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

Point Source Drip Emitter

- 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

Line Source Tape

- 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

Micro Spray/Sprinkler

- 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

Subsurface Irrigation

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

- 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.

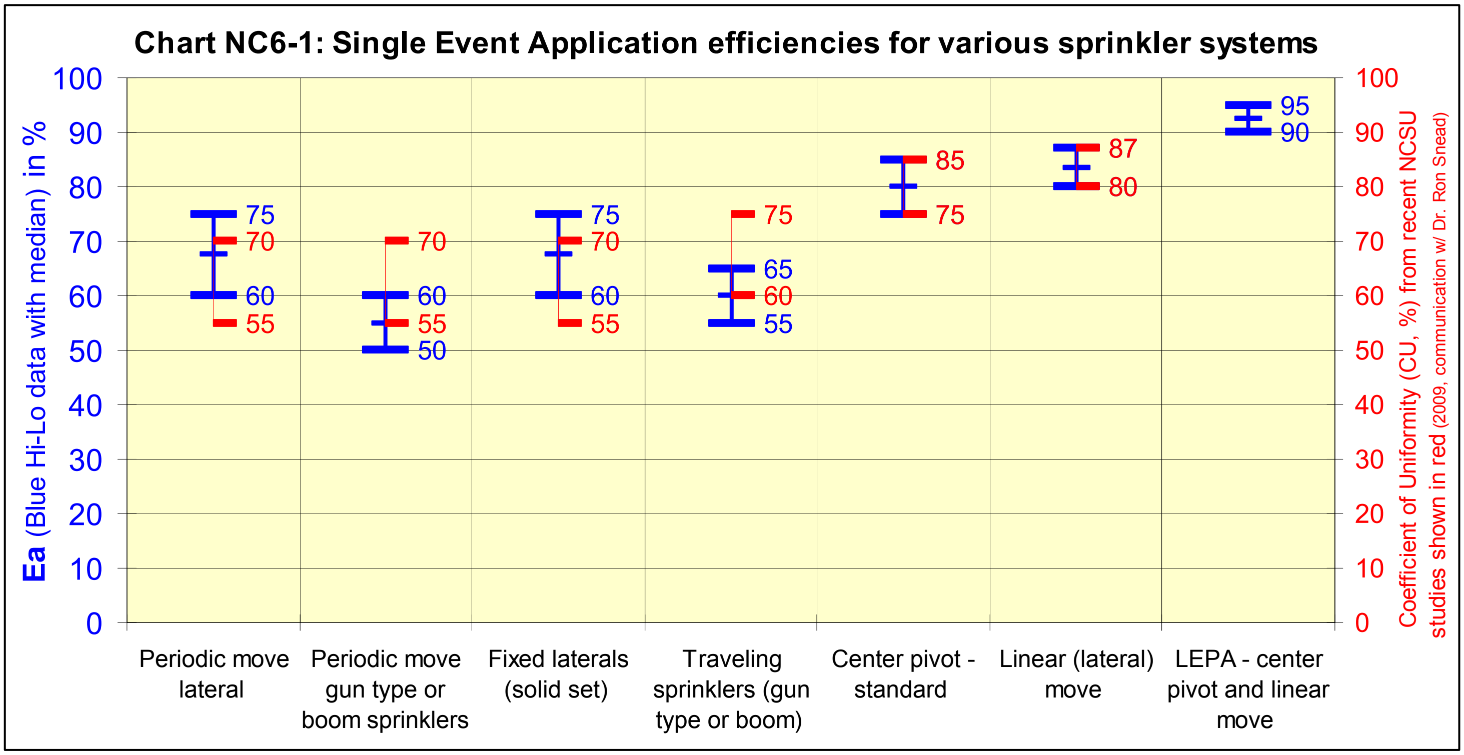
Periodic Move Systems include handmove laterals, side roll laterals, end tow laterals, hose fed (pull) laterals, gun type sprinklers, boom sprinklers, and perforated pipe. Continuous Move/Self Move Systems include center pivots, linear move laterals, and traveling gun sprinklers.

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.

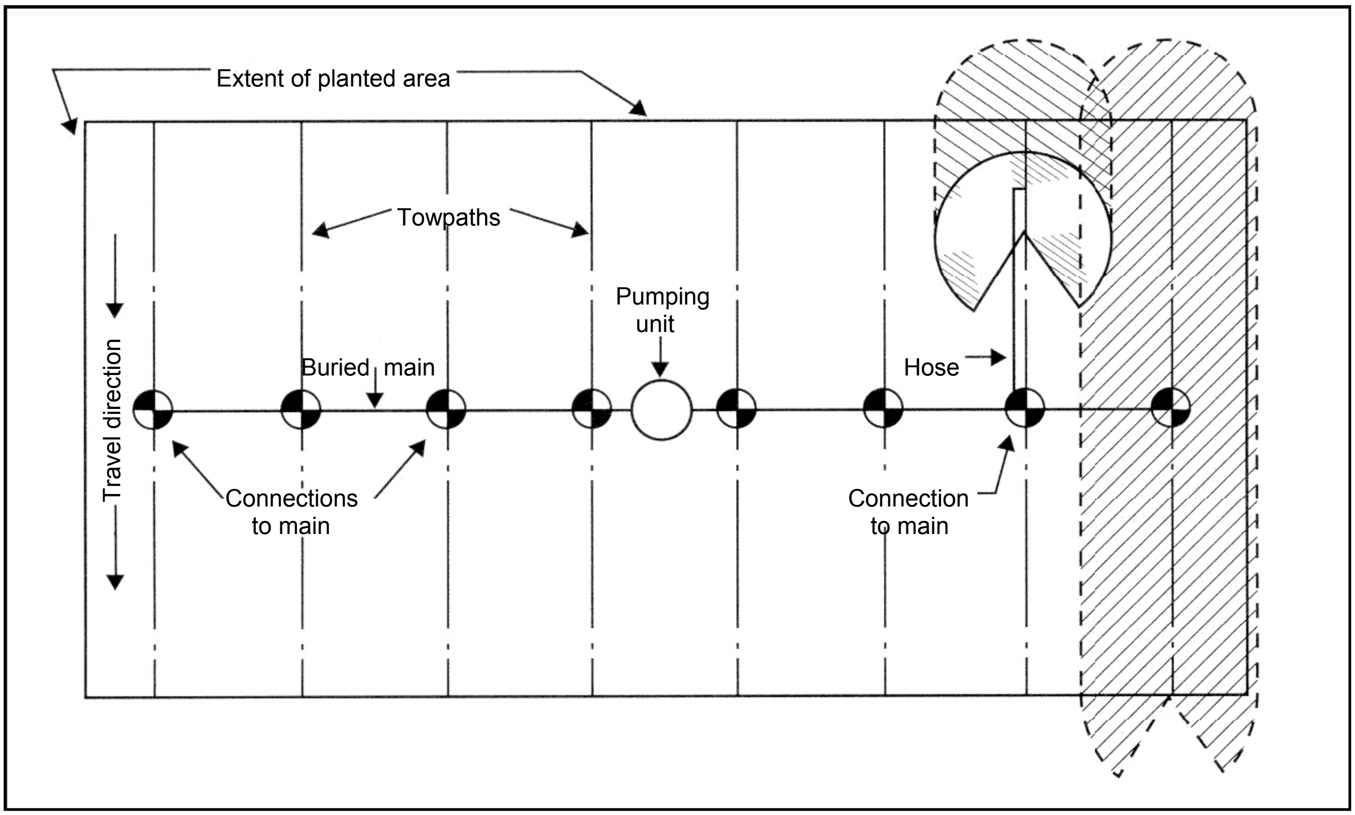


Figure NC6-1 Traveling gun type sprinkler system layout

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