sheet for North Carolina agriculture. You will note some of the numbers vary from information given in this guide. This is not a discrepancy, but an indicator of how variable numbers can be, depending on the data collection and evaluation methods.

North Carolina State Fact Sheet

USDA Economic Research Service: http://www.ers.usda.gov/statefacts/
Data updated July 3, 2007

Population, Income, Education, and Employment

Population			
	Rural *	**Urban ***	**Total**
Year			
1980	2,083,621	3,796,474	5,880,095
1990	2,217,336	4,411,301	6,628,637
2000	2,563,889	5,485,424	8,049,313
2006 (latest estimates)	2,703,195	6,153,310	8,856,505

More information on North Carolina population
• County-level Population Data
• Rural Population and Migration Briefing Room
• Contact John Cromartie, 202-694-5421.

Income			
	Rural *	**Urban ***	**Total**
Per-capita income (2005 dollars)			
2004	25,990	32,634	30,571
2005	26,447	33,088	31,041
Percent change	1.8	1.4	1.5
Earnings per job (2005 dollars)			
2004	31,898	43,077	40,156
2005	32,147	43,233	40,360
Percent change	0.8	0.4	0.5
Poverty rate (percent)			
1979	17.7	13.2	14.8
1989	16.0	11.4	13.0

1999	14.9	11.1	12.3
2004 (latest model-based estimates)	15.6	13.1	13.8

More information on North Carolina poverty rates
• County-level Poverty Data
• Rural Income, Poverty, and Welfare Briefing Room
• See important notes about decennial and model-based intercensal poverty estimates
• Contact Robert Gibbs, 202-694-5423

Education (Persons 25 and older)			
	Rural *	**Urban ***	**Total**
Percent not completing high school			
1980	52.4	41.1	45.2
1990	37.1	26.4	30.0
2000	27.3	19.2	21.9
Percent completing high school only			
1980	27.0	28.4	27.8
1990	30.7	28.1	29.0
2000	32.2	26.7	28.4
Percent completing some college			
1980	11.5	15.0	13.8
1990	20.8	25.0	23.6
2000	26.0	27.8	27.2
Percent completing college			
1980	9.2	15.5	13.2
1990	11.4	20.4	17.4
2000	14.5	26.3	22.5

More information on North Carolina education
• County-level Education Data
• Rural Labor and Education Briefing Room
• Contact Robert Gibbs, 202-694-5423

Employment			
	Rural *	**Urban ***	**Total**
Total number of jobs			
2004	1,304,697	3,688,351	4,993,048
2005	1,326,656	3,792,856	5,119,512

Unemployment rate (percent)			
2005	5.9	4.9	5.2
2006	5.5	4.5	4.8

More information on North Carolina unemployment rates
• County-level Unemployment and Median Household Income Data
• Rural Labor and Education Briefing Room
• Contact Lorin Kusmin, 202-694-5429

Percent employment change			
2003-2004	2.5	1.7	1.9
2004-2005	1.2	2.5	2.1
2005-2006	2.0	3.9	3.4

Percent of 2002 employment in farm and farm-related jobs			
Total	20.4	15.1	16.5
Production	3.6	1.1	1.8
Farm inputs	0.3	0.2	0.2
Processing & marketing	5.6	2.9	3.6
Wholesale & retail trade	9.8	10.0	9.9

More information on farm employment
• Farm and Farm-Related Employment data
• Contact Tim Parker, 202-694-5435

* Urban and rural (metro and nonmetro) defintions are based on the Office of Management and Budget (OMB) June 2003 classification. See Measuring Rurality: New Definitions in 2003 for more information.

More information on socioeconomic conditions
• Rural Emphasis Page
• Contact Tim Parker, 202-694-5435.

Farm Characteristics

1992, 1997 and 2002 Census of Agriculture			
	1992	**1997**	**2002**
Total land area (million acres)	31.18	31.18	31.17
Total farmland (million acres)	8.94	9.44	9.08
Percent of total land area	28.7	30.3	29.1
Cropland (million acres)	5.58	5.70	5.47
Percent of total farmland	62.4	60.4	60.3
Percent in pasture	15.0	16.2	12.2
Percent irrigated	1.9	2.6	4.4

Harvested Cropland (million acres)	4.00	4.27	4.31
Woodland (million acres)	2.61	2.79	2.52
Percent of total farmland	29.3	29.5	27.8
Percent in pasture	19.4	18.3	18.8
Pastureland (million acres)	0.38	0.42	0.61
Percent of total farmland	4.2	4.5	6.7
Land in house lots, ponds, roads, wasteland, etc. (million acres)	0.37	0.53	0.48
Percent of total farmland	4.1	5.7	5.3
Conservation practices			
Farmland in conservation or wetlands reserve programs (million acres)	0.09	0.15	0.18
Percent of total farmland	1.0	1.6	2.0
Average farm size (acres)	172	160	168
Farms by size (percent)			
1 to 99 acres	61.2	66.3	67.1
100 to 499 acres	31.2	26.9	25.6
500 to 999 acres	4.9	4.1	4.0
1000 to 1,999 acres	2.0	1.9	2.2
2,000 or more acres	0.7	0.8	1.0
Farms by sales (percent)			
Less than $9,999	51.7	59.7	63.7
$10,000 to $49,999	23.0	18.0	15.9
$50,000 to $99,999	7.0	4.9	4.1
$100,000 to $499,999	14.0	10.9	9.7
More than $500,000	4.0	6.5	6.6
Tenure of farmers			
Full owner (farms)	29,242	35,904	34,489
Percent of total	56.4	60.7	64.0

Part owner (farms)	17,572	18,231	16,030
Percent of total	33.9	30.8	29.7
Tenant owner (farms)	5,040	4,985	3,411
Percent of total	9.7	8.4	6.3
Farm organization			
Individuals/family, sole proprietorship (farms)	45,273	51,913	48,672
Percent of total	87.3	87.8	90.3
Family-held corporations (farms)	1,415	2,084	1,652
Percent of total	2.7	3.5	3.1
Partnerships (farms)	4,750	4,663	3,209
Percent of total	9.2	7.9	6.0
Non-family corporations (farms)	174	196	171
Percent of total	0.3	0.3	0.3
Others - cooperative, estate or trust, institutional, etc. (farms)	242	264	226
Percent of total	0.5	0.4	0.4
Characteristics of principal farm operators			
Average operator age (years)	54.7	54.8	56.1
Percent with farming as their primary occupation	52.8	45.6	58.7
Men (persons)	47,914	53,874	48,574
Women (persons)	3,940	5,246	5,356

More information on farm characteristics
• Census of Agriculture
• Contact NASS Customer Service, 1-800-727-9540.

Data from the 1992 Census of Agriculture is not adjusted for coverage. See Coverage Adjustment from NASS.

Farm Financial Indicators

Farm income and value added data		
	2004	**2005**
Number of farms	52,000	52,000
	Thousands $	
Final crop output	3,043,352	2,561,592
+ Final animal output	5,341,791	5,589,570
+ Services and forestry	1,821,111	1,832,847
= Final agricultural sector output	10,206,253	9,984,009
- Intermediate consumption outlays	5,090,539	5,141,167
+ Net government transactions	77,299	1,030,025
= Gross value added	5,193,013	5,872,867
- Capital consumption	527,452	544,371
= Net value added	4,665,561	5,328,496
- Factor payments	1,679,356	1,712,062
Employee compensation (total hired labor)	549,859	576,825
Net rent received by nonoperator landlords	850,870	813,024
Real estate and nonreal estate interest	278,627	322,213
= Net farm income	2,986,205	3,616,434

More information on farm income
• Farm Income Data
• Farm Income and Costs Briefing Room
• Contact Roger Strickland, 202-694-5592.

Farm balance sheet

• Estimation of State-level Balance Sheets has been suspended. See the Farm Balance Sheet data page for more information.

Top Commodities, Exports, and Counties

Top 5 agriculture commodities, 2005			
	Value of receipts thousand $	**Percent of state** total farm receipts	**Percent of US value**
1. Broilers	2,231,782	27.0	10.7
2. Hogs	2,099,170	25.4	14.0
3. Greenhouse/nursery	975,142	11.8	6.0
4. Turkeys	491,832	6.0	15.6
5. Tobacco	407,590	4.9	37.2
All commodities	8,264,020		3.5

More information on North Carolina's top agriculture commodities
• Leading commodities for cash receipts
• Contact Larry Traub, 202-694-5593.

Top 5 agriculture exports, estimates, FY 2006		
	Rank among states	**Value - million $**
1. Tobacco unmfd.	1	407.2
2. Live animals and meat	6	350.0
3. Poultry and products	3	281.8
4. Cotton and linters	7	272.9
5. Other	10	246.6
Overall rank	9	2,045.1

More information on agricultural exports
• State Export Data
• Agricultural Trade Briefing Room
• Contact Nora Brooks, 202-694-5211.

Top 5 counties in agricultural sales 2002		
	Percent of state total receipts	**Million $**
1. Duplin County	10.3	715.3
2. Sampson County	9.7	675.7
3. Wayne County	4.6	317.7
4. Union County	3.8	261.3
5. Bladen County	3.7	254.6
State total		6,961.7

More information on agricultural sales
• Census of Agriculture
• Contact NASS Customer Service, 1-800-727-9540.

Data Source: Prepared by Economic Research Service, USDA, Washington, DC.

APPENDIX B – Wastewater Irrigation Design Parameters Worksheet

UNITED STATES DEPARTMENT OF AGRICULTURE

SOIL CONSERVATION SERVICE

4405 Bland Road
Raleigh N. C. 27609
919-790-2886

October 9, 1995

NORTH CAROLINA BULLETIN NO. 210-6-1

SUBJECT: ENG - Irrigation Design Parameters Worksheet

Purpose: To provide a worksheet for irrigation design parameters to be supplied by the irrigation dealer and installer.

Expiration Date: September 30, 1996

Attached is a copy of a new worksheet the purpose of which is to communicate site specific irrigation information between field office personnel and the irrigation system designer/supplier. Table 1 sets forth the site specific field parameters and is to be completed by the Field Office personnel. The remaining tables are to be completed by the designer and a copy returned to the Field Office. Only minimal information is required and it is the responsibility of the designer to consider all relevant factors for each particular site and address them as appropriate.

This worksheet is a result of joint efforts of many NRCS and DSWC folks from across the state.

This use of this worksheet is optional, but it is highly recommended that this form or a similar form by utilized.

Additional copies of this worksheet may be obtained from your Area Office

Harry J. Gibson
State Conservation Engineer

Dist: SOS
AC
O
ENG
DSWC
DEM

IRRIGATION SYSTEM DESIGN PARAMETERS

Landowner/Operator Name: ____________________ County: __________

Address: ____________________

____________________ Date: __________

Telephone: ____________________

TABLE 1 - Field Specifications [1]

Field Number[2]	Approximate Maximum Useable Size of Field[3] (acres)	Soil Type	Slope (%)	Crop(s)	Maximum Application Rate [4] (in/hr)	Maximum Application per Irrigation Cycle[4] (inches)	Comments

[1] Table to be completed in its entirety by Field Office personnel and forwarded to the irrigation system designer.

[2] See attached map provided by the Field Office for field location(s).

[3] Total field acreage minus required buffer areas.

[4] Refer to N. C. Irrigation Guide, Field Office Technical Guide, Section II G. Annual application must not exceed the agronomic rates for the soil and crop used.

TABLE 2 - Traveling Irrigation Gun Settings

Make, Model and Type of Equipment:

Field No[1] and Hydrant No[2]	Travel Speed (ft/min)	Application Rate (in/hr)	TRAVEL LANE Effective Width (ft)	Effective Length (ft)	Wetted Diameter (feet)	Nozzle Diameter (inches)	EQUIPMENT SETTINGS Operating Pressure @ Gun (psi)	Operating Pressure @ Reel (psi)	Arc Pattern[3]	Comments

[1]See attached map provided by the Field Office for field location(s).
[2]Show separate entries for each hydrant location in each field.
[3]Use the following abbreviations for various arc patterns: F (full circle), TQ (three quarters), TT (two thirds), H (half circle), T (one third), Q (one quarter). May also use degree of arc in degrees.

TABLE 3 - Solid Set Irrigation Gun Settings

Make, Model and Type of Equipment:

Field No[1] and Line No[2]	Number of Hydrants	Wetted Diameter (feet)	Hydrant Spacing (ft) Along Pipeline	Hydrant Spacing (ft) Between Pipelines	Application Rate (in/hr)	OPERATING PARAMETERS Nozzle Diameter (inches)	OPERATING PARAMETERS Operating Pressure @ Gun (psi)	OPERATING PARAMETERS Operating Time @ Hydrant (hr)	Comments

[1]See attached map provided by the Field Office for field location(s).
[2]Show separate entries for each pipeline with hydrants in each field.

TABLE 4 - Irrigation System Specifications

	Traveling Irrigation Gun	Solid Set Irrigation
Flow Rate of Sprinkler (gpm)		
Operating Pressure at Pump (psi)		
Design Precipitation Rate (in/hr)		
Hose Length (feet)		XXXXXXXX
Type of Speed Compensation		XXXXXXXX
Pump Type (PTO, Engine, Electric)		
Pump Power Requirement (hp)		

TABLE 5 - Thrust Block Specifications[1]

Designer may provide thrust block details on separate sheet.

LOCATION	THRUST BLOCK AREA (sq. ft.)
90° Bend	
Dead End	
Tee	

[1] See USDA-NRCS Field Office Technical Guide, Section IV, Practice Code 430-DD.

IRRIGATION SYSTEM DESIGNER

Name: ______________________________

Company: ______________________________

Address: ______________________________

Phone: ______________________________

REQUIRED DOCUMENTATION

The following details of design and materials must accompany all irrigation designs:

1. A scale drawing of the proposed irrigation system which includes hydrant locations, travel lanes, pipeline routes, thrust block locations and buffer areas where applicable.
2. Assumptions and computations for determining total dynamic head and horsepower requirements.
3. Computations used to determine all mainline and lateral pipe sizes.
4. Sources and/or calculations used for determining application rates.
5. Computations used to determine the size of thrust blocks and illustrations of all thrust block configurations required in the system.
6. Manufacturer's specifications for the irrigation pump, traveler and sprinkler(s).
7. Manufacturer's specifications for the irrigation pipe and/or USDA-NRCS standard for **Irrigation Water Conveyance**, N.C. Field Office Technical Guide, Section IV, Practice Code 430-DD.

8. **The information required by this form are the minimum requirements. It is the responsibility of the designer to consider all relevant factors at a particular site and address them as appropriate.**

9. **Irrigation pipes should not be installed in lagoon or storage pond embankments without the approval of the designer.**

NOTE: A buffer strip _____ feet wide or wider must be maintained between the limits of the irrigation system and all perennial streams and surface waters per **DEHNR-DEM Code Section 15A NCAC 2B .0200 - Waste Not Discharged to Surface Waters.**

Narrative of Irrigation System Operation

Describe the operation of the system in the space provided below or on a similar sheet most convinient to the designer/supplier.

Include procedures such as start-up, shut-down, winterization and regular maintenance of all equipment.

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