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INFLUENCE OF MICROTOPOGRAPHY ON RESTORED HYDROLOGY AND OTHER WETLAND FUNCTIONS

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Abstract. Two prior converted wetland sites located in eastern North Carolina were restored and evaluated. Two micropographic treatments were established at each site. One treatment was the existing agricultural microtopographic relief: a relatively smooth, flat soil surface. For the other treatment, the land surface was randomly shaped to establish irregular contours with high ridged areas and depressional furrows. Microtopography was established using tillage equipment normally used in agricultural and silvicultural operations. Each site was instrumented to measure hydrologic parameters such as water table depth, surface depressional storage, and outflow. Outlets were also instrumented to collect water samples for water quality analysis. Microtopographic features were characterized by relative elevation class in terms of number of features, elevation, extent, proportion of surface area and degree of clustering. A comparison of these features were made between contoured and smooth plots within the two sites and between contoured plots and nearby forested reference plots. Roughing of the soil surface resulted in higher average water table depths and reduced the amount of outflow from restoration treatments by approximately 30% compared to the smooth microtopography treatments. Rough microtopography also reduced peak outflow rates and increased duration of outflow events. The contoured fields were more species-rich than the smooth fields

Keywords. wetland restoration, microtopography, water table control, wetland hydrology

INTRODUCTION

Large wetland losses have been documented in North Carolina and across the U.S. (Dahl 1990). In eastern North Carolina, as well as much of the southeastern U.S. and Ohio Valley, alteration included drainage and conversion to primarily agriculture or silviculture. Restoration of prior converted wetlands (i.e. wetlands which were drained for agricultural/ silvicultural development in the past) will require the reversal of many of the agricultural conversion activities described by Lilly (1981). Wetlands conversion to agriculture typically included: construction of a major canal system (3-6 m deep on 0.8 or 1.5 km grid spacings) and roads; timber harvest; construction of parallel field ditches (typically 1 m deep on 100 m spacings); stump removal, windrowing and burning of woody vegetation; and various degrees of land surface grading and shaping (generally referred to as "crowning"). Land shaping and grading as part of the agricultural conversion process removed the natural microtopography that provided elevation heterogeneity and hydrologic variability.

In 1990, the United States Department of Agriculture (USDA) Food, Agriculture, Conservation, and Trade Act introduced the Wetland Reserve Program (WRP), a voluntary cost-share program designed to return some of the nations prior converted farmlands back to their original wetland state. Under the WRP, private landowners offer a permanent easement for lands restored to wetland status, in exchange for cash compensation as well as cost-share assistance for the cost of practices used to restore wetland conditions. Only "farmed wetlands" and "prior converted wetlands" are eligible for restoration under the WRP. To be considered a prior converted wetland under the WRP, an agricultural field must have hydric soils and have undergone conversion prior to December 23, 1985. In 1993, the Emergency Wetlands Reserve Program (EWRP) was added to the existing WRP to enroll prior converted cropland susceptible to flooding and too expensive to protect through the construction of levees and berms. By July 2000, 915,175 acres of wetlands were enrolled nationally under the WRP, with a total of 18,216 acres enrolled in North Carolina (USDA, 2000). As conservation efforts such as the WRP continue to promote the restoration of prior converted lands, guidelines are needed that address how best to restore wetland hydrology and function.

Partial failures in meeting restoration success criteria have been documented for many types of wetlands (NRC, 2001; Pfeifer and Kaiser, 1995; Kusler and Kentula, 1990). A common reason for failure is a lack of restoration of wetland hydrologic functions. Wetland hydrology is often sited as the primary driving force influencing wetland development, function, and persistence (Gosselink and Turner, 1978; LaBaugh, 1986; Novitzki, 1989; Sharitz et al.., 1990). Though restoration efforts have become more common in the past decade, the link between microtoprography, wetland hydrology and other functions is poorly understood at the present time (Hunt and Krabbenhoft, 1996; Davis, 1994; Shaffer et al.,1999). The purpose of this paper is to summarize the effects of microtoprographic restoration on wetland functions for two restored wetlands sites.

METHODS

Two prior converted wetland sites located in eastern North Carolina were restored. One site is located on the Pamlico Plain of the Lower Coastal Plain within Beaufort County, North Carolina near the town of Aurora. The second site is located on the Talbot Plain of the Lower Coastal Plain within Craven County, North Carolina near the town of Vanceboro, approximately 50 km southwest of the Beaufort County site.

Restoration of the two field sites began in the spring of 1995. Sites were tilled in February and March 1995 to suppress native annual vegetation. Two microtopographic treatments were established at each site. One treatment was the existing agricultural microtopographic relief: a relatively smooth, flat soil surface. For the other treatment, the land surface was randomly shaped to establish irregular contours with high ridged areas and depressional furrows (Fig. 1). Microtopography was established using a disk with the circular blades turned such that displaced soil was pushed to the outside edges, creating depressions within the path of the disk and ridges of soil on the edge of the disk path. After tillage operations were completed, tree seedlings were planted on half of the treatment plots at each site at a density of approximately 270 plants/ha.

Flashboard riser type water control structures were installed in each of the four field ditches at each site as a means for measuring outflow from the experimental plots. Boards and 60 degree, V-notch weirs were installed during May 1995 at both sites to begin the process of restoring wetland hydrology. On two field ditches, the weirs were installed at an elevation approximately 15 centimeters above the average land surface. Therefore, surface ponding to a depth of 15 centimeters would be necessary for water to leave the site. For the remaining two field ditches, weirs were installed at an elevation 15 centimeters below the average land surface. Earthen berms were created around the perimeter of the entire site to prevent ponded surface water from running off-site before running into the field ditches. Berms were also constructed between experimental treatments to prevent surface runoff from flowing between treatment plots. Combinations of the two water table management and two microtopography treatments made up the four hydrologic treatments monitored at each site: high water table management and smooth topography, low water table management and smooth topography, high water table management and rough topography, and low water table management and rough topography. Two replicates of these treatments were established at each site, for a total of eight, approximately 0.9 ha, experimental treatment plots at each site.

The initial state of the soil was determined at each site once the topographic treatments had been implemented. A complete profile description was made in each pit and soil samples were collected. Twenty-six soil profile descriptions were completed at each. Redox electrodes were installed at a depth of 150 mm to measure rooting zone redox potential. Thermocouples were installed at two sampling locations within each plot to measure soil temperature at 150 and 500 mm soil depths.

Installation of field instruments began in the spring of 1995 and was completed during the summer of 1996. Hydrologic data collected at each site included: water table depth at six locations within each experimental plot with one location being an automated stage recorder, level of water in the field ditches, and precipitation. Five, 32 mm diameter poly vinyl chloride (PVC) wells were installed within each experimental treatment to determine groundwater gradients across individual treatment plots. All wells were installed within the instrumentation transects (Fig. 2) to a depth of 2 meters, and were perforated from the bottom to within 15 cm of the soil surface. Water table measurements from these observation wells were recorded weekly using a steel tape. Water table recorders were installed on four inch diameter PVC wells during the summer of 1996 in order to provide a continuous record of water table depth (see Figure 2 for installation locations). Continuous stage recorders were also installed at the outlets of the field ditches, at locations shown in Figure 2, to provide a continuous record of water levels within the field ditches. Data from these recorders were used to compute the amount of outflow from the experimental plots by recording the depth of water flowing over the weirs in the water control structures. Manual and automated rainfall gauges were installed at both sites to record precipitation.

Ten m x ten m subplot quadrats were laid out and configured in each of the treatment plots and in reference forest. Each subplot was divided into a 1/3 m by 1/3 m grid, and the elevation at each point on the grid determined to within 2.5 mm with a laser lever. There were 961 gird points per quadrat and approximately 42,000 elevations measured. Each tree or shrub with a measurable diameter at breast height (dbh) within the forested plots was mapped and its dbh recorded. For each quadrat, five microtopographic zones were defined by dividing the range of elevations into five equal portions. Each quadrat was treated as a series of 1/3 s 1/3 m pixels with each pixel designed as a member of a contiguous topographical feature in two dimensional space. The extent (surface area) of each microtopographic feature was defined as the number of contiguous pixels of a given elevation class. The mean numbers, elevations, and extents of microtopographic features were compared across treatments and tested for equivalency, with a null hypothesis of difference between the two means and one standard deviation of the mean of the reference forests as the tolerance for equivalence.

Vegetation sample schemes depended on surface contouring. In the contoured treatments, 0.45 m x 0.45 m (0.2 m^2) quadrats along four transects perpendicular to the field ditches were established which yielded 596 and 625 quadrats at Aurora and Vanceboro, respectively. A 0.2 m^2 quadrat encompassed only one microtopographic feature, keeping the elevation within the quadrat as homogenous as possible. The quadrats were placed so that each was centered on one microtopographic feature such that quadrats were not always contiguous along the transects. Only two transects were used for the smooth treatments with 214 and 287 contiguous 0.2 m^2 quadrats at Aurora and Vanceboro, respectively. Each quadrat was assigned to one of five microtopographic classes: mound, lower mound, neutral, upper trough and trough. Within each quadrat, the percentage cover of each plant species within the 0.2 m^2 quadrat was estimated using cover classes of 0.1%, 1%, 2%, 3%, 4%, 5% and in increments of 5% thereafter. Vascular plants were identified to the species lever whenever possible. For more details on statistical analysis of microtopography and vegetation, see Scherrer et al., 2001.

RESULTS

Microtopography - Figure 3 shows a one dimensional comparison between surface roughness of the smooth and rough microtopography treatments established at each site. Two estimates of surface roughness were estimated; 1) the maximum amount of surface storage which must be filled before surface runoff from the plot to the field ditch would occur, and 2) the amount of local depressional storage that must be filled before movement of trapped water between depressions would occur. On smooth microtopography treatments, maximum surface storage and local depression storage values averaged 3.1 and 0.6 cm, respectively, while on rough microtopography treatments, values averaged 8.2 and 2.2 cm, respectively. Therefore, the roughing of the soil surface achieved a greater than two-fold increase in the amount of surface storage available.

The created microtopography is evident in maps of contoured plots, Figure 4. Comparisons of the microtopographic features of the smooth and contoured plots are shown in Table 1. Generally, contoured plots had more features that were smaller in area and taller in elevation than smooth plots. Microtopographic features were most often regularly distributed in contoured plots and randomly distributed in smooth plots. The contoured plots had more features than the forested plots; while the forested plots had taller features and a greater range in feature height. These

Table 1. Comparison of microtopographic features in contoured and smooth fields and reference forests. Means that were equivalent (the null hypothesis was difference) are indicated by E; means that were different (the null hypothesis was equivalence, tested after the means were not demonstrated to be equivalent) are indicated by D. (After Scherrer, 2000)

Aurora

Number of plots		**Contoured vs. Forested**					**Contoured vs. Smooth**				
Contoured	8	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
Forested	10										
Smooth	4										
Number of features per plot											
Contoured mean (sd)		13 (4)	36 (6)	56 (7)	44 (7)	17 (4)	13 (4)	36 (6)	56 (7)	44 (7)	17 (4)
Forested/smooth mean (sd)		5 (2)	15(4)	22 (5)	19 (4)	6 (2)	13 (4)	35 (6)	33 (6)	30 (5)	16 (4)
comparison of means		**D**	**D**	**D**	**D**	**D**	**E**	**E**	**D**	**D**	**E**
p-value		<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	.0427	.0001	.0150	.0223
Elevation (m above baseline)											
Contoured mean (sd)		.31 (.06)	.24 (.04)	.18 (.03)	.11 (.03)	.05 (.02)	.31 (.06)	.24 (.04)	.18 (.03)	.11 (.03)	.05 (.02)
Forested/smooth mean (sd)		.46 (.07)	.33 (.06)	.24 (.05)	.17 (.04)	.06 (.04)	.17 (.03)	.13 (.02)	.10 (.02)	.06 (.02)	.03 (.01)
comparison of means		**D**	**D**	**D**	**D**	**E**	**D**	**D**	**D**	**D**	**D**
p-value		<.0001	<.0001	<.0001	<.0001	.0002	<.0001	<.0001	<.0001	<.0001	<.0001
Extent in area (number of pixels per feature)											
Contoured mean (sd)		4 (6)	7 (10)	7 (15)	5 (8)	4 (7)	4 (6)	7 (10)	7 (15)	5 (8)	4 (7)
Forested/smooth mean (sd)		5 (7)	10 (18)	19 (36)	17 (45)	9 (21)	4 (8)	6 (9)	12 (28)	8 (17)	5 (11)
comparison of means		**E**	**E**	**E**	**E**	**E**	**E**	**E**	**E**	**E**	**E**
p-value		<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
Percent of plot surface in zone											
Contoured mean (sd)		6	26	39	22	7	6	26	39	22	7
Forested/smooth mean (sd)		2	15	43	34	5	6	21	41	25	8
comparison of means (pooled across zones)						**D**					**D**
p-value						<.0001					<.0001
Clustering of features											
Contoured		**Random**	**Regular**	**Regular**	**Regular**	**Regular**	**Random**	**Regular**	**Regular**	**Regular**	**Regular**
Forested/smooth		**Random**	**Random**	**Regular**	**Random**	**Random**	**Random**	**Clustered**	**Regular**	**Random**	**Random**

differences were attributed to the source of the feature. In the forested plots, features were predominately the result of tree fall with the mounds the result of tipping of the root ball while in the contoured plots, the feature height was limited by the implement used. The range in feature elevation averaged 27 cm for the contoured plots compared to 38 cm in the forested plots.

Water Table - Average difference, average absolute difference, and the coefficient of determination (R^2) were calculated for each replicate pair at each site (Table 2). Average difference was calculated as:

$$\frac{\sum (WL1i - WL2i)}{n} \qquad [1]$$

where *WL1* and *WL2* were daily (instantaneous measurements at 12:00 PM), paired water table measurements between treatment replicates, and *n* was the number of paired observations. The average difference parameter provides an estimate of how much wetter or dryer, on average, one treatment replicate was with respect to the other replicate. Average absolute difference is an estimator of the variability between treatment replicates and was calculated as:

$$\frac{\sum \left[abs(WL1i - WL2i)\right]}{n} \qquad [2]$$

The standard coefficient of determination, R^2, is provided as another estimator of the variability between treatment replicates.

Water table depths between replicates at the Beaufort County site were found to be similar, with average absolute differences ranging from 5.2 to 6.7 cm and R^2 values ranging from 0.94 to 0.97. Water table depths between replicates at the Craven County site were more variable, due in part to greater variation in water table depths between wet and dry periods at the Craven site as compared to the Beaufort Site. At the Craven County site, the largest average absolute difference between replicates, 28.3 cm, occurred between the high water table, rough microtopography treatment plots. This was primarily attributed to different water levels in the field ditches on either side of the treatment plots.

Water table hydrographs between replicate treatments were used to create one composite hydrograph representing each hydrologic treatment, thereby simplifying comparisons between treatments. Composite hydrographs were determined by averaging water table depths between paired observations from treatment replicates. Average difference, average absolute difference, and R^2 values were then calculated between treatments at each site (Table 3), providing a means of comparing the variability between treatments with the variability between replicates.

For the Beaufort County site, variability between treatments was generally greater than variability between replicates. However, variability between the low/rough and high/smooth treatments, and between the high/smooth and high/rough treatments was similar to that observed between replicates at the site. For the Craven County site, the variability between treatments was similar to the variability observed between replicates, except for comparisons between the high/smooth treatment and other treatments at the site. This indicates that there was little difference between the low/smooth, low/rough, and high/rough treatments at the Craven County site.

Table 2. Comparison of water table hydrographs between replicate treatments from January 1996 through December 1998.

Treatment	Average Difference (cm)	Average Absolute Difference (cm)	Coefficient of Determination, R^2
Beaufort County site Treatments:			
low / smooth	1.2	6.1	0.94
low / rough	5.8	6.7	0.95
high / rough	4.6	5.2	0.97
high / smooth	1.2	5.5	0.94
Craven County site Treatments:			
low / smooth	7.9	9.8	0.93
low / rough	10.4	10.7	0.94
high / rough	28.3	28.3	0.91
high / smooth	2.74	7.6	0.96

Table 3. Comparison of water table hydrographs between hydrologic treatments from January 1996 through December 1998.

Treatment Comparisons	Beaufort County Site			Craven County Site		
	Average Difference (cm)	Average Absolute Difference (cm)	Coefficient of Determination, R^2	Average Difference, (cm)	Average Absolute Difference (cm)	Coefficient of Determination, R^2
low/smooth vs. low/rough	14.2	14.6	0.91	2.18	7.15	0.94
low/smooth vs. high/smooth	16.5	17.1	0.76	13.8	16.4	0.90
low/smooth vs. high/rough	20.8	21.0	0.68	8.6	11.0	0.93
low/rough vs. high/smooth	2.3	5.4	0.91	9.9	18.1	0.78
low/rough vs. high/rough	7.1	8.5	0.82	6.2	10.3	0.92
high/smooth vs. high/rough	5.1	6.4	0.92	1.6	12.8	0.85

For comparing differences in relative wetness between experimental treatments, five hydroperiod criteria were calculated for each experimental treatment. Criteria were based on the average number of days (based on 3 years of data) during the growing season or during the year in which the water table depth was less than 30 cm deep or 0 cm deep (at the soil surface). The growing seasons for both sites were determined from the respective county soil surveys. For Beaufort County, the growing season extends from March 13 through November 25, while for

Craven County the season extends from March 18 through November 14. The specific criteria are described below and are shown graphically in Figures 5a and 5b for the Beaufort and Craven sites:

- Criteria 1: Average number of days during the *growing season* with the water table at or above the soil surface
- Criteria 2: Average number of days during the *year* with the water table at or above the soil surface
- Criteria 3: Average number of days during the *growing season* with the water table less than 30 cm deep
- Criteria 4: Average number of days during the *year* with the water table less than 30 cm deep
- Criteria 5: Longest number of consecutive days with the water table less than 30 cm deep during the growing season.

At the Beaufort site, the driest hydrologic treatment involved low water table management and smooth microtopography. The wettest conditions were experienced on the high water table, rough microtopography treatments which averaged 59 more days per year meeting Criteria 4 than the low water table, smooth microtopography treatments. Rough microtopography treatments at the Beaufort County site displayed wetter conditions throughout the study period as compared to the smooth treatments, due to the increased amount of surface storage on the rough treatments (Fig. 6). Rough microtopography increased the average number of days per year meeting Criteria 2 by 65 days (a 650% increase) and the number of days per year meeting Criteria 4 by 40 days (a 24% increase) on the low water table management treatments. On the high water management treatment, rough microtopography increased the number of days satisfying Criteria 2 by 40 days (an 80% increase) and Cirteria 4 by 7 days (a 3% increase). This would indicate surface topography has a greater influence on water table hydrology as the relative wetness of the site is decreased. The data also indicate that similar water table hydrology can be achieved with different levels of water table control and surface microtopography. For example, hydroperiods for the low water table, rough microtopography treatments at the Beaufort County site were very similar to those observed on the high water table, smooth microtopography treatments (Fig. 5a).

The Craven County site experienced much drier conditions than the Beaufort County site (Fig. 7), due in part to the inability to maintain the intended water table depths. Direct lateral seepage was observed to the channelized stream adjacent to the site. Seepage around the water control structures was also observed and allowed water in the field ditches to be discharged before reaching the desired outlet depth. Inspection of the soil profiles indicated that the soils of the Craven site were formed under naturally drier conditions than those of the Beaufort County site. Of twenty-six soil pits dug at each site, 100% and 70% of the profile descriptions were determined to be hydric at the Beaufort and Craven sites, respectively (Smith, 1998). This suggests that the Craven site, in its natural pre-drained state, was a marginal wetland, only partially supporting wetland functions.

<u>Outflow</u> - Outflow data were collected at each of the restoration sites from January 1996 through December 1998. In this report, *outflow* is defined as the combined volume of water from both subsurface drainage and surface runoff which left the sites through the water control structure outlets (i.e. over the weirs).

At the Beaufort County site, outflow occurred on all restoration treatments. However it was noticed during the spring of 1997 that some ponded water on the treatment plots was escaping over the berms in low areas, particularly on the high water table management treatments where the water level was ponded to a depth of 15 cm. During the summer of 1997, construction equipment was used to increase the height of the berms around the individual treatment plots, eliminating the flow of water over the berms. However, containment of ponded water on the high water table management treatments remained problematic, due to the activity of rodents and other burrowing animals.

Monthly outflow volumes are presented in Figure 8 for the low water table treatments at the Beaufort County site. The treatment involving roughing of the soil surface reduced total outflow amounts by an average of 4.4 cm, or approximately 30%. On the rough microtopography treatments, more precipitation was trapped in depressional storage. This resulted in more time for infiltration and evapotranspiration of ponded water and reduced the total amount of outflow from the rough treatment plots. Duration of outflow events was increased on the rough treatments due to both the more tortuous flow paths for surface runoff and the time necessary for ponded surface water to infiltrate and flow via subsurface drainage toward the field ditches (Fig. 9). On average, duration of outflow was increased by approximately 30% on the rough treatments as compared to the smooth treatments.

Plant Communities: Effects of the high and low water table treatments were evident in plant community compositional trends at the Beaufort site, but not at Craven site due again to the drier conditions at the Craven site. McKinney (1997) and Scherrer (2000) found that the topographic and hydrologic differences resulting in different emergent plant communities. Species like *Andropogon virginicus* L. (broomsedge) and *Solidago candensis* Torr. & Gray (goldenrod) were associated with mounds (higher elevation) while *Polygonum densiflorum* Meissner (dense-flower smartweed), *Ludwigia repens* Forster (creeping seedbox), *Ludwigia alternifolia* L. (seedbox) and *Typha latifolia* L. (cattail) were more often associated with wetter, lower elevations. There was a significantly greater number of species in contoured plots (5.3 species) than in smooth plots (4.9 species) (p-value = 0.0046).

CONCLUSIONS

Restoration efforts involving water table control and contouring were successful at creating a spectrum of hydrologic conditions, ranging from relatively dry conditions on the low water table management, smooth microtopography treatments to very wet conditions on the high water table management, rough microtopography treatments. The Craven County site displayed much lower water table depths and drier soil conditions than the Beaufort County site throughout the study period. The Craven County site was restored to a marginal wetland at best, and most likely continues to lean toward being an upland. Based on soil types at the two field sites, the Craven County site appears to historically be a drier site than the Beaufort County site. Though both sites contain hydric soils, the Roanoke soil of the Beaufort site is a wetter soil under undrained conditions than the Leaf soil at the Craven site. This indicates that even under natural, undrained conditions, the Craven County site may have been only a marginal wetland.

Microtopography treatments were found to influence the amount, intensity, and duration of outflow and distribution of plant species. The use of rough microtopography decreased total outflow volume, decreased outflow intensity, and typically increased the duration of outflow events over the smooth microtopography treatments. Contouring of the soil surface more closely approximated the microtopography found in the forested conditions although differences in extent of features and height of features still existed. The result demonstrate that a variety of microsites within the fields was established; however, structural improvement in the microtopography could be made by selection of an implement more suited to establishment of the desired microtopographic features prior to construction.

The water table hydrology data collected from this research indicate that a similar water table response can be induced by various combinations of water table control and surface roughing. For example, water table hydrographs and hydroperiods were similar between the low water table management, rough microtopography treatments and the high water table management, smooth microtopography treatments.. Roughing of the soil surface enhanced development of redoximorphic features. Considering these functional benefits coupled with the hydrologic impacts presented herein, roughing of the surface is recommended as a restoration practice to enhance wetland function on relatively flat, smooth agricultural fields. However, relative differences in vegetation composition, soil chemistry, and hydrology between raised and depressional microtopography sites will likely be site dependent, varying with soil characteristics and degree of topographic manipulation.

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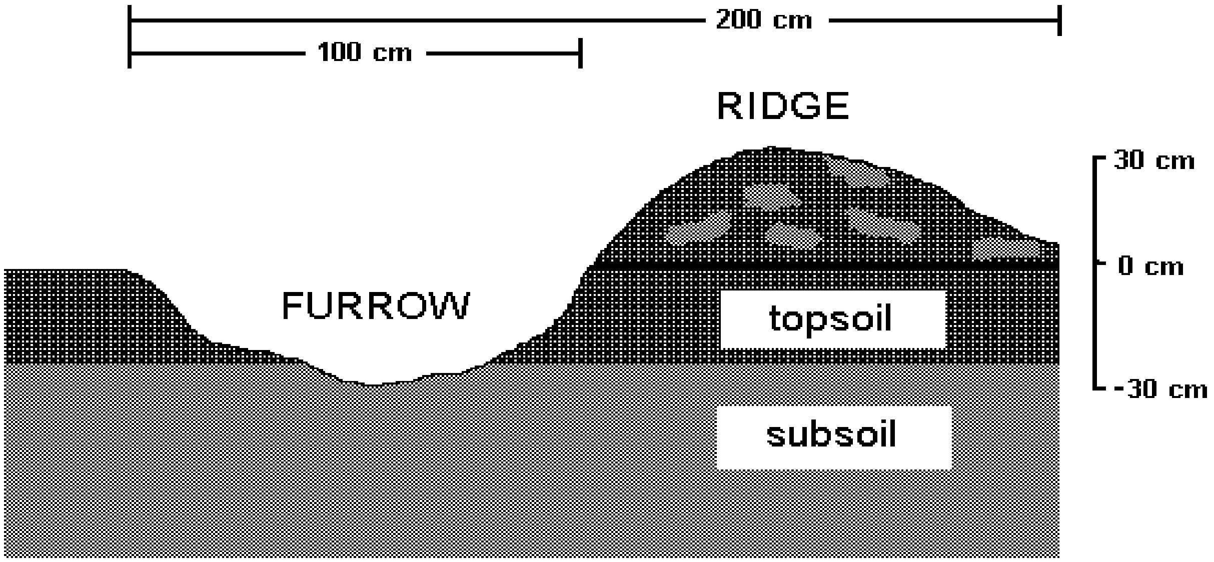

Figure 1. Rough microtopography imposed on one-half of the restoration sites.

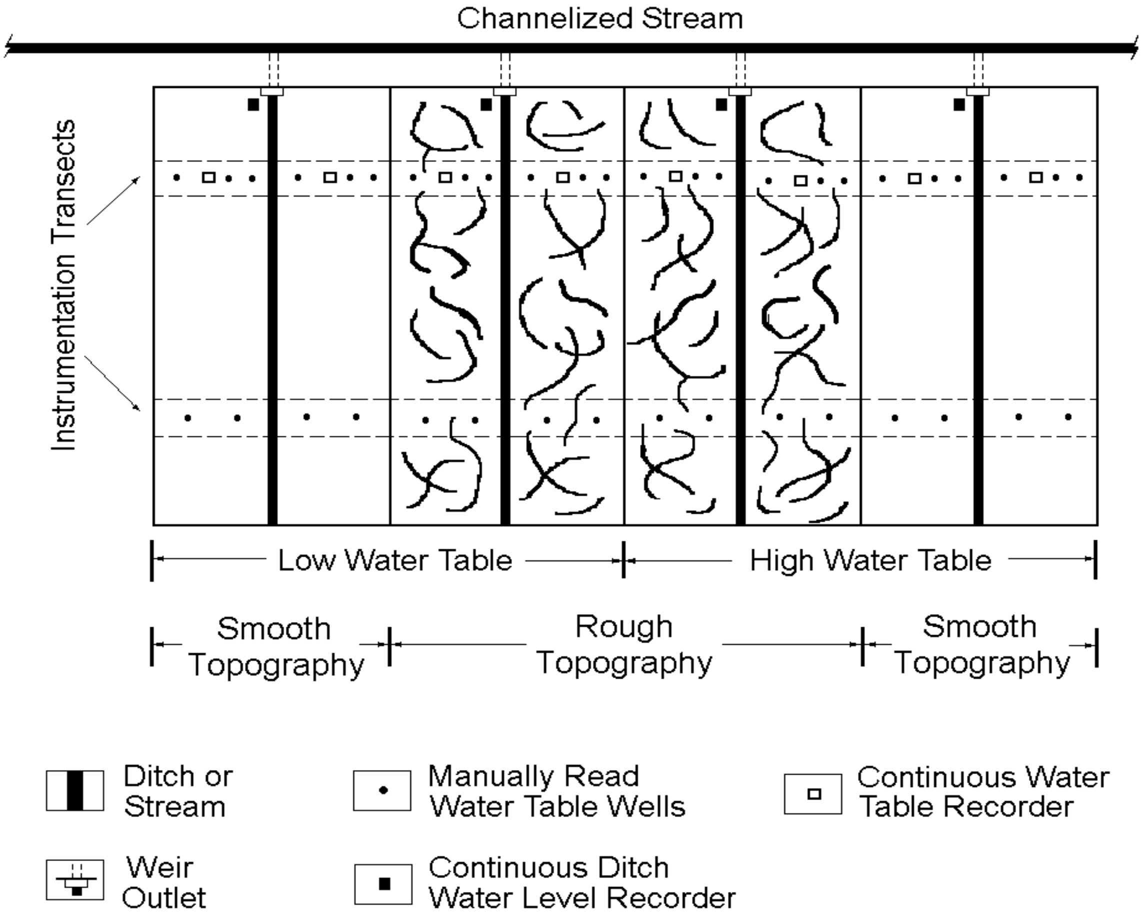

Figure 2. Layout of experimental treatments and instrumentation. Individual plots were approximately 35 m wide by 300 m long.

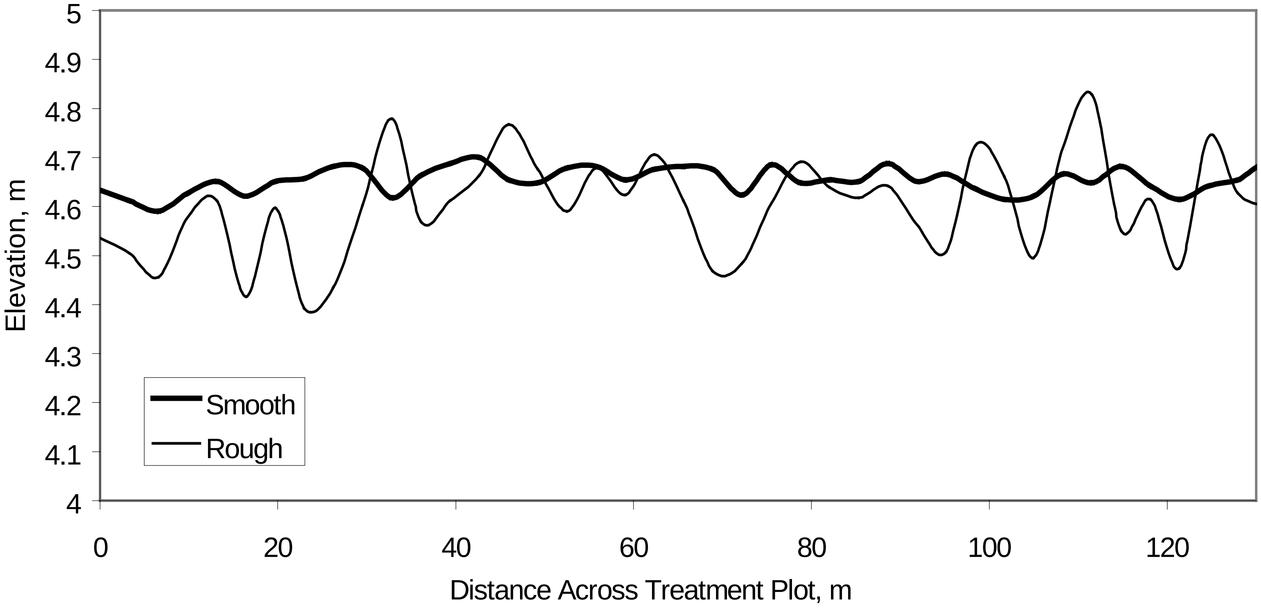

Figure 3. Comparison between the surface roughness of the smooth and rough microtopography treatments.

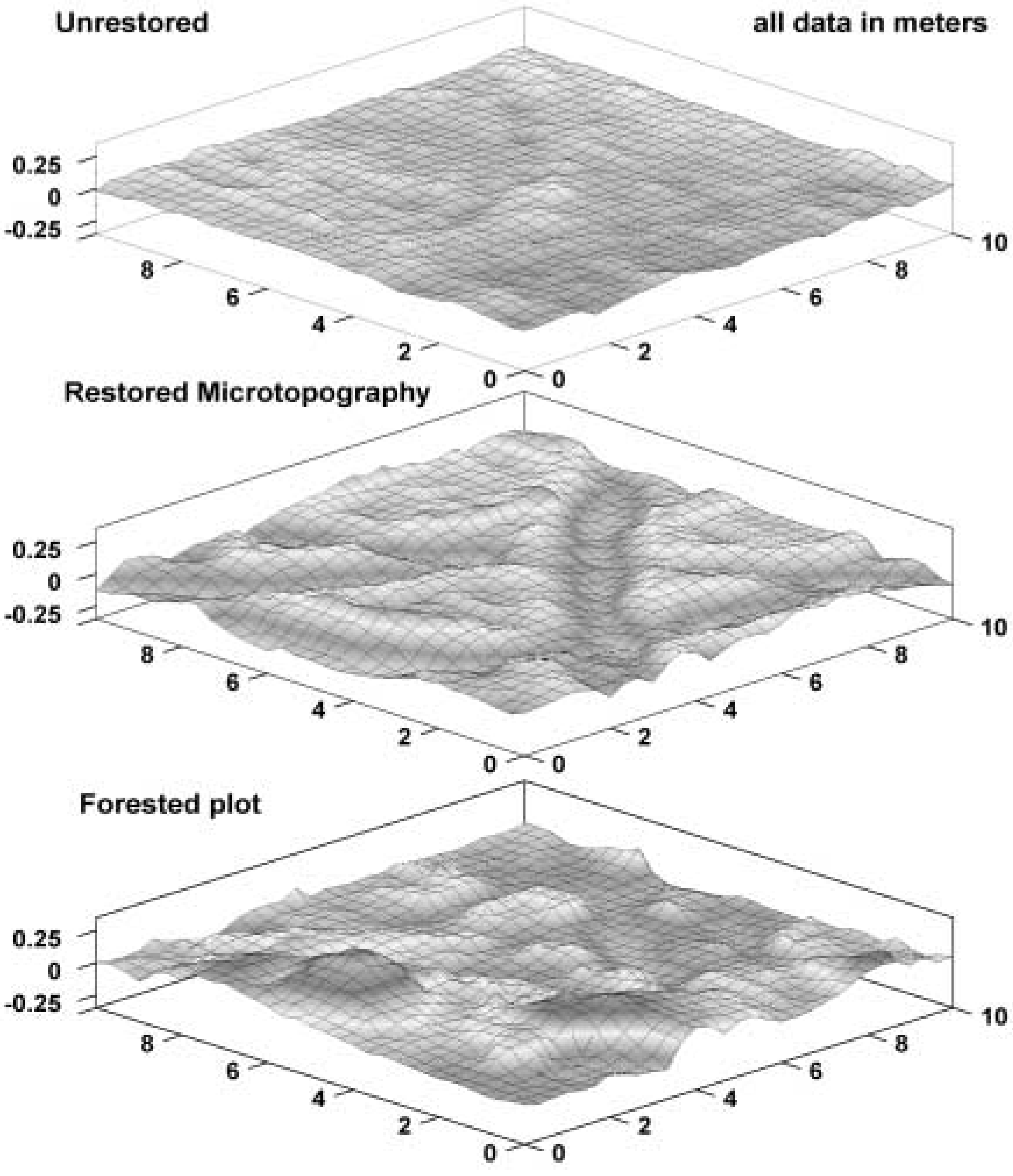

Figure 4. Example comparison of 3D microtopographic features of smooth (unrestored), contoured (restored) and forested treatments.

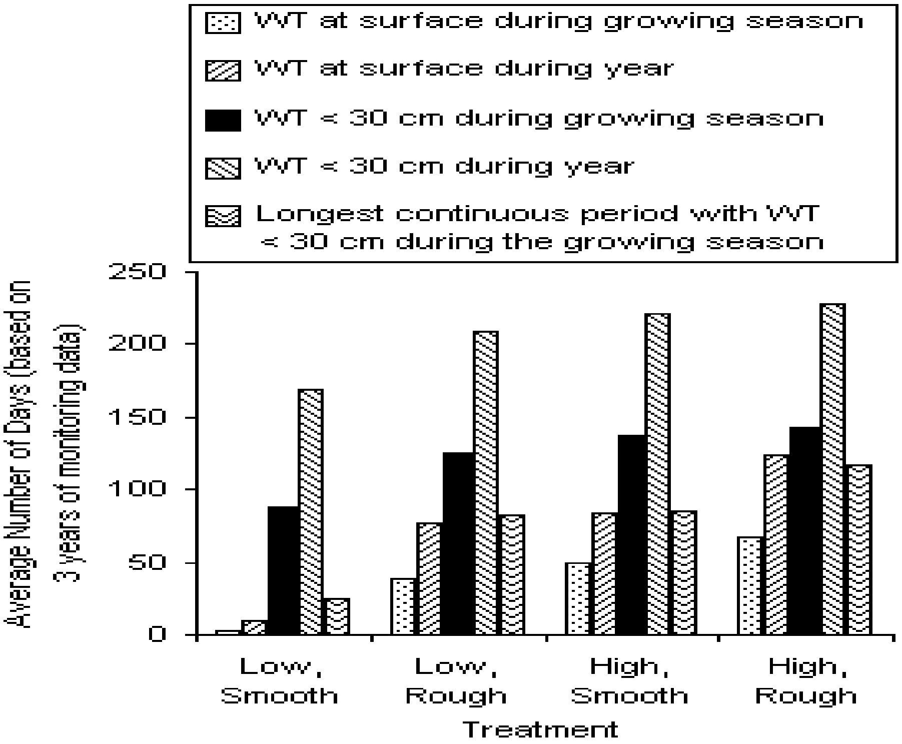

Figure 5a. Comparison of hydroperiod criteria for the Beaufort County site.

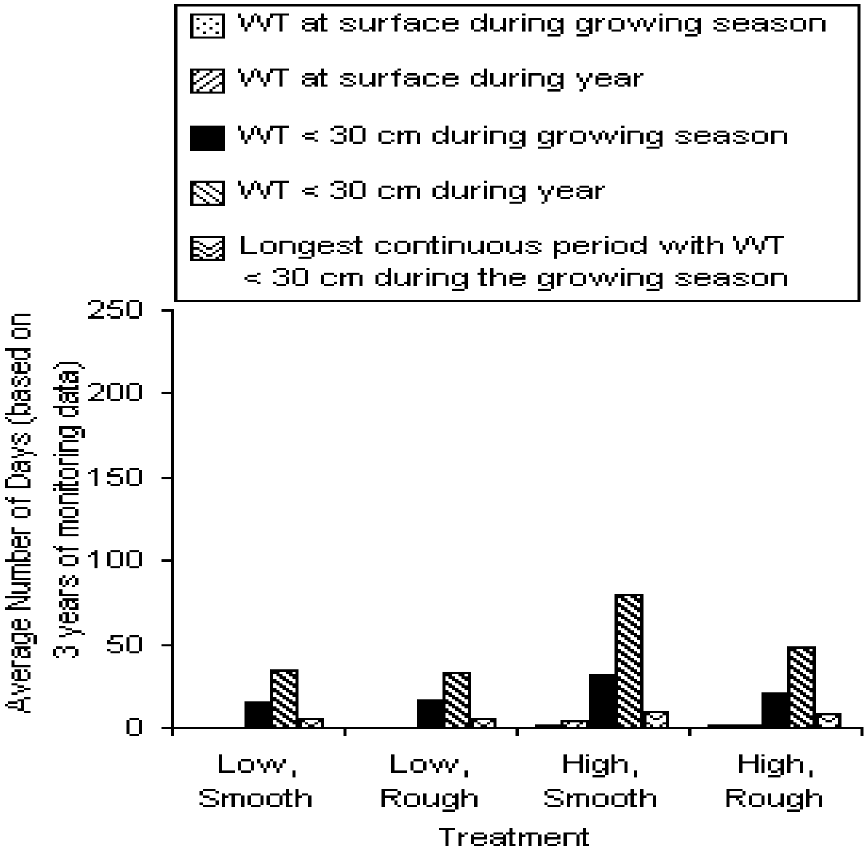

Figure 5b. Comparison of hydroperiod criteria for the Craven County site.

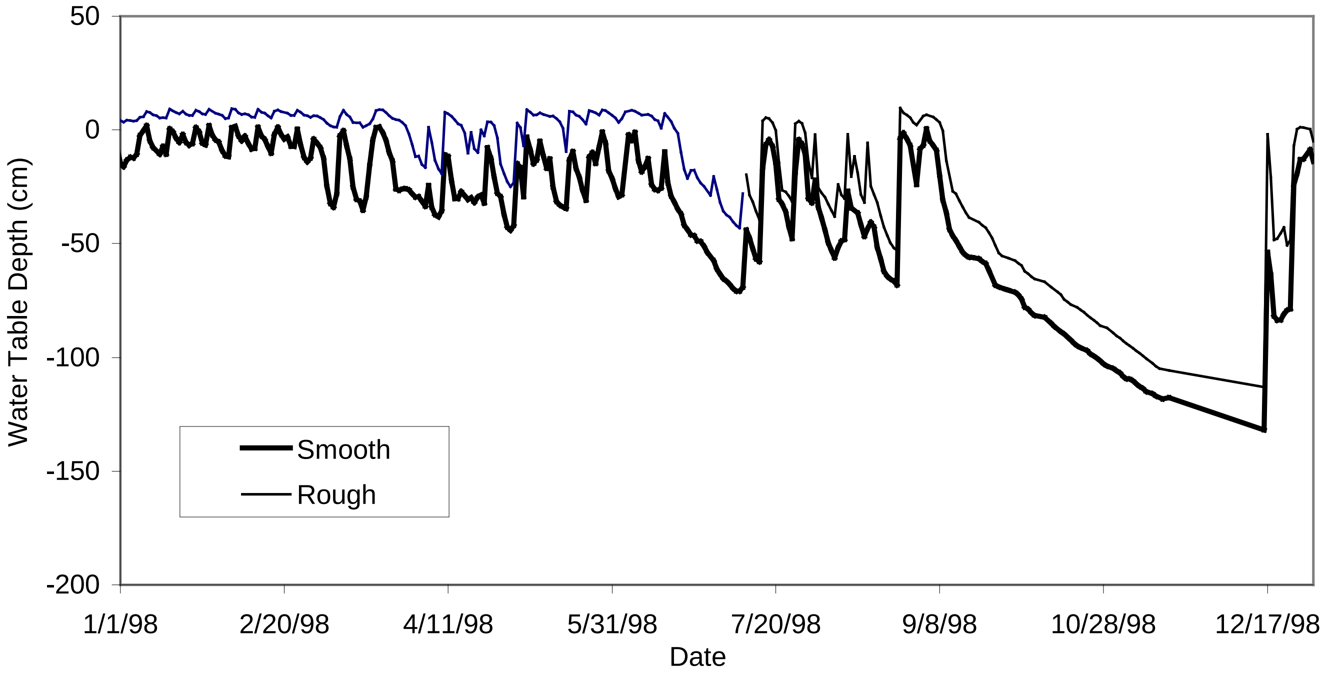

Figure 6. Comparison between water table depths for two different microtopography treatments. Water table management level (approximately 15 cm below average land surface) was the same for each treatment.

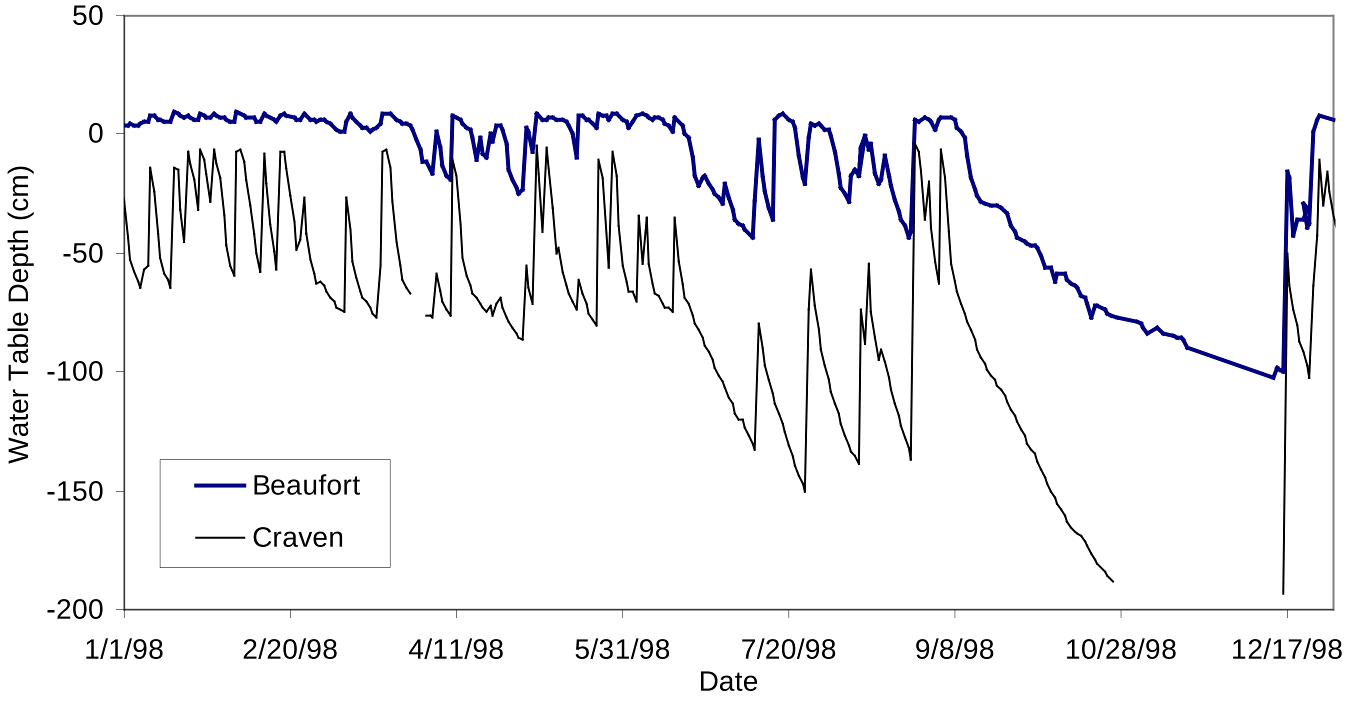

Figure 7. Comparison of water table hydrographs for the same hydrologic treatment (low water table, rough microtopography) at the Beaufort and Craven County sites.

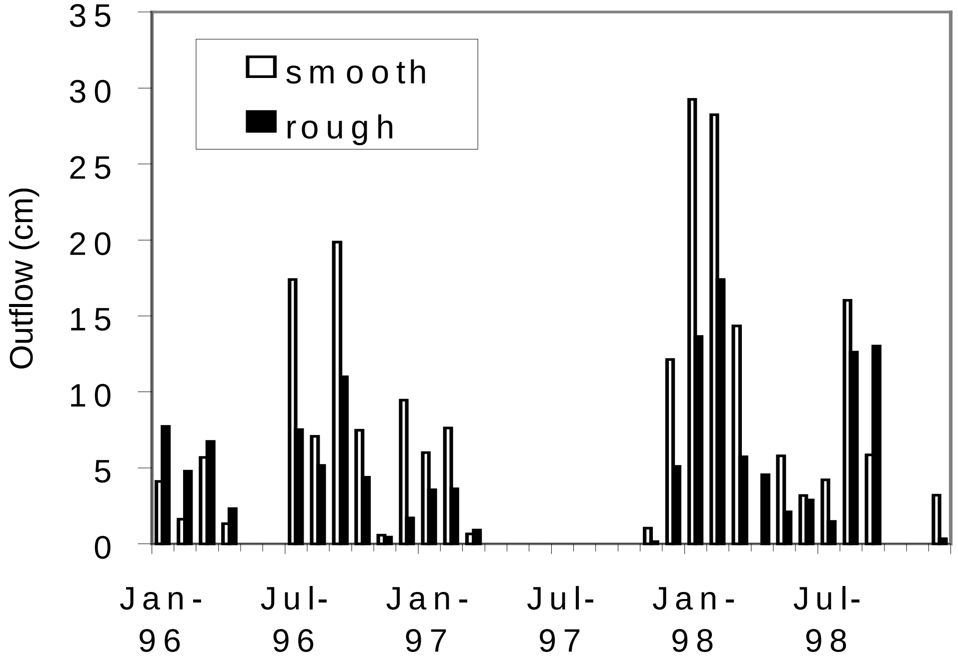

Figure 8. Comparison between monthly outflow amounts between the smooth and rough microtopography, low water table management treatments at the Beaufort County site.

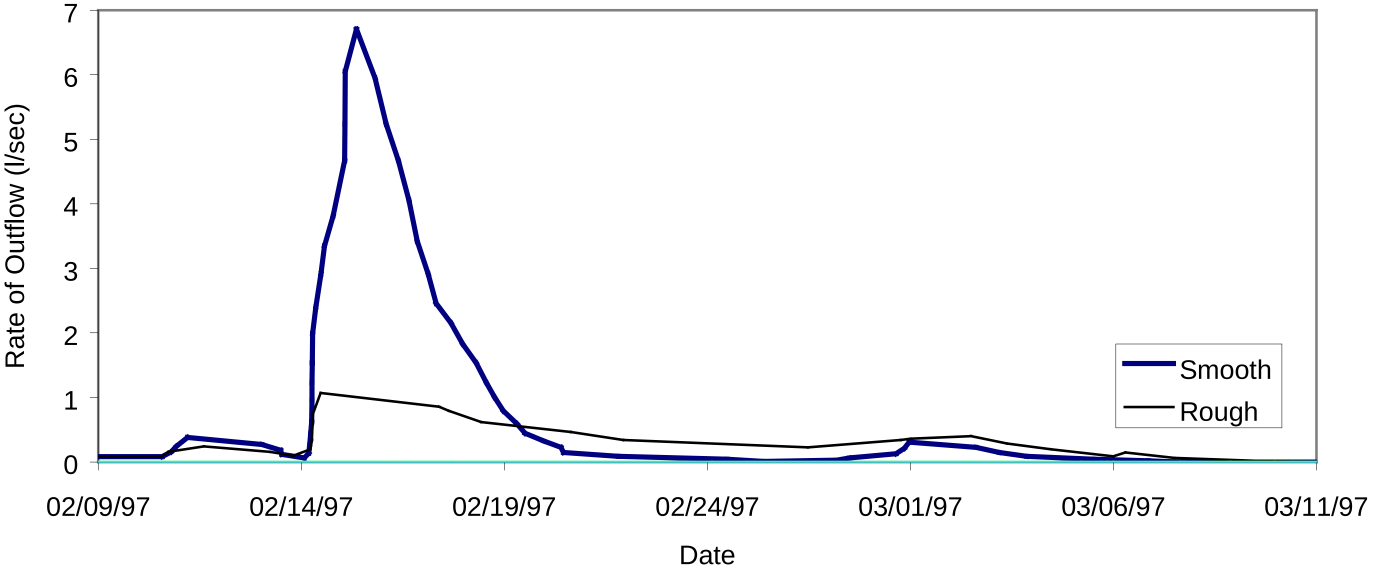

Figure 9. Comparison of outflow hydrographs between the smooth and rough microtopography, low water table treatments at the Beaufort County site.