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Evaluation of Water Table Dynamics in Relation to Soil Morphological Indicators of Seasonal Wetness

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Abstract:

Soil morphological features such as low chroma (2 or less) soil colors are used as indicators of the seasonal high water table (SHWT) for onsite wastewater system (OWS) design in North Carolina and many other states. OWS drainfield trenches are installed at least 30 cm above the low chroma colors to ensure aerobic conditions for wastewater treatment. The objective of this study was to evaluate the accuracy of low chroma soil colors in predicting the depth of the SHWT for some common soil series in Pitt County, North Carolina. Monitoring wells with automated water level loggers were installed at 7 locations and programmed to record water levels every 0.5 hours during the typical wet season from December 2011 to May 2012. Soil profiles were described, including the depth to low chroma colors, during the installation of the monitoring wells. An automated rain gauge was used to record hourly precipitation. Rainfall and well hydrograph data were used with the weighted rainfall index interpretation method to determine the depth to SHWT. The depth to SHWT was compared to the depth of low chroma colors to assess accuracy. The depths to SHWT were on average 9 ± 26 cm greater than low chroma color depths. However, for 3 of 7 sites, the SHWT was closer to the surface than the low chroma colors. Also, the low chroma soil colors and SHWT depths varied by an absolute value of 20 ± 16 cm. The use of low chroma soil colors for OWS design in some soils may result in less than 30 cm of separation to the actual SHWT, possibly reducing OWS treatment efficiency.

Keywords: Redoximorphic, soil colors, groundwater, onsite wastewater

1. Introduction:

1.1 Onsite Wastewater Systems: In North Carolina, there are approximately 2 million OWS in operation, with as many as 30,000 – 40,000 more systems being installed every year (Hoover, 2004). OWS work by dispensing human wastewater from the septic tank to the drainfield trenches, where it infiltrates the soil, undergoing processes that reduce the concentration of pollutants such as nutrients, bacteria, and viruses (Robertson et al., 1991; Scandura and Sobsey, 1997; Humphrey et al., 2010; Humphrey et al., 2011; Humphrey and O'Driscoll, 2011c). OWS pollutant treatment efficiency is typically enhanced as the vertical distance between the drainfield trenches and water table increases (Karathanasis et al., 2006a; Karathanasis et al., 2006b; Humphrey et al., 2011). Therefore, OWS should be installed in areas with adequate separation from the water table.

Groundwater levels in North Carolina are typically highest during the winter months, due to less evaporation and transpiration. However, site evaluations for the issuance of OWS permits must occur throughout the year, not just the wet season. Therefore, an accurate estimate of the depth to seasonal high water table (SHWT) that can be conducted quickly, inexpensively, and throughout the year is important for determining site suitability. In North Carolina, the SHWT is defined as the depth at which the soil is saturated with groundwater for at least 14 consecutive days in most years with average rainfall totals. During drier years, fewer (than 14) days of continuous saturation are used as the predictive duration of saturation needed for the SHWT determination. For example, if the recurrence frequency of wet season rainfall is between 30 and 49.9%, then 3 consecutive days are the required duration of saturation for SHWT. Without groundwater and rainfall data, the SHWT is considered to be the depth where low chroma soil colors occupy at least 2% of the soil volume. OWS drainfield trenches must be installed at least 30 cm above the SHWT (or low chroma colors) for systems installed in sandy loam and finer textured soils (15A NCAC 18A. 1995m.). The 30 cm separation should allow for aerobic conditions beneath the drainfield trenches during the wet season, if the low chroma colors are accurate predictors of the SHWT.

1.2 Low Chroma Soil Colors: Low chroma colors are a redoximorphic feature resulting from the depletion of oxygen and reduction and loss of iron from the soil. Oxidized iron imparts bright yellow, red, and orange coatings on soil grains (Figure 1) (Richardson and Vepraskus, 2001). Under anaerobic conditions, microorganisms can oxidize organic matter by using ferric iron (Fe^{3+}) as a terminal electron acceptor, thus reducing ferric iron to ferrous iron (Fe^{2+}) (Mitsch and Gosselink, 2000). Ferrous iron is mobile and can leach out of the soil when the water table declines resulting in a loss of the iron-rich, high chroma colors (red, brown, yellow) and leaving the low chroma (grey, white) colors of the mineral grains (Figure 1) (Richardson and Vepraskus, 2001). For this process to occur, it is essential that there is a source labile organic matter, anaerobic conditions, iron, microorganisms, and a sufficient amount of time (Vepraskas, 1994). If any of these conditions are not present, low chroma colors may not form.

Fiedler and Sommer (2004) found a nearly linear relationship between soil color and percentage of time the soil is saturated, indicating that the presence of low chroma colors is directly related to the duration of soil saturation. Similarly, Morgan and Stolt (2006) found that as redoximorphic features within the soil increases, the amount of time that the water table is present also increases. However, other factors such as drainage modifications or relict features (Greenberg and Wilding, 1998) may lead to false estimates of water table depth using low chroma soil presence as an indicator. Humphrey and O’Driscoll (2011a) found that low chroma color presence was typically within 22 cm of the measured SHWT for some fine textured soils, but not as accurate in sandy soils with low iron content. Research has shown that low chroma soil colors correspond to different durations and frequencies of saturation for different soil series (Severson et al., 2008; Humphrey and O’Driscoll, 2011a; Humphrey and O’Driscoll, 2011b).

Figure 1: Soil profile with higher chroma colors (orange/brown) between 1 and 2 mark, and low chroma colors (grey) below 2 mark.

Therefore, more research is needed to determine the accuracy of low chroma soil colors as indicators of the SHWT for soils typically used for onsite wastewater systems. The objective of this study was to assess how closely the measured SHWT was to low chroma colors (2 or less) at 7 sites in Pitt County, North Carolina.

2. Methods:

2.1 Site Selection and Description:

Seven sites in Pitt County, North Carolina (Figure 2) were selected for the study. Groundwater wells were installed by hand, using soil augers. Wells were constructed of 5 cm diameter, solid PVC, with 0.90 m sections of screen at the bottom. Soil profiles were described at each site during the well installations using the texture by feel method (Brady and Weil, 2004), a Munsell color chart, and tape measure. The depth to low chroma soil colors (2% or more by volume) was recorded. The depth to these conditions was used to determine the predicted depth of the SHWT. Other soil colors were also described until the chroma 2 or less depth was reached. The results were analyzed by 2 individuals to ensure greater accuracy in determining soil color. Soil profile descriptions were compared to soil characteristics in the Soil Survey of Pitt County, North Carolina to determine the soil series.

Figure 2: Study sites were located in Pitt County, North Carolina, USA

2.2 Groundwater and Precipitation Monitoring:

Automated *HOBO* water-level loggers (Onset Computer Corporation, 2012) were placed at each of the sites (7 wells and 7 loggers) to record the water level every 30 minutes. Another logger was placed above ground at the sites to record air pressure and to correct for atmospheric pressure changes which can influence water level logger readings. The pressure readings were converted to water levels and displayed on spreadsheets using *HOBO* software (Onset Computer Corporation, 2012). Manual groundwater depths were read bi-monthly using a *Solinist Model 107* Temperature Level and Conductivity Meter (2012). The water level data was compared to the depth at which low chroma colors occupied at least 2% of the soil volume. The number of times the water table rose above the low chroma color depth was reported as frequency of saturation. Cumulative saturation was the total duration of time the water table was above the low chroma color depth during the study. Continuous saturation was the longest maintained duration of saturation at or above the low chroma color depth observed during the study. An automated rain gauge was installed on site to determine hourly precipitation and for observation of water table responses to precipitation events. Long term precipitation data for Greenville, NC was obtained from the North Carolina State Climate Office (2012). The mean long-term monthly precipitation for Dec – May, was compared to measured precipitation to determine how representative the rainfall during the study was compared to a typically year. The onsite rainfall data was compared to historic precipitation records to determine the recurrence frequency of the observed rainfall during the wet season. The duration (days or hours) of continuous saturation for SHWT determinations is dependent upon the rainfall received during wet season, with longer durations required during abnormally wet seasons, and shorter durations during relatively dry seasons (15A NCAC 18A .1942e 7). The depth to SHWT was compared to the low chroma soil color depths to determine the accuracy of soil morphology in predicting saturation characteristics for different soils.

3. Results and Discussion:

3.1 Soils: The soils at the study sites included one Lynchburg (Fine-loamy, siliceous, thermic Aeric Paleaquult), two Goldsboro (Fine-loamy, siliceous, thermic, Aquic Paleudult), and four Ocilla (Loamy, siliceous, thermic, Aquic Arenic Paleudult) series. The Goldsboro soils were labeled Goldsboro 1 or 2, and the Ocilla soils were labeled Ocilla 1,2, 3, or 4.

3.2 Precipitation: The cumulative precipitation during the wet season of the study (December 2011 – May 2012) totaled 33.9 cm compared to the historic average of 46.4 (Figure 3). Therefore, Pitt County received 12.5 cm less rainfall than average. The precipitation for the wet season was within the frequency range of 30-49.5% of normal. Therefore the seasonal high water table would be considered the depth at which groundwater saturates the soil continuously for 72 consecutive hours or 3 days using the interpretation method and weighted rainfall index (15A NCAC 18A .1942 (e) 7). Water tables were lowest at the beginning and end of the wet season, coinciding with fewer precipitation events and amounts (Figures 4, 5, and 6). Groundwater was typically highest during February and March, the months with the most rainfall (Figures 4, 5, and 6).

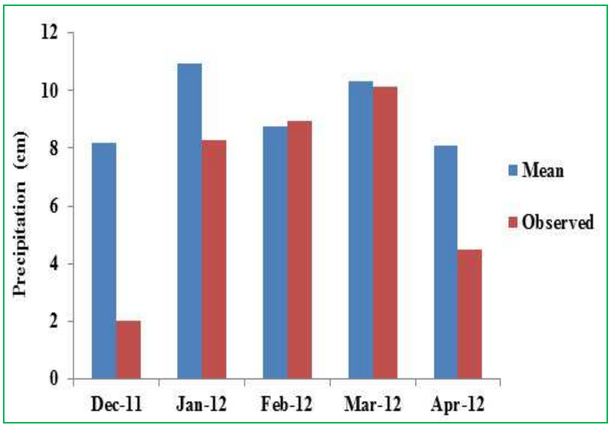

Figure 3: Mean and observed monthly precipitation during the study period.

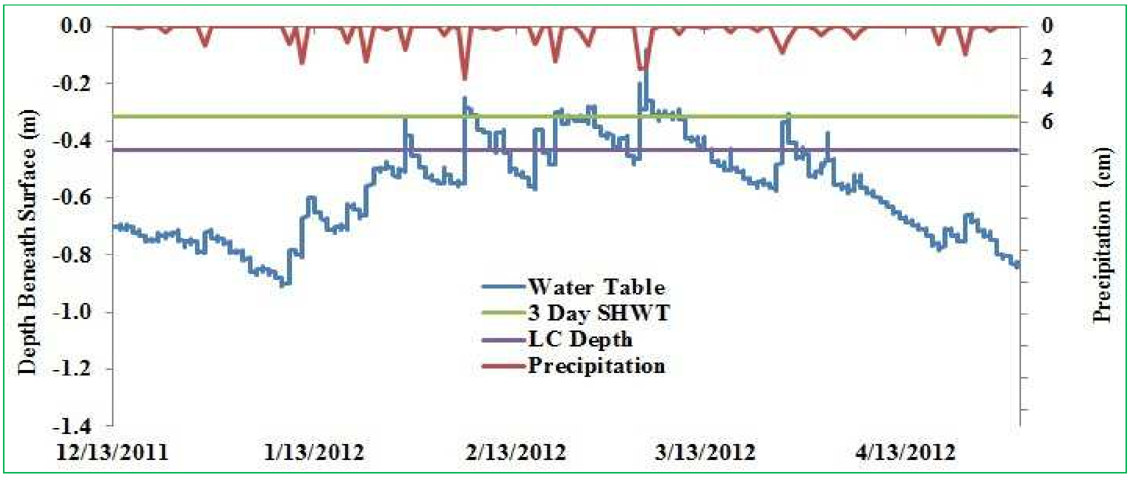

Figure 4. Water table dynamics relative to low chroma soil colors and rainfall for a Lynchburg soil.

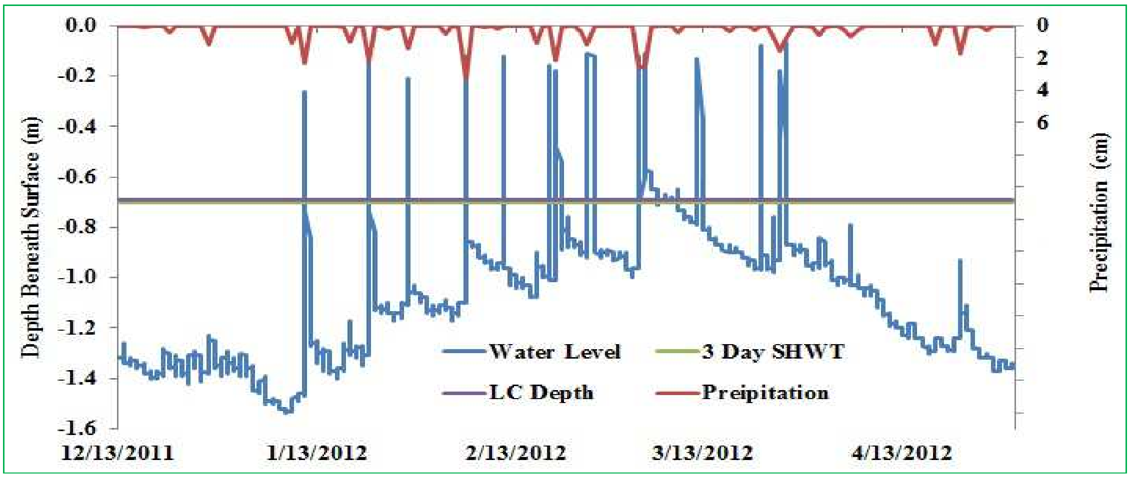

Figure 5. Water table dynamics relative to low chroma soil colors and rainfall for Goldsboro (2) soil.

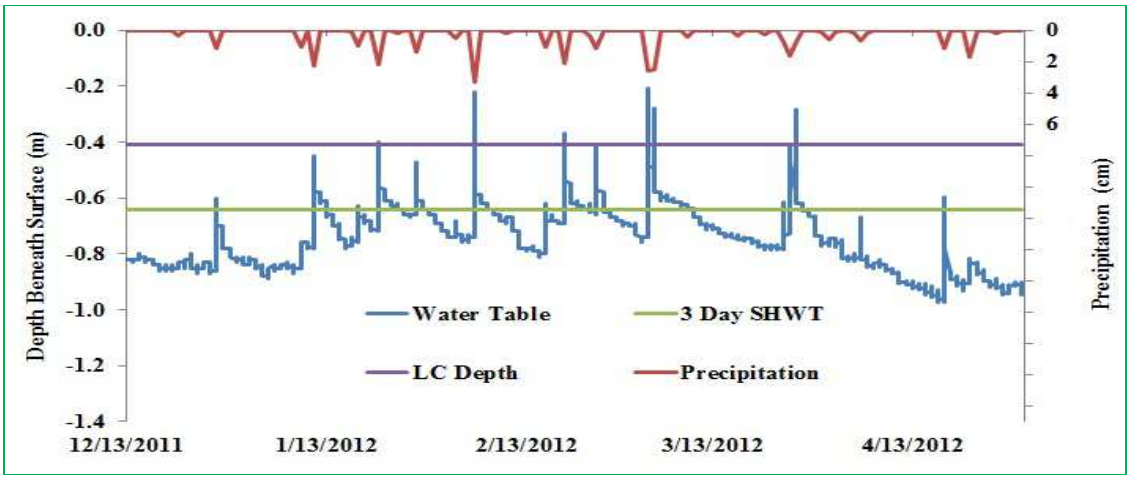

Figure 6. Water table dynamics relative to low chroma soil colors and rainfall for an Ocilla (4) soil.

3.3 Low Chroma Colors and Seasonal High Water Table Results:

The depth to the low chroma colors was on average 9 ± 26 cm shallower than the observed SHWT for the 7 sites (Table 1). However, the absolute mean difference between low chroma colors and SHWT was 20 ± 16 cm, and for three of the seven sites, the SHWT was shallower than the low chroma soil colors (Table 1). Groundwater rose more than 30 cm above the low chroma colors for 4 of 7 sites and rose 29 cm above low chroma colors for another site (Table 1). The mean duration of continuous saturation at the low chroma soil color depth was 8 days, and the average frequency above the low chroma colors was 9 times. The water table was at or above the low chroma soil color depth for an average of 10.4 days or 14.4% of the wet season. For the Lynchburg and Goldsboro soils, the low chroma colors were within 11 cm of the SHWT. However, the water table was closer to the soil surface than the indicators for Goldsboro 2 and Lynchburg. Low chroma soil colors were less accurate predictors of the SHWT for the Ocilla series (mean 30 cm difference) than the Lynchburg (11 cm) and Goldsboro (6 cm). For three of the four Ocilla soils, the SHWT was deeper than the low chroma soil colors (Table 1).

Table 1: Depth to low chroma colors, 14 day seasonal high water table, and water table dynamic statistics for the Lynchburg series (Ly), Goldsboro series (Go), and Ocilla series (Oc) soils.

Site	Water Table Depth Range (cm)	Low Chroma Depth (cm)	Depth to 3-Day SHWT (cm)	Absolute Difference / Difference (cm)	Continuous Saturation at Low Chroma Depth (days)	Freq. Above Low Chroma Colors	Cumulative Saturation Low Chroma Colors (Days / %)
Ly	8 - 91	43	32	11 / 11	35.2	13	35.2 / 25.3
Go1	7 - 154	69	70	1 / -1	2.1	16	7.8 / 5.6
Go2	5 - 84	46	36	10 / 10	8.5	7	11.1 / 8
Oc1	7 - 109	36	87	51 / -51	0.2	4	0.4 / 0.3
Oc2	15 - 102	61	41	20 / 10	8.4	14	45.1 / 32.6
Oc3	16 - 99	36	63	27 / -27	0.3	2	0.4 / 0.3
Oc4	21 - 98	41	64	23 / -23	0.5	8	1.0 / 0.7
Avg		47	56	20 / -9	8	9	14.4 / 10.4
SDV		13	20	16 / 26	13	5	18.3 / 13.2

Prior research has indicated that the duration of saturation of low chroma soil colors differs with different soil series, but that the mean SHWT was typically within 18-22 cm of the low chroma color depths for many coastal plain soils (Severson et al., 2008; Humphrey and O'Driscoll, 2011a). Our findings are in agreement with previous research as the mean absolute difference between SHWT and low chroma colors was 20 cm. Also, for this research, two Goldsboro series were evaluated and the mean duration of continuous saturation was 5.3 days, similar to the mean of 6 days of continuous saturation for four Goldsboro series sites reported by Humphrey and O'Driscoll (2011) in Carteret County, NC. The mean frequency of water table inundation of the low chroma color depths for the Goldsboro series sites was also similar for this study (11.5 times) and the Humphrey and O'Driscoll (2011) study (14 times). Because the water table dynamics for soils of the same series are similar, an important part of the site evaluation process for OWS suitability should be identifying the soil series, in addition to recording depth to low chroma colors.

Low chroma soil colors were the least accurate indicators of the SHWT for the Ocilla series with a mean difference of 20 cm, and mean absolute difference of 30 cm. However, for three of the 4 Ocilla sites (Oc1, Oc3, Oc4), the SHWT was deeper than the low chroma soil colors. Therefore, had an OWS been installed 30 cm above the low chroma colors, more than 30 cm of separation to the SHWT would have occurred. For the Ocilla series, it is possible that infiltrating rainwater may have "perched" on the more clay rich, less permeable B subsurface horizon, creating saturated and anaerobic conditions necessary for iron reduction and formation of low chroma colors (Brady and Weil, 2004). Soils with perched water tables have saturation and low chroma colors at the depth of perching, but drier conditions below the perching depth. It is also possible that for the Ocilla series, it takes less saturation time to form anaerobic conditions than the other soils studied.

In order for OWS to function properly, aerobic soil conditions beneath the drainage trenches are necessary. In North Carolina, a minimum of 30 cm of separation between the trench bottom and SHWT is required to approve an OWS installed in sandy loam and more fine textured soils. Some sites in this study would not have met that criteria had low chroma soil colors been used as the indicator, and had the trenches been installed the minimum elevation above the indicators. More specifically, for 3 of the 7 sites (Ly, Go2, and Oc2), the SHWT was closer to the soil surface than the low chroma soil colors by an average of 15 cm. This would have resulted in a mean separation of only 15 cm rather than 30 cm for the three sites, possibly compromising groundwater quality. Even though there was below normal precipitation, the water table was at or above the low chroma soil color depth for an average of 14% of study period and the water table rose above low chroma colors an average of 9 times for the sites. For three sites (Go1, Go2, and Oc3) the water table rose more than 30 cm above low chroma colors indicating that direct wastewater discharge to groundwater would have occurred if OWS trenches were installed the minimum elevation above the water table indicators. For another site (Oc1) groundwater spiked 29 cm above the low chroma color depths. While some direct discharge of effluent to groundwater is expected during extreme precipitation events (hurricanes, tropical storms, etc.,) the goal of OWS design criteria should be to limit the frequency and duration of direct discharges for typical storms. Again, the study sites received below average precipitation and the largest single rainfall event (4 cm) was not unordinary for the region.

4.0 Conclusions:

The use of low chroma soil colors as indicators of the seasonal high water table for the study sites was a quick, relatively accurate method, but 3 of 7 sites had actual SHWT an average of 15 cm above low chroma colors. To increase the likelihood of achieving an actual 30 cm separation form OWS trench to SHWT, an additional 15 cm or more should be added to the separation distance requirements from low chroma colors for these soil series. This would result in a 45 cm or more separation from the low chroma colors to OWS trench. Low chroma colors seem to correlate to different saturation characteristics for different soils. More research is needed comparing saturation characteristics of low chroma colors for soil series commonly used for onsite wastewater treatment and dispersal systems. With a database of soil series and saturation characteristics, OWS performance may be enhanced by using soil series information when determining OWS suitability and designing the systems.

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References:

1) Brady N.C. and Weil R.R. (2004): Elements of the Nature and Properties of Soils. 2nd Edn., Pearson Education Inc., Upper Sadler River, New Jersey, USA. 101, 183.
2) Fiedler, S. and Sommer M. (2004): Water and Redox Conditions in Wetland Soils—Their Influence on Pedogenic Oxides and Morphology. *Soil Sci. Soc. Am. J.,* 68: 326–335
3) Greenberg, W.A., and Wilding L.P. (1998): Evidence for contemporary and relict redoximorphic features of an Alfisol in East-Central Texas. p. 227–246. In M.C. Rabenhorst et al. (ed.) Quantifying soil hydromorphology. SSSA Spec. Pub. 54. SSSA: Madison, WI.
4) Hoover, MT, (2004): Soil Facts: Septic Systems and Their Maintenance, AG-439-13. North Carolina Cooperative Extension Service.
5) Humphrey, C.P. and O'Driscoll M.A. (2011a): Evaluation of soil colors as indicators of the seasonal high water table in coastal North Carolina. *Institutional Journal of Soil Science*, 6(2): 103-113.
6) Humphrey, C.P. & O'Driscoll, M.A. (2011b): Cumulative Saturation of Low Chroma Soil Colors and Shallower Depths: Implications for On-site Wastewater System Design. *International Journal of Soil Science*, 6 (4), 249-258.
7) Humphrey, C.P. & O'Driscoll, M.A. (2011c): Biogeochemistry of Groundwater Beneath On-site Wastewater Systems in a Coastal Watershed. *Universal Journal of Environmental Research and Technology*, 1(3) 320-328.
8) Humphrey, C. P., O'Driscoll, M. A., & Zarate, M. A. (2010): Controls on Groundwater Nitrogen Contributions from On-site Wastewater Systems in Coastal North Carolina. *Journal of Water Science and Technology 62 (6)*, 1448-55.
9) Humphrey, C. P., O'Driscoll, M. A., & Zarate, M. A. (2011): Evaluation of On-site Wastewater System E. coli Contributions to Shallow Groundwater in Coastal North Carolina. *Journal of Water Science and Technology 63 (4), 789-795.*
10) Karathanasis, A.D., T.G. Mueller, B. Boone and Y.L. Thompson. (2006a): Nutrient removal from septic effluents as affected by soil thickness and texture. *Journal of Water and Health*, 4: 177-195
11) Karathanasis A.D., Mueller T.G., Boone B. and Thompson Y.L. (2006b): Effect of soil depth and texture on fecal bacteria removal from septic effluents. *Journal of Water and Health* 4 (3) 395-404. DOI: 10.2166/wh.2006.043
12) Mitsch, W.J. and J.G. Gosselink. (2000): Wetlands. 3rd Edn., John Wiley & Sons Inc., New York. 160-170.
13) Morgan, C.P., and Stolt M.H. (2006): Soil Morphology-Water Table Cumulative Duration Relationships in Southern New England. *Soil Sci. Soc. Am. J.,* 70: 816–824.
14) North Carolina Climate Office. (2012): Rainfall data for Greenville, North Carolina. http://www.nc-climate.ncsu.edu/ (Accessed August, 2012).
15) Onset Computer Corporation. (2012): *Hobo* water level loggers. 470 MacAurthur Blvd., Bourne, MA, 02532.
16) Richardson, J.L. and M.J. Vepraskas, (2001): Wetland Soils: Genesis, Hydrology, Landscapes and Classification. Lewis Publ., Boca Raton, FL. 163-174.
17) Robertson, W.D., Cherry, J.A., and Sudicky, E.A. (1991): Groundwater Contamination From 2 Small Septic Systems on Sand Aquifers. *Ground Water* 29 (1) 82-92.
18) Scandura, J.E., and Sobsey, M.D. (1997): Viral and bacterial contamination of groundwater from on-site sewage treatment systems. *Water Science and Technology* 35 (11-12) 141-146.
19) Severson, E.D., Lindbo D.L., and Vepraskas M.J. (2008): Hydropedology of a coarse-loamy catena in the lower Coastal Plain, NC. *Catena* 73: 189-196.
20) Solinst Canada Ltd. (2012): Solinst Model 107 TLC Meter. 35 Todd Rd. Georgetown, Ontario Canada L7G 4R8. Website: www.solinst.com
21) Vepraskas, M.J. (1994): Redoximorphic features for identifying aquic conditions. Tech. Bull. 301. North Carolina State University, Raleigh NC, USA.