METHODS TO DETERMINE LATERAL EFFECT OF A DRAINAGE DITCH ON WETLAND HYDROLOGY

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ABSTRACT. *A method was developed to estimate the lateral effect of a single drainage ditch on wetland hydrology. The method can be used to calculate the distance of influence of a single ditch constructed through a wetland, where the distance of influence is defined as the width of a strip adjacent to the ditch that is drained such that it will no longer satisfy the wetland hydrologic criterion. Simulation analyses were conducted with DRAINMOD to define the minimum, or threshold, drainage intensity that would result in failure of a site to satisfy the wetland hydrologic criterion. Analyses were conducted for five hydric soils spanning a wide range of profile hydraulic transmissivities. DRAINMOD was used to predict water table fluctuations between parallel ditches for a 50-year period of climatological record. For each soil, simulations were conducted for a range of ditch spacings and depths to determine the combinations that would result in the land midway between the ditches just barely satisfying the wetland hydrologic criterion. Analyses were conducted for climatological conditions for three locations in eastern North Carolina. Results for Wilmington, North Carolina, showed that the threshold drainage intensities would result in water table drawdown from an initially ponded surface to a depth of 25 cm in approximately 6 days. That is, ditch depths and spacings sufficient to lower the water table from the surface to a depth of 25 cm in a threshold time of about 6 days would result in hydrologic conditions that would just barely satisfy the wetland hydrologic criterion for that location. The threshold time is denoted T_{25} and is used as a surrogate for quantifying the water table drawdown rate of sites that barely satisfy the wetland hydrologic criterion. T_{25} was found to depend somewhat on drain depth, but it was essentially constant for all five of the soils examined. Similar results were obtained for the other two locations, but because of differences in weather and in the growing season, the threshold time (T_{25}) was found to be dependent on location. The T_{25} value is also dependent on surface depressional storage, decreasing with increasing storage. The discovery that water table conditions barely satisfying the wetland hydrologic criterion are well correlated to the time required for water table drawdown of 25 cm (T_{25} values) makes it possible to predict the effects of subsurface drains on wetland hydrology. The lateral effect of a single ditch on wetland hydrology can be computed by using T_{25} values in solutions to the Boussinesq equation for water table drawdown due to drainage to a single drain. While the method was developed for drainage ditches, it may also be used for subsurface drains.*

Keywords. *Drainage, DRAINMOD, Hydric soils, Hydrology, Water table, Wetland hydrology, Wetlands.*

Drainage ditches are sometimes constructed adjacent to, or through, wetlands. One example is in the construction of highways, where drainage systems are necessary to lower the water table under and adjacent to the road. Drainage ditches or subsurface drains (tile or plastic drain tubing) in agricultural lands may also be located close to wetlands. These drainage systems and associated structures may change the hydrology of adjacent wetlands. The purpose of this article is to present a method for determining the lateral effect of a drainage ditch on the hydrology of wetlands. The method was developed to answer the following question: Given that a ditch is to be constructed through or adjacent to a wetland, how far away from the ditch will the hydrology be changed such that it no longer satisfies the wetland hydrologic criterion? While the question is posed for a drainage ditch, the same method can be used to approximate the lateral effect of a subsurface drain.

Computer simulation models such as DRAINMOD (Skaggs, 1978) and WATRCOM (Parsons et al., 1987, 1991) have been developed for predicting the hydrology of drained and undrained wetland soils. These models can be applied to evaluate the impacts of a single drainage ditch on adjacent wetlands. However, input data requirements (detailed soil properties, site characteristics, vegetation parameters, and weather data), plus the necessity of user training, limits the usefulness of these models for screening and other routine applications. The goal of this article is to develop relatively simple methods that can be used to determine the lateral effect of a drain located adjacent to a wetland.

Before proceeding, it is necessary to define the hydrologic criterion for wetlands. The criterion may be expressed as follows: a site has wetland hydrology if, during the growing season, the water table is normally within 30 cm of the surface for a continuous critical duration. The 1987 U.S. Army Corps of Engineers Wetland Delineation Manual (USACE, 1987) specifies the critical duration as 5% to 12.5%

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of the length of the growing season. Recognizing the uncertainty in the data supporting a critical duration, the National Research Council Committee (NRC, 1995) recommended that a duration of 14 days be used until more definitive limits could be determined. The lower limit of 5% of the growing season is used in most cases in North Carolina, and is assumed in this article to define the critical duration. The growing season is defined for this purpose as the period between the average last date having 28°F (−2°C) in the spring to the average first date of 28°F (−2°C) in the fall, as given in the published county Soil Survey. Finally, the word "normally" in the criterion is defined as meaning that conditions satisfying the criterion occur at least once in two years on average (e.g., 25 out of 50 years).

THRESHOLD DRAINAGE INTENSITIES

Computer simulation analyses were conducted to determine the maximum, or threshold, drainage intensities that result in hydrologic conditions midway between parallel drainage ditches that marginally satisfy the wetland hydrologic criterion. Analyses were conducted for five North Carolina hydric soils: Arapahoe (coarse-loamy, mixed, nonacid, thermic Typic Humaquepts), Coxville (clayey, kaolinitic, thermic Typic Paleaquults), Portsmouth (fine-loamy, mixed, thermic Typic Umbraquults), Rains (fine-loamy siliceous, thermic Typic Paleaquults), and Wasda (fine-loamy, mixed, acid, thermic Typic Humaquepts). Soil property inputs for DRAINMOD for Arapahoe, Rains, Coxville, and Wasda were obtained from Skaggs and Nassehzadeh-Tabrizi (1986). Inputs for Portsmouth were the same as those used by Skaggs et al. (1995). A summary of the soil property inputs is given in table 1. The soil properties for each series were obtained for a specific location; they do not necessarily represent "average" or midrange values for each series. Note that the profile depths and hydraulic conductivities vary over a wide range among the soils considered. Thus, the simulations and associated analyses were conducted for sites that included a wide spectrum, from soils that respond rapidly to drainage, to those that respond very slowly.

Simulations were conducted for each soil using weather data from Wilmington, Wilson, and Plymouth, N.C., for a 50-year period (1951-2000). Simulations were conducted for ditch depths of 120 cm (4 ft), 90 cm (3 ft), and 60 cm (2 ft). The ditch spacings were varied until the wetland criterion was satisfied in 25 of the 50 years. This ditch spacing was identified as the threshold spacing, L_t (see Skaggs et al. 1994; Hunt et al., 2001). Results are summarized in table 2 for Wilmington, N.C. The threshold ditch spacings varied from a low of 35 m for the Coxville soil with a ditch depth of 60 cm to a high of 226 m for the Arapahoe loamy sand with a ditch depth of 120 cm (table 2).

As applied in this study, DRAINMOD predicted the water table depths at a point midway between two parallel ditches. Therefore, the land midway between ditches spaced as given in table 2 would just barely satisfy the wetland hydrologic criterion for Wilmington, N.C. How can this information be used to determine the lateral effect, or zone of influence, of a single ditch (shown for a highway drainage situation in fig. 1)? One method that has been used is to assume that the lateral effect is one-half of the threshold spacing (table 2). However, the water table midway between parallel ditches spaced at the threshold spacing will be lower (i.e., the soil at that point will be drier) than would be the case at a distance of one-half the threshold spacing from a single ditch. To check the logic of this assertion, consider the effect of a second ditch parallel to, and located a distance of L_t from the roadside ditch (fig. 2). This ditch would cut off seepage from the zone beyond the threshold distance and cause greater water table drawdown at the midpoint than would occur if the second ditch were not there. So the width of the strip of land, adjacent to and influenced by a single drainage ditch, such that it no longer satisfies the wetland criterion, would be less than $L_t/2$. While an analysis based on the assumption of a second parallel drain allows determination of the maximum lateral influence of a single drainage ditch, a closer estimate is needed. Furthermore, with all of the required inputs and analysis of outputs, this method would require multiple DRAINMOD runs to determine L_t.

Table 1. Soil properties for five eastern North Carolina soils considered in this study.

Soil Series	Drainable Porosity (cm cm^{-1})[a]	Profile Depth (cm)	Depth Increment (cm)	K (cm h^{-1})	K_e[b] (cm h^{-1})
Arapahoe loamy sand	0.022	300	0-70	5	12.7
			70-300	15	
Coxville sandy loam	0.023	200	0-20	5	1.27
			20-120	0.75	
			120-200	1.0	
Portsmouth sandy loam	0.028	215	0-30	15	6.5
			30-120	2	
			120-215	8	
Rains sandy loam	0.048	200	0-100	4	2.5
			100-200	1	
Wasda muck	0.04	200	0-30	20	3.7
			30-80	0.4	
			80-200	1.0	

[a] Drainable porosity for the water table depth range of 0 to 25 cm.
[b] Effective lateral hydraulic conductivity (K_e) of profile when water table is at the surface.

$$K_e = (K_1 d_1 + K_2 d_2 + K_3 d_3 + \ldots)/(d_1 + d_2 + d_3 + \ldots)$$

where $K_1, K_2, \ldots, K_n$ are the hydraulic conductivities and $d_1, d_2, \ldots, d_n$ are the depths of layers 1, 2, ..., n.

WATER TABLE DRAWDOWN FOR THRESHOLD DITCH SPACING AND DEPTH

A relatively simple method of approximating the lateral effect of a single ditch was derived from the threshold drainage conditions given in table 2. Based on DRAINMOD analyses, the threshold ditch spacings provided drainage

Table 2. Threshold ditch spacings (L_t, m) as a function of soil and ditch depth for a surface depressional storage of 2.5 cm at Wilmington, N.C. The determinations are based on DRAINMOD simulations for a 50-year period of climatological record (1951-2000).

	Ditch Depth		
Soil	60 cm	90 cm	120 cm
Arapahoe loamy sand	153	198	226
Coxville sandy loam	35	43	48
Portsmouth sandy loam	85	105	121
Rains sandy loam	36	46	51
Wasda muck	38	50	57

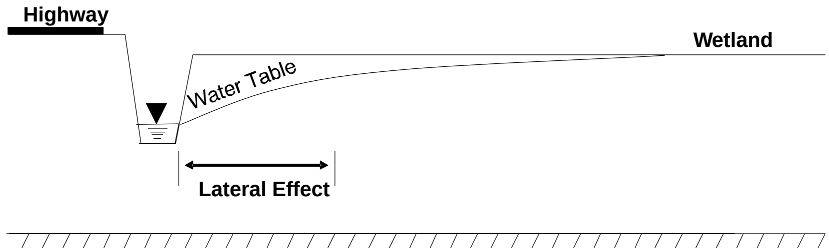

Figure 1. Schematic of highway ditch showing the lateral effect of the ditch on wetland hydrology.

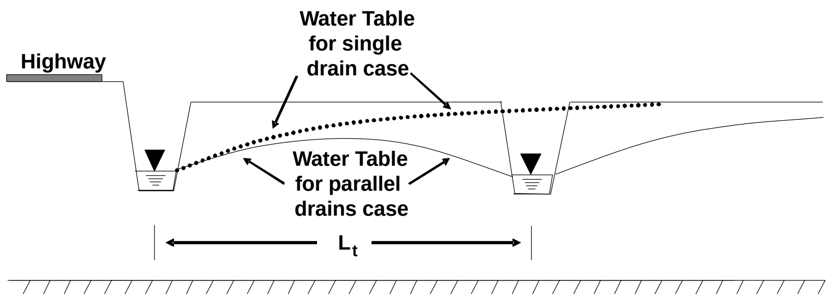

Figure 2. Schematic of parallel ditches showing the effect of a second ditch on the water table depth.

rates that resulted in water table conditions midway between the ditches that just satisfied the wetland hydrologic criterion. We first examined drainage rates for threshold conditions. Average drainage rates for water table depths of 0 to 30 cm are given in table 3 for threshold ditch spacings at Wilmington. Drainage rates (q) when the water table was at the surface and at 30 cm deep were calculated with the Hooghoudt equation and averaged to get the $\underline{q}$ values in table 3. While average drainage rates for threshold conditions were similar (0.12 to 0.14 cm d^{-1}) for Arapahoe, Coxville, and Portsmouth, rates for Wasda and Rains soils were 1.5 to 2 times greater (table 3). Drainable porosities (f) for the 0 to 30 cm depth are also given in table 3. Because the wetland hydrologic criterion is based on water table depth, and the rate of water table drawdown is directly proportional to drainage rate and inversely proportional to f, it is logical that soils with larger f values would require larger drainage rates to satisfy threshold conditions for wetland hydrology. For example, the drainable porosity for the Rains soil (f = 0.048) is about twice that of the Coxville soil (f = 0.023) when the water table is in the top 30 cm of the profile (table 3). Thus, about twice as much water would have to be removed from the Rains to lower the water table from the surface to a 30 cm depth than from the Coxville, other factors being equal. Note that the ratio $\underline{q}/f$ is nearly constant for threshold conditions for

Table 3. Average drainage rates when the water table is in the top 30 cm of the profile for ditch spacings corresponding to threshold conditions for wetland hydrology at Wilmington, N.C. Ditch depth is 120 cm and surface depressional storage is 2.5 cm.

Soil	$\underline{q}$, 0−30 cm (cm d^{-1})	f, 0-30 cm	$\underline{q}/f$ (cm d^{-1})
Arapahoe	0.12	0.022	5.4
Coxville	0.12	0.023	5.4
Portsmouth	0.14	0.028	5.0
Rains	0.23	0.048	4.8
Wasda	0.19	0.04	4.8

the five soils at Wilmington (table 3). These results indicate that sites just satisfying threshold conditions for wetland hydrology would have similar rates of drainage-induced water table drawdown when the water table is in the top part of the profile.

Water table fluctuations are dependent on rates of drainage, evapotranspiration (ET), and rainfall. The effect of drainage for the threshold spacings of table 2 can be characterized by examining the rate of water table drawdown that would occur in the absence of ET and rainfall. Midpoint water table drawdown was predicted for the threshold ditch spacing for each soil and drain depth given in table 2. Because both hydraulic conductivity and drainable porosity may vary with depth, water table drawdown was calculated with a modification of the method originally presented by Bouwer and van Schilfgaarde (1963). The modified method (Skaggs, 2005) is both simple and versatile and can be easily applied using a PC spreadsheet. It uses the Hooghoudt equation to calculate drainage rates and a water balance to determine the time required for incremental water table drawdown, in a manner similar to that used in DRAINMOD.

Results for Wilmington are plotted in figure 3 for a ditch depth of 120 cm (4 ft) for all five soils studied. Note that the water table recession curves for the threshold ditch spacings for all five soils are similar, especially when the water table is in the upper part of the profile, and that they intersect at a water table depth of about 25 cm. That is, the ditch spacings that would result in conditions that satisfy the wetland hydrologic criterion in 25 of 50 years would, if the water table were initially coincident with the surface, provide a midpoint drawdown of 25 cm in 6.1 days. This is the drawdown that would occur in the absence of ET and rainfall (i.e., due to drainage alone). The time required for 25 cm drawdown varied among the five soils from 5.7 to 6.3 days, with an average of 6.1 days (table 4). Thus, we may conclude, based on the results presented in figure 3 and table 4, that, for a 1.2 m ditch depth, a spacing sufficient to cause a 25 cm

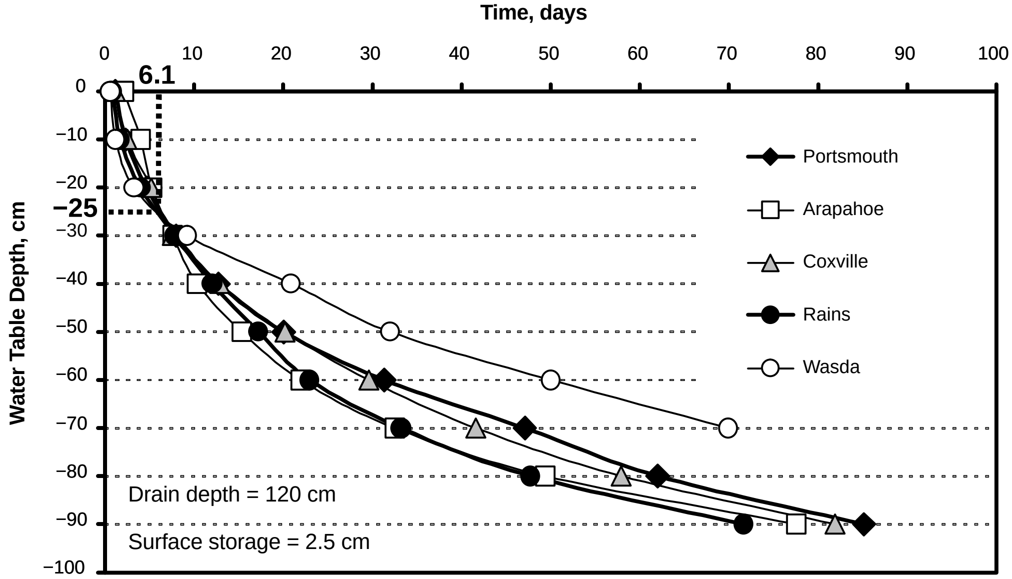

Figure 3. Predicted midpoint water table drawdown for threshold ditch spacings of five North Carolina soils. Results are for a ditch depth of 120 cm and surface depressional storage of 2.5 cm. Time for water table drawdown of 25 cm (T_{25}) is approximately 6.1 days for all soils.

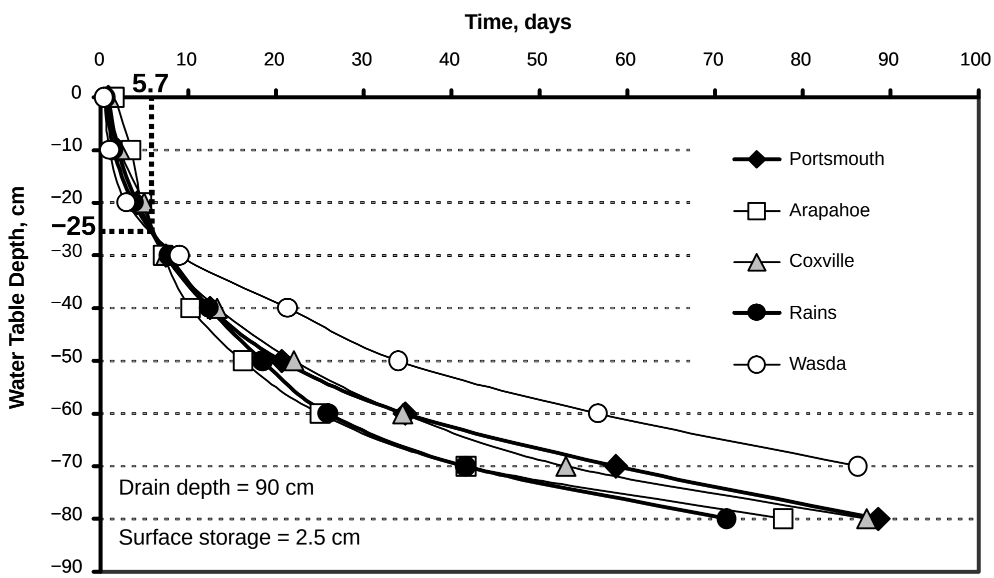

Figure 4. Predicted midpoint water table drawdown for threshold ditch spacings of 5 North Carolina soils. Results are for a ditch depth of 90 cm and surface depressional storage of 2.5 cm. Time for water table drawdown of 25 cm (T25) is approximately 5.7 days for all soils.

Table 4. Time (T_{25}, days) required for 25 cm drawdown midway between ditches spaced such that the wetland hydrologic criterion is marginally satisfied (a threshold wetland). Results were obtained for sites having surface depressional storage of 2.5 cm located near Wilmington, N.C.

	Depth		
Soil	60 cm	90 cm	120 cm
Arapahoe	4.9	5.6	6.3
Coxville	5.6	6.1	6.3
Portsmouth	5.3	5.7	6.2
Rains	5.2	5.7	5.8
Wasda	4.9	5.4	5.7
Mean	5.2	5.7	6.1
Std. Dev.	0.3	0.3	0.3

drawdown in approximately 6.1 days will result in water table fluctuations over the long run that will satisfy the wetland hydrologic criterion in 25 of 50 years at Wilmington, N.C. Results were similar for the 90 cm ditch depth, with the time required for 25 cm drawdown somewhat shorter at 5.7 days (fig. 4). The time required for 25 cm drawdown was 5.2 days for a 60 cm ditch depth (table 4). Similar results were obtained for the other two locations and are presented later in this article.

Results given in figures 3-4 and table 4 indicate that, for a given location, drain depth, and surface depressional storage, sites that marginally satisfy the wetland hydrologic criterion have a nearly unique water table drawdown rate. This threshold drawdown rate can be characterized by the time (T_{25}) required for water table drawdown from the soil surface to a depth of 25 cm. That is, T_{25} is defined as the time required for the water table, in a site that marginally satisfies the wetland hydrologic criterion, to be drawn down, by drainage alone, from the surface to a depth of 25 cm. Based on an analysis of five soils having a wide range of properties, T_{25} depends on location (because of differences in weather) and surface depressional storage, but not soil type.

The fact that the rate of water table drawdown in the field is dependent on both drainage and ET has been well understood for a long time (e.g., Skaggs, 1975). The effect of ET is considered in DRAINMOD and is reflected in the threshold ditch spacings (L_t in table 2) and, consequently, in the T_{25} values in table 4. The T_{25} values, obtained from figures 3 and 4, characterize threshold drawdown rates that would occur in the absence of ET for a site barely satisfying the wetland hydrologic criterion.

PREDICTING WATER TABLE DRAWDOWN AND LATERAL EFFECT OF A SINGLE DITCH

The results shown in figures 3 and 4, and the interpretation given above, provide the basis for a relatively simple method of determining the lateral effect of a single drainage ditch on wetland hydrologic status. Methods published several years ago by Skaggs (1976), and more recently by Cooke et al. (2001), can be used to predict the effect of a single drainage ditch on water table drawdown in a semi−infinite medium (inset, fig. 5). The water table elevations (h) at any time (t) and distance from the ditch (x) were obtained from numerical solutions to the Boussinesq equation and are plotted in nondimensional form in figure 5. In addition to h_0, x, and t, the solution depends on the vertical distance from the water level in the ditch to the restrictive layer (d), the effective lateral hydraulic conductivity (K_e), and the drainable porosity (f). Solutions plotted in figure 5 can be used directly to determine the distance from the ditch (x) where water table drawdown will be 25 cm in time $t = T_{25}$. From results presented in figures 3-4 and table 4, we know that a site having these drainage characteristics (for ET = 0) will marginally satisfy the wetland hydrologic criterion. Thus, the x value calculated in this way may be used to represent the lateral effect of a single ditch on wetland status.

It is important to note that the lateral effect of a drainage ditch on wetland hydrology depends very much on its definition. We have chosen to define the “lateral effect” as being the width of that strip of land adjacent to the ditch that has had its hydrology modified such that it no longer satisfies wetland hydrologic criterion. This does not mean that the water table fluctuations and hydrology beyond that strip have not been affected. The effect has simply not been sufficient to prevent it from satisfying the wetland hydrologic criterion.

EXAMPLE FOR A 1.2 m DITCH DEPTH AT WILMINGTON

Application of the method will be demonstrated by considering an example shown schematically in figure 6. The soil is Arapahoe loamy sand having an effective hydraulic conductivity (K) of 3.0 m d^{-1} (12.7 cm h^{-1}) and drainable porosity (f) of 0.022 for water table depth from 0 to 25 cm. We want to find the x value for which drawdown is 25 cm in $t = T_{25} = 6.1$ days. From the dimensions $d = 180$ cm, $h = 275$ cm, and $h_0 = 300$ cm, we know that:

$$D = d/h_0 = 180/300 = 0.6$$

and

$$H = h/h_0 = 275/300 = 0.917.$$

Using these H and D values with the plotted numerical solutions (fig. 5) gives:

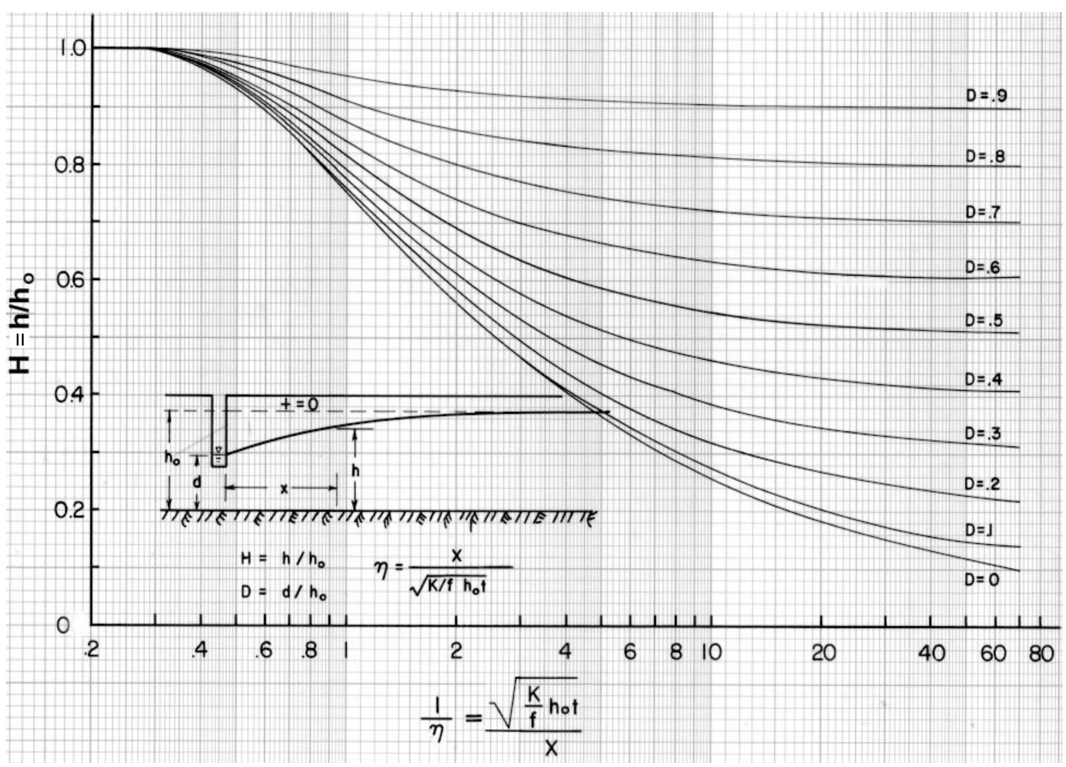

Figure 5. Nondimensional solutions to the Boussinesq equation for water table drawdown due to drainage to a single ditch (after Skaggs, 1976).

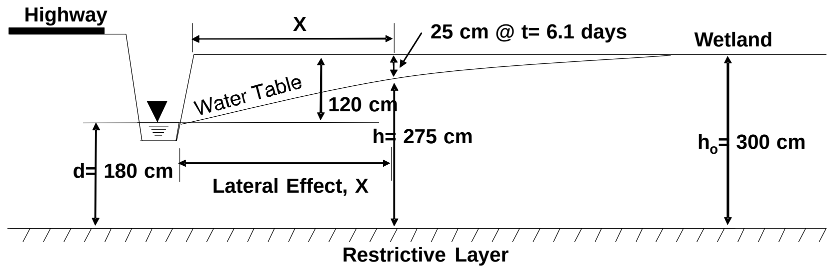

Figure 6. Example application of the proposed method to estimate lateral effect of highway ditches.

$$\frac{\sqrt{\frac{K}{f} h_0 t}}{x} = 0.66$$

Substituting known values of K = 3.0 m d^{-1}, f = 0.022, t = T_{25} = 6.1 days, and h_0 = 3.0 m, and solving for x gives x = 76 m = 250 ft. Note that the 76 m width is 33% less than the 113 m width that would have been estimated by using one-half of the threshold spacing of 226 m (table 2).

Effect of Location on Threshold Time for 25 cm Drawdown

Location affects two factors important to wetland hydrology. First, it affects the numerical values in the criterion. The beginning and ending dates of the growing season vary from county to county, so both the window of time and the duration (5% of the growing season) over which the water table must satisfy the criterion are affected by the location. Second, rainfall and ET vary with location, so it is logical that a threshold drainage intensity sufficient to prevent the wetland criterion from being satisfied at one location would not necessarily prevent the criterion from being satisfied at another location where precipitation is greater or ET is lower.

Simulations similar to those described above for Wilmington were conducted for eastern North Carolina locations near Plymouth and Wilson. The critical duration (5% of the growing season) was 11 days for Plymouth and 12 days for Wilson as compared to 14 days for Wilmington (table 5). Threshold ditch spacings and T_{25} values were determined for all five soils for both locations. Average T_{25} values for a 120 cm ditch depth varied from 6.1 days for Wilmington to 12 days for Wilson (table 5). Other factors remaining constant, the lateral effect of a ditch would increase with T_{25}. For instance, if the example considered above had been near Wilson rather than Wilmington, t = T_{25} = 12 days would have been used in the calculations, instead of t = T_{25} = 6.1 days, and the lateral effect would have been calculated to be 107 m rather than 76 m. Because of lower rainfall and a shorter growing season at Wilson, compared to Wilmington, a slower drainage rate is required for a site to satisfy the wetland hydrologic criterion. A slower drainage rate translates to a longer time (T_{25}) for a 25 cm drawdown. For the same ditch depth, K, and f values, this larger T_{25} time results in a wider lateral effect than that calculated for Wilmington.

Note that the T_{25} value of 12 days for Wilson is equal to the "continuous critical duration" parameter in the wetland hydrologic criterion (5% of the growing season = 12 days) for this location. This equality is coincidental and should not be used as a means of estimating T_{25}. Results of analyses (not shown) for many locations in North Carolina indicate that T_{25} values cannot be inferred directly from the wetland hydrologic criterion. For example, the T_{25} value of 6.1 days for a 120 cm ditch depth at Wilmington is less than half of the 14 day (5% of the growing season) "critical duration" in the criterion (table 5). In some cases, the T_{25} value may be close to 5% of the growing season (Wilson is an example), but in most cases it will not. T_{25} values need to be determined and tabulated on a county-by-county basis for subsequent use in calculating lateral effects of a ditch or subsurface drain on wetland hydrology. DRAINMOD analyses are under way to determine these values for N.C. counties.

The effect of location on lateral impact of a 120 cm deep drainage ditch is given in table 6 for three soils (Arapahoe, Portsmouth, and Rains). While the T_{25} values vary by a factor of 2 (6.1 days for Wilmington to 12 days for Wilson, table 5), the lateral effect is proportional to the square root of T_{25}, and thus is only about 40% greater for Wilson than Wilmington (table 6).

Effect of Surface Depressional Storage

Results presented in figures 3-4 and tables 2-6 were obtained for surface depressional storage (S) of 2.5 cm (1 in.). Surface depressional storage is an important factor affecting wetland hydrology. It is defined for this analysis as the average depth of water that can be stored in depressions on the site before runoff will occur. The capacity to store water on the surface depends on surface roughness and the average depth and distribution of surface depressions. Other factors remaining equal, the wetness of a site increases with increasing surface storage. After heavy rainfall, the depressions will be full and water will remain ponded on the surface

Table 5. Effect of location on threshold time for 25 cm water table drawdown to determine lateral effect of 120 cm deep drainage ditch. Results based on average values obtained for five eastern North Carolina soils. Surface depressional storage is 2.5 cm.

Location	Annual Precip. (mm)	Growing Season	5% of Growing Season (days)	T_{25} (days)
Wilmington	1400	27 Feb.-26 Nov.	14	6.1
Plymouth	1300	30 March-7 Nov.	11	8.9
Wilson	1140	20 March-12 Nov.	12	12

Table 6. Lateral effect (in mm) of a single 120 cm deep drainage ditch, as calculated using the proposed method for three soils at three eastern North Carolina locations. Surface depressional storage is 2.5 cm.

Soil	K (cm h^{-1})	Wilmington	Plymouth	Wilson
Arapahoe	13.0	76	92	107
Portsmouth	6.5	38	47	54
Rains	2.4	17	21	24

Table 7. Effect of surface depressional storage (S) on average T25 values for Wilmington, Plymouth, and Wilson, N.C.

	Ditch Depth		
S (cm)	60 cm	90 cm	120 cm
Wilmington			
2.5	5.4 days	5.9 days	6.1 days
5.0	3.2	3.4	3.7
Plymouth			
2.5	7.9	8.1	8.9
5.0	4.0	4.4	4.7
Wilson			
2.5	11.2	11.4	12.0
5.0	6.2	6.7	7.1

until it infiltrates and drains away or is removed by ET. Thus, the greater the surface storage, the longer the water table stays at or near the surface following periods of heavy rainfall. It follows that the threshold drain spacing required for a site midway between parallel drains to marginally satisfy the wetland hydrologic criterion decreases with increasing depressional storage. That is, for example, the threshold ditch spacing for a site with S = 5 cm would be less than that for a site with S = 2.5 cm. A set of DRAINMOD simulations was conducted for all soils and locations for S = 5 cm and the corresponding threshold ditch spacings, and T_{25} values were determined as described above for S = 2.5 cm. As expected, the T_{25} values decreased with increased surface depressional storage. A summary of T_{25} values for S = 2.5 and 5.0 cm is given in table 7 for the three ditch depths and three locations considered. The T_{25} values given are averages of results obtained for the five soils analyzed.

The effect of surface depressional storage on predicted lateral effects of a 1.2 m deep drainage ditch on a Portsmouth soil is shown in table 8 for all three locations. The lateral effect distances were calculated from the average T_{25} values for each location (table 7) in the same way as demonstrated in the example (fig. 6). Results indicate that the distance of influence of a drainage ditch decreases with increase in surface depressional storage (table 8).

The results in tables 7 and 8 may at first seem counterintuitive. The wetness, or length of time a site is saturated, increases with surface depressional storage. So it might seem logical that a drainage ditch adjacent to such areas would have greater impact than it would in areas with less depressional storage. While it is true that the ditch may remove more water from the wetter area, its distance of influence, or lateral effect, will be shorter, as shown in table 8. Consider the case where S is very large (e.g., >60 cm) such that water is continuously ponded on the surface. A drainage ditch adjacent (but not hydraulically connected) to the area would certainly remove more water than would a similar ditch on a drier site, and it could reduce the depth of ponding. But the impact of the ditch, in terms of changing the duration that water is ponded on the surface, and the wetland hydrologic status, could be negligible. Thus, in the limit, when surface depressional storage is very large, the lateral impact on wetland hydrologic status would be small, and could be negligible, consistent with trends in tables 7 and 8.

Table 8. Effect of surface depressional storage (S) on lateral effect of a 120 cm deep drainage ditch in a Portsmouth sandy loam at three eastern North Carolina locations.

S (cm)	Wilmington	Plymouth	Wilson
2.5	38 m	47 m	54 m
5.0	30	34	42

Limitations of the Method

The method presented herein was developed for wetland sites that have slow natural drainage rates and where the primary source of water is precipitation that falls directly on the site. These conditions would hold for wetlands in bottom lands near streams or rivers and in the broad, relatively flat inter-stream divides, where a large percentage of North Carolina's fresh water wetlands are located. It would not be directly applicable for wetlands where the major source of water is due to flooding caused by runoff from upstream or upslope catchments, or from hillside seeps.

Summary

A method was developed to estimate the lateral effect of a single drainage ditch on wetland hydrology. The method is based on the time required for water table drawdown in an initially saturated profile with the water table coincident with the surface. DRAINMOD simulation analyses showed that sites barely satisfying the wetland hydrologic criterion have drainage intensities that provide water table drawdown from the surface to a depth of 25 cm in about 6 days for Wilmington, North Carolina. The threshold draw down time (T_{25}) was found to depend moderately on ditch depth but was nearly constant among soils having a wide range of profile transmissivities and drainable porosities. T_{25} was found to depend strongly on surface depressional storage, decreasing as surface storage increased. T_{25} also depended strongly on location, which affects both the growing season and weather variables. Values for T_{25} can be determined by conducting a series of DRAINMOD simulations on a county-by-county basis. Once the T_{25} values are determined, published solutions for water table drawdown due to a single drain can be used to estimate the lateral effect of a drainage ditch or a subsurface drain on wetland hydrology.

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