ABSTRACT

SEVERSON, ERIK. Evaluation of Several Methods of Predicting Historic Water Table Levels (Under the direction of Dr. David Lindbo)

Redoximorphic features (iron depletions) and their location in the soil indicate seasonal high water tables, which are the critical factors in siting onsite wastewater disposal systems. According to rule “.1942 Soil Wetness” (15NCAC 18A, 2005), soil wetness conditions are determined by soil morphology is the first occurrence (≥ 2% by volume) of chroma 2 or less iron depletions Soil wetness regulations have created a need for more research in soil hydrology.

The general objective of this study is to define relationships between soil morphology and water table in order to confirm or establish three water table monitoring and interpretation procedures; Calibration, Threshold, and Weighted Rainfall Index (WRI) methods. These methods are used or recognized by state regulatory agencies. Specific objectives of this study are; 1. to evaluate relationships between observed water table dynamics and soil morphology; and 2. to compare NCDENR methods of determining soil wetness to the soil morphological indicator of soil wetness

Three experimental sites on the Lower Coastal Plain (LCP) were established to encompass different soil types and properties. The Richlands Site contained coarse-loamy textured soils, the Vanceboro Site contained clayey soils, and the Cool Springs Site contained sandy soils. Automated recording water table level wells monitored a total of 20 plots in transects of clayey Aquic Hapludults (Craven) and Aeric Paleaquults (Lenoir); sandy Typic Udipsamments (Tarboro and its wet-end variant) and Aquic Udipsamments (Seabrook); and coarse-loamy Aquic Paleuduults (Foreston and its wet-end variant) and Aeric Paleaquults (Stallings) for over 365 days. These water table and on-site rainfall data (one rain gauge was located at each site) were used as input information for the hydrologic model DRAINMOD (Skaggs, 1978) to independently predict 30-yr historic water table levels for each soil. Using long-term weather data, soil wetness conditions for each method were determined for each of the 20 plots.

DRAINMOD was calibrated to achieve a match between measured and observed water tables in each plot by using the methodology outlined by He, et al. (2002) and in

accordance to rule .1942 (f) (NCAC 2005). Once the model was calibrated, long-term water table levels were predicted using historic (+30 yr) rainfall data from the nearest weather station in order to determine the probability that a site will be saturated for a 14-d continuous period with a recurrence frequency of 30%. These values were then related to the depth of the first occurrence of three types of redox features (iron concentrations, ≤ 2 and ≤ 3 chroma iron depletions).

The Threshold method is a modified form of the Threshold Wetland Simulation (TWS) as reported by Hunt et al., 2001. The requirements for obtaining the soil wetness conditions by the Threshold method were the same as those for the calibration method (14-d continuous period with a recurrence frequency of 30%). This method uses one representative soil in that can be extrapolated to other similar soils. The depths of soil wetness conditions predicted by this method were never more than 12 cm different from those wetness conditions predicted by the Calibration method at all sites.

The soil wetness conditions determined by the WRI method is a sliding scale of saturation durations based on monitored rainfall data only. Those values that were obtained were variable within each plot, ranging (at all sites) from ponded conditions (0 cm) to 65 cm below the surface. Therefore, the wetness conditions predicted by this method are split into two groups, WRI-H (water table depth of 0 cm) and WRI-L (water table depth of 65 cm) for each plot. In the case of multiple years of analysis, the shallowest depth predicted by this method is the soil wetness condition (15NCAC 18A .1942, 2005). The soil wetness condition acquired by the WRI method could not be determined for every year of analysis due to lack of required rainfall.

The Calibration, Threshold, and WRI methods of determining soil wetness conditions have specific relationships with the soil morphological indicator of wetness (chroma ≤ 2 depletions). For all the soils at the Richlands site and the Lenoir soils of the Vanceboro site, wetness conditions predicted by the different methods (except WRI-H) were higher in the soil profile than the morphology suggests. The level of soil wetness conditions predicted by all methods (except WRI-H) for the Craven soils of the Vanceboro site and the Tarboro (and its variant) were deeper than the levels of chroma ≤ 2 depletion or color occurrences. The wetness conditions predicted by most methods for the Seabrook soils of the Cool Springs site matched the level of the chroma ≤ 2 color occurrence.

Soil wetness conditions depths predicted by the Calibration and Threshold methods related best with the depth to different redox features in the following soils. For all soil plots of the Richlands site, the average depth to soil wetness conditions determined by the Calibration method (43 cm) related best with average depth of first occurrence of iron concentrations (43 cm). The average depth of Calibration wetness condition (30 cm) related best with average depth of ≥3 depletions (32 cm) in the Lenoir soils. There was not a consistent relationship in the Aquic Hapludults between the average calibrated soil wetness condition (102 cm) and the average depth of chroma ≤ 2 depletions (52 cm). The average depth to chroma ≥3 depletions (112 cm) of the wet and dry end of the Tarboro soils related best with the average depth of soil wetness determined by Calibration method (110 cm). The average soil wetness depths obtained by the Calibration method for the Seabrook soils (55 cm) related best with depth of chroma ≤2 depletions (52 cm).

EVALUATION OF SEVERAL METHODS OF PREDICTING HISTORIC WATER TABLE LEVELS

By
Erik D. Severson

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APPROVED BY:

Dr. D.L Lindbo (chair)	Dr. M.J. Vepraskas (co-chair)
Dr. R.O. Evans	Dr. A. Amoozegar

BIOGRAPHY

Erik Donnally Severson is from Atlanta, GA. He received his Bachelor of Science degree in Environmental Science from Virginia Tech in 2000. In 2000-2001, he mapped soils in West Virginia, South Carolina, and Maryland and evaluated soils and sites for the land application of septic tank waste in Virginia for a private consulting firm based in Christiansburg, VA. In 2002 he worked for the NCDOT as an environmental specialist. Currently, he is a research assistant in NC State University.

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1. Introduction

Municipal sewer systems were not available to many people living in rural and outlying suburban areas due to economic and logistical constraints. These people must treat and dispose of their sewage by using an onsite wastewater disposal system (OSWS). According to the U.S. Census Bureau (1990), more than one-third of the homes in the southeast and an estimated 48% of North Carolina citizens use OSWS as their method of domestic waste disposal for single-family dwellings.

A typical septic system consists of four components: the source (home), the septic tank, the absorption drainfield, and the soil beneath the drainfield. Wastewater flows from the home to the septic tank (an oxygen depleted environment). In the septic tank solids settle to the bottom and grease floats to the top and a clarified liquid exits the tank. The septic tank effluent (STE) then flows to a distribution device where the effluent was evenly distributed into the drainfield. The drainfield most commonly consists of drainpipe laid in a 3-ft wide, 1-ft deep gravel filled trench. The aerobic soil beneath the drainfield treats the wastewater before it flows to the underlying groundwater.

There were several reasons a drainfield must be placed in suitable, aerated soils. First, soils must be able to accept the additional hydrologic load of the STE. Second, the soil acts as a treatment media for the STE through physical and biochemical processes before it enters groundwater. For example, ammonia-N was converted to nitrate-N. This process requires well-aerated soil. Soils located below the water table have all pores occupied by water and have limited oxygen transfer from the atmosphere, thus treatment potential was limited. If the drainfield and soil beneath it become saturated and anaerobic, the level of treatment was reduced. Harmful bacteria may survive, STE filtration was reduced, and ammonia-N can be directly discharged to groundwater. To ensure proper treatment of this waste, there must be suitable, aerobic soil material through which the STE may flow. However, improper function of OSWS can occurred because the systems were installed into soils that were excessively permeable, impermeable, or saturated.

When installed in suitable soils, septic systems provide a safe and efficient treatment method for domestic waste. Sites with suitable soils in the Lower Coastal Plain region were being utilized at a rapid rate for development. The depth to the bottom of the septic system drainfield must be 30 cm above the water table (46 cm for sandy soils). The siting of septic systems was based on understanding the relationship between soil features and the water table in these soils.

Drainage was used to lower water tables in eastern North Carolina. Soils were traditionally drained by ditches and drain tubing for agricultural and forestry purposes. Development was forcing the conversion of these drained agricultural fields and forestlands to roads and land based waste treatment systems. Thus, it was important to understand the soil-water table relationships of these soils.

Soil scientists and OSWW practitioners use soil morphology to predict the depth to a seasonal high water table (SHWT) and make interpretation of soil suitability to maintain proper function of an OSWS. The depth to SHWT was estimated by using the first morphological indication of gray (≤ 2 chroma) redoximorphic (redox) iron depletions. Specifically, soil wetness conditions, was defined in title "15A NCAC 18A .1942 Soil Wetness" regulation (NCAC, 2005) as bodies of low chroma color (chroma ≤ 2, value ≥4 in the Munsell Color notation) that occupy 2% or more of the soil volume in a given horizon. Rule .1942 in its entirety is shown in Appendix I.

This methodology has been used in North Carolina for over 25 years and has for the most part been acceptable. However, this approach could lead to misinterpretation of the soil morphology in the following ways: 1) wetness without indicators; due to low carbon or Fe contents, or oxygenated water; or 2) indicators of wetness but no actual wetness. In the latter case, a site may be hydrologically altered (drained), inherit gray color from parent material, or have a gray E horizon. When morphology was in question, there were two general approaches to assess the soil wetness conditions of a given soil, monitoring and modeling. These approaches were outlined in separate methods by the NCDENR OSWWS. These methods were referred to as: the Weighted Rainfall Index (WRI), Calibration, and the Threshold.

The WRI method (NCAC, 2005) uses daily rainfall and daily water table depths to assess the depth to soil wetness. The monitoring period extends from December 15 through April 15. The soil wetness conditions were determined by a sliding scale of the duration (number of consecutive days) of saturation. The saturation durations were based on the cumulative rainfall from December 15 to April 15. The more rainfall there was at a given site, the longer the required duration of saturation. This method was not applicable in years where the monitored period was too dry.

The remaining methods were a combination of monitoring and modeling. These methods use a hydrologic model (DRAINMOD, Skaggs et al., 1978) to compute historic (30+ yr) water table levels on the basis of rainfall data and soil properties (K_{sat}, drainable porosity, etc). Although this model was developed for flat agricultural land with a parallel drainage network, it has also been shown to adequately simulate water table levels in natural landscapes of this region (He, et al. 2002). For the purpose of determining soil wetness conditions for the OSWS site evaluation, two variations of DRAINMOD have been utilized: 1. Calibration Method, and 2. Threshold Method. The Calibration Method was recognized by rule .1942 (NCAC, 2005), while the Threshold method was not. Nonetheless both were applicable for OSWS evaluation.

The Calibration Method determines the appropriate DRAINMOD inputs in order to calibrate the model for a specific well (He et al. 2002). Short term monitored rainfall and well data were used to "calibrate" the model. DRAINMOD was calibrated by adjusting input parameters to achieve the best possible match between the observed and predicted hydrographs in a four-month period (January 1 to April 30). After calibration, long-term climate data from the nearest weather station were used to simulate the historic water table fluctuations. The soil wetness condition was then determined by the model to be the highest level predicted that was saturated for a 14-day continuous period between January 1 and April 30 with a recurrence frequency of 30 percent (an average of at least 9 years in 30).

The Threshold method was a modified version of the Threshold Wetland Simulation Method (TWS) described by Hunt et al. (2001). The TWS method compare a wetland hydrograph to a simulated one using DRAINMOD simulated water table fluctuations. For OSWW wetness determinations, the threshold level (depth) was user defined, usually deeper than 30 cm in the profile and with a required duration of saturation of 14 days. Historic water tables fluctuations of each plot were simulated by DRAINMOD in a similar fashion to the Calibration Method, using a combination of the same long-term and short-term weather, soil, and hydrology inputs. The criteria for soil wetness conditions by this method were the same as the Calibration Method: the highest water level predicted by the model to be saturated for a 14-day continuous period between January 1 and April 30 with a recurrence frequency of 30 percent (an average of at least 9 years in 30). There was no measure of success for this method.

With the models described above, it should be possible to simulate historic site conditions by augmenting DRAINMOD with background soil, site, and hydrology information. Once this information was obtained, soil wetness conditions by the Calibration, Threshold, and WRI methods could be compared to the soil morphological indicator of wetness (chroma ≤ 2 depletions). In order to understand the relationship between redox features and computer simulated water levels, it was important to first have a working knowledge of what redox features were, how they form and how they relate to water tables along different landscape positions.

2. Literature Review

Soils were judged by onsite evaluators for their ability to accept and sustain a working OSWS. Accurate assessment of the water table regime was necessary for design purposes. This assessment was performed in three general ways (i) direct observation of soil morphology, in particular, shallowest depth to the occurrence of redox depletion (redox feature); (ii) direct observation of soil water tables via a well(s); and (iii) predictions of water tables through a computerized hydrologic model such as DRAINMOD using historical climatic data. This review will encompass the current knowledge of formation redoximorphic features and their relationship to measured and predicted soil water tables.

2.1 Soil Morphology

Soil morphology was the physical composition of the soil, which includes its texture, structure, color, and consistence, its biological, chemical, and mineral properties of the horizontal layers, and the thickness and arrangement of these layers (Soil Survey staff, 1999, Buol et al., 2003). The layers, or horizons, were almost parallel to the ground surface, and have distinct characteristics as a function of soil forming processes. Each horizon is distinguished from adjacent horizons by a change in any of the morphological features such as a change in texture or color. Morphology was best examined in the field where all the horizons can be exposed along a vertical face, which extends into the parent material. Morphology was relatively constant over time and thus observable at any given point within a year (Buol et al., 2003).

Morphological features such as soil color, and specifically redoximorphic features, were a function of the chemical reactions within a given horizon. Matrix color was the dominant color in the soil. Mottles were spots or blotches of color in the soil that differ from the matrix color (Buol et al., 2003). The pattern may relate to the aeration or drainage of the soil. Well-drained soils usually have uniform bright colors. Soils with a fluctuating water table have a mottled pattern of gray, yellow, and/or orange colors (Buol et al., 2003). Mottles were a generic term for redoximoprhic features.

2.1.1 Soil Color

Soil color, the most obvious and easily observed soil characteristic, was a morphological feature of concern with respect to OSWS's. Soil color has three quantifiable variables: hue, value, and chroma (Buol et. al., 2003). Hue was the dominant color related to the wavelength of light (red, brown, or yellow). Value was a measure of degree of light reflected of a color (lightness or darkness). Chroma was a measure of the purity or strength of the dominant wavelength of light reflected (color intensity). Since the description of soil color was subjective, a standardized measurement system, in the form of the Munsell Color Charts (www.munsell.com) was created. Each chart contains 29 to 42 color chips enabling the user to best fit the soil color to a particular chip. All chips on a given page have the same spectral color, or hue. Soil held next to the chips enables a visual match thus giving the proper Munsell notation. For example, a notation of 10 YR 5/6 was a soil with a color of 10YR hue, value of 5, and a chroma of 6. The color was light brownish yellow.

Soil color was controlled by several components. In general, humified organic matter coating mineral grains controls dark colors in surface horizons (Vepraskas, 2000, Buol et al., 2003). The red to yellow colors of the subsoil were due to iron oxide coatings on mineral grains. Even in low amounts, these iron oxides have high pigmenting power (Schwertmann and Taylor, 1977). Since organic matter usually decreases with depth, subsoil color was controlled either by parent material and/or iron oxides.

Soil color can also be a function of a horizon's redox status. Oxidation of iron occurred during periods of aeration. Hydrolysis and oxidation reactions release reduced (Fe^{2+}) iron bound in primary silicate minerals. Iron (Fe^{3+}) that was released precipitates as iron oxides (Fe_2O_3) due to its low solubility (Schwertmann and Taylor, 1977). The precipitated iron oxides then uniformly distributed throughout the matrix in aerated soils, or can be segregated into concentrations and depletions in soils with a fluctuating water table.

2.1.2 Redoximorphic Features

Evidence of wetness in soils was marked by redoximorphic features as a result of redox reactions of C, Mn, Fe, and S in seasonally saturated soil (Vepraskas, 2000). These features form from the reduction, movement, and oxidation of these compounds. Redox features may be; (i) organic-C based, (ii) Mn-based, (iii) Fe-based, and (iv) S-based. Examples of the C-based features was the accumulation of organic material over the whole surface layer, providing evidence of anaerobic conditions, and hindered organic matter decomposition due to the soil being saturated. Mn-based features manifest themselves as black masses and gray depletions. The Fe-based features occurred as red masses (redox or iron concentrations) or gray depletions (redox or iron depletions). Finally the S-feature was apparent by rotten egg smell.

Iron based redoximorphic features were morphological features formed from oxidation-reduction reactions in seasonally saturated soils (Soil Survey Staff, 1999; Vepraskas, 2000). They were identified in the field by the loss (depletion) or gain (concentration) of pigmentation (color) compared with the matrix color (Schoeneberger et al., 1998). The relative change in color was due to the reduction, translocation and oxidation of Fe oxides. Concentrations have high chroma (6 chroma or higher in Munsell notation), while depletions have low chroma colors. Factors that affect redox reactions can include type and amount of organic matter, slope and water movement, and temperature (Vepraskas and Wilding, 1983; Evans and Franzmeier, 1986). Gray colors usually indicate a lack of iron on particle surface. Redox features were generally widespread features, permanent unless destroyed by further reduction or mixing, and need Fe to form. In some cases, gray colors may mean there has never been any iron present (Vepraskas, 1999; 2000).

Redox concentrations were defined as an apparent accumulation of oxidized iron (Soil Survey Staff, 1999; Schoeneberger et al., 1998). They were noted by a higher iron oxide content and chroma than the surrounding matrix. They form by iron moving, oxidizing and precipitating. Typical mineral composition of concentrations includes goethite, ferrihydrite, and lepidicrocite (Schwertmann and Taylor, 1989), producing red, orange, yellow, and brown colors. There were three types of redox concentrations: iron masses, iron in pore linings, and nodules and concretions. Iron masses were soft, non-cemented, easily crushed accumulations of iron oxides within peds, away from cracks or root channels. The size of these masses depends on the size of the structural aggregate.

Pore linings were iron accumulations around ped surfaces, cracks, and root channels. These may be at any depth that roots occur within the profile, and do not need live roots to form. Oxidized rhizospheres have iron oxidized around an active root bringing oxygen into a saturated environment. Nodules and concretions were usually round, cemented iron that was not easily crushed. They were not a reliable indicator of current redox processes because of the uncertainty of their origin (Vepraskas, 2000). They were thought to have either formed in place or been deposited.

Redox depletions were zones of iron loss. They were defined as bodies of low chroma ≤ 2 and value of 4 or more, where Fe, Mn, and perhaps clay have been stripped from the area (Soil Survey Staff 1999; Vepraskas, 1999). Depletions can occurred as ≤ 3 chroma depletions (Vepraskas and Wilding, 1983, Franzmeier et al., 1983). These depletions were not interpreted as indicators of the SHWT by NCDNR OSWW section. They do indicate the partial removal of iron oxide coatings from mineral grains, however, not as complete as iron removal on the ≤ 2 chroma depletions. Depletions can occurred along pore linings, root channels, ped surfaces, or ped interiors. Evidence of iron reduction was readily identifiable in the field. In many cases, the iron has been reduced for substantial periods (Hayes and Vepraskas, 2000; Veneman et al., 1998).

A reduced matrix is when the entire horizon is a redox depletion (Vepraskas, 2000). Once exposed, iron within the gray (reduced) matrix will begin to oxidize within 30 minutes of exposure (Vepraskas, 2000). Gleys colored matricies are a sign of permanent saturation. Colors found in the Munsell Color Chart "Gley Pages" can be bluish, greenish, or purplish hues of gray colors, probably due to iron associated with a carbonate, phosphate, or sulfate anion (Schwertmann and Taylor, 1989).

2.2 Redox chemistry and morphology

Redox reactions were the most significant chemical reactions in soils with fluctuating water tables. These reactions control soil color, organic matter content, and soil water chemistry, particularly levels of nitrate, iron, and sulphur. In subsoil environments decaying roots and dissolved organic C typically provide the labile organic matter necessary for biochemical reduction with temperatures above biological zero, which is set at 5° C (Menongial et al., 1993, Menongial, 1996).

Oxidation was a loss of electrons (e^-) while reduction was a gain of electrons during a chemical reaction involving electron transfer. If oxygen was present, electrons produced in organic matter decomposition were accepted by O_2 to make water.

$$\mathbf{4e^- + O_2 + 4H^+ \rightarrow 2H_2O \qquad (2.1)}$$

When all oxygen was depleted, the soil becomes anaerobic.

Redox potential was theoretically based on the quantity of e^- available in the soil solution, which was measured as potential electron activity (pe) which can be converted into redox potential Eh (mv):

$$\mathbf{Eh = .059\ pe \qquad (2.2)}$$

Recent soil hydromorphology studies employ redox electrodes with monitoring wells to assess soil redox potential by measuring Eh (Hayes, 1998, Karthenasis et al., 2003, D'Amore et al., 2004). Field measurements of voltage were converted to Eh by adding a correction factor of 200 mv. The presence of reduced iron in soil solution was determined by the use of an Eh-pH diagram (Vepraskas, 2000) as calculated by:

$$\mathbf{Eh = 1235\text{-}177pH \ \ (pH < 7.5) \qquad (2.3)}$$

Magnitude and sign of voltage must be recorded and pH of soil solution must be known. Redox potential measurements were highly variable; therefore measurements should include at least 5 separate probes at a given depth in the soil and should be no more than 6 inches apart within the same horizon. Potentials range from +1 volt to –1 volt (+1000 mv to –1000 mv). Aerated soils tend to have higher Eh values (1000 to 500 mv) while soils with reduced iron have lower potentials (around 500 mv, depending on pH to – 400 mv). Salt bridges were used to connect the reference electrode to the soil as outlined by Pickering and Veneman (1983), thus improving and stabilizing the readings.

When soils become saturated, aerobic microbes utilize and deplete the remaining O_2 in the system. Aerobic microbes then die or become dormant and obligate and anaerobic bacteria dominate. During anaerobic respiration soil organic matter was oxidized, and other oxidized soil components act as electron acceptors and become reduced (Ponnamperuma; 1972, Faulkner and Patrick, 1992; and Vepraskas, 2000).

Electron acceptors in soil systems generally follow this scheme with increasing reduction:

(1) Denitrification

$$\mathbf{2NO_3^- + 10e^- + 12H^+ \rightarrow N_2 + 2H_2O} \qquad \mathbf{(2.4)}$$

(2) Manganese Reduction

$$\mathbf{MnO_2 + 2e^- + 4H^+ \rightarrow Mn^{2+} + 2H_2O} \qquad \mathbf{(2.5)}$$

(3) Iron Reduction

$$\mathbf{Fe_2O_3 + 2e^- + 6H^+ \rightarrow 2Fe(II) + 3H_2O} \qquad \mathbf{(2.6)}$$

(4) Sulfate Reduction

$$\mathbf{SO_4^- + 8e^- + 10H^+ \rightarrow H_2S + 4H_2O} \qquad \mathbf{(2.7)}$$

(5) Carbon Dioxide Reduction

$$\mathbf{CO_2 + 8^e + 8H^+ \rightarrow CH^{4+} + 2H_2O} \qquad \mathbf{(2.8)}$$

(adapted from McBride, 1994, and Mitsch and Gosselink, 1993)

Reduction in soils was attributed to the lack of air in soil pores. Oxygen was reduced first, making the soil anaerobic, followed by nitrate, manganese oxides, then iron oxides, sulphur and lastly carbon. Each element acts as an electron acceptor until it was fully consumed. By its virtue of position in the reduction sequence, iron reduction must occurred when oxygen, nitrate, and Mn oxides have been fully exhausted. Once the soil drains and oxygen enters the pores, aerobic microbes dominate and oxygen once again becomes the primary electron acceptor.

Four conditions must be satisfied simultaneously for iron reduction (Faulkner and Patrick, 1992; Menongial et al., 1996; Vepraskas, 1999): (i) lack of dissolved oxygen; (ii) a source of soluble organic matter (electron source); (iii) active bacteria to decompose organic matter with soil temperatures above biological zero (5° C); and (iv) stagnant, waterlogged soils. Also, a source of Fe(III) was needed for its reduction. Iron reduction was decreased or stopped when any of these conditions were absent. When all factors were acting in concert, bacteria decomposing the soluble organic matter will reduce Fe(III) to Fe(II). If any of the steps in the above sequence does not occur, iron reduction may not occur. It has been shown that soils must be saturated for an average of 21 days for iron reduction to occur (Hayes and Vepraskas, 2000; He et al., 2002).

2.3 Redox feature formation

Fe-based redox features form from the reduction, movement and oxidation of iron. Iron oxides coat soil mineral (often silicate) surfaces, giving a reddish, yellowish, or brownish characteristic color. When saturation occurred, oxygen diffusion into the soil was slowed, and oxygen was depleted by microbes decomposing organic matter (Menongial et al., 1996). The microbes then reduce any remaining NO_3^- and Mn, and the next element in the sequence of reduction, Fe. Iron oxides dissolve and become colorless in solution; gray color remains because that was the color of silicate mineral grains without the Fe oxide coating. Mobile Fe^{2+} ions then move with soil water and may re-oxidize upon soil drying (oxidation) or they may be leached from the system. Areas of re-oxidation include entrapped oxygen within peds, root channels and cracks, or anywhere oxygen reenters the soil (Vepraskas, 2000).

Oxidized rhizospheres form in flooded soils where actively respiring plant roots bring oxygen into the rooting zone, thus causing Fe^{2+} to oxidize and precipitate as Fe^{3+} around the root channels. Pore linings can develop at any depth in the soil profile. As the soil drains, the soluble iron can be oxidized (Evans and Franzmeier, 1986; Vepraskas 2000). These points were either pores within peds (masses), tubular pores or voids; or along ped faces

Redox depletions of chromas greater than 2 can occur if they were formed by the same process of iron loss seen in chroma 2 depletions. Chroma 3 colors can indicate the presence of remaining Fe oxides on the particle surfaces (Vepraskas, 1999), natural mineral color, low amounts (<1%) of organic matter, or oxygenated water. These soils can be reduced for short periods, but may be waterlogged for long periods (Vepraskas and Wilding, 1983; Evans and Franzmeier, 1986). Chroma ≤ 3 depletions were associated with saturation, but have been found to be saturated and reduced for a lesser time period than chroma ≤ 2 depletions (Franzmeier et al., 1983; Evans and Franzmeier, 1986). Chroma 3 depletions have been shown to be a good indication of a water table (Daniels et al., 1987; Veneman et al., 1998).

2.4 Seasonal High Water Table Estimations

The water table was defined as the upper surface of ground water (Soil Survey Staff, 1999). A seasonal high water table was the highest level of the saturated zone, persisting in the soil continuously for at least 2 weeks within 2 meters of the soil surface (Goodwin, 1989; Barnhill, 1992). Soils that have a seasonal high water table were classified according to the depth to water table, kind of water table, and time of year when water table was highest. The normal depth range of a seasonal saturation or zone of saturation of the natural undrained soil was given to the nearest half-foot in NRCS soil surveys. Three kinds of seasonal high water tables were recognized within the soil (1) apparent, (2) perched and (3) anthric, or artificially ponded (Soil. Survey Staff, 1999).

(1) An apparent water table was the level at which water stands in a freshly dug, unlined borehole after adequate time for adjustments in the surrounding soil.
(2) A perched water table was one that exists in the soil above an unsaturated zone. A water table may be inferred to be perched on the basis of general knowledge of the water levels of an area, the landscape position, the permeability of soil layers,

and from other evidence. To prove that a water table was perched, the water levels in boreholes must be observed to fall when the borehole was extended.

(3) An anthric water table occurred due to controlled artificial ponding for food and fiber production. The subsoils were not usually saturated.

The depth of the SHWT, or soil wetness condition was stated by rule .1942a in North Carolina (15NCAC 18A, 2005) as 2% redox depletions by soil volume, observed in the field as having a low chroma color (less than or equal to 2, value greater than in the Munsell Color Book notation). It was assumed that in periods of normal rainfall, water will raise to this level.

Advantages to using chroma ≤ 2 depletions include the ability to make determinations on a wide variety of soils at minimal cost at any time of the year, without prior knowledge of rainfall and hydrology (Buol et al., 2003). Low chroma colors result from numerous periods of reduction/oxidation cycles occurring over many years, which make this estimation method a reliable indicator of seasonal groundwater elevation. Evaluations using this approach may be an inaccurate assessment of the saturation because it does not predict how long the water table remains at a given depth, nor does it predict the frequency of saturation

2.5 Misinterpretation Possibilities

Predicting depths to a seasonal high water table within areas having sandy soils can be difficult (Veneman et al. 1998). Redox feature development may be hindered by: 1) lack of carbon source (Daniels and Buol, 1992; Vepraskas, 1999); 2) low Fe in parent material, causing the lack of contrast between matrix and redox feature; 3) aerated or oxygenated water inhibiting reduction (Faulkner and Patrick, 1992); and/or (4) unstable root channels and cracks that only remain open for short periods (Vepraskas, 2000). Depletions may be confused with sand grains “stripped” of iron in sandy soils. These stripped grains usually cannot be affirmatively tied to water table dynamics. The SHWT was best estimated in sandy soils with identification of redox concentrations in conjunction with depletions (Veneman et al., 1998).

In addition, eluvial horizons typically posses low chroma matrix colors due to their low Fe content and clay content to a lesser extent. Some coarser textured soils have a gray-colored E horizon directly below the topsoil. Incomplete breakdown of soil organic matter in the topsoil results in the formation of organic acids, which causes extensive leaching in underlying soil layers unrelated to anaerobic soil conditions (Veneman et al., 1998). The iron was stripped from the sand gains by the process of chemical complexation (podzolization) resulting in gray colors.

Low chroma colors may not always be present, even though the soil has distinct periods of saturation. Many studies have demonstrated the existence of soils with significant wetness periods that do not exhibit low chroma redox features (Simonson and Boersma, 1972; Pickering and Veneman, 1984; Evans and Franzmeier, 1986; Griffin et al., 1992; James and Fenton, 1993; Mokma and Sprecher, 1994a; Wakely et al., 1996; Vepraskas et al., 1999). Dark red-colored soils have such high iron contents that low chroma mottles were masked (Mokma and Sprecher, 1994b). Other situations, where wet soil conditions do not necessarily cause distinct low chroma colors, occurred in soils with organic matter distributed throughout the soil profile, such as in frequently flooded fluvial soils (Lindbo, 1997).

Sometimes soils exhibit low chroma colors that do not result from seasonal anaerobic conditions. Soils can inherit low chroma colors from their geologic parent materials because the parent material may not contain enough iron to coat mineral grains (Veneman et al., 1998). Insufficient iron could have been released from the parent material during soil formation and unable to give the soil a uniform brown appearance.

In general, redox depletions can reliably predict the level of seasonal saturation and reduction in the soil if the site has not been hydrologically altered. Drainage ditches and subsurface tile drains alter hydrology, and redox depletions may no longer be reliable indicators of the saturation and anaerobic conditions (Lindbo, 1997, Hayes and Vepraskas, 2000). Features observed at hydrologically altered sites were referred to as relict features. Some of these relict features were distinguished in the field by having sharp, distinct boundaries. Active, contemporary redox features have diffuse boundaries and were indicative of a fluctuating water table (Vepraskas, 1999).

2.6 Water table- Redox feature correlations

Relationships between SHWT's and redoximorphic features in soils have been studied over the past three decades (Daniels et al., 1971; Franzmeier et al., 1983; Vepraskas and Wilding, 1983; Pickering and Veneman, 1984; Evans and Franzmeier, 1986). As documented by Veneman et al. (1998) in a review of soil hydromorphology studies, correlation between SHWT depths and redoximorphic features has been shown in much of the literature. The researchers note two principal findings: i) redox concentrations along with redox depletions were more accurate than the use of a single factor in assessing SHWT's and ii) significant saturation may occurred without strong redoximorphic feature development.

West et al. (1998) monitored water tables for three years in a plinthite bearing clayey transect as well as a sandy catena in the Coastal Plain of southwest Georgia, finding that horizons with redox concentrations were saturated 20% of the time, horizons with redox depletions were saturated 40% of the time, and horizons with reduced matrices (whole horizon reduced) were saturated 50% of the time.

In the Upper Coastal Plain of Virginia a strong correlation between SHWT depth and the depth to redox concentrations and depletions was observed (Genthner et al., 1998). They also showed the depth to redox depletions or a reduced matrix underestimated the height of the SHWT in well-drained soils, whereas in more poorly drained soils the opposite was true. Approximately 75% of the time during the 4-yr monitoring period a piezometer identified a perched water table. This horizon had 10YR 6/4 redox depletions in a 10YR 5/8 matrix.

Weekly and biweekly water table measurements were made for ten years in some typical soils of the North Carolina Coastal Plain: Udults, Aquults and Aquods (Daniels et al, 1987). They showed that chroma 3 mottles can be used as a reliable indicator for a water table presence. Further studies in the coastal plain showed a well-defined relationship between morphology and water table levels was observed in spodosols with the indication that the top of Bh horizons represented the average depth of water tables (Daniels et al., 1987). As the mean monthly water table rose closer to the surface, so did the tops of the Bh horizons. Soils with an abundance of morphological features of wetness generally had higher average water table depths than the better-drained soils with fewer features at a greater depth.

Water table depths and oxygen levels were measured bi-weekly in forested systems on two toposequences derived from silty loess over loamy glacial till (Evans and Franzmeier, 1986). Oxygenated water perched above dense till flowed laterally to the drainageways. Udalfs on the shoulder and backslope positions had lower water tables than the more poorly drained Aquolls and Aqualfs occurring in drainageways and upland swales. However, these well and moderately well drained soils showed higher water table depths (above 1 m) and durations (>30 days) than were reported in published soil surveys. These soils had 3 chroma depletions and matricies and 4 chroma clay films, which were indicators of occasional saturation with short periods of reducing conditions. The Aquolls and Aqualfs were saturated at least half the study period and had low oxygen contents (< 5 mg/kg) for greater than 60% of the time. Three significant oxygen-water table regimes were proposed; (i) saturated and reduced, (ii) saturated and oxidized, and (iii) non-saturated and oxidized.

Data from a Mollisol catena showed that redox features in the moderately well drained to the very poorly drained end of the transects overestimated the duration of saturation (Steinwand and Fenton, 1995). The shallowest level at which greater than 2% redox features occurred in MWD-SWP-PD pedons on lower backslopes and footslopes were saturated less amount of time (avg. of 21% of study period) than the surface horizons of the well-drained members (approximately 34% of study period). These differences were accounted for by a lack of soluble organic matter with greater depth in the well drained member (Vepraskas and Wilding, 1983), or the presence of oxygenated water in the lower landscape positions resulting from through flow (Evans and Franzmeier, 1986; Ransom and Smeck, 1986). The stronger gleying and accumulation of organic matter in lower landscapes was apparently relict feature that formed before artificial drainage (James and Fenton, 1993).

Duration of saturation in soils of the Goldsboro-Lynchburg-Rains catena varied slightly with distance away from an individual drainage ditch (Hayes and Vepraskas, 2000). However, within 30 m of the ditch, water tables were lower and fluctuated more often and redox potential was lower (< 500 mv) for a shorter period than those soils away from the ditch. Reduced iron (Fe II) was discharged into the argillic horizons of soils adjacent to the ditch from upslope soils and was oxidized when water tables falls, thus creating more oxidized iron (Fe III) masses closer to the ditch.

Redox Feature Summary

Iron-based redox features have been shown by many studies to indicate the presence of a fluctuating water table (Veneman et al., 1998). Wetness conditions were determined morphologically by the indication of ≤ 2 chroma depletions occurring in exactly 2% of soil volume (15A NCAC 18A, 2005).   These depletions need stagnant, oxygen-depleted water, organic matter, temperatures above 5° C, a source of iron, and sufficient time (21 days) to form (Vepraskas, 1999; Hayes and Vepraskas, 2000; He et al., 2000). Other iron-based redox features identified by field observations such as chroma ≤ 3 depletions and iron concentrations were formed by the same basic principals as the chroma ≤ 2 depletions but were saturated for shorter periods of time. Nevertheless, chroma ≤ 3 depletions and iron concentrations were related to water-table fluctuation (Vepraskas and Wilding, 1983; Genther et al., 1998; West, et al., 1998).

2.7 Computer Simulated Water Tables

The hydrologic model DRAINMOD (Skaggs, 1978) has been extensively used in the USA to analyze the long-term effects of drainage on water table fluctuations. It was used to simulate and analyze water table management over a long period of climate record (e.g., 20 to 40 yr). The model predicts the level of saturation (water table) and can be queried to determine how often the soil was saturated within a given depth for a specific duration during any period in a year. DRAINMOD has been verified in extensive field experiments on a wide range of soils, crops, and climates (Skaggs, 1982; Fouss et al., 1987).

Once the long-term (+30 yr period) daily water table data and soil and site properties were gathered, saturation durations can be computed for any soil depth. One major advantage of using simulation models was that the effects of annual and seasonal variability of weather can be considered in the analysis. Another advantage was that the required input data for model calibration can be acquired in a short period (4 months) and the long-term simulations using historic rainfall data can be obtained (within minutes), instead of taking 30 years to monitor actual site hydrology.

The relationship between long-term hydrology and soil morphology was examined in a study of typical Coastal Plain soils (Norfolk catena) by He et al. (2000; 2002). DRAINMOD was calibrated for 21 plots using short-term rainfall and measured water table data. Input parameters to the model such as equivalent depth to a restrictive layer, evapotranspiration (ET), drain depth and spacing, depressional storage, and drainable porosity were adjusted individually to fit measured water table data with predicted values. This relationship was quantified by an absolute standard deviation over the study period and was generally less than 20 cm. The effects of slope on drainage rates were not investigated. Soil property inputs included lateral saturated hydraulic conductivity (K) and the soil moisture characteristic. Crop inputs were the rooting depth for each plot.

The research of He et al., 2002 was based on three assumptions: (i) water table levels could be predicted for individual soil plots (21 total at two sites) by treating each plot in isolation, (ii) subsurface drainage rates were estimated by using the Hooghout equation, using drain depth and spacing, and the depth to a restrictive layer to tabulate the drainage flux (the calibration was for a virtual drainage network); and (iii) deep seepage rates were virtually zero and incorporated into subsurface water losses.

DRAINMOD, when calibrated, can accurately simulate water table levels for a site with a single perimeter ditch rather than a series of parallel ditches. Input parameters such as drain depth and spacing, drainable porosity, and depth to the impermeable layer were adjusted by trial and error to minimize the difference between measured and simulated hydrographs. Simulated water table levels were sensitive to drain spacing. The exact location of the impermeable layer was unknown, so the depth to the impermeable layer was determined by trial and error (He et al, 2002). The values that were used for the depth to the impermeable layer did affect water table depths in the dry season. Large drainable porosity values of O horizons were used to minimize water-table fluctuations at and near the soil surface. After successful calibration, the model can compute long-term water table levels by using historic rainfall data.

DRAINMOD allows the estimation of historic water table fluctuations over 30-year periods. The long-term water table fluctuation data could also be used to compute the saturation durations at the depth redox features occurred. This approach was less expensive than annual measurements of water table levels.

Changes in wastewater regulations (15NCAC 18A .1942, 2005) and possible misinterpretation of soil morphology have warranted more research in soil morphology-water table relationships. The purpose of this study was to provide current research to test the regulations set forth in Rule .1942. The specific objectives of this research were:

1) Monitor rainfall and the hydrology of the soils of three experimental sites in the lower Coastal Plain

2) Simulate site conditions using rainfall and actual and virtual input parameters as outlined by He, 2000 and in accordance with rule .1942 (NCDENR, 2004)

3) Compare three methods of determining soil wetness conditions to wetness features determined from soil morphology

3. Materials and Methods

3.1 Experimental Sites

Three sites located in the Lower Coastal Plain (LCP) consisting of a drainage catena from well to very poorly drained soils were selected as the study sites. Site 1 was located near the town on Richlands and will be referred to as the Richlands site. Site 2 was located near the town of Vanceboro, and will be referred to as the Vanceboro site. The third site, referred to as the Cool Springs site, was located on Weyerhaueser's Cool Springs Environmental Education Center near the town of Aksin. The sites were selected based on three criteria, landowner cooperation, minimal influence of man on hydrology, and desired sequence of soils. These soils were chosen to represent the variable textures and morphologies of typical soils found in the LCP. An overview map of the Coastal Plain showing the experimental sites was shown in (Figure 3.1):

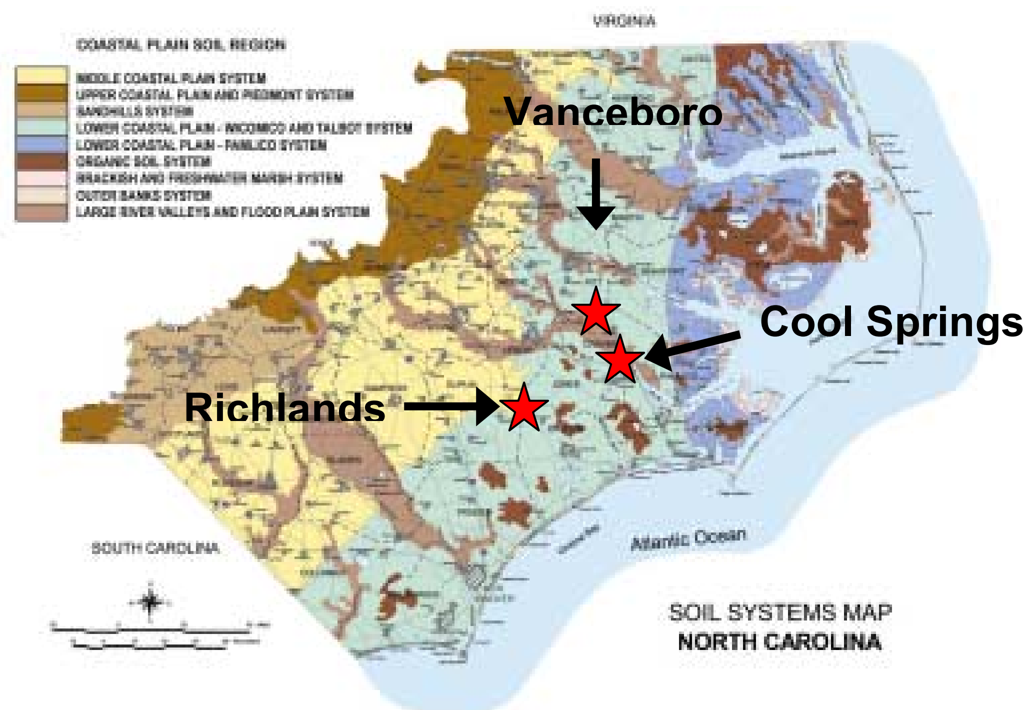

Figure 3.1 Map of eastern NC showing the three experimental sites on the Lower Coastal Plain. Richlands site was in Onslow Co., and the Cool Springs and Vanceboro sites were both in Craven Co (Map taken from Daniels et al., 1999).

At each site, 2 or 3 transects consisting of 5 to 6 soil plots (well drained moderately well drained, somewhat poorly drained, poorly drained, very poorly drained) were identified for a total of 33 plots. The transects follow a general pattern of well drained to poorly drained positions (Figure 3.2).

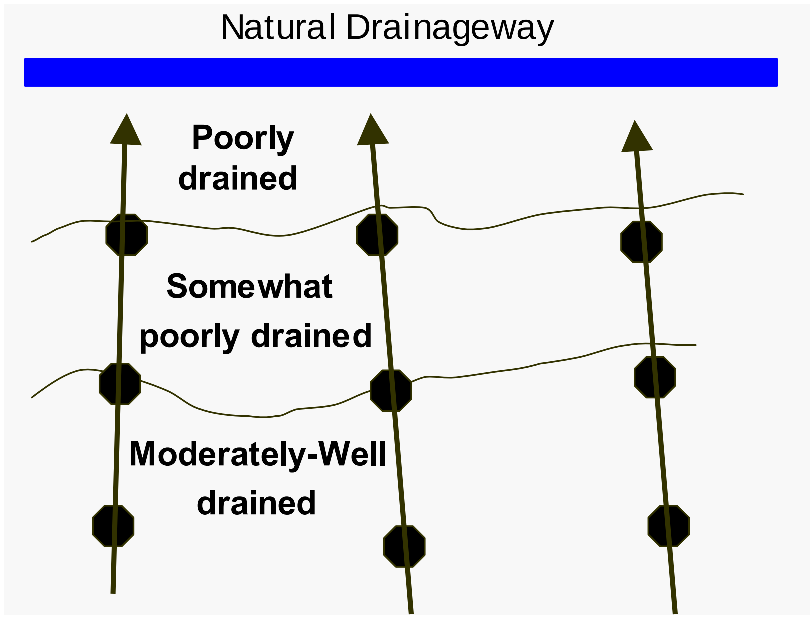

Figure 3.2 Generalized layout of soil plots (octagons) along transects and their landscape positions. The moderately well drained positions were highest in elevation, sloping downward though the somewhat-poorly drained plots, toward the lowest point on the local landscape, a natural drainageway.

Each soil plot, (represented by the black octagons in Fig. 3.2), was instrumented with an automated water table monitoring well, and a PVC check well. One transect from each site was instrumented with redox probes, salt bridges, and thermocouples in addition to the wells. One rain gauge per site was located away from the soil plots in an open area.

The hydrodynamics of each soil plot were characterized by a shallow (<2 m) groundwater system raising from the bottom to the surface (endosaturation). Episaturation (perched water table) occurred when the soil below the restrictive layer was unsaturated within 2 m of the surface. Both types of saturation were apparent at the experimental sites.

3.1.1 Richlands Site

General Characteristics

The Richlands site was located in Onslow County, NC, approximately 2.9 km south-southwest of the intersection of State Roads 1230 and 1229, and 320 m west from State Road 1230 (Haw Branch Rd.) at N 34º11’24”, and 77º39’0”. The site was located near or on the Cape Fear/New river drainage divide on a slight ridge within an interstream divide of the Lower Coastal Plain. The soils in the area were permeable and formed in loamy marine sediments. The soil drainage catena consisted of four coarse-loamy, endosaturated soils from moderately-well drained to poorly-drained: Foreston (Coarse-loamy, siliceous, semiactive, thermic Aquic Paleudults), and unnamed transition, referred to as the wet Foreston soil with redox depletions occurring higher in the profile than in the Foreston soil, but lower in the profile than the Stallings (Coarse-loamy, siliceous, semiactive, thermic Aeric Paleaquults) containing a buried spodic horizon occurring at 0.8 m, and Torhunta (Coarse-loamy, siliceous, active, acid, thermic Typic Humaquepts). The upland vegetation was dominated by longleaf pine (*Pinus palustris*) grading into American Holly (*Ilex opaca*), greenbrier (*smilax, sp*.).

There were several drainage features at this site. A 1.8-m deep, 2-m wide road ditch was located about 280 m from the edge of the site and had no apparent effect on the site’s hydrology. Also present on-site was a 1.5-m deep, 3-m wide channelized stream located in a perpendicular fashion in relation to the plots, from 100 to 150 m from the plot lowest on the landscape and 250 meters from the plot highest on the landscape. The road ditch flowed south then flows southwest into the 3-m wide ditch, which had a vertical distance of 0.4 m from the bottom of the stream to the stream bank, eventually draining into the Cape Fear River.

Soil Plots

The site consisted of a total of 12 soil plots, four plots along three transects. Three transects, each containing four plots were oriented in a northwestern to a southeastern direction. The transects were at least 50 m apart from each other and at least 80 m long were selected at the site. Each soil plot was no further than 20 m apart on all transects. The distance from the moderately well drained plots (highest elevations) to the paved road was 245 m. A rain gauge was located about 180 m northwest of the highest plot on transect 3 on the edge of a cleared field. The distance from the plots with the lowest elevation and the stream was 40 to 60 m (Figure 3.3).

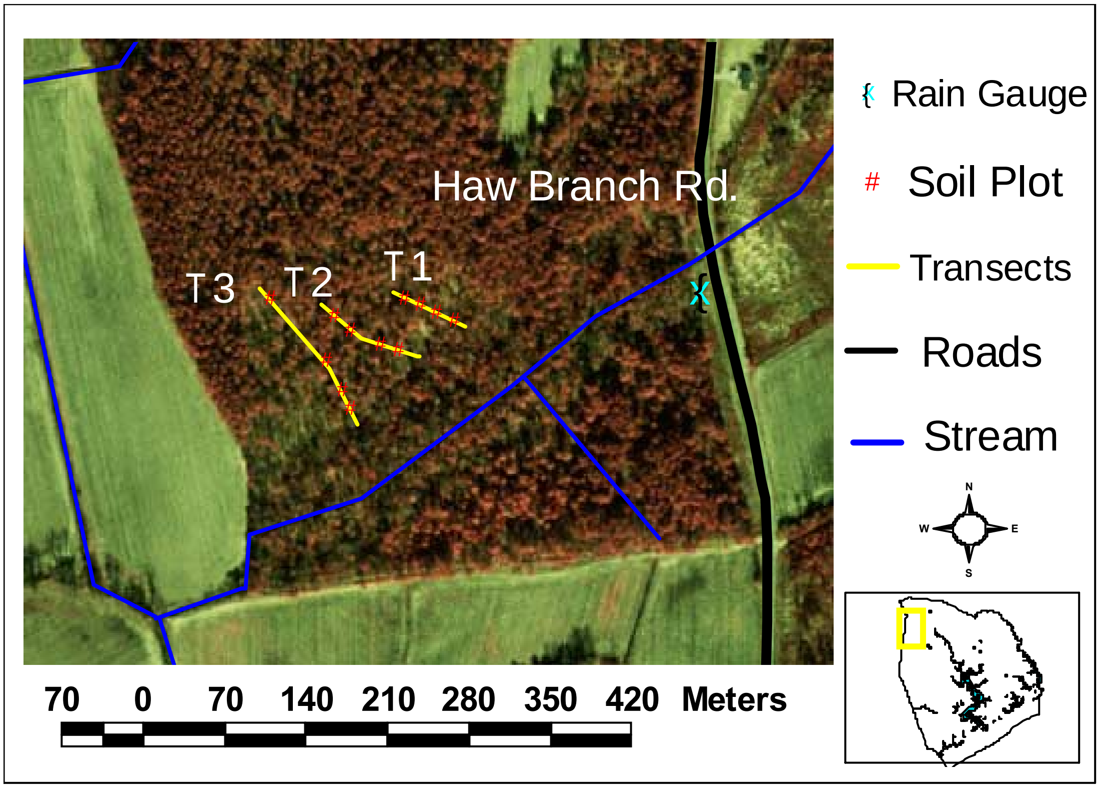

Figure 3.3 Layout of the Richlands site showing relative plot locations and their relationships between certain features such as roads, streams, and the rain gauge.

The soil plots were named as follows: 1Fo (Foreston), 1wFo (wet Foreston), 1St (Stallings), 1To (Torhunta), 2Fo, 2 wFo, 2 St, 2 To, 3 Fo, 3 wFo, 3 St, and 3 To. The numbers represent transects and the letters indicate the initials of the soil type. The Foreston, wet Foreston, and the Stallings plots were considered for analysis in this study. Relative elevations of the ground surface at all wellhead locations and the stream were determined at each site by a surveyor's transit (Fig 3.4).

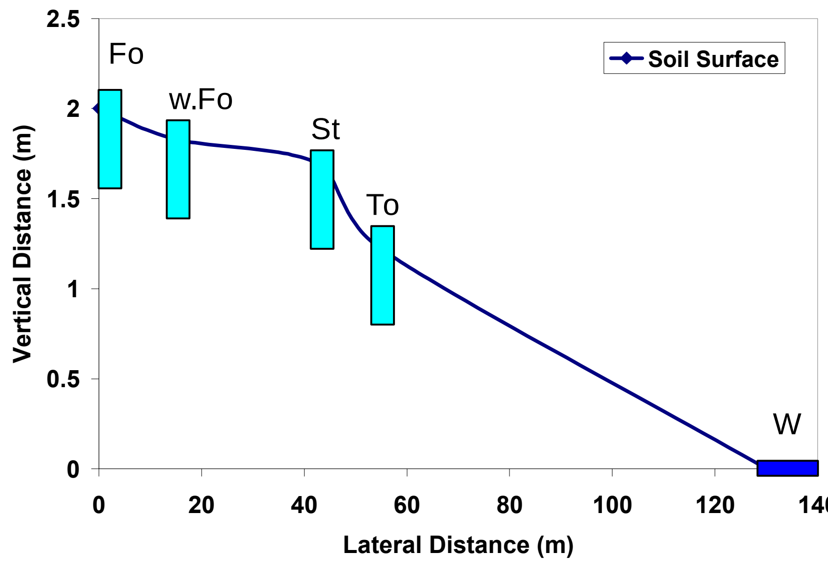

Fig 3.4 Relative elevation of the Foreston (Fo), wet Foreston (w.Fo.), Stallings (St), and Torhunta (To) soil plots along a transect 1 of the Richlands site. The stream (W) was shown at zero elevation.

The Foreston, wet Foreston, and Stallings plots were located on uplands while the Torhunta plots were located in a wetland on the lowest portion of the landscape (Figure 3.4). The Foreston plots were highest in elevation on the local landscape, located on the summit position. The wet Foreston plots were slightly lower on the landscape, on the backslope position, The Stallings plots were slightly lower in elevation than the wet Foreston plots and were located on the footslope position. The Torhunta plots were located on the toeslope position. The average slopes were 1% between the Foreston and wet Foreston plots, 0.5% between the wet Foreston and Stallings plots, and 4% between the Stallings and Torhunta plots. An elevation drop of 0.4 m occurred between the Stallings and Torhunta soils, enough to yield changes in soil morphology and inferred hydrology.

3.1.2 Vanceboro Site

General Characteristics

The Vanceboro site was located in Craven County, NC, approximately 6.4 km northwest of Vanceboro on North Carolina Highway 43, 1.3 km northeast on State Road 1644 (Clark Road), 107 m northwest on a non-maintained road, and 5 m northeast of the road at N35º21'0" and W 77º10'48". The site was on the edge of a broad interstream divide on a short sideslope near a drainageway. Soils were slowly permeable, on Coastal Plain upland that formed in clayey sediments. The soil drainage catena consisted of three endo- and apparent episaturated clayey soils from moderately well drained to poorly drained: Craven (Fine, mixed subactive, thermic Aquic Hapludults), Lenoir (Fine, mixed, semiactive, thermic Aeric Paleaquults), and a sandier version of the Leaf (Fine, mixed, active, thermic Typic Albaquults). Vegetation was dominated by a 40 year-old stand of loblolly pine (*Pinus taeda L.*), and red maple (*Acer rubrum L.*) in the uplands. The poorly drained member of the toposequecnce was comprised of greenbrier (*smilax, sp*.), red maple, loblolly pine, and yellow poplar (*Lilodendron tulipefera*).

Several drainage features occurred at this site. A shallow (1.1-m deep, 2-m wide) road ditch along Clark Rd. was located about 110 m from the edge of the site running parallel to the transects. The road ditch flowed northeast into a natural stream, which had a vertical distance of 0.3 m from the bottom of the stream to the stream bank, eventually draining into the Neuse River. This stream flowed northwest, perpendicular to the transect orientation.

Soil Plots

The site consisted of a total of 9 soil plots, 3 plots along 3 transects. The three transects, each containing three plots were oriented in a northeastern to a southwestern direction. Each transect was at least 50 m apart from each other and 80 m in length. Each soil plot was no further than 20 m apart. The distance from the moderately well drained plots (highest elevations) to the dirt road was 25 m. The rain gauge was located about 180 m northwest of the highest plot on transect 3 on the edge of a cleared field. The distance from the plots with the lowest elevation and the stream was 40 to 60 m (Figure 3.5).

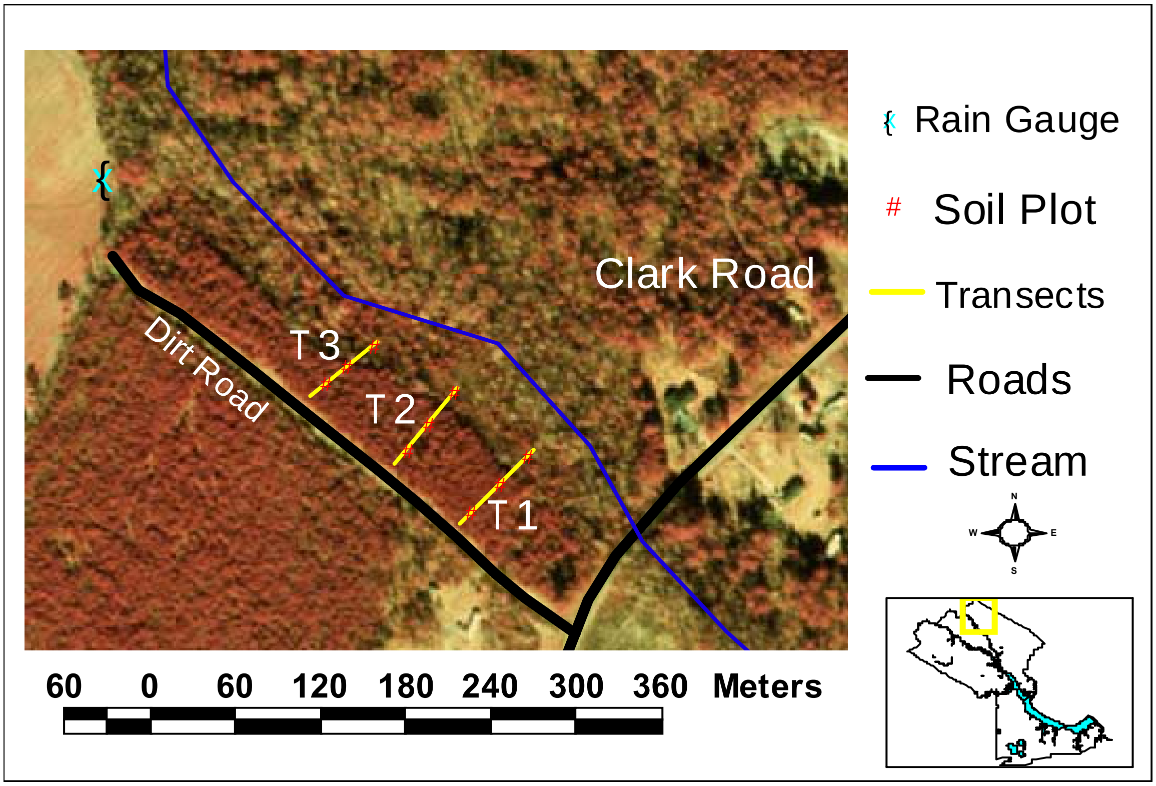

Figure 3.5 Layout of Vanceboro site showing plot locations along transects (i.e. T1) and their relationships between certain features such as roads, streams, and the rain gauge.

Plots were named as follows: 1Cr (Craven), 1Le (Lenoir), 1La (Leaf), 2Cr, 2Le, 2La, 3Cr, 3Le, and 3La. Numbers represent transects and the letters indicate the initials of the soil type. Craven and Lenoir plots were considered for analysis in this study. Relative elevations of the ground surface at all wellhead locations and stream were determined by a surveyor's transit (Figure 3.6).

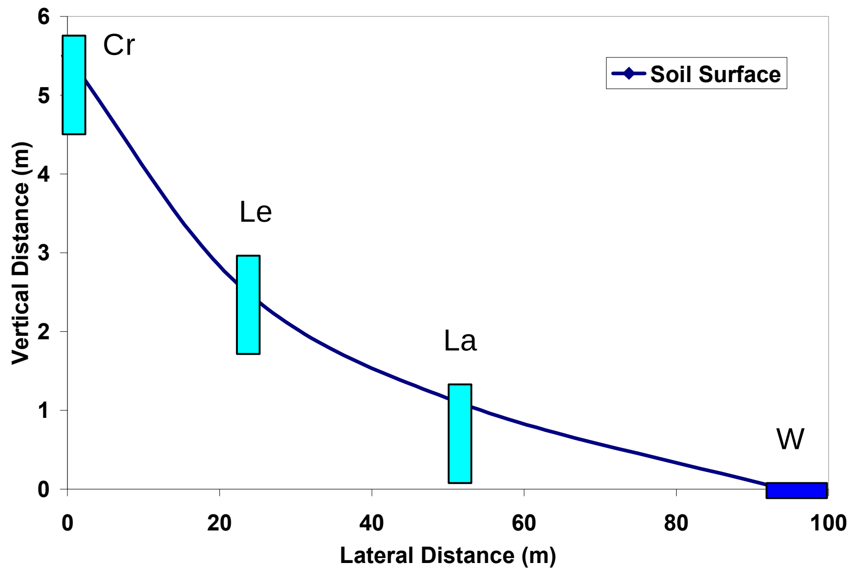

Figure 3.4 Relative elevations of Craven (Cr), Lenoir (Le), and Leaf (La) soil plots and natural stream (W) along transect 2 of the Vanceboro site.

The Craven and Lenoir soils were on uplands while the Leaf soils were in wetlands. The Craven plots were highest in elevation on the local landscape, located on the shoulder position. The Lenoir plots were lower on the landscape, on the backslope position, while the Leaf plots were on the toeslope position. The slope was 5-6% between the Craven and Lenoir soils and 2% between the Lenoir and Leaf soils.

3.1.3 Cool Springs Site

General Characteristics

The Cool Springs site was located in Craven County, NC, on a the Weyerhaueser Company's Cool Springs Environmental Education Center approximately 7 km southwest of Askin, NC on State Road 1435,and about 0.5 km from Road 1435 on a private gravel road at N 35º11'24", and W 77º5'24". There was a 0.3 m road ditch on State Road 1435. Soil transects were established perpendicular to a natural back swamp. The site morphology was a gently undulating low ridge of Swift Creek stream terrace, draining into the Neuse River. The soils of this site were endosaturated, with the water table elevation controlled by the level of the backswamp. The soil drainage catena consisted of six sandy soils, five of which were named, and a transition soil from well drained to very poorly drained: Tarboro (Mixed, thermic Typic Udipsamments), an unnamed soil, referred to as wet Tarboro between Tarboro and Seabrook (Mixed, thermic Aquic Udipsamments), Mandarin (Sandy, siliceous, thermic Oxyaquic Alorthods), Leon (Sandy, siliceous, thermic Aeric Alaquods), and Lynn Haven (Sandy, siliceous, thermic Typic Alaquods). Vegetation consisted of loblolly pine, longleaf pine, white oak (*Quercus alba L.*), water oak (*Quercus nigra L.*), sweetgum (*Liquidambar styraciflua L.*), and red maple. American holly and greenbrier dominated the understory.

Soil Plots

Two transects, oriented in a northwestern to a southeastern direction contained six plots each Transect 1 was 34 m southeast of transect 2. Each soil plot was no further than 10 m apart on both transects. The distance from the well-drained plots (highest elevations) to the paved road was 235 m. The rain gauge was located about 6 m southwest of the highest plot on transect 1. The distance from the plots with the lowest elevation and the backswamp was 3 to 4 m (Figure 3.7).

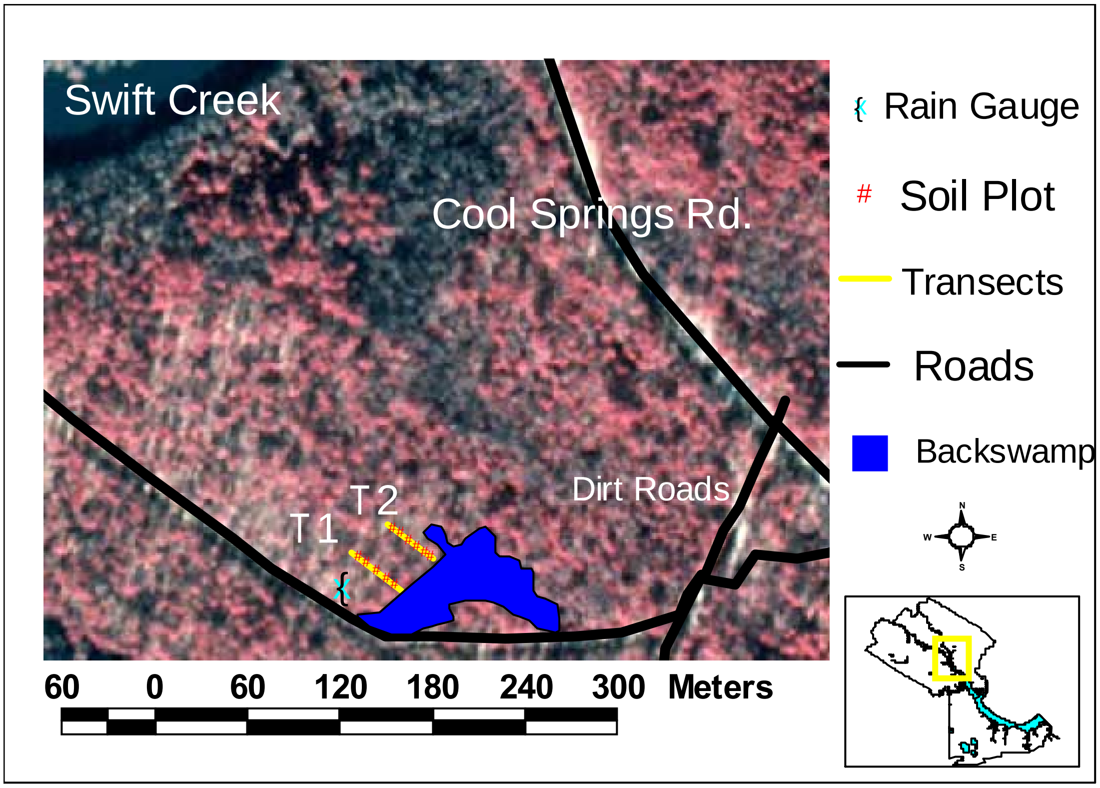

Figure 3.7 Site layout of the Cool Springs site showing relative plot locations and their relationships between certain features such as roads, backswamp, and the rain gauge.

The plots were named as follows: 1Ta (Tarboro), 1 w.Ta (wet Tarboro), 1Se (Seabrook), 1Mn (Mandarin), 1Ln (Leon), 1LH (Lynn Haven), 2 wTa, 2Se, 2Ma, 2Ln, and 2LH. Numbers represent transects and the letters indicate the initials of the soil type. Only the Tarboro, the wet Tarboro, and the Seabrook plots were considered for analysis in this study. Relative elevations of the ground surface at all wellhead locations and the backswamp were determined at each site by a surveyor's transit (Fig. 3.8).

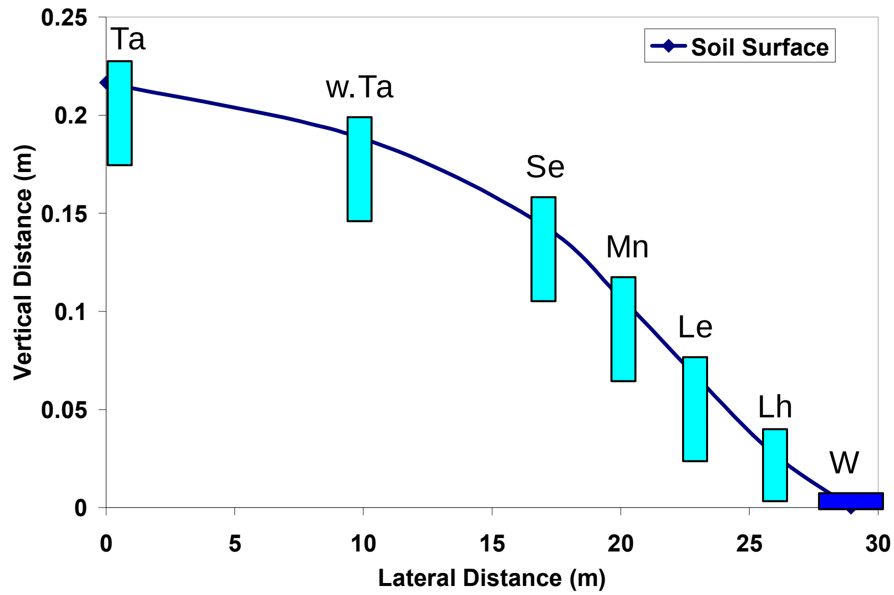

Fig 3.8 Relative elevation of six soil plots along a transect 1 of the Cool Springs site.

All but two plots were located on uplands. The Leon and Lynn haven plots were in wetlands adjacent to the backswamp. The Tarboro plots were highest in elevation on the local landscape, located on the summit position. The wet Tarboro plots were slightly lower on the landscape, on the upper shoulder position, The Seabrook and Mandarin plots were slightly lower in elevation than the wet Tarboro plots and were located on the sideslope position. The Leon and Lynn Haven plots were located on the footslope position. The slope was 0.4% between the Tarboro though Seabrook plots and 2% from the Seabrook plots to the Lynn Haven. The Lynn Haven soils were about 13 cm higher than the elevation of the swamp.

3.2 Water Table Fluctuations

Water table levels were recorded daily at 12:00 am in each plot of the three experimental sites using RDS and Ecotone™ automated monitoring wells (Remote Data Systems, Inc. 163 Brunswick Electric Road, Suite 1B Whiteville, North Carolina 28472).

Model WL-40 (1m) wells were used in plots 1Le and 3Le in the Vanceboro site, and in plots 1T, 2T, and 3T of the Richlands site. The remaining plots utilized the 1-m and 2-m versions of the Ecotone^{TM} wells. Water table levels were monitored at the Vanceboro site from 6/13/04 until 1/11/05 (580-d). The Richlands site was monitored from 6/11/04 until 1/11/05 (582-d). The Cool Springs site was monitored from 3/12/04 to 1/11/05 (306-d). Stored data from the automated wells were periodically downloaded into either a handheld HP 48GX series calculator or m500 series handheld Palm™ pilot. Data were then downloaded onto a personal computer. To ensure the accuracy of the automated wells, manual check wells were installed at each plot. The wells were installed by a 7.5-cm auger hole to a 1.25- 2.3 m depth below the soil surface and were measured weekly and compared with the automated well data.

The automated wells were installed at each plot by digging a 10-cm diameter auger hole to a depth of 1.25 to 2.3 m below the soil surface, inserting the PVC slotted well screen, and backfilling the space between the soil and well screen with graded coarse sand. A 5-cm layer of bentonite pellets was placed on top of the sand to seal the well to prevent run-on from surrounding areas from affecting the hydrology of the well. An annulus, or cone of native soil was placed above the bentonite to wick rainfall away from the well.

3.3 Rainfall

Rainfall at each site was measured by Onset's Data Logging Rain Gauge (RG2). The monitoring period varied, with the Vanceboro and Richlands sites beginning in June 2003, while the Cool Springs rainfall monitoring period began March 2004. The monitoring period ended at 1/11/05 for all sites. The self-contained, battery-powered rainfall data collection and recording system included a HOBO Event data logger (Onset Computer Corp. PO Box 3450 Pocasset, MA 02559-3450) integrated into a tipping-bucket rain gauge. A time and date stamp was stored for each 0.25 mm tip event for detailed analysis. Stored data were downloaded by a HOBO data logger and analyzed using the BoxCar Pro4.3 software. The automated rain gauges were supplemented by a cylindrical 280 mm capacity manual rain gauge from the Ben Meadows Co. (PO Box 5277Janesville WI USA 53547-5277). The rain gauges were mounted on a wooden platform 1.25-m above the ground, in adjacent open areas ranging from 10 m to 200 m from the well locations.

3.4 Temperature

Air and soil temperatures were measured weekly by thermocouples at 15 cm above the soil surface, at the surface, and 50 cm below the surface (+15, 0, and 50 cm). Thermocouples at the Richlands and Vanceboro sites were installed in each plot on each transect from June 2003 until December 2003. From January 2004 until November 2004, temperature was measured from plots on only one transect. This was done because there was little to no variation of soil and air temperatures within transects of each site.

Separate thermocouples were used for each depth increment. These were made using wire from Omega Engineering, Inc. (One Omega Drive Stamford, Connecticut 06907-0047 P.O. Box 4047). Thermocouple construction followed that of Hayes (1998).

3.5 Redox Potential and soil pH

All plots in one transect at each site were equipped with 3 sets of 5 redox electrodes (15-120 cm) (15 electrodes per plot, 195 electrodes total), and a salt bridge (13 total) for iron reduction potential determination. A detailed construction method for the electrodes was given by Hayes (1998). Voltage was measured in the field weekly and sometimes biweekly at each depth for each plot using an Accument AP60 Series Portable Meters Fisher Scientific Co (Pittsburgh, PA) and an Ag/AgCl, KCL saturated reference electrode from Jensen Instruments (Tacoma, WA). Three salt bridges (agar and KCL filled PVC pipes) were installed at each plot to provide a contact to the soil at the level of the electrodes. The field readings were concerted to Eh values by adding a conversion factor of 200 mV.

Soil pH values were measured in the laboratory using slurry of soil to water ratio of 1:2. The measurements were taken with AR series bench top pH meter from Fisher Scientific.

3.6 Soil Sampling

Soil profile descriptions were made at each plot using soil pits and hand augured sampling. Soil pits were dug by a backhoe and measured approximately (1.5 m x 2 m x 2 m) about 2-3 m from the water table monitoring well in an attempt to avoid interference with the hydrology. Pit faces were cleaned and photographed. Profile descriptions were made at each pit face by standard soil survey criteria and nomenclature (Soil Surv. Div. Staff, 1999, Schoeneberger et al. 1998) to a depth of 1.5-2 m. Morphological features such as horizonation and visual estimation of aerial extent of redoximoprhic features were made. Pit sampling provided a large lateral and vertical view of the soil profile in place, allowing for accurate description of percent redoximophic features, horizon boundaries, and soil structure.

Three undisturbed soil cores (7.6 cm diameter by 7.6 cm height) were collected at 3 to 4 depths in each pit at breaks in apparent hydraulic conductivity, estimated either by texture or other morphological changes. This was done using Uhland core sampler (Uhland, 1950) made of a hammer to drive the cores buffered by a ring adapter within a cutting head sleeve into the soil. The cores were sampled by creating a horizontal ledge into the pit face for each representative depth. The cores ere then stored for further laboratory analysis

3.7 Water Movement

Vertical saturated hydraulic conductivities (K_{sat}) were determined on each core by the constant head method (Klute and Dirksen, 1986). Core bottoms were covered by a layer of cheesecloth and placed in a tray of water for 24-hr to allow core saturation. After saturation, the cores were placed on a constant head apparatus and a constant head was maintained and outflows were measured in plastic cups. Conductivities were computed by Darcy's Law directly:

$$\mathbf{K_{sat} = Q \times L / (At\Delta H)} \qquad \textbf{(3.1)}$$

where K_{sat} was the saturated hydraulic conductivity (cm/h) of the porous material, Q (cm^3) was the volume of water flowing into the core in time, t (hr), A was the cross sectional area of the core (cm^2), L was the length of the core (7.6 cm), and **ΔH is** the hydraulic head difference between the top and bottom of the core, ΔH, was also determined. The cores were oven dried and bulk density was determined to calculate the volumetric water content.

In situ K_{sat} was measured in the field for three representative layers of each soil type using the Compact Constant Head Permeameter (CCHP)(Amoozegar, 1992). A 6-cm diameter hole was dug to the desired depth. The hole wall was scraped with a brush as to remove any smearing caused by the auger, and the bottom cleaned with a special auger head. The CCHP was placed beside the hole on a stable elevation so the vertical distance from the bottom of the hole to the reference level of the permeameter was measured.

Water from the CCHP was poured into the hole until a constant head of around 15 cm was maintained. Water continued to flow until a steady state was reached. The flow rate was measured at varying time intervals depending on expected rates. Steady state was assumed once three consecutive flow rates were approximately equal. The Glover solution (Zangar, 1953) was used to calculate $K_{sat:}$

$$\mathbf{K_{sat} = CQ/(2\pi H^2)} \qquad \mathbf{(3.2)}$$

$$\mathbf{C = \sinh^{-1}(H/r) - (r^2/ H^2+1)^{1/2} + r/H} \qquad \mathbf{(3.3)}$$

Where:

Q = steady-state flow rate (cm^3/h)

H = depth of water in auger hole (cm)

r = radius of the hole (cm)

3.8 Modeling Water Tables

Redox features in soils were evidence of periodic wetness (Daniels, 1971; Pickering and Veneman, 1984; Evans and Franzmeier, 1986; Veneman et al, 1998; Vepraskas, 1999).

These features do not indicate the duration of saturation and reduction. Historic water tables can be predicted by hydrologic models such as DRAINMOD. Modeling accounts for annual and seasonal weather variability. These data can then be used to correlate predicted long-term water levels to soil color patterns.

Hydrologic analyses were performed on the well-drained, moderately well drained, and somewhat poorly drained soils, totaling 20 plots. Poorly drained soils were not considered (10 plots). Daily historic (or long-term) water table levels were predicted for the selected plots from 1/1/70 to 12/31/03 (34-yr) for the Vanceboro and for the Cool Springs sites, and from 1/1/71 to12/31/03 (33-yr) at the Richlands site.

The water table fluctuations were modeled using three methods, the Calibration Method, the Threshold Method, and the Weighted Rainfall Index (WRI) Method. The Calibration and WRI methods were declared by the soil wetness regulations (15A NCAC 18A .1942). The Threshold Method, adapted from the Threshold wetland simulation (TWS) was a method used by consultants to give an approximate, qualitative measure of the soil wetness condition. These Calibration and Threshold methods require the hydrologic model, DRAINMOD for its use and application. The WRI method does not require DRAINMOD. However, for this study, DRAINMOD was used to apply the WRI method to long-term water table simulations.

3.9 DRAINMOD description

DRAINMOD, developed at North Carolina State University (Skaggs, 1978, 1980), was a hydrologic model that predicts water table levels through time from input data consisting of precipitation, potential evapotranspiration (PET), infiltration, runoff, and subsurface drainage (Skaggs, 1999). DRAINMOD was developed to analyze soils with shallow water tables in a parallel drainage network that occurred on flat landscapes of the Tidewater region, but has been proven effective to apply to non-drained landscapes in the coastal plain (Hunt et al., 2001; He et al., 2002).

The model uses a surface and subsurface water balance for a soil plot, determined on a daily and hourly basis, to simulate a water table depth over time. A surficial water balance was also computed for a time increment using

$$\mathbf{P = I + \Delta S + RO} \qquad \textbf{(3.4)}$$

where P was precipitation (cm), S was the change in volume of water stored on the surface (cm), and RO was the surface runoff (cm). The subsurface water balance for a time increment t was (Skaggs, 1999):

$$\mathbf{\Delta V_A = D + ET + ES - I} \qquad \textbf{(3.5)}$$

where ΔV_A was change of water free pore space or air volume (cm), D was drainage (or subirrigation) from the soil profile (cm), ET was evapotranspiration (cm), DS was deep seepage (cm), and I was infiltration entering the soil profile (cm).

Water can accumulate in small depressions on the surface. If the pores were filled with water before they can drain and ponded water exceeds the depression's capacity, surface water runoff can occurred. The amount of water (measured in cm) held in the plot area generally depends on the landscape position and visual estimates of the topography (Gayle and Skaggs, 1978; He, 2000). Depressional storage values for smooth surfaces were low (e.g. 0.25 cm) in well-drained upland positions, and high (>1.5 cm) for plots in lower elevations.

Water not leaving the plot area by runoff can seep into the soil profile. Infiltration rates were calculated in DRAINMOD by the Green-Ampt equation (Green and Ampt, 1911):

$$\mathbf{f = A/F + B} \qquad \textbf{(3.7)}$$

where: f was infiltration rate (cm/h), F was cumulative infiltration (cm), and A and B was parameters that were derived from the saturated vertical hydraulic conductivity and the soil moisture characteristic.

The relationship of parameters A and B with WTD were calculated in this application using the soil preparation program within DRAINMOD (Workman et al., 1994).

Infiltrating water moves downward by gravity through an unsaturated soil toward the water table. The amount of water removed from soil pores during drainage was a DRAINMOD input and was deemed the ‘volume drained’, which was a function of the soil water characteristic and water table depth. Volume drained values for water table positions ranging from the top to the bottom of the soil profile in increments of 10 cm were created for each horizon by the soil preparation program in DRAINMOD (Workman et al., 1994). The volume drained values increase with depth of water table. The slope of the volume drained versus the WTD was known as the drainable porosity (Workman et al., 1994). If drainable porosity was known, then the relationship between the WTD and amount drained can be quickly obtained (Skaggs, 1980). The simulated rise and fall of water tables over time were achieved by the use of this relationship (Workman et al., 1994) when water was added or removed from a plot area.

Water loss can occurred from the soil by evaporation from the soil surface and by transpiration from plants-evapotranspiration (ET). Rooting depth, the only plant factor considered in the model, was determined from each soil pit. Increased plant activity during the summer was a major contributor to elevated ET levels. The plants absorb available water through suction, which in turn lowers water table depths. ET rates were usually highest in the summer and lowest in the winter months

Water moves up from the water table via capillary action. These functions can be estimated in DRAINMOD for each horizon from the soil water characteristics and the K_{sat} values using the soil preparation program. The Millington and Quirk procedure in the soil preparation program was used in DRAINMOD to obtain estimates of the unsaturated conductivity function (Workman et al., 1994).

Water moving down through the soil profile was quantified in DRAINMOD. Drainable porosity was a measure of the volume of water drained from the soil plot for each unit change of the WTD (Workman et al., 1994, He, 2000). The drainable porosity values have a large influence on how much the water table will fluctuate as the soil pores gain or lose water.

Water was removed from the soil profile either by lateral movement or vertically downward through a restrictive layer. Water below the water table flows laterally toward drains. The rates of subsurface drainage were determined by DRAINMOD in one of two ways depending on the ambient drainage status. For non-ponded conditions, the subsurface drainage rate was computed using the steady-state Hooghoudt equation (Bouwer and van Schilfgaarde, 1963). Theoretically, the water table was elliptically shaped between parallel drains and most drainage occurred below the soil surface by water moving laterally toward the drains. The highest point of the elliptical shaped water table was the midpoint between the drains. The Hooghoudt equation may be written as:

$$\mathbf{q = \frac{(8Kd_e m + 4Km^2)}{L^2}} \qquad \mathbf{(3.6)}$$

where q was drainage rate (cm/h), d_e was the effective depth of the restrictive layer below the drain (cm), m was the water table height above the drain (cm) in the soil plot which was assumed to be located at a point midway between ditches, K was the effective lateral saturated hydraulic conductivity (cm/h), and L was the horizontal distance between drains (cm). All plots were simulated as conventionally drained.

The water table may rise to the surface of the drains in response to rainfall events. In such cases, the water table does not have the elliptical shape assumed in Hooghoudt equation, and an equation developed by Kirkham (1957) was used in DRAINMOD to quantify drainage.

Water was also lost from a drained area due to lateral seepage to a stream (distance measured in cm). The rate of lateral seepage to or from the stream was approximated using the Dupuit assumptions (Workman et al. 1994). The equation used in DRAINMOD was

$$\mathbf{ql = HORTK\ [(DEPTHH + y)2 - RIVERH2]\ /\ (2\ RIVERL)} \qquad \mathbf{(3.7)}$$

where HORTK was the effective lateral hydraulic conductivity in cm/h, y was the height of the water table above the drains; and RIVERH was the elevation of the water level in the stream in cm. DRAINMOD also requires the thickness of the transmissive layer (cm).

3.9.1 Model Inputs

General inputs needed to run DRAINMOD for all methods of determining historic water table fluctuations include: on-site water table data, on-site rainfall data, historic rainfall data, drainage system inputs, on-site soil properties, DRAINMOD soil input files, and plant rooting depth. Raw weather data was converted by a utility program to create DRAINMOD formatted input files. Historic climate data were obtained from the nearest available data source to the sites. The Clinton Horticultural Crops Research station in Samson County was used for the Richlands site. The Craven County Airport data were used for the Vanceboro and Cool Springs sites. These data were obtained using the state's climate office (http://www.nc-climate.ncsu.edu/agnet/).

On-site water table and rainfall data were taken as indicated by section 3.3 and 3.4. Observed water tables from 1/1/04 to 4/30/04 for the Richlands and Vanceboro sites and from 4/1/04 to 8/31/04 for the Cool Springs site were used to create short-term water table DRAINMOD input files (.OBS). Example input data for .OBS files were shown in Table 3.1)

Table 3.1 Sample of raw data to create .OBS files in DRAINMOD.

Year	Julian Day	WTD (cm)	Outflow (cm)
2003	340	-90.42	-99
2003	341	-92.20	-99
2003	342	-95.76	-99
2003	343	-99.57	-99
2003	344	-102.62	-99

The first and second columns of the input file were the year and the day of the year. The third and fourth columns were the water-table depth (WTD in cm) and the outflow (cm) for that day. The outflow values of -99cm were used to approximate little to no outflow.

Short-term rainfall input files were developed from rainfall gauge data taken within 180 m of the sites. Rainfall files were developed using the on-site daily rainfall data from 1/1/04 to 4/30/04 in the Richlands and Vanceboro sites. Rain data from 4/1/04 until 8/31/04 were used from the Cool Springs site due to the unavailability of January through April data. A utility program in DRAINMOD converted raw data (Table 3.2) to formatted input files (.RAI).

Table 3.2 Sample columnar raw rainfall data to be converted into appropriate DRAINMOD format

Year	**Julian Day**	**Rainfall (in)**
2003	344	1.69
2003	345	0
2003	346	0
2003	347	0
2003	348	1.23

The first and second column of the raw data were the year and day of year. The third column was the rainfall amount in inches for the given day.

Short-term temperature files were developed using daily maximum and minimum temperature data recorded at the weather stations from 1/1/04 to 4/30/04 for the Richlands and Vanceboro sites, and from 4/1/04 to 8/31/04 for the Cool Springs site. The utility program used raw temperature data (table 3.3) and created a daily maximum and minimum temperature file in DRAINMOD format (.TEM file).

Table 3.3 Sample raw temperature data to be converted into appropriate DRAINMOD format

Year	**Julian Day**	**Maximum Temp (^{o}F)**	**Minimum Temp (^{o}F)**
2003	340	46.4	33.8
2003	341	44.6	26.6
2003	342	48.2	23
2003	343	60.8	24.8
2003	344	71.6	39.2

The first and second columns of the input file were the year and the day of the year. The third and fourth columns were the maximum and minimum temperatures (^{o}F), respectively, for that day.

Long-term rainfall (.RAI) and temperature (.TEM) files were developed from daily temperature and hourly or daily rainfall data collected over a 30-year period from the closest available weather stations. These files were developed using daily rainfall and temperature data from 1/1/70 through 12/31/03 for the Vanceboro and Cool Springs sites (New Bern), and from 1/1/71 to 12/31/03 for the Richlands site (Clinton, NC). Daily rain data were distributed in DRAINMOD for 5 hours staring at 17:00.

DRAINMOD estimates potential evapotranspiration (PET) using the Thornthwaite (1948) method. The PET estimates were increased or decreased on monthly basis with a correction factors due to seasonal temperature changes. The following monthly multiplication factors were obtained from the DRAINMOD Users' Manual (Workman et al., 1994): 2.01, 2.32, 2.10, 1.72, 1.23, 1.00, 0.86, 0.82, 0.92, 1.05, 1.22, and 1.44 for January through December, respectively.

There were several categories of drainage parameters that were required inputs to determine subsurface drainage in DRAINMOD. Examples include drain depth, drain spacing, depth to impermeable layer, initial depth to water table, and surface storage. The drains used in analysis were virtual ones and simulated in DRAINMOD as ditches.

Subsurface drainage rates were changed in response to changing drain spacing. As drain spacing increases, the drainage rate decreased for a given WTD, thus bringing the water tables closer to the soil surface. The drainage rates varied with a plot's landscape position. Plots higher on the landscape had deeper water tables and drained faster than those at lower landscape positions, which usually had higher water table levels. Closer drain spacings were used for plots of higher elevations, and larger drain spacings were used to simulate the plots lower in elevation.

Increasing drain spacing had the same effect on the water table fluctuations as reducing the hydraulic gradient (Skaggs, 1999; He et al., 2002). Deeper, closely spaced ditches resulted in large hydraulic gradients with high drainage rates, as would be found in a moderately well drained soil. On the other hand, widely spaced ditches resulted in smaller hydraulic gradients with slow drainage rates, as would be found in a poorly drained soil.

The depressional storage parameter represents the average depths of minor depressions on the surface that hold water over the landscape (Gayle and Skaggs, 1978). It has a little effect on the calibrated plots, even with the Lenoir soils, in which the water tables rose often within 30cm. Depressional storage values were lowest in the upland areas and increased with decreasing landscape position. These values were determined by visual estimates of topography. The highest depressional storage value of 0.7 cm was found for the Lenoir plots. The lowest value was estimated at the best-drained soils, the Tarboro, Craven and Foreston plots (0.25 cm), and the Seabrook plot from the first transect (0.2 cm).

Lateral water flow downslope to a receiving stream or water body was approximated only at the Richlands site. The input variables for this component were the thickness and hydraulic conductivity of the transmissive layer, represented by a groundwater flow downslope; hydraulic head of the receiving waters, which value was determined based on respective plot elevation data; and distance of receiving waters, which was determined by each plots distance to the point to which water will exit the site. The measured distance decreased with decreasing landscape position on the hillslope. The transmissive layer, based on deep borings (+3 m) was sandy material, transmitting water rapidly (≥20 cm/h). The lateral seepage component was not used in the Vanceboro and Cool Springs sites because the simulated drainage rates were excessive with respect to monitored hydrographs to the point that no change in drain spacing or depth or K would produce agreements with the simulated and measured water table fluctuations.

Soil and Site inputs for DRAINMOD, including depths of soil horizons, estimated saturated hydraulic conductivity of each horizon, depth and spacing of drainage features were selected (Appendix C) and a soil data file closest to the soil series identified. To satisfy an objective of this study, related soil files instead of site-specific DRAINMOD soil files were used as ordained by the Soil Wetness rule .1942 (15 NCAC 18, 2005).

DRAINMOD soil files created for the Goldsboro Soil were used for the Richlands, the Rains soil file for the soils of Cool Springs sites to simulate the sandier soils, while the Portsmouth soil was used to approximate the clayey soils of the Vanceboro site. The data contained in these files were used as starting points of Calibration, and were highly modified. Nevertheless this did follow the methods outlined in rule .1942 (15NCAC 18A, 2005). These soil files contain soil water characteristic and the volume drained from the soil per 10 cm unit decrease in water table level. The soil water characteristic along with hydraulic conductivity and drainable porosity were recognized as important soil properties in modeling soil water movement (Workman et al. 1994). The values for the soil input files were shown in Appendix C.

The impermeable layer was typically thought to be tight marine clay, and had very low Ksat values, thus precluding water flow downward through the layer. The shallower the restrictive layer, the higher (i.e., closer to the surface) the predicted water tables. Actual depths to the impermeable layer were typically deeper (+3 m) than the depths the water tables were monitored. The model required a specific depth be put in where a restrictive layer effectively begins. The values for all the plots were determined by trial and error and ranged between 75 and 175 cm for all sites (Table 3.4). Clayey Bt horizons with hydraulic conductivity values of 0.1 cm/h or less at the Vanceboro sites occurred high in the profiles, yet were not the true impermeable layer. However, these clay layers can perch water high in the profile, and may produce conditions favorable for the formation of redox features.

The depth to rooting, also an input parameter, occurred within the topsoil of all plots. This input value was variable with time, having deeper rooting depths during summer months as opposed to shorter rooting depths in the winter months.

Final drainage parameters for all plots were given in Table 3.4.

Table 3.4 Drainage input parameters used in the Calibration Method for the Richlands, Vanceboro, and Cool Springs sites, obtained by calibration to represent the best relationship between observed and predicted water tables of all soil plots.

Site	Soil	Plot	Drain	Drain	Depth from Drain to	Surface
			Depth	Spacing	Imperm. Layer	storage
			--------------------cm---------------------------			
Richlands	Foreston	1 Fo	131	11500	119	0.25
		2 Fo	129	11700	121	0.25
		3 Fo	120	11900	130	0.25
	Wet	1 wF	131	15000	119	0.35
	Foreston	2 wF	119	13700	131	0.35
		3 wF	120	13300	130	0.35
	Stallings	1 St	121	12700	129	0.45
		2 St	113	14000	137	0.45
		3 St	115	11000	135	0.45
Vanceboro	Craven	1 Cr	200	8500	75	0.25
		2 Cr	155	10200	120	0.25
		3 Cr	135	10200	140	0.25
	Lenoir	1 Le	76	5150	174	0.7
		2 Le	77	5090	173	0.7
		3 Le	75	4900	175	0.3
Cool	Tarboro	1 Ta	115	400	250	0.25
Springs						
	Wet	1 wTa	104	900	200	0.2
	Tarboro	2 wTa	98	700	227	0.25
	Seabrook	1 Se	58	4000	130	0.55
		2 Se	65	2000	231	0.25

There were differences in drain spacings for some plots found in the same soil due to elevation differences and location on the landscape, which affected drainage rates. The effect of elevation differences on spacing parameter values can be seen by comparing elevation and spacing values of plot 1C to those of plot 2C at the Vanceboro site. Plot 1C was 23.5 cm higher in elevation than plot 2C. Plot 2C required wider drain spacings than plot 1C because its lower elevation caused its natural drainage rate to be lower. Once the drain spacing parameter was determined, the drain depth parameter was adjusted. The predicted water table was raised with decreased drain depth. Drain depths ranged from 25 to 131cm.

3.9.2 Assumptions

This research was based on the assumptions that were made for the modeled experimental plots as outlined by He et al. (2002): (1) subsurface drainage rates were simulated in landscapes of gently rolling topography by using the Hooghoudt equation applied to a virtual drainage network, (2) deep seepage losses were lumped with subsurface drainage. Plots were treated in isolation to simulate water table fluctuations at each soil plot.

3.10 Methods of Soil Wetness Condition Determination

Soil wetness conditions were determined by three separate methods, which were recognized and used by the NCDENR OSWW section. These methods were the Calibration, Threshold, and WRI. These methods were DRAINMOD simulated water table data obtained from site-specific short-term data and long-term climate data from weather stations. A step-by-step procedure for each method will be outlined in the following sections.

3.10.1 Calibration Method

The model Calibration Method was designed for use in determining the appropriate DRAINMOD inputs in order to calibrate the model for a specific well (Skaggs, 1982). DRAINMOD was used to predict daily water levels over at least a 30-year historic time period after the model was calibrated using the hydrology and rainfall observations made on the sites from Jan. 1, 2004 to August 2004 as outlined by rule .1942 (15A NCAC 18A, 2005). The criteria for soil wetness condition were determined to be the shallowest level predicted by the model to be saturated for a 14-day continuous period between January 1 and April 30 with a recurrence frequency of 30 percent (i.e. 9 years in 30) (15A NCAC 18A .1942). Model calibration was considered successful when the standard error and average absolute deviation between observed and predicted hydrographs were < 20 cm (Skaggs, 1982; He, 2000).

Soil wetness conditions was determined by the Calibration Method by a process outlined in the following steps:

1. Measure on-site rainfall, temperature and water table depth (well data) (from Jan.-April 2004, Richlands and Vanceboro sites, April – Aug. 2004 at Cool Springs site) and convert this data into .OBS (observed well data), .TEM (temperature), and .RAI (rainfall) files. If measured temperature is not available, create a .TEM file using daily maximum and minimum temperature data for the 4-month period obtained from the nearest weather station.

2. Input observed and measured soil properties such as horizon depths, K_{sat} , etc. Use non-site specific but related .SIN soil files (i.e. Goldsboro) to approximate drainable porosity, infiltration, and other information.

3. Adjust DRAINMOD parameters (drain spacing, drain depth, lateral K_{sat}, depth to impermeable layer, and surface storage values) and data in the .SIN files by trial and error until the mean absolute deviation between the measured hydrograph and simulated hydrograph is < 20 cm (Equation 3.8). The agreement between monitored and predicted daily water table depths is quantified by the absolute deviation, α:

$$\boldsymbol{\alpha = \frac{\Sigma \left| Y_m - Y_p \right|}{n}} \qquad \textbf{(3.8)}$$

where n is number of days in the observed period, Y_m is monitored WTD at midnight of each day (cm), and Y_p is corresponding predicted WTD (cm). This step is the most time consuming of all modeling procedures. Horizon depths were a fixed value, but some measured inputs such as K_{sat} were used as a starting point of calibration and were then changed accordingly. Drainable porosity values in the .SIN files were also changed. Even if site-specific soil files were created, drainable porosity values would still have to be adjusted to achieve a best match between measured and observed hydrology (Figure 3.9).

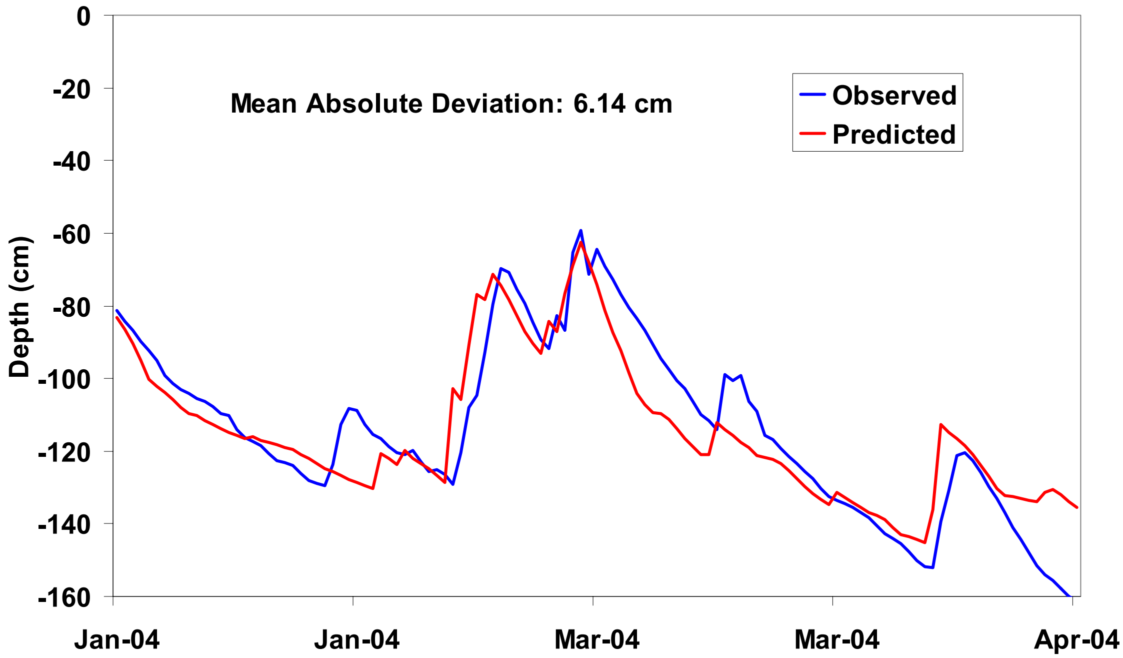

Fig 3.9 Example of a successful calibration for the Foreston 1 plot. The mean absolute deviation from a comparison of measured and predicted hydrographs was 6.14 cm.

4. Once the model is successfully calibrated, run 30-year DRAINMOD simulations using long-term climate data files developed from the closest weather station (Clinton, Newbern).

5. Query DRAINMOD for the shallowest depth to which the soil is saturated for 14 consecutive days or longer for at least 30% of long-term record. This is done by using the hydrologic analysis, which needs the starting and ending date (Jan. 1-April 30), threshold water table depth (WTD) (this value was changed to meet the appropriate criteria for the method), and number of consecutive days of saturation. These were entered in the Wetland Analysis section of the Water Management Options tab of the General Information screen.

6. Examine the bottom of the wetland output files (.WET). This value should be the long-term threshold value that met the criteria set forth in step 5. The .WET files (fig. 3.10) give a year-by-year list of the number of periods meeting the criteria and the longest period in each year that satisfies the water table depth criteria.

D R A I N M O D --- HYDROLOGY EVALUATION
****** INTERIM EXPERIMENTAL RELEASE ******
Number of periods with water table closer than 52.00 cm
for at least 14 days. Counting starts on day
1 and ends on day 365 of each year

YEAR	Number of Periods of 14 days or more with WTD < 52.00 cm	Longest Consecutive Period in Days
1971	1	14
1972	0	13
1973	0.	12.
1974	0.	8.
1975	0.	10.
1976	1.	14.
1977	0.	13.
1978	1.	36.
1979	1.	27.
1980	0.	8.
1981	0.	10.
1982	0.	11.
1983	2.	22.
1984	0.	13.
1985	1.	17.
1986	0.	5.
1987	2.	18.
1988	0.	13.
1989	1.	21.
1990	0.	9.
1991	0.	6.
1992	0.	11.
1993	1.	22.
1994	0.	7.
1995	0.	13.
1996	0.	13.
1997	0.	8.
1998	1.	36.
1999	1.	20.
2000	0.	13.
2001	0.	7.
2002	0.	12.
2003	1.	16.

Number of Years with at least one period = 12 out of 33 years.

Fig 3.10 Wetland hydrology output file (.WET) example for the Fo 1 plot.

The first column of figure 3.10 is the year, the second column is the number of time the soil is saturated at or above the threshold level, 52 cm, for a 14-d or more continuous period, and the third column is the maximum predicted duration of saturation. The bottom of this file is a total of the number of years the soil is saturated out of the total years of analysis.

7. The soil wetness condition by this method is the threshold value that indicates saturation at that level for a 14-day continuous period at least once per year, in at least 30% of the years (i.e. 9/30).

All the plots from all sites were successfully calibrated by using the Calibration method. From January 1 to April 30 in the Richlands and Vanceboro sites and April 1 to August 31 for the Cool Springs site, the predicted and observed water table depths for most plots at all sites were in good agreement with the average deviations ranging from 6.14 cm to 16.8 cm. The average mean absolute deviations between measured and simulated water table levels were 10.79 cm for the Richlands site, 10.04 cm for the Vanceboro site, and 9.86 cm for the Cool Springs site (Table J.1).

3.10.2 Threshold Simulation Method

Historic water table fluctuations of each plot were simulated by DRAINMOD in a similar fashion to the Calibration Method, using a combination of the same long-term and short-term weather, soil, and hydrology inputs. The criteria for soil wetness conditions by this method were the same as the Calibration Method: the highest water level predicted by the model to be saturated for a 14-day continuous period between January 1 and April 30 with a recurrence frequency of 30 percent (an average of at least 9 years in 30).

The method used in this study is a modified version of the Threshold Wetland Simulation Method (TWS) created by Hunt et al. (2001). The TWS method compared the hydrograph of a real wetland to a simulated one using DRAINMOD simulated water table fluctuations. The threshold level of DRAINMOD analysis is 30 cm (Hunt et al., 2001) and the required duration is 5% of the growing season, or 12-d in 50% of the years as set by the definition of wetland hydrology (USACE, 1987). For this study the threshold level was user defined, usually deeper in the profile than 30 cm and the required duration of saturation was 14-d in 9 out of 30 years.

The Threshold Method is a more qualitative assessment of the soil wetness condition than the Calibration Method. It can tell you that a site is “drier” or “wetter” than the user defined threshold level, yet cannot predict how much wetter or drier the site is compared to the threshold level. Also, there is no measure of success for this method. The measure of success for the Calibration Method is that the average absolute error is < 20 cm.

In the Threshold method, one set of input values were established to be extrapolated to the other similar plots at a given site. For example, one model created for the Foreston 2 plot can be used to predict the hydrology of the other Foreston plots. This can be advantageous because it was less time consuming in determining the soil wetness condition than the Calibration Method, where every plot must have its own model.

The Threshold Simulation method employs a process that was similar to that of the Calibration Method. Yet the sequence of steps to determine the soil wetness condition was the reverse. The threshold level (depth to wetness condition) was known, not the desired result, as with Calibration. While using long-term weather data, the model was adjusted to simulate saturation at a given level (threshold level) for 14 or more continuous days once or more per year in 30% of all the years. Once this was done, simulated hydrographs produced for the short-term (4-month) record were compared to observed data. The process that was used to obtain soil wetness conditions by the Threshold Method was outlined below:

1. Select a soil plot that best represents (e.g., w Fo. 1) a set of similar soil plots, which had median value for most soil properties and hydrology within that set.

2. User sets the threshold depth (e.g., 50cm), entered in the Wetland Analysis section of the Water Management Options tab of the General Information screen. This level was used as a starting point in analysis, which was set at the level of ≤ 2 chroma depletions.

3. Input observed and measured soil properties such as horizon depths, K_{sat}, etc. Use non-site specific .SIN soil files (e.g., Goldsboro) to approximate drainable porosity, infiltration, and other soil related information.

4. Inputs in the Wetland Analysis section were: starting and ending date Jan. 1- April 30, and number of consecutive days of saturation, which were 14.

5. Then run 30-year DRAINMOD simulation using long-term climate data files (.TEM, and .RAI files) developed from the closest weather station (Clinton, Newbern).

6. Adjust the model parameters, mainly drain spacing, by trial and error to achieve the saturation for a 14-day continuous period at the chosen depth in the soil. Examining .WET output files for the number of years out of the long-term record (i.e. 10/33-yr) the model predicted saturation at or above the threshold level.

7. Once the model was adjusted to meet the criteria in step 6, user switches long-term climate files with the short-term ones (rainfall and temperature) and measured on-site well data, .OBS files (Jan.- April 2004, Richlands and Vanceboro sites, April – Aug. 2004 at Cool Springs site) and run short-term simulations.

8. The hydrographs of measured data were compared to the simulated hydrograph. If the predicted hydrograph had water tables above those in the measured hydrograph, then the site was *drier* than the threshold value (Figure. 3.11).

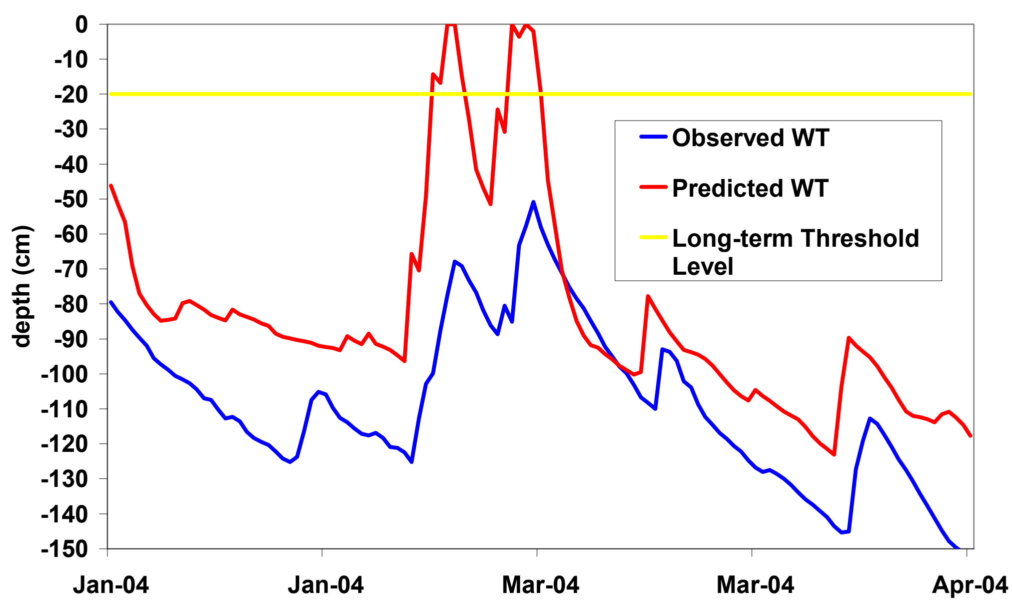

Figure. 3.11 Comparative hydrographs of observed vs. simulated hydrographs for the wet Foreston 1 plot. The yellow line (20 cm) was the level at which was saturated for 14 consecutive days or longer for at least 30% of long-term record. The threshold level in this example was exaggerated to show a substantial difference in predicted and observed hydrographs.

If the simulated hydrograph had water tables below those of the measured hydrograph, then the site was *wetter* than the threshold value (Figure. 3.12).

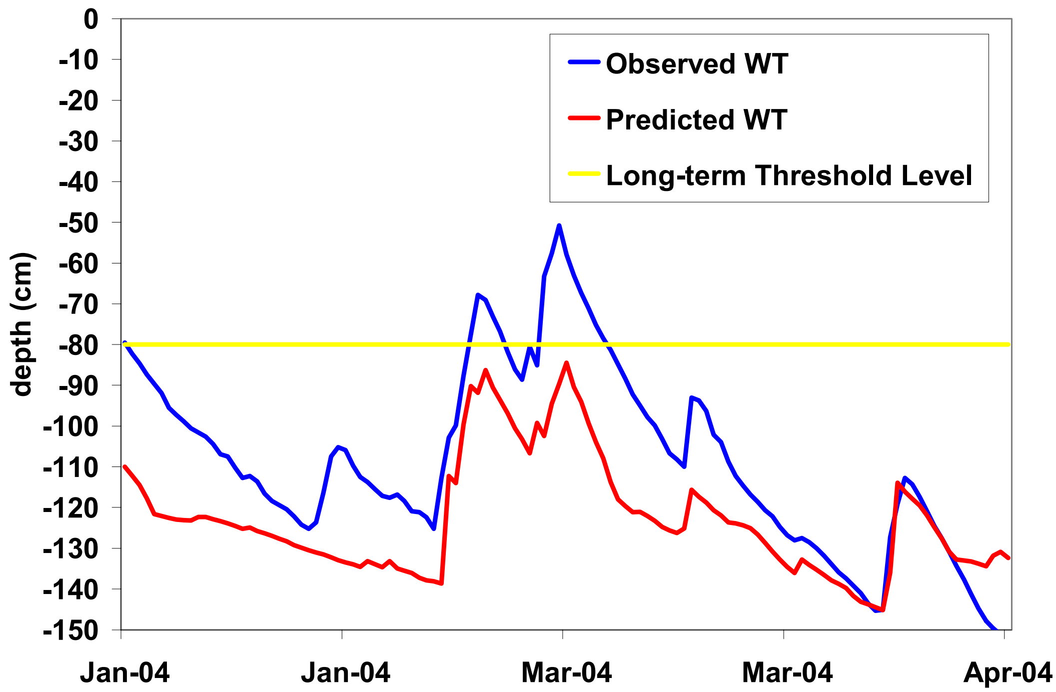

Fig. 3.12 Comparative hydrographs of observed vs. simulated hydrographs for the wet Foreston 1 plot. The yellow line (80 cm) was the level at which was saturated for 14 consecutive days or longer for at least 30% of long-term record. The threshold level in this example was exaggerated to show a substantial difference in predicted and observed hydrographs. This was an example of the observed hydrograph being 'wetter than' the predicted hydrograph.

The simulated hydrographs in figures 3.11 and 3.12 were exaggerated to demonstrate the procedure. For this study, long-term threshold levels for wetter or drier hydrographs were less obvious, typically 15 cm deeper or shallower than the long-term threshold levels producing approximately equal hydrographs.

If the simulated hydrograph had water tables below those of the measured hydrograph, then the site was *approximately equal to* the threshold value (Figure. 3.13).

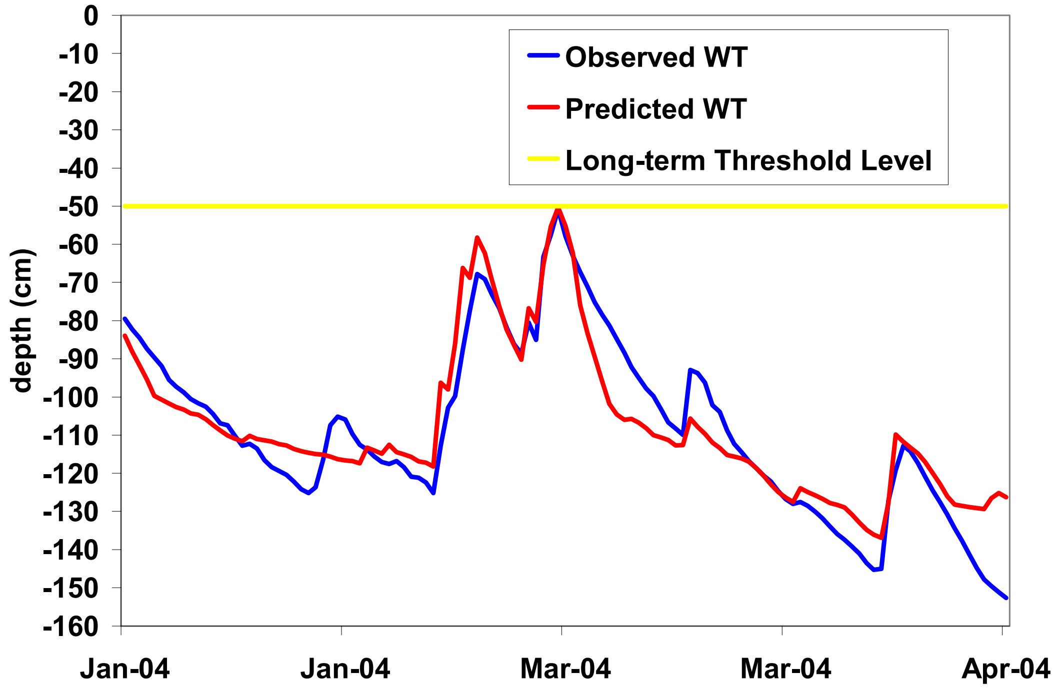

Fig. 3.13 Comparative hydrographs of the approximate match between observed vs. simulated hydrographs for the wet Foreston 1 plot. The yellow line (50 cm) was the level at which was saturated for 14 consecutive days or longer for at least 30% of long-term record.

The soil wetness condition determined by this method was the long-term threshold level yielding an approximate match between the short-term simulated hydrograph and the measured hydrograph. Once the soil wetness condition was found for one plot (e.g., w Fo. 1), then the adjusted model could be used to determine the soil wetness condition of other similar plots (e.g., wFo. 2 & 3) using the same model (step 9), altering only one parameter, usually drain spacings.

9. Repeat steps 5-8 for all plots in consideration until 3 predicted hydrographs (wetter, drier and approximately equal to the observed hydrograph) were produced using plot-specific .OBS files. These hydrographs should be similar to but not exactly like Figures 3.11, 3.12 and 3.13. Figure 3.14 was an example of an approximate match between observed and predicted hydrology for the Foreston 2 plot, using the same model.

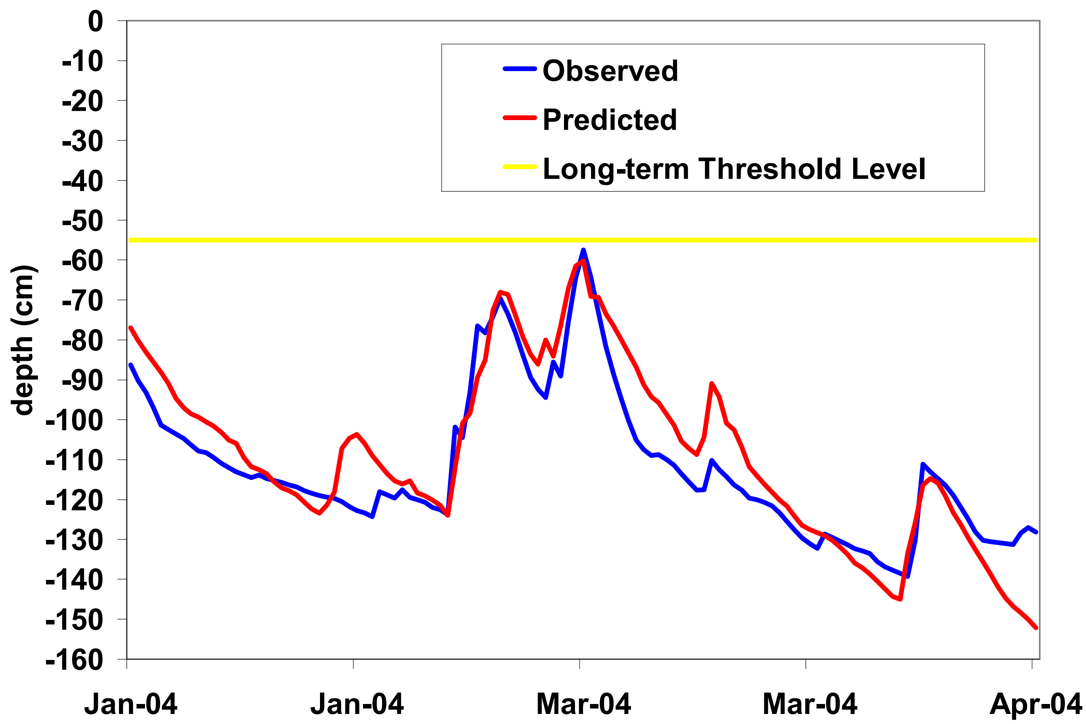

Figure 3.14 Comparative hydrographs of the approximate match between observed and simulated hydrographs for the Foreston 2 plot. The yellow line (55 cm) was the level at which was saturated for 14 consecutive days or longer for at least 30% of long-term record.

The predicted hydrograph in Figure 3.14 was created for the Foreston 2 plot using soil property information that was similar, but not specific to this plot, but specific to the plot that was considered to have the median value of soil properties within the group, which in this case was the wet Foreston 2 plot. By using the Threshold method, soil information (K_{sat}, soil boundaries, drainable porosity, etc.) the w Fo 2 plot was extrapolated to all the other wet Foreston and Foreston plots.

In practice, the inputs for the long-term simulation that barely satisfies the criteria in step 6 should produce an approximate hydrograph for each landscape position at a given location. Thus, only one long-term simulation should be necessary to be compared with the measured hydrographs of each plot. In this study, unique threshold levels were used to compare with the measured hydrographs of each plot. When using this method, it is not critical to find the exact wetness condition, yet to determine if a given plot is wetter or drier than the threshold conditions. In order to compare the soil wetness conditions by the

Threshold method to those found by other methods, an approximate match of the simulated hydrograph having threshold values that satisfied the criteria in step 6 to the measured hydrograph was needed.

A summary of all the drain spacings that correlate to long-term threshold levels for all soil plots contained within the Foreston/ wet Foreston group were shown in Table 3.5.

Table 3.5 Long-term Threshold Levels and their corresponding drain spacings that were used to obtain hydrographs that were approximately equal to, wetter and drier than the measured hydrographs by the Threshold Method for the for the Foreston/ wet Foreston plots at the Richlands site. The drain depth was 127 cm.

Long-term Threshold Level (cm)	Drain Spacing (m)
30	181
39	152
42	145
45	141
48	135
53	125
60	109
75	91

As expected, the deeper the Long-term threshold levels were in the profile, the closer the drain spacing was to simulate progressively drier conditions (Table 3.5). One model was used for the Foreston and wet Foreston plots due to their similarities in hydrology. The Stallings plots experienced saturation pattern similar to the Foreston and wet Foreston plots, however, since they were lower on the landscape, the Stallings plots had hydrographs that peaked a day later than the other plots, thus requiring a new model separate from the Foreston/wet Foreston model.

Soil wetness conditions by the Threshold Method were obtained for the Vanceboro and the Cool Springs sites using the same procedures outlined for the Foreston/wet Foreston soils of the Richlands site. At the Vanceboro site, peaks and valleys in the hydrographs occurred in a similar fashion to each other, yet the Craven plots had much deeper average water table depths than the Lenoir plots. This in turn affected the modeling strategy by this method, therefore a separate model was set up for each soil type.

Summary tables of the drain spacing that matches with the threshold level (wetness condition by this method) for the Craven and Lenoir soils were shown in Tables 3.6 and 3.7.

Table 3.6 Long-term Threshold Levels and their corresponding drain spacings that were used to obtain hydrographs that were approximately equal to, wetter and drier than the measured hydrographs by the Threshold Method for the for the Craven plots at the Vanceboro site. Drain depth was 205 cm.

Long-term Threshold Level (cm)	Drain Spacing (m)
36	184
51	132
66	118
81	100
96	97
106	87
111	93
136	68
166	49

Table 3.7 Long-term Threshold Levels and their corresponding drain spacings that were used to obtain hydrographs that were approximately equal to, wetter and drier than the measured hydrographs by the Threshold Method for the for the Lenoir plots at the Vanceboro site. Drain depth was 75 cm.

Long-term Threshold Level (cm)	Drain Spacing (m)
6	93
10	83
14	76
17	70
20	67
26	57
32	49
37	48
40	42
49	36

With respect to the modeling effort, all of the soil plots of the Cool Springs site were lumped together due to slight changes in average water table depths. The main difference between determining the soil wetness conditions at this site as opposed to the other sites was that the main parameter to be altered was the drain depth, rather than the drain spacing. This was evidence that the drain depth controls the simulated hydrology of the plots. This can be due to the nature of these sandy soils with high drainable porosity values (Appendix C.6-8).

The drain spacing does however have an effect on the number of years out of 30 years a plot was saturated at a given level. Therefore, a relative scale was developed to account for the drain in the calibration process. Plots with lower average water tables had closer drain spacing than those plots with higher average water tables (i.e. Tarboro plot has a drain spacing of 4 m while the Se 1 plot has a spacing of 40 m). The drain depth used in the Threshold method that corresponded to a given threshold level was 7 m (Table 3.8). The Se2 plot had lower effective drain radius (5, 20 cm) than the rest of the plots due to the drain depth being close to the surface (11, 41 cm).

Table 3.8 Long-term Threshold Levels and their corresponding drain depths that were used to obtain hydrographs that were approximately equal to, wetter and drier than the measured hydrographs by the Threshold Method for the for the soils of the Cool Springs site.

Long-term Threshold Level (cm)	Drain Depth (cm)
11*	11
41**	41
65	65
90	90
100	100
105	105
110	110
125	125
130	130
145	145

*effective radius=5 cm, **effective radius= 20 cm, all others had effective radius of 30 cm.

To summarize this method, one model with a set of soil and drainage input parameters that best represented the whole sample size was created for each set of plots with similar soil properties and water-table fluctuations. With one set of long-climate data, multiple threshold levels were set to give a level that was saturated continuously for 14 days for at least 30% of the time. Different threshold levels were found by altering primarily the drainage spacing (drain depth for Cool Springs site) to approximate the soil wetness condition, and yield simulated hydrographs that were drier and wetter than the approximate match, for each different soil type. The total numbers of long-term threshold levels obtained were variable, depending on the number of plots analyzed. Separate models were necessary when two soils on the same catena have large elevation differences, thus resulting in drastic hydrograph differences (e.g., Craven vs. Lenoir soils).

3.10.3 Interpretation Method for Direct Monitoring Procedure (WRI Method)

Direct observation of water tables from wells can be used in place of morphology in determining depth to soil wetness conditions according to the Weighted Rainfall Index (WRI) method (15NCAC 18 .1942 e). This method was rainfall driven and cannot be used if the on-site measured rainfall from December to April was less than the site's historic rainfall index for January to April rainfall with a 30 percent recurrence frequency (drier than the 9th driest year of 30, on average).

Soil wetness conditions were determined for all sites by the WRI Method Procedure by the following process:

1. Record daily water table depths and rainfall from December to April.
2. Calculate 4 month cumulative rainfall for site by:

$$\mathbf{WRI = 0.5P_D + P_J + P_F + P_M + 0.5P_A} \qquad \mathbf{(3.9)}$$

where: WRI = weighted rainfall index for December to April, P_D = Total December rainfall, P_J = Total January rainfall, P_F = Total February rainfall, P_M = Total March rainfall, and P_A = Total April rainfall.

3. Compare the 4-month (Jan. – April) cumulative rainfall from the site to contour maps (Figure 3.15) prepared by the NCDENR OSWW section using data collected from the nearest Weather Service Stations. The maps represent cumulative rainfall for January through April rainfall with a 30%, 50%, 70% and 80% recurrence frequency.

The Richlands site will be used as an example showing how step 3 was taken. If the monitored rainfall were 20 inches (51 cm), then the precipitation would fall in above the 19" and 19.5" isopleths. This would place the rainfall in the 80th –100th percentile of the historic rainfall record. Monitoring periods having rainfall below the 30th percentile amount cannot be used by this method. If the rainfall were lower than 19", then the site would be in a lower rainfall percentile (Figure 3.15).

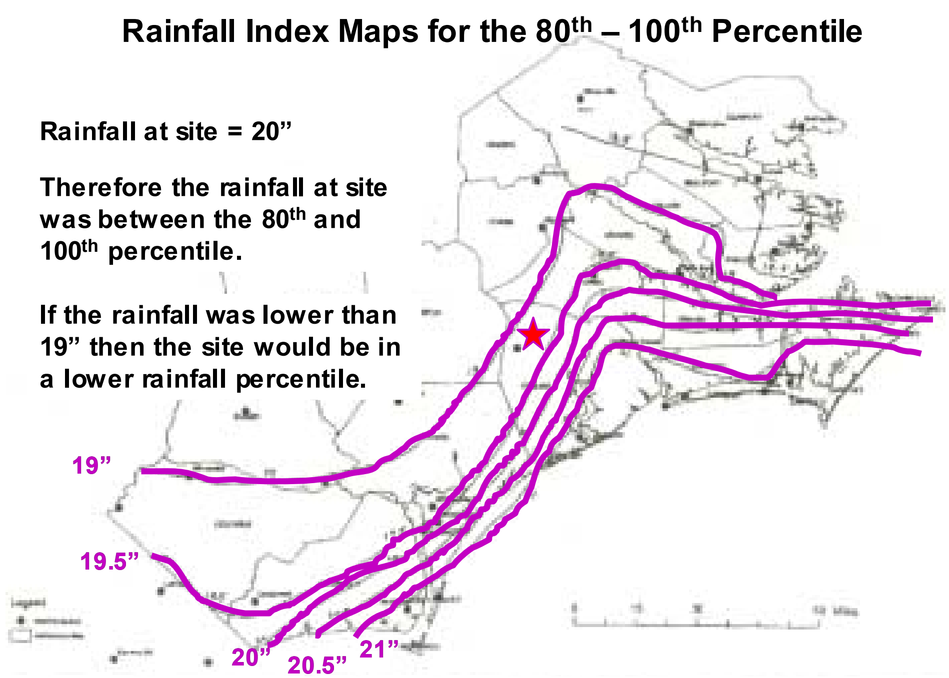

Figure 3.15 Rainfall index map prepared by NCDENR OSWWS showing the Richlands site, whose rainfall fell above the ≥80th percentile.

4. Once the rainfall index has been determined (e.g., 80th percentile) the required duration of saturation for soil wetness conditions for a given rainfall category was determined. Again, from the contour maps, the site's rainfall index for the December through April

monitoring period were compared to the long-term (historic) December to April weighted rainfall index at different expected recurrence frequencies (Table 3.9).

Table 3.9 Parameters for determining the soil wetness condition by the RWI method.

Recurrence Frequency Range January to April Weighted Rainfall Index	Number of Consecutive Days of Continuous Saturation for Soil Wetness Condition
30% to 49.9% (dry)	3 days or 72 hours
50% to 69.9%	6 days or 144 hours
70% to 79.9%	9 days or 216 hours
80% to 100% (wet)	14 days or 336 hours

(adapted from NCDENR; **15A NCAC 18A .1942**)

In dry years, the water table only has to reach a given level in the profile continuously for 3-d. In soils with water tables that spike close to the surface for short durations, the water table, by this method would be deemed at that shallow point, when the average monitored and calibration water table were much deeper.

5. Soil wetness conditions were determined as the highest level that was continuously saturated for the number of consecutive days during the January through April monitoring period (Table 3.9).

In practice, only one monitored season was required for this method. For this study, the required duration was attained for a given year based on its rainfall (source: nearest weather station). The historic water levels (hydrographs) were determined by DRAINMOD analysis for each usable year based on the calibrated models. The level to which the soil was saturated, for all usable years, for a 3 to 14-d continuous period (determined from steps 1-4) is shown in Figure 3.16.

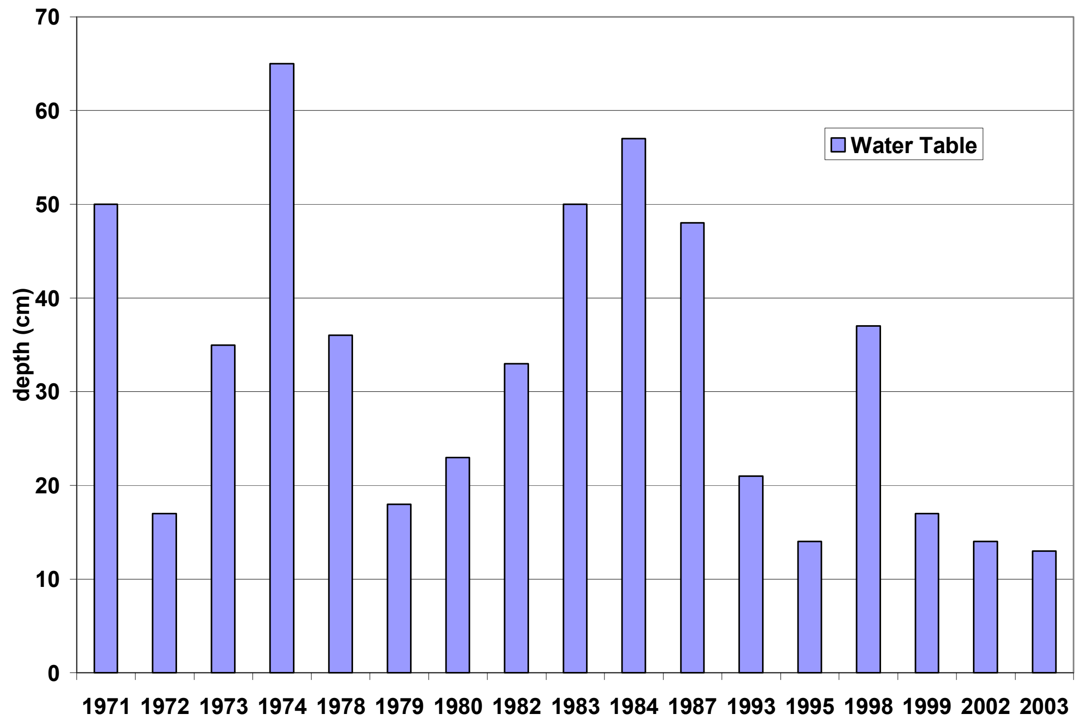

Figure 3.16 Range of historic soil wetness conditions as obtained from the WRI method for the Foreston 1 plot.

In cases with multiple years of analysis by the WRI method, the year in which the wetness conditions were shallowest will be used as the soil wetness conditions (15A NCAC 18A .1942, 2005). In the case for the Foreston 1 plot, the shallowest soil wetness conditions were 12 cm (Figure 3.16). This level was referred to as the WRI-H, or highest level of soil wetness conditions predicted during the +30-yr simulated period. The lowest (or deepest) level to which the soil wetness conditions were estimated by the WRI method was 65 cm (Figure 3.16). This will be referred to as the WRI-L level. The rainfall for the 2004 monitoring period was insufficient to satisfy the requirements of the method at all sites; therefore the soil wetness conditions could not be determined by the WRI method.

This method was valid only if the rainfall that was measured exceeds the site's historic rainfall record (30th percentile). If there was not enough rainfall to satisfy the method, it cannot be used. The years that were omitted were due to the monitored period of that year lacking the required rainfall.

4. RESULTS AND DWASCUSSION

4.1 Rainfall and Temperature

Rainfall data were obtained by monitoring all sites and from National Weather Service (NWS) data. Daily rainfall observations were made at the Richlands site from August 2003- December 2004; at the Vanceboro site from July 2003 to December 2004; and from February 2004-December 2004 at the Cool Springs site. A 'normal' rainfall range was obtained from long-term (30-yr) rain data provided by the national weather service rain stations WETS tables. WETS tables use daily maximum and minimum observations to calculate average daily maximum and minimum temperatures for each month. The 30 % value (30th percentile) represents the threshold for which 70 % of all precipitation amounts can be expected to exceed this value. Conversely, the 70% (70th percentile) value represents the threshold for which 30 % of all precipitation amounts can be expected to exceed its value. The 50% (50th percentile) value was the average amount of monthly rainfall. On-site measured rain data were compared with the 'normal' range of monthly precipitation in Figure 4.1.

Figure 4.1 On-site Rainfall compared with 'normal' range of rainfall distribution for the Richlands (a), Vanceboro (b), and Cool Springs (c) sites.

Rainfall exceeded the 70th percentile for August, October and December of 2003; and January, May, June and August of 2004 for the Richlands site (Figure 4.1a). Heavy precipitation fell due to hurricane activity in the fall of 2003. Conversely, the months of September and November of 2003; and March, July and December of 2004 were dry months that did not exceed the 30th percentile months. All other months were in the category of 'normal' rainfall. July, September, December of 2003 and February and June of 2004 were months that had above the 70th percentile of rainfall at the Vanceboro site (Figure 4.1b). January, March, July, November, and December of 2004 had rainfall that fell below the 30th percentile. All other months had rainfall that fell between the 30th and the 70th percentile of rain. June and September of 2004 were wet periods, while March, July and November were dry periods at the Cool Springs site (Figure 4.1 c). All other months had rainfall that fell in the 'normal' range.

Temperature

Temperature was monitored at the Vanceboro and Richlands sites at each plot until 11/18/03. There was little difference (less than 2 degrees C) between transects, so, only the middle transects of the two sites were monitored. Air and ground surface temperatures were variable when compared with the more stable temperatures 50 cm below the surface, which were not affected by diurnal temperature fluctuations Fig. 4.2.

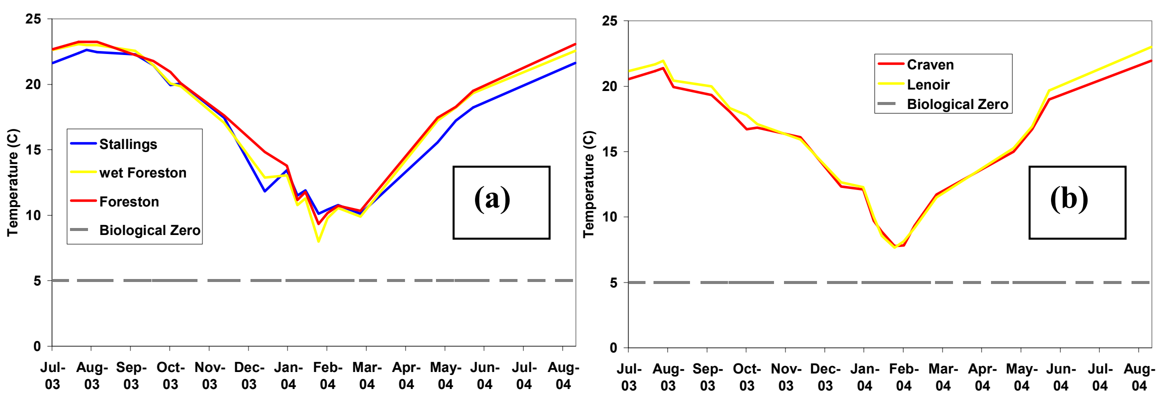

Figure 4.2 Soil temperatures measured at 50 cm depth for the Richlands (a) and Vanceboro (b) sites.

The soil temperature varied less than 0.6 ° C from the Foreston to the Stallings plots (Figure 4.2a). Soil temperatures at 50 cm varied little (less than 0.4 °C on average) between the Craven and Lenoir soils (Figure 4.2b). All soil temperatures remained above biological zero (5°C) throughout the year showing that low temperatures would not likely prevent microorganisms from developing reducing conditions in these soils.

4.3 RICHLANDS SITE

4.3.1 General Conditions

The soils of the Richlands site consisted of moderately well (Foreston) to somewhat poorly drained (Stallings) soils that formed in loamy marine sediments with slow surface runoff and moderate infiltration (Barnhill, 1992). Foreston soils occurred on the summit, the wet Foreston on the sideslopes, and the Stallings soils on the footslope position. The wet Foreston plots were 0.3 m lower in elevation than the Foreston plots, over a 17-m lateral distance. The Stallings plots were 0.1m lower than the wet Foreston plots over a 23-m lateral distance. The average slopes were 1% between the Foreston and wet Foreston plots, 0.5% between the wet Foreston and Stallings plots.

4.3.2 Foreston Soils

Redoximorphic features increased in abundance with depth (Table 4.1). Most of these were associated with root channel linings, occurring in a diffuse pattern that extended into the matrix. Roots were common in the surface horizons, and decreased with depth, with only coarse and medium sized roots persisting. Depletions occurred around both live and dead roots and were surrounded by soft iron concentrations in a halo fashion. Concentrations having red centers (7.5YR hues and redder) and surrounded by brown and yellowish brown (10YR hues), become more common with depth. Redox depletions occurring deeper than 1 m in the profile often occurred as white (10YR 8/1) clean washed sand grains, evidence of the total removal of iron oxide coatings. Chroma ≤ 3 depletions often occurred in conjunction with fewer (<2%) concentrations, which occurred higher in the profile than the ≤ 2 chroma depletions. Little structural development was encountered and consistencies were very friable throughout the profile. Full profile descriptions of all plots are presented in Appendix B.

Table 4.1 Soil morphological features for the Foreston 1 plot.

			Feature abundance				
Horizon	Depth	Matrix	Iron	depletions		Textural	Structure*
	Cm	color	concentrations	Chroma ≤ 3	Chroma ≤ 2	class	
			%				
A	0–10	2.5Y 2/1	0	0	0	fs	1mgr
AE	10–18	2.5Y 4/2	0	0	0	fls	1msbk/sg
E/A	18–25	5Y 6/4	0	0	0	fs	1msbk/sg
E	25–34	5Y 8/6	0	0	0	fs	sg
BE	34–43	2.5Y 7/6	0	0	0	fls	1csbk
Bt1	43–56	2.5Y 6/6	0	0	0	sl	1csbk
Bt2	56–69	10YR 7/8	5	10	0	sl	1csbk
Bt3	69–79	2.5Y 6/8	7	15	3	sl	1csbk
Bt4	79–94	10YR 6/6	2	10	20	sl	1csbk
BC	94–102	10YR 7/4	15	5	30	ls	1csbk

*1= weak; m= medium, c= coarse; gr= granular, sbk= subangular blocky, sg= single grain

Redox Feature Depth

Depths to the first occurrence of each redox feature are summarized for the Foreston soils in Table 4.2. The first occurrence was marked by 2% or more (18NCAC 15A .1942) of the soil volume in a given horizon. Iron concentrations occurred at an average depth of 48 cm. The average depth to chroma ≤ 3 depletions was 53 cm. The average depth to chroma ≤ 2 depletions was 65 cm, which was the depth of soil wetness conditions as set by rule .1942b (NCAC, 2005). All redox features occurred shallowest in the profile in the Foreston 3 plot. The chroma ≤ 2 depletions occurred deepest (71 cm) in the Foreston 2 plot (which was the highest elevation at the site) and shallowest in the Foreston 3 plot (65 cm).

Table 4.2 Redox features and their depths in the Foreston plots.

Soil	Concentrations	Chroma ≤ 3 depletions	Chroma ≤ 2 depletions
	---------------------------cm---------------------------		
Foreston 1	52	56	69
Foreston 2	50	53	71
Foreston 3	43	51	56
average	48	53	65

Saturation Durations

The soil wetness condition by morphology was the level which chroma ≤ 2 depletion occurred. Based on this, at the level of concentration occurrence, the plots were saturated for an average of 13.7% and 13.3% of the monitored and predicted data records. The monitored duration of saturation was higher (16.9%) than the long-term record (15.6%) at the level of chroma ≤ 3 depletion occurrence. The soils were saturated for 26.9% of the monitored record and 22.5% of the predicted record at the level of chroma ≤ 2 depletions occurrence. The average duration of saturation at the level of all redox features was similar for both the long term and monitored record (Tables 4.3 and 4.4).

Table 4.3 Saturation durations at the level of redox feature occurrence for the monitored period for the Foreston plots of all three transects.

Soil	Concentrations	Chroma ≤ 3 depletions	Chroma ≤ 2 depletions
	-------------------------------%------------------------------		
Foreston 1	11.5	13.6	22.5
Foreston 2	13.3	15.4	31.1
Foreston 3	16.4	21.7	27.1
average	13.7	16.9	26.9

Table 4.4 Saturation durations at the level of redox feature occurrence for the simulated, long-term period for the Foreston plots of all three transects.

Soil	Concentrations	Chroma ≤ 3 depletions	Chroma ≤ 2 depletions
	-----------------------------%---------------------------		
Foreston 1	12.4	14.5	21.2
Foreston 2	12.7	14.8	24.8
Foreston 3	14.8	17.6	21.6
average	13.3	15.6	22.5

Soil Wetness Conditions-Monitored and Modeled

The soil wetness conditions as determined by monitored data, Calibration, Threshold and WRI methods are shown in Table 4.5 for the Foreston plots. The average depth to which the soils were saturated continuously for 14 days during the monitored period was 47 cm.

The calibration wetness condition depths also averaged 47 cm. Threshold soil wetness condition depths averaged 51 cm. The WRI soil wetness condition depths ranged from an average low of 9 cm to an average high of 60 cm. The WRI soil wetness condition could not be determined for 2004 due to the lack of rainfall required by the method.

Table 4.5 Soil wetness conditions determined by observation and by the three methods of using DRAINMOD simulated data for the Foreston plots.

Soil	**Monitored 14-d**	**Calibration**	**Threshold**	**WRI-H**	**WRI-L**	**WRI 2004**
	---------------------------------------cm-----------------------------------					
Foreston 1	51	52	59	13	65	-
Foreston 2	49	48	53	11	60	-
Foreston 3	41	41	42	4	54	-
average	47	47	51	9	60	-

<u>Hydrology-redox feature relationships</u>

Average depths to redox features and average soil wetness conditions by the varying methods are shown in Tables 4.2 and 4.5 for the Foreston plots. The depths to all redox features had a relationship to every method of soil wetness condition determinations (Figure 4.3). Since the chroma ≤ 2 depletions were the field indicator of soil wetness (15NCAC 18A .1942), the relationship between them and the other methods of soil wetness determinations was most important of all redox features.

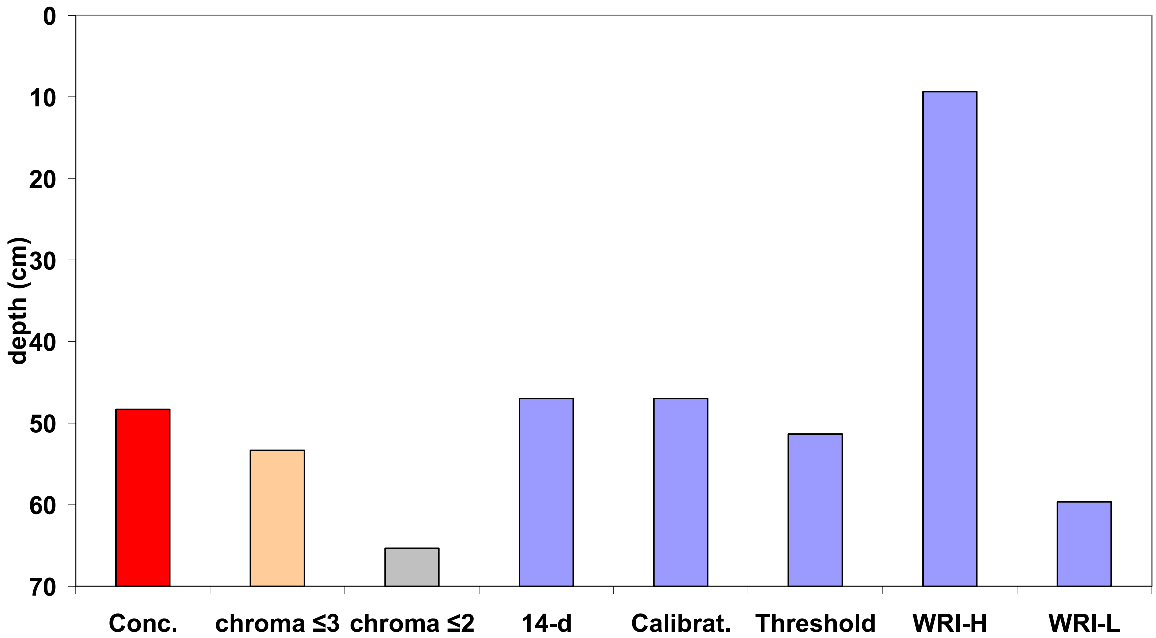

Figure 4.3 Average depth to Soil Wetness Conditions predicted by various methods all redox features for the Foreston plots.

Chroma ≤ 2 depletions

The chroma ≤ 2 depletions occurred at an average at 65 cm below the surface in the Foreston soils. This depth was deeper than all of the methods to determine soil wetness conditions (Figure 4.3). More specifically, this depth was 18 cm deeper than the average monitored data and average Calibration wetness conditions, 14 cm deeper than the Threshold method, 56 cm deeper than the WRI-H, and 5 cm deeper than the WRI-L (Figure 4.3). The method that predicted soil wetness conditions closest to the chroma ≤ 2 depletions was the WRI-L. However, this level was achieved only once or twice out of a potential 30 year period (see Figure 3.16). All methods of soil wetness condition determinations were more conservative than the morphological indicator of soil wetness for the Foreston plots.

Chroma ≤ 3 depletions

The chroma ≤ 3 depletions occurred on average at 53 cm below the surface. This depth was 6 cm deeper than the average monitored data and average Calibration wetness conditions, 2 cm deeper than the Threshold method, 44 cm deeper than the WRI-H, and 7 cm shallower than the WRI-L (Figure 4.3). The method that predicted soil wetness conditions closest to the chroma ≤ 3 depletions was the Threshold method.

Concentrations

Iron concentrations occurred at an average at 48 cm below the surface (Figure 4.3). This depth was 1 cm deeper than the average monitored data and average Calibration wetness conditions, 3 cm shallower than the Threshold method, 39 cm deeper than the WRI-H, and 12 cm shallower than the WRI-L. The method that predicted soil wetness conditions closest to the iron concentrations was the monitored data and the Calibration method.

4.3.3 Wet Foreston Soils

Redox features in the wet Foreston plots (Table 4.6) occurred in a similar pattern and sequence as in the Foreston soils (Table 4.1), but these features were closer to the soil surface and increased in abundance. Subsoil matrix colors had slightly more yellow hues than those of the Foreston soils (Table 4.1). Dark brown colors and root-masses persisted deeper in the topsoil than in the Foreston plots.

Table 4.6 Soil morphological features for the wet Foreston 1 plot.

			Feature abundance				
Horizon	**Depth**	**Matrix**	**Iron**	**depletions**		**Textural**	**Structure***
	cm	**Color**	**concentrations**	**Chroma ≤ 3**	**Chroma ≤ 2**	**class**	
			-------------------------%-------------------				
A1	0–5	2.5Y 2.5/1	0	0	0	fs	sg
A2	5–11	2.5Y 3/1	0	0	0	fs	1mgr
AE	11–21	2.5Y 4/3	0	0	0	fls	1csbk
EA	21–28	5Y 7/6	0	0	0	fs	1csbk
BE	28–37	2.5Y 7/6	0	0	0	fls	1csbk
Bt1	37–46	2.5Y 6/6	0	0	0	fsl	1csbk
Bt2	46–58	2.5Y 6/6	3	5	0	fsl	1csbk
Bt3	58–69	2.5Y 6/6	12	10	10	fsl	1csbk
Bt4	69–81+	10YR 7/4	17	0	20	fsl	1csbk

*1= weak; m= medium, c= coarse; gr= granular, sbk= subangular blocky, sg= single grain

Redox Feature Depths

Redox feature depths are summarized in Table 4.7. Iron concentrations occurred at an average depth of 44 cm for the Foreston soils. The average depth to chroma ≤ 3 depletions was 51 cm. The average depth to chroma ≤ 2 depletions was 59 cm. Concentrations occurred at a close proximity to the chroma ≤ 3 depletions in the wFo 1 and w Fo 2 plots. The chroma ≤ 3 depletions occurred 1 cm above the depth to which chroma ≤ 2 depletions occurred in the wet Fo 3 plot.

Table 4.7 Redox features and their depths in the wet Foreston plots.

Soil	Concentrations	Chroma ≤ 3 depletions	Chroma ≤ 2 depletions
	----------------------------cm--------------------------		
wForeston 1	44	47	58
wForeston 2	46	48	61
wForeston 3	42	58	59
average	44	51	59

Saturation Durations

The monitored saturation durations were similar to the long-term saturation durations (Tables 4.8 and 4.9), yet the long-term ones were slightly higher than the observed ones. The saturation durations increase with increasing depth in the profile. Redox features occurred at varying depths in the profile (Table 4.6) that corresponded to specific saturation durations (Tables 4.7 and 4.8). At the levels of concentration occurrence, the soils were saturated for an average 10.0% of the monitored period and 13.1% of the historic record. At the depth to chroma ≤ 3 depletions occurrence, the soils were saturated for an average 14.0% and 16.1% of the monitored and historic periods respectively. The soils were saturated during the monitored period at this level for an average of 19.9% of the time, and 21.1% of the long-term predicted data record at the level of chroma ≤ 2 depletions.

Table 4.8 Saturation durations for the Monitored period of the wet Foreston plots.

Soil	Concentrations	Chroma ≤ 3 depletions	Chroma ≤ 2 depletions
	----------------------------%------------------------		
wet Foreston 1	11.5	12.4	21.3
wet Foreston 2	9.7	11.4	19.1
wet Foreston 3	8.9	18.3	19.2
average	10.0	14.0	19.9

Table 4.9 Saturation durations for the long-term simulated record of the wet Foreston plots

Soil	Concentrations	Chroma ≤ 3 depletions	Chroma ≤ 2 depletions
	---------------------------------%---------------------------------		
wet Foreston 1	13.9	14.6	21.0
wet Foreston 2	13.2	14.0	21.8
wet Foreston 3	12.3	19.8	20.6
average	13.1	16.1	21.1

Soil Wetness Conditions

The soil wetness conditions as determined by the Calibration, Threshold and WRI methods are shown in Table 4.10 for the wet Foreston plots. The average depth to which the soils were saturated continuously for 14 days during the monitored period was 50 cm. The calibration wetness condition depths averaged 44 cm. Threshold soil wetness condition depths averaged 50 cm. The WRI soil wetness condition depths ranged from an average low of 7 cm to an average high of 57 cm. The WRI soil wetness conditions could not be determined for 2004.

Table 4.10 Soil wetness conditions determined by observation and by the three methods of using DRAINMOD simulated data for the wet Foreston plots.

Soil	Monitored 14-d	Calibration	Threshold	WRI-H	WRI-L	WRI 2004
	-----------------------------------cm-------------------------------------					
w Foreston 1	50	46	53	1	56	-
w Foreston 2	50	44	48	10	58	-
w Foreston 3	51	43	48	10	58	-
average	50	44	50	7	57	-

Hydrology-redox feature relationships

Average depths to redox features and average soil wetness conditions by the varying methods are shown in Tables 4.7 and 4.10 for the wet Foreston plots (Figure 4.4).

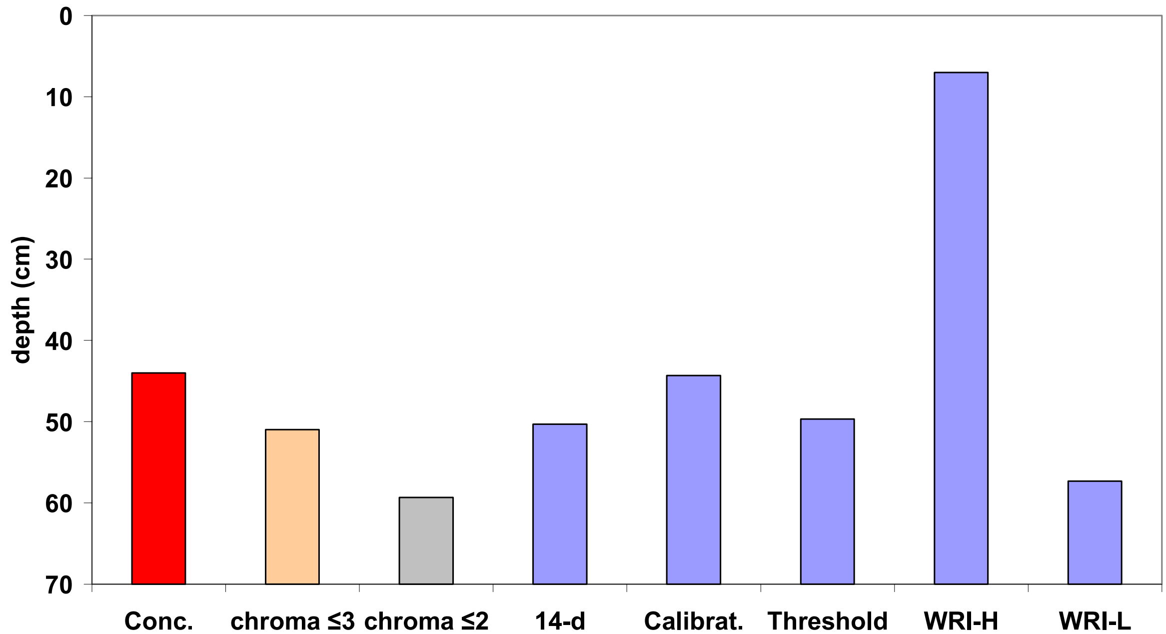

Figure 4.4 Average depth to Soil Wetness Conditions predicted by various methods and all redox features for the wet Foreston plots.

Chroma ≤ 2 depletions

These depletions occurred at an average of 59 cm below the surface in the wet Foreston soils. This depth was deeper than all of the methods to determine soil wetness conditions (Figure 4.4). More specifically, this depth was 9 cm deeper than the average monitored data, 15 cm deeper than the average Calibration wetness conditions, 9 cm deeper than the Threshold method, 52 cm deeper than the WRI-H, and 2 cm deeper than the WRI-L (Figure 4.3). The method that predicted soil wetness conditions closest to the chroma ≤ 2 depletions was the WRI-L. However, this level was achieved only once out of a potential 30 year period (see. Figure 3.16). With the exception of the WRI-L, all methods of soil wetness conditions determinations were more conservative than the morphological indicator of soil wetness for the wet Foreston plots.

Chroma ≤ 3 depletions

The chroma ≤ 3 depletions occurred at an average of 51 cm below the surface. This depth was 1 cm deeper than the average monitored data, 7 cm deeper than the average

Calibration wetness conditions, 1 cm deeper than the Threshold method, 44 cm deeper than the WRI-H, and 6 cm shallower than the WRI-L (Figure 4.4). The method that predicted soil wetness conditions closest to the chroma ≤ 3 depletions was the Threshold method and the monitored data.

Concentrations

Iron concentrations occurred at an average of 44 cm below the surface. This depth was 6 cm shallower than the average monitored data, the same level as the average Calibration wetness conditions, 6 cm shallower than the Threshold method, 37 cm deeper than the WRI-H, and 13 cm shallower than the WRI-L (Figure 4.4). The method that predicted soil wetness conditions closest to the iron concentrations was the Calibration method.

4.2.4 Stallings Soils

Redox features in the Stallings soils (Table 4.11) occurred in a similar sequence to the wet Foreston plots (Table 4.7) and Foreston soils (Table 4.1). The redox features occurred shallowest and were most abundant in the subsoil of all the plots. There was a discontinuous pinkish gray (7.5YR 6/2) buried spodic layer present that was brittle when dry, yet friable when moist.

Table 4.11 Soil morphological features for the Stallings1 plot.

			Feature abundance				
Horizon	**Depth**	**Matrix**	**Iron**	**depletions**		**Textural**	**Structure***
	cm	**Color**	**concentrations**	**Chroma ≤ 3**	**Chroma ≤ 2**	**class**	
			---------------------%----------------				
Oi	0–2.5	-	-	-	-	-	-
A	2.5–10	2.5Y 3/1	0	0	0	fs	1mgr/sg
AE	10–17	2.5Y 4/2	0	0	0	fls	1csbk
EA	17–27	2.5Y 5/4	0	0	0	fs	1csbk/sg
E	27–32	2.5Y 7/6	0	0	0	fs	sg
Bt1	32–41	2.5Y6/6	0	0	0	fsl	1csbk
Bt2	41–56	2.5Y 7/6	7	12	5	fsl	1csbk
Bt3	56–70	2.5Y 7/4	15	15	20	fsl	1csbk
BC	70–79+	2.5Y 7/4	27	0	47	ls	1csbk

*1= weak; m= medium, c= coarse; gr= granular, sbk= subangular blocky, sg= single grain
There was a thicker layer of un-decomposed needles and leaves.

Redox Feature Depths

Redox feature depths are summarized for the Stallings soils in Table 4.12. Iron concentrations occurred at an average depth of 37 cm. The average depth to chroma ≤ 3 depletions was 40 cm. The average depth to chroma ≤ 2 depletions was 44 cm. Concentrations occurred at a close proximity to the chroma ≤ 3 depletions in the St 1 and St 3 plots. The chroma ≤ 3 depletions occurred 3 cm above the depth to which chroma ≤ 2 depletions occurred in the St 2 and 3 plots.

Table 4.12 Redox features and their depths in the Stallings plots.

		depletions	
Soil	**Concentrations**	**Chroma ≤ 3**	**Chroma ≤ 2**
	--------------------------cm----------------------		
Stallings 1	34	37	41
Stallings 2	41	47	50
Stallings 3	36	37	40
average	37	40	44

Saturation Durations

As with the Foreston and wet Foreston soils, the saturation durations increased with increasing depth in the profile. Redox features occurred at varying depths in the profile that corresponded to specific saturation durations (Tables 4.13 and 4.14). The soils were saturated at the level of concentration occurrence for an average of 10.1% during the monitored period and 12.3% of the long-term predicted data record. The soils were saturated at the level of chroma ≤ 3 depletions occurrence for an average of 12.1% during the monitored period and 13.9% of the long-term predicted data record. The soils were saturated at the level of chroma ≤ 2 depletions occurrence for an average of 14.1% during the monitored period and 15.3% of the long-term predicted data record.

Table 4.13 Saturation durations at the level of redox feature occurrence for the monitored period for the Stallings plots of all three transects.

Soil	Concentrations	Chroma ≤ 3 depletions	Chroma ≤ 2 depletions
	------------------------------%------------------------------		
Stallings 1	12.6	13.6	15.1
Stallings 2	10	14.7	15.4
Stallings 3	7.7	8.1	11.8
average	10.1	12.1	14.1

Table 4.14 Saturation durations at the level of redox feature occurrence for the simulated period for the Stallings plots of all three transects.

Soil	Concentrations	Chroma ≤ 3 depletions	Chroma ≤ 2 depletions
	------------------------------%------------------------------		
Stallings 1	9.5	11.5	13.9
Stallings 2	13.6	15.8	16.9
Stallings 3	13.7	14.3	15.2
average	12.3	13.9	15.3

Soil Wetness Conditions

The soil wetness conditions as determined by the Calibration, Threshold and WRI methods are shown in Table 4.15 for the Stallings plots. The soil wetness condition by the monitored data was deeper at 49c m than those determined by the Calibration method at 37 , cm and the Threshold method at 40 cm. The wetness conditions determined by the Threshold method (40 cm) were deeper than that of the Calibration method (37 cm). The WRI-L wetness conditions were the deepest of all the methods at 50 cm. The wetness condition determined by the WRI-H averaged 2 cm below the soil surface. The WRI soil wetness conditions could not be determined for 2004.

Table 4.15 Soil wetness conditions determined by observation and by the three methods of using DRAINMOD simulated data for the Stallings plots.

Soil	Monitored 14-d	Calibration	Threshold	WRI-H	WRI-L	WRI 2004
	----------------------------------cm--					
Stallings 1	45	35	40	4	51	-
Stallings 2	51	39	43	1	52	-
Stallings 3	52	37	36	1	48	-
average	49	37	40	2	50	-

Hydrology-redox feature relationships

Average depths to redox features and average soil wetness conditions by the varying methods are shown in Tables 4.12 and 4.14 for the Stallings plots (Figure 4.5).

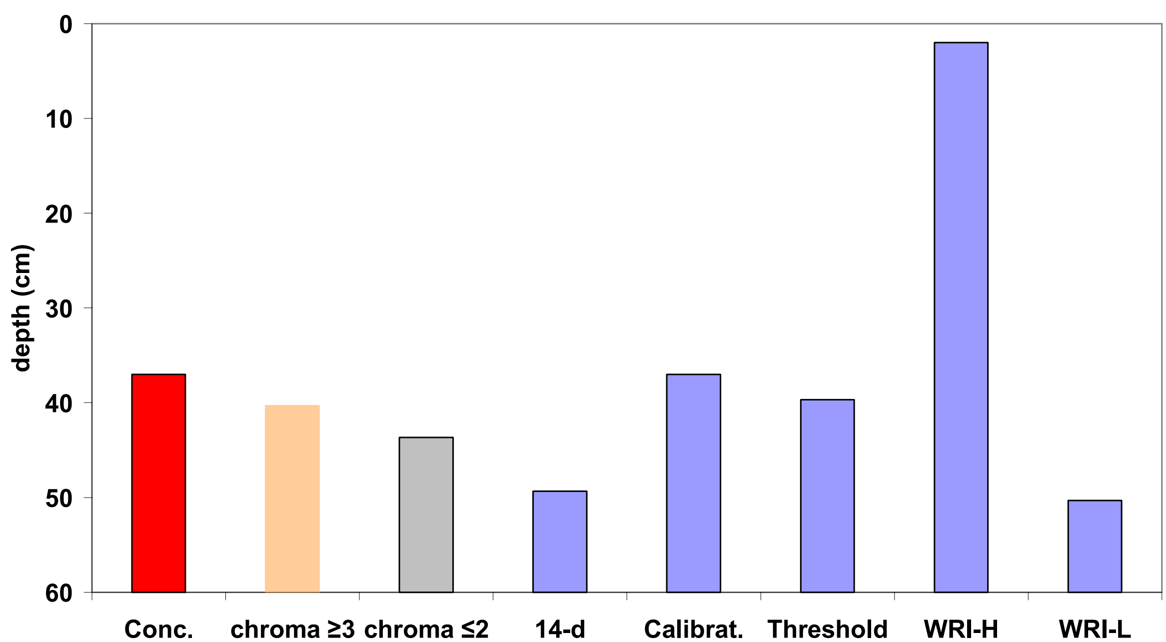

Figure 4.5 Average depth to Soil Wetness Conditions predicted by various methods and all redox features for the Stallings plots.

Chroma ≤ 2 depletions

These depletions occurred at an average of 44 cm below the surface in the Stallings soils. This depth was 5 cm shallower than the average monitored data, 7 cm deeper than the average Calibration wetness conditions, 4 cm deeper than the Threshold method, 42 cm deeper than the WRI-H, and 6 cm shallower than the WRI-L (Figure 4.5). The method that predicted soil wetness conditions closest to the chroma ≤ 2 depletions was the WRI-L. However, this level was achieved only once or twice out of a potential 30 year period (see Figure 3.16). With the exception of the WRI-L and the monitored data, all other methods of soil wetness conditions determinations were more conservative than the morphological indicator of soil wetness for the Stallings plots.

Chroma ≤ 3 depletions

The chroma ≤ 3 depletions occurred at an average of 40 cm below the surface. This depth was 9 cm shallower than the average monitored data, 3cm deeper than the average Calibration wetness conditions, at the same level of the Threshold method, 38 cm deeper than the WRI-H, and 10 cm shallower than the WRI-L (Figure 4.5). The method that predicted soil wetness conditions closest to the chroma ≤ 3 depletions was the Threshold method.

Concentrations

Iron concentrations occurred at an average of 37 cm below the surface. This depth was 12 cm shallower than the average monitored data, exactly the same level as the average Calibration wetness conditions, 3 cm shallower than the Threshold method, 35 cm deeper than the WRI-H, and 13 cm shallower than the WRI-L (Figure 4.5). The method that predicted soil wetness conditions closest to the iron concentrations was the Calibration method.

4.3.5 Summary of soils at the Richlands site

The average depths to redox feature occurrence are shown in Table 4.16. Iron concentrations occurred highest in the profile, followed by chroma ≤ 3 depletions, and then the chroma ≤ 2 depletions, which occurred deepest in the profiles. All features occurred deepest in the Foreston soils, more shallow in the wet Foreston, and finally the shallowest in the Stallings soils.

Table 4.16 Average depths of all redox features by soil type.

		Depletions	
Soil	**Concentrations**	**Chroma ≤ 3**	**Chroma ≤ 2**
n=3	---------------------------cm-------------------------		
Foreston	48	53	65
wet Foreston	44	51	59
Stallings	37	40	44

Saturation Durations

The average saturation durations at the level of all redox features were similar for both the long term and monitored record (Tables 4.17 and 4.18). At the level of concentration occurrence, the plots were saturated for an average of 11.3% and 12.9% of the monitored and predicted data records, respectively. The monitored duration of saturation was lower (14.3%) than the long-term record (15.2%) at the level of chroma ≤ 3 depletion occurrence. The soils were saturated for a site average 20.3% of the monitored record and 19.6% of the predicted record of chroma ≤ 2 depletions occurrence. Durations of saturation at the level of chroma ≤ 2 depletion occurrence for both monitored and historic data periods of all pedons were lower for the more poorly drained soils, by virtue of these features occurring higher in the profiles of plots in lower landscape positions than those plots in higher positions.

Table 4.17 Average saturation durations at the level of redox feature occurrence for the Monitored period of all plots.

Soil	**Concentrations**	**Chroma ≤ 3 depletions**	**Chroma ≤ 2 depletions**
n=3	-----------------------------%-----------------------------		
Foreston	13.7	16.9	26.9
wet Foreston	10.0	14.0	19.9
Stallings	10.1	12.1	14.1

Table 4.18 Average saturation durations during the simulated period of all plots.

Soil	Concentrations	Chroma ≤ 3 depletions	Chroma ≤ 2 depletions
n=3	------------------------------%----------------------------		
Foreston	13.3	15.6	22.5
wet Foreston	13.1	16.1	21.1
Stallings	12.3	13.9	15.3

Soil Wetness Condition –Monitored and Modeled

The average wetness conditions by monitored and modeled data are summarized in Table 4.19. The WRI method was not applicable in the year 2004 due to lack of rainfall required to satisfy the method.

Table 4.19 Summary of average soil wetness conditions determined by monitored and DRAINMOD simulated data, by soil type.

Soil	14-d	Calibration	Threshold	WRI-H	WRI-L	WRI 2004
n=3	---cm-----------------------------------					
Foreston	47	47	51	9	60	-
Wet Foreston	50	44	50	7	57	-
Stallings	49	37	40	2	50	-

Wetness conditions predicted by the Threshold method were deeper than those predicted by the Calibration method. The WRI-H method predicted wetness conditions near the soil surface, while the WRI-L predicted wetness conditions deepest of all methods.

4.4 VANCEBORO SITE

4.4.1 General Conditions

The soils at this site were consisted of moderately well drained Craven soils on the shoulder landscape position and the somewhat poorly drained Lenoir soils on the footslope position. They were slowly permeable soils that formed in fine-textured marine sediments with high surface runoff (Goodwin, 1989) that were on a low ridge and sideslopes on uplands near a natural drainageway. At this site, the elevation difference between the Craven and

Lenoir plots was 0.7 m over a 16 m lateral distance within a given transect. The average slope between the Craven and Lenoir plots was 5.5%. Wetness conditions and moderate shrink-swell potential of the slowly permeable, clayey subsoil limits the use of these soils for building development and OSWS.

4.4.2 Craven Soils

Redoximorphic features increased in abundance with depth (Table 4.20) and were associated with root channels, cracks, and ped surfaces within the matrix. Depletions around root channels were surrounded by iron concentrations in the surficial layers (10 –20 cm). Concentrations had red centers (7.5YR hues and redder) surrounded by lighter colors, brown and yellowish brown (10YR hues) and become more common with depth. Redox depletions, with depth in the profile, often occurred chiefly of light gray (10YR 7/2) low chroma bodies. Chroma ≤ 3 depletions occurred as depleted matrix material and ped coatings around the subangular blocks of the argillic horizons. Full profile descriptions for all plots are located in Appendix B.

Table 4.20 Soil morphological features for the Craven 1 plot.

			Feature abundance				
Horizon	Depth	Matrix	Iron	depletions		Textural	Structure*
	cm	color	concentrations	Chroma ≤ 3	Chroma ≤ 2	class	
			--------------------------%--------------------				
Ap	0–10	2.5Y 5/2	0	0	0	l	1mgr
AE	10–24	2.5Y 6/2	2	0	0	sil	1msbk
Bt1	24–37	10YR 6/6	0	0	0	c	3fabk
Bt2	37–47	10YR 6/6	7	5	0	c	3mabk
Bt3	47–69	10YR 6/6	12	7	2	c	3msbk
Bt4	69–91	10YR 6/8	20	0	20	cl	2cabk
Bt5	91–102+	2.5Y 6/6	12	0	35	cl	2csbk

*1= weak, 2= moderate, 3= strong; f= fine, m= medium, c= coarse; gr= granular, abk= angular blocky, sbk= subangular blocky

Redox Feature Depths

Depths to 2% or more of the soil volume as redox features are summarized in Table 4.21. Iron concentrations occurred at an average depth of 15 cm for the Craven soils. The average depth to chroma ≤ 3 depletions was 31 cm. The average depth to chroma ≤ 2 depletions was 52 cm, which was the depth of soil wetness conditions as set by rule .1942b (NCAC, 2005). For the Craven 1 and 2 plots, the redox features occurred in the lower topsoil, as few fine concentrations along root channels. For all Craven plots, concentrations occurred in the argillic horizons as soft iron masses. The chroma ≤ 3 depletions occurred as ped coatings on ped faces and depleted matrix material beginning in the middle argillic horizons. The chroma ≤ 2 depletions occurred in the argillic horizons at the level in the profile where there was a clay decrease.

Table 4.21 Redox features depths of the Craven plots.

Soil	Concentrations	Chroma ≤ 3 depletions	Chroma ≤ 2 depletions
	---------------------------cm----------------------------		
Craven 1	10	37	47
Craven 2	16	25	55
Craven 3	20	30	53
average	15	31	52

Saturation Durations

The average duration of saturation at the level of all redox features were lower for both the long-term and monitored record (Tables 4.22 and 4.23). At the level of concentration occurrence, the plots were saturated for an average of 0.1% and 0.5% of the monitored and predicted data records, respectively. The monitored duration of saturation was higher (0.2%) than the long-term record (0.8%) at the level of chroma ≤ 3 depletion occurrence. The soils were saturated for 1.1% of the monitored record and 2.7% of the predicted record at the level of chroma ≤ 2 depletions occurrence.

Table 4.22 Saturation durations at the level of redox feature occurrence for the monitored period for the Craven plots.

Soil	Concentrations	Chroma ≤ 3 depletions	Chroma ≤ 2 depletions
	------------------------------%------------------------------		
Craven 1	0.0	0.0	0.0
Craven 2	0.2	0.3	1.4
Craven 3	0.0	0.2	2.0
average	0.1	0.2	1.1

Table 4.23 Saturation durations at the level of redox feature occurrence for the simulated, long-term period for the Craven plots.

Soil	Concentrations	Chroma ≤ 3 depletions	Chroma ≤ 2 depletions
	------------------------------%------------------------------		
Craven 1	0.1	0.2	0.4
Craven 2	0.5	0.7	2.7
Craven 3	0.8	1.4	5.0
average	0.5	0.8	2.7

<u>Soil Wetness Conditions</u>

The soil wetness conditions determined by monitored data, Calibration, Threshold and WRI methods are shown in Table 4.24 for the Craven plots. The average depth to which the soils were continuously saturated for 14 days during the monitored period was 102 cm. The calibration wetness condition depths also averaged 102 cm. Threshold soil wetness condition depths averaged 94 cm. The WRI soil wetness condition depths ranged from an average high of 30 cm to an average low of 123 cm. The WRI soil wetness conditions could not be determined for 2004 due to the monitored period being too dry to satisfy the requirements for the method.

Table 4.24 Soil wetness conditions determined by observation and by the three methods of using DRAINMOD simulated data for the Craven plots.

Soil	Monitored 14-d	Calibration	Threshold	WRI-H	WRI-L	WRI 2004
	------------------------------cm------------------------------					
Craven 1	139	139	136	43	158	-
Craven 2	92	89	81	25	114	-
Craven 3	74	78	66	23	98	-
average	102	102	94	30	123	-

<u>Hydrology-redox feature relationships</u>

Average depths to redox features and average soil wetness conditions by the varying methods are shown in Tables 4.21 and 4.24 respectively, for the Craven plots. The relationship between Redox features and wetness condition predicted by all methods was unclear. Chroma ≤ 2 depletions were the soil indicator of soil wetness (15NCAC 18A

.1942), therefore, the relationship between them and the other methods of soil wetness determinations was most important of all redox features (Figure 4.6).

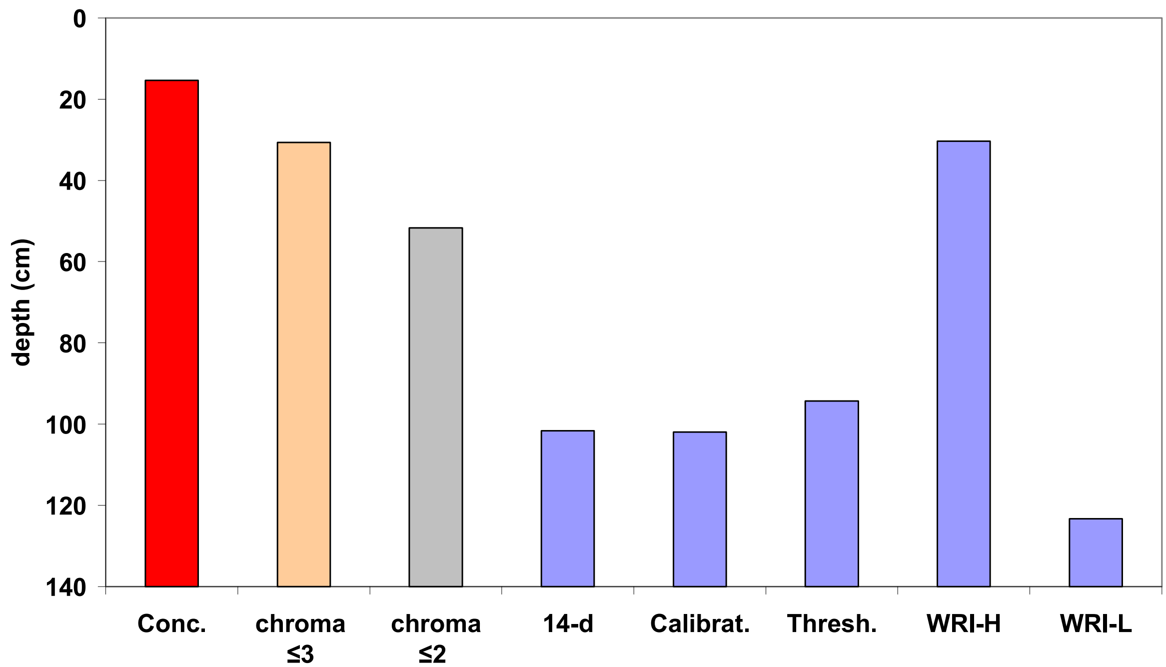

Figure 4.6 Average depth to Soil Wetness Conditions predicted by various methods and all redox features for the Craven plots.

Chroma ≤ 2 depletions

The chroma ≤ 2 depletions occurred at an average of 52 cm below the surface in the Craven soils. This depth was 50 cm shallower than the average monitored data and the average Calibration wetness conditions, 42 cm shallower than the Threshold method, 22 cm shallower than the WRI-H, and 71 cm shallower than the average level WRI-L (Figure 4.6).

The chroma ≤ 2 depletions occurred consistently shallower than all methods except the WRI-H, which was the method that predicted soil wetness conditions closest to the chroma ≤ *2* depletions. This level was achieved only once out of a potential 30 year period (see Figure 3.16). This shows that most of the methods were more liberal than what the soil morphology suggests.

Chroma ≤ 3 depletions

The chroma ≤ 3 depletions occurred at an average of 31 cm below the surface. This depth was 71 cm shallower than the average monitored data and the average Calibration wetness conditions, 63 cm shallower than the level of the Threshold method, 1 cm deeper than the WRI-H, and 92 cm shallower than the WRI-L (Figure 4.6). The method that predicted soil wetness conditions consistently closest to the chroma ≤ 3 depletions was the WRI-H. However, this level was achieved once out of a potential 30-year period (see. Figure 3.16).

Concentrations

Iron concentrations occurred at an average of 15 cm below the surface. At this level, the soils were rarely saturated. This depth was 87 cm shallower than the average monitored data, the same level as the average Calibration wetness conditions, 79 cm shallower than the Threshold method, 15 cm shallower than the WRI-H, and 108 cm shallower than the WRI-L (Figure 4.6). The method that predicted soil wetness conditions consistently closest to the iron concentrations was the WRI-H. This level was achieved once out of a potential 30-year period (see Figure 3.16).

4.4.3 Lenoir Soils

Redox features percentages increased with depth (Table 4.25) and were associated with root channels, cracks, and ped surfaces within the matrix. The Lenoir soils had very pale brown (10YR 7/3) ped coatings, and gray matricies at the bottom of the profile (Table 4.20). Roots were prevalent in the surface horizons, and generally decreased with depth, with only coarse and medium sized roots persist. Strong and moderate structural units occurred as angular and subangular blocks. Soil consistencies were friable in the topsoil and were firm in the subsoil (Table 4.20). Full profile descriptions for all plots are presented in Appendix B.

Table 4.25 Soil morphological features for the Lenoir 1 plot.

			Feature abundance				
Horizon	Depth	Matrix	Iron	depletions		Textural	Structure*
	cm	color	concentrations	Chroma ≤ 3	Chroma ≤ 2	class	
			---------------------%---------------------				
Ap	0–10	2.5Y 5/2	0	0	0	L	1mgr
AE	10–25	10YR 5/3	5	0	0	sl	1cabk
BE	25–36	10YR 6/4	7	0	0	sl	1msbk
Bt1	36–53	2.5Y 6/6	12	5	0	cl	3msbk
Bt2	53–62	2.5Y 6/4	22	7	10	c	2mabk
Bt3	62–72	10YR 7/3	30	0	25	cl	2mabk
Btg	72–84+	N/7	45	5	50	scl	1csbk

*1= weak, 2= moderate, 3= strong; f= fine, m= medium, c= coarse; gr= granular, abk= angular blocky, sbk= subangular blocky

Redox Feature Depths

Redox features in the Lenoir plots (Table 4.26) occurred in a similar sequence in the Craven soils (Table 4.20), but were greater in abundance. Iron concentrations occurred at an average depth of 15 cm. The average depth to chroma ≤ 3 depletions was 32 cm. The average depth to chroma ≤ 2 depletions was 48 cm. The redox features occurred throughout the topsoil as dendritic concentration along root channels. The chroma ≤ 3 depletions occurred as ped coatings on ped faces throughout the argillic horizons. The chroma ≤ 2 depletions occurred within the peds of the argillic horizons.

Table 4.26 Redox features and their depths in the Lenoir plots.

Soil	Concentrations	Chroma ≤ 3 depletions	Chroma ≤ 2 depletions
	---------------------------cm----------------------------		
Lenoir 1	10	36	51
Lenoir 2	16	28	44
Lenoir 3	18	33	48
average	15	32	48

Saturation Durations

Saturation durations at the level of redox feature occurrence are summarized for monitored data (Table 4.27) and for long-term predicted data (Table 4.28). Iron concentrations occurred at an average depth of 15 cm. At this level the soils were saturated for an average 3.8% of the monitored period and 5.7% of the historic record, respectively. The average depth to chroma ≤ 3 depletions was 32 cm and was saturated at this level for an average 8.1% and 13.4% of the monitored and historic periods, respectively. The average depth to chroma ≤ 2 depletions was 48 cm. The soils were saturated during the monitored period at this level for an average of 14.6% of the time, and 23.5% of the long-term predicted data record.

Table 4.27 Saturation durations for the Monitored period of the Lenoir plots.

Soil	Concentrations	Chroma ≤ 3 depletions	Chroma ≤ 2 depletions
	------------------------------%-------------------------		
Lenoir 1	4.6	10.8	17.1
Lenoir 2	3.7	7.2	14.1
Lenoir 3	3.1	6.4	12.5
average	3.8	8.1	14.6

Table 4.28 Saturation durations for the long-term simulated record of the Lenoir plots

Soil	Concentrations	Chroma ≤ 3 depletions	Chroma ≤ 2 depletions
	----------------------------%----------------------------		
Lenoir 1	7.5	21.0	31.7
Lenoir 2	6.2	10.4	20.9
Lenoir 3	3.4	8.9	18.0
average	5.7	13.4	23.5

Soil Wetness Conditions

The soil wetness conditions as determined by the Calibration, Threshold and WRI methods are shown in Table 4.29 for the Lenoir plots. The soil wetness condition by the monitored data was similar (27 cm), but shallower than those determined by the Calibration method at 30 cm. The wetness conditions determined by the Threshold method (28 cm) were shallower than the Calibration method. The WRI-L wetness conditions (37 cm) were the deepest of all the methods. The wetness condition determined by the WRI-H averaged close to the soil surface at 7 cm.

Table 4.29 Soil wetness conditions determined by observation and by the three methods of using DRAINMOD simulated data for the Lenoir plots.

Soil	Monitored 14-d	Calibration	Threshold	WRI-H	WRI-L	WRI 2004
	--cm--------------------------------					
Lenoir 1	17	21	17	0	28	-
Lenoir 2	28	31	26	0	34	-
Lenoir 3	35	37	40	13	50	-
average	27	30	28	4	37	-

Hydrology-redox feature relationships

Redox features of the Lenoir soil had a consistent relationship with its hydrology (Figure 4.7) compared to the Craven plots (Figure 4.5). Calibration soil wetness conditions were shallower than both types of depletions (Table 4.28), more specifically, 21 cm shallower than chroma ≤ 2 depletions. This would imply that the wetness conditions predicted by the Calibration method were more conservative than the soil morphological indicator of soil wetness condition (chroma ≤ 2) suggested.

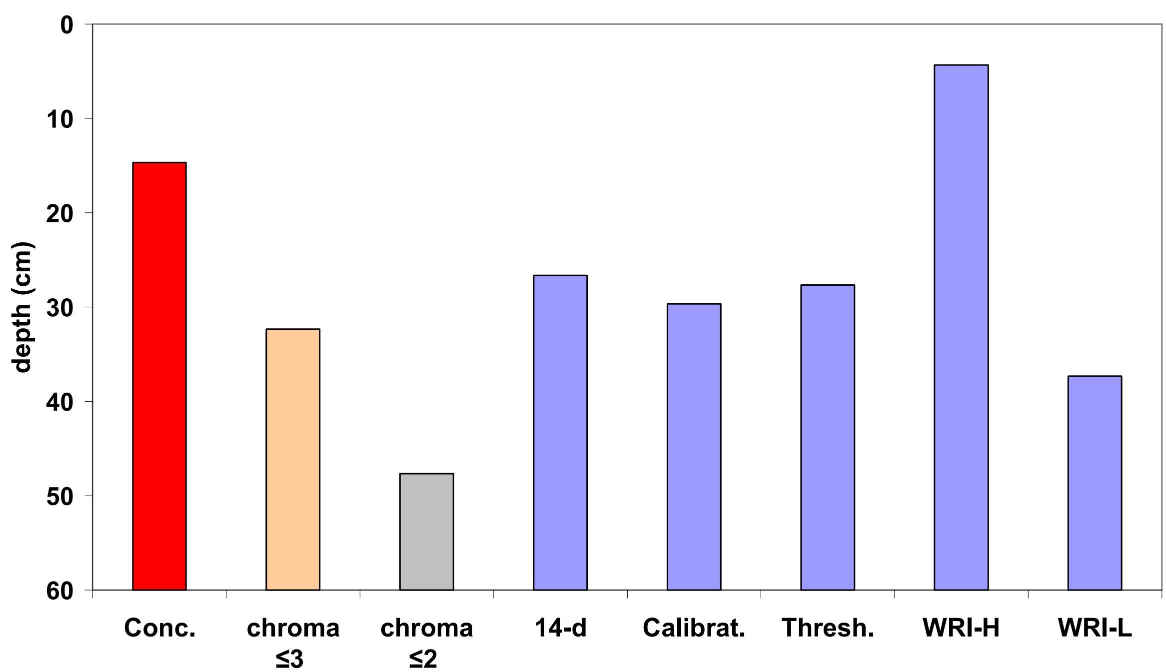

Figure 4.7 Average depth to Soil Wetness Conditions predicted by various methods and all redox features for the Lenoir plots.

Chroma ≤ 2 depletions

The chroma ≤ 2 depletions occurred at an average of 48 cm below the surface. This depth was 21 cm deeper than the average monitored data, 12 cm deeper than the average Calibration wetness conditions, 20 cm deeper than the Threshold method, 44 cm deeper than the WRI-H, and 11cm deeper than the WRI-L (Figure 4.7).

The chroma ≤ 2 depletions occurred consistently deeper than all methods of soil wetness conditions determination, showing that most of the methods were more conservative than the morphology suggested. The method that produced a level of soil wetness comparable to the chroma ≤ 2 depletions was the WRI-L.

Chroma ≤ 3 depletions

The chroma ≤ 3 depletions occurred at an average of 48 cm. This depth was 5 cm deeper than the average monitored data, 2 cm deeper than the average Calibration wetness conditions, 4 cm deeper than the level of the Threshold method, 28 cm deeper than the WRI-H, and 5 cm shallower than the WRI-L (Figure 4.7). The method that predicted average soil wetness conditions consistently closest to the chroma ≤ 3 depletions was the Calibration method (30 cm).

Concentrations

Iron concentrations occurred at an average of 15 cm below the surface. This depth was 12 cm shallower than the average monitored data, 15 cm shallower than the average Calibration wetness conditions, 13 cm shallower than the Threshold method, 11 cm deeper than the WRI-H, and 22 cm shallower than the WRI-L (Figure 4.7). The method that consistently predicted soil wetness conditions closest to the iron concentrations was the WRI-H level. This level was achieved only once or twice out of a potential 30 year period (see Figure 3.16).

4.4.4 Summary of soils at the Vanceboro site

All the redox features of the soils of the Vanceboro site occurred at a similar depth. However, at the depth of their first occurrence, the chroma ≤ 2 depletions were more abundant in the Lenoir (4.26) soils than they were in the Craven soils (4.20). The chroma ≤ 2 depletions occurred deeper in the profile for the Lenoir 1 plot due to the fact that the land surface was at one time scraped, sheared and flattened in the area of the Craven plots, thus reducing the amount of topsoil and exposing the subsoil closer to the surface.

Average depth to all redox features by soil type Table 4.30. Iron concentrations occurred highest in the profile (15 cm), followed by chroma ≤ 3 depletions (32 cm), and then the chroma ≤ 2 depletions, which occurred deepest in the profiles (50 cm).

Table 4.30 Average depths of all redox features by soil type.

		depletions	
Soil n=3	**Concentrations**	**Chroma ≤ 3**	**Chroma ≤ 2**
	---------------------------cm-----------------------		
Craven	15	31	52
Lenoir	15	32	48

Saturation Durations

The average saturation durations at the level of all redox features were similar for both the long term and monitored record (Tables 4.31 and 4.32). At the level of concentration occurrence, the plots were saturated for an average of 2.0% and 3.1% of the monitored and predicted data records, respectively. The monitored duration of saturation was (4.2%) of the long-term record (7.1%) at the level of chroma ≤ 3 depletion occurrence. The soils were saturated for a site average of 7.9% for the monitored record and 13.1% of the predicted record of chroma ≤ 2 depletions occurrence.

Table 4.31 Average saturation durations at the level of redox feature occurrence for the Monitored period of all plots.

Soil	**Concentrations**	**Chroma ≤ 3 depletions**	**Chroma ≤ 2 depletions**
	-----------------------------%---------------------------		
Craven	0.1	0.2	1.1
Lenoir	3.8	8.1	14.6
average	2.0	4.2	7.9

Table 4.32 Average saturation durations during the simulated period of all plots.

Soil	Concentrations	Chroma ≤ 3 depletions	Chroma ≤ 2 depletions
	--------------------------%------------------------------		
Craven	0.5	0.8	2.7
Lenoir	5.7	13.4	23.5
average	3.1	7.1	13.1

Soil Wetness Conditions

The average site wetness conditions by monitored data were similar to (65) the wetness conditions determined by the Calibration (66 cm) and Threshold (61 cm) methods (Table 4.33). The Threshold method produced an average wetness condition was 5 cm shallower than those predicted by the Calibration method. The average WRI-L was a predicted 17 cm below the soil surface. The average WRI-H was the deepest wetness condition predicted by any method (80 cm).

Table 4.33 Summary of average soil wetness conditions determined by monitored and DRAINMOD simulated data, by soil type.

Soil	14-d	Calibration	Threshold	WRI-H	WRI-L	WRI 2004
	------------------------------------cm----------------------------------					
Craven	102	102	94	30	123	-
Lenoir	27	30	28	4	37	-

Hydrology-redox feature relationships

A clear relationship was observed between seasonal saturation and redoximorphic features for the footslope/sideslope soils (Lenoir) as shown in Figure 4.6. The chroma ≤ 2 depletions occurred deeper in the profile than the monitored and predicted data suggest that the soil wetness conditions occurred (Table 4.33). The relationship was not as clear for the shoulder pedons (Craven) as shown in Figure 4.5. The chroma ≤ 2 depletions occurred shallower than most of the levels of soil wetness conditions predicted by the various methods (Figure 4.5).

There were two apparent water table dynamics of the Craven soils, shallow perching conditions and deeper groundwater. This supports the notion that there was not a good relationship between groundwater levels and redoximporphic features, in episaturated soils. Clayey horizons, especially deeper in a soil, might reduce oxygen diffusion rates to the point of maintaining redox features in soils only periodically saturated (Megonigal et al. 1993). Hydraulically restrictive horizons in the subsoil were common features on the Coastal Plain and have been implicated in perching water, inducing lateral flow across the landscape (Daniels et al., 1971).

The Lenoir soils were located on the footslope landscape position and receive both ground and surface water from upslope. Monitored well data does not distinguish the vertical groundwater movement from lateral inflow of perched conditions. Improper site instrumentation may result in inaccurate correlations between redox features and hydrology.

4.5 COOL SPRINGS SITE

4.5.1 General Conditions

This site contained well to somewhat poorly drained, very rapidly permeable soils that formed in sandy stream terrace deposits with low surface runoff (Goodwin, 1989). These soils were on a low ridge on a gently undulating ridge on the Swift Creek stream terrace. The soils of the Cool Springs site were well drained Tarboro soils on the summit, moderately well drained wet Tarboro on the upper shoulder, and somewhat poorly drained Seabrook soils on the sideslope. Elevation differences between the Tarboro and Seabrook soils were slight (0.07 m) yet there was a definite difference in soil properties between the plots, the depth to redox features in particular. Redox depletions occurred 10-20 cm higher in the profile in the lower plots than in the plots in higher elevations.

The slope between the highest and lowest plots average 4.7%. A back swamp was located at 0.22 m below the local summit. The sand grains were medium sized (0.25 to 0.5mm) throughout most of the profile, but increase in size to coarse sand at the bottom of the pedons, perhaps showing evidence of another sandy deposit. High seepage rates in the higher elevation plots and wetness conditions in the lower slope positions limit the use of these soils for building development and OSWS.

4.5.2 Tarboro Soil

Morphological features for the Tarboro 1 plot are shown in Table 4.34. Weakly developed B-horizons high in these profiles had colors light olive brown (2.5Y 5/6) and weak fine granular structure. The colors in the middle of the profiles tended to become more yellow (2.5YR 7/4) and then become slightly redder (10YR 5/6) at the bottom of the profile. Overall structures were weak to none (single grain) and have loose consistencies.

Table 4.34 Soil morphological features for the Tarboro 1 plot.

				Feature abundance			
Horizon	Depth	Matrix	Iron	Depletions		Textural	Structure
	cm	color	conc.	Chroma ≤ 3	Chroma ≤ 2	class	
			---------------------%----------------				
Oi	0–5	-	-	-	-	-	-
A	5–13	2.5Y 3/2	0	0	0	s	sg
Bw1	13-25	2.5Y 4/4	0	0	0	s	1fgr
Bw2	25-48	2.5Y 5/6	2	0	0	s	1fgr
BC	48-71	2.5Y 7/6	0	0	0	s	1fgr/sg
C1	71-99	2.5Y 7/4	2	0	5	s	sg
C2	99-127	10YR 7/6	15	0	10	s	sg
C3	127-140+	10YR 5/6	30	10	10	s	sg

*1= weak; f= fine, c= coarse; gr= granular, sg= single grain

Coarse, splotchy iron concentrations (7.5YR 5/6) were associated with brown (10YR 4/3) decayed organic bodies. Low chroma depletions range from coarse to fine in size, occurred deep in the profile and were associated with root channels. Chroma ≤ 3 depletions occurred as irregular splotches within the matrix, deep in the profile (Table 4.35).

There was little contrast between depletion and matrix colors, due to low Fe in parent material, oxygenated water inhibiting iron reduction or unstable root channels remaining open for short periods that fill in when the root decomposes (Vepraskas, 2000). All redox features were less distinct and not as well defined as those associated with finer textured soils of this study, thus increasing the difficulty of seasonal high water table estimations.

Clean washed sand grains “stripped” of iron occurred throughout these profiles. They were pale yellow in color (2.5Y 8/2). However, they were not determined to be redox depletions if they were not associated with iron concentrations. These features could be in-filled root channels stripped of iron by leaching organic acids. In order to support this conclusion the features need to be compared to water table measurements.

Redox Feature Depth

Depths to the first occurrence of each redox feature are shown for the Tarboro soils in Table 4.35. Iron concentrations occurred at depth of 25 cm. The depth to chroma ≤ 3 depletions was 127 cm. The average depth to chroma ≤ 2 colors was 71 cm, which was the depth of soil wetness conditions as set by rule .1942b (NCAC 2005). Yet the chroma ≤ 2 depletions may be due to stripping or infilling of root channels and not true redox depletions.

Table 4.35 Redox features and their depths in the Tarboro plot.

Soil	Concentrations	Chroma ≤ 3 depletions	Chroma ≤ 2 colors
	--------------------------cm--------------------------		
Tarboro 1	25	127	71

Saturation Durations

Redox features occurred at varying depths in the profile that corresponded to saturation durations (Tables 4.36 and 4.37). At the level of concentration occurrence, the plots were never saturated during the monitored and predicted data records. The monitored duration of saturation was lower (17.7%) than the long-term record (52.8%) at the level of chroma ≤ 3 depletion occurrence. The soils were never saturated during the monitored record and 0.2% of the predicted record at the level of chroma ≤ 2 color occurrence.

Table 4.36 Saturation durations at the level of redox feature occurrence for the monitored period for the Tarboro plots of all three transects.

Soil	Concentrations	Chroma ≤ 3 depletions	Chroma ≤ 2 Colors
	----------------------------%----------------------------		
Tarboro	0	17.7	0

Table 4.37 Saturation durations at the level of redox feature occurrence for the simulated, long-term period for the Tarboro plots of all three transects.

Soil	Concentrations	Chroma ≤ 3 depletions	Chroma ≤ 2 depletions
	--------------------------%	----------------------------	
Tarboro	0.0	52.8	0. 2

Soil Wetness Conditions-Monitored and Modeled

The soil wetness conditions as determined by monitored data, Calibration, Threshold and WRI methods are shown in Table 4.38 for the Tarboro plot. The depth to which the soils were saturated continuously for 14 days during the monitored period and the calibration wetness condition depth was 116 cm. Threshold soil wetness condition depths average was 121 cm. The WRI soil wetness condition depths ranged from a high of 88 cm to a low of 116 cm. The WRI soil wetness conditions could not be determined for 2004 due to the lack of rainfall required by the method.

Table 4.38 Soil wetness conditions determined by observation and by the three methods of using DRAINMOD simulated data for the Tarboro plot.

Soil	Monitored 14-d	Calibration	Threshold	WRI-H	WRI-L	WRI 2004
	-------------------------------------cm-------------------------------------					
Tarboro	131	116	125	88	116	-

Hydrology-redox feature relationships

Average depths to redox features and average soil wetness conditions by the varying methods are shown in Tables 4.35 and 4.38 for the Tarboro plot (Figure 4.8).

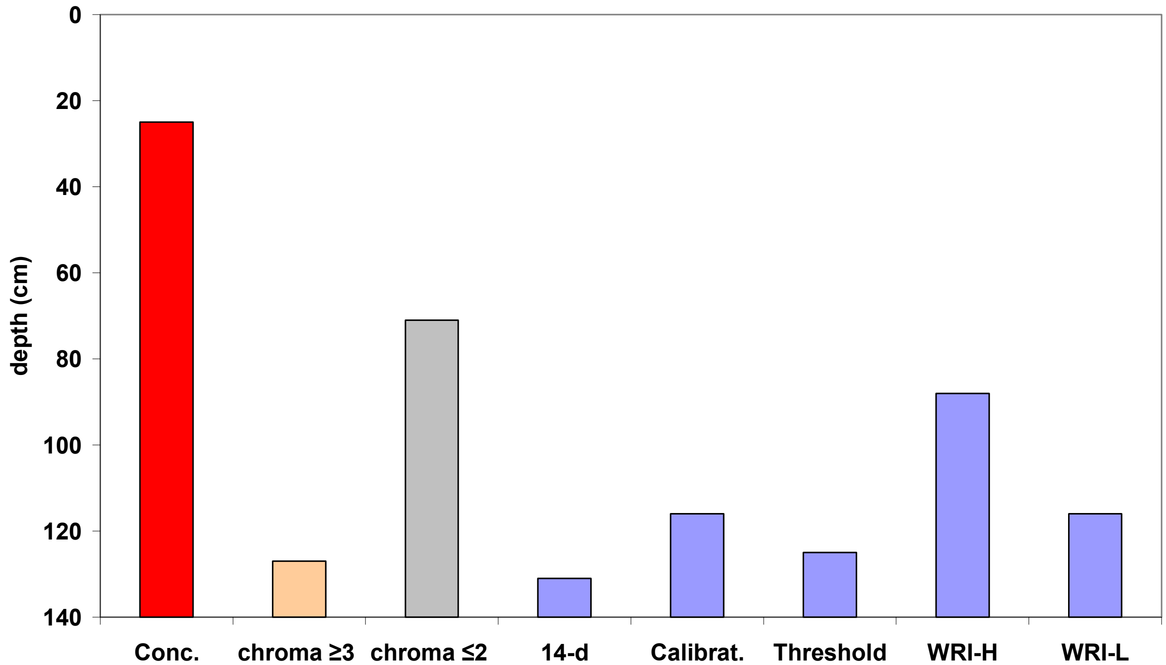

Figure 4.8 The depth to Soil Wetness Conditions predicted by various methods and all redox features for the Tarboro soil.

Chroma ≤ 2 colors

These colors occurred at 71 cm. This depth was deeper than all of the methods to determine soil wetness conditions (Figure 4.8). More specifically, this depth was 60 cm shallower than the monitored data and 45 cm shallower than the Calibration wetness conditions, 54 cm shallower than the Threshold method, 17 cm shallower than the WRI-H, and 45 cm shallower than the WRI-L (Figure 4.8). The method that predicted soil wetness conditions closest to the chroma ≤ *2* colors was the WRI-H. However, this level was achieved only once or twice out of a potential 30 year period (see Figure 3.16). All methods of soil wetness conditions determinations were deeper than the chroma ≤ 2 colors. Again, these colors may not be true redox features, but due to stripping of sand grains or infilling of root channels.

Chroma ≤ 3 depletions

The chroma ≤ 3 depletions occurred at 127 cm below the surface. This depth was 4 cm shallower than the monitored data and 11 cm deeper than the Calibration wetness conditions, 2 cm deeper than the Threshold method, 39 cm deeper than the WRI-H, and 11 cm deeper than the WRI-L (Figure 4.8). The method that predicted soil wetness conditions closest to the chroma ≤ 3 depletions was the Threshold method, aside from the monitored data.

Concentrations

Iron concentrations occurred at 25 cm below the surface. This depth was 106 cm shallower than the monitored data and 91 cm shallower than the Calibration wetness conditions, 100 cm shallower than the Threshold method, 63 cm shallower than the WRI-H, and 91cm shallower than the WRI-L (Figure 4.8). The method that predicted soil wetness conditions closest to the iron concentrations was the WRI-H. All methods to predict soil wetness were substantially deeper than iron concentration occurrence.

4.5.3 Wet Tarboro Soils

The morphological features of the wet Tarboro soils were generally the same as the Tarboro soils, with a few exceptions. Redox features in the wet Tarboro plots occurred in a similar pattern and sequence as in the Tarboro soils, but these features were closer to the soil surface and increase in abundance. Subsoil matrix colors had slightly more yellow hues than those of the Tarboro soils (Table 4.39). The Bw horizons had less thickness than the Tarboro soil. As with the Tarboro soil, the chroma ≤ 2 colors may not be true redox features, but stripping of sand grains or infilling of root channels.

Table 4.39 Soil morphological features for the wet Tarboro 1 plot.

			Feature abundance				
Horizon	**Depth**	**Matrix**	**Iron**	**Depletions**		**Textural**	**Structure***
	cm	**color**	**concentrations**	**Chroma ≤ 3**	**Chroma ≤ 2**	**class**	
			---------------------%---------------------				
A	0–8	2.5Y 4/1	0	0	0	s	sg
AB	8–20	2.5Y 5/3	0	0	0	s	sg
Bw	20-38	2.5Y 5/6	0	0	0	s	1fgr
BC	38-50	2.5Y 6/6	0	0	0	s	0m
C1	50-69	10YR 7/6	1	0	3	s	0m
C2	69-97	2.5Y 7/4	6	0	15	s	sg
C3	97-116	2.5Y 6/6	10	15	10	s	sg
C4	116-125	2.5Y 6/6	10	5	12	s	sg

*0= structureless, 1= weak; gr= granular, sg= single grain, m= massive

Redox Feature Depths

Redox feature depths are summarized in Table 4.40. Iron concentrations occurred at an average depth of 41 cm. The average depth to chroma ≤ 3 depletions was 100 cm. The average depth to chroma ≤ 2 colors was 56 cm. While concentrations occurred close to the surface in the wet Tarboro 2 plot, the other redox features occurred at similar depths for both plots.

Table 4.40 Redox features and their depths in the wet Tarboro plots.

Soil	Concentrations	Chroma ≤ 3 depletions	Chroma ≤ 2 depletions
	------------------------cm------------------------		
wet Tarboro 1	69	97	50
wet Tarboro 2	13	102	61
Average	41	100	56

Saturation Durations

The monitored saturation and long-term saturation durations are summarized in Tables 4.41 and 4.42). At the levels of concentration occurrence, the soils were never saturated during the monitored period and 0.2% of the historic record. At the depth to chroma ≤ 3 depletions occurrence, the soils were saturated for an average 7.4% and 19.2% of the monitored and historic periods respectively. There was a substantial difference in saturation durations at this level from plot 1 to plot 2. This difference was due to the fact that the chroma ≤ 3 depletions occurred lower in the profile in plot 2 and by its deeper position, being saturated for a longer period of time. The soils were never saturated during the monitored period and 0.2% of the long-term predicted data record at the level of chroma ≤ 2 colors.

Table 4.41 Saturation durations for the Monitored period of the wet Tarboro plots.

Soil	Concentrations	Chroma ≤ 3 depletions	Chroma ≤ 2 depletions
	---------------------------%---------------------------		
wet Tarboro 1	0.0	2.0	0.0
wet Tarboro 2	0.0	12.8	0.0
average	0.0	7.4	0.0

Table 4.42 Saturation durations for the long-term simulated record of the wet Tarboro plots

Soil	Concentrations	Chroma ≤ 3 depletions	Chroma ≤ 2 depletions
	------------------------------%-------------------------		
wet Tarboro 1	0.3	3.5	0.1
wet Tarboro 2	0.0	34.9	0.3
average	0.2	19.2	0.2

Soil Wetness Conditions

The soil wetness conditions as determined by the Calibration, Threshold and WRI methods are shown in Table 4.43 for the wet Tarboro plots. The average depth to which the soils were saturated continuously for 14 days during the monitored period was 99 cm. The calibration wetness condition depths were an average 101 cm. Threshold soil wetness condition depths average 105 cm. The WRI soil wetness condition depths ranged from an average high of 81 cm to an average low of 101 cm. The WRI soil wetness conditions could not be determined for 2004.

Table 4.43 Soil wetness conditions determined by observation and by the three methods of using DRAINMOD simulated data for the wet Tarboro plots.

Soil	Monitored 14-d	Calibration	Threshold	WRI-H	WRI-L	WRI 2004
	-----------------------------------cm--------------------------------					
W Tarboro 1	117	104	110	85	104	-
W Tarboro 2	109	98	100	76	98	-
average	113	101	105	81	101	-

Hydrology-redox feature relationships

Average depths to redox features and average soil wetness conditions by the varying methods are shown in Tables 4.40 and 4.43 for the wet Tarboro plots (Figure 4.9).

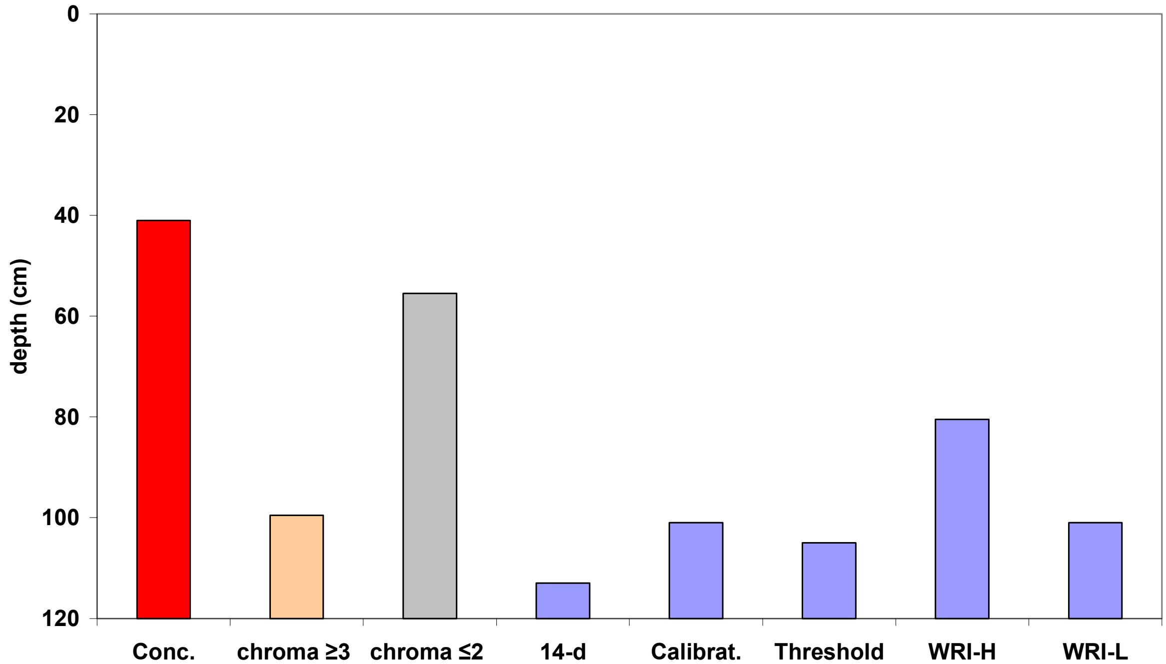

Figure 4.9 Average depth to Soil Wetness Conditions predicted by various and all redox features for the wet Tarboro plots.

Chroma ≤ 2 colors

These colors occurred at an average of 56 cm below the surface in the wet Tarboro soils. This depth was shallower than all of the methods to determine soil wetness conditions (Figure 4.9). This depth was 61 cm shallower than the average monitored data, 45 cm shallower than the average Calibration wetness conditions, 49 cm shallower than the Threshold method, 25 cm shallower than the WRI-H, and 45 cm shallower than the WRI-L (Figure 4.9). The method that predicted soil wetness conditions closest to the chroma ≤ *2* colors was the WRI-H. However, this level was achieved only once or twice out of a potential 30 year period (see Figure 3.16). All methods of soil wetness conditions determinations were more conservative than the level of chroma ≤ *2* color occurrence.

Chroma ≤ 3 depletions

The chroma ≤ 3 depletions occurred at an average of 100 cm below the surface. This depth was 13 cm shallower than the average monitored data, 1cm shallower than the average Calibration wetness conditions, 5 cm shallower than the Threshold method, 19 cm deeper than the WRI-H, and 1 cm shallower than the WRI-L (Figure 4.9). The method that predicted soil wetness conditions closest to the chroma ≤ 3 depletions was the Calibration method and the WRI-L method. The WRI-L wetness condition does not reach this level not in most years.

Concentrations

Iron concentrations occurred at an average of 41 cm below the surface. This depth was 72 cm shallower than the average monitored data, and 60 cm shallower than the average Calibration wetness conditions, 64 cm shallower than the Threshold method, 40 cm deeper than the WRI-H, and 60 cm shallower than the WRI-L (Figure 4.9). All the methods yielded a deeper level of wetness conditions than the level of concentration occurrence. The method that predicted soil wetness conditions closest to the iron concentrations was the WRI-H method.

4.5.4 Seabrook Soils

Redox features in the Seabrook soils (Table 4.44) occurred in a similar sequence to the wet Tarboro plots and Tarboro soils. A morphological feature that was unique to the Seabrook soils was the presence of an incipient spodic horizon beginning shallow (23 cm) in the profile. Unlike the wet Tarboro and Tarboro soils, the chroma ≤ 2 colors may indeed be true redox features, and would need to be supported with well data.

Table 4.44 Soil morphological features for the Seabrook 1 plot.

			Feature abundance				
Horizon	**Depth**	**Matrix**	**Iron**	**depletions**		**Textural**	**Structure***
	cm	**color**	**Concentrations**	**Chroma ≤ 3**	**Chroma ≤ 2**	**class**	
			---------------------%---------------				
A	0–10	2.5Y 4/1	0	0	0	s	Sg
E	10–23	2.5Y 6/2	0	0	0	s	sg
Bs	23-39	2.5Y 5/6	0	0	0	s	1fgr
BC	39-58	10YR 6/4	0	0	0	s	1fgr
C1	58-81	2.5Y 7/6	0	0	3	s	sg
C2	81-102	2.5Y 7/4	20	2	5	s	sg

*1= weak; gr= granular, sg= single grain

Redox Feature Depths

Redox feature depths are shown for the Seabrook soils in Table 4.45. Iron concentrations occurred at an average depth of 43 cm. The average depth to chroma ≤ 3 depletions was 81 cm. The average depth to chroma ≤ 2 depletions was 52 cm. Concentrations occurred higher in the profile in the Seabrook 2 plot.

Table 4.45 Redox features and their depths in the Seabrook plots.

Soil	Concentrations	depletions Chroma ≤ 3	Chroma ≤ 2
	----------cm----------		
Seabrook 1	58	81	55
Seabrook 2	28	81	48
average	43	81	52

Saturation Durations

Redox features occurred at varying depths in the profile (Table 4.45) that corresponded to specific saturation durations (Tables 4.46 and 4.47). The soils were saturated at the level of concentration occurrence during the monitored period for an average of 0.7% and 19.4% of the long-term predicted data record. The soils were saturated at the level of chroma ≤ 3 depletions occurrence for an average of 17.6% during the monitored period and 62.3% of the long-term predicted data record. The soils were saturated at the level of chroma ≤ 2 depletions occurrence for 0.7% of the monitored period and 16.7% of the long-term predicted data record. The saturation durations for the predicted record were higher for the Seabrook 1 plot at the level of concentration and chroma ≤ 2 depletion occurrence due to the fact that these features occurred lower in the profile in the Seabrook 1 vs. the Seabrook 2 plot.

Table 4.46 Saturation durations at the level of redox feature occurrence for the monitored period for the Seabrook plots of all three transects.

Soil	Concentrations	Chroma ≤ 3 depletions	Chroma ≤ 2 depletions
	----------------------------%------------------------------		
Seabrook 1	1.3	16.3	1.3
Seabrook 2	0	18.8	0
average	0.7	17.6	0.7

Table 4.47 Saturation durations at the level of redox feature occurrence for the simulated period for the Seabrook plots of all three transects.

Soil	Concentrations	Chroma ≤ 3 depletions	Chroma ≤ 2 depletions
	----------------------%-----------------------		
Seabrook 1	38.3	68.3	31.6
Seabrook 2	0.4	56.2	1.8
average	19.4	62.3	16.7

<u>Soil Wetness Conditions</u>

The soil wetness conditions as determined by the Calibration, Threshold and WRI methods are shown in Table 4.48 for the Seabrook plots. The average depth to soil wetness condition by the monitored data was 86 cm, by the Calibration method were at 55 cm and the Threshold method were 53 cm. The WRI-L wetness conditions were the deepest of all the methods at 60 cm. The wetness condition determined by the WRI-H was an average of 33 cm below the soil surface. The WRI wetness conditions could not be determined for 2004.

Table 4.48 Soil wetness conditions determined by observation and by the three methods of using DRAINMOD simulated data for the Seabrook plots.

Soil	Monitored 14-d	Calibration	Threshold	WRI-H	WRI-L	WRI 2004
	-----------------------------------cm------------------------------					
Seabrook 1	85	44	41	29	56	-
Seabrook 2	86	65	65	36	64	-
average	86	55	53	33	60	-

Hydrology-redox feature relationships

Average depths to redox features and average soil wetness conditions by the varying methods are shown in Tables 4.45 and 4.48 for the Seabrook plots. Again, the chroma ≤ 2 colors indeed seem to be true redox features.

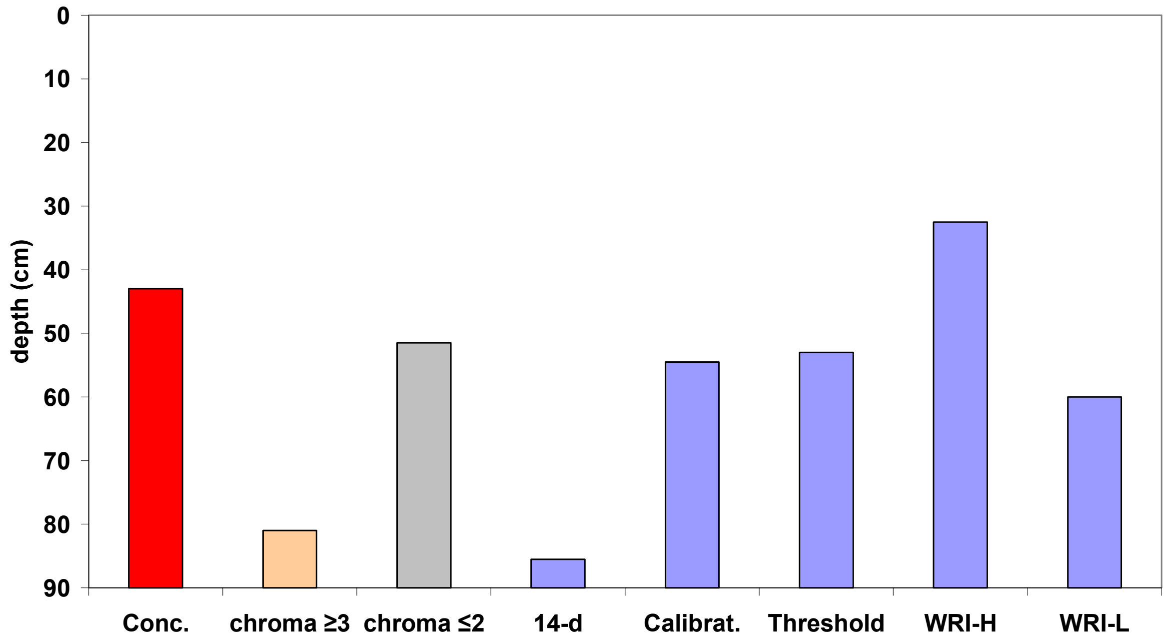

Figure 4.10 Average depth to Soil Wetness Conditions predicted by various methods and all redox features for the Seabrook plots.

Chroma ≤ 2 depletions

These depletions occurred at an average of 52 cm below the surface in the Seabrook soils. This depth was 34 cm shallower than the average monitored data, 3 cm shallower than the average Calibration wetness conditions, 1 cm shallower than the Threshold method, 19 cm deeper than the WRI-H, and 8 cm shallower than the WRI-L (Figure 4.10). The method that predicted soil wetness conditions closest to the chroma ≤ 2 depletions was the Threshold method.

Chroma ≤ 3 depletions

The chroma ≤ 3 depletions occurred at an average of 81 cm below the surface. This depth was 5 cm shallower than the average monitored data, 26 cm deeper than the average

Calibration wetness conditions, 28 cm deeper than the average Threshold method, 48 cm deeper than the WRI-H, and 21 cm deeper than the WRI-L (Figure 4.10). The method that predicted soil wetness conditions closest to the chroma ≤ 3 depletions, aside from the monitored data was the Calibration method.

Concentrations

Iron concentrations occurred at an average of 43 cm below the surface. This depth was 43 cm shallower than the average monitored data, 12 cm shallower than the Calibration wetness conditions, 10 cm shallower than the average Threshold method, 10 cm deeper than the average WRI-H, and 17 cm shallower than the WRI-L (Figure 4.10). The method that predicted soil wetness conditions closest to the iron concentrations was the Threshold and WRI-H method.

4.5.5 Summary of soils at the Cool Springs site

The average depths of redox feature occurrence are shown in Table 4.49. Iron concentrations occurred highest in the profile, followed by chroma ≤ 2 depletions, and then the chroma ≤ 3 depletions, which occurred deepest in the profiles. All features occurred deepest in the Tarboro soils, more shallow in the wet Tarboro, and finally the shallowest in the Seabrook soils.

Table 4.49 Average depths of all redox feature by soil type.

Soil	**Concentrations**	**Chroma ≤ 3**	**Chroma ≤ 2**
n=3	**-------------------------cm-------------------------**		
Tarboro	25	127	71
Wet Tarboro	41	100	56
Seabrook	43	81	52

<u>Saturation Durations</u>

At the depth of average concentration occurrence, the plots were never saturated for an average during the monitored period and an average of 6.5% during the predicted data records, respectively (Tables 4.50 and 4.51). The monitored duration of saturation was lower

(12.1%) than the long-term record (44.8%) at the level of chroma ≤ 3 depletion occurrence. The soils were never saturated for the monitored record and 5.7% of the predicted record of chroma ≤ 2 depletions occurrence. Durations of saturations at the level of chroma ≤ 2 depletion occurrence for both monitored and historic data periods of all pedons were lower for the more poorly drained soils, by virtue of these features occurring higher in the profiles of plots in lower landscape positions than those plots in higher positions.

Table 4.50 Average saturation durations at the level of redox feature occurrence for the Monitored period of all plots.

Soil	Concentrations	Chroma ≤ 3 depletions	Chroma ≤ 2 depletions
n=3	----------------------------	%	------------------------------
Tarboro	0.0	11.4	0.0
wet Tarboro	0.0	9.2	0.0
Seabrook	0.0	15.8	0.0
averages	0.0	12.1	0.0

Table 4.51 Average saturation durations during the simulated period of all plots.

Soil	Concentrations	Chroma ≤ 3 depletions	Chroma ≤ 2 depletions
n=3	----------------------------	%	----------------------------
Tarboro	0.0	52.8	0. 2
wet Tarboro	0.2	19.2	0.2
Seabrook	19.4	62.3	16.7
averages	6.5	44.8	5.7

Hydrology-redox feature relationships

An evident relationship existed between measured and predicted soil wetness conditions with chroma ≤ 3 depletions for all plots (Figures 4.7, 4.8, and 4.9). As shown by Figure 4.9, the Seabrook plots distinguish themselves from the other plots in the fact that the chroma ≤ 2 depletions occurred higher in the profile than the other plots, have higher average saturation durations at the level of those feature's occurrences, and have substantially shallower levels of predicted soil wetness conditions (Table 4.52).

Table 4.52 Summary of average soil wetness conditions determined by monitored and DRAINMOD simulated data, by soil type.

Soil	14-d	Calibration	Threshold	WRI-H	WRI-L
n=3	------------------------------------cm---------------------------				
Tarboro	131	116	125	88	116
wet Tarboro	113	101	105	81	101
Seabrook	86	55	53	33	60

Therefore, the relationships between hydrology and chroma ≤ 2 depletions were split in two groups at the Cool Springs site, i) Tarboro (Figure 4.8) and wet Tarboro plots (Figure 4.9), and ii) the Seabrook plots (Figure 4.10).

Summary

The soils of the Cool Springs site had a unique redox feature pattern occurrence. As with the other sites, the concentrations occurred highest in the profile. The differentiation came with the chroma ≤ 2 depletions occurred next followed by the chroma ≤ 3 depletions, which were deepest in the profile. The chroma ≤ 2 depletions could have been mistaken for clean washed sand grains or in-filled root channels in the Tarboro and wet Tarboro soils, but were observed in conjunction with iron concentrations.

At the level of these redox feature occurrences, the relationship between the measured and predicted wetness conditions was broken into two categories i) the combined averages of the Tarboro and wet Tarboro plots, and ii) the Seabrook plots. In general, the soil morphology (chroma 2 depletions) suggested more conservative soil wetness conditions than do the Calibration, Threshold, and WRI methods for the first category. The level of ≤ 3 chroma depletions occurrence matched best with the hydrology for the first category, while chroma. ≤ 2 depletions matched best with the second category.

5. CONCLUSIONS

A total of 20 plots at three sites on the Lower Coastal Plain were selected for this study. Each site had soils with different morphological features, mainly texture. The soils of the Vanceboro site experience endosaturation and were assumed to have episaturation as well, while soils of the Cool Springs and the Richlands site were endosaturated, relative to the 2-m monitoring depth. All soils contained varying abundance of iron based redoximorphic features, including redox concentrations and depletions. These depletions were broken into two categories, those depletions whose chroma color was ≤ 3, and those whose color was ≤ 2.

Little temperature difference was observed among the sites and transects within each site. Each monitored plot had similar diurnal fluctuations. The soil temperature was never measured below biological zero (5 °C), therefore, it was assumed that there was year-round potential for microbially mediated iron reduction. The lower winter temperatures, however, may have increased the time needed to reduce iron.

DRAINMOD was calibrated to achieve a match between measured and observed water table levels. The sites were not drained, so a virtual drainage network was assumed for all sites. Model parameters were adjusted to achieve the least absolute standard deviation between measured and simulated data. The calibration parameters included: virtual drain spacing, virtual drain depth, depth to restrictive layer, depressional storage, and drainable porosity of the subsurface horizons. Once the model was calibrated, long-term water table levels were predicted using historic rainfall data from the nearest weather station to estimate the duration and frequency that a site would be saturated at the depth of the first occurrence of each type of redox feature. The wetness condition was defined as the shallowest depth that was saturated for 14 continuous day period for at least 30% of the long-term weather record.

Soil wetness conditions were determined in accordance to the NCDENR-OSWW rule ".1942 SOIL WETNESS CONDITIONS" (15A NCAC 18A, 2005) for all 20 soil plots using both observed morphology and DRAINMOD simulated data. This study determined the viability and accuracy of the Calibration, Threshold, and WRI methods of determining long-term water table depths and their relationships to redox features by comparing morphology to monitored/modeled data. Specific conclusions with reference to the experimental sites were as follows:

<u>Richlands Site</u>

Foreston Soils

1. Average depth to soil wetness conditions determined by:

    i) Calibration method were 18 cm above the chroma ≤ 2 depletions.

    ii) Threshold method were 14 cm above the chroma ≤ 2 depletions, but 4 cm below the calibration method.

    iii) WRI soil wetness conditions ranged from 9 to 60 cm with only 17 out of 33 years usable.

2. The average depth of soil wetness condition determined by the Calibration method (47 cm) related best to average depth of redox concentrations occurrence (48 cm).

Wet Foreston Soils

1. Average depth to soil wetness conditions determined by:

    i) Calibration method were 15 cm above the chroma ≤ 2 depletions.

    ii) Threshold method were 9 cm above the chroma ≤ 2 depletions, but 6 cm below the calibration method.

    iii) WRI soil wetness conditions ranged from 7 to 57 cm with only 17 out of 33 years usable.

2. The average depth of soil wetness conditions determined by the Calibration method (44 cm) related best to average depth of redox concentrations occurrence (44 cm).

Stallings Soils

1. Average depth to soil wetness conditions determined by:

i) Calibration method were 18 cm above the chroma ≤ 2 depletions.

ii) Threshold method were 14 cm above than chroma ≤ 2 depletions, but 4 cm below the calibration method.

iii) WRI soil wetness conditions ranged from 9 to 60 cm with only 17 out of 33 years usable.

2. The average depth of soil wetness conditions determined by the Calibration method (37 cm) related best to average depth of redox concentrations occurrence (37 cm).

Vanceboro Site

Craven Soils

1. Average depth to soil wetness conditions determined by:

i) Calibration method were 50 cm below the chroma ≤ 2 depletions.

ii) Threshold method were 42 cm below the chroma ≤ 2 depletions, but 8 cm above the calibration method.

iii) WRI soil wetness conditions ranged from 30 to 123cm with only 23 out of 34 years usable.

2. Average soil wetness conditions for all methods showed no consistent relationship with any redox feature.

Lenoir Soils

1. Average depth to soil wetness conditions determined by:

i) Calibration were 12 cm above the chroma ≤ 2 depletions.

ii) Threshold were 20 cm above the chroma ≤ 2 depletions, but 8 cm below the calibration method.

iii) WRI soil wetness conditions ranged from 4 to 37 cm with only 23 out of 34 years usable.

2. Average depth to soil wetness conditions by the Calibration method (30 cm) related best with the average depth of chroma 3 depletions (32 cm).

Cool Springs Site

Tarboro

1. Average depth to soil wetness conditions determined by:

   i) Calibration method were 45 cm below the chroma ≤ 2 depletions.

   ii) Threshold method were 54 cm below the chroma ≤ 2 depletions, and 9 cm below the calibration method.

2. Average depth to soil wetness conditions by the Threshold method (125) related best with the average depth of chroma ≤ 3 depletions (127).

Wet Tarboro soils

1. Average depth to soil wetness conditions determined by:

   i) Calibration method were 45 cm below the chroma ≤ 2 depletions.

   ii) Threshold method were 49 cm below the chroma ≤ 2 depletions, and 4 cm below the calibration method.

2. Average depth to soil wetness conditions for the Calibration method (101 cm) related best with average depth to chroma ≤ 3 depletions occurrence (100 cm).

Seabrook Soils

1. Average depth to soil wetness conditions determined by:

   ii) Calibration method were 3 cm below the level of chroma ≤ 2 depletions.

ii) Threshold method were 1 cm below the level of chroma ≤ 2 depletions, and 2 cm below the calibration method.

2. Average depth to soil wetness conditions for Threshold method (53 cm) related best with the average depth to chroma ≤ 2 depletions (52 cm).

Well data from soils with a perched water table (Craven soils at the Vanceboro site) may not accurately convey the dynamics of the water table. For soils with perching conditions, a series of piezometers at different depths could provide greater detail and capture the intricacies of water flow. However, no piezometer was installed in this study. It was assumed that the Craven soils were endosaturated, but it was apparent only in the latter portion of the study that there were indeed two water table dynamics occurring, a perched water table on and within the clay layer, and a deeper groundwater table, which spiked very rarely and only for brief periods not exceeding three days.

The depth of soil wetness conditions of the WRI method could not be determined for every year of analysis due to lack of required rainfall. Those values that were obtained were variable within each plot, ranging from ponded conditions (0 cm) to 65 cm below the surface. This suggests that using this method alone was not as reliable as using a combination of factors to determine the water table.

Overall, the Calibration method was most reliable way to predict long-term water table levels according to North Carolina state regulation (15A NCAC 18A .1942) This method and other methods predicted wetness conditions at a more conservative depth than the expressed soil morphology.

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APPENDIX A

MEASURED RAINFALL FOR ALL SITES

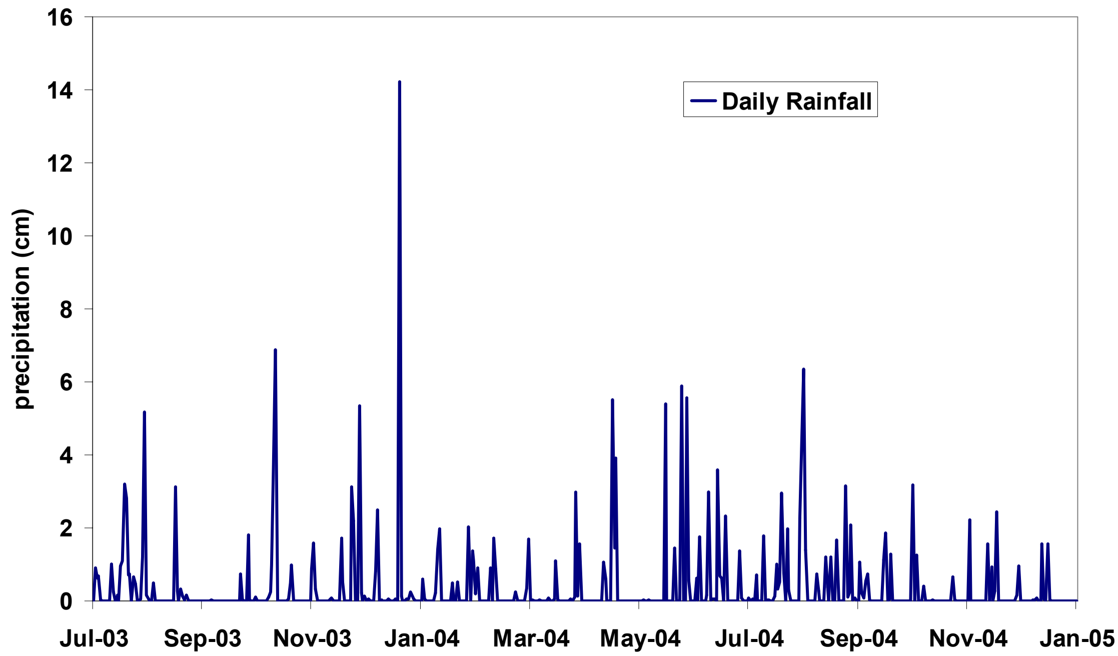

Figure A.1 Measured daily rainfall at the Richlands site.

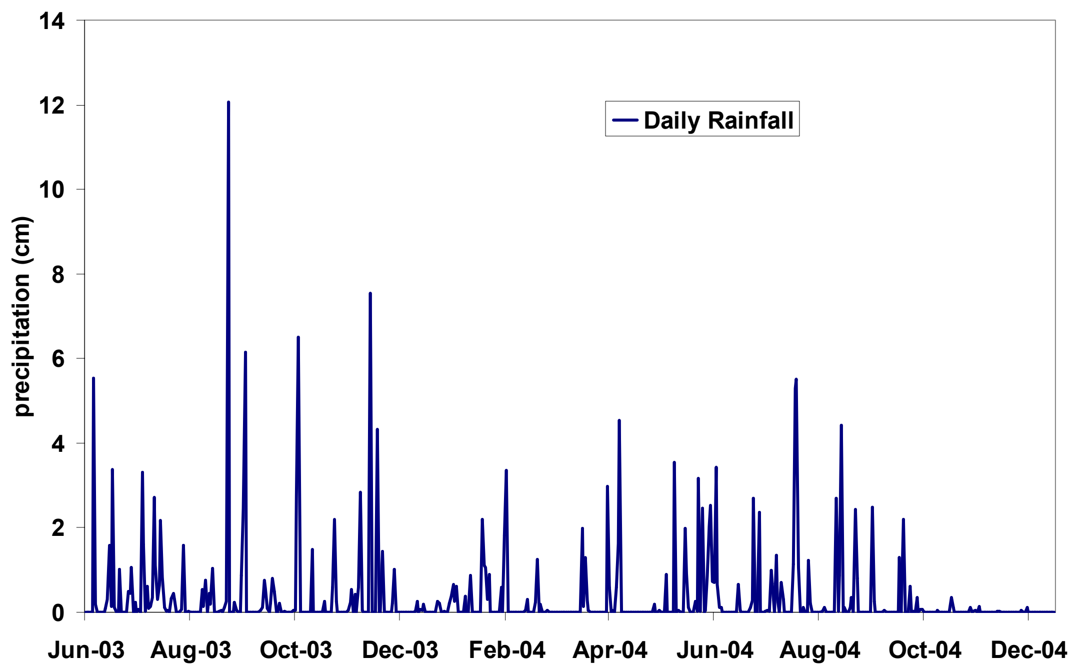

Figure A.2 Measured daily rainfall at the Vanceboro site.

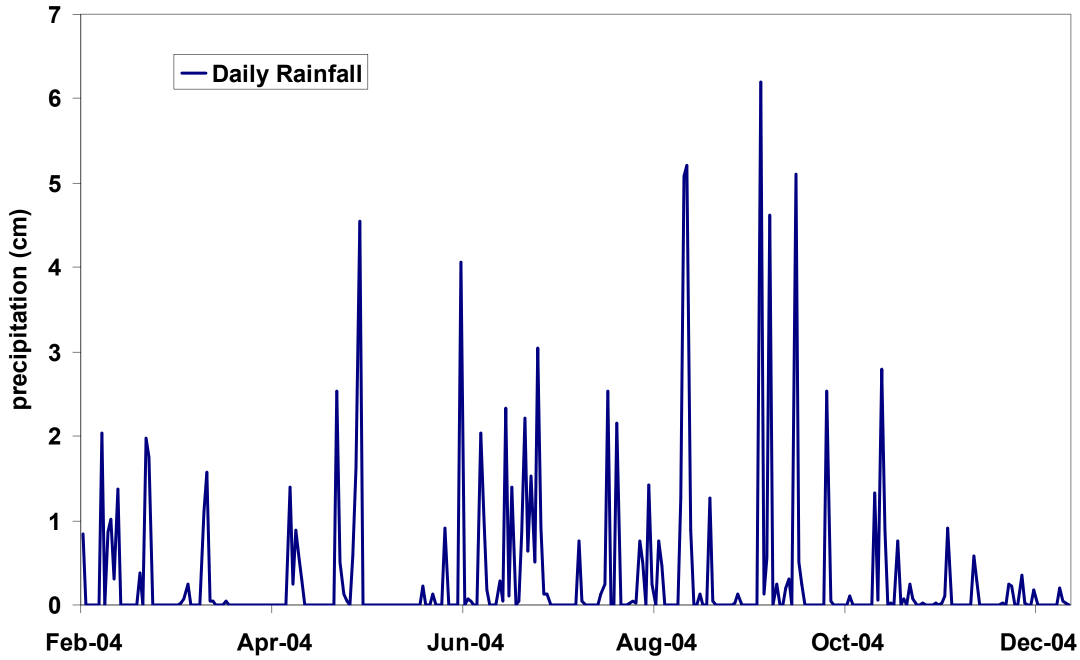

Figure A.3 Measured daily rainfall at the Cool Springs site.

APPENDIX B

SOIL PROFILE DESCRIPTIONS FOR ALL PLOTS IN ALL EXPEPERIMENTAL SITES

RICHLANDS SITE

Foreston 1

A—0 to 10 cm; black (2.5Y 2/1); fine sand; granular breaking into single grain; loose; many fine roots and few medium roots; abrupt smooth boundary.

AE—10 to 18 cm; dark grayish brown (2.5Y 4/2); fine loamy sand; weak, coarse subangular blocky breaking into single grain; very friable; many fine roots and few medium roots; abrupt wavy boundary.

E/A—18 to 25 cm; pale olive (5Y6/4) fine sand; weak coarse subangular blocky that breaks into single grain; very friable; common fine and medium roots; clear, irregular boundary.

E—25 to 34 cm; yellow (5Y 8/6) fine sand, single grain; loose; few medium roots; clear wavy boundary.

BE—34 to 43 cm; yellow (2.5Y 7/6) fine loamy sand; weak coarse subangular blocky; very friable, few medium roots; gradual smooth boundary.

Bt1—43 to 56 cm; olive yellow (2.5Y 6/6) fine sandy loam; weak coarse subangular blocky structure, very friable; few fine roots; clear smooth boundary.

Bt2—56 to 69 cm; yellow (10YR 7/8) fine sandy loam; common (10%) light yellowish brown (2.5Y 6/3) depletions and common (5%) strong brown (7.5YR 5/8) iron concentrations surrounding root channels; weak coarse subangular blocky structure; friable; few medium roots; clear smooth boundary.

Bt3—69 to 79 cm; olive yellow (2.5Y6/8) fine sandy loam; common (15%) light yellowish brown (2.5Y 6/3) and common (3%) light gray (2.5Y 7/2) depletions and common (7%) strong brown (7.5YR 5/8) iron concentrations surrounding root channels; weak coarse subangular blocky structure, very friable; few fine and medium roots; clear smooth boundary.

Bt4—79 to 94 cm; brownish yellow (10YR 6/6) fine sandy loam; many (20%) light gray (2.5Y 7/2) and common (10%) light yellowish brown (2.5Y 6/3) depletions within the matrix and surrounding few (2%) reddish yellow (5YR 6/8) iron concentrations; weak coarse subangular blocky structure; very friable; few medium roots; gradual smooth boundary.

BC—94 to 102 cm; very pale brown (10YR 7/4) fine sandy loam with lenses of loamy sand, many (30%) white (2.5Y 8/1) clean washed sand grains within the matrix and surrounding, common (15%) strong brown (7.5YR5/8) around root channels and common (5%) light yellowish brown (10YR 6/4) depletions within matrix; weak coarse subangular blocky structure; very friable; few fine roots.

Wet Foreston 1

A1—0 to 5cm; black (2.5Y 2.5/1) fine sand; granular breaking into single grain; loose; many fine roots and few medium roots; abrupt smooth boundary.

A2—5 to 11cm; very dark gray (2.5Y 3/1) fine sand; granular breaking into single grain; loose; many fine roots and few medium roots; clear smooth boundary.

AE—11 to 21cm; olive brown (2.5Y 4/3) fine loamy sand; weak coarse subangular blocky breaking into single grain; very friable; many fine roots and few medium roots; abrupt wavy boundary.

EA—21 to 28cm; yellow (5Y 7/6) fine sand; weak coarse subangular blocky that breaks into single grain; very friable; common fine and medium roots; clear, irregular boundary.

BE—28 to 37cm; yellow (2.5Y 7/6) fine loamy sand; weak coarse subangular blocky; very friable, few medium roots; gradual smooth boundary.

Bt1—37 to 46cm; olive yellow (2.5Y 6/6) fine sandy loam; weak coarse subangular blocky structure, very friable; few fine roots; clear smooth boundary.

Bt2—46 to 58cm;olive yellow (2.5Y 6/6) fine sandy loam; common (5%) light yellowish brown (2.5Y 6/3) depletions and common (3%) strong brown (7.5YR 5/8) iron concentrations surrounding root channels; weak coarse subangular blocky structure; friable; few medium roots; clear smooth boundary.

Bt3—58 to 69cm; yellow (2.5Y 6/6) fine sandy loam; common (10%) light yellowish brown (2.5Y 6/3) and common (10%) light gray (2.5Y 7/2) depletions and common (12%) strong brown (7.5YR 5/8) iron concentrations surrounding root channels; weak coarse subangular blocky structure, very friable; few fine and medium roots; clear smooth boundary.

Bt4—69 to-81cm; very pale brown (10YR 7/4) fine sandy loam with lenses of loamy sand; many (20%) white (2.5Y 8/1) clean washed sand grains within the matrix and surrounding common (15%) brownish yellow (10YR 6/8) and common (2%) reddish yellow (5YR 6/8) around root channels and within matrix; weak coarse subangular blocky structure; very friable; few fine roots.

Stallings 1

Oi—0 to 2.5cm; undecomposed leaves and twigs.

A—2.5 to 10cm; very dark gray (2.5Y 3/1) fine sand; granular breaking into single grain; loose; many fine roots and few medium roots; clear smooth boundary.

AE—10 to 17cm; dark grayish brown (2.5Y 4/2) fine loamy sand; weak coarse subangular blocky breaking into single grain; very friable; many fine roots and many medium roots; abrupt wavy boundary.

EA—17 to 27cm; light olive brown (2.5Y 5/4) fine sand; weak coarse subangular blocky that breaks into single grain; very friable; common fine and medium roots; clear, irregular boundary.

E—27 to 32cm; yellow (2.5Y 7/6) fine sand; single grain; loose; few medium roots; clear wavy boundary.

Bt1—32 to 41cm; olive yellow (2.5Y 6/6) fine sandy loam; weak coarse subangular blocky structure, very friable; few fine roots; clear smooth boundary.

Bt2—41 to 56cm; yellow (2.5Y 7/6) fine sandy loam; common (12%) pale yellow (2.5Y 7/3) depletions and common (5%) light gray (2.5Y 7/2) surrounding(7%) yellowish brown (10YR 5/8) iron concentrations around root channels; weak coarse subangular blocky structure; friable; few medium roots; clear smooth boundary.

Bt3—56 to 70cm; pale yellow (2.5Y 7/4) fine sandy loam; many (20%) light gray (2.5Y 7/2) and common (15%) pale yellow (2.5Y 7/3) depletions in the matrix and around root channels surrounding common (15%) reddish yellow (7.5YR 6/8) concentrations; weak coarse subangular blocky structure; friable; few medium roots; clear smooth boundary.

BC—70 to 79cm; pale yellow (2.5Y 7/4) loamy sand; many (40%) white (10YR 8/1) clean washed sand grains in the matrix, many (25%) yellowish brown (10YR 5/6) concentrations surrounding common (2%) reddish yellow (7.5YR 5/8) concentrations, and common (10%) light gray (2.5Y 7/2) depletions around root channels; weak coarse subangular blocky structure; friable; few medium roots; 2% rounded white gravel.

Foreston 2

Oi—0 to 2.5cm; undecomposed leaves and twigs.

A—2.5 to 10cm; very dark gray (10YR 3/1) fine sand; granular breaking into single grain; loose; many fine roots and few medium roots; clear smooth boundary.

AE—10 to 19cm; brown (10YR 4/3) fine loamy sand; weak, coarse subangular blocky breaking into single grain; very friable; many fine roots and few medium roots; clear wavy boundary.

EA—19 to 28cm; light yellowish brown (2.5Y 6/4) fine sand; weak coarse subangular blocky that breaks into single grain; very friable; common fine and medium roots; clear, irregular boundary.

E—28 to 37cm; olive yellow (2.5Y 6/6) fine sand, single grain; loose; few medium roots; clear wavy boundary.

BE—37 to 53cm; brownish yellow (10YR 6/6) fine loamy sand; weak coarse subangular blocky; very friable, few medium roots; gradual smooth boundary.

Bt1—53 to 71cm; yellow (10YR 7/6) fine sandy loam; common (10%) pale yellow (2.5Y 7/3) depletions and common (5%) yellowish brown (10YR 5/8) iron concentrations surrounding root channels; weak coarse subangular blocky structure; friable; few medium roots; clear smooth boundary.

Bt2—71 to 81cm; yellow (2.5Y 7/6) fine sandy loam; many (20%) pale yellow (2.5Y 7/3) and common (5%) pale yellow (2.5Y 8/2) depletions and common (15%) yellowish brown (10YR 5/8) iron concentrations surrounding root channels; weak coarse subangular blocky structure; friable; few medium roots; clear smooth boundary.

Bt3—81 to 94+cm; pale yellow (2.5Y 7/4) fine sandy loam with a decrease in clay content from above horizon; common (17%) pale yellow (2.5Y 8/2) depletions surrounded in a halo fashion by common (10%) pale olive (10YR 6/4) depletions; and many (20%) yellowish brown (10YR 5/8) iron concentrations surrounding root channels; weak coarse subangular blocky structure; very friable; few medium roots.

Wet Foreston 2

Oi—0 to3 cm; undecomposed leaves and twigs.

A1—3 to 10cm; black (2.5Y 2.5/1) fine sand; granular breaking into single grain; loose; many fine roots and few medium roots; clear smooth boundary.
A2—10 to 20cm; very dark gray (2.5Y 3/1) fine sand; granular breaking into single grain; loose; many fine and medium roots; clear smooth boundary.

EA—20 to 33cm; olive brown (2.5Y 4/3) fine loamy sand; weak coarse subangular blocky breaking into single grain; very friable; many fine roots and few medium roots; abrupt wavy boundary.

BE—33 to 48cm; light olive brown (2.5Y 5/4) fine loamy sand; weak coarse subangular blocky; very friable, few medium roots; gradual smooth boundary.

Bt1—48 to 61cm; light olive brown (2.5Y 5/6) fine sandy loam; common (10%) light yellowish brown (2.5Y 6/3) and few (1%) gray (2.5Y 7/2) depletions and common (5%) yellowish brown (10YR 5/8) iron concentrations surrounding root channels; weak coarse subangular blocky structure; friable; few medium roots; clear smooth boundary.

Bt2—61 to 76cm; olive yellow (2.5Y 6/6) fine sandy loam; common (15%) light yellowish brown (2.5Y 6/3) and common (12%) light gray (2.5Y 7/2) depletions and common (15%) brownish yellow (10YR 6/8) iron concentrations surrounding root channels; weak coarse subangular blocky structure, very friable; few fine and medium roots; clear gradual boundary.

Bt3—76 to 102cm; yellow (2.5Y 7/6) fine sandy loam; many (22%) light gray (2.5Y 7/2) and many (20%) light yellowish brown (2.5Y 6/3) depletions within the matrix and surrounding, many (20%) strong brown (7.5YR 5/8) and few (1%) yellowish red (5YR 5/8) around root channels and; weak coarse subangular blocky structure; very friable; few fine roots; few 2cm wide, 4.5 cm long diameter white, smooth, ovular pebbles.

Stallings 2

Oi—0 to 2cm; undecomposed leaves and twigs.

A1—2 to 10cm; very dark gray (2.5Y 3/1) fine sand; granular breaking into single grain; loose; many fine roots and few medium roots; clear smooth boundary.

A2—10 to 20cm; dark grayish brown (2.5Y 4/2) fine loamy sand; weak coarse subangular blocky breaking into single grain; very friable; many fine roots and many medium roots; abrupt wavy boundary.

AE—20 to 28cm; light olive brown (2.5Y 5/3) fine loamy sand; weak coarse subangular blocky breaking into single grain; very friable; many fine roots and many medium roots; clear wavy boundary.

BE—28 to 41cm; light yellowish brown (2.5Y 6/4) fine loamy sand; weak coarse subangular blocky; very friable, few medium roots; gradual smooth boundary.
Bt1—41 to 50cm; light yellowish brown (2.5Y 6/4) fine sandy loam; few (1%) yellowish red (5YR 5/8) iron concentrations around root channels; weak coarse subangular blocky structure, very friable; few fine roots; clear smooth boundary.

Bt2—50 to 61cm; yellow (2.5Y 7/6) fine sandy loam; few (3%) light gray (10YR 7/1) depletions around root channels; weak coarse subangular blocky structure, very friable; few fine roots; clear smooth boundary.

BC—61 to 86cm; olive yellow (2.5Y 6/6) loamy fine sand; many (35%) white (5Y 8/1) clean washed sand grains within the matrix and around root channels; common (10%) brownish yellow (10YR 6/8) surrounding common (5%) yellowish red (5YR 5/8) concentrations in a halo fashion with matrix and around root channels; weak coarse subangular blocky structure; very friable; few medium roots; gradual smooth boundary.

C—86 to 97cm; light brown (7.5YR 6/4) and yellowish brown (10YR 5/8) sand and lenses of loamy sand; many (20%) white (5Y 8/1) clean washed sand grains within matrix; massive; firm.

Possible 2 in front of C

Foreston 3

Oi—0 to 5cm; undecomposed leaves and twigs.

A1—5 to 14cm; very dark gray (10YR 3/1) fine sand; weak medium granular breaking into single grain; loose; many fine roots and few medium roots; clear smooth boundary.

A2—14 to 22cm; very dark grayish brown (2.5Y 3/2) fine sand; granular breaking into single grain; loose; many fine roots and few medium roots; clear smooth boundary.

EA—22 to 30cm; light olive brown (2.5Y 5/3) fine loamy sand; weak, coarse subangular blocky breaking into single grain; very friable; many fine roots and few medium roots; clear wavy boundary.

BE—30 to 43cm; light olive brown (2.5Y 5/6) fine loamy sand; few (1%) reddish yellow (7.5YR 6/8) concentrations in root channels; weak coarse subangular blocky; very friable, few medium roots; gradual smooth boundary.

Bt1—43 to 56cm; brownish yellow (10YR 6/6) fine sandy loam; common (10%) yellowish brown (10YR 5/8) surrounding common (5%) yellowish brown yellowish red (5YR 5/6) iron concentrations surrounding root channels, few (1%) light gray (10YR 7/2) depletions in root channels; weak coarse subangular blocky structure; friable; few medium roots; clear smooth boundary.

Bt2—56 to 79cm; olive yellow (2.5Y 6/6) fine loamy sand; many (20%) light brownish gray (2.5Y 6/2) depletions and common (12%) yellowish brown (10YR 5/8) and (7%) yellowish brown yellowish red (5YR 5/6) iron concentrations surrounding root channels; weak coarse subangular blocky structure; very friable; few medium roots; clear gradual boundary.

BC—79 to 127cm; light brownish gray (2.5Y 6/2) and olive yellow (2.5Y 6/6)
(15%) loamy sand with yellowish brown (10YR 5/8) and (12%) yellowish red (5YR 5/6) iron concentrations surrounding root channels; weak coarse subangular blocky structure; very friable; few medium roots; clear smooth boundary.

Wet Foreston 3

Oi—0 to 2cm; undecomposed leaves and twigs

A1—2 to 10cm; very dark gray (2.5Y 3/1) fine sand; weak medium granular breaking into single grain; loose; many fine roots and few medium roots; clear smooth boundary.

A2—10 to 15cm; very dark grayish brown (2.5Y 3/2) fine sand; weak medium granular breaking into single grain; loose; many fine and medium roots; clear smooth boundary.
EA—15 to 23cm; olive brown (2.5Y 4/4) fine loamy sand; weak coarse subangular blocky breaking into single grain; very friable; many fine roots and few medium roots; abrupt wavy boundary.

BE—23 to 33cm; light olive brown (2.5Y 5/6) fine loamy sand; weak coarse subangular blocky; very friable, few medium roots; gradual smooth boundary.

Bt1—33 to 43cm; light olive brown (2.5Y 6/6) fine sandy loam; weak coarse subangular blocky structure; friable; few medium roots; clear smooth boundary.

Bt2—43 to 59cm; light olive brown (2.5YR 6/6) fine sandy loam common faint (5%) light yellowish brown (10YR 5/4) depletions within the matrix and surrounding, common (5%) yellowish brown (10YR 5/8) and few (1%) strong brown (7.5YR 5/8) around root channels and; weak coarse subangular blocky structure; very friable; few medium roots, clear smooth boundary.

Bt3—59 to 80cm; brownish yellow (10YR 6/6) fine sandy loam; with common (10%) strong brown (7.5YR 5/8) concentrations surrounding common (10%) light yellowish brown (2.5Y 6/3) and common (5%) light brownish gray (2.5Y 6/2); weak coarse subangular blocky structure; very friable; few medium roots; gradual smooth boundary.

Bt4—80 to 98cm; light olive brown (2.5Y 6/6) fine sandy loam; many (20%) yellowish brown (10YR 5/8) concentrations surrounding common (10%) light gray (2.5Y 7/2) and common (10%) light olive brown (2.5Y 5/4); weak coarse subangular blocky structure; very friable; few fine roots; gradual smooth boundary.
BC—98 to 117cm; olive (5Y 5/4) fine loamy sand; many (20%) gray (2.5Y 6/2) depletions surrounded by common (12%) brownish yellow (10YR 6/8) concentrations in root channels and within the matrix, weak coarse subangular blocky structure; very friable; few fine roots.

Stallings 3

Oi—0 to 5cm; undecomposed leaves and twigs.

A1—5 to 13cm; very dark gray (2.5Y 3/1) fine sand; granular breaking into single grain; loose; many fine roots and few medium roots; clear smooth boundary.

A2—13 to 18cm; dark grayish brown (2.5Y 4/2) fine loamy sand; weak coarse subangular blocky breaking into single grain; very friable; many fine roots and many medium roots; abrupt wavy boundary.

E/A—18 to 27cm; dark grayish brown (2.5Y 4/2) and light yellowish brown (2.5Y 6/4) fine loamy sand; weak coarse subangular blocky breaking into single grain; very friable; many fine roots and many medium roots; clear wavy boundary.

BE—27 to 40cm; light yellowish brown (2.5Y 6/4) fine loamy sand; weak coarse subangular blocky; very friable, few medium roots; gradual smooth boundary.

Bt1—40 to 57cm; light yellowish brown (2.5Y 6/4) fine sandy loam, with common (15%) light brownish gray (2.5Y 6/2) depletions surrounded by few (2%) yellowish brown (10YR 5/8) concentrations in root channels and pores in the matrix; weak coarse subangular blocky structure,; very friable; few medium roots; gradually smooth boundary.

Bt2—57 to 77cm; pale yellow (2.5.Y 7/3) loamy fine sand; with many (35%) clean washed white (10YR 8/1) sand grains, and common (5%) yellowish brown (10YR 5/8); weak coarse subangular blocky structure; very friable; few medium roots; gradually smooth boundary.

BC—77 to 104cm; light yellowish brown (10YR 6/4) fine sandy loam; with many (20%) light gray (7.5YR 7/1) and many (25%) light gray (10YR 7/2) depletions surrounding common (5%) brownish yellow (10YR 6/8) and few (1%) strong brown (7.5YR 5/6) concentrations; weak coarse subangular blocky structure; friable; few fine roots.

Bt2 could be an E, and BC could be B't, or differing strata

VANCEBORO SITE

Craven 1

Ap-- 0-10 cm; grayish brown (2.5Y 5/2) loam; weak medium granular structure; very friable; common fine and medium roots; clear smooth boundary.

AE—10-24 cm; light brownish gray (2.5Y 6/2) silt loam; few (2%) distinct yellowish brown (10YR 5/6) concentrations around root channels, weak subangular blocky structure parting to weak granular; very friable; few fine and medium roots; clear wavy boundary

Bt1—24-37 cm; brownish yellow (10YR 6/6) clay; strong fine and medium angular blocky structure; firm; slightly sticky, slightly plastic; thin discontinuous clay films on ped faces; common medium roots; clear smooth boundary.

Bt2—37-47 cm; brownish yellow (10YR 6/6) clay; common (7%) fine distinct reddish yellow (7.5YR 6/8) concentrations strong medium angular blocky structure; firm; sticky, plastic; very apparent clay films on ped faces(10YR 6/3); common medium roots; clear smooth boundary.

Bt3—47-69cm; brownish yellow (10YR 6/6) clay; common (10%) medium reddish yellow (7.5YR 6/8) diffuse concentrations surrounding few (2%) fine red (2.5YR 5/6) concentrations; few (2%) fine light brownish gray (10YR 6/2) depletions around root channels, strong medium subangular blocky structure; very firm, sticky, plastic; thin continuous clay films on ped faces; few .5cm diameter roots; clear wavy boundary.

Bt4—69-91 cm; light brownish yellow (10YR 6/8) clay loam; many (20%) medium distinct light gray (10YR 7/1) within peds, common (15%) medium distinct reddish yellow (7.5YR 6/8), and common (5%) fine distinct red (2.5YR 5/6) concentrations as masses; moderate coarse angular blocky structure; firm, sticky, plastic; thin continuous clay films on faces of peds; few 10cm diameter roots; gradual wavy boundary.

Bt5—91-102+cm; olive yellow (2.5Y 6/6) clay loam; many (35%) white (N/8) depletions within peds, common (7%) light gray (10YR 7/1) ped coats, and common (5%) medium distinct reddish yellow (7.5YR 6/8), moderate coarse subangular blocky structure; friable, sticky; thin-continuous clay films on ped faces.

Lenoir 1

Ap—0-10 cm; grayish brown (10YR 5/2) loam; weak medium granular structure; very friable; many fine and common medium roots; clear smooth boundary.

AE—10-25 cm; brown (10YR 5/3) sandy loam; common (5%) fine, dendritic yellowish brown (10YR 5/6) concentrations in root channels; weak coarse subangular blocky that parts to medium granular structure; very friable; common fine roots; abrupt wavy boundary.

BE—25-36 cm; light yellowish brown (10YR 6/4) sandy loam; common (7%) yellowish brown (10YR 5/6) concentrations in root channels; weak medium subangular blocky structure, few pockets of remnant E horizon; friable; few medium roots; clear broken boundary.

Bt1—36-51 cm; light olive brown (2.5Y 6/6) clay loam; common (12%) medium yellowish brown (10YR 5/8) masses, and common (5%) medium distinct very pale brown (10YR 7/3) coatings on ped faces; strong to moderate medium subangular blocky structure; friable, slightly plastic, sticky; few medium roots; common faint clay films ped faces; clear smooth boundary.

Bt2—51-70 cm; light yellowish brown (2.5Y 6/4) clay; common (17%) medium yellowish brown (10YR 5/8) masses, surrounding common (5%) fine distinct red (2.5YR 5/6) sharp concentrations; common (7%) very pale brown (10YR 7/3) coatings on ped faces; and common (10%) light gray (10YR 7/2) depletions around root channels moderate medium angular blocky structure; firm, plastic, sticky; few medium roots; common faint clay films ped faces; clear smooth boundary.

Bt3—70-84 cm; very pale brown (10YR 7/3) clay loam, many (25%) medium light gray (2.5Y 7/2) depletions within peds; common (20%) medium, distinct reddish yellow (7.5YR 5/8) diffuse concentrations within peds; and common (10%) distinct red (2.5YR 5/6) sharp concentrations within peds; moderate medium angular blocky structure; firm; plastic; slightly sticky; few fine roots; common clay films on ped faces; gradual wavy boundary.

Btg—84-98 cm; white (N/8) and light gray (N/7) sandy clay loam; many (30%) medium reddish yellow (7.5YR 6/8) clear to diffuse concentrations around common (15%) fine distinct red (2.5YR 5/6) masses within peds and around root channels; common (5%) very pale brown (10YR 7/3) depletions as ped coats; weak coarse subangular blocky structure; friable; common clay films on ped faces.

Craven 2

Ap-- 0-16 cm; grayish brown (2.5Y 5/2) loam; weak medium granular structure; very friable; common fine and medium roots; clear smooth boundary.

E—16-25 cm; pale yellow (2.5Y 7/3) sandy loam; common (10%) olive yellow (2.5Y 6/6) concentrations around root linings; few (1%) distinct light gray (2.5Y 7/1) halo depletions around concentrations; weak subangular blocky structure parting to weak granular; very friable; few fine and medium roots; clear wavy boundary

Bt1—25-40 cm; olive yellow (2.5Y 6/6) clay; common (5%) yellowish red (5YR 5/8) concentrations; few (2%) light olive brown (2.5Y 5/3) depletions around concentrations; moderate medium subangular blocky structure; firm sticky, plastic; thin continuous clay films on ped faces; common medium roots; clear smooth boundary.

Bt2—40-55 cm; brownish yellow (10YR 6/6) clay; common (5%) distinct yellowish red (5YR 5/8) concentrations; strong medium angular blocky structure; firm; sticky, plastic; thin continuous clay films on ped faces; common medium roots; clear smooth boundary.

Bt3—55-67; yellowish brown (10YR 5/6) sandy clay loam; common (10%) distinct yellowish red (5YR 5/8) concentrations; common (7%) medium light yellowish brown (10YR 6/4) depletions around root channels and within peds, surrounding common (7%) light gray (10YR 7/2) depletions surrounding concentrations, weak medium subangular.

Lenoir 2

Ap—0-16 cm; grayish brown (10YR 5/2) loam; weak medium granular structure; very friable; many fine and common medium roots; clear smooth boundary.

E—16-28 cm; pale yellow (2.5Y 7/3) sandy loam; common (20%) fine, dendritic yellowish brown (10YR 5/6) concentrations in root channels; weak coarse subangular blocky that parts to medium granular structure; very friable; common fine roots; clear wavy boundary.

Bt1—28-44 cm; light yellowish brown (10YR 6/4) clay loam; common (12%) strong brown (7.5YR 5/6) concentrations in peds; strong medium subangular blocky structure; friable; sticky, plastic; few medium roots; common clay films on ped faces; few clay film and soil filled worm casts; clear wavy boundary.

Bt2—44-58 cm; light yellowish brown (10YR 6/4) clay; common (17%) medium strong brown (7.5YR 5/8) masses, and common (3%) fine distinct red (2.5YR 5/6) concentrations within peds and around root channels; few (2%) medium light gray (5Y 7/1); strong medium subangular blocky structure; firm, plastic, sticky; few medium roots; common pale yellow (2.5Y 7/3) clay films ped faces; clear smooth boundary.

Bt3—58-76 cm; pale yellow (2.5Y 7/3) clay; common (15%) medium brownish yellow (10YR 6/8) masses, surrounding common (10%) fine distinct red (2.5YR 5/6) sharp concentrations; common (4%) very pale brown (10YR 7/3) coatings on ped faces; and common (20%) light gray (N/7) depletions around root channels; moderate medium angular blocky structure; firm, plastic, sticky; few medium roots; common faint clay films ped faces; clear smooth boundary.

Btg—76-91 cm; light gray (10YR 7/1) clay loam, many (25%) medium brownish yellow (10YR 6/8) masses; common (10%) fine distinct red (2.5YR 5/6) sharp concentrations; moderate medium angular blocky structure; firm, plastic, sticky; few medium roots; common faint clay films ped faces; clear smooth boundary.

BCg—91-112cm; light gray (10YR 7/1) clay loam; common (10%) coarse brownish yellow (10YR 6/8) masses diffuse concentrations around common (5%) fine distinct red (2.5YR 5/6) masses within peds; common (5%) very pale brown (10YR 7/3) coatings on ped faces; weak coarse subangular blocky structure; friable; common clay films on ped faces.

Craven 3

Ap1-- 0-11 cm; dark grayish brown (2.5Y 4/2) loam; weak medium angular blocky parting to granular structure; very friable; common fine and medium roots; clear smooth boundary.

Ap2—11-20 cm; light olive brown (2.5Y 5/3) sandy loam; few (1%) olive yellow (2.5Y 6/6) concentrations around root linings; weak to moderate subangular blocky, showing evidence of compaction; firm; few fine and medium roots; abrupt wavy boundary

Bt1—20-30 cm; light yellowish brown (2.5Y 6/4) clay loam; common (5%) light gray (2.5Y 7/2) parts of remnant E horizon down root cracks; weak medium subangular blocky structure; friable; slightly sticky, plastic; thin discontinuous clay films on ped faces; common medium roots; clear smooth boundary.

Bt2—30-43 cm; olive yellow (2.5Y 6/6) clay; common (10%) fine distinct strong brown (7.5YR 5/8) concentrations; strong medium subangular blocky structure; firm; sticky, plastic; thin continuous light yellowish brown (2.5Y 6/4) clay films on ped faces; common medium roots; clear smooth boundary.

Bt3—43-53 cm; light yellowish brown (2.5Y 6/4) clay loam; common (10%) fine distinct strong brown (7.5YR 5/8) concentrations; common (7%) medium pale yellow (2.5Y 7/3) and few (1%) light gray (2.5Y 7/1) depletions around root channels and within peds; moderate medium subangular blocky structure; friable, sticky, slightly plastic; thin continuous clay films on ped faces and root linings and grains apparent; few fine roots; clear smooth boundary.

Bt4—53-67 cm; light yellowish brown (2.5Y 6/4) clay loam; common (15%) fine distinct strong brown (7.5YR 5/8) concentrations; common (10%) medium pale yellow (2.5Y 7/3) and common (20%) light gray (2.5Y 7/1) depletions around root channels and within peds; moderate medium subangular blocky structure; friable, sticky, slightly plastic; thin continuous clay films on ped faces and root linings; few fine roots; clear smooth boundary.

BCt1—67-80cm; strong brown (7.5YR 5/8) sandy clay loam; many coarse (30%) light gray (10YR 7/1) depletions within peds; many (23%) medium yellowish brown (2.5Y 6/4) depletions within peds; common (7%) fine red (2.5YR 5/6) concentrations around root holes and surrounding depletions; weak subangular blocky structure, friable, sticky, slightly plastic; thin continuous clay films on ped faces and root linings gradual wavy boundary.

BCt2—80-91cm; strong brown (7.5YR 5/8) sandy loam; common (20%) medium yellow (10YR 7/8); common medium (5%) pale yellow (5Y 8/2) clean washed sand grains within matrix; few (2%) fine red (2.5YR 5/6) iron coatings on ped faces and pore linings; weak subangular and blocky and coarse platy structure; some peds break evenly along horizontal fracture planes; common fine roots congregate along these fractures; friable, sticky; slightly plastic; thin continuous clay films on ped faces and root linings gradual wavy boundary.

BCt3 –91-112cm; yellow (10YR 7/8) sandy loam; common (20%) medium strong brown (7.5YR 5/8) concentrations within peds; common (5%) light gray (2.5Y 7/2) depletions around root channels; weak subangular blocky structure; firm with shovel, friable in hand; slightly sticky; slightly plastic thin discontinuous light yellowish brown (10YR 6/4) clay films on ped faces and root linings.

Lenoir 3

Ap1-- 0-18 cm; dark grayish brown (2.5Y 4/2) loam; weak medium angular blocky parting to granular structure; very friable; common fine and medium roots; clear smooth boundary.

Ap2—18-28 cm; light olive brown (2.5Y 5/3) sandy loam; common (5%) olive yellow (2.5Y 6/6) concentrations around root linings; weak to moderate subangular blocky, showing evidence of compaction; firm; few fine and medium roots; abrupt wavy boundary.

E—28-33 cm; pale yellow (2.5Y 7/3) sandy loam; common (20%) fine, dendritic yellowish brown (10YR 5/6) concentrations in root channels; weak coarse subangular blocky that parts to medium granular structure; very friable; common fine roots; clear wavy boundary.

BE—33-48 cm; light yellowish brown (10YR 6/4) sandy loam; common (7%) yellowish brown (10YR 5/6) concentrations in root channels, common (12%) pale yellow (2.5Y 7/3) depletions; weak medium subangular blocky structure, friable; few medium roots; clear wavy boundary.

Bt1—48-56 cm; light olive brown (2.5Y 6/6) clay loam; common (12%) medium yellowish brown (10YR 5/8) masses, few (2%) medium light gray (5Y 7/1) depletions, and common (5%) medium distinct very pale brown (10YR 7/3) coatings on ped faces; strong to moderate medium subangular blocky structure; friable, slightly plastic, sticky; few medium roots; common faint clay films ped faces; clear smooth boundary.

Bt2—56-69 cm; light yellowish brown (2.5Y 6/4) clay; common (15%) medium yellowish brown (10YR 5/8) masses, surrounding common (5%) fine distinct red (2.5YR 5/6) sharp concentrations; common (5%) very pale brown (10YR 7/3) coatings on ped faces; and common (10%) light gray (10YR 7/2) depletions around root channels moderate medium angular blocky structure; firm, plastic, sticky; few medium roots; common faint clay films ped faces; clear smooth boundary.

Bt3—69-80 cm; very pale brown (10YR 7/3) clay loam, many (25%) medium light gray (2.5Y 7/2) depletions within peds; common (20%) medium, distinct reddish yellow (7.5YR 5/8) diffuse concentrations within peds; and common (10%) distinct red (2.5YR 5/6) sharp concentrations within peds; moderate medium angular blocky structure; firm; plastic; slightly sticky; few fine roots; common clay films on ped faces; gradual wavy boundary.

Btg1—80-91 cm; light gray (N/7) sandy clay loam; many (30%) medium reddish yellow (7.5YR 6/8) clear to diffuse concentrations around common (15%) fine distinct red (2.5YR 5/6) masses within peds and around root channels; common (5%) very pale brown (10YR 7/3) depletions as ped coats; weak coarse subangular blocky structure; friable; common clay films on ped faces.

Btg2—91-107cm; light gray (10YR 7/1) clay loam; common (10%) coarse brownish yellow (10YR 6/8) masses diffuse concentrations around common (5%) fine distinct red (2.5YR 5/6) masses within peds; common (5%) very pale brown (10YR 7/3) coatings on ped faces; weak coarse subangular blocky structure; friable; common clay films on ped faces.

COOL SPRINGS SITE

Tarboro

Oi – 0 to 5 cm; partially decomposed organic matter; clear smooth boundary.

A – 5 to 13 cm; very dark gray brown (2.5Y 3/2) sand, single grain; loose; many medium and common fine roots; 50% organic coated organic; gradual wavy boundary.

Bw1 – 13 to 25 cm; olive brown (2.5Y 4/4) sand; weak fine subangular and moderate medium granular structure; very friable; slightly brittle in places; 10% clean washed sand grains; many fine roots; gradual wavy boundary.

Bw2 – 25 to 48 cm; light olive brown (2.5Y 5/6) sand; weak fine subangular blocky structure; many fine and common medium roots; few (2%) fine faint olive yellow (10YR 6/6) concentrations; 10% clean washed sand grains; gradual wavy boundary.

BC– 48 to 71 cm; yellow (2.5Y 7/6) sand; weak fine and medium subangular blocky structure; very friable; loose in places; common fine roots; 12% clean washed sand grains; gradual smooth boundary.

C1 – 71 to 99 cm; pale yellow (2.5Y 7/4) sand; common (2%) strong brown (7.5YR 5/6) around common (5%) pale yellow (2.5Y 8/2) clean washed sand grains around root channels; single grain; loose; common medium roots; common (10%) pale yellow (2.5Y 8/2) clean washed sand grains, gradual wavy boundary.

C2 – 99 to 127 cm; yellow (10YR 7/6) sand; common (15%) medium strong brown (7.5YR 5/6) diffuse pore linings; single grain; loose; common medium and coarse roots; common (10%) pale yellow (2.5Y 8/2) clean washed sand grains; gradual wavy boundary.

C3– 127 to 140 cm; yellow brown (10YR 5/6) sand; many (30%) coarse strong brown (7.5YR 5/6) splotches within matrix; surrounding and intermingled with common (10%) brown (10YR 4/3) decayed organic bodies; and common (10%) coarse pale yellow (2.5Y 7/4) depletions; single grain; loose; common medium roots; common (10%) pale yellow (2.5Y 8/2) clean washed sand grains.

Wet Tarboro 1

A – 0 to 8 cm; dark gray (2.5Y 4/1) sand, single grain; loose; many coarse and medium and common fine roots; 50% organic coated organic; gradual wavy boundary.

AB – 8 to 20 cm; light olive brown (2.5Y 5/3) sand; single grain; loose; 10% clean washed sand grains; many fine roots; gradual wavy boundary.

Bw – 20 to 38 cm; light olive brown (2.5Y 5/6); weak fine subangular blocky structure; very friable; loose in places; many fine and common medium roots; 10% clean washed sand grains; gradual wavy boundary.

BC– 38 to 50 cm; olive yellow (2.5Y 6/6) sand; massive; very friable; loose in places; common fine roots; 5% clean washed sand grains; gradual smooth boundary.

C1 – 50 to 69 cm; yellow (10YR 7/6) sand; few (1%) strong brown (7.5YR 5/6) fine diffuse masses in matrix and around root linings; single grain; loose; common medium roots; common (3%) pale yellow (2.5Y 8/2) clean washed sand grains, gradual wavy boundary.

C2 – 69 to 97 cm; pale yellow (2.5Y 7/4) sand; common (5%) medium faint strong brown (7.5YR 4/6) clear and common (10%) distinct reddish yellow (7.5YR 7/6) clear pore linings indiscriminately intermingled with common (10%) brown (10YR 4/3) decayed organic bodies; single grain; loose; common medium and coarse roots; common (15%) pale yellow (2.5Y 8/2) clean washed sand grains; gradual wavy boundary.

C3– 97 to 116 cm; olive yellow (2.5Y 6/6) sand; common (15%) medium pale yellow (5Y 7/3) depletions within matrix; adjacent to common (10%) coarse strong brown (7.5YR 5/6) coarse diffuse concentrations as splotches around common (5%) brown (10YR 4/3) decayed organic bodies; single grain; loose; common medium roots; common (10%) pale yellow (2.5Y 8/2) washed sand grains.

C4—116 to 125 cm; olive yellow (2.5Y 6/6) sand; common (5%) medium pale yellow (5Y 7/3) and common (5%) light gray (2.5Y 7/1) medium depletions within matrix and around root channels; adjacent to common (10%) coarse strong brown (7.5YR 5/6) coarse diffuse concentrations as splotches around common (5%) brown (10YR 4/3) decayed organic bodies; single grain; loose; common medium roots; common (5%) pale yellow (2.5Y 8/2) washed sand grains.

Seabrook 1

A – 0 to 10 cm; dark gray (2.5Y 4/1) sand, single grain; loose; many coarse and medium and common fine roots; 50% organic coated organic; gradual wavy boundary.

E – 10 to 23 cm; light brownish gray (2.5Y 6/2) sand; single grain; loose; 10% clean washed sand grains; many fine roots; gradual wavy boundary.

Bs – 23 to 39 cm; light olive brown (2.5Y 5/6) sand; weak fine subangular blocky structure; very friable; loose in places; common weakly cemented bands and nodules of olive brown (2.5Y 4/4) sand; many fine and common medium roots; 10% clean washed sand grains; gradual wavy boundary.

BC– 39 to 58 cm; light yellowish brown (10YR 6/4) sand; many (35%) light olive brown (2.5Y 5/4) fine and medium organic streaks from above horizon; weak fine subangular blocky structure; very friable; loose in places; common fine roots; 5% clean washed sand grains; gradual smooth boundary.

C1 – 58 to 81 cm; yellow (2.5Y 7/6) sand; common (3%) medium pale yellow (2.5Y 8/2) coarse diffuse depletions in matrix and intermingled with common (20%) faint brown (10YR 4/3) decayed organic bodies and around root linings; single grain; loose; common medium roots; common (5%) white (2.5Y 8/1) clean washed sand grains, gradual wavy boundary.

C2 – 81 to 102 cm; pale yellow (2.5Y 7/4) sand; common (15%) medium clear reddish yellow (7.5YR 6/8) and common (5%) distinct reddish brown (2.5YR 4/4) clear and diffuse splotchy masses within the matrix and in pore linings indiscriminately intermingled with common (10%) brown (10YR 4/3) decayed organic bodies; few (2%) pale yellow (2.5Y 8/3) depletions surrounding root holes; single grain; loose; common medium roots; common (5%) white (2.5Y 8/2) washed sand grains.

Wet Tarboro 2

A – 0 to 5 cm; dark gray (10YR 4/1) sand, single grain; loose; many medium and common fine roots; 50% organic coated organic; gradual wavy boundary.

AB – 5 to 13cm; yellowish brown (10YR 5/4) sand; single grain; loose; common medium, and coarse roots; 30% clean washed sand grains; gradual smooth boundary.

Bw – 13 to 24 cm; olive yellow (2.5Y 6/6) and light olive brown (2.5Y 5/4); common (3%) fine yellowish brown (10YR 5/6) faint concentrations within matrix; weak fine subangular blocky structure; loose in places; common medium roots; gradual wavy boundary.

C1– 24 to 38 cm; olive yellow (2.5Y 6/8) sand; few (1%) fine yellowish brown (10YR 5/8) medium diffuse concentrations within the matrix around few (10%) light olive brown (2.5Y 5/4) faint medium organic bodies; single grain; loose; common fine roots; 2% clean washed sand grains; gradual smooth boundary.

C2 – 38 to 61 cm; olive yellow (2.5Y 6/6) sand; common (2%) fine yellowish brown (10YR 5/8) and few (1%) yellowish red (5YR 5/8) pore linings and clear irregular masses surrounding and intermingled with common (3%) brown (10YR 4/3) decayed organic bodies; single grain; loose; common medium roots; common (5%) pale yellow (2.5Y 8/2) clean washed sand grains.

C3 – 61 to 79 cm; yellow (2.5Y 7/6) sand; common (3%) fine reddish yellow (5YR 5/6) pore linings and clear irregular masses surrounding and intermingled with common (15%) brown (10YR 4/3) decayed organic bodies; single grain; loose; common medium and coarse roots; common (10%) pale yellow (2.5Y 8/2) clean washed sand grains.

C4 – 79 to 102 cm; olive yellow (2.5Y 6/6) sand; common (10%) coarse brownish yellow (10YR 6/8) pore linings and clear irregular masses within matrix surrounding and intermingled with many (20%) brown (10YR 4/3) decayed organic bodies; common (15%) light gray (10YR 7/2) clean washed sand grains; loose; common medium roots.

2C5 – 102 to 122 cm; brownish yellow (10YR 6/8) coarse sand; common (20%) coarse pale yellow (2.5Y 8/3) diffuse depletions within the matrix surrounding common (5%) yellowish red (5YR 5/8) concentrations around active and decayed medium and fine roots.

Seabrook 2

A – 0 to 6 cm; very dark gray (2.5Y 3/1) sand, single grain; loose; many medium and common fine roots; 50% organic coated organic; gradual wavy boundary.

Bw – 6 to 17 cm; light olive brown (2.5Y 5/4) sand; weak fine subangular blocky structure; very friable; loose in places; common medium, and coarse roots; 10% clean washed sand grains; gradual smooth boundary.

BC – 17 to 28 cm; olive yellow (2.5Y 6/6) sand; common (20%) light olive brown (2.5Y 5/4) common fine weakly cemented bands and nodules of organic coated sand grains; few (1%) fine yellowish brown (10YR 5/8) faint concentrations within matrix; weak fine subangular blocky structure; loose in places; common medium roots; gradual wavy boundary.

C1– 28 to 48 cm; yellow (10YR 7/6) sand; few (2%) fine yellowish brown (10YR 5/8) medium diffuse concentrations within the matrix around few (2%) brown (10YR 4/3) faint medium organic bodies; single grain; loose; common fine roots; 2% clean washed sand grains; gradual smooth boundary.

C2 – 48 to 66 cm; yellow (2.5Y 7/6) sand; common (5%) fine yellowish brown (10YR 5/8) pore linings and clear irregular masses surrounding and intermingled with common (5%) brown (10YR 4/3) decayed organic bodies; single grain; loose; common medium roots; few (3%) pale yellow (2.5Y 8/2) clean washed sand grains.

C3 – 66 to 81 cm; olive yellow (2.5Y 6/6) sand; common (7%) fine reddish yellow (5YR 5/6) pore linings and clear irregular masses surrounding and intermingled with many (15%) brown (10YR 4/3) decayed organic bodies; single grain; loose; common medium roots; common (5%) pale yellow (2.5Y 8/2) clean washed sand grains.

C4 – 81 to 91 cm; yellow (10YR 7/6) sand; common (12%) fine reddish yellow (5YR 5/6) pore linings and clear irregular masses surrounding and intermingled with many (25%) brown (10YR 4/3) decayed organic bodies; common (10%) light gray (10YR 7/2) depletions around root channels single grain; loose; common medium roots.

APPENDIX C

SAMPLE OF DRAINMOD INPUTS FOR THE SOILS AT ALL OF THE EXPERIMENTAL SITES

C.1 DRAINMOD inputs for plot 2 Fo at the Richlands site

****

D R A I N M O D 5.1

LAST UPDATE: SEPT 1999
LANGUAGE FORTRAN 77/90

DRAINMOD WAS A FIELD-SCALE HYDROLOGIC MODEL DEVELOPED FOR THE DESIGN OF SUBSURFACE DRAINAGE SYSTEMS. THE MODEL WAS DEVELOPED BY RESEARCHERS AT THE DEPT. OF BIOLOGICAL AND AGRICULTURAL ENGINEERING, NORTH CAROLINA STATE UNIVERSITY UNDER THE DIRECTION OF R. W. SKAGGS.

****

DATA READ FROM INPUT FILE: C:\Drainmod\inputs\Foreston2Calibration.prj
Cream selector (0=no, 1=yes) = 0

TITLE OF RUN
****

Foreston 2

CLIMATE INPUTS
******* ******

```
DESCRIPTION                    (VARIABLE)     VALUE   UNIT
-----------------------------------------------------------------------------
FILE FOR RAINDATA ..............C:\DRAINMOD\WEATHER\RICHLAND.RAI
FILE FOR TEMPERATURE/PET DATA ..C:\DRAINMOD\WEATHER\RICHLONG.TEM
RAINFALL STATION NUMBER..........................(RAINID)       1
TEMPERATURE/PET STATION NUMBER...................(TEMPID)        1
STARTING YEAR OF SIMULATION..................(START YEAR)      1971   YEAR
STARTING MONTH OF SIMULATION................(START MONTH)        1   MONTH
ENDING YEAR OF SIMULATION......................(END YEAR)      2003   YEAR
ENDING MONTH OF SIMULATION....................(END MONTH)        12   MONTH
TEMPERATURE STATION LATITUDE...................(TEMP LAT)      34.16   DEG.MIN
HEAT INDEX..........................................(HID)      85.00
```

ET MULTIPLICATION FACTOR FOR EACH MONTH
2.52 3.30 2.39 1.69 1.31 .99 .90 .87 .94 1.20 1.45 2.01

DRAINAGE SYSTEM DESIGN
****

*** CONVENTIONAL DRAINAGE ***

JOB TITLE:

Foreston 2

```
                 STMAX =  .25 CM              SOIL SURFACE
+       __/)___________________________________________________/)__
                           :                        :
                           :                        :
                           :                        :
                           :                        :
                           :                        :
              ADEPTH =250. CM                 DDRAIN =129. CM
                           :                        :
                           :                        :
                 :    O-------------SDRAIN =11700. CM -----------O  -
                           :    *                   :
                     : EFFRAD =**** CM                        :
                   :                      HDRAIN =121. CM
                           :                        :
                           :                        :
                   - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
                                      :
                                      :
                                      :
                   :                    IMPERMEABLE LAYER
+       ___________________________________________________________
                   //////////////////////////////////////////////////////////////////
```

DEPTH (CM)	SATURATED HYDRAULIC CONDUCTIVITY (CM/HR)
.0 - 33.0	13.000
33.0 - 95.0	2.000
95.0 - 114.0	3.000
114.0 - 152.0	8.000
152.0 - 250.0	15.000

DEPTH TO DRAIN = 129.0 CM
EFFECTIVE DEPTH FROM DRAIN TO IMPERMEABLE LAYER = 121.0 CM
DISTANCE BETWEEN DRAINS = 11700.0 CM
MAXIMUM DEPTH OF SURFACE PONDING = .25 CM
EFFECTIVE DEPTH TO IMPERMEABLE LAYER = 250.0 CM
DRAINAGE COEFFICIENT(AS LIMITED BY SUBSURFACE OUTLET) = 2.50 CM/DAY
MAXIMUM PUMPING CAPACITY (SUBIRRIGATION MODE) = 2.50 CM/DAY

ACTUAL DEPTH FROM SURFACE TO IMPERMEABLE LAYER = 250.0 CM
SURFACE STORAGE THAT MUST BE FILLED BEFORE WATER
CAN MOVE TO DRAIN = .25 CM
FACTOR -G- IN KIRKHAM EQ. 2-17 = 4.44

*** SEEPAGE LOSS INPUTS ***

No seepage due to field slope

No seepage due to vertical deep seepage

Lateral Deep Seepage
thickness of conveyance layer (cm)= 100.000000
hydraulic head at offsite sink/source (cm)= 40.000000
distance to offsite sink/source (cm)= 30000.000000
lateral conductivity of conveyance layer (cm/hr)= 10.000000

*** end of seepage inputs ***

WIDTH OF DITCH BOTTOM = 200.0 CM
SIDE SLOPE OF DITCH (HORIZ:VERT) = .50 : 1.00

INITIAL WATER TABLE DEPTH = 79.0 CM

DEPTH OF WEIR FROM THE SURFACE

DATE	1/ 1	2/ 1	3/ 1	4/ 1	5/ 1	6/ 1
WEIR DEPTH	129.0	129.0	129.0	129.0	129.0	129.0

DATE	7/ 1	8/ 1	9/ 1	10/ 1	11/ 1	12/ 1
WEIR DEPTH	129.0	129.0	129.0	129.0	129.0	129.0

SOIL INPUTS
****

TABLE 1

DRAINAGE TABLE

VOID VOLUME (CM)	WATER TABLE DEPTH (CM)
.0	.0
1.0	43.3
2.0	64.0
3.0	81.2
4.0	95.9
5.0	112.8
6.0	132.5
7.0	144.7
8.0	152.7
9.0	166.2

10.0	179.7
11.0	193.2
12.0	204.5
13.0	213.6
14.0	222.6
15.0	231.6
16.0	240.7
17.0	249.7
18.0	258.8
19.0	267.8
20.0	276.8
21.0	285.9
22.0	294.9
23.0	304.0
24.0	313.0
25.0	322.0
26.0	331.1
27.0	340.1
28.0	349.2
29.0	358.2
30.0	367.2
35.0	412.4
40.0	457.6
45.0	502.8
50.0	548.0
60.0	638.4
70.0	728.8
80.0	819.2
90.0	909.6

1 TABLE 2

SOIL WATER CHARACTERISTIC VS VOID VOLUME VS UPFLUX

HEAD (CM)	WATER CONTENT (CM/CM)	VOID VOLUME (CM)	UPFLUX (CM/HR)
.0	.3640	.00	.5000
10.0	.3500	.10	.4500
20.0	.3400	.35	.4000
30.0	.3220	.60	.3700
40.0	.3000	.90	.2200
50.0	.2720	1.20	.1000
60.0	.2530	1.80	.0250
70.0	.2420	2.30	.0100
80.0	.2340	2.92	.0050
90.0	.2290	3.59	.0037
100.0	.2240	4.29	.0025
110.0	.2176	4.78	.0015
120.0	.2112	5.56	.0010
130.0	.2048	5.90	.0007
140.0	.1984	6.30	.0003
150.0	.1920	7.80	.0000
160.0	.1908	8.54	.0000
170.0	.1896	9.28	.0000
180.0	.1884	10.02	.0000
190.0	.1872	10.76	.0000

200.0	.1860	11.50	.0000
210.0	.1856	12.61	.0000
220.0	.1853	13.71	.0000
230.0	.1849	14.82	.0000
240.0	.1845	15.93	.0000
250.0	.1842	17.03	.0000
260.0	.1838	18.14	.0000
270.0	.1834	19.24	.0000
280.0	.1831	20.35	.0000
290.0	.1827	21.46	.0000
300.0	.1823	22.56	.0000
350.0	.1805	28.09	.0000
400.0	.1787	33.63	.0000
450.0	.1768	39.16	.0000
500.0	.1750	44.69	.0000
600.0	.1713	55.75	.0000
700.0	.1677	66.81	.0000
800.0	.1640	77.88	.0000
900.0	.1603	88.94	.0000

GREEN AMPT INFILTRATION PARAMETERS

W.T.D. (CM)	A (CM)	B (CM)
.000	.000	.000
50.000	1.200	.750
100.000	2.700	1.250
150.000	4.400	2.000
200.000	5.300	2.000
500.000	26.000	2.000
1000.000	26.000	2.000

TRAFFICABILITY
****

REQUIREMENTS	FIRST PERIOD	SECOND PERIOD
-MINIMUM AIR VOLUME IN SOIL (CM):	3.00	3.00
-MAXIMUM ALLOWABLE DAILY RAINFALL(CM):	1.20	1.20
-MINIMUM TIME AFTER RAIN BEFORE TILLING CAN CONTINUE:	2.00	2.00

WORKING TIMES

-DATE TO BEGIN COUNTING WORK DAYS:	4/ 1	12/31
-DATE TO STOP COUNTING WORK DAYS:	5/ 1	12/31
-FIRST WORK HOUR OF THE DAY:	8	8
-LAST WORK HOUR OF THE DAY:	20	20

CROP
****

SOIL MOISTURE AT WILTING POINT = .17

HIGH WATER STRESS: BEGIN STRESS PERIOD ON   4/10
END STRESS PERIOD ON   8/18
CROP WAS IN STRESS WHEN WATER TABLE WAS ABOVE 30.0 CM

DROUGHT STRESS: BEGIN STRESS PERIOD ON   4/10
END STRESS PERIOD ON   8/18

MO	DAY	ROOTING DEPTH(CM)
1	1	10.0
3	1	13.0
4	15	16.0
4	30	11.0
12	31	10.0

WASTEWATER IRRIGATION
****

NO WASTEWATER IRRIGATION SCHEDULED:

***** Wetlands Parameter Estimation *****

Start Day =   1   End Day = 365
Threshold Water Table Depth (cm) = 48.0
Threshold Consecutive Days   =   14

Fixed Monthly Pet Values

1 .00   2 .00   3 .00   4 .00   5 .00   6 .00   7 .00   8 .00   9 .00   10 .00   11 .00   12 .00

Mrank indicator = 0

***************************** END OF INPUTS *****************************

----------RUN STATHISTICS ----------   time: 11/17/2004 @ 16:59
input file: C:\Drainmod\inputs\Foreston2Calibration.prj
parameters: free drainage   and yields not calculated
drain spacing =   11700. cm   drain depth = 129.0 cm

C.2 DRAINMOD inputs for plot 2 wFo at the Richlands site

****

D R A I N M O D 5.1

Copyright 1980-99 North Carolina State University
LAST UPDATE: SEPT 1999
LANGUAGE FORTRAN 77/90

DRAINMOD WAS A FIELD-SCALE HYDROLOGIC MODEL DEVELOPED FOR THE DESIGN OF SUBSURFACE DRAINAGE SYSTEMS. THE MODEL WAS DEVELOPED BY RESEARCHERS AT THE DEPT. OF BIOLOGICAL AND AGRICULTURAL ENGINEERING, NORTH CAROLINA STATE UNIVERSITY UNDER THE DIRECTION OF R. W. SKAGGS.

****

DATA READ FROM INPUT FILE: C:\Drainmod\inputs\WF2Calibration.prj
Cream selector (0=no, 1=yes) = 0

TITLE OF RUN
****

wet Foreston 2

CLIMATE INPUTS
******* ******

```
 DESCRIPTION                    (VARIABLE)   VALUE  UNIT
-----------------------------------------------------------------------------
FILE FOR RAINDATA ..............C:\DRAINMOD\WEATHER\FC3RAIN2.RAI
FILE FOR TEMPERATURE/PET DATA ..C:\DRAINMOD\WEATHER\FCTEMP.TEM
RAINFALL STATION NUMBER..........................(RAINID)       1
TEMPERATURE/PET STATION NUMBER...................(TEMPID)       1
STARTING YEAR OF SIMULATION..................(START YEAR)     2003   YEAR
STARTING MONTH OF SIMULATION................(START MONTH)       12   MONTH
ENDING YEAR OF SIMULATION......................(END YEAR)     2004   YEAR
ENDING MONTH OF SIMULATION....................(END MONTH)        4   MONTH
TEMPERATURE STATION LATITUDE...................(TEMP LAT)    34.16   DEG.MIN
HEAT INDEX..........................................(HID)    85.00
```

ET MULTIPLICATION FACTOR FOR EACH MONTH
2.52 3.30 2.39 1.69 1.31 .99 .90 .87 .94 1.20 1.45 2.01

DRAINAGE SYSTEM DESIGN
****

*** CONVENTIONAL DRAINAGE ***

JOB TITLE:

wet Foreston 2

```
                 STMAX =  .35 CM              SOIL SURFACE
+    __/)______________________________________________________/)__
                        :                           :
                        :                           :
                        :                           :
                        :                           :
                        :                           :
           ADEPTH =250. CM                   DDRAIN =119. CM
                        :                           :
                        :                           :
                   :   O------------SDRAIN =13700. CM -----------O  -
                        :   *                        :
                     : EFFRAD =**** CM                    :
                    :                       HDRAIN =131. CM
                        :                           :
                        :                           :
                   - - - - - - - - - - - - - - - - - - - - - - - - - -
                                     :
                                     :
                                     :
                    :                        IMPERMEABLE LAYER
+    ______________________________________________________________
                    ////////////////////////////////////////////////////
```

DEPTH (CM)	SATURATED HYDRAULIC CONDUCTIVITY (CM/HR)
.0 - 20.0	20.000
20.0 - 56.0	9.000
56.0 - 80.0	4.000
80.0 - 120.0	8.000
120.0 - 250.0	16.000

DEPTH TO DRAIN = 119.0 CM
EFFECTIVE DEPTH FROM DRAIN TO IMPERMEABLE LAYER = 130.7 CM
DISTANCE BETWEEN DRAINS = 13700.0 CM
MAXIMUM DEPTH OF SURFACE PONDING =   .35 CM
EFFECTIVE DEPTH TO IMPERMEABLE LAYER = 249.7 CM
DRAINAGE COEFFICIENT(AS LIMITED BY SUBSURFACE OUTLET) = 2.50 CM/DAY

MAXIMUM PUMPING CAPACITY (SUBIRRIGATION MODE) = 2.50 CM/DAY
ACTUAL DEPTH FROM SURFACE TO IMPERMEABLE LAYER = 250.0 CM
SURFACE STORAGE THAT MUST BE FILLED BEFORE WATER
CAN MOVE TO DRAIN = .25 CM
FACTOR -G- IN KIRKHAM EQ. 2-17 = 4.18

*** SEEPAGE LOSS INPUTS ***

No seepage due to field slope

No seepage due to vertical deep seepage

Lateral Deep Seepage
thickness of conveyance layer (cm)= 100.000000
hydraulic head at offsite sink/source (cm)= 40.000000
distance to offsite sink/source (cm)= 24500.000000
lateral conductivity of conveyance layer (cm/hr)= 10.000000

*** end of seepage inputs ***

WIDTH OF DITCH BOTTOM = 200.0 CM
SIDE SLOPE OF DITCH (HORIZ:VERT) = .50 : 1.00

INITIAL WATER TABLE DEPTH = 88.0 CM

DEPTH OF WEIR FROM THE SURFACE

DATE	1/ 1	2/ 1	3/ 1	4/ 1	5/ 1	6/ 1
WEIR DEPTH	119.0	119.0	119.0	119.0	119.0	119.0

DATE	7/ 1	8/ 1	9/ 1	10/ 1	11/ 1	12/ 1
WEIR DEPTH	119.0	119.0	119.0	119.0	119.0	119.0

SOIL INPUTS
****

TABLE 1

DRAINAGE TABLE

VOID VOLUME (CM)	WATER TABLE DEPTH (CM)
.0	.0
1.0	43.3
2.0	64.0
3.0	81.2
4.0	95.9
5.0	112.8
6.0	132.5
7.0	144.7
8.0	152.7

9.0	166.2
10.0	179.7
11.0	193.2
12.0	204.5
13.0	213.6
14.0	222.6
15.0	231.6
16.0	240.7
17.0	249.7
18.0	258.8
19.0	267.8
20.0	276.8
21.0	285.9
22.0	294.9
23.0	304.0
24.0	313.0
25.0	322.0
26.0	331.1
27.0	340.1
28.0	349.2
29.0	358.2
30.0	367.2
35.0	412.4
40.0	457.6
45.0	502.8
50.0	548.0
60.0	638.4
70.0	728.8
80.0	819.2
90.0	909.6

TABLE 2

SOIL WATER CHARACTERISTIC VS VOID VOLUME VS UPFLUX

HEAD (CM)	WATER CONTENT (CM/CM)	VOID VOLUME (CM)	UPFLUX (CM/HR)
.0	.3640	.00	.5000
10.0	.3500	.10	.4500
20.0	.3400	.35	.4000
30.0	.3220	.60	.3700
40.0	.3000	.90	.2200
50.0	.2720	1.20	.1000
60.0	.2530	1.80	.0250
70.0	.2420	2.30	.0100
80.0	.2340	2.92	.0050
90.0	.2290	3.59	.0037
100.0	.2240	4.29	.0025
110.0	.2176	4.78	.0015
120.0	.2112	5.56	.0010
130.0	.2048	5.90	.0007
140.0	.1984	6.30	.0003
150.0	.1920	7.80	.0000
160.0	.1908	8.54	.0000
170.0	.1896	9.28	.0000

180.0	.1884	10.02	.0000
190.0	.1872	10.76	.0000
200.0	.1860	11.50	.0000
210.0	.1856	12.61	.0000
220.0	.1853	13.71	.0000
230.0	.1849	14.82	.0000
240.0	.1845	15.93	.0000
250.0	.1842	17.03	.0000
260.0	.1838	18.14	.0000
270.0	.1834	19.24	.0000
280.0	.1831	20.35	.0000
290.0	.1827	21.46	.0000
300.0	.1823	22.56	.0000
350.0	.1805	28.09	.0000
400.0	.1787	33.63	.0000
450.0	.1768	39.16	.0000
500.0	.1750	44.69	.0000
600.0	.1713	55.75	.0000
700.0	.1677	66.81	.0000
800.0	.1640	77.88	.0000
900.0	.1603	88.94	.0000

GREEN AMPT INFILTRATION PARAMETERS

W.T.D. (CM)	A (CM)	B (CM)
.000	.000	.000
50.000	1.200	.750
100.000	2.700	1.250
150.000	4.400	2.000
200.000	5.300	2.000
500.000	26.000	2.000
1000.000	26.000	2.000

TRAFFICABILITY
****

REQUIREMENTS	FIRST PERIOD	SECOND PERIOD
-MINIMUM AIR VOLUME IN SOIL (CM):	3.00	3.00
-MAXIMUM ALLOWABLE DAILY RAINFALL(CM):	1.20	1.20
-MINIMUM TIME AFTER RAIN BEFORE TILLING CAN CONTINUE:	2.00	2.00

WORKING TIMES

-DATE TO BEGIN COUNTING WORK DAYS:	4/ 1	12/31
-DATE TO STOP COUNTING WORK DAYS:	5/ 1	12/31
-FIRST WORK HOUR OF THE DAY:	8	8
-LAST WORK HOUR OF THE DAY:	20	20

CROP
****

SOIL MOISTURE AT WILTING POINT = .17

HIGH WATER STRESS: BEGIN STRESS PERIOD ON   4/10
END STRESS PERIOD ON   8/18
CROP WAS IN STRESS WHEN WATER TABLE WAS ABOVE 30.0 CM

DROUGHT STRESS: BEGIN STRESS PERIOD ON   4/10
END STRESS PERIOD ON   8/18

MO	DAY	ROOTING DEPTH(CM)
1	1	10.0
3	1	13.0
4	15	16.0
4	30	11.0
12	31	10.0

WASTEWATER IRRIGATION
****

NO WASTEWATER IRRIGATION SCHEDULED:

***** Wetlands Parameter Estimation *****

Start Day =   1   End Day = 365
Threshold Water Table Depth (cm) = 44.0
Threshold Consecutive Days   =   14

Fixed Monthly Pet Values

1 .00   2 .00   3 .00   4 .00   5 .00   6 .00   7 .00   8 .00   9 .00   10 .00   11 .00   12 .00

Mrank indicator = 0

***************************** END OF INPUTS *****************************

----------RUN STATHISTICS ----------   time: 11/18/2004 @ 2: 3
input file: C:\Drainmod\inputs\WF2Calibration.prj
parameters: free drainage   and yields not calculated
drain spacing =   13700. cm   drain depth = 119.0 cm

> Computational Statistics   <
**> Start Computations   = 123.589

C.3 DRAINMOD inputs for plot 2 St at the Richlands site

```
*******************************************************************************

                                   D R A I N M O D  5.1

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                                 LAST UPDATE: SEPT 1999
                                 LANGUAGE FORTRAN 77/90

          DRAINMOD WAS A FIELD-SCALE HYDROLOGIC MODEL DEVELOPED FOR
           THE DESIGN OF SUBSURFACE DRAINAGE SYSTEMS. THE MODEL WAS
            DEVELOPED BY RESEARCHERS AT THE DEPT. OF BIOLOGICAL AND
           AGRICULTURAL ENGINEERING, NORTH CAROLINA STATE UNIVERSITY
                        UNDER THE DIRECTION OF R. W. SKAGGS.

*******************************************************************************

      DATA READ FROM INPUT FILE: C:\Drainmod\inputs\Stallings2Calibration.prj
                        Cream selector (0=no, 1=yes) =  0

                                  TITLE OF RUN
                                  ************

                               Stallings 2

                                 CLIMATE INPUTS
                                 ******* ******

    DESCRIPTION                 (VARIABLE)    VALUE   UNIT
-----------------------------------------------------------------------------
FILE FOR RAINDATA ..............C:\DRAINMOD\WEATHER\RICHLAND.RAI
FILE FOR TEMPERATURE/PET DATA ..C:\DRAINMOD\WEATHER\RICHLONG.TEM
RAINFALL STATION NUMBER..........................(RAINID)         1
TEMPERATURE/PET STATION NUMBER...................(TEMPID)         1
STARTING YEAR OF SIMULATION..................(START YEAR)      1971   YEAR
STARTING MONTH OF SIMULATION................(START MONTH)        1   MONTH
ENDING YEAR OF SIMULATION......................(END YEAR)      2003   YEAR
ENDING MONTH OF SIMULATION....................(END MONTH)        12   MONTH
TEMPERATURE STATION LATITUDE...................(TEMP LAT)      34.16   DEG.MIN
HEAT INDEX..........................................(HID)      85.00

                     ET MULTIPLICATION FACTOR FOR EACH MONTH
                 2.52  3.30  2.39  1.69  1.31   .99   .90   .87   .94  1.20  1.45  2.01
```

DRAINAGE SYSTEM DESIGN
****
*** CONVENTIONAL DRAINAGE ***

JOB TITLE:

Stallings 2

```
                    STMAX =  .45 CM              SOIL SURFACE
+      __/)________________________________________________________/)__
                         :                              :
                         :                              :
                         :                              :
                         :                              :
                         :                              :
             ADEPTH =250. CM                      DDRAIN =113. CM
                         :                              :
                         :                              :
                   :   O-------------SDRAIN =14000. CM -----------O  -
                         :    *                         :
                     : EFFRAD =**** CM                          :
                    :                         HDRAIN =137. CM
                         :                              :
                         :                              :
                   - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
                                       :
                                       :
                                       :
                    :                          IMPERMEABLE LAYER
+      ________________________________________________________________
                    ///////////////////////////////////////////////////////////////////
```

DEPTH (CM)	SATURATED HYDRAULIC CONDUCTIVITY (CM/HR)
.0 - 20.0	18.000
20.0 - 51.0	5.000
51.0 - 80.0	9.000
80.0 - 130.0	1.000
130.0 - 250.0	19.000

DEPTH TO DRAIN = 113.0 CM
EFFECTIVE DEPTH FROM DRAIN TO IMPERMEABLE LAYER = 136.6 CM
DISTANCE BETWEEN DRAINS = 14000.0 CM
MAXIMUM DEPTH OF SURFACE PONDING = .45 CM
EFFECTIVE DEPTH TO IMPERMEABLE LAYER = 249.6 CM
DRAINAGE COEFFICIENT(AS LIMITED BY SUBSURFACE OUTLET) = 2.50 CM/DAY
MAXIMUM PUMPING CAPACITY (SUBIRRIGATION MODE) = 2.50 CM/DAY

ACTUAL DEPTH FROM SURFACE TO IMPERMEABLE LAYER = 250.0 CM
SURFACE STORAGE THAT MUST BE FILLED BEFORE WATER
CAN MOVE TO DRAIN = .25 CM
FACTOR -G- IN KIRKHAM EQ. 2-17 = 4.03

*** SEEPAGE LOSS INPUTS ***

No seepage due to field slope

No seepage due to vertical deep seepage

Lateral Deep Seepage
thickness of conveyance layer (cm)= 100.000000
hydraulic head at offsite sink/source (cm)= 40.000000
distance to offsite sink/source (cm)= 25000.000000
lateral conductivity of conveyance layer (cm/hr)= 8.000000

*** end of seepage inputs ***

WIDTH OF DITCH BOTTOM = 200.0 CM
SIDE SLOPE OF DITCH (HORIZ:VERT) = .50 : 1.00

INITIAL WATER TABLE DEPTH = 86.0 CM

DEPTH OF WEIR FROM THE SURFACE

DATE	1/ 1	2/ 1	3/ 1	4/ 1	5/ 1	6/ 1
WEIR DEPTH	113.0	113.0	113.0	113.0	113.0	113.0

DATE	7/ 1	8/ 1	9/ 1	10/ 1	11/ 1	12/ 1
WEIR DEPTH	113.0	113.0	113.0	113.0	113.0	113.0

SOIL INPUTS
****

TABLE 1

DRAINAGE TABLE

VOID VOLUME (CM)	WATER TABLE DEPTH (CM)
.0	.0
1.0	43.3
2.0	64.0
3.0	81.2
4.0	95.9
5.0	112.8
6.0	132.5
7.0	144.7
8.0	152.7
9.0	166.2

10.0	179.7
11.0	193.2
12.0	204.5
13.0	213.6
14.0	222.6
15.0	231.6
16.0	240.7
17.0	249.7
18.0	258.8
19.0	267.8
20.0	276.8
21.0	285.9
22.0	294.9
23.0	304.0
24.0	313.0
25.0	322.0
26.0	331.1
27.0	340.1
28.0	349.2
29.0	358.2
30.0	367.2
35.0	412.4
40.0	457.6
45.0	502.8
50.0	548.0
60.0	638.4
70.0	728.8
80.0	819.2
90.0	909.6

TABLE 2

SOIL WATER CHARACTERISTIC VS VOID VOLUME VS UPFLUX

HEAD (CM)	WATER CONTENT (CM/CM)	VOID VOLUME (CM)	UPFLUX (CM/HR)
.0	.3640	.00	.5000
10.0	.3500	.10	.4500
20.0	.3400	.35	.4000
30.0	.3220	.60	.3700
40.0	.3000	.90	.2200
50.0	.2720	1.20	.1000
60.0	.2530	1.80	.0250
70.0	.2420	2.30	.0100
80.0	.2340	2.92	.0050
90.0	.2290	3.59	.0037
100.0	.2240	4.29	.0025
110.0	.2176	4.78	.0015
120.0	.2112	5.56	.0010
130.0	.2048	5.90	.0007
140.0	.1984	6.30	.0003
150.0	.1920	7.80	.0000
160.0	.1908	8.54	.0000
170.0	.1896	9.28	.0000
180.0	.1884	10.02	.0000

190.0	.1872	10.76	.0000
200.0	.1860	11.50	.0000
210.0	.1856	12.61	.0000
220.0	.1853	13.71	.0000
230.0	.1849	14.82	.0000
240.0	.1845	15.93	.0000
250.0	.1842	17.03	.0000
260.0	.1838	18.14	.0000
270.0	.1834	19.24	.0000
280.0	.1831	20.35	.0000
290.0	.1827	21.46	.0000
300.0	.1823	22.56	.0000
350.0	.1805	28.09	.0000
400.0	.1787	33.63	.0000
450.0	.1768	39.16	.0000
500.0	.1750	44.69	.0000
600.0	.1713	55.75	.0000
700.0	.1677	66.81	.0000
800.0	.1640	77.88	.0000
900.0	.1603	88.94	.0000

GREEN AMPT INFILTRATION PARAMETERS

W.T.D. (CM)	A (CM)	B (CM)
.000	.000	.000
50.000	1.200	.750
100.000	2.700	1.250
150.000	4.400	2.000
200.000	5.300	2.000
500.000	26.000	2.000
1000.000	26.000	2.000

TRAFFICABILITY
****

REQUIREMENTS	FIRST PERIOD	SECOND PERIOD
-MINIMUM AIR VOLUME IN SOIL (CM):	3.00	3.00
-MAXIMUM ALLOWABLE DAILY RAINFALL(CM):	1.20	1.20
-MINIMUM TIME AFTER RAIN BEFORE TILLING CAN CONTINUE:	2.00	2.00
WORKING TIMES		
-DATE TO BEGIN COUNTING WORK DAYS:	4/ 1	12/31
-DATE TO STOP COUNTING WORK DAYS:	5/ 1	12/31
-FIRST WORK HOUR OF THE DAY:	8	8
-LAST WORK HOUR OF THE DAY:	20	20

CROP
****

SOIL MOISTURE AT WILTING POINT =   .17

HIGH WATER STRESS: BEGIN STRESS PERIOD ON 4/10
END STRESS PERIOD ON 8/18
CROP WAS IN STRESS WHEN WATER TABLE WAS ABOVE 30.0 CM

DROUGHT STRESS: BEGIN STRESS PERIOD ON 4/10
END STRESS PERIOD ON 8/18

MO	DAY	ROOTING DEPTH(CM)
1	1	10.0
3	1	13.0
4	15	16.0
4	30	11.0
12	31	10.0

WASTEWATER IRRIGATION
****

NO WASTEWATER IRRIGATION SCHEDULED:

***** Wetlands Parameter Estimation *****

Start Day = 1 End Day = 365
Threshold Water Table Depth (cm) = 38.0
Threshold Consecutive Days = 14

Fixed Monthly Pet Values

1 .00 2 .00 3 .00 4 .00 5 .00 6 .00 7 .00 8 .00 9 .00 10 .00 11 .00 12 .00

Mrank indicator = 0

**************************** END OF INPUTS ****************************

----------RUN STATHISTICS ---------- time: 11/19/2004 @ 13:14
input file: C:\Drainmod\inputs\Stallings2Calibration.prj
parameters: free drainage and yields not calculated
drain spacing = 14000. cm drain depth = 113.0 cm

C.4 DRAINMOD inputs for plot 2 Cr at the Vanceboro site

****

D R A I N M O D 5.1

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LAST UPDATE: SEPT 1999
LANGUAGE FORTRAN 77/90

DRAINMOD WAS A FIELD-SCALE HYDROLOGIC MODEL DEVELOPED FOR THE DESIGN OF SUBSURFACE DRAINAGE SYSTEMS. THE MODEL WAS DEVELOPED BY RESEARCHERS AT THE DEPT. OF BIOLOGICAL AND AGRICULTURAL ENGINEERING, NORTH CAROLINA STATE UNIVERSITY UNDER THE DIRECTION OF R. W. SKAGGS.

****

DATA READ FROM INPUT FILE: C:\Drainmod\inputs\Craven2.prj
Cream selector (0=no, 1=yes) = 0

TITLE OF RUN
****

Craven 1

CLIMATE INPUTS
******* ******

```
    DESCRIPTION                         (VARIABLE)     VALUE   UNIT
-----------------------------------------------------------------------------
FILE FOR RAINDATA ..............C:\DRAINMOD\WEATHER\NEWVANCE.RAI
FILE FOR TEMPERATURE/PET DATA ..C:\DRAINMOD\WEATHER\NEWVANCE.TEM
RAINFALL STATION NUMBER..........................(RAINID)         1
TEMPERATURE/PET STATION NUMBER...................(TEMPID)         1
STARTING YEAR OF SIMULATION..................(START YEAR)       2003   YEAR
STARTING MONTH OF SIMULATION................(START MONTH)        12   MONTH
ENDING YEAR OF SIMULATION......................(END YEAR)       2004   YEAR
ENDING MONTH OF SIMULATION....................(END MONTH)         4   MONTH
TEMPERATURE STATION LATITUDE...................(TEMP LAT)      35.43   DEG.MIN
HEAT INDEX..........................................(HID)      76.00
```

ET MULTIPLICATION FACTOR FOR EACH MONTH
2.01 2.32 2.10 1.72 1.23 1.00 .86 .82 .92 1.05 1.22 1.44

DRAINAGE SYSTEM DESIGN

****

*** CONVENTIONAL DRAINAGE ***

JOB TITLE:

Craven 1

```
                         STMAX =  .25 CM              SOIL SURFACE
+       __/)_____________________________________________________________/)__
                                  :                            :
                                  :                            :
                                  :                            :
                                  :                            :
                                  :                            :
                     ADEPTH =275. CM                      DDRAIN =155. CM
                                  :                            :
                                  :                            :
                        :    O-------------SDRAIN =10200. CM -----------O  -
                                  :    *                       :
                             : EFFRAD =**** CM                          :
                           :                          HDRAIN =120. CM
                                  :                            :
                                  :                            :
                        - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
                                               :
                                               :
                                               :
                          :                          IMPERMEABLE LAYER
+       ______________________________________________________________________
                          ////////////////////////////////////////////////////////////////////
```

DEPTH (CM)	SATURATED HYDRAULIC CONDUCTIVITY (CM/HR)
.0 - 10.0	10.000
10.0 - 56.0	2.000
56.0 - 130.0	13.000
130.0 - 178.0	19.000
178.0 - 275.0	25.000

DEPTH TO DRAIN = 155.0 CM
EFFECTIVE DEPTH FROM DRAIN TO IMPERMEABLE LAYER = 120.0 CM
DISTANCE BETWEEN DRAINS = 10200.0 CM
MAXIMUM DEPTH OF SURFACE PONDING = .25 CM
EFFECTIVE DEPTH TO IMPERMEABLE LAYER = 275.0 CM
DRAINAGE COEFFICIENT(AS LIMITED BY SUBSURFACE OUTLET) = 2.50 CM/DAY
MAXIMUM PUMPING CAPACITY (SUBIRRIGATION MODE) = 2.50 CM/DAY
ACTUAL DEPTH FROM SURFACE TO IMPERMEABLE LAYER = 275.0 CM

SURFACE STORAGE THAT MUST BE FILLED BEFORE WATER
CAN MOVE TO DRAIN = .15 CM
FACTOR -G- IN KIRKHAM EQ. 2-17 = 4.97

*** SEEPAGE LOSS INPUTS ***

No seepage due to field slope

No seepage due to vertical deep seepage

No seepage due to lateral deep seepage

*** end of seepage inputs ***

WIDTH OF DITCH BOTTOM = 200.0 CM
SIDE SLOPE OF DITCH (HORIZ:VERT) = .50 : 1.00

INITIAL WATER TABLE DEPTH = 182.0 CM

DEPTH OF WEIR FROM THE SURFACE

DATE	1/ 1	2/ 1	3/ 1	4/ 1	5/ 1	6/ 1
WEIR DEPTH	155.0	155.0	155.0	155.0	155.0	155.0

DATE	7/ 1	8/ 1	9/ 1	10/ 1	11/ 1	12/ 1
WEIR DEPTH	155.0	155.0	155.0	155.0	155.0	155.0

SOIL INPUTS
****

TABLE 1

DRAINAGE TABLE

VOID VOLUME (CM)	WATER TABLE DEPTH (CM)
.0	.0
1.0	30.6
2.0	43.4
3.0	56.9
4.0	76.3
5.0	89.2
6.0	100.4
7.0	111.0
8.0	121.9
9.0	134.5
10.0	146.0
11.0	156.7
12.0	166.3
13.0	175.4
14.0	184.3
15.0	192.9
16.0	201.6

17.0	210.1
18.0	218.7
19.0	227.3
20.0	235.8
21.0	241.6
22.0	244.8
23.0	247.9
24.0	253.4
25.0	263.2
26.0	273.0
27.0	282.9
28.0	292.7
29.0	302.5
30.0	312.3
35.0	361.5
40.0	410.6
45.0	459.7
50.0	508.8
60.0	607.1
70.0	705.3
80.0	803.5
90.0	901.8

TABLE 2

SOIL WATER CHARACTERISTIC VS VOID VOLUME VS UPFLUX

HEAD (CM)	WATER CONTENT (CM/CM)	VOID VOLUME (CM)	UPFLUX (CM/HR)
.0	.3655	.00	1.0000
10.0	.3325	.20	.7000
20.0	.3270	.60	.4500
30.0	.3205	.95	.2500
40.0	.3155	1.69	.0900
50.0	.3105	2.60	.0550
60.0	.3070	3.18	.0230
70.0	.3035	3.68	.0165
80.0	.3000	4.18	.0100
90.0	.2965	5.07	.0088
100.0	.2930	5.96	.0075
110.0	.2909	6.91	.0067
120.0	.2888	7.85	.0060
130.0	.2867	8.64	.0058
140.0	.2846	9.43	.0055
150.0	.2825	10.37	.0038
160.0	.2808	11.31	.0020
170.0	.2791	12.41	.0018
180.0	.2774	13.51	.0015
190.0	.2757	14.66	.0010
200.0	.2740	15.82	.0005
210.0	.2722	16.99	.0004
220.0	.2704	18.15	.0002
230.0	.2686	19.32	.0001
240.0	.2668	20.49	.0000
250.0	.2650	23.65	.0000

260.0	.2631	24.67	.0000
270.0	.2612	25.69	.0000
280.0	.2593	26.71	.0000
290.0	.2574	27.73	.0000
300.0	.2555	28.74	.0000
350.0	.2450	33.83	.0000
400.0	.2330	38.92	.0000
450.0	.2200	44.01	.0000
500.0	.2085	49.10	.0000
600.0	.1900	59.28	.0000
700.0	.1790	69.46	.0000
800.0	.1733	79.64	.0000
900.0	.1675	89.82	.0000

GREEN AMPT INFILTRATION PARAMETERS

W.T.D. (CM)	A (CM)	B (CM)
.000	.000	.000
50.000	1.200	.750
100.000	6.500	1.200
150.000	10.000	1.500
200.000	12.000	1.500
500.000	15.000	1.500
1000.000	15.000	1.500

TRAFFICABILITY
****

REQUIREMENTS	FIRST PERIOD	SECOND PERIOD
-MINIMUM AIR VOLUME IN SOIL (CM):	3.90	3.90
-MAXIMUM ALLOWABLE DAILY RAINFALL(CM):	1.20	1.20
-MINIMUM TIME AFTER RAIN BEFORE TILLING CAN CONTINUE:	2.00	2.00
WORKING TIMES		
-DATE TO BEGIN COUNTING WORK DAYS:	4/ 1	12/32
-DATE TO STOP COUNTING WORK DAYS:	5/ 1	12/32
-FIRST WORK HOUR OF THE DAY:	8	8
-LAST WORK HOUR OF THE DAY:	20	20

CROP
****

SOIL MOISTURE AT WILTING POINT = .17

HIGH WATER STRESS: BEGIN STRESS PERIOD ON 4/10
END STRESS PERIOD ON 8/18
CROP WAS IN STRESS WHEN WATER TABLE WAS ABOVE 30.0 CM

DROUGHT STRESS: BEGIN STRESS PERIOD ON 4/10
END STRESS PERIOD ON 8/18

MO	DAY	ROOTING DEPTH(CM)
1	1	3.0
4	16	3.0
5	4	4.0
5	17	15.0
6	1	25.0
6	20	30.0
7	18	30.0
8	20	20.0
9	24	10.0
9	25	3.0
12	31	3.0

WASTEWATER IRRIGATION
****

NO WASTEWATER IRRIGATION SCHEDULED:

***** Wetlands Parameter Estimation *****

Start Day = 1 End Day = 365
Threshold Water Table Depth (cm) = 89.0
Threshold Consecutive Days = 14

Fixed Monthly Pet Values

1 .00 2 .00 3 .00 4 .00 5 .00 6 .00 7 .00 8 .00 9 .00 10 .00 11 .00 12 .00

Mrank indicator = 0

***************************** END OF INPUTS *****************************

----------RUN STATHISTICS ---------- time: 11/15/2004 @ 21:48
input file: C:\Drainmod\inputs\Craven2.prj
parameters: free drainage and yields not calculated
drain spacing = 10200. cm drain depth = 155.0 cm

C.5 DRAINMOD inputs for plot 2 Le at the Vanceboro site

```
******************************************************************************

                              D R A I N M O D  5.1

                 Copyright 1980-99 North Carolina State University
                          LAST UPDATE: SEPT 1999
                          LANGUAGE FORTRAN 77/90

        DRAINMOD WAS A FIELD-SCALE HYDROLOGIC MODEL DEVELOPED FOR
         THE DESIGN OF SUBSURFACE DRAINAGE SYSTEMS. THE MODEL WAS
          DEVELOPED BY RESEARCHERS AT THE DEPT. OF BIOLOGICAL AND
        AGRICULTURAL ENGINEERING, NORTH CAROLINA STATE UNIVERSITY
                   UNDER THE DIRECTION OF R. W. SKAGGS.

******************************************************************************


        DATA READ FROM INPUT FILE: C:\Drainmod\inputs\Lenoir2Calib.prj
                     Cream selector (0=no, 1=yes) =  0

                              TITLE OF RUN
                              ************


                                 Lenoir



                             CLIMATE INPUTS
                             ******* ******

DESCRIPTION                      (VARIABLE)     VALUE   UNIT
-----------------------------------------------------------------------------
FILE FOR RAINDATA ..............C:\DRAINMOD\WEATHER\VRAIN12-.RAI
FILE FOR TEMPERATURE/PET DATA ..C:\DRAINMOD\WEATHER\NEWVANCE.TEM
RAINFALL STATION NUMBER..........................(RAINID)         1
TEMPERATURE/PET STATION NUMBER...................(TEMPID)         1
STARTING YEAR OF SIMULATION..................(START YEAR)      2003   YEAR
STARTING MONTH OF SIMULATION................(START MONTH)        12   MONTH
ENDING YEAR OF SIMULATION......................(END YEAR)      2004   YEAR
ENDING MONTH OF SIMULATION....................(END MONTH)         4   MONTH
TEMPERATURE STATION LATITUDE...................(TEMP LAT)      35.47   DEG.MIN
HEAT INDEX..........................................(HID)      75.00


                  ET MULTIPLICATION FACTOR FOR EACH MONTH
          2.01  2.32  2.10  1.72  1.23  1.00   .86   .82   .92  1.05  1.22  1.44
```

DRAINAGE SYSTEM DESIGN
****

*** CONTROLLED DRAINAGE ***

JOB TITLE:

Lenoir 2

```
                STMAX =  .70 CM               SOIL SURFACE
+      __/)______________________________________________________/)__
                          :                              :
                          :                              :
                          :                              :
                          :                              :
                          :                              :
           ADEPTH =250. CM                        DDRAIN = 77. CM
                          :                              :
                          :                              :
                 :    O-------------SDRAIN = 5090. CM -----------O  -
                          :    *                          :
                    : EFFRAD =**** CM                          :
                  :                          HDRAIN =168. CM
                          :                              :
                          :                              :
                - - - - - - - - - - - - - - - - - - - - - - - - - -
                                       :
                                       :
                                       :
                 :                      IMPERMEABLE LAYER
+      _____________________________________________________________
                 ////////////////////////////////////////////////////
```

DEPTH (CM)	SATURATED HYDRAULIC CONDUCTIVITY (CM/HR)
.0 - 30.0	8.000
30.0 - 41.0	1.100
41.0 - 121.0	.050
121.0 - 200.0	4.000
200.0 - 250.0	6.000

DEPTH TO DRAIN = 77.0 CM
EFFECTIVE DEPTH FROM DRAIN TO IMPERMEABLE LAYER = 167.5 CM
DISTANCE BETWEEN DRAINS = 5090.0 CM
MAXIMUM DEPTH OF SURFACE PONDING = .70 CM
EFFECTIVE DEPTH TO IMPERMEABLE LAYER = 244.5 CM
DRAINAGE COEFFICIENT(AS LIMITED BY SUBSURFACE OUTLET) = 2.50 CM/DAY

MAXIMUM PUMPING CAPACITY (SUBIRRIGATION MODE) = 2.50 CM/DAY
ACTUAL DEPTH FROM SURFACE TO IMPERMEABLE LAYER = 250.0 CM
SURFACE STORAGE THAT MUST BE FILLED BEFORE WATER
CAN MOVE TO DRAIN = .70 CM
FACTOR -G- IN KIRKHAM EQ. 2-17 = 2.94

*** SEEPAGE LOSS INPUTS ***

No seepage due to field slope

No seepage due to vertical deep seepage

No seepage due to lateral deep seepage

*** end of seepage inputs ***

WIDTH OF DITCH BOTTOM = 200.0 CM
SIDE SLOPE OF DITCH (HORIZ:VERT) = .50 : 1.00

INITIAL WATER TABLE DEPTH = 88.0 CM

DEPTH OF WEIR FROM THE SURFACE

```
------------------------------
DATE         1/ 1   2/ 1   3/ 1   4/ 1   5/ 1   6/ 1
WEIR DEPTH   120.0  120.0  120.0  120.0  120.0  120.0

DATE         7/ 1   8/ 1   9/ 1   10/ 1  11/ 1  12/ 1
WEIR DEPTH   120.0  120.0  120.0     120.0
```

SOIL INPUTS
****

TABLE 1

DRAINAGE TABLE

VOID VOLUME (CM)	WATER TABLE DEPTH (CM)
.0	.0
1.0	28.8
2.0	42.2
3.0	53.8
4.0	60.1
5.0	66.8
6.0	73.4
7.0	80.1
8.0	87.2
9.0	94.3
10.0	102.4
11.0	114.5
12.0	127.4

13.0	142.3
14.0	167.5
15.0	183.8
16.0	201.6
17.0	210.1
18.0	218.7
19.0	227.3
20.0	235.8
21.0	241.6
22.0	244.8
23.0	247.9
24.0	253.4
25.0	263.2
26.0	273.0
27.0	282.9
28.0	292.7
29.0	302.5
30.0	312.3
35.0	361.5
40.0	410.6
45.0	459.7
50.0	508.8
60.0	607.1
70.0	705.3
80.0	803.5
90.0	901.8

1 TABLE 2

SOIL WATER CHARACTERISTIC VS VOID VOLUME VS UPFLUX

HEAD (CM)	WATER CONTENT (CM/CM)	VOID VOLUME (CM)	UPFLUX (CM/HR)
.0	.3655	.00	1.0000
10.0	.3325	.20	.7000
20.0	.3270	.60	.4500
30.0	.3205	1.05	.2500
40.0	.3155	1.89	.0900
50.0	.3105	2.40	.0550
60.0	.3070	3.98	.0230
70.0	.3035	5.48	.0165
80.0	.3000	6.98	.0100
90.0	.2965	8.39	.0088
100.0	.2930	9.80	.0075
110.0	.2909	10.63	.0067
120.0	.2888	11.45	.0060
130.0	.2867	12.19	.0058
140.0	.2846	12.93	.0055
150.0	.2825	13.22	.0038
160.0	.2808	13.51	.0020
170.0	.2791	14.16	.0018
180.0	.2774	14.81	.0015
190.0	.2757	15.31	.0010
200.0	.2740	15.82	.0005
210.0	.2722	16.99	.0004
220.0	.2704	18.15	.0002

230.0	.2686	19.32	.0001
240.0	.2668	20.49	.0000
250.0	.2650	23.65	.0000
260.0	.2631	24.67	.0000
270.0	.2612	25.69	.0000
280.0	.2593	26.71	.0000
290.0	.2574	27.73	.0000
300.0	.2555	28.74	.0000
350.0	.2450	33.83	.0000
400.0	.2330	38.92	.0000
450.0	.2200	44.01	.0000
500.0	.2085	49.10	.0000
600.0	.1900	59.28	.0000
700.0	.1790	69.46	.0000
800.0	.1733	79.64	.0000
900.0	.1675	89.82	.0000

GREEN AMPT INFILTRATION PARAMETERS

W.T.D. (CM)	A (CM)	B (CM)
.000	.000	.000
50.000	1.200	.750
100.000	6.500	1.200
150.000	10.000	1.500
200.000	12.000	1.500
500.000	15.000	1.500
1000.000	15.000	1.500

TRAFFICABILITY
****

REQUIREMENTS	FIRST PERIOD	SECOND PERIOD
-MINIMUM AIR VOLUME IN SOIL (CM):	3.90	3.90
-MAXIMUM ALLOWABLE DAILY RAINFALL(CM):	1.20	1.20
-MINIMUM TIME AFTER RAIN BEFORE TILLING CAN CONTINUE:	2.00	2.00

WORKING TIMES		
-DATE TO BEGIN COUNTING WORK DAYS:	4/ 1	12/32
-DATE TO STOP COUNTING WORK DAYS:	5/ 1	12/32
-FIRST WORK HOUR OF THE DAY:	8	8
-LAST WORK HOUR OF THE DAY:	20	20

CROP
****

SOIL MOISTURE AT WILTING POINT = .17

HIGH WATER STRESS: BEGIN STRESS PERIOD ON 4/10
END STRESS PERIOD ON 8/18
CROP WAS IN STRESS WHEN WATER TABLE WAS ABOVE 30.0 CM

DROUGHT STRESS: BEGIN STRESS PERIOD ON 4/10
END STRESS PERIOD ON 8/18

MO	DAY	ROOTING DEPTH(CM)
1	1	3.0
4	16	3.0
5	4	4.0
5	17	15.0
6	1	25.0
6	20	30.0
7	18	30.0
8	20	20.0
9	24	10.0
9	25	3.0
12	31	3.0

WASTEWATER IRRIGATION
****

NO WASTEWATER IRRIGATION SCHEDULED:

***** Wetlands Parameter Estimation *****

Start Day = 1 End Day = 365
Threshold Water Table Depth (cm) = 5.0
Threshold Consecutive Days = 6

Fixed Monthly Pet Values

1 1.00 2 1.00 3 1.00 4 1.00 5 1.00 6 1.00 7 1.00 8 1.00 9 1.00 10 1.00 11 1.00 12 1.00

Mrank indicator = 0

***************************** END OF INPUTS *****************************

----------RUN STATHISTICS ---------- time: 11/28/2004 @ 17:46
input file: C:\Drainmod\inputs\Lenoir2Calib.prj
parameters: controlled drainage and yields not calculated
drain spacing = 5090. cm drain depth = 77.0 cm

C.6 DRAINMOD inputs for plot Ta at the Cool Springs site

```
******************************************************************************

                         D R A I N M O D  5.1

            Copyright 1980-99 North Carolina State University
                       LAST UPDATE: SEPT 1999
                        LANGUAGE FORTRAN 77/90

     DRAINMOD WAS A FIELD-SCALE HYDROLOGIC MODEL DEVELOPED FOR
      THE DESIGN OF SUBSURFACE DRAINAGE SYSTEMS. THE MODEL WAS
       DEVELOPED BY RESEARCHERS AT THE DEPT. OF BIOLOGICAL AND
      AGRICULTURAL ENGINEERING, NORTH CAROLINA STATE UNIVERSITY
               UNDER THE DIRECTION OF R. W. SKAGGS.

******************************************************************************


  DATA READ FROM INPUT FILE: C:\Drainmod\inputs\Coolsprings.prj
              Cream selector (0=no, 1=yes) =  0

                          TITLE OF RUN
                          ************


                         Tarboro



                         CLIMATE INPUTS
                         ******* ******

   DESCRIPTION                   (VARIABLE)    VALUE   UNIT
---------------------------------------------------------------------------
FILE FOR RAINDATA ..............C:\DRAINMOD\WEATHER\NEWCOOL.RAI
FILE FOR TEMPERATURE/PET DATA ..C:\DRAINMOD\WEATHER\COOLSPRI.TEM
RAINFALL STATION NUMBER..........................(RAINID)        1
TEMPERATURE/PET STATION NUMBER...................(TEMPID)        1
STARTING YEAR OF SIMULATION..................(START YEAR)     2004   YEAR
STARTING MONTH OF SIMULATION................(START MONTH)       4   MONTH
ENDING YEAR OF SIMULATION......................(END YEAR)     2004   YEAR
ENDING MONTH OF SIMULATION....................(END MONTH)        8   MONTH
TEMPERATURE STATION LATITUDE...................(TEMP LAT)     35.47   DEG.MIN
HEAT INDEX..........................................(HID)     75.00


              ET MULTIPLICATION FACTOR FOR EACH MONTH
   2.01  2.32  2.10  1.72  1.23  1.00   .86   .82   .92  1.05  1.22  1.44


                      DRAINAGE SYSTEM DESIGN
```

```
                              *********************
                         *** CONVENTIONAL DRAINAGE ***
                               JOB TITLE:


                              Tarboro


                    STMAX =  .20 CM              SOIL SURFACE
+     __/)_______________________________________________________/)__
                         :                            :
                         :                            :
                         :                            :
                         :                            :
                         :                            :
               ADEPTH =250. CM                 DDRAIN =115. CM
                         :                            :
                         :                            :
                   :   O-------------SDRAIN =  400. CM -----------O  -
                         :   *                        :
                     : EFFRAD =**** CM                     :
                   :                           HDRAIN =109. CM
                         :                            :
                         :                            :
                   - - - - - - - - - - - - - - - - - - - - - - - - - - - -
                                      :
                                      :
                                      :
                   :                         IMPERMEABLE LAYER
+     ___________________________________________________________________
                   ///////////////////////////////////////////////////////
```

DEPTH (CM)	SATURATED HYDRAULIC CONDUCTIVITY (CM/HR)
.0 - 75.0	25.000
75.0 - 110.0	20.000
110.0 - 224.1	25.000

DEPTH TO DRAIN = 115.0 CM
EFFECTIVE DEPTH FROM DRAIN TO IMPERMEABLE LAYER = 109.1 CM
DISTANCE BETWEEN DRAINS =   400.0 CM
MAXIMUM DEPTH OF SURFACE PONDING =   .20 CM
EFFECTIVE DEPTH TO IMPERMEABLE LAYER = 224.1 CM
DRAINAGE COEFFICIENT(AS LIMITED BY SUBSURFACE OUTLET) = 2.50 CM/DAY
MAXIMUM PUMPING CAPACITY (SUBIRRIGATION MODE) =   2.50 CM/DAY
ACTUAL DEPTH FROM SURFACE TO IMPERMEABLE LAYER = 250.0 CM
SURFACE STORAGE THAT MUST BE FILLED BEFORE WATER
  CAN MOVE TO DRAIN = .20 CM
FACTOR -G- IN KIRKHAM EQ. 2-17 = 4.56

*** SEEPAGE LOSS INPUTS ***

No seepage due to field slope

No seepage due to vertical deep seepage

No seepage due to lateral deep seepage

*** end of seepage inputs ***

WIDTH OF DITCH BOTTOM = 100.0 CM
SIDE SLOPE OF DITCH (HORIZ:VERT) = .50 : 1.00

INITIAL WATER TABLE DEPTH = 75.0 CM

DEPTH OF WEIR FROM THE SURFACE

DATE	1/ 1	2/ 1	3/ 1	4/ 1	5/ 1	6/ 1
WEIR DEPTH	115.0	115.0	115.0	115.0	115.0	115.0

DATE	7/ 1	8/ 1	9/ 1	10/ 1	11/ 1	12/ 1
WEIR DEPTH	115.0	115.0	115.0	115.0	115.0	115.0

DRAINMOD has changed the final entry in the SOIL WATER CHARACTERISTIC TABLE to:

X(IVREAD)	XVOL(IVREAD)	FLUX(IVREAD)
1000.	100.	0.0

(entered values had WTD <1000. or vol. drained <100.)

** SEE DRAINMOD USERS MANUAL FOR EXPLANATION **

SOIL INPUTS
****

TABLE 1

DRAINAGE TABLE

VOID VOLUME (CM)	WATER TABLE DEPTH (CM)
.0	.0
1.0	14.0
2.0	23.3
3.0	31.3
4.0	37.5
5.0	44.3
6.0	51.4
7.0	58.6
8.0	65.0
9.0	71.3

10.0	77.5
11.0	83.8
12.0	90.0
13.0	95.6
14.0	101.0
15.0	106.0
16.0	112.1
17.0	122.7
18.0	133.3
19.0	143.8
20.0	154.4
21.0	165.0
22.0	175.5
23.0	186.1
24.0	196.7
25.0	207.2
26.0	217.8
27.0	228.4
28.0	239.0
29.0	249.5
30.0	260.1
35.0	312.9
40.0	365.8
45.0	418.6
50.0	471.5
60.0	577.2
70.0	682.9
80.0	788.6
90.0	894.3

1 TABLE 2

SOIL WATER CHARACTERISTIC VS VOID VOLUME VS UPFLUX

HEAD (CM)	WATER CONTENT (CM/CM)	VOID VOLUME (CM)	UPFLUX (CM/HR)
.0	.3700	.00	.2000
10.0	.3000	.60	.1000
20.0	.2820	1.60	.0800
30.0	.2720	2.80	.0250
40.0	.2660	4.40	.0112
50.0	.2580	5.80	.0058
60.0	.2540	7.20	.0031
70.0	.2480	8.80	.0018
80.0	.2440	10.40	.0010
90.0	.2410	12.00	.0004
100.0	.2380	13.80	.0000
110.0	.2360	15.80	.0000
120.0	.2340	16.75	.0000
130.0	.2320	17.69	.0000
140.0	.2300	18.64	.0000
150.0	.2280	19.58	.0000
160.0	.2272	20.53	.0000
170.0	.2264	21.48	.0000
180.0	.2256	22.42	.0000

190.0	.2248	23.37	.0000
200.0	.2240	24.31	.0000
210.0	.2236	25.26	.0000
220.0	.2232	26.21	.0000
230.0	.2228	27.15	.0000
240.0	.2224	28.10	.0000
250.0	.2219	29.04	.0000
260.0	.2215	29.99	.0000
270.0	.2211	30.94	.0000
280.0	.2207	31.88	.0000
290.0	.2203	32.83	.0000
300.0	.2199	33.78	.0000
350.0	.2178	38.51	.0000
400.0	.2158	43.24	.0000
450.0	.2137	47.97	.0000
500.0	.2117	52.70	.0000
600.0	.2076	62.16	.0000
700.0	.2034	71.62	.0000
800.0	.1993	81.08	.0000
900.0	.1952	90.54	.0000

GREEN AMPT INFILTRATION PARAMETERS

W.T.D. (CM)	A (CM)	B (CM)
.000	.000	.000
50.000	1.200	1.000
100.000	3.300	1.000
150.000	6.000	1.000
200.000	9.200	1.000
500.000	25.000	1.000
1000.000	25.000	1.000

TRAFFICABILITY
****

REQUIREMENTS	FIRST PERIOD	SECOND PERIOD
-MINIMUM AIR VOLUME IN SOIL (CM):	3.90	3.90
-MAXIMUM ALLOWABLE DAILY RAINFALL(CM):	1.20	1.20
-MINIMUM TIME AFTER RAIN BEFORE TILLING CAN CONTINUE:	2.00	2.00
WORKING TIMES		
-DATE TO BEGIN COUNTING WORK DAYS:	3/15	12/32
-DATE TO STOP COUNTING WORK DAYS:	4/30	12/32
-FIRST WORK HOUR OF THE DAY:	8	8
-LAST WORK HOUR OF THE DAY:	20	20

CROP
****

SOIL MOISTURE AT WILTING POINT = .17

HIGH WATER STRESS: BEGIN STRESS PERIOD ON   3/15
END STRESS PERIOD ON   11/15
CROP WAS IN STRESS WHEN WATER TABLE WAS ABOVE 30.0 CM

DROUGHT STRESS: BEGIN STRESS PERIOD ON 11/15
END STRESS PERIOD ON   11/15

MO	DAY	ROOTING DEPTH(CM)
1	1	30.0
12	31	30.0

WASTEWATER IRRIGATION
****

NO WASTEWATER IRRIGATION SCHEDULED:

***** Wetlands Parameter Estimation *****

Start Day =   1   End Day = 365
Threshold Water Table Depth (cm) = 104.0
Threshold Consecutive Days   =   14

Fixed Monthly Pet Values

1 1.00   2 1.00   3 1.00   4 1.00   5 1.00   6 1.00   7 1.00   8 1.00   9 1.00   10 1.00   11 1.00   12 1.00

Mrank indicator = 0

****************************** END OF INPUTS ******************************

----------RUN STATHISTICS ----------   time: 12/16/2004 @ 4:57
input file: C:\Drainmod\inputs\Coolsprings.prj
parameters: free drainage   and yields not calculated
drain spacing =   400. cm   drain depth = 115.0 cm

C.7 DRAINMOD inputs for plot wTa 1 at the Cool Springs site

****

D R A I N M O D 5.1

LAST UPDATE: SEPT 1999
LANGUAGE FORTRAN 77/90

DRAINMOD WAS A FIELD-SCALE HYDROLOGIC MODEL DEVELOPED FOR THE DESIGN OF SUBSURFACE DRAINAGE SYSTEMS. THE MODEL WAS DEVELOPED BY RESEARCHERS AT THE DEPT. OF BIOLOGICAL AND AGRICULTURAL ENGINEERING, NORTH CAROLINA STATE UNIVERSITY UNDER THE DIRECTION OF R. W. SKAGGS.

****

DATA READ FROM INPUT FILE: C:\Drainmod\inputs\Coolsprings.prj
Cream selector (0=no, 1=yes) = 0

TITLE OF RUN
****

wet Tarboro

CLIMATE INPUTS
******* ******

```
DESCRIPTION                        (VARIABLE)     VALUE   UNIT
-----------------------------------------------------------------------------
FILE FOR RAINDATA ..............C:\DRAINMOD\WEATHER\NEWCOOL.RAI
FILE FOR TEMPERATURE/PET DATA ..C:\DRAINMOD\WEATHER\COOLSPRI.TEM
RAINFALL STATION NUMBER..........................(RAINID)        1
TEMPERATURE/PET STATION NUMBER...................(TEMPID)        1
STARTING YEAR OF SIMULATION..................(START YEAR)      2004   YEAR
STARTING MONTH OF SIMULATION................(START MONTH)        4   MONTH
ENDING YEAR OF SIMULATION......................(END YEAR)      2004   YEAR
ENDING MONTH OF SIMULATION....................(END MONTH)        8   MONTH
TEMPERATURE STATION LATITUDE...................(TEMP LAT)      35.47   DEG.MIN
HEAT INDEX..........................................(HID)      75.00
```

ET MULTIPLICATION FACTOR FOR EACH MONTH
2.01 2.32 2.10 1.72 1.23 1.00 .86 .82 .92 1.05 1.22 1.44

DRAINAGE SYSTEM DESIGN
****

*** CONVENTIONAL DRAINAGE ***

JOB TITLE:

wet Tarboro

```
                         STMAX =  .20 CM              SOIL SURFACE
+      __/)______________________________________________________/)__
                               :                           :
                               :                           :
                               :                           :
                               :                           :
                               :                           :
                   ADEPTH =200. CM                    DDRAIN =104. CM
                               :                           :
                               :                           :
                       :   O------------SDRAIN =  900. CM -----------O  -
                               :    *                      :
                          : EFFRAD =**** CM                     :
                        :                        HDRAIN = 96. CM
                               :                           :
                               :                           :
                       - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
                                          :
                                          :
                                          :
                       :                         IMPERMEABLE LAYER
+      ______________________________________________________________
                       ///////////////////////////////////////////////////////////////////
```

DEPTH (CM)	SATURATED HYDRAULIC CONDUCTIVITY (CM/HR)
.0 - 75.0	25.000
75.0 - 110.0	20.000
110.0 - 200.0	25.000

DEPTH TO DRAIN = 104.0 CM
EFFECTIVE DEPTH FROM DRAIN TO IMPERMEABLE LAYER = 96.0 CM
DISTANCE BETWEEN DRAINS =   900.0 CM
MAXIMUM DEPTH OF SURFACE PONDING =   .20 CM
EFFECTIVE DEPTH TO IMPERMEABLE LAYER = 200.0 CM
DRAINAGE COEFFICIENT(AS LIMITED BY SUBSURFACE OUTLET) = 2.50 CM/DAY
MAXIMUM PUMPING CAPACITY (SUBIRRIGATION MODE) =   2.50 CM/DAY
ACTUAL DEPTH FROM SURFACE TO IMPERMEABLE LAYER = 200.0 CM
SURFACE STORAGE THAT MUST BE FILLED BEFORE WATER
CAN MOVE TO DRAIN = .20 CM

FACTOR -G- IN KIRKHAM EQ. 2-17 = 3.93

*** SEEPAGE LOSS INPUTS ***

No seepage due to field slope

No seepage due to vertical deep seepage

No seepage due to lateral deep seepage

*** end of seepage inputs ***

WIDTH OF DITCH BOTTOM = 100.0 CM
SIDE SLOPE OF DITCH (HORIZ:VERT) = .50 : 1.00

INITIAL WATER TABLE DEPTH = 62.0 CM

DEPTH OF WEIR FROM THE SURFACE

DATE	1/ 1	2/ 1	3/ 1	4/ 1	5/ 1	6/ 1
WEIR DEPTH	104.0	104.0	104.0	104.0	104.0	104.0

DATE	7/ 1	8/ 1	9/ 1	10/ 1	11/ 1	12/ 1
WEIR DEPTH	104.0	104.0	104.0	104.0	104.0	104.0

DRAINMOD has changed the final entry in the SOIL WATER CHARACTERISTIC TABLE to:

X(IVREAD)	XVOL(IVREAD)	FLUX(IVREAD)
1000.	100.	0.0

(entered values had WTD <1000. or vol. drained <100.)

** SEE DRAINMOD USERS MANUAL FOR EXPLANATION **

SOIL INPUTS
****

TABLE 1

DRAINAGE TABLE

VOID VOLUME (CM)	WATER TABLE DEPTH (CM)
.0	.0
1.0	14.0
2.0	23.3
3.0	31.3
4.0	37.5
5.0	44.3
6.0	51.4
7.0	58.6

8.0	65.0
9.0	71.3
10.0	77.5
11.0	83.8
12.0	90.0
13.0	95.6
14.0	101.0
15.0	106.0
16.0	112.1
17.0	122.7
18.0	133.3
19.0	143.8
20.0	154.4
21.0	165.0
22.0	175.5
23.0	186.1
24.0	196.7
25.0	207.2
26.0	217.8
27.0	228.4
28.0	239.0
29.0	249.5
30.0	260.1
35.0	312.9
40.0	365.8
45.0	418.6
50.0	471.5
60.0	577.2
70.0	682.9
80.0	788.6
90.0	894.3

TABLE 2

SOIL WATER CHARACTERISTIC VS VOID VOLUME VS UPFLUX

HEAD (CM)	WATER CONTENT (CM/CM)	VOID VOLUME (CM)	UPFLUX (CM/HR)
.0	.3700	.00	.2000
10.0	.3000	.60	.1000
20.0	.2820	1.60	.0800
30.0	.2720	2.80	.0250
40.0	.2660	4.40	.0112
50.0	.2580	5.80	.0058
60.0	.2540	7.20	.0031
70.0	.2480	8.80	.0018
80.0	.2440	10.40	.0010
90.0	.2410	12.00	.0004
100.0	.2380	13.80	.0000
110.0	.2360	15.80	.0000
120.0	.2340	16.75	.0000
130.0	.2320	17.69	.0000
140.0	.2300	18.64	.0000
150.0	.2280	19.58	.0000
160.0	.2272	20.53	.0000

170.0	.2264	21.48	.0000
180.0	.2256	22.42	.0000
190.0	.2248	23.37	.0000
200.0	.2240	24.31	.0000
210.0	.2236	25.26	.0000
220.0	.2232	26.21	.0000
230.0	.2228	27.15	.0000
240.0	.2224	28.10	.0000
250.0	.2219	29.04	.0000
260.0	.2215	29.99	.0000
270.0	.2211	30.94	.0000
280.0	.2207	31.88	.0000
290.0	.2203	32.83	.0000
300.0	.2199	33.78	.0000
350.0	.2178	38.51	.0000
400.0	.2158	43.24	.0000
450.0	.2137	47.97	.0000
500.0	.2117	52.70	.0000
600.0	.2076	62.16	.0000
700.0	.2034	71.62	.0000
800.0	.1993	81.08	.0000
900.0	.1952	90.54	.0000

GREEN AMPT INFILTRATION PARAMETERS

W.T.D. (CM)	A (CM)	B (CM)
.000	.000	.000
50.000	1.200	1.000
100.000	3.300	1.000
150.000	6.000	1.000
200.000	9.200	1.000
500.000	25.000	1.000
1000.000	25.000	1.000

TRAFFICABILITY
****

REQUIREMENTS	FIRST PERIOD	SECOND PERIOD
-MINIMUM AIR VOLUME IN SOIL (CM):	3.90	3.90
-MAXIMUM ALLOWABLE DAILY RAINFALL(CM):	1.20	1.20
-MINIMUM TIME AFTER RAIN BEFORE TILLING CAN CONTINUE:	2.00	2.00
WORKING TIMES		
-DATE TO BEGIN COUNTING WORK DAYS:	3/15	12/32
-DATE TO STOP COUNTING WORK DAYS:	4/30	12/32
-FIRST WORK HOUR OF THE DAY:	8	8
-LAST WORK HOUR OF THE DAY:	20	20

CROP
****

SOIL MOISTURE AT WILTING POINT = .17

HIGH WATER STRESS: BEGIN STRESS PERIOD ON 3/15
END STRESS PERIOD ON 11/15
CROP WAS IN STRESS WHEN WATER TABLE WAS ABOVE 30.0 CM

DROUGHT STRESS: BEGIN STRESS PERIOD ON 11/15
END STRESS PERIOD ON 11/15

MO	DAY	ROOTING DEPTH(CM)
1	1	30.0
12	31	30.0

WASTEWATER IRRIGATION
****

NO WASTEWATER IRRIGATION SCHEDULED:

***** Wetlands Parameter Estimation *****

Start Day = 1 End Day = 365
Threshold Water Table Depth (cm) = 44.0
Threshold Consecutive Days = 14

Fixed Monthly Pet Values

1 1.00 2 1.00 3 1.00 4 1.00 5 1.00 6 1.00 7 1.00 8 1.00 9 1.00 10 1.00 11 1.00 12 1.00

Mrank indicator = 0

***************************** END OF INPUTS *****************************

----------RUN STATHISTICS ---------- time: 12/16/2004 @ 4:35
input file: C:\Drainmod\inputs\Coolsprings.prj
parameters: free drainage and yields not calculated
drain spacing = 900. cm drain depth = 104.0 cm

C.8 DRAINMOD inputs for plot Se 1 at the Cool Springs site

****

D R A I N M O D 5.1

Copyright 1980-99 North Carolina State University
LAST UPDATE: SEPT 1999
LANGUAGE FORTRAN 77/90

DRAINMOD WAS A FIELD-SCALE HYDROLOGIC MODEL DEVELOPED FOR THE DESIGN OF SUBSURFACE DRAINAGE SYSTEMS. THE MODEL WAS DEVELOPED BY RESEARCHERS AT THE DEPT. OF BIOLOGICAL AND AGRICULTURAL ENGINEERING, NORTH CAROLINA STATE UNIVERSITY UNDER THE DIRECTION OF R. W. SKAGGS.

****

DATA READ FROM INPUT FILE: C:\Drainmod\inputs\Coolsprings.prj
Cream selector (0=no, 1=yes) = 0

TITLE OF RUN
****

Seabrook 1

CLIMATE INPUTS
******* ******

```
DESCRIPTION                    (VARIABLE)    VALUE   UNIT
-----------------------------------------------------------------------------
FILE FOR RAINDATA ..............C:\DRAINMOD\WEATHER\NEWCOOL.RAI
FILE FOR TEMPERATURE/PET DATA ..C:\DRAINMOD\WEATHER\COOLSPRI.TEM
RAINFALL STATION NUMBER...........................(RAINID)        1
TEMPERATURE/PET STATION NUMBER...................(TEMPID)        1
STARTING YEAR OF SIMULATION..................(START YEAR)      2004   YEAR
STARTING MONTH OF SIMULATION................(START MONTH)         4   MONTH
ENDING YEAR OF SIMULATION......................(END YEAR)      2004   YEAR
ENDING MONTH OF SIMULATION....................(END MONTH)         8   MONTH
TEMPERATURE STATION LATITUDE...................(TEMP LAT)      35.47   DEG.MIN
HEAT INDEX..........................................(HID)      75.00
```

ET MULTIPLICATION FACTOR FOR EACH MONTH
2.01 2.32 2.10 1.72 1.23 1.00 .86 .82 .92 1.05 1.22 1.44

DRAINAGE SYSTEM DESIGN
****

*** CONVENTIONAL DRAINAGE ***

JOB TITLE:

Seabrook 1

```
                    STMAX =  .55 CM               SOIL SURFACE
+       __/)____________________________________________________________/)__
                           :                                  :
                           :                                  :
                           :                                  :
                           :                                  :
                           :                                  :
             ADEPTH =130. CM                          DDRAIN = 58. CM
                           :                                  :
                           :                                  :
                   :    O-------------SDRAIN = 4000. CM -----------O  -
                           :    *                             :
                       : EFFRAD =**** CM                              :
                     :                              HDRAIN = 72. CM
                           :                                  :
                           :                                  :
                   - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
                                              :
                                              :
                                              :
                    :                         IMPERMEABLE LAYER
+       ____________________________________________________________________________
                    ////////////////////////////////////////////////////////////////////
```

DEPTH (CM)	SATURATED HYDRAULIC CONDUCTIVITY (CM/HR)
.0 - 75.0	25.000
75.0 - 110.0	20.000
110.0 - 200.0	25.000

DEPTH TO DRAIN = 58.0 CM
EFFECTIVE DEPTH FROM DRAIN TO IMPERMEABLE LAYER = 72.0 CM
DISTANCE BETWEEN DRAINS = 4000.0 CM
MAXIMUM DEPTH OF SURFACE PONDING = .55 CM
EFFECTIVE DEPTH TO IMPERMEABLE LAYER = 130.0 CM
DRAINAGE COEFFICIENT(AS LIMITED BY SUBSURFACE OUTLET) = 2.50 CM/DAY
MAXIMUM PUMPING CAPACITY (SUBIRRIGATION MODE) = 2.50 CM/DAY

ACTUAL DEPTH FROM SURFACE TO IMPERMEABLE LAYER = 130.0 CM
SURFACE STORAGE THAT MUST BE FILLED BEFORE WATER
CAN MOVE TO DRAIN = .55 CM
FACTOR -G- IN KIRKHAM EQ. 2-17 = 2.79

*** SEEPAGE LOSS INPUTS ***

No seepage due to field slope

No seepage due to vertical deep seepage

No seepage due to lateral deep seepage

*** end of seepage inputs ***

WIDTH OF DITCH BOTTOM = 100.0 CM
SIDE SLOPE OF DITCH (HORIZ:VERT) = .50 : 1.00

INITIAL WATER TABLE DEPTH = 69.0 CM

DEPTH OF WEIR FROM THE SURFACE

DATE	1/ 1	2/ 1	3/ 1	4/ 1	5/ 1	6/ 1
WEIR DEPTH	58.0	58.0	58.0	58.0	58.0	58.0

DATE	7/ 1	8/ 1	9/ 1	10/ 1	11/ 1	12/ 1
WEIR DEPTH	58.0	58.0	58.0	58.0	58.0	58.0

DRAINMOD has changed the final entry in the SOIL WATER CHARACTERISTIC TABLE to:

X(IVREAD)	XVOL(IVREAD)	FLUX(IVREAD)
1000.	100.	0.0

(entered values had WTD <1000. or vol. drained <100.)

** SEE DRAINMOD USERS MANUAL FOR EXPLANATION **

SOIL INPUTS
****

TABLE 1

DRAINAGE TABLE

VOID VOLUME (CM)	WATER TABLE DEPTH (CM)
.0	.0
1.0	14.0
2.0	23.3
3.0	31.3
4.0	37.5
5.0	44.3

6.0	51.4
7.0	58.6
8.0	65.0
9.0	71.3
10.0	77.5
11.0	83.8
12.0	90.0
13.0	95.6
14.0	101.0
15.0	106.0
16.0	112.1
17.0	122.7
18.0	133.3
19.0	143.8
20.0	154.4
21.0	165.0
22.0	175.5
23.0	186.1
24.0	196.7
25.0	207.2
26.0	217.8
27.0	228.4
28.0	239.0
29.0	249.5
30.0	260.1
35.0	312.9
40.0	365.8
45.0	418.6
50.0	471.5
60.0	577.2
70.0	682.9
80.0	788.6
90.0	894.3

1 TABLE 2

SOIL WATER CHARACTERISTIC VS VOID VOLUME VS UPFLUX

HEAD (CM)	WATER CONTENT (CM/CM)	VOID VOLUME (CM)	UPFLUX (CM/HR)
.0	.3700	.00	.2000
10.0	.3000	.60	.1000
20.0	.2820	1.60	.0800
30.0	.2720	2.80	.0250
40.0	.2660	4.40	.0112
50.0	.2580	5.80	.0058
60.0	.2540	7.20	.0031
70.0	.2480	8.80	.0018
80.0	.2440	10.40	.0010
90.0	.2410	12.00	.0004
100.0	.2380	13.80	.0000
110.0	.2360	15.80	.0000
120.0	.2340	16.75	.0000
130.0	.2320	17.69	.0000
140.0	.2300	18.64	.0000
150.0	.2280	19.58	.0000

160.0	.2272	20.53	.0000
170.0	.2264	21.48	.0000
180.0	.2256	22.42	.0000
190.0	.2248	23.37	.0000
200.0	.2240	24.31	.0000
210.0	.2236	25.26	.0000
220.0	.2232	26.21	.0000
230.0	.2228	27.15	.0000
240.0	.2224	28.10	.0000
250.0	.2219	29.04	.0000
260.0	.2215	29.99	.0000
270.0	.2211	30.94	.0000
280.0	.2207	31.88	.0000
290.0	.2203	32.83	.0000
300.0	.2199	33.78	.0000
350.0	.2178	38.51	.0000
400.0	.2158	43.24	.0000
450.0	.2137	47.97	.0000
500.0	.2117	52.70	.0000
600.0	.2076	62.16	.0000
700.0	.2034	71.62	.0000
800.0	.1993	81.08	.0000
900.0	.1952	90.54	.0000

GREEN AMPT INFILTRATION PARAMETERS

W.T.D. (CM)	A (CM)	B (CM)
.000	.000	.000
50.000	1.200	1.000
100.000	3.300	1.000
150.000	6.000	1.000
200.000	9.200	1.000
500.000	25.000	1.000
1000.000	25.000	1.000

TRAFFICABILITY
****

REQUIREMENTS	FIRST PERIOD	SECOND PERIOD
-MINIMUM AIR VOLUME IN SOIL (CM):	3.90	3.90
-MAXIMUM ALLOWABLE DAILY RAINFALL(CM):	1.20	1.20
-MINIMUM TIME AFTER RAIN BEFORE TILLING CAN CONTINUE:	2.00	2.00

WORKING TIMES

-DATE TO BEGIN COUNTING WORK DAYS:	3/15	12/32
-DATE TO STOP COUNTING WORK DAYS:	4/30	12/32
-FIRST WORK HOUR OF THE DAY:	8	8
-LAST WORK HOUR OF THE DAY:	20	20

CROP

****

SOIL MOISTURE AT WILTING POINT = .17

HIGH WATER STRESS: BEGIN STRESS PERIOD ON 3/15
END STRESS PERIOD ON 11/15
CROP WAS IN STRESS WHEN WATER TABLE WAS ABOVE 30.0 CM
DROUGHT STRESS: BEGIN STRESS PERIOD ON 11/15
END STRESS PERIOD ON 11/15

MO	DAY	ROOTING DEPTH(CM)
1	1	30.0
12	31	30.0

WASTEWATER IRRIGATION
****

NO WASTEWATER IRRIGATION SCHEDULED:

***** Wetlands Parameter Estimation *****

Start Day = 1 End Day = 365
Threshold Water Table Depth (cm) = 12.0
Threshold Consecutive Days = 14

Fixed Monthly Pet Values

1 .00 2 .00 3 .00 4 .00 5 .00 6 .00 7 .00 8 .00 9 .00 10 .00 11 .00 12 .00

Mrank indicator = 0

***************************** END OF INPUTS *****************************

----------RUN STATHISTICS ---------- time: 12/16/2004 @ 4: 6
input file: C:\Drainmod\inputs\Coolsprings.prj
parameters: free drainage and yields not calculated
drain spacing = 4000. cm drain depth = 58.0 cm

APPENDIX D

MEASURED HYDROGRAPHS AND REDOX FEATURE DEPTHS FOR ALL PLOTS AT EVERY STUDY SITE

RICHLANDS SITE

FORESTON SOILS

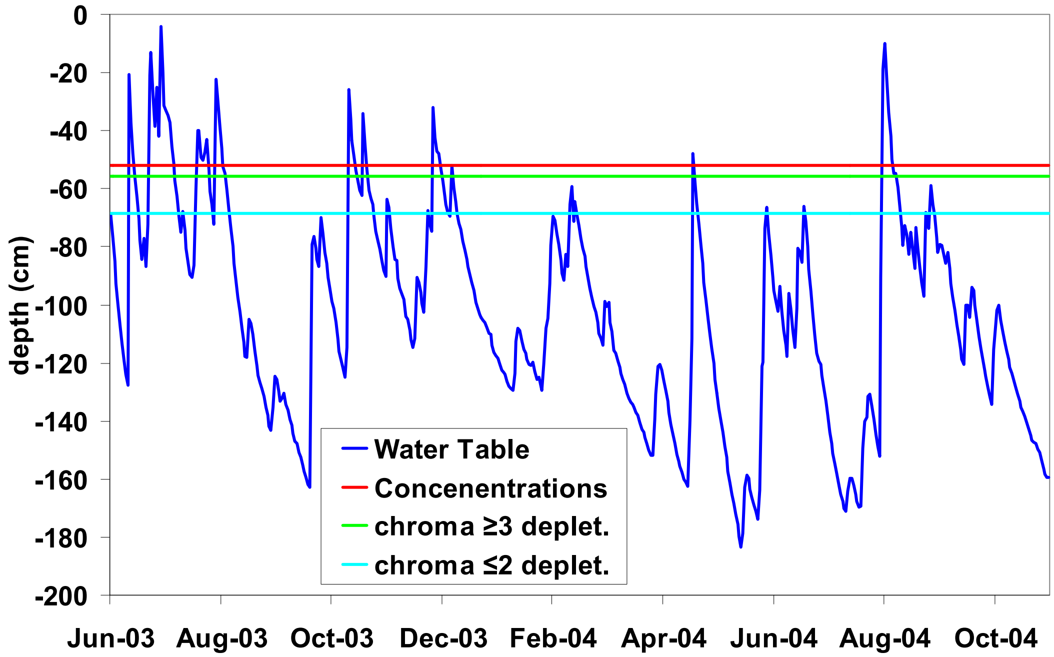

Figure D.1 Measured hydrograph and redox feature depths for the Foreston 1 plot.

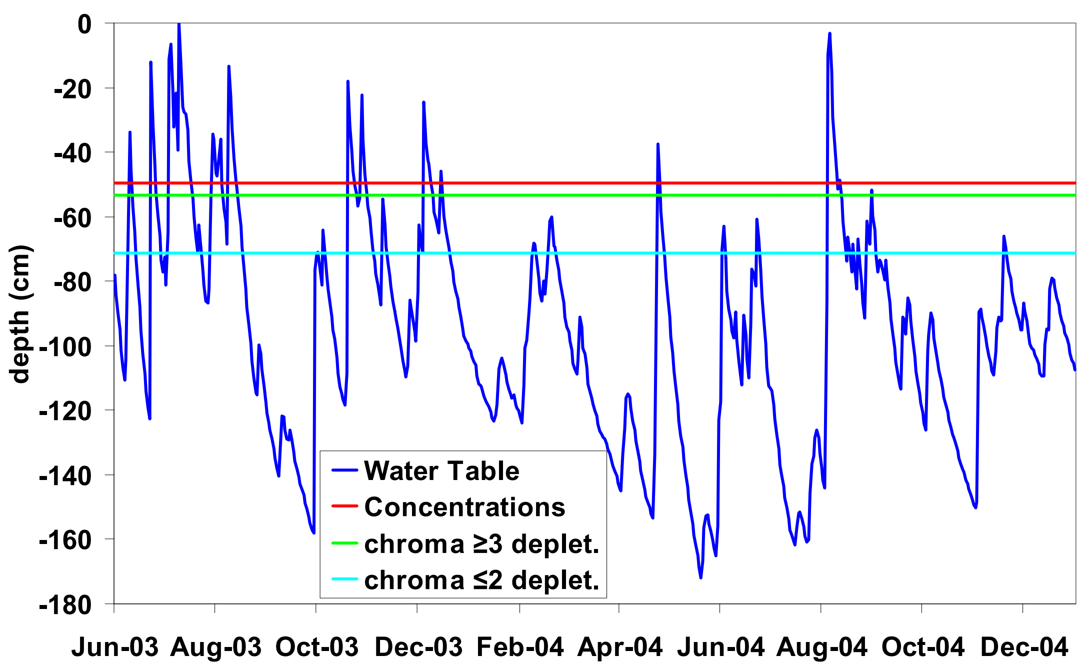

Figure D.2 Measured hydrograph and redox feature depths for the Foreston 2 plot.

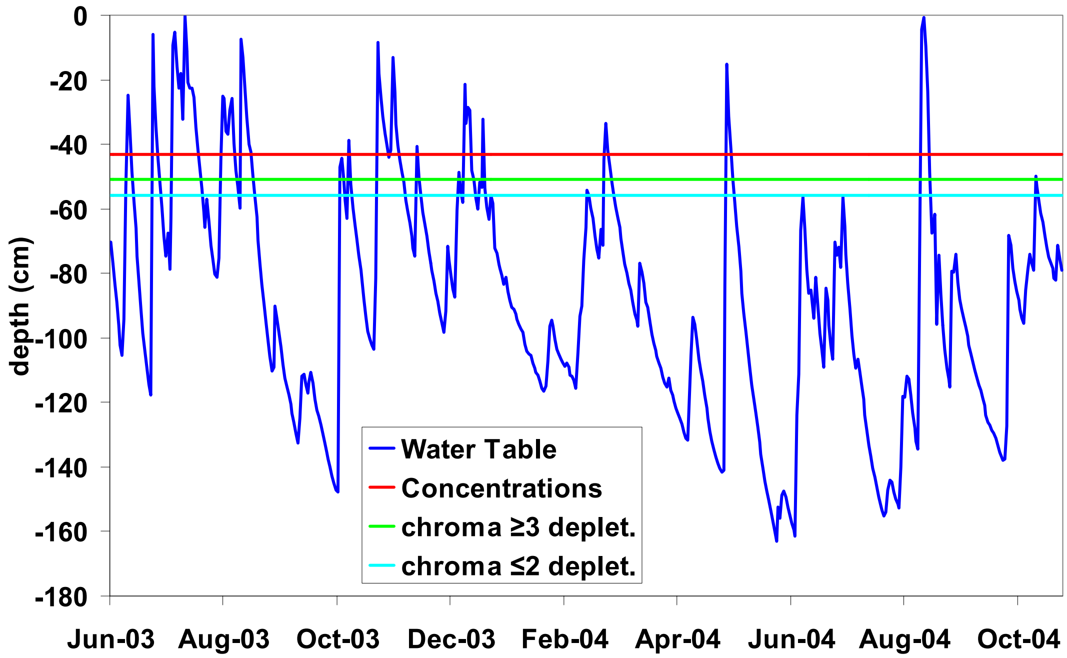

Figure D.3 Measured hydrograph and redox feature depths for the Foreston 3 plot.

Wet FORESTON SOILS

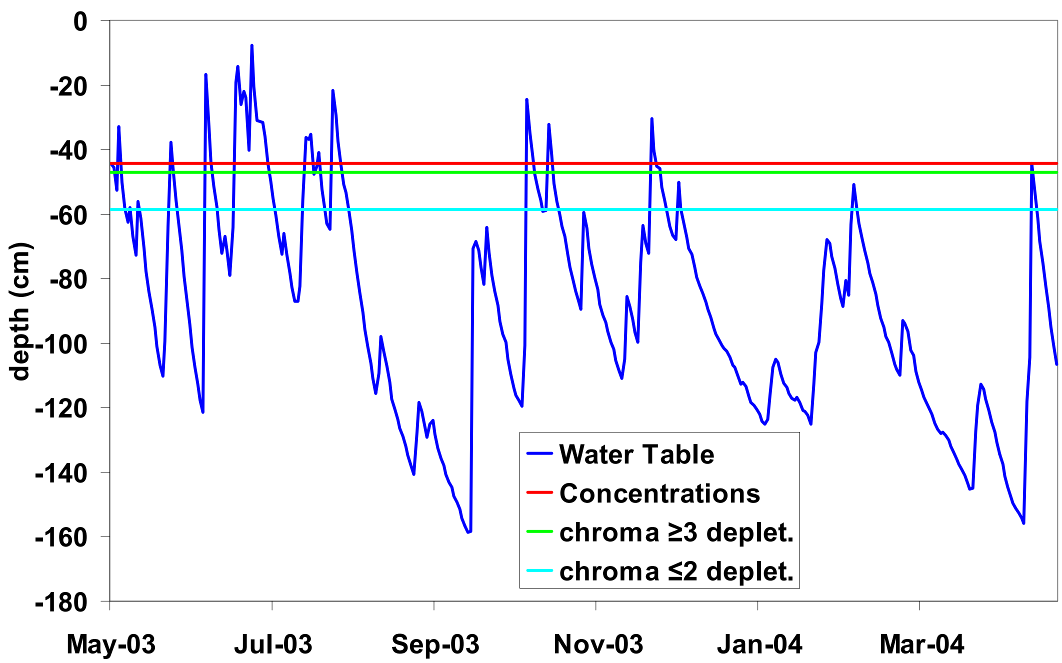

Figure D.4 Measured hydrograph and redox feature depths for the wet Foreston 1 plot.

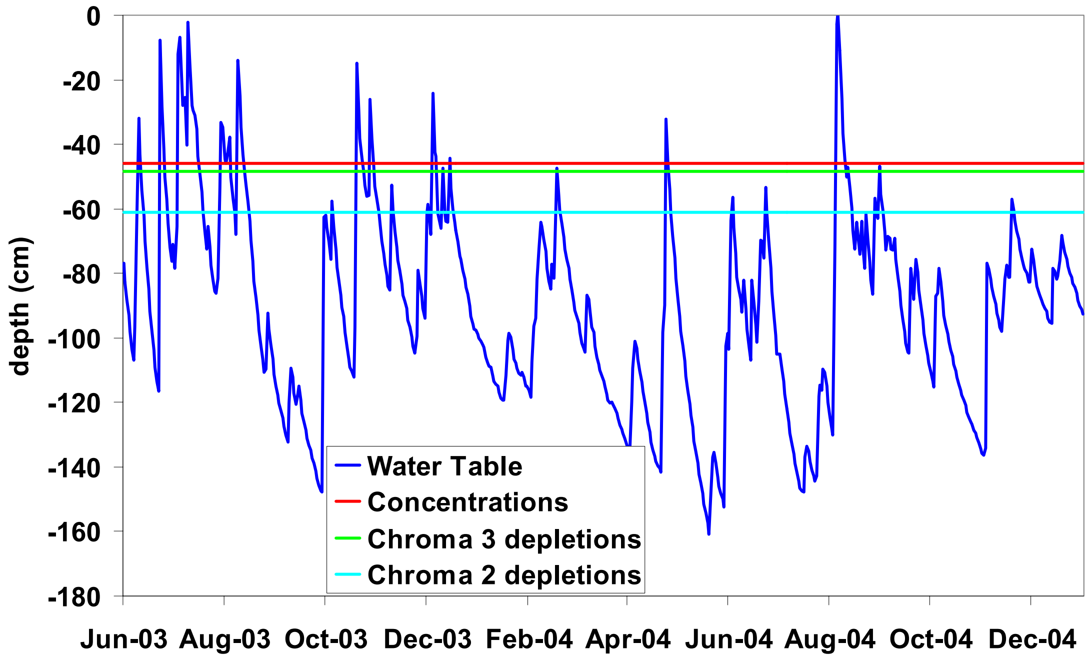

Figure D.5 Measured hydrograph and redox feature depths for the wet Foreston 2 plot.

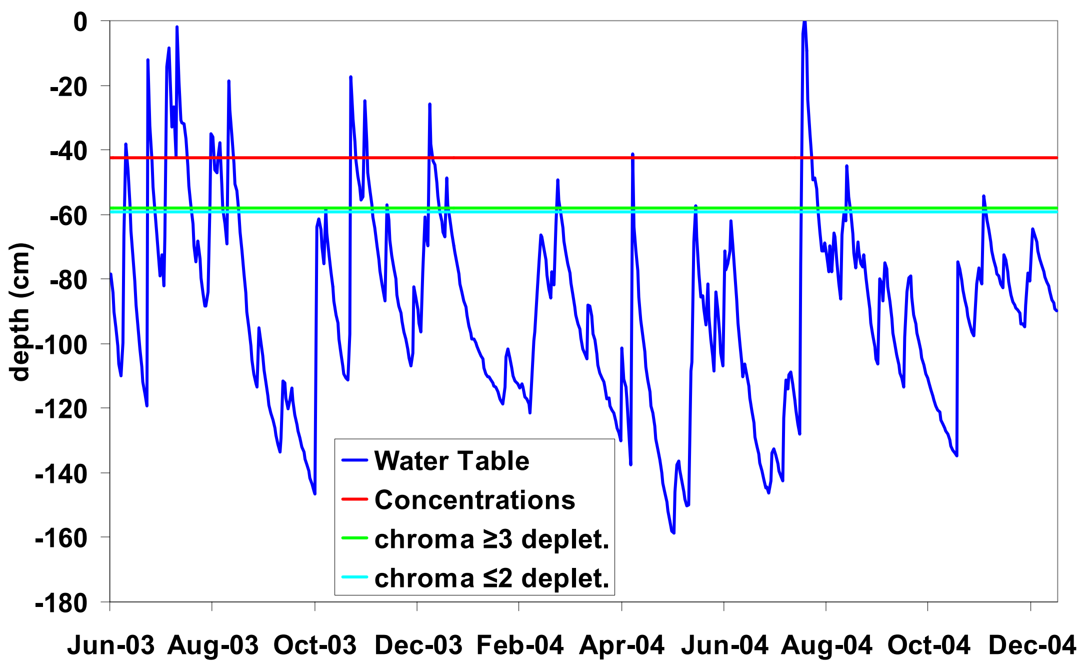

Figure D.6 Measured hydrograph and redox feature depths for the wet Foreston 3 plot.

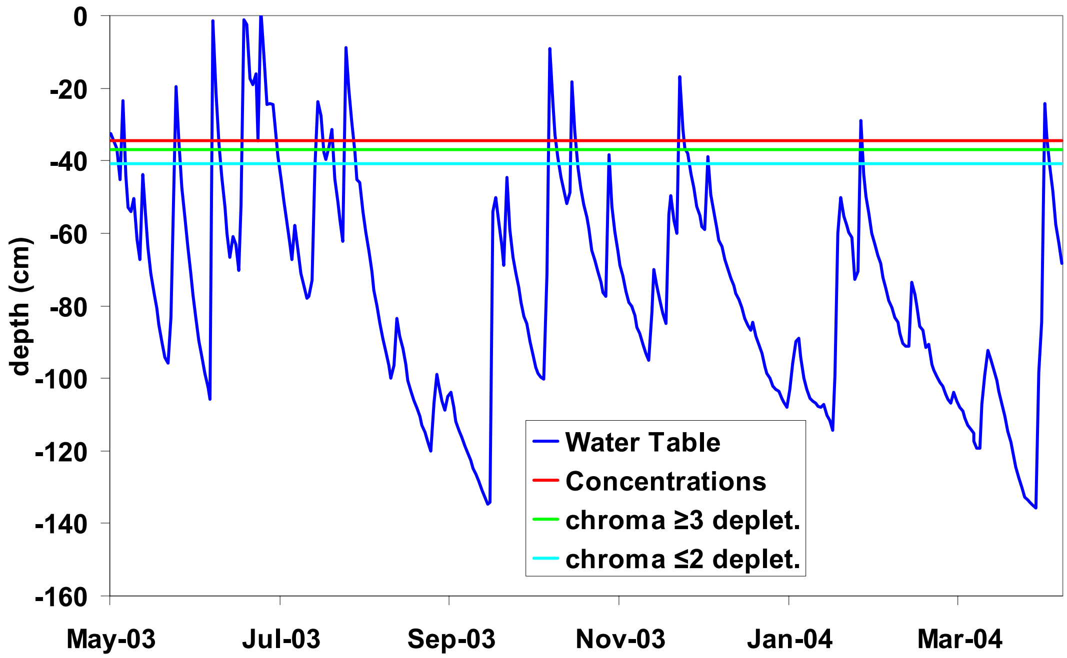

Figure D.7 Measured hydrograph and redox feature depths for the Stallings 1 plot.

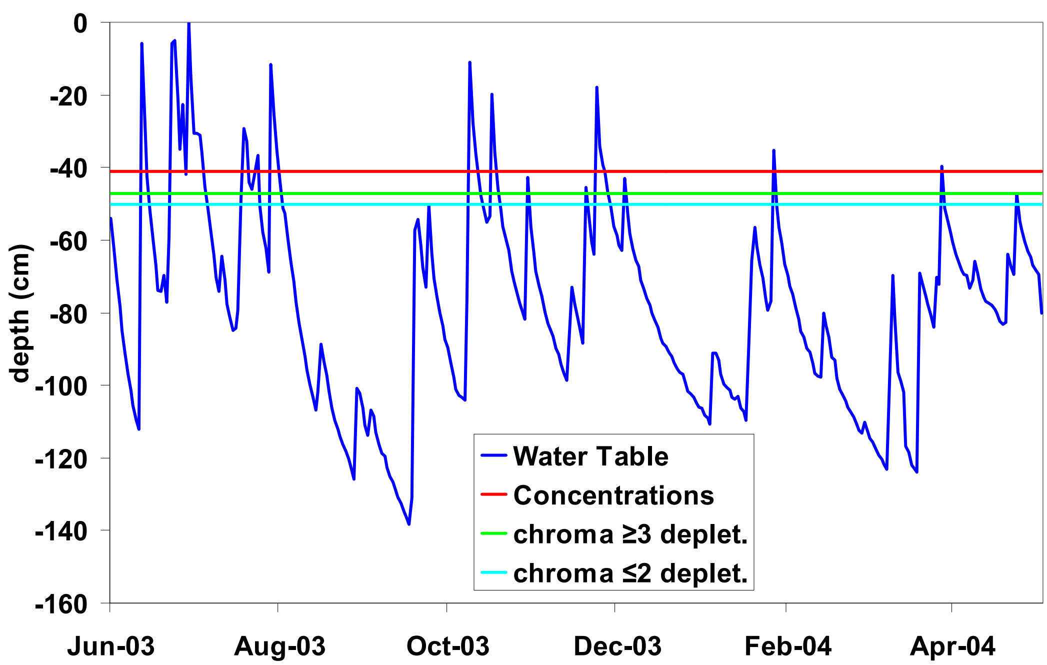

Figure D.8 Measured hydrograph and redox feature depths for the Stallings 2 plot.

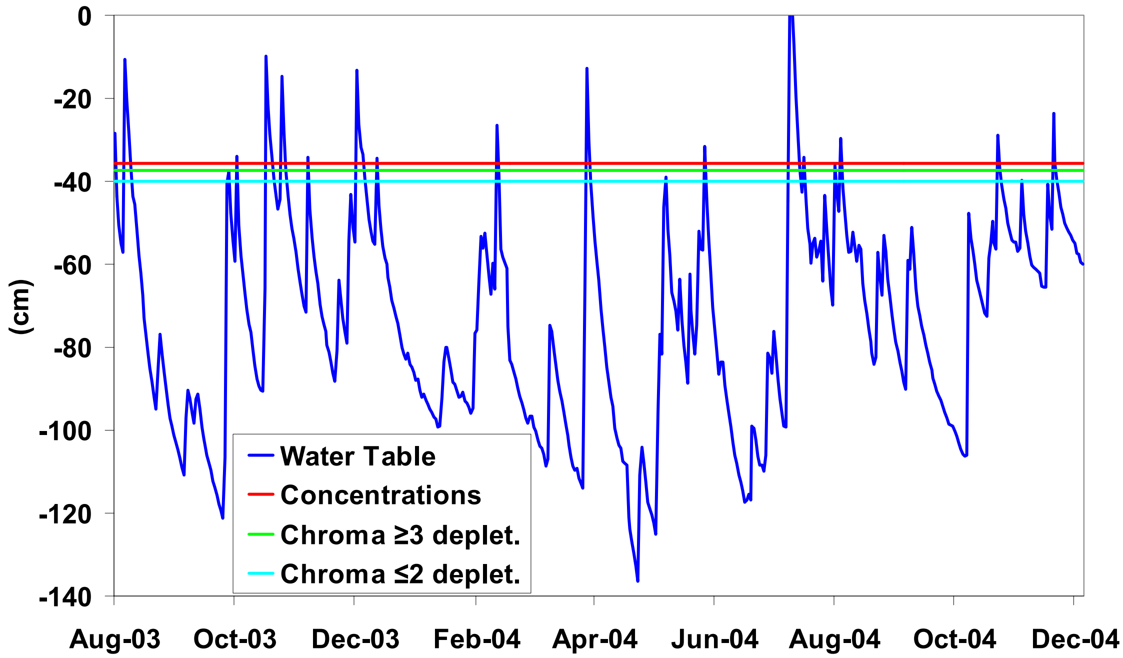

Figure D.9 Measured hydrograph and redox feature depths for the Stallings 3 plot.

VANCEBORO SITE

CRAVEN SOILS

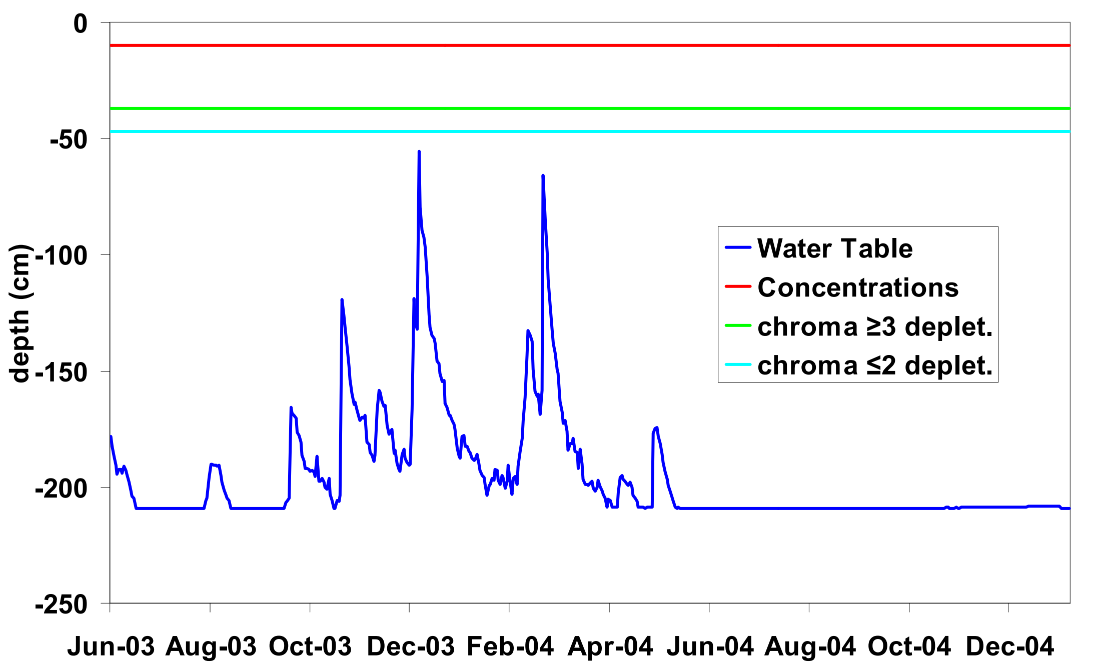

Figure D.10 Measured hydrograph and redox feature depths for the Craven 1 plot.

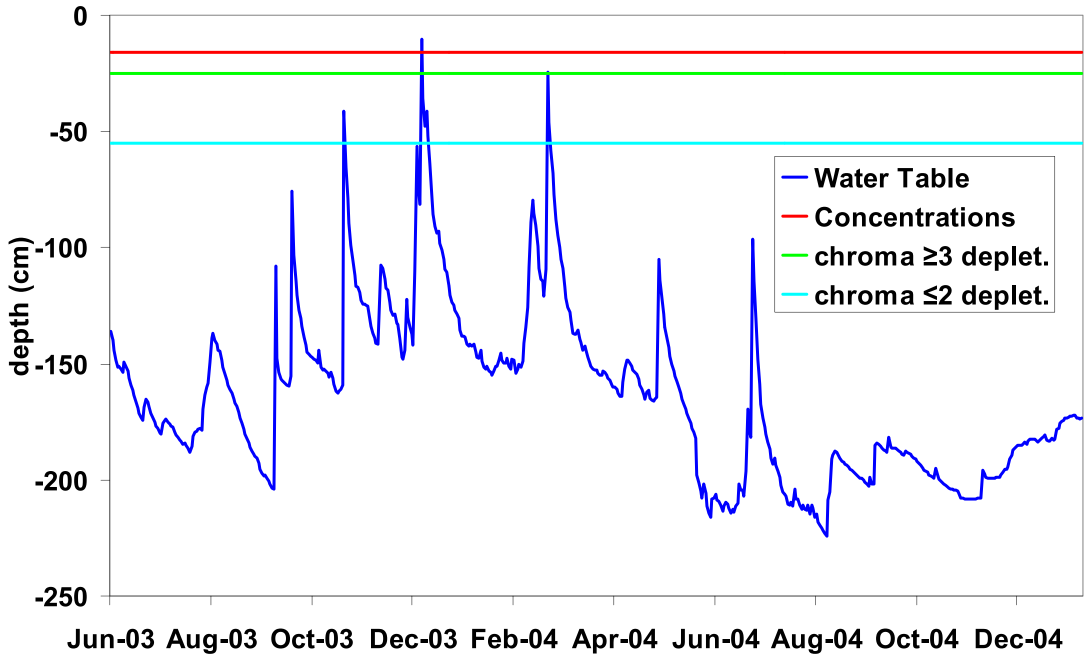

Figure D.11 Measured hydrograph and redox feature depths for the Craven 2 plot.

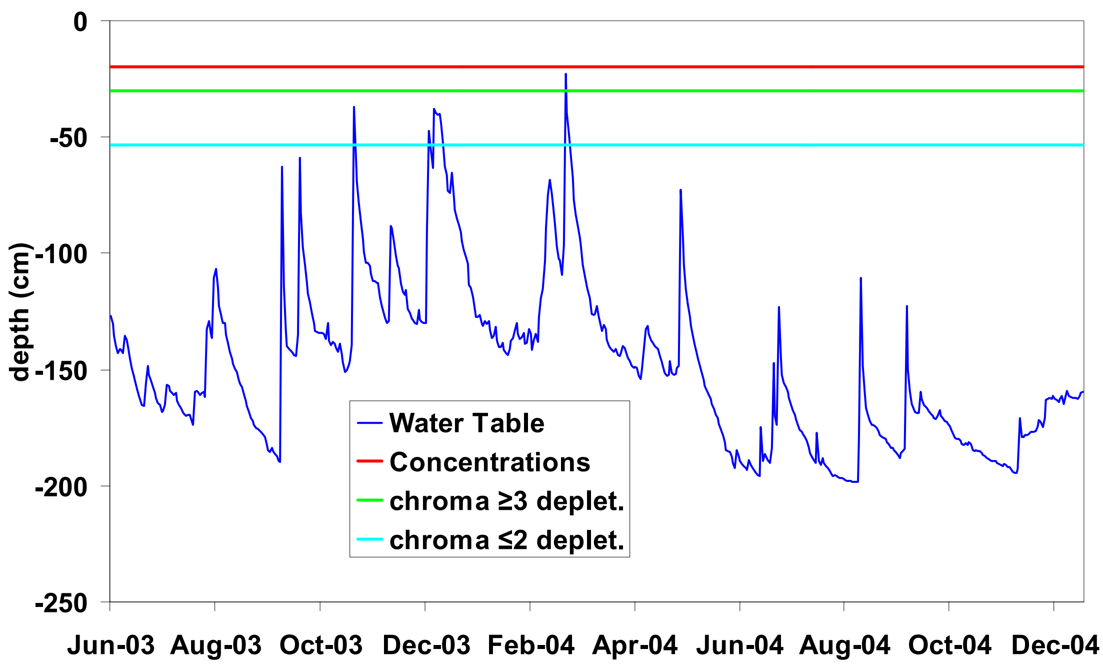

Figure D.12 Measured hydrograph and redox feature depths for the Craven 3 plot.

LENOIR SOILS

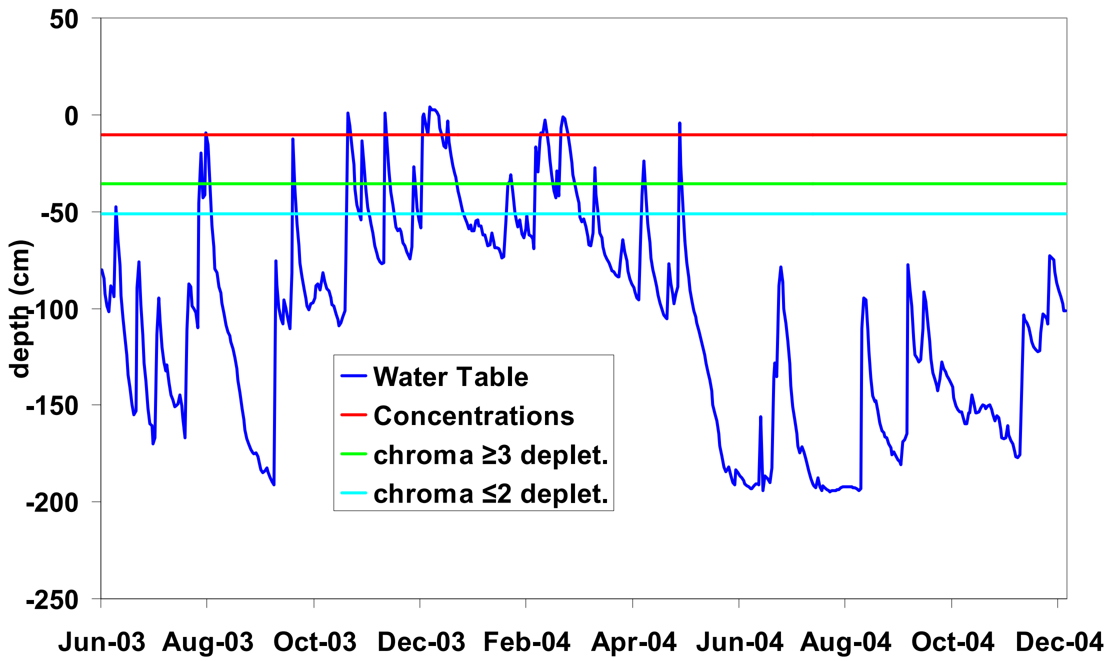

Figure D.13 Measured hydrograph and redox feature depths for the Lenoir 1 plot.

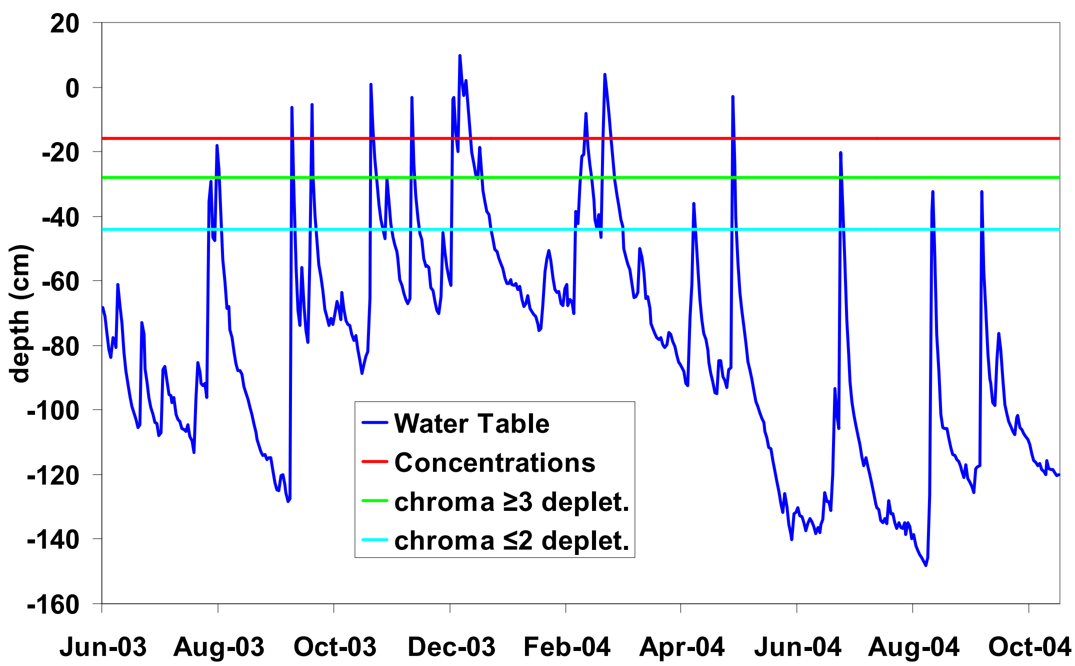

Figure D.14 Measured hydrograph and redox feature depths for the Lenoir 2 plot.

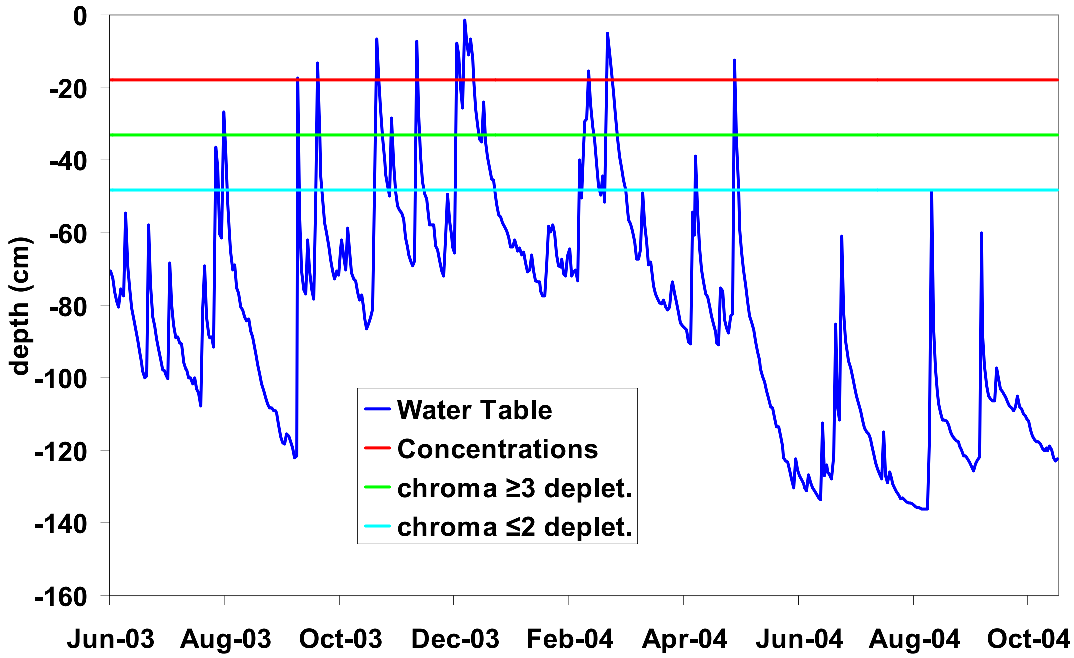

Figure D.14 Measured hydrograph and redox feature depths for the Lenoir 3 plot.

COOL SPRINGS SITE

TARBORO SOIL

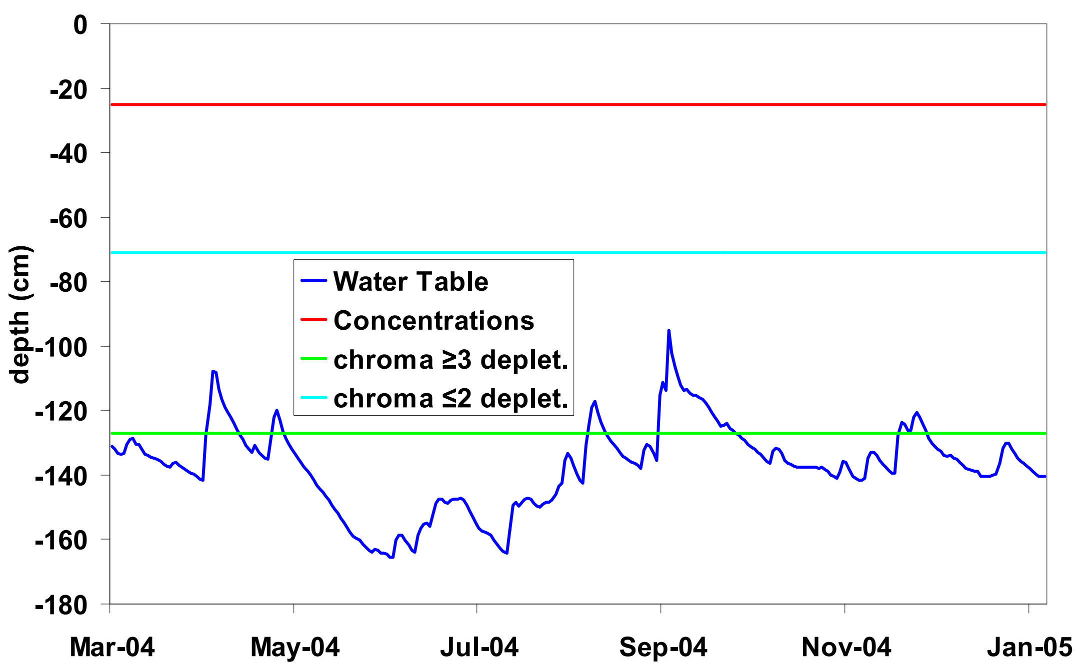

Figure D.16 Measured hydrograph and redox feature depths for the Tarboro plot.

Wet TARBORO SOILS

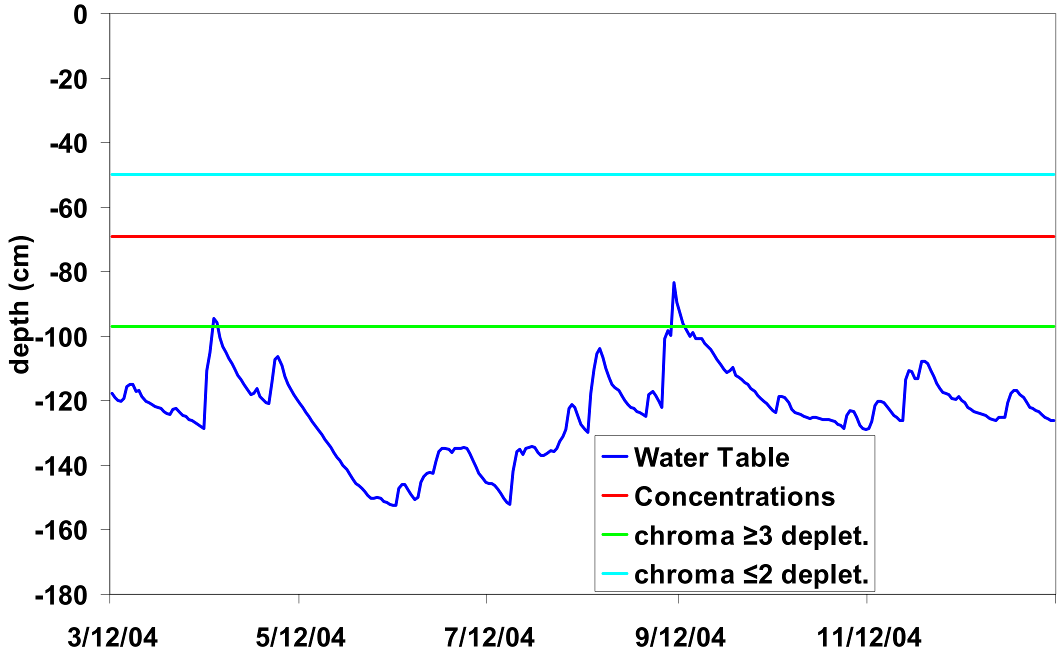

Figure D.17 Measured hydrograph and redox feature depths for the wet Tarboro 1 plot.

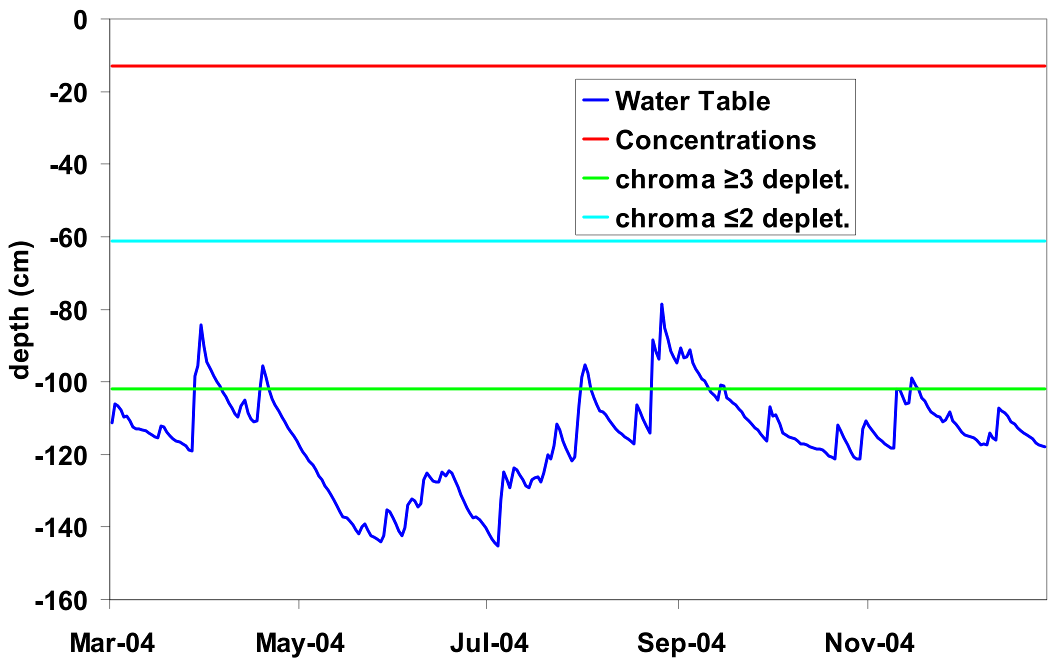

Figure D.19 Measured hydrograph and redox feature depths for the wet Tarboro 2 plot.

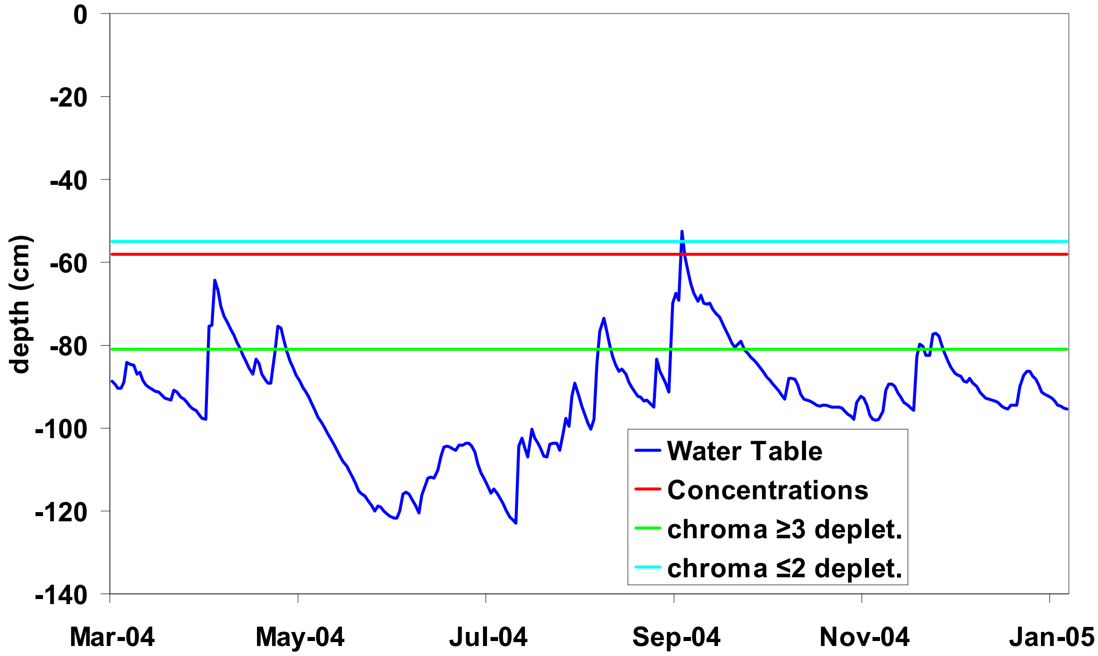

Figure D.18 Measured hydrograph and redox feature depths for the Seabrook 1 plot.

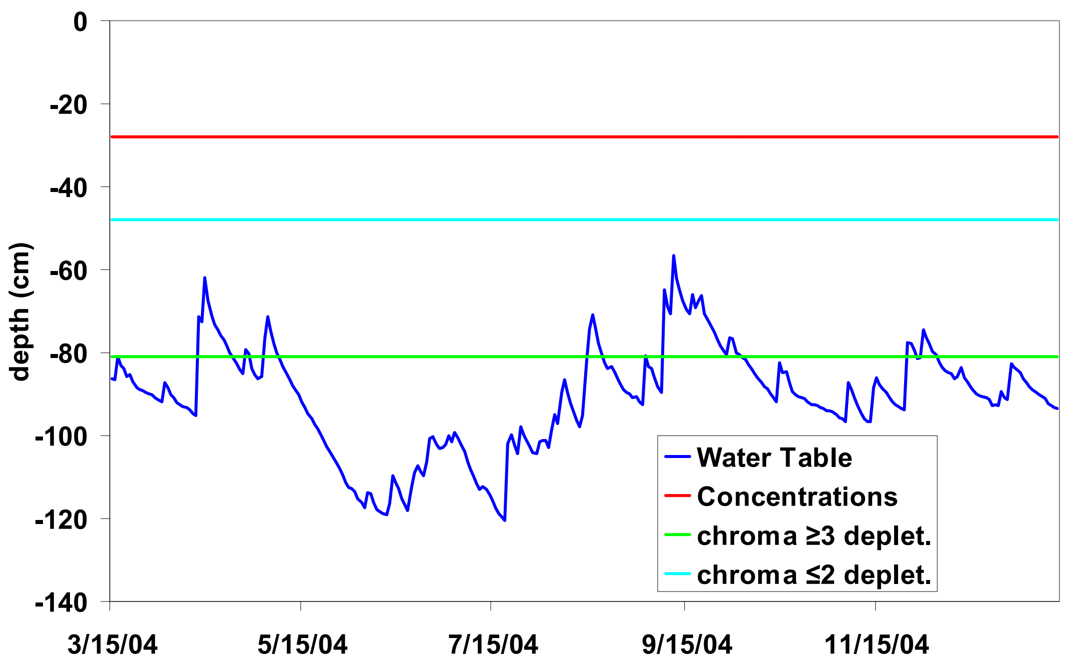

Figure D.20 Measured hydrograph and redox feature depths for the Seabrook 2 plot.

APPENDIX E

OBSERVED AND PREDICTED HYDROGRAPHS OBTAINED BY THE CALIBRATION METHOD FOR ALL PLOTS AT EVERY STUDY SITE

RICHLANDS SITE
FORESTON SOILS

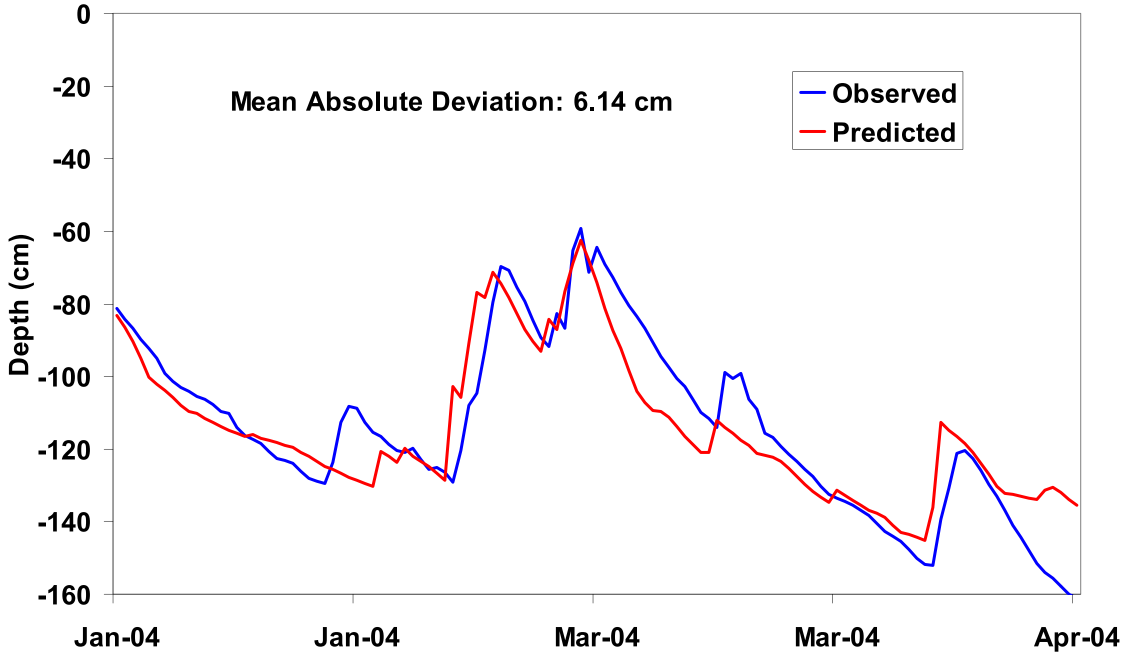

Figure E.1 Mean absolute deviation between the observed and predicted hydrographs obtained by the Calibration method for Foreston 1 plot.

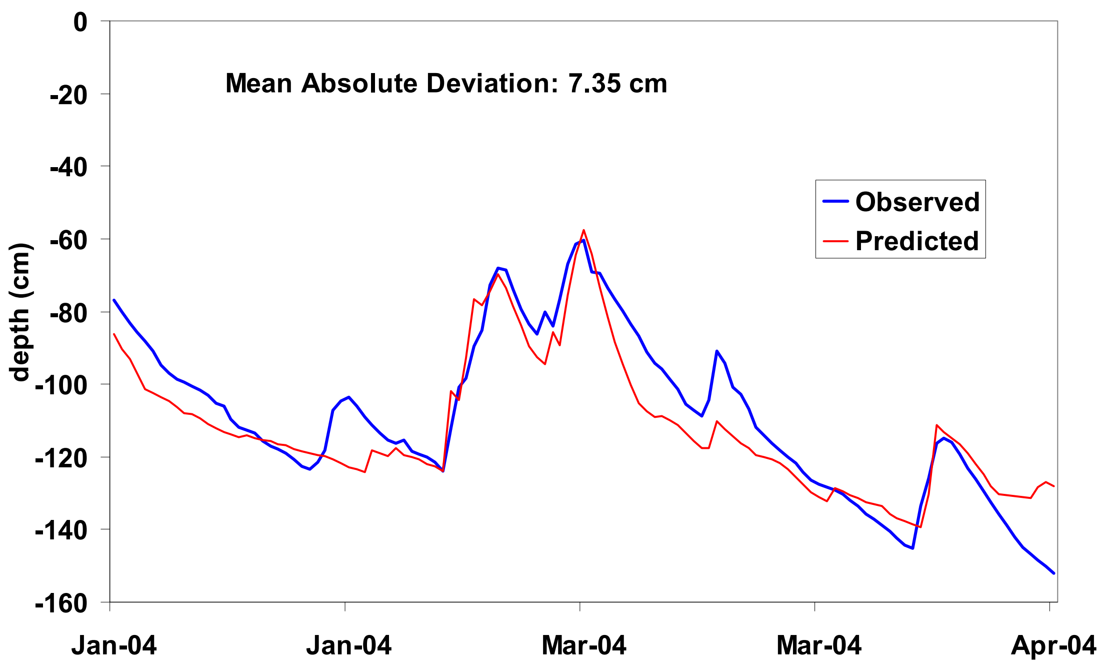

Figure E.2 Mean absolute deviation between the observed and predicted hydrographs obtained by the Calibration method for Foreston 2 plot.

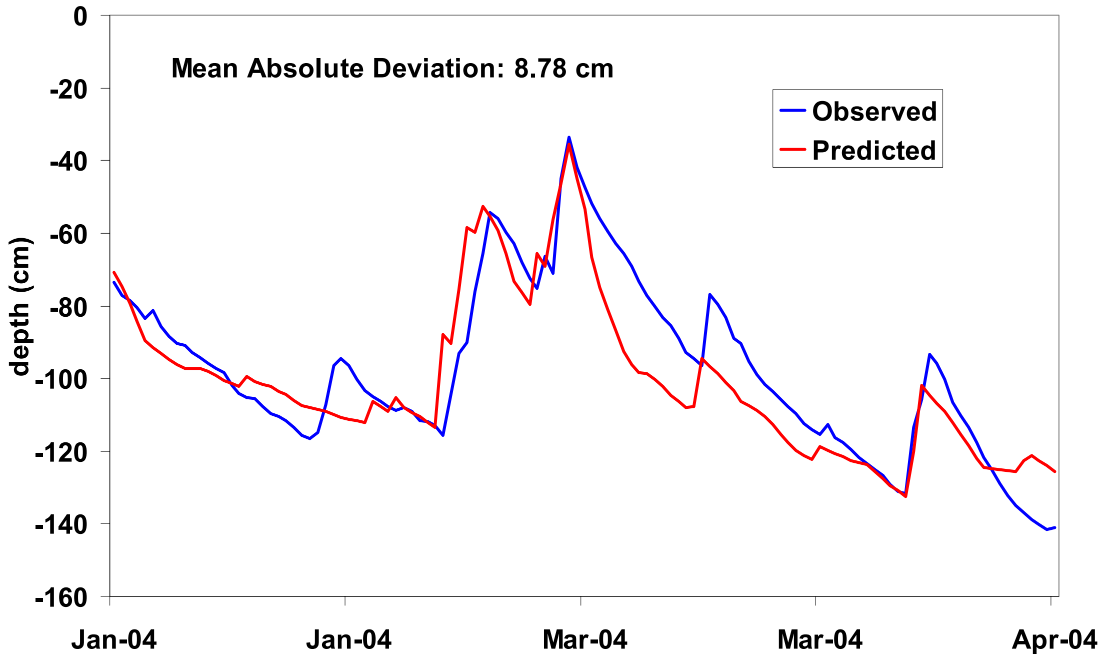

Figure E.3 Mean absolute deviation between the observed and predicted hydrographs obtained by the Calibration method for Foreston 3 plot.

WET FORESTON SOILS

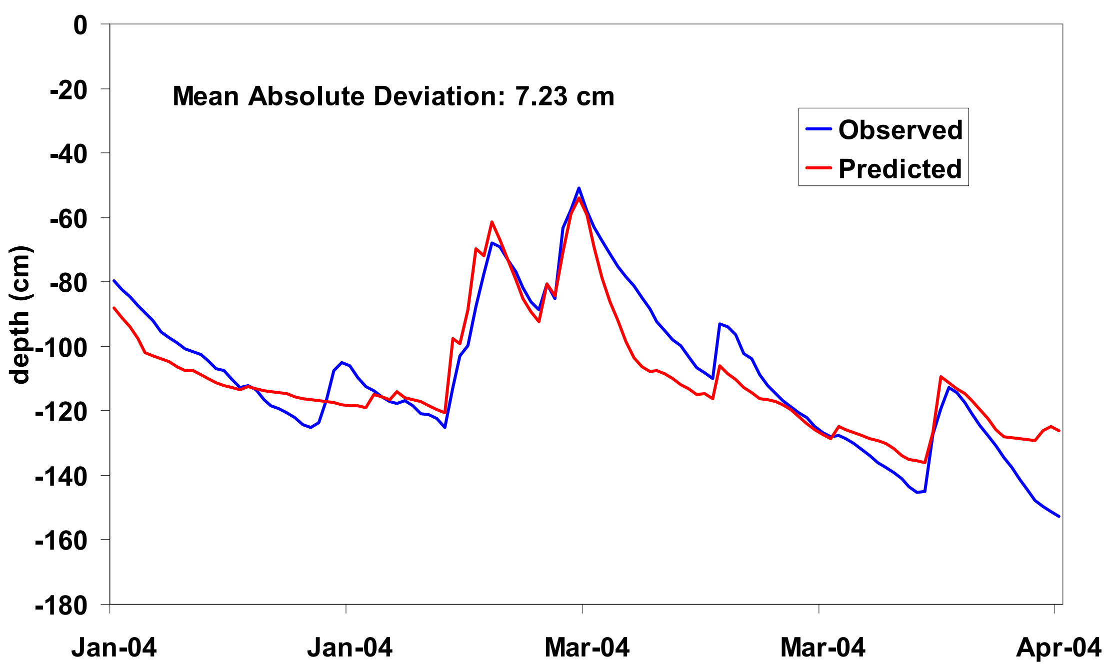

Figure E.4 Mean absolute deviation between the observed and predicted hydrographs obtained by the Calibration method for wet Foreston 1 plot.

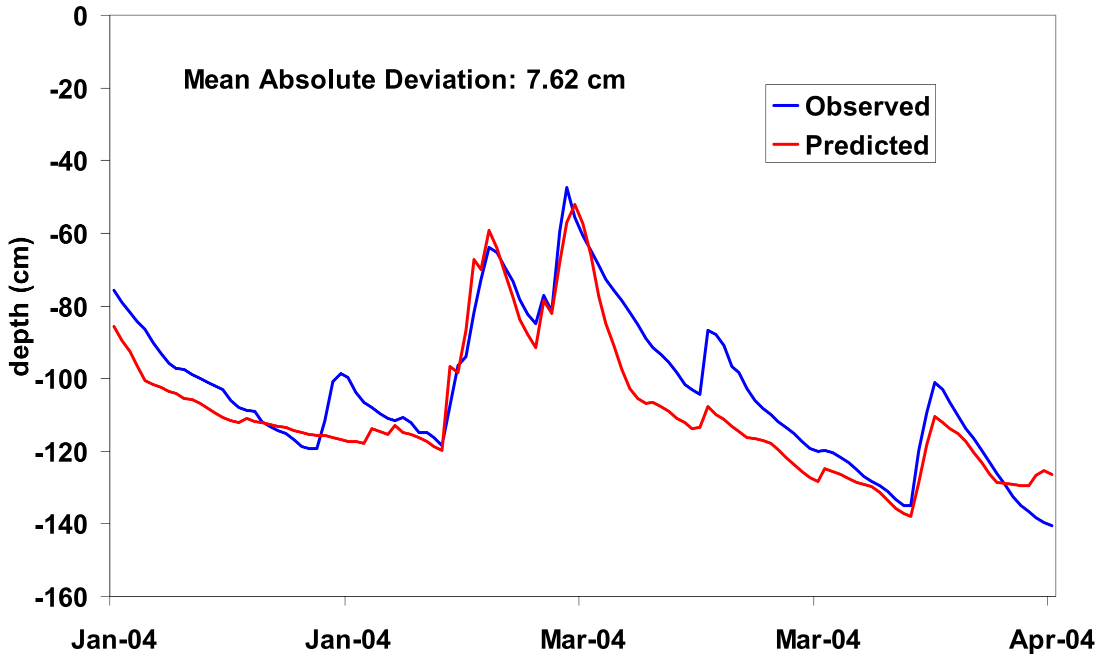

Figure E.5 Mean absolute deviation between the observed and predicted hydrographs obtained by the Calibration method for wet Foreston 2 plot.

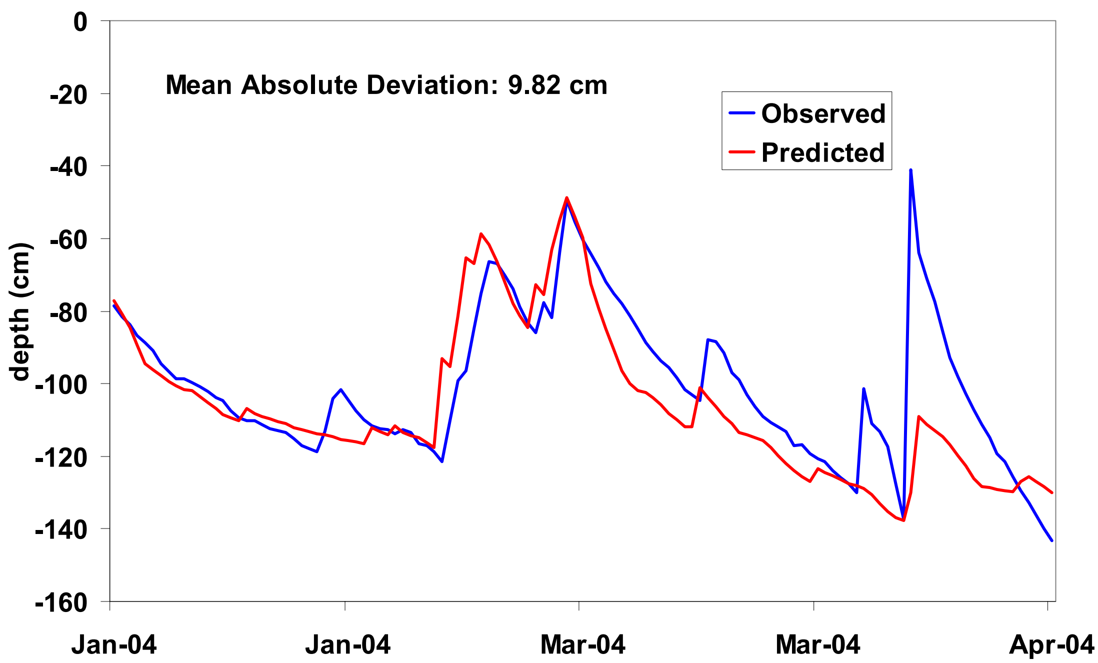

Figure E.6 Mean absolute deviation between the observed and predicted hydrographs obtained by the Calibration method for wet Foreston 3 plot.

STALLINGS SOILS

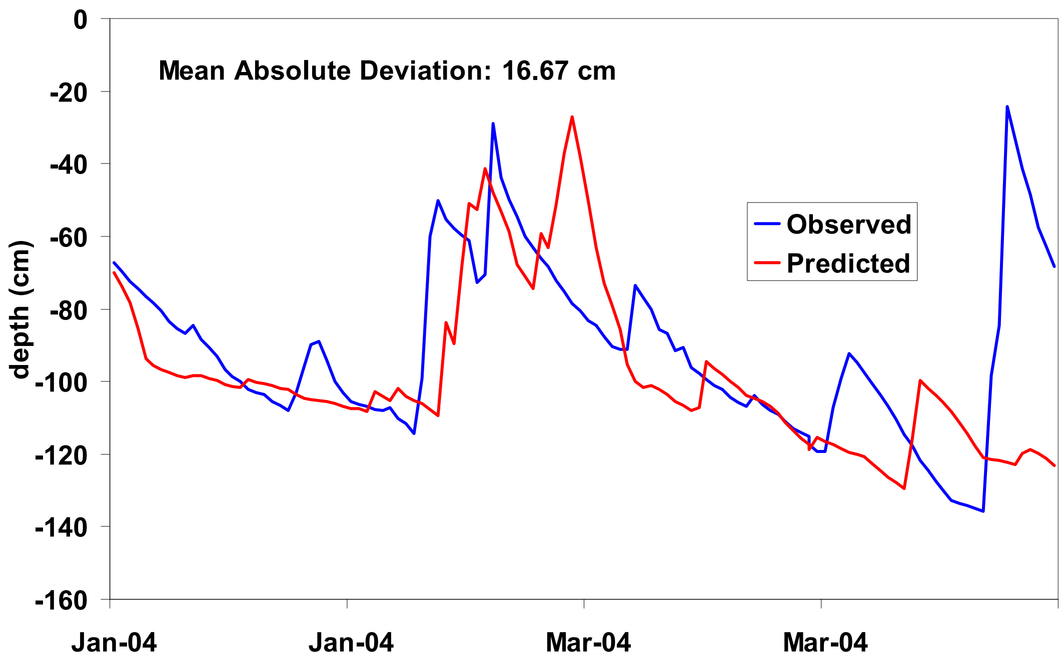

Figure E.7 Mean absolute deviation between the observed and predicted hydrographs obtained by the Calibration method for Stallings 1 plot.

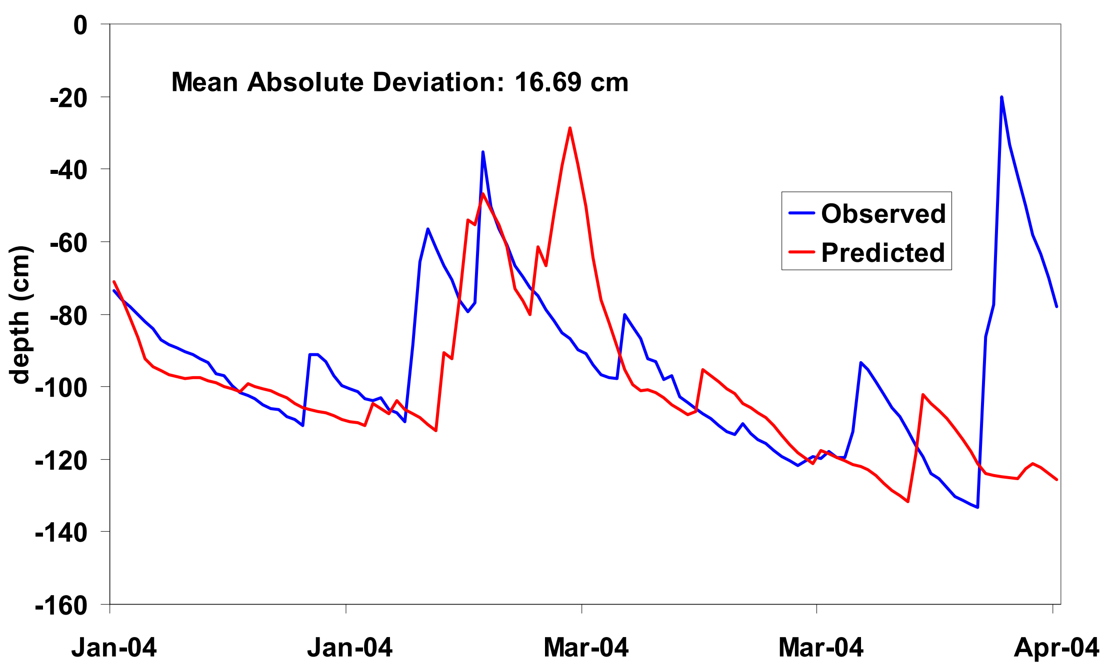

Figure E.8 Mean absolute deviation between the observed and predicted hydrographs obtained by the Calibration method for Stallings 2 plot.

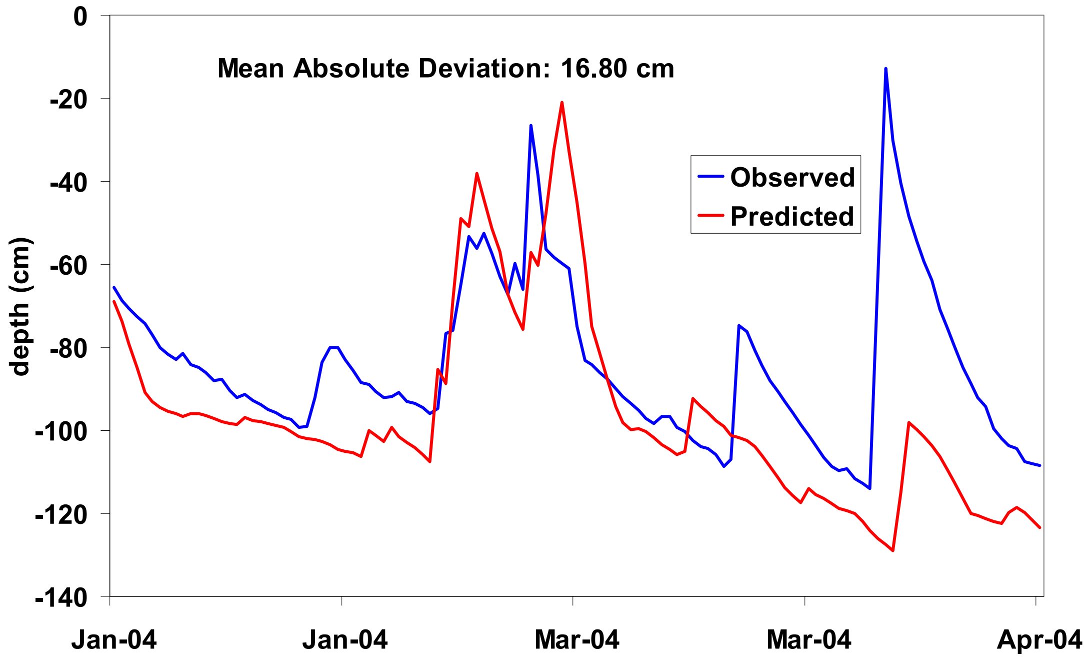

Figure E.9 Mean absolute deviation between the observed and predicted hydrographs obtained by the Calibration method for Stallings 3 plot.

VANCEBORO SITE

CRAVEN SOILS

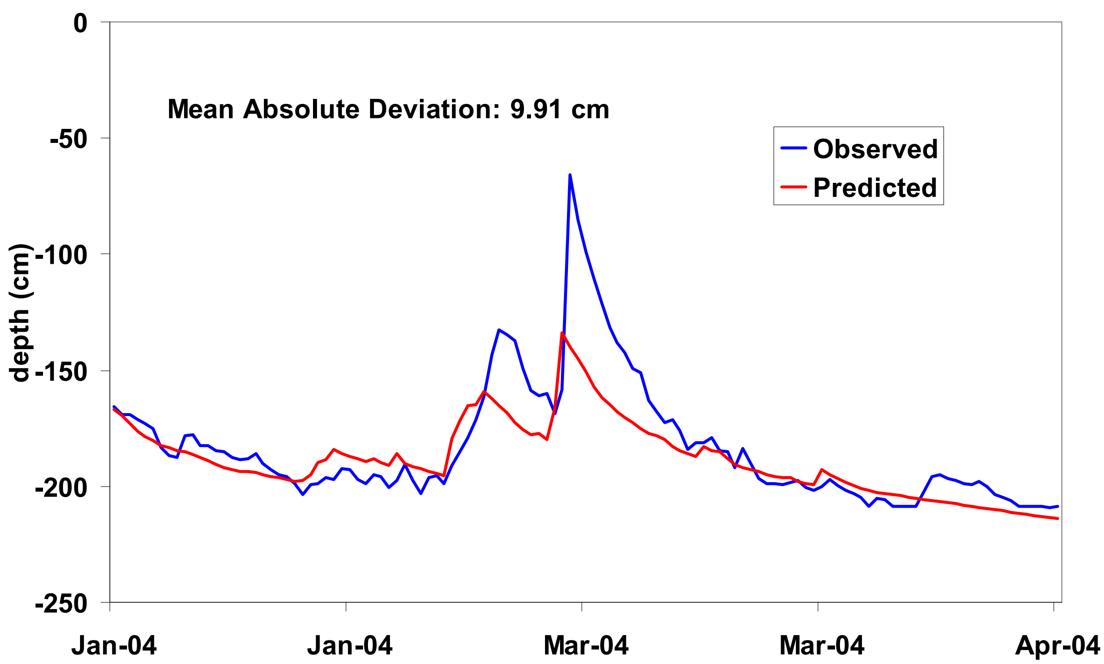

Figure E.10 Mean absolute deviation between the observed and predicted hydrographs obtained by the Calibration method for Craven 1 plot.

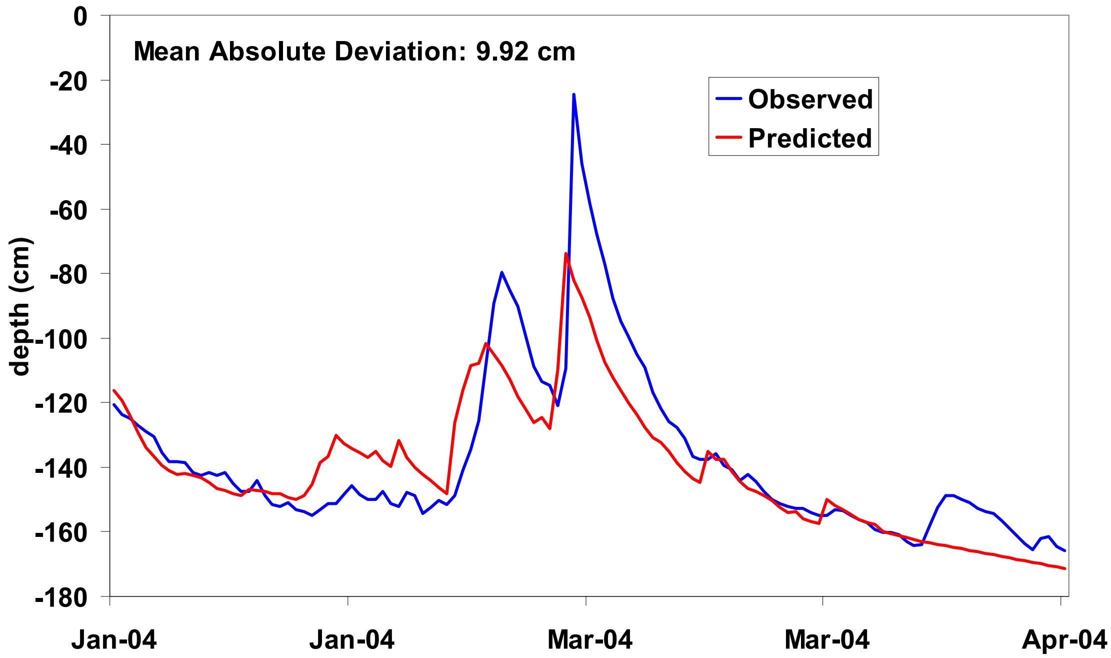

Figure E.11 Mean absolute deviation between the observed and predicted hydrographs obtained by the Calibration method for Craven 2 plot.

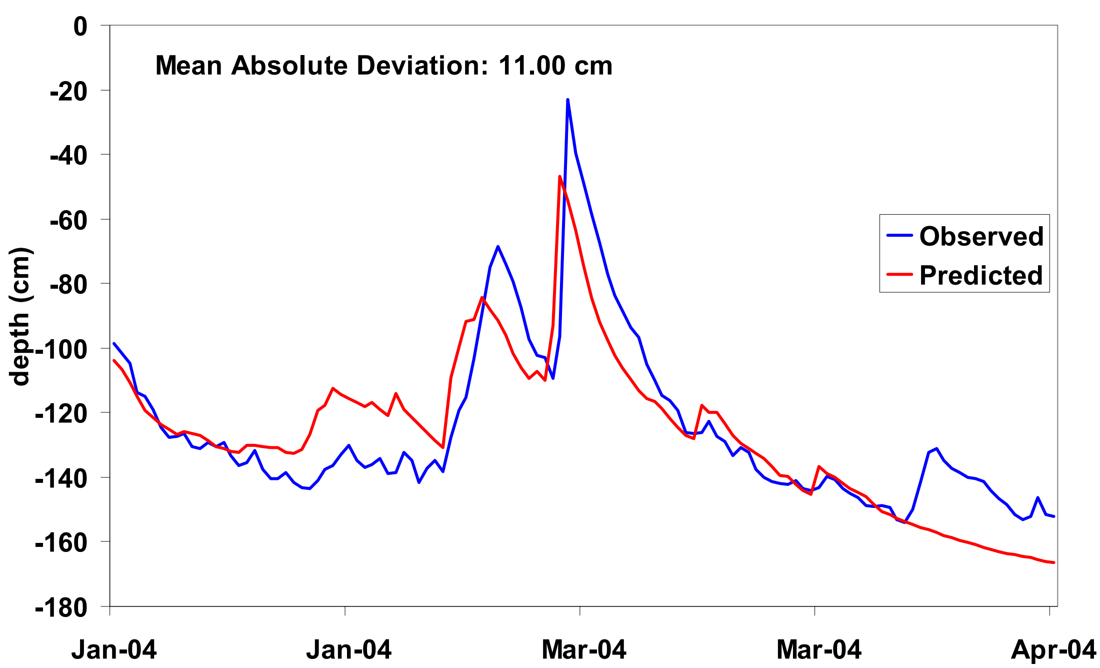

Figure E.12 Mean absolute deviation between the observed and predicted hydrographs obtained by the Calibration method for Craven 3 plot.

LENOIR SOILS

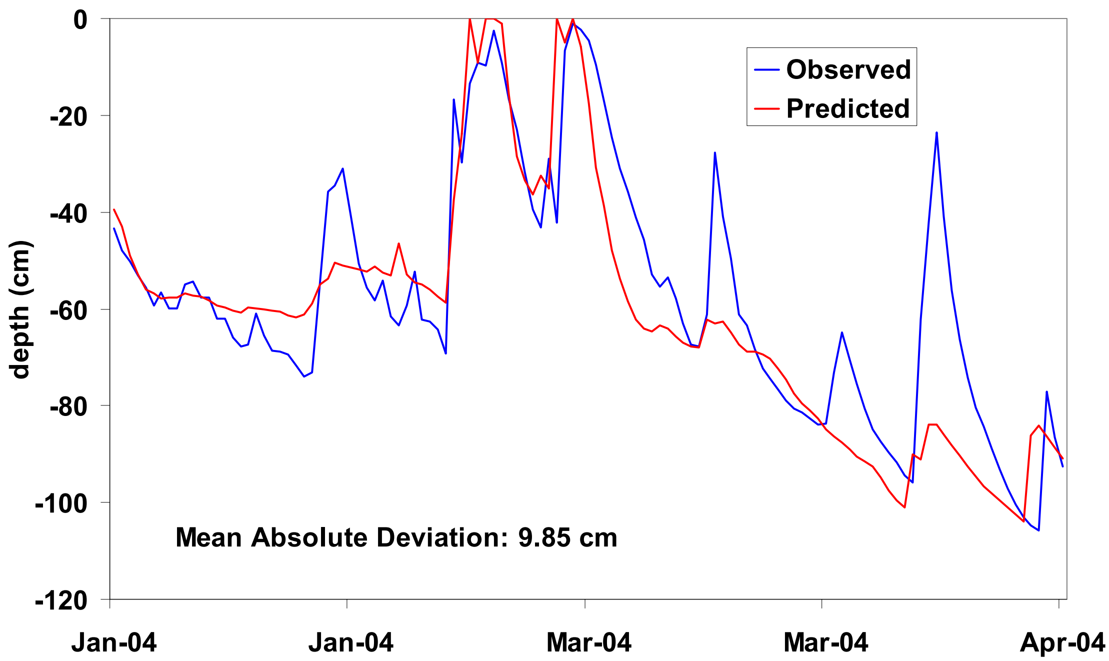

Figure E.13 Mean absolute deviation between the observed and predicted hydrographs obtained by the Calibration method for Lenoir 1 plot.

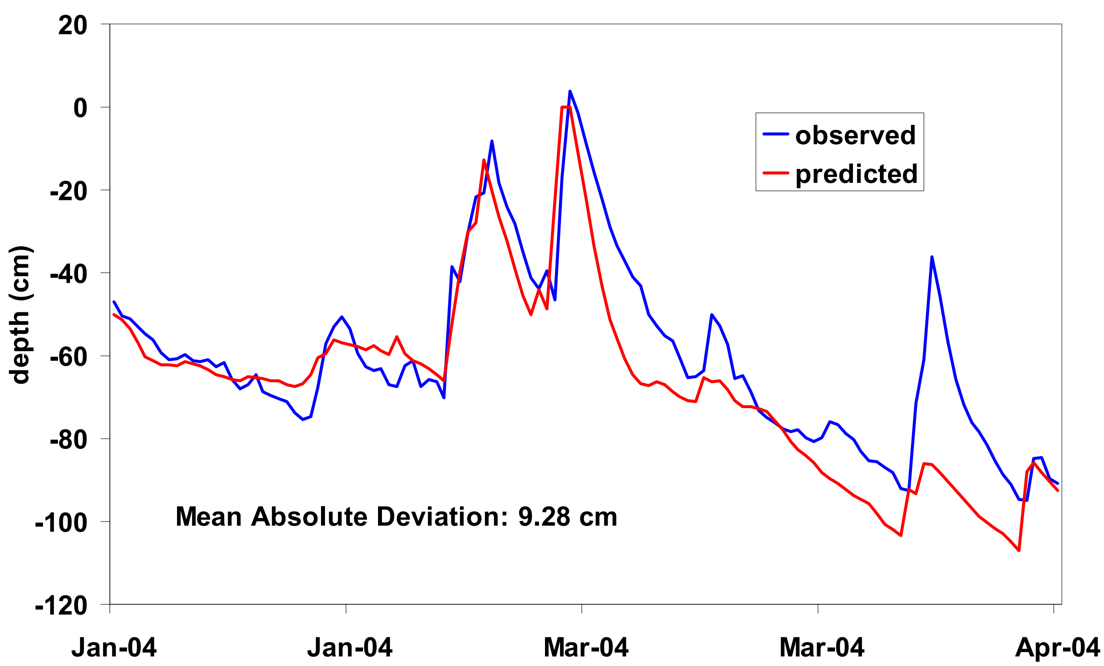

Figure E.14 Mean absolute deviation between the observed and predicted hydrographs obtained by the Calibration method for Lenoir 2 plot.

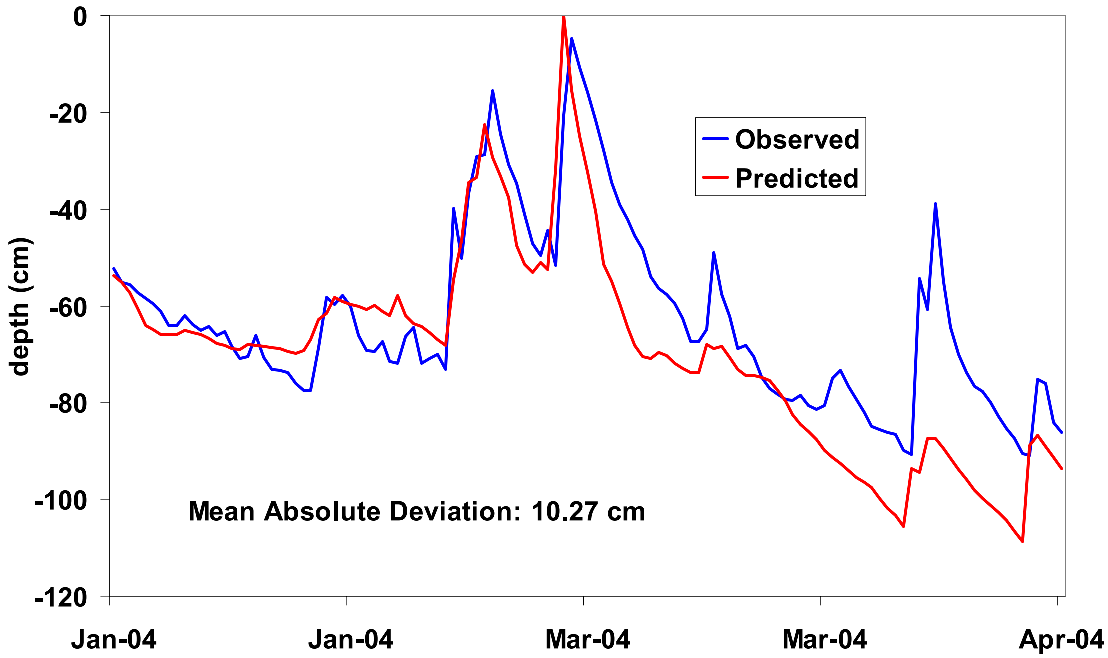

Figure E.15 Mean absolute deviation between the observed and predicted hydrographs obtained by the Calibration method for Lenoir 3 plot.

COOL SPRINGS SITE- TARBORO SOIL

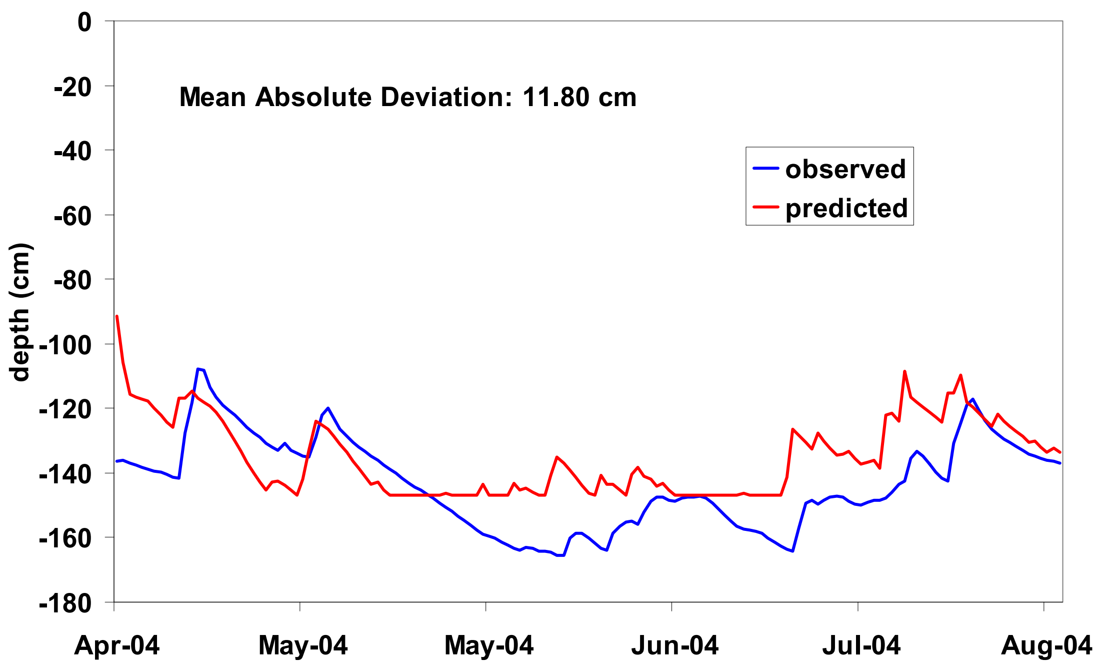

Figure E.16 Mean absolute deviation between the observed and predicted hydrographs obtained by the Calibration method for Tarboro plot.

Wet TARBORO SOILS

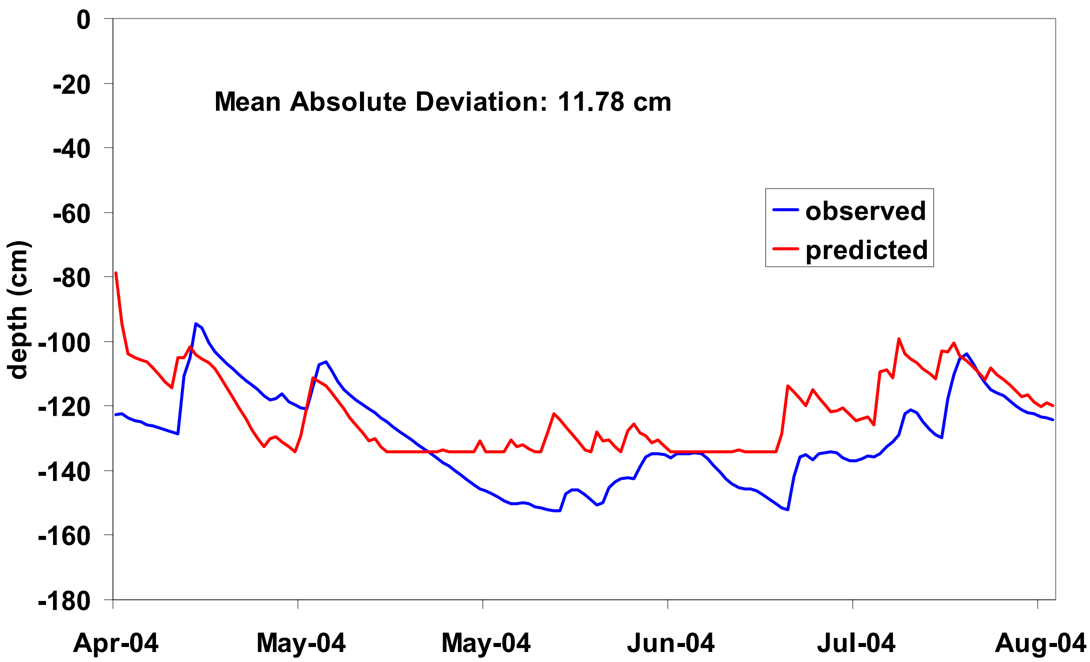

Figure E.17 Mean absolute deviation between the observed and predicted hydrographs obtained by the Calibration method for wet Tarboro 1 plot.

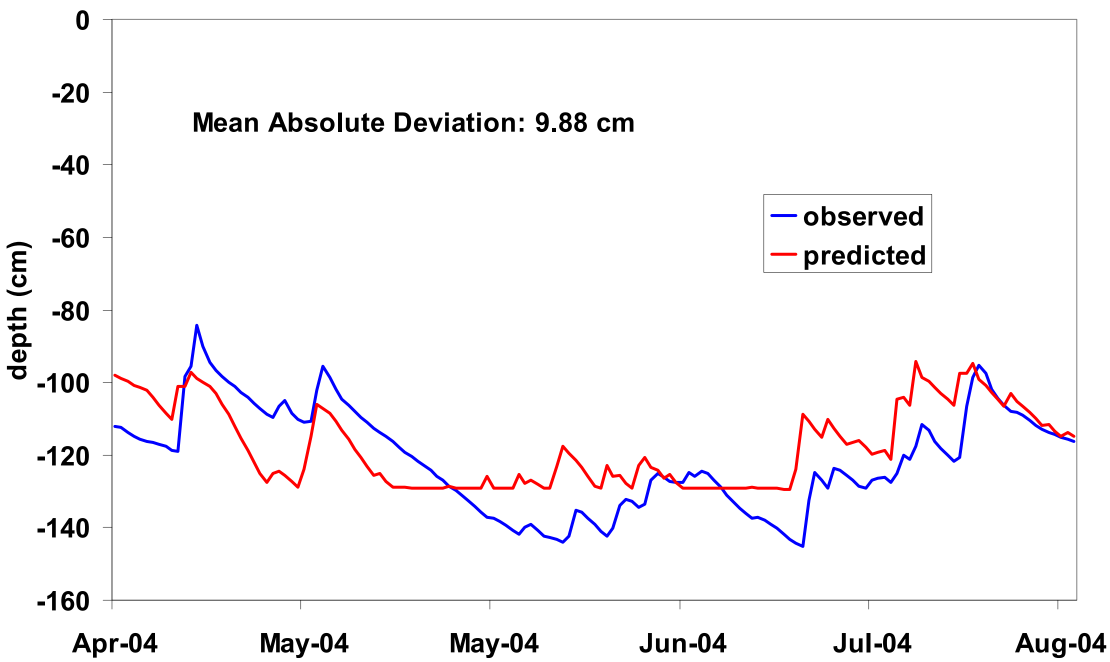

Figure E.18 Mean absolute deviation between the observed and predicted hydrographs obtained by the Calibration method for wet Tarboro 2 plot.

SEABROOK SOILS

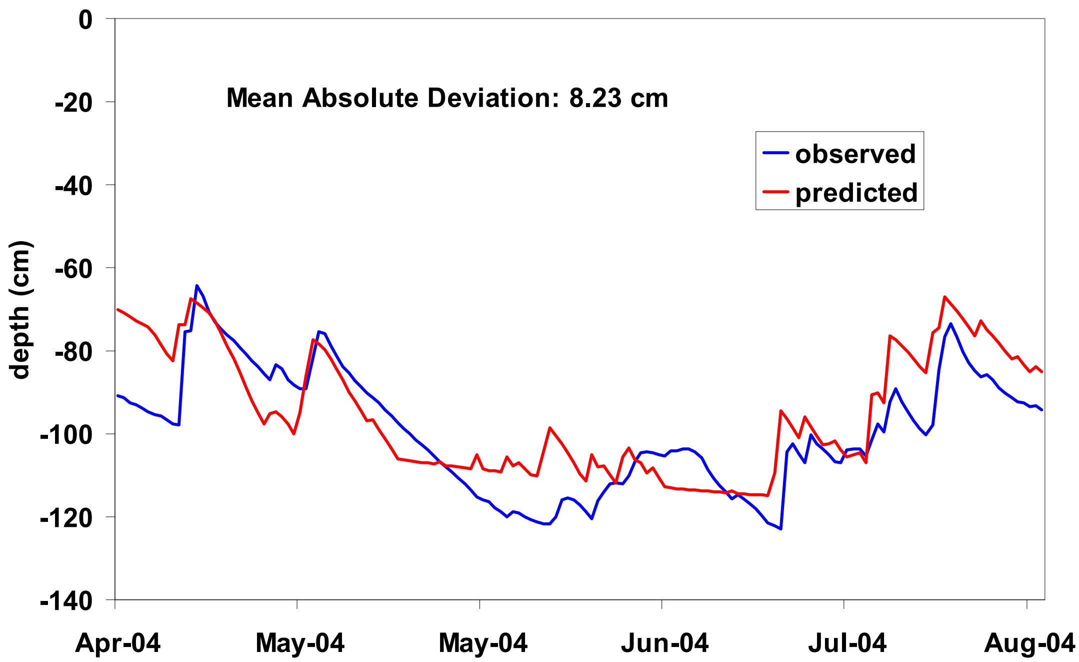

Figure E.19 Mean absolute deviation between the observed and predicted hydrographs obtained by the Calibration method for Seabrook 1 plot.

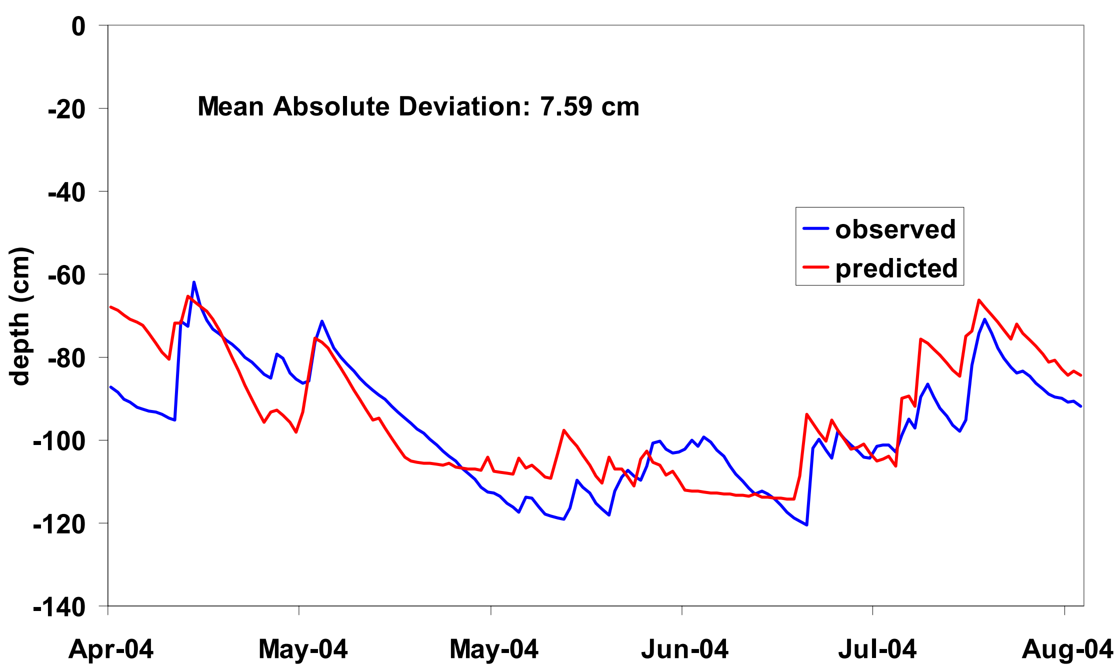

Figure E.20 Mean absolute deviation between the observed and predicted hydrographs obtained by the Calibration method for Seabrook 2 plot.

APPENDIX F

COMPARATIVE HYDROGRAPHS OF OBSERVED AND SIMULATED DATA FOR VARYING THRESHOLD LEVELS FOR SELECTED PLOTS AT ALL STUDY SITES

RICHLANDS SITE
FORESTON SOILS

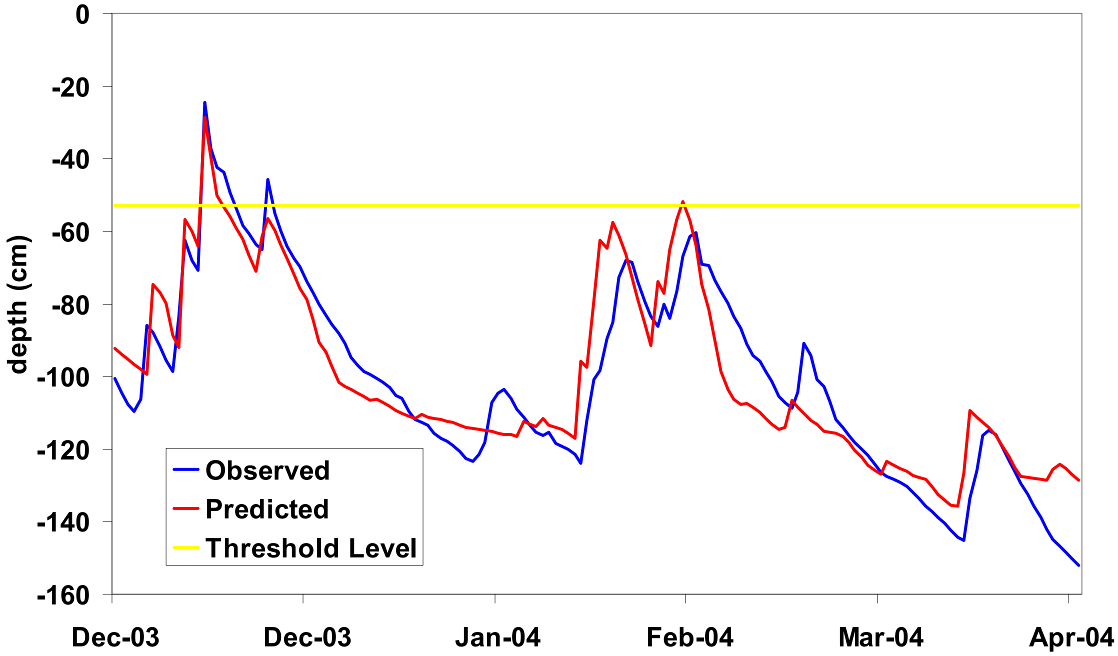

Figure F.1 Comparative hydrographs from the simulated data period produced the Threshold method for the Foreston 2 plot that was an approximate match to the observed data.

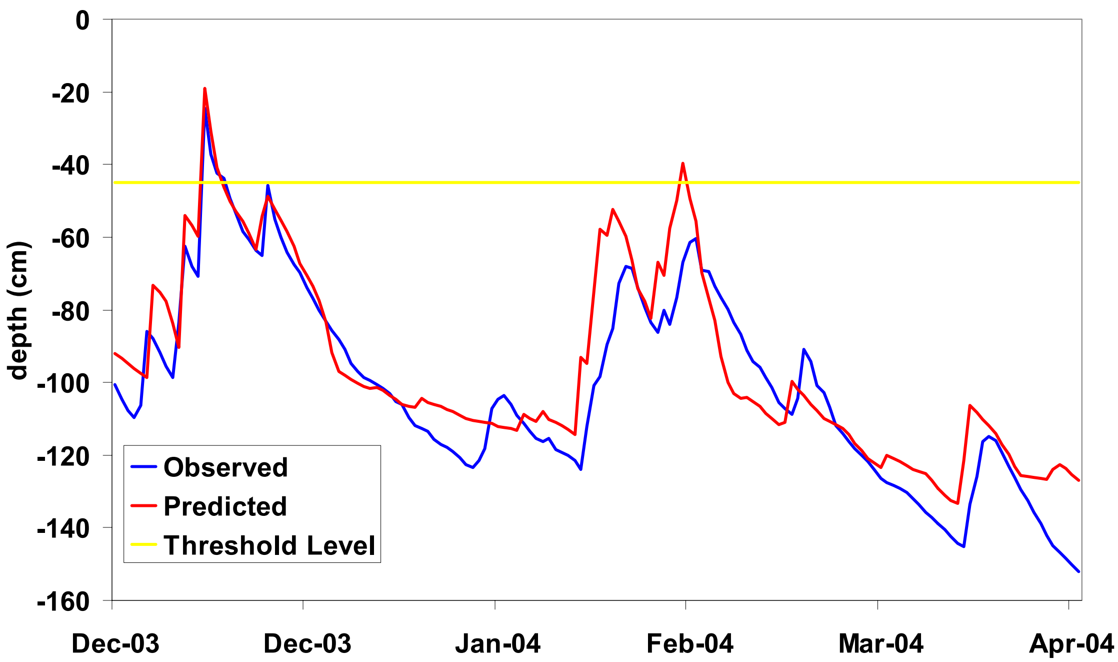

Figure F.2 Comparative hydrographs from the simulated data period produced the Threshold method for the Foreston 2 plot that was 'wetter' than the observed data.

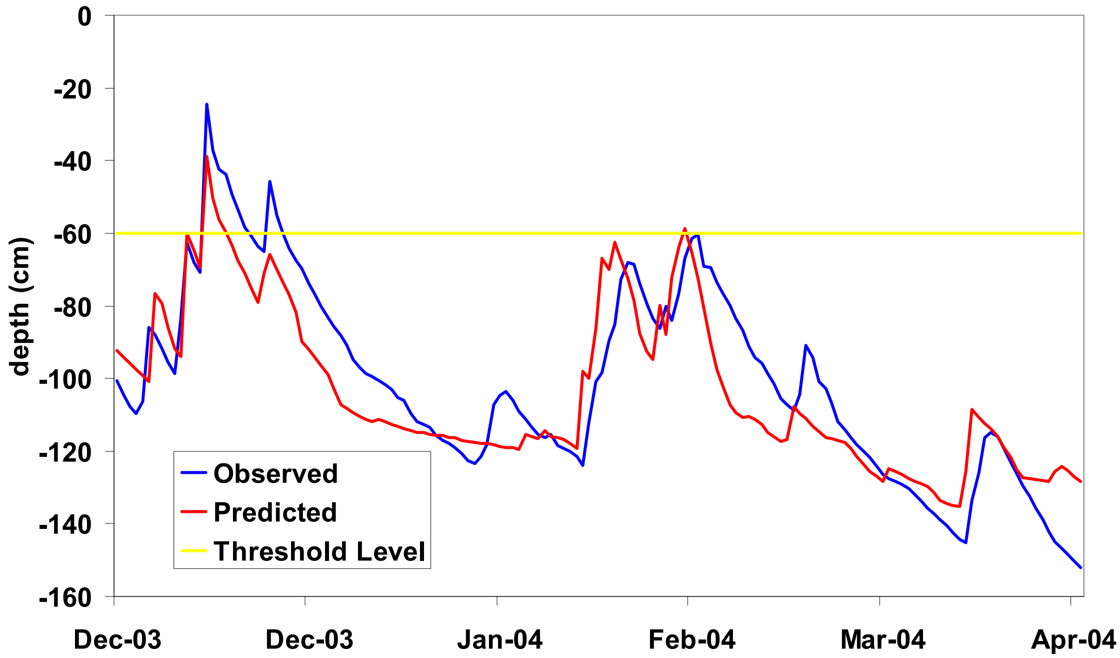

Figure F.3 Comparative hydrographs from the simulated data period produced the Threshold method for the Foreston 2 plot that was 'drier' than the observed data.

WET FORESTON SOILS

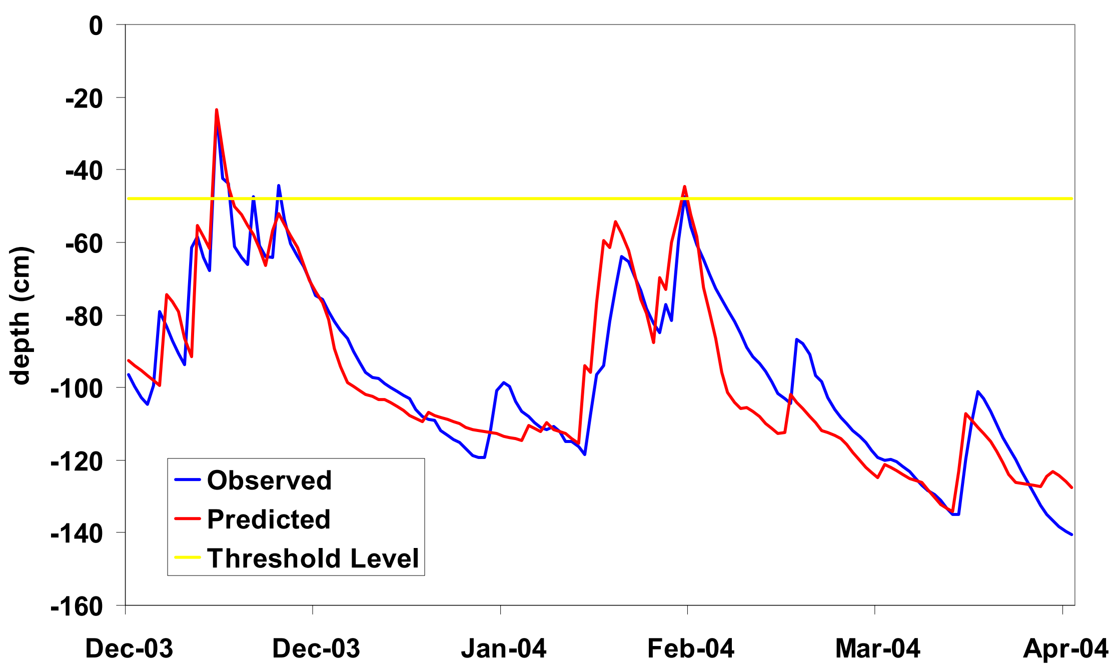

Figure F.4. Comparative hydrographs from the simulated data period produced the Threshold method for the wet Foreston 2 plot that was an approximate match to the observed data.

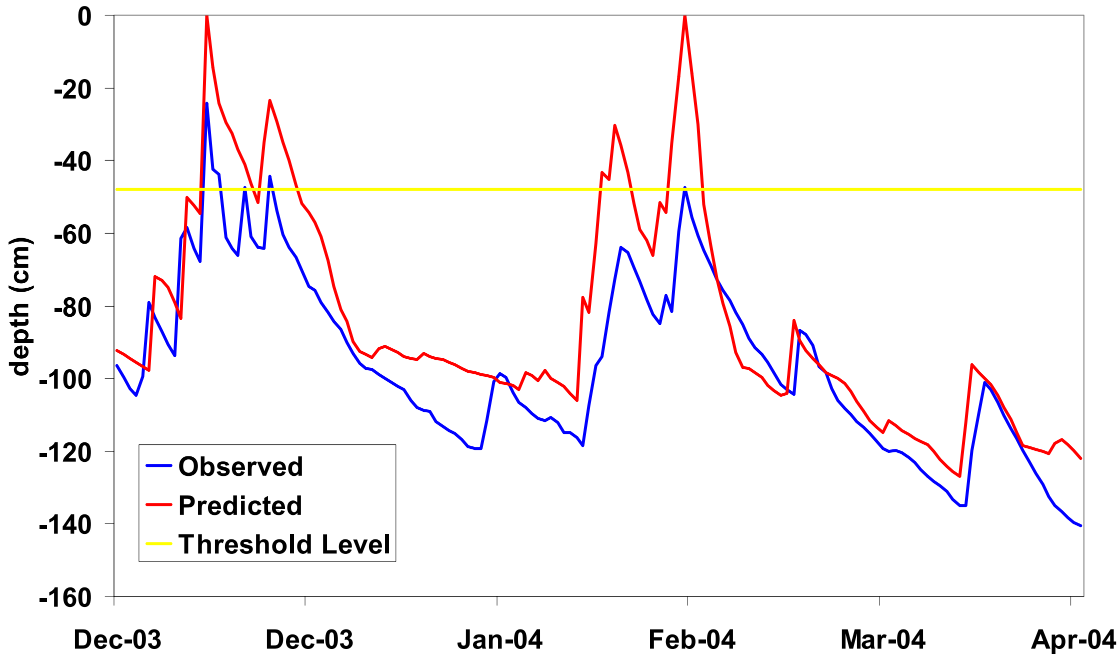

Figure F.5 Comparative hydrographs from the simulated data period produced the Threshold method for the wet Foreston 2 plot that was 'wetter' than the observed data.

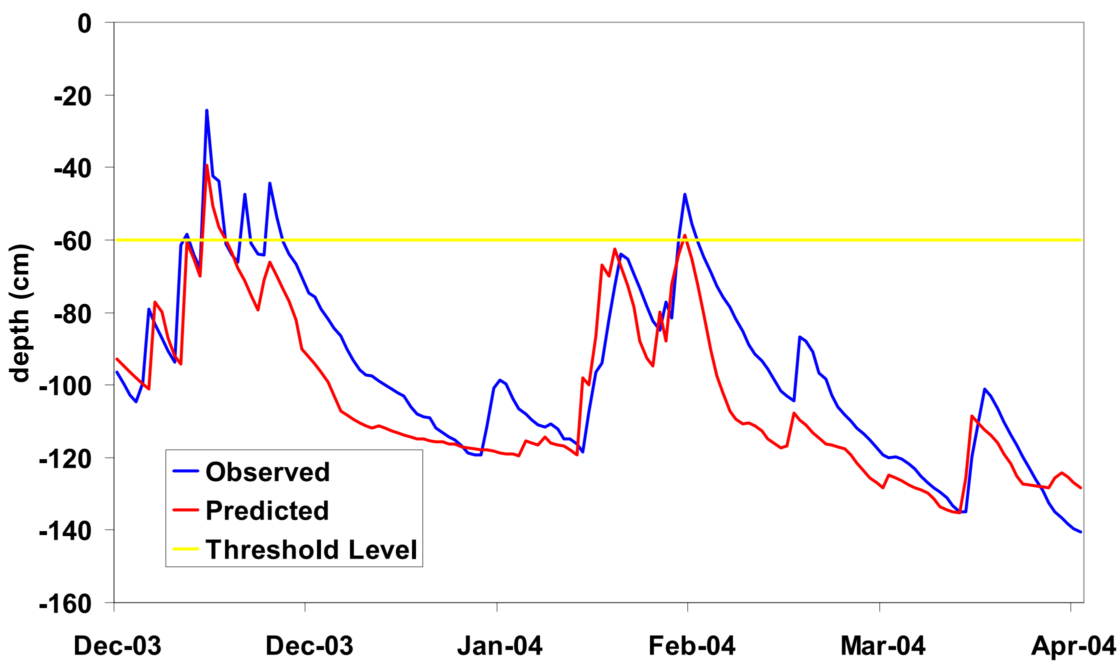

Figure F.6 Comparative hydrographs from the simulated data period produced the Threshold method for the Foreston 2 plot that was 'drier' than the observed data.

STALLINGS SOILS

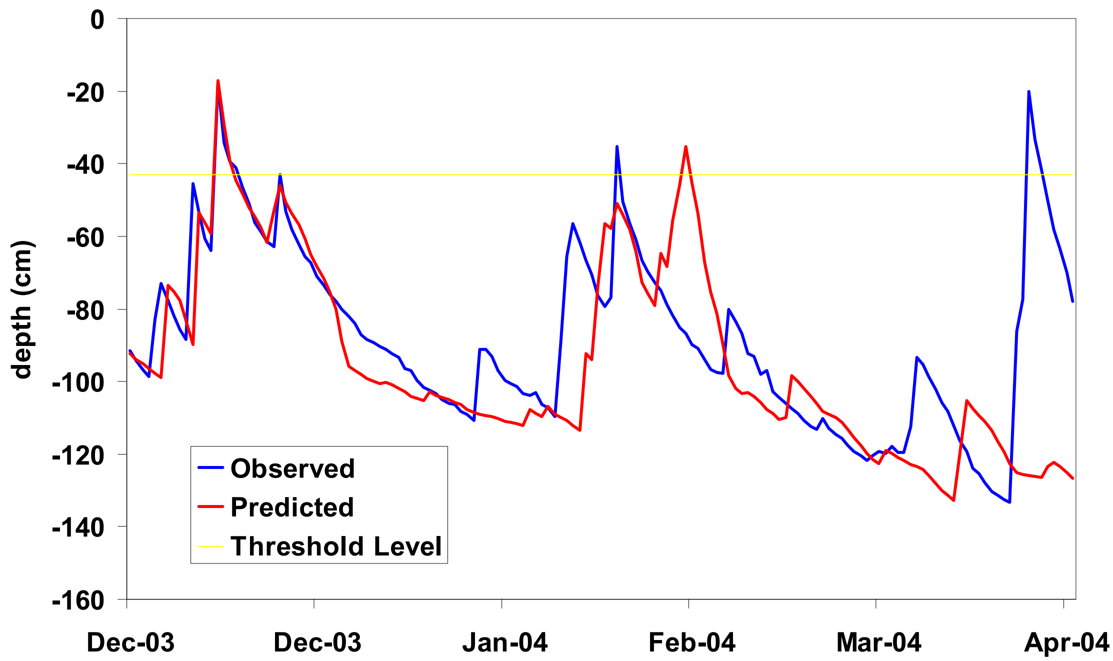

Figure F.7. Comparative hydrographs from the simulated data period produced the Threshold method for the Stallings 2 plot that was an approximate match to the observed data.

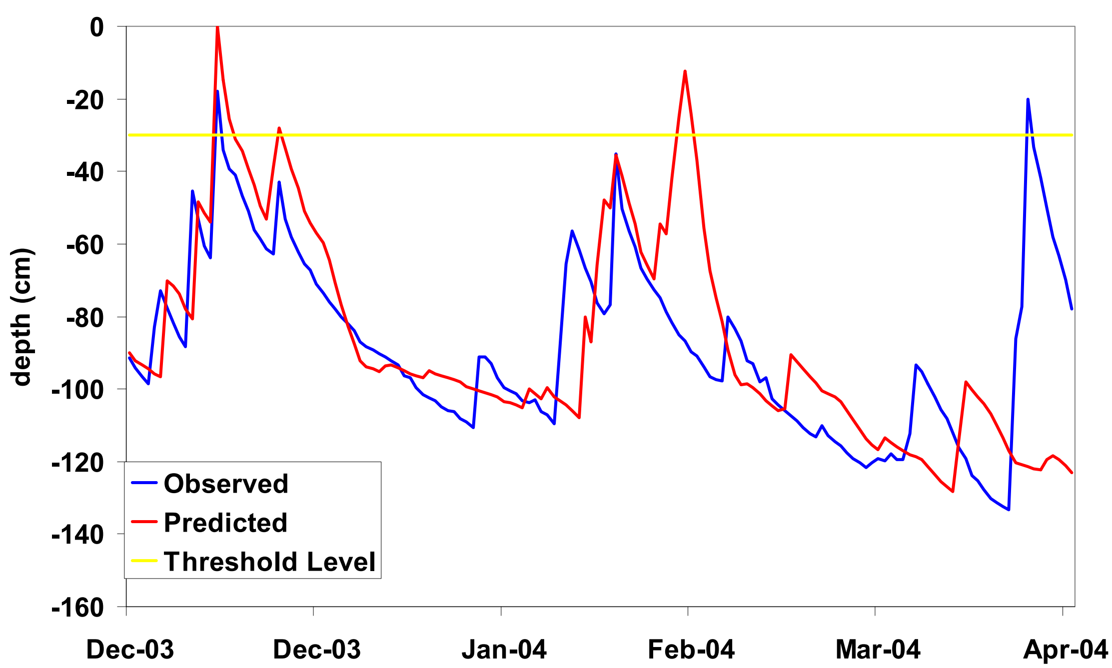

Figure F.8 Comparative hydrographs from the simulated data period produced the Threshold method for the Stallings 2 plot that was 'wetter' than the observed data.

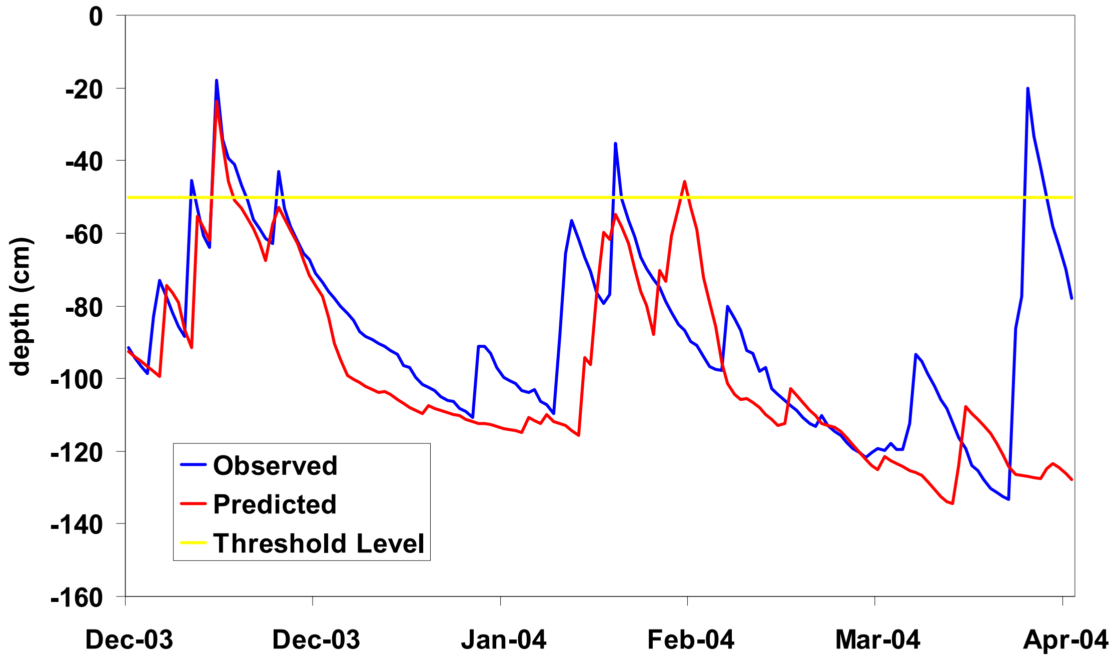

Figure F.9 Comparative hydrographs from the simulated data period produced the Threshold method for the Stallings 2 plot that was 'drier' than the observed data.

VANCEBORO SITE

CRAVEN SOILS

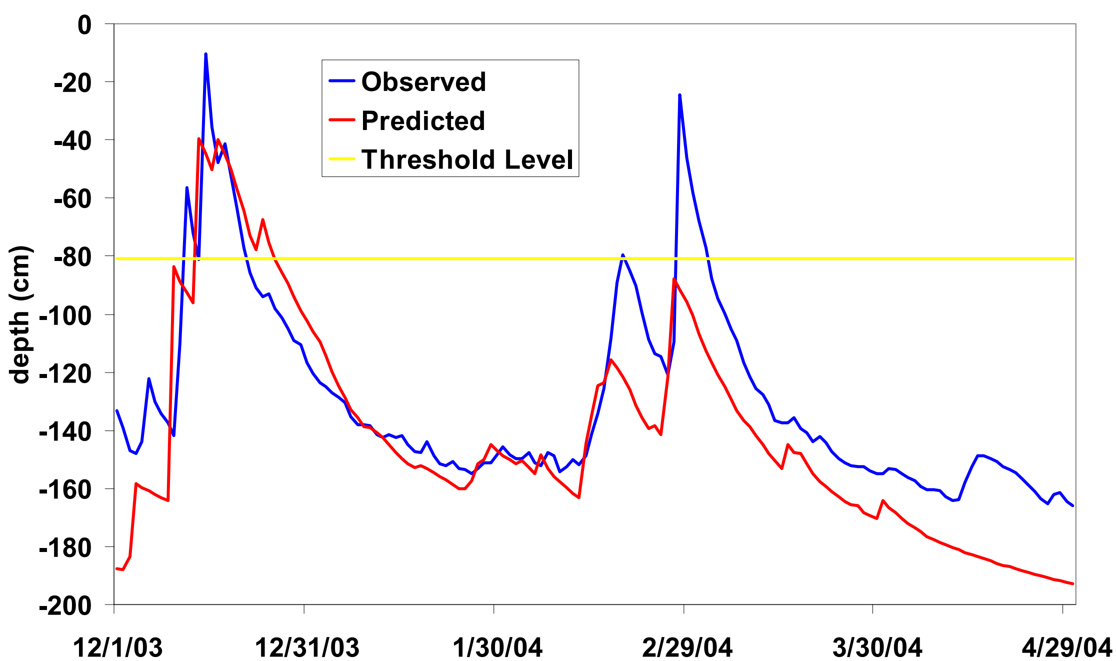

Figure F.10. Comparative hydrographs from the simulated data period produced the Threshold method for the Craven 2 plot that was an approximate match to the observed data.

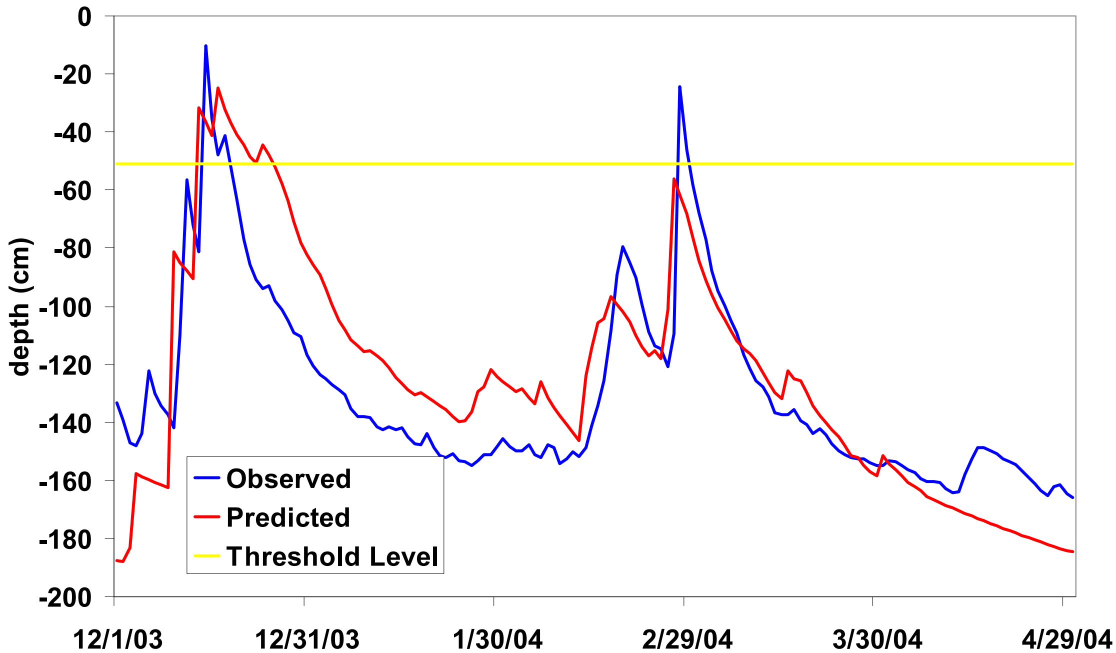

Figure F.11 Comparative hydrographs from the simulated data period produced the Threshold method for the Craven 2 plot that was 'wetter' than the observed data.

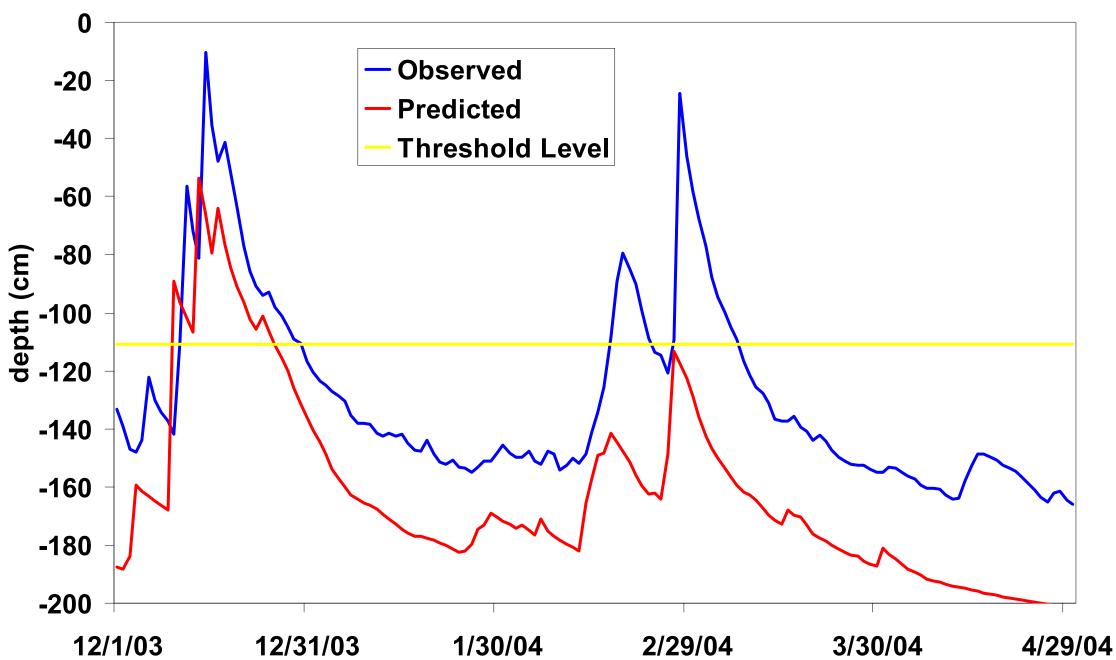

Figure F.12 Comparative hydrographs from the simulated data period produced the Threshold method for the Craven 2 plot that was 'drier' than the observed data.

LENOIR SOILS

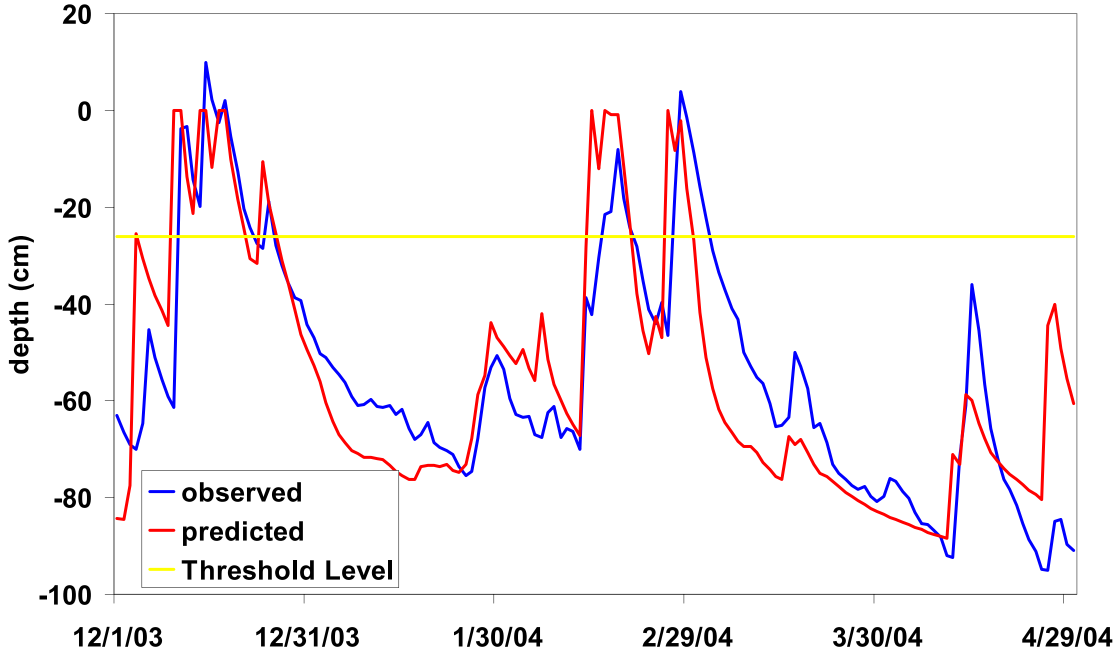

Figure F.13. Comparative hydrographs from the simulated data period produced the Threshold method for the Lenoir 2 plot that was an approximate match to the observed data.

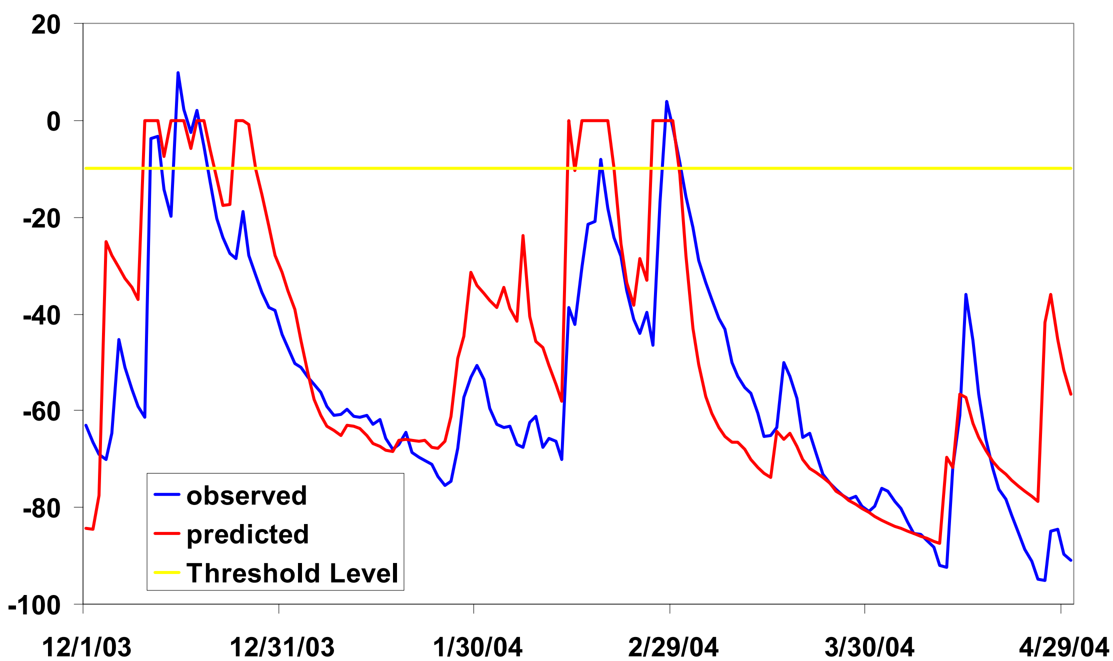

Figure F.14 Comparative hydrographs from the simulated data period produced the Threshold method for the Craven 2 plot that was ‘wetter’ than the observed data.

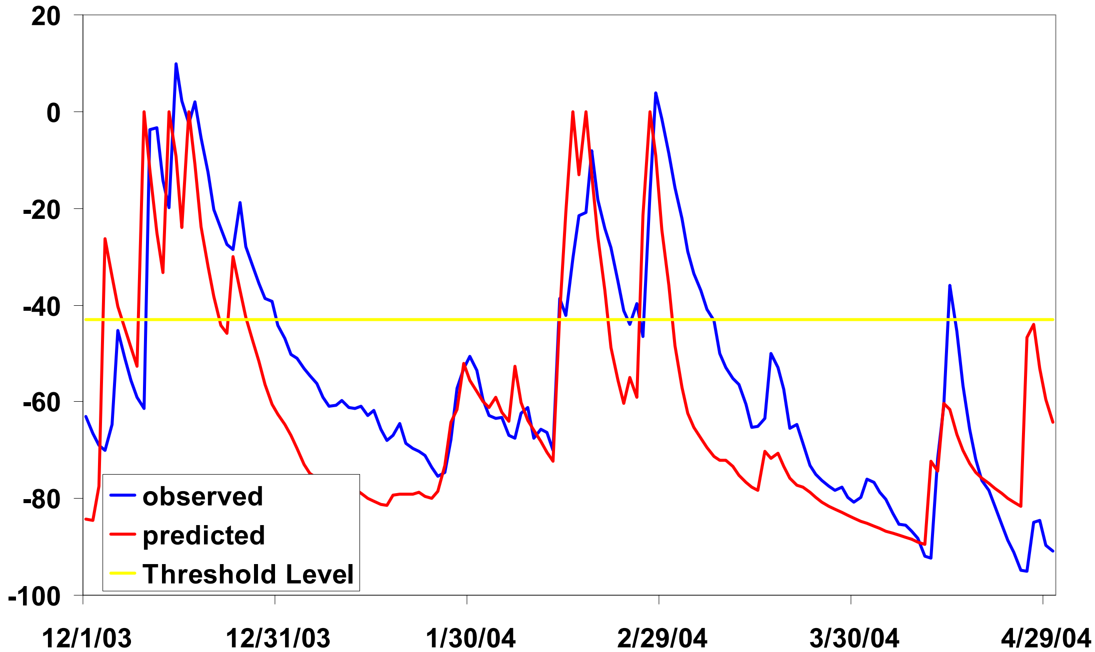

Figure F.15 Comparative hydrographs from the simulated data period produced the Threshold method for the Lenoir 2 plot that was 'drier' than the observed data.

COOL SPRINGS SITE

TARBORO SOIL

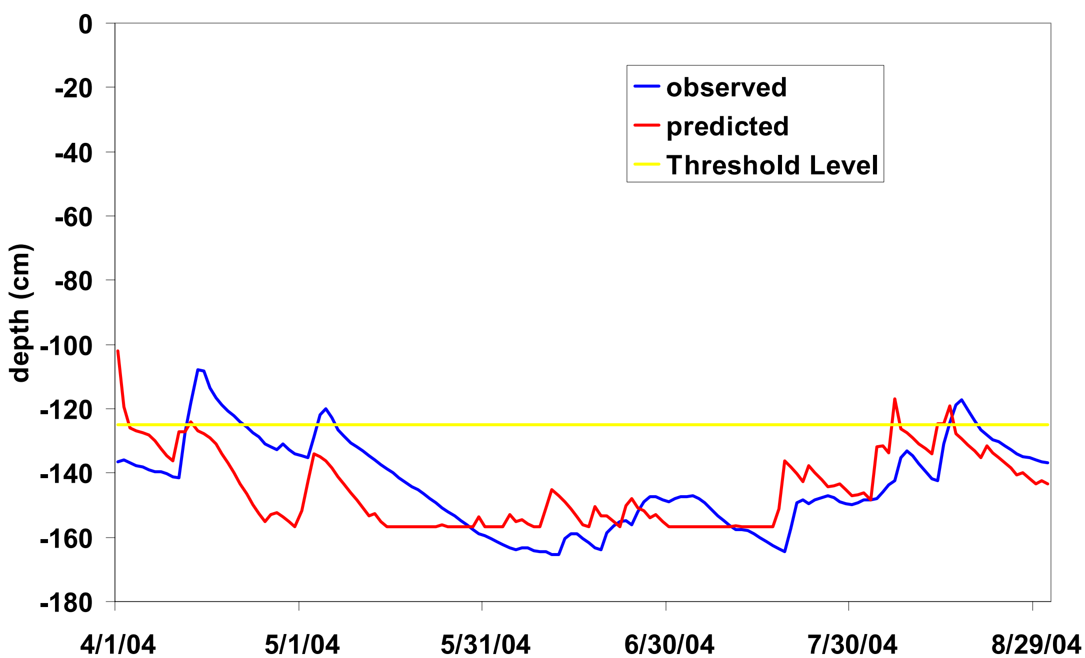

Figure F.16. Comparative hydrographs from the simulated data period produced the Threshold method for the Tarboro plot that was an approximate match to the observed data.

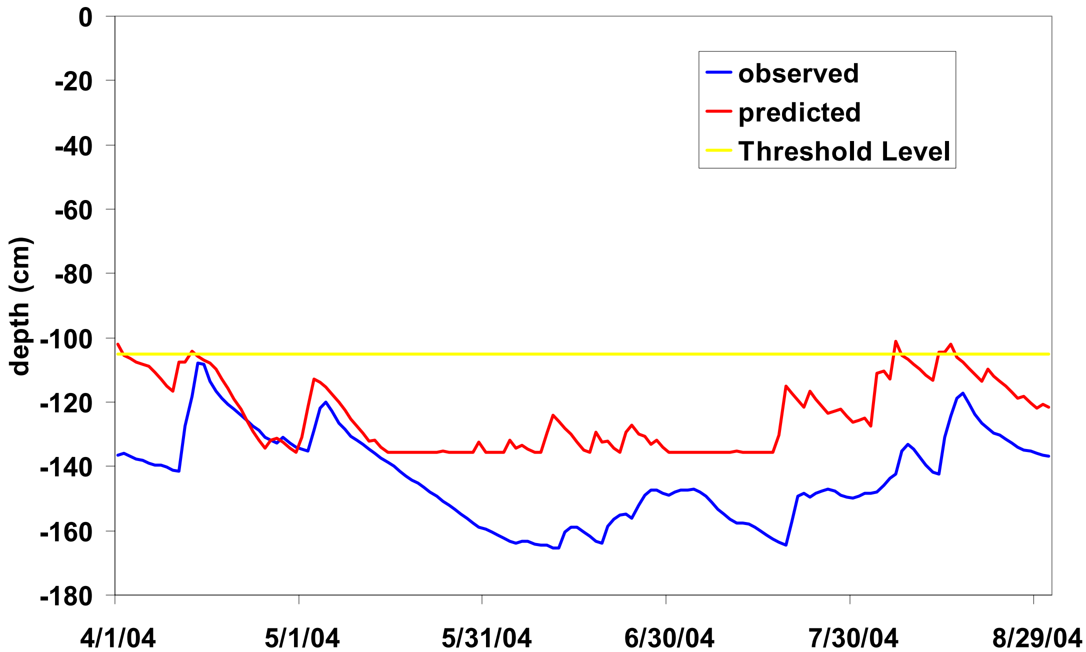

Figure F.17 Comparative hydrographs from the simulated data period produced the Threshold method for the Tarboro plot that was 'wetter' than the observed data.

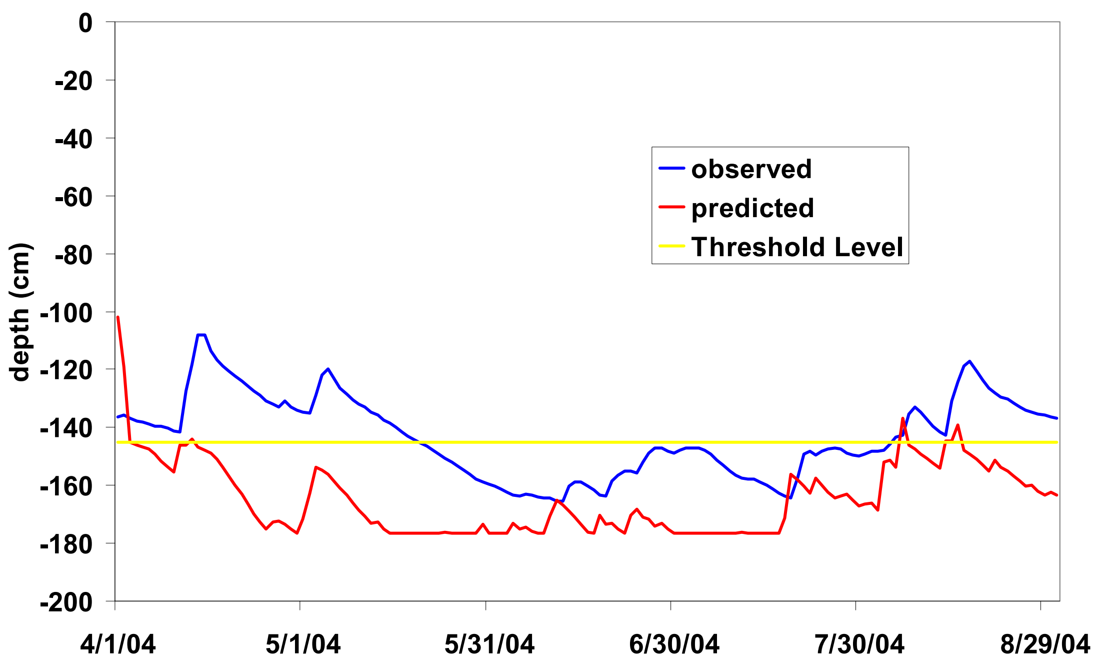

Figure F.18 Comparative hydrographs from the simulated data period produced the Threshold method for the Tarboro plot that was 'drier' than the observed data.

WET TARBORO SOILS

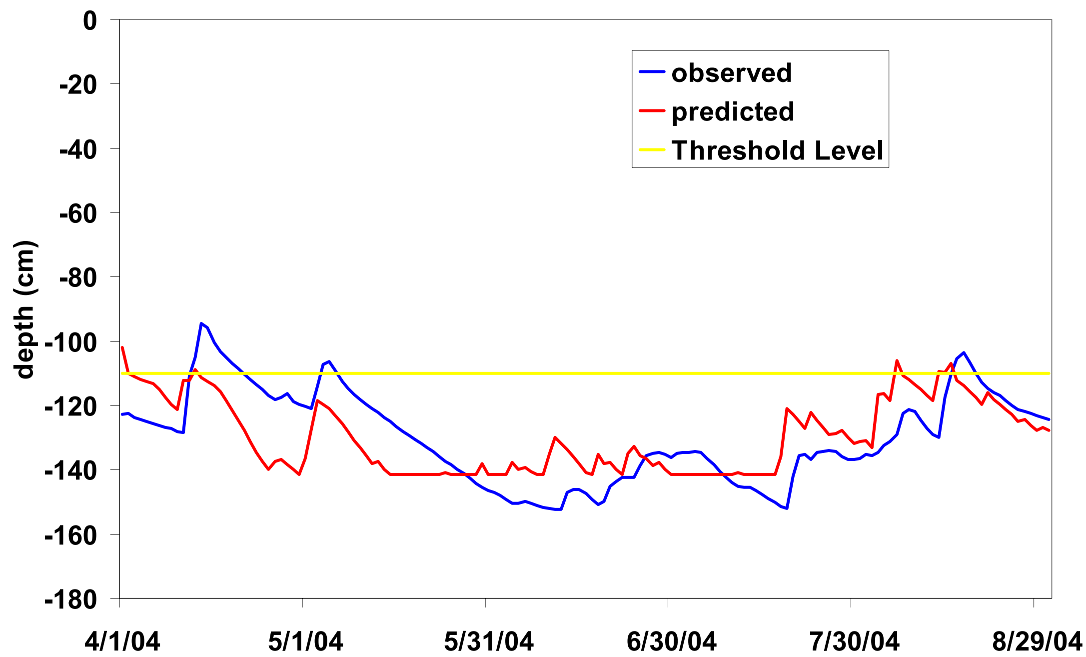

Figure F.19. Comparative hydrographs from the simulated data period produced the Threshold method for the wet Tarboro 1 plot that was an approximate match to the observed data.

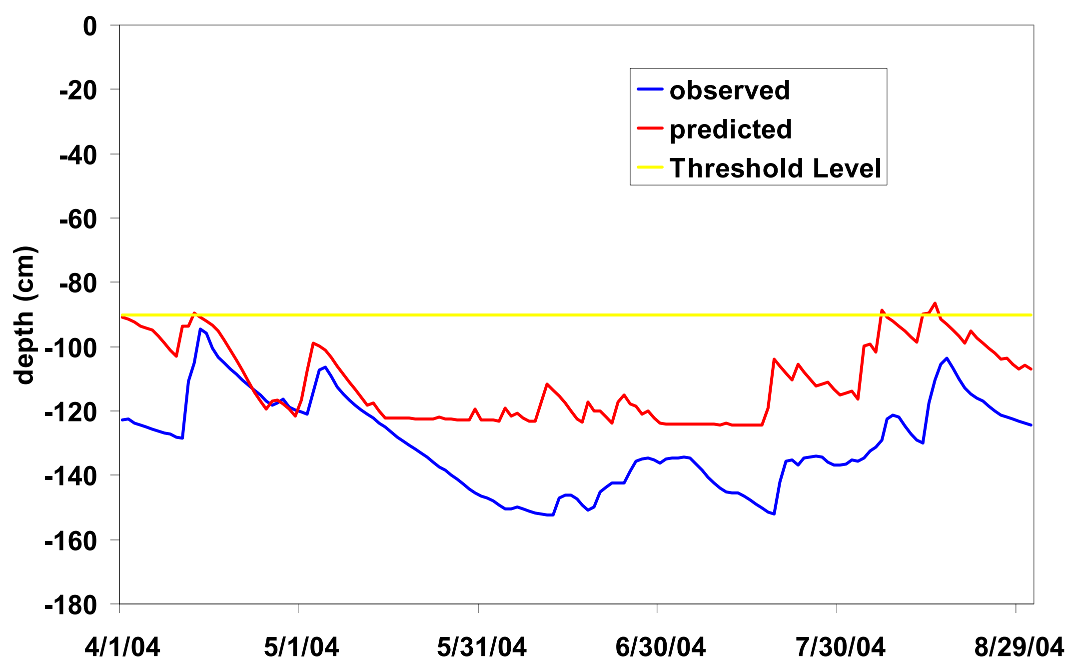

Figure F.20 Comparative hydrographs from the simulated data period produced the Threshold method for the wet Tarboro 1 plot that was 'wetter' than the observed data.

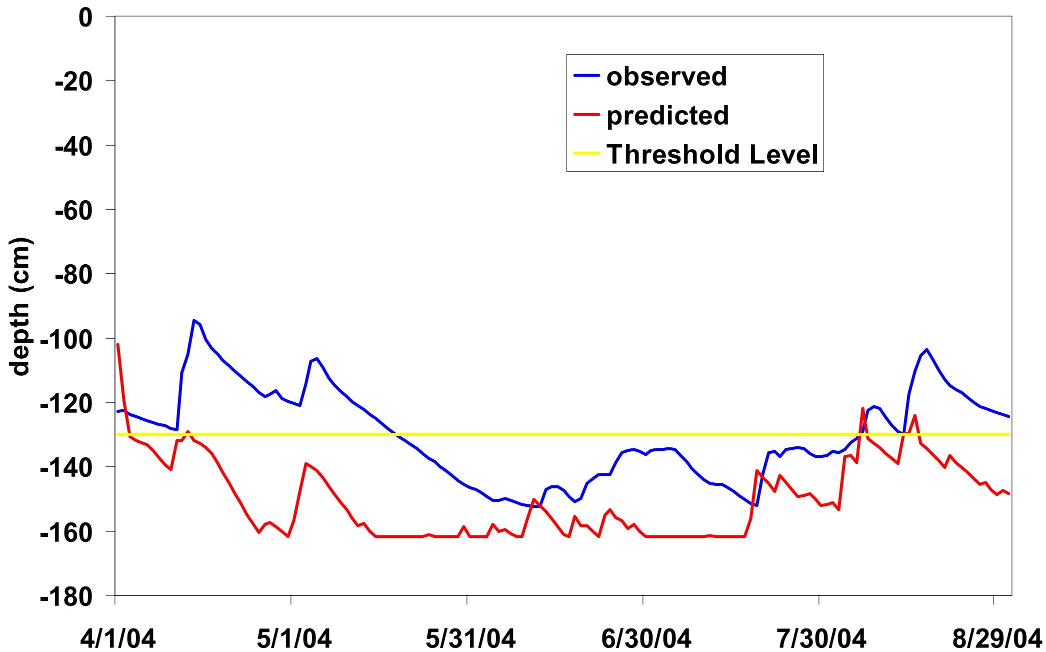

Figure F.21 Comparative hydrographs from the simulated data period produced the Threshold method for the wet Tarboro 1 plot that was 'drier' than the observed data.

SEABROOK SOILS

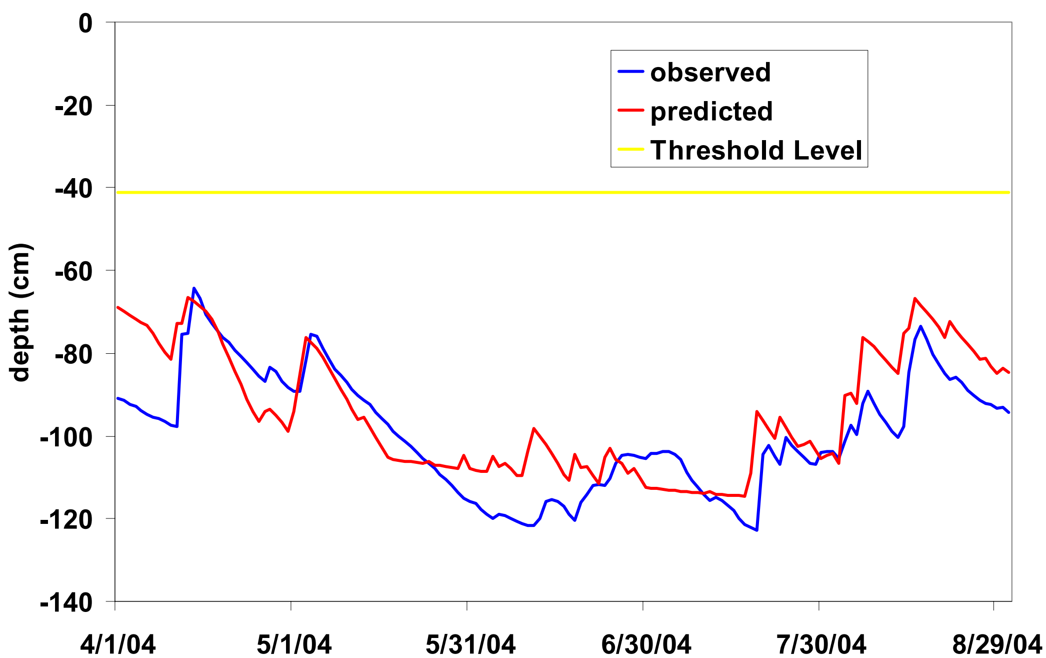

Figure F.22. Comparative hydrographs from the simulated data period produced the Threshold method for the Seabrook 1 plot that was an approximate match to the observed data.

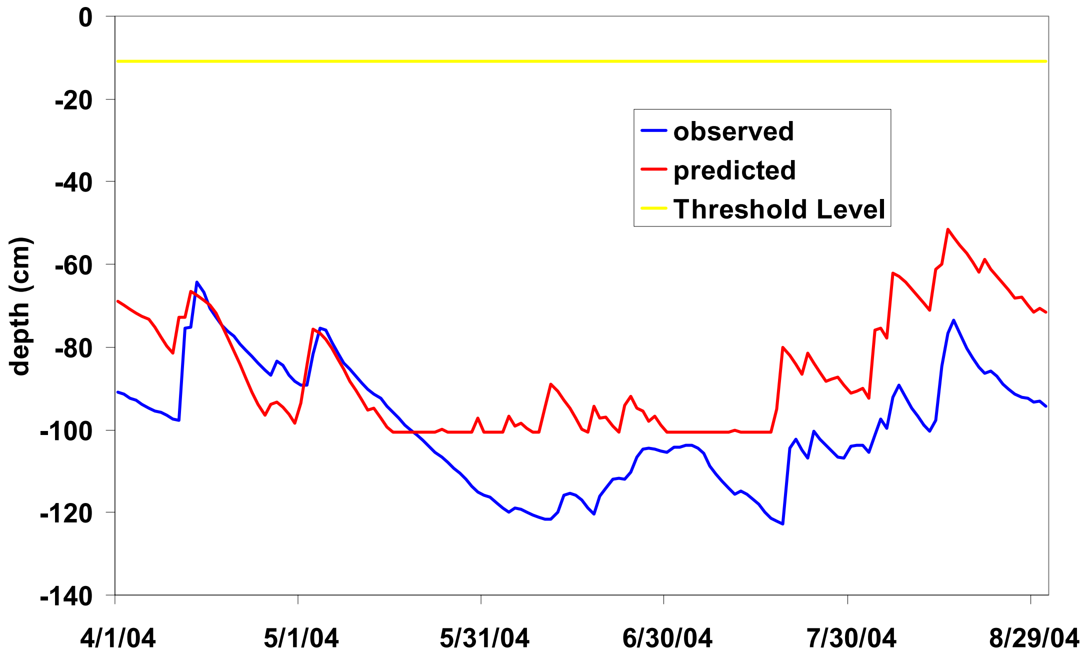

Figure F.23 Comparative hydrographs from the simulated data period produced the Threshold method for the Seabrook 1 plot that was 'wetter' than the observed data.

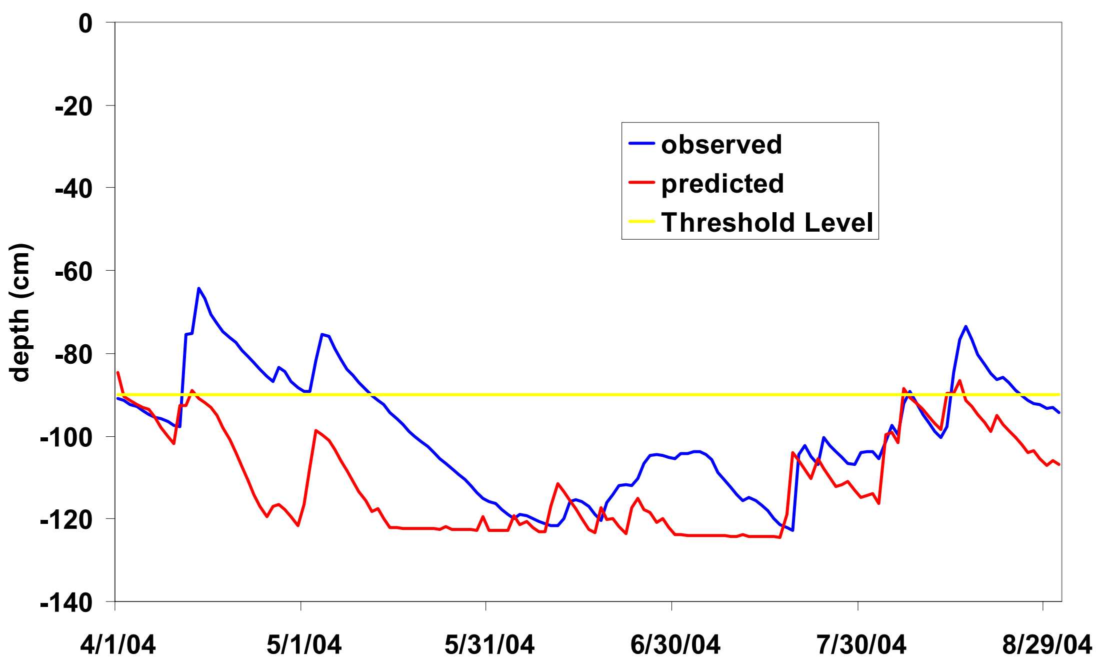

Figure F.24 Comparative hydrographs from the simulated data period produced the Threshold method for the Seabrook 1 plot that was 'drier' than the observed data.

APPENDIX G

HISTORIC SOIL WETNESS CONDITIONS OBTAINED BY THE WRI METHOD FOR SELECTED PLOTS AT EVERY STUDY SITE

RICHLANDS SITE

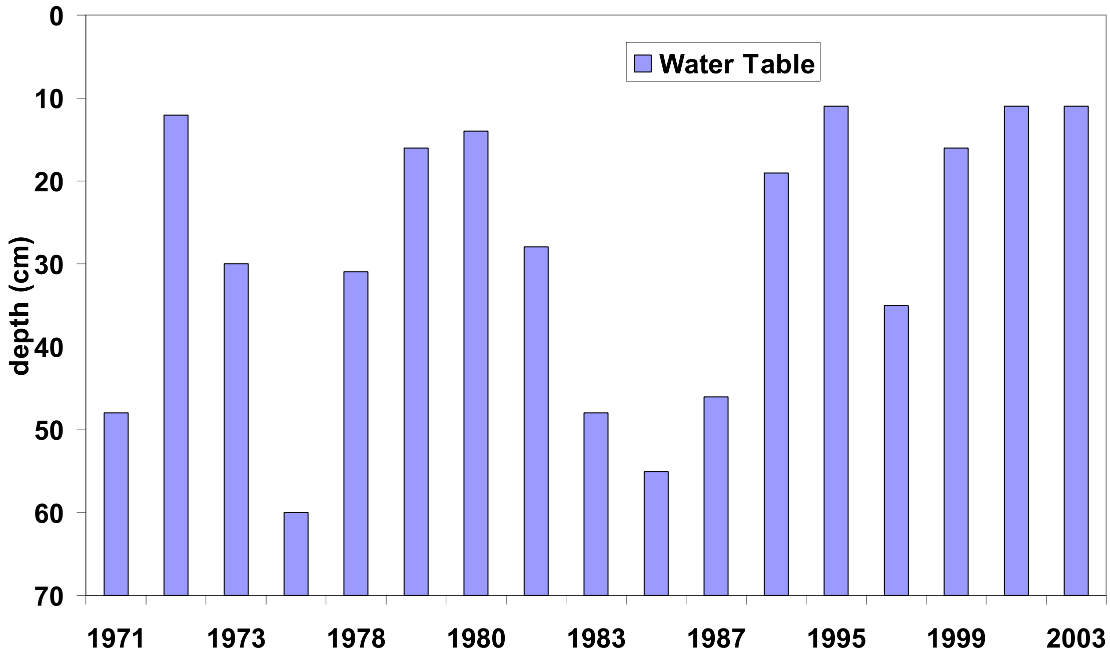

Figure G.1 Historic wetness conditions predicted by the WRI method for the Foreston 2 plot.

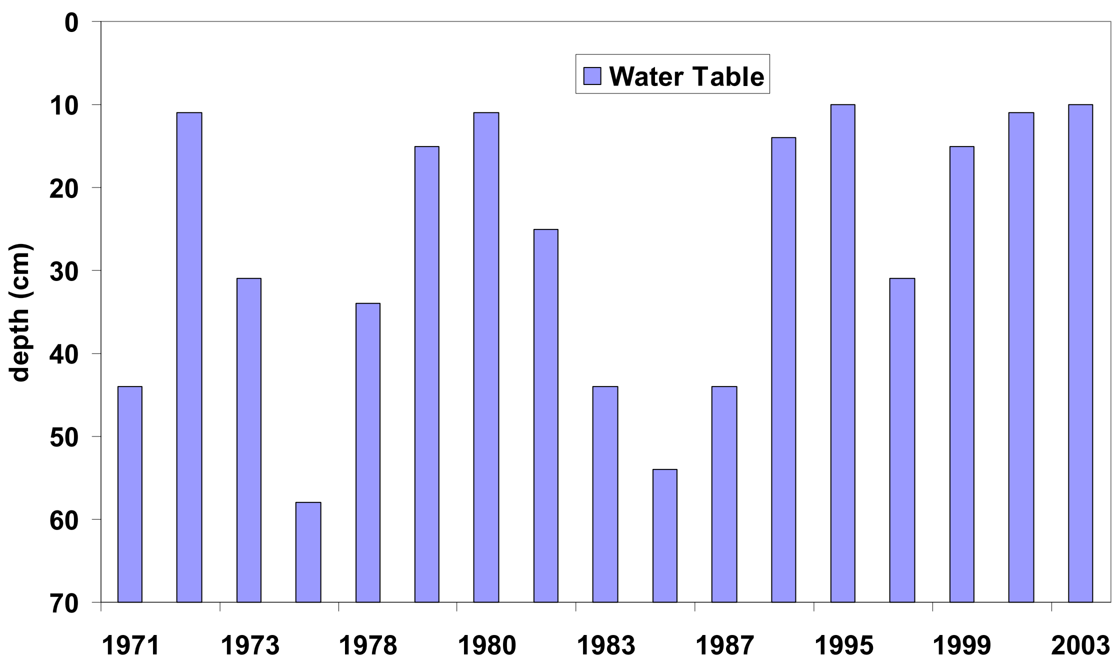

Figure G.2 Historic wetness conditions predicted by the WRI method for the wet Foreston 2 plot.

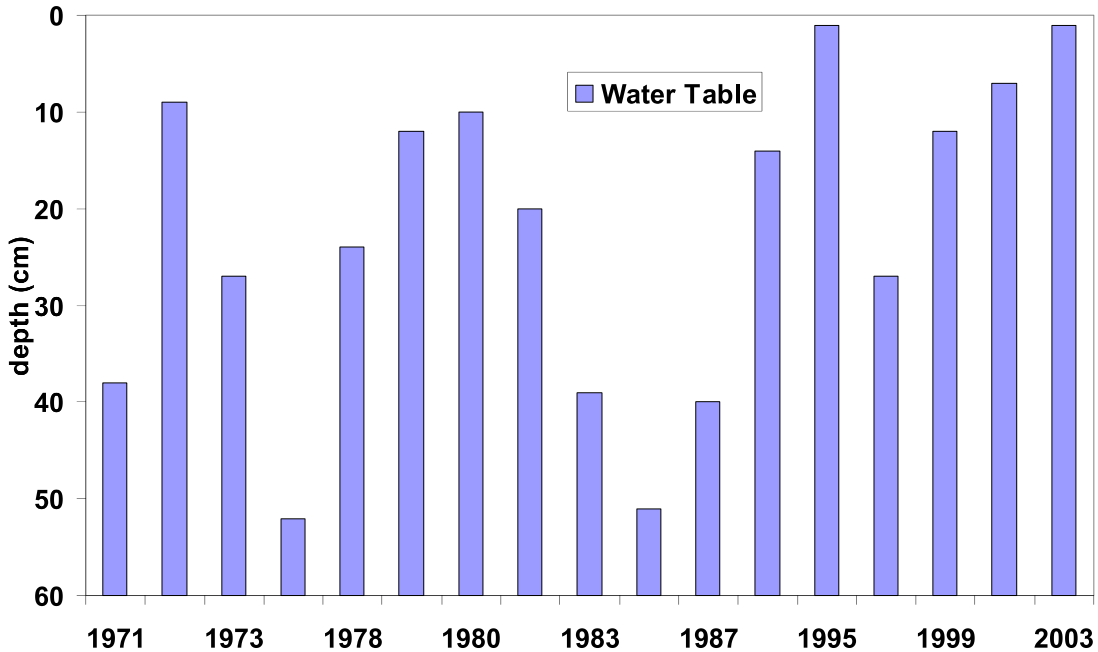

Figure G.3 Historic wetness conditions predicted by the WRI method for the Stallings 2 plot.

VANCEBORO SITE

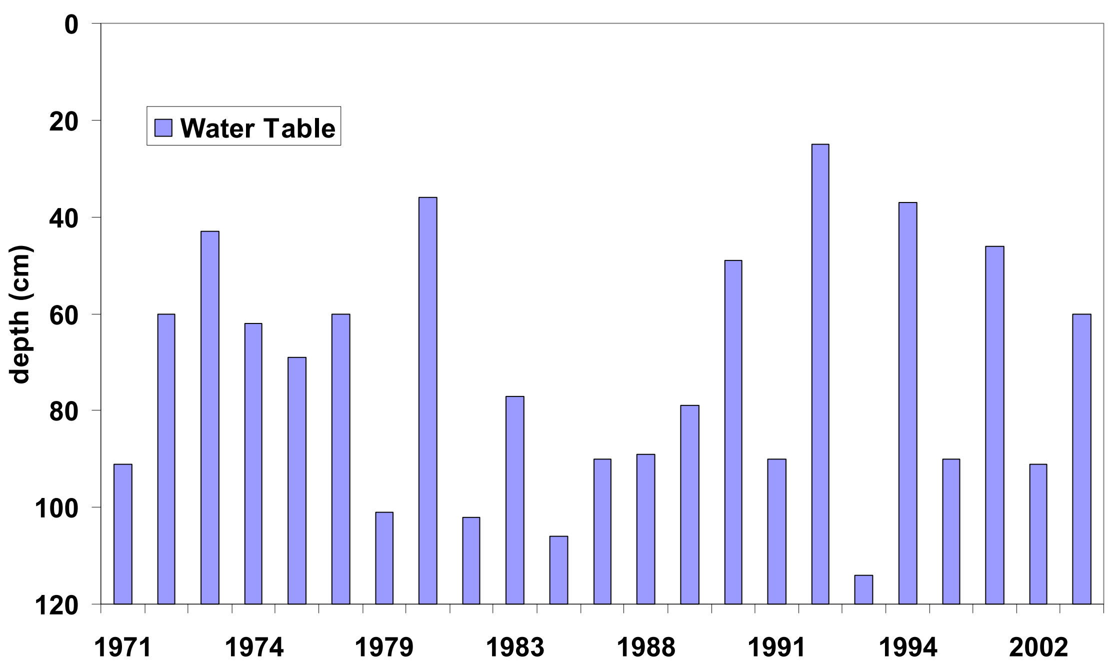

Figure G.4 Historic wetness conditions predicted by the WRI method for the Craven 2 plot.

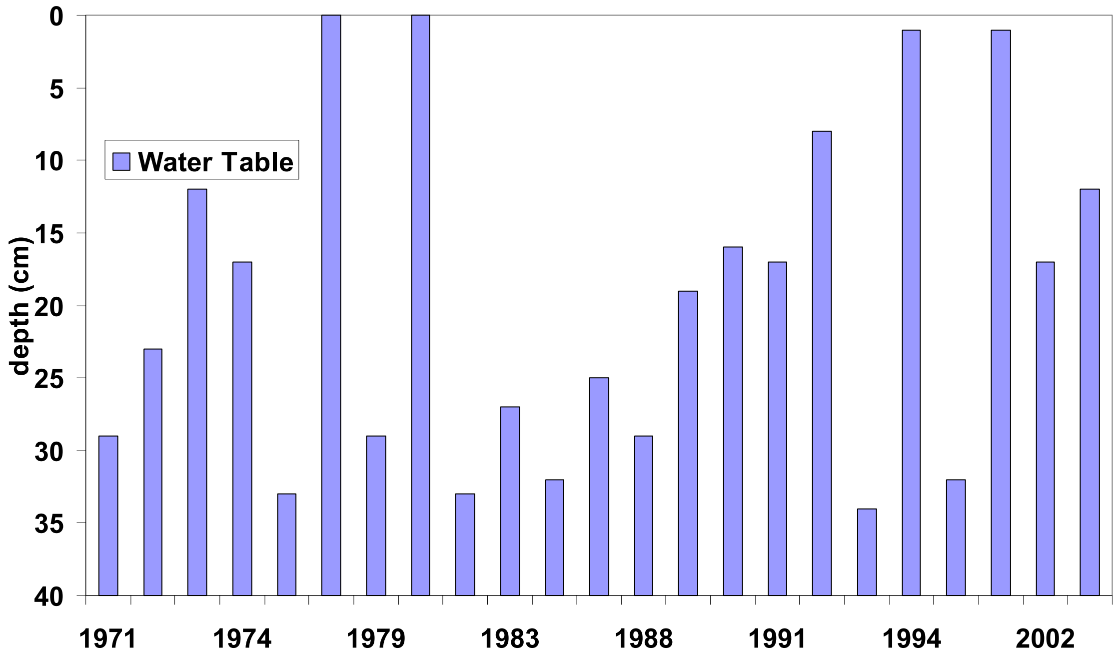

Figure G.5 Historic wetness conditions predicted by the WRI method for the Lenoir 2 plot.

COOL SPRINGS SITE

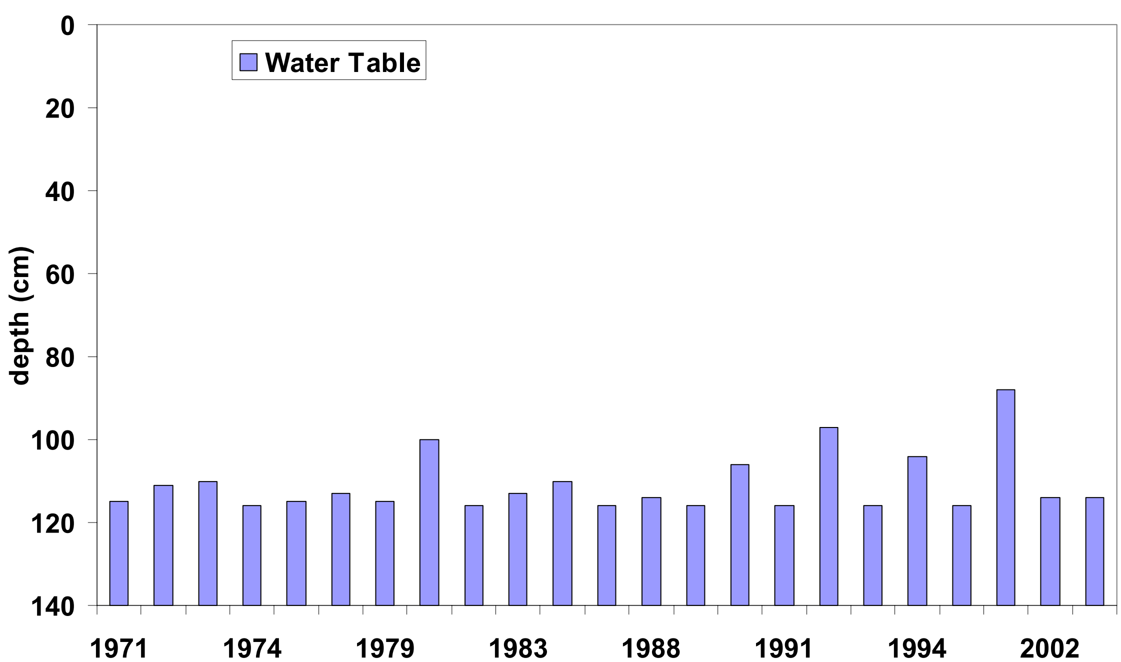

Figure G.6 Historic wetness conditions predicted by the WRI method for the Tarboro plot.

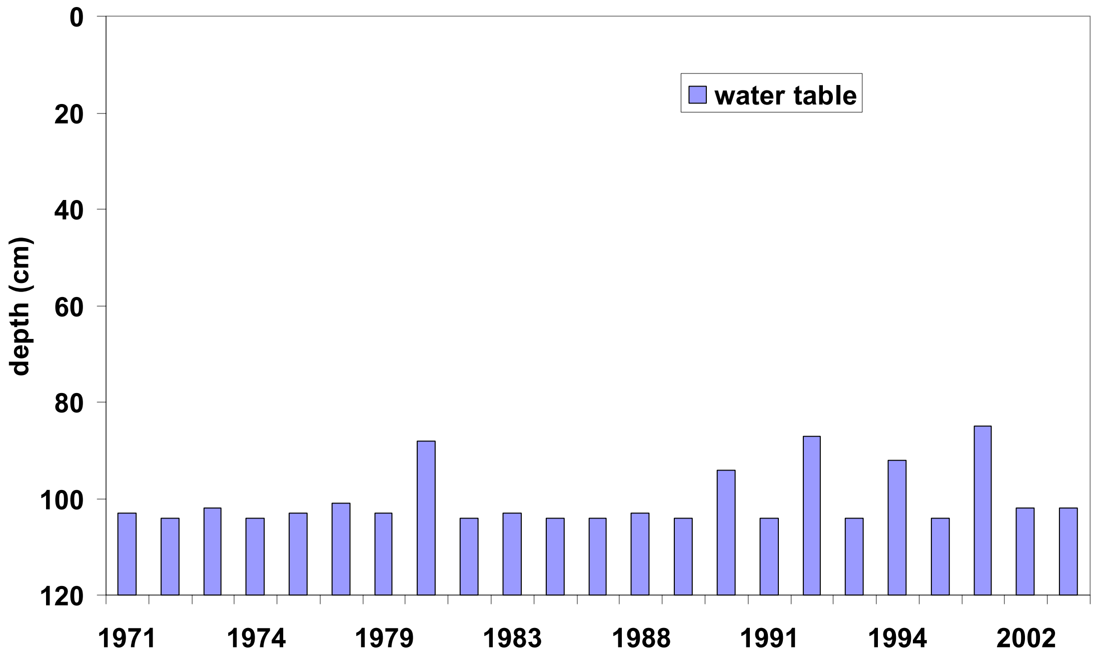

Figure G.7 Historic wetness conditions predicted by the WRI method for the wet Tarboro 1 plot.

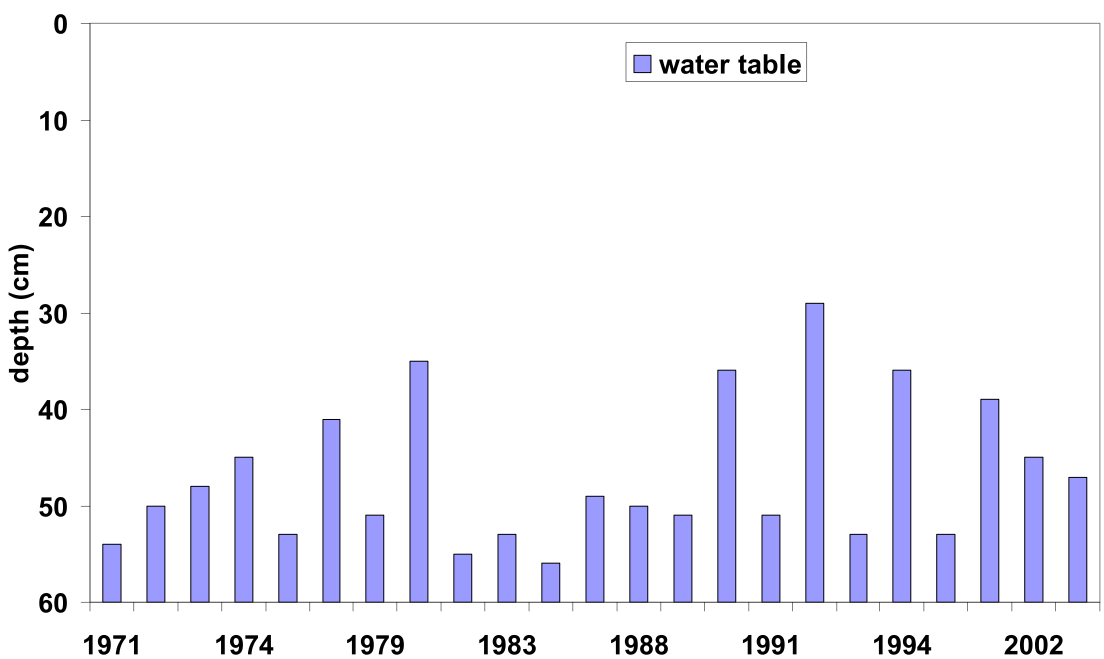

Figure G.8 Historic wetness conditions predicted by the WRI method for the Seabrook 1 plot.

APPENDIX H

SOIL PHYSICAL PROPERTIES OF SELECTED PLOTS OF THE RICHLANDS AND VANCEBORO SITES

Table I.1 Saturated hydraulic conductivities of the soils in transect 2 of the Richlands site.

Foreston 2		Wet Foreston 2		Stallings 2	
Depth cm	K_{sat} cm/h	Depth cm	K_{sat} cm/h	Depth cm	K_{sat} cm/h
10	7.55	15	13.9	15	14.7
31	3.36	36	13.57	41	1.03
51	0.22	61	3.33	71	0.33
71	0.34	86	5.3		

Table I.2 Saturated hydraulic conductivities of the soils in transect 2 of the Vanceboro site.

Craven 2		Lenoir 2	
Depth cm	K_{sat} cm/h	Depth cm	K_{sat} cm/h
10	0.48	10	1.26
31	0.34	31	1.2
61	0.27	51	0.25
89	0.92	91	0.05

APPENDIX I

15A NCAC 18A .1942 SOIL WETNESS CONDITIONS

(a) Soil wetness conditions caused by seasonal high-water table, perched water table, tidal water, seasonally saturated soil or by lateral water movement shall be determined by field evaluation for soil wetness colors and field observations, and may be assessed by well monitoring, computer modeling, or a combination of monitoring and modeling as required by this Rule. All sites shall be evaluated by an Authorized Agent of the Department using Basic Field Evaluation Procedures pursuant to Paragraph (b) of this Rule.
(b) Basic Field Evaluation Procedures:

(1) A soil wetness condition shall be determined by the indication of colors of chroma 2 or less (Munsell Color Charts) at =2% of soil volume in mottles or matrix of a horizon or horizon subdivwasion. However, colors of chroma 2 or less which were relic from minerals of the parent material shall not be considered indicative of a soil wetness condition.

(2) A Soil wetness condition shall also be determined by the periodic direct observation or indication of saturated soils or a perched water table, or lateral water movement flowing into a bore hole, monitoring well, or open excavation above a less permeable horizon or horizon subdivision, that may occurred without the presence of colors of chroma 2 or less. A soil wetness condition caused by saturated soils or a perched water table shall be confirmed to extend for at least three consecutive days. The shallowest depth to soil wetness condition determined by Subparagraph (b)(1) or (b)(2) of this Rule shall take precedence.

(c) Site Suitability as to Soil Wetness: Initial suitability of the site as to soil wetness shall be determined based upon the findings of the Basic Field Evaluation Procedures made pursuant to Paragraph (b) of this Rule. Sites where soil wetness conditions were greater than 48 inches below the naturally occurring soil surface shall be considered SUITABLE with respect to soil wetness. Sites where soil wetness conditions were between 36 and 48 inches below the naturally occurring soil surface shall be considered PROVWASIONALLY SUITABLE with respect to soil wetness. Sites where soil wetness conditions were less than 36 inches below the naturally occurring soil surface shall be considered UNSUITABLE with respect to soil wetness. Sites where a soil wetness condition was determined based upon the observation or indication of lateral water movement within 48 inches of the naturally occurring soil surface shall be considered UNSUITABLE, except when such water can be intercepted in accordance with 15A NCAC 18A .1956(4).

(d) Alternative Procedures for Soil Wetness Determination: The Owner or the Owner's Legal Representative (Applicant) shall have the opportunity to submit documentation that the soil wetness condition and resultant site classification be alternately determined and reclassified by direct monitoring, computer modeling, or a combination of monitoring and modeling, in accordance with a Direct Monitoring Procedure, Monitoring and Modeling Procedure, or Modeling Procedure made pursuant to Paragraphs (e), (f), or (g) of this Rule. This determination shall take precedence over the determination made pursuant to the Basic Field Evaluation Procedures [Paragraph (b) of this Rule], when the conditions of Paragraphs (e), (f), or (g) of this Rule were met. Determination by one of these Monitoring or Modeling procedures shall also be required when:

(1) the Owner proposes to use a wastewater system requiring a deeper depth to a soil wetness condition than the depth determined by the Basic Field Evaluation Procedures pursuant to Paragraph (b) of this Rule; or
(2) the Owner proposes to use sites with Group III or IV soil within 36 inches of the surface and where drainage modifications were proposed to be made, including the installation of subsurface drain tile, open drainage ditches, or surface landscape modifications, or on such sites when fill was proposed to be used in conjunction with existing or proposed drainage modifications. Final determination of soil wetness condition for these sites shall be made pursuant to the Modeling Procedure in Paragraph (g) of this Rule

(e) Direct Monitoring Procedure. Soil wetness conditions may be determined by direct observation of the water surface in wells during periods of typically high water elevations utilizing the following monitoring procedures and interpretation method.

(1) The applicant shall notify the local health department of the intent to monitor water surface elevations by submitting a proposal that includes a site plan, well and soil profile at each monitoring location, and a monitoring plan no later than 30 days prior to the

monitoring period. An applicant other than the property owner shall have written authorization from the owner to be the owner's legal representative. Soil wetness and rainfall monitoring shall be conducted under the responsible charge of a third-party consultant or by the property owner or the owner's agent. A third party consultant was qualified when licensed or registered in accordance with G.S. 89C (Engineers), G.S. 89E (Geologists), G.S. 89F (Soil Scientists), or G.S. 90A Article 4 (Registered Sanitarians), if required. The Owner shall submit the name(s) of the consultant(s) performing any monitoring on their behalf to the local health department.

(2) The applicant shall submit a site plan showing proposed sites for wastewater system, shall provide the longitude and latitude of the site, location of monitoring wells, and all drainage features that may influence the soil wetness conditions, and specify any proposed fill and drainage modifications.

(3) The applicant shall submit a monitoring plan indicating the proposed number, installation depth, screening depth, soil and well profile, materials and installation procedures for each monitoring well, and proposed method of analysis. A minimum of three water level monitoring wells shall be installed for water surface observation at each site. Additional wells shall be required for sites handling systems with a design flow greater than 600 gallons per day (minimum of one additional well per 600 gallons per day increment).

(4) The local health department shall be given the opportunity to conduct a site visit and verify the appropriateness of the proposed plan. Well locations shall include portions of the initial and replacement drainfield site(s) containing the most limiting soil/site conditions. Prior to installation of the wells the local health department shall approve the plan. If the plan was disapproved, the local health department shall include specific changes necessary for approval of the monitoring plan.

(5) Wells shall extend at least five feet below the natural soil surface, or existing soil surface for fill installed prior to July 1, 1977 meeting the requirements for consideration of a site with existing fill of G.S. 130A- 341 and the rules adopted pursuant thereto. However, a well or wells, which extend(s) down only 40 inches may be used if they provide a continuous record of the water table for at least half of the monitoring period, and one or more shallower wells may be required on sites where shallow lateral water movement or perched soil wetness conditions were anticipated.

(6) Water surface in the monitoring wells shall be recorded at least daily from January 1 to April 30, taken at the same time during the day (plus or minus three hours). A rain (precipitation) gauge was required within one-half mile of the site. At least daily rainfall shall be recorded beginning no later than December 1 through April 30 (the end of the well monitoring period).

(7) Interpretation Method for Direct Monitoring Procedure: The following method of determining depth to soil wetness condition from water surface observations in wells shall be used when the 60-day weighted rainfall index for the January through April monitoring period equals or exceeds the site's long-term (historic) 60-day weighted rainfall index for January to April rainfall with a 30 percent recurrence frequency (wetter than the 9th driest year of 30, on average). The 60-day weighted rainfall index for the monitoring period and historic rainfall record shall be computed as:

$$WRI_{60} = 0.5P_D + P_J + P_F + P_M + 0.5P_A$$

Where WRI_{60} = 60-day weighted rainfall index for January to April

P_D = Total December rainfall

P_J = Total January rainfall

P_F = Total February rainfall

P_M = Total March rainfall

P_A = Total April rainfall

The Department shall prepare contour maps for each county where this interpretation procedure was proposed. Contours shall be prepared following standard interpolation procedures using normalized data collected from all National Weather Service Stations, or equivalent, from which appropriate data were available, at least prior to February 1 of the monitoring season. Data from each station shall be normalized by fitting a 2-parameter gamma distribution to the 60-day weighted rainfall index computed for at least the most recent three decades of historic data, in accordance with procedures outlined in Chapter 18 of the National Engineering Handbook, NRCS, USDA. From this fitted distribution, the 60- day weighted rainfall index for January through April rainfall with a 30%, 50%, 70% and 80% recurrence frequency shall be computed for each Station, to provide the raw data points from which the contour maps shall be prepared. From these maps, the site's 60-day weighted rainfall index for the January through April monitoring period shall be compared to the long-term (historic) January to April 60-day weighted rainfall index at different expected recurrence frequencies. The soil wetness condition shall be determined as the highest level that was continuously saturated for the number of consecutive days during the January through April monitoring period shown in the following table:

Recurrence Frequency Range January to April 60-Day Weighted Rainfall Index	Number of Consecutive Days of Continuous Saturation for Soil Wetness Condition
30% to 49.9%	3 days or 72 hours
50% to 69.9%	6 days or 144 hours
70% to 79.9%	9 days or 216 hours
80% to 100%	14 days or 336 hours

(8) If monitoring well data was collected during monitoring periods that span multiple years, the year which yields the highest (shallowest) soil wetness condition shall be applicable.

(f) Monitoring and Modeling Procedure: A combination of monitoring and modeling may be used to determine a soil wetness condition utilizing the following monitoring procedures and interpretation method. (1) The procedures described for the Direct Monitoring Procedure in Subparagraphs (e)(1), (2), (3), (4), (5), and (6) of this Rule shall be used to monitor water surface elevation and precipitation for determining soil wetness conditions by a combination of direct observation and modeling, except that the rainfall gauge and each monitoring well shall use a recording device and a data file (DRAINMOD-compatible) shall be submitted with the report to the local health department (devices shall record rainfall at least hourly and well water level at least daily).
(2) The ground water simulation model DRAINMOD shall be used to predict daily water levels over at least a 30 year historic time period after the model was calibrated using the water surface and rainfall observations made on-site during the monitoring period. The soil wetness condition shall be determined as the highest level predicted by the model to be saturated for a 14-day continuous period between January 1 and April 30 with a recurrence frequency of 30 percent (an average of at least 9 years in 30).

(A) Weather input files, required to run the DRAINMOD, shall be developed from hourly rainfall gauge data taken within a half-mile of the site and from daily temperature and hourly or daily rainfall data collected over a minimum 30-year period from the closest available National Weather Service, or equivalent, measuring station to the site. DRAINMOD weather data files on file with the Department shall be made available upon request to the applicant or applicant's consultants. Daily maximum and minimum temperature data for the January 1 through April 30 monitoring period, plus for at least 30 days prior to this period, shall be obtained from the closest available weather station.

(B) Soil and Site inputs for DRAINMOD, including a soils data file closest to the soil series identified, depths of soil horizons, estimated saturated hydraulic conductivity of each horizon, depth and spacing of drainage features and depression storage, shall be selected in accordance with procedures outlined in the DRAINMOD Users Guide, and guidance was also available in Reports 333 and 342 of the University of North Carolinas Water

Resources Research Institute. DRAINMOD soils data files on file with the Department shall be made available upon request to the applicant or applicant's consultants.

C) Inputs shall be based upon site specific soil profile descriptions Soil and site input factors shall be adjusted during the model calibration process to achieve a best fit by least squares analysis of the daily observations over the whole monitoring period (mean absolute deviation between measured and predicted values no greater than eight inches), and to achieve the best possible match between the highest water table depth during the monitoring period (measured-vs predicted) that was saturated for 14 consecutive days.

(D) For sites intended to receive over 1500 gallons per day, the soil wetness determination using DRAINMOD shall take into consideration the impact of wastewater application on the projected water table surface.

(E) The ground water simulation analysis shall be prepared and submitted to the local health department by individuals qualified to use DRAINMOD by training and experience and who were licensed or registered in North Carolina if required in G.S. 89C (Engineers), G.S. 89E (Geologists), and G.S. 89F (Soil Scientists). The local health department or Owner may request a technical review by the Department prior to approval of the soil wetness condition determination.

(g) Modeling Procedure: A soil wetness condition may be determined by application of DRAINMOD to predict daily water levels over at least a 30 year historic time period after all site-specific input parameters have been obtained, as outlined in the DRAINMOD Users Guide. This modeling procedure shall be used when a ground water lowering system was proposed for a site with Group III or IV soils within 36 inches of the naturally occurring soil surface. This procedure shall also be used to evaluate sites with Group III or IV soils within 36 inches of the naturally occurring soil surface, where the soil wetness
condition was initially determined using a procedure described in Paragraphs (e) or (f) of this Rule and where drainage modifications were proposed or when fill was proposed to be used in conjunction with existing or proposed drainage modifications. The soil wetness condition shall be determined as the highest level predicted by the model to be saturated for a 14-day continuous period between January 1 and April 30 with a recurrence frequency of 30 percent (an average of at least 9 years in 30).

(1) Weather input files, required to run DRAINMOD, shall consist of hourly rainfall and daily temperature data collected over the entire period of record but for at least a 30-year period from the closest available National Weather Service, or equivalent, measuring station to the site. DRAINMOD weather data files on file with the Department shall be made available upon request to the applicant or applicant's consultants.

(2) Soil and Site inputs for DRAINMOD, including a soils data file closest to the soil series identified, depths of soil horizons, hydraulic conductivity of each horizon, depth and spacing of proposed drainage features and surface storage and drainage parameters, shall be selected in accordance with procedures outlined in the DRAINMOD User's Guide. DRAINMOD soils data files on file with the Department shall be made available upon request to the applicant or applicant's consultants. Inputs shall include:

(A) Soil input file with the soil moisture characteristic curve and data for the soil profile that was closest to the described soil profile that was present on the site;

(B) Soil horizon depths determined on site;

(C) Site measured or proposed drain depth and spacing, and drain outlet elevation;

(D) In-situ saturated hydraulic conductivity measurements for at least three representative locations on the site and at each location for at least three most representative soil horizons within five feet of the surface. Conductivity measurements shall be for one representative soil horizon at or above redoximorphic depletion features and two representative soil horizons at and below redoximorphic concentration features at each location on the site;

(E) All other model parameters based upon the DRAINMOD User's Guide, or other accepted values consistent with the simulation model; and

(F) A sensitivity analysis shall be conducted for the following model parameters:

(i) Soil input files for at least two other most closely related soil profiles;
(ii) Saturated hydraulic conductivity of each of horizons measured on-site;
(iii) Drain depth and spacing; and
(iv) Surface storage and depth of surface flow inputs.

The sensitivity analysis shall be used to evaluate the range of soil and site characteristics for choosing input parameters related to the soil profiles, hydraulic conductivity input values based upon the range of hydraulic conductivity values measured on the site, and inputs for surface and subsurface drainage features based upon the range of possible elevations and distances that occurred or may occurred after installation of improvements. The sensitivity analysis shall establish which parameters were most critical for determination of the depth to soil wetness condition. Conservative values for the most critical parameters shall be used in applying the model to the site.

(3) For sites designed to receive over 600 gallons per day, the soil wetness determination using DRAINMOD shall take into consideration the impact of wastewater application on the projected water table surface.
(4) The ground water simulation analysis shall be prepared and submitted to the local health department by individuals qualified to use DRAINMOD by training and experience and who were licensed or registered in North Carolina if required in G.S. 89C (Engineers), G.S. 89E (Geologists), and G.S. 89F (Soil Scientists). The local health department shall submit the ground water simulation analysis to the Department for technical review prior to approval of the soil wetness condition determination.

(h) A report of the investigations made for the Direct Monitoring Procedure, Monitoring and Modeling Procedure or Modeling Procedure pursuant to Paragraphs (e), (f), or (g) of this Rule shall be prepared prior to approval of the soil wetness condition determination. Reports prepared by a licensed or registered professional shall bear the professional seal of the person(s) whom conducted the investigation (Engineer, Geologist, Soil Scientist or Registered Sanitarian). A request for technical review of the report by the Department shall include digital copies of monitoring data and digital copies of model inputs, output data, and graphic results, as applicable.

(j) Where the site was UNSUITABLE with respect to soil wetness conditions, it may be reclassified PROVWASIONALLY SUITABLE if a modified, alternative or innovative system can be installed in accordance with 15A NCAC 18A .1956,.1957, or .1969.

History Note: Authority G.S. 130A-335(e):
Eff. July 1, 1982;
Amended Eff. January 1, 1990;
Temporary Amendment Eff. June 24, 2003; April 17, 2002;
Amended Eff. May 1, 2004.

APPENDIX J

CALIBRATION METHOD SUCCESS CRITERIA FOR ALL PLOTS AT ALL SITES

Table J.1 A summary of average absolute deviations used for comparison of observed water table fluctuations with calibrated water tables all sites.

Richlands			**Vanceboro**			**Cool springs**	
plot	**dev.**		**plot**	**dev.**		**plot**	**dev.**
----------------------------------cm--------------------------------------							
1Fo	6.14						
2Fo	7.35		1Cr	9.91		1Ta	11.80
3Fo	8.78		2Cr	9.92		1wTa	11.78
1WFo	7.23		3Cr	11.0		2 wTa	9.88
2WFo	7.62		1Le	9.85		1Se	8.23
3WFo	9.82		2Le	9.28		2Se	7.59
1St	16.67		3Le	10.27			
2St	16.69						
3St	16.80						
average	10.79		average	10.04		average	9.86