A PRELIMINARY ANALYSIS OF THE HYDROLOGIC REGIME AND WETLAND PLANT COMMUNITIES OF THE MANCHESTER CEDAR SWAMP

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Abstract—Preliminary data was obtained to document existing hydrologic conditions and plant community composition for Atlantic white cedar (*Chamaecyparis thyoides*) (cedar), cedar/giant rhododendron, black gum, and red maple wetlands at the Manchester Cedar Swamp. Twenty-three piezometers were installed in eight transects located throughout each plant community. Water level was measured bi-weekly for one year. Hydroperiod, mean water level, and water table fluctuation were determined. At each of the piezometer locations ground cover and shrub strata were sampled using one and three meter box plots, respectively, and the tree stratum was sampled using a five-factor prism. Species were sampled and dominant species were used to calculate a Wetland Site Index for each piezometer. R^2 regression analysis was used to correlate this data with mean water level. This study will make it possible to observe the long-term effects of development on the hydrology and plant community composition of the Manchester Cedar Swamp.

Keywords: Atlantic white cedar, Manchester Cedar Swamp, hydrology, disturbance, community composition, stratum, water level

INTRODUCTION

Hydrology and the Cedar Community

Hydrology is a critical environmental parameter regulating, in part or in entirety, many wetland functions and variables such as moisture availability, supply of nutrients, substrate aeration, export of metabolic products, and the temperature regime of the soil (Hemond and others 1987). In turn, those same functions and variables largely determine the biotic composition, structure, and function of wetland ecosystems (Richter and others 1996). As such, hydrology has often been cited as the dominant factor determining wetland plant species composition (Golet and Lowry 1987, Gosselink and Turner 1978, Laderman 1989, Lowry 1984); therefore, hydrologic studies are becoming an integral component of ecological research (Hemond and others 1987).

Sperduto & Ritter (1994) believe that the hydroperiod and mean water level are the primary determinants of species composition and canopy density in the cedar community, and it is thought that the hydroperiod is one of the most essential of the hydrologic parameters in maintaining the integrity of the biotic environment (Gosselink and Turner 1978) as the hydroperiod is one of the factors responsible for controlling seed germination. Although adapted to saturated soil conditions, cedar seedlings appear to be intolerant of prolonged inundation (Rodgers and others 2003) so may not survive such conditions.

Throughout its geographic range, the cedar community is adapted to a wide variety of hydrologic conditions, however, cedar is intolerant of changes in hydrologic conditions specific to its locale. Cedar has a hydrologic regime that is characterized by seasonal inundation and a shallow water table (Laderman 1989). The hollows surrounding the hummocks upon which cedar typically grow have a water level that ranges from approximately 1.2 meters above ground surface (AGS) to 0.3 meters below ground surface (BGS) (Laderman 1989). Ehrenfeld & Schneider (1993) determined that hummocks are on average 50 to 75 cm above the low points in the hollows. Hummock and hollow topography in the cedar community is pronounced and hollows are often wet throughout the growing season (Sperduto and Nichols, 2004). Sphagnum and cedar find their own niche in this environment, based upon soil moisture, creating the undulating surface characteristic of cedar wetlands. Hanks (1985) found that depth to the water table, or depth of surface water, in large part determines plant community composition. Since hydrologic regime varies from year to year and from wetland to wetland, documenting hydrologic regime for each wetland basin is ideal, but in most cases is not practical due to the time required to collect many years of data.

Few studies have been completed that quantitatively document the hydrologic regime of cedar wetlands (Laderman 1989); however, several studies have qualitatively documented the effect of altered hydrologic regime on the cedar community (Baldwin 1965; Motzkin 1991; Ahrens 1997). The findings of these studies indicate that there is a high likelihood for degradation of the cedar community following human or other disturbance adjacent to the wetland basin or upgradient within the watershed. Since the establishment and continued success of the cedar community is largely dependent upon a consistent hydrologic regime, even subtle changes in hydrologic regime can impede the ecological success of the cedar community (Ehrenfeld & Schneider 1991).

Ehrenfeld & Schneider (1993) concluded that urbanization alters hydrology. Schneider and Ehrenfeld (1987) studied 18 cedar wetlands located in the New Jersey Pinelands in undisturbed watersheds. Data from this study suggests that along a gradient ranging from undisturbed sites to disturbed sites, in undeveloped watersheds, there is a gradient of impact indicated in species composition, water level, and water quality that corresponds to the gradient of disturbance. This same study also found that human modifications to swamp drainage or stream channels have a major influence on water table dynamics in cedar wetlands. In the absence of these modifications, there was a slight trend toward drier conditions (lower water tables) as proximity of the wetland to development increased. This study concluded that urbanization has a substantial impact on the cedar community. Urbanization alters hydrologic regime by changing drainage pathways and creating increased impervious surface area. Both altered drainage and increased impervious surface area will alter hydrology, change the source of input and channel flow. In addition, even minimal placement of roads in proximity to wetlands can impact the condition of those wetlands by altering water levels and allowing invasive plant species to colonize the site (Ehrenfeld & Schneider 1983).

Site Description

Within the study area are approximately 16 hectares of wetland. The general topography of the study area is characterized by steep slopes and rocky ledges that protrude through shallow soil. The steep slopes and shallow soils increase the likelihood of flash flows during storm events. The slopes form ridges that divide the study area into three subwatersheds, each containing the wetland basins included in the study. The topography within each wetland basin is characterized by extensive and well-defined hummocks and hollows characteristic of cedar wetlands. The wetland basins are located at an elevation of approximately 106 m above mean sea level approximately 60 km inland from the Atlantic coast.

METHODS

Hydrologic Monitoring

Twenty-three piezometers were installed within the study area to document the existing hydrologic regime of each plant community, as shown in figure 1. The piezometers were installed in eight transects located within three subwatersheds. Within each transect individual piezometers were placed approximately 30 m apart within the hollows of the hummock and hollow topography. The elevational gradient between the hollows and surrounding hummocks was not measured. Transects were located within the wetland basins on the downgradient side of potential development locations. Piezometers were distributed as follows: seven in the cedar/giant rhododendron community (Watershed 1); six in the cedar community and five in the northern black gum community (Watershed 2); three in the southern black gum community and two in the red maple community (Watershed 3).

The water level at each piezometer was obtained bi-weekly for one year (24 monitoring events) to obtain data representing one complete hydroperiod. Water level monitoring commenced on January 2, 2000, and culminated on December 17, 2000. Water level measurements were obtained using either a Seattle Co. Water Level Indicator Model 51453, or a Solinst Water Level Indicator Model 101. During each monitoring event, three measurements were recorded: depth to water (DTW), depth to ground (DTG), and, if surface water was present, depth of surface water.

It has been observed in this study, and others, that piezometers float up and down with the sphagnum mat. As sphagnum expands and contracts with the raising and lowering of the water table, the skin friction of the sphagnum on the outside of the piezometer causes it to move up and down accordingly (Hemond et al. 1987).The piezometer cannot be considered a stable reference point since it has a tendency to "float"; therefore, it may be inaccurate to obtain DTW without obtaining DTG, under similar conditions in the absence of some form of reference datum, to account for possible vertical movement of the piezometer.

Vegetation Sampling

On June 16 and 17, 2000, all herbaceous growth, tree seedlings, shrubs, and saplings were sampled at each piezometer. Box plots were placed around each piezometer. The piezometer was used as the plot centrum to obtain vegetation data from the same location as water level data. Herbaceous and low woody vegetation were grouped and collectively called ground cover. Individuals within a one m^2 box plot were sampled. All woody vegetation over 0.91 m in height within a three m^2 box plot was sampled. All individuals within the box plots were identified to species and percent areal cover was estimated, with the exception of sphagnum.

Percent areal cover was determined based upon the methods set forth in the "1987 U.S. Army Corps of Engineers Federal Manual for Delineating and Identifying Jurisdictional Wetlands" (the Manual) and dominance was identified based upon the "50/20" rule, which is stated in the Manual as follows: "for each stratum in the plant community, dominant species are the most abundant plant species (when ranked in descending order of abundance and cumulatively totaled) that immediately exceed 50 percent of the total dominance measure for the stratum, plus any additional species that individually comprise 20 percent or more of the total dominance measure for the stratum. The list of dominant species is then combined across strata." However, for the purposes of this study I did not complete the final step of combining dominant species across strata as I wanted to compare variation among strata.

On September 24, 2000, and October 8, 2000, tree species were sampled using a basal area prism with a factor of five. All individuals within the plot determined by the prism were identified to species, diameter at breast height (DBH) was measured, and health was assessed. Sampled trees were put into one of three health categories: healthy tree, less vigorous tree, and dead tree. A healthy tree was defined as a tree with a visual estimation of a live crown ratio (LCR) greater than 30 percent. A less vigorous tree was defined as a tree with a LCR less than 30 percent. A dead tree was defined as a tree with a LCR of zero. The LCR was determined based upon a visual estimation of the measured height of the live branches divided by the total measured height of the tree multiplied by 100.

Plant Communities and Water Level

To define the relationship between vegetation and mean water level, vegetation sampling results for the ground cover and shrub strata were correlated with the mean water level for each piezometer. To correlate the data, the Region 1 wetland indicator status (R1IND), a representation of occurrence frequency based upon the likelihood of occurrence in a wetland, was obtained for each species included in the sample for both the ground cover and shrub strata. Dominant species were determined according to the method outlined in the Manual. An Ecological Site Index (ESI) was assigned to each R1IND category then applied to all dominant species based upon the midpoint of the category's range. The ESI was then used to derive the Wetland Site Index (WSI). The WSI is a 100- point scale that measures the propensity for a species to occur in a wetland, or "wetlandness," with 1 representing a dry site and 100 representing a wet site. The WSI was determined for each dominant species by multiplying the midpoint value by the ESI and then dividing the result by the sum of the midpoint values for all dominant species. The WSI for all dominant species was then summed to derive a WSI representative of each piezometer location.

RESULTS AND DISCUSSION

Hydrology

To quantify hydrologic regime three parameters were analyzed: hydroperiod, mean water level, and water table fluctuation. Piezometer A1 was excluded from any calculation involving mean water level as it was determined to be an outlier due to it's location on the wetland boundary. Also, data obtained at piezometer D1 on May 21st was not used in calculations of water table fluctuation due to the extreme low measurement.

Hydroperiod— The hydroperiod represents the rise and fall of the water table in a wetland over time with one year representing one complete hydroperiod. Using the modifiers presented in Cowardin (1979), the wetlands in this study are defined as Seasonally Flooded and Seasonally Flooded/Saturated. According to Cowardin, Seasonally Flooded wetlands are those in which surface water is present for extended periods, especially early in the growing season, but is absent by the end of the growing season in most years. When surface water is absent, the water table is often near the ground surface. Saturated wetlands are those in which the substrate is saturated to the surface for extended periods during the growing season, but surface water is seldom present. The results show that water levels in piezometers located within the same watershed fluctuate together, and when graphed they depict a similar hydroperiod, indicative of a strong hydrologic connection. figures 2 - 6 illustrate the hydroperiod for each watershed.

Mean water level—Differences in mean water level between plant communities were statistically significant (P = .22x10E-9) among all plant communities. Comparisons between each plant community are shown in table 1. Mean annual water level for each plant community was calculated as follows: cedar/giant rhododendron (1.0 cm BGS); cedar (9.4 cm BGS); northern black gum (4.3 BGS); southern black gum (1.3 BGS); and red maple (10.4 BGS). In Lowry (1984), the mean annual water level over the 6 year period for the 6 cedar swamps was 0.7 cm AGS. The annual mean, maximum, and minimum water levels for each piezometer are shown as figure 7.

Water table fluctuation— To obtain mean annual fluctuation, the mean water level for each monitoring event was calculated for each piezometer. From this the mean annual water level was calculated for each plant community. The lowest mean annual water level within the community was then subtracted from the highest mean annual water level to yield mean annual fluctuation. When analyzed, differences in water table fluctuation were found to be statistically significant overall (P = 0.7702); however, comparisons between the northern black gum community and the cedar/giant rhododendron, southern black gum, and red maple communities were not (table 2).

Mean annual fluctuation for each plant community was as follows: cedar/giant rhododendron (23.2 cm); cedar (24.5 cm); northern black gum (33.2 cm); southern black gum (27.6 cm); and red maple (28.3 cm). The range of fluctuation for each plant community was as follows: cedar/giant rhododendron (26.8 cm BGS to 21.3 cm AGS); cedar (42.7 cm BGS to 0.9 cm AGS); northern black gum (56.1 cm BGS to 16.2 cm AGS); southern black gum (20.7 cm BGS to 13.4 cm AGS); and red maple (28.7 cm BGS to 2.7 cm AGS).

Vegetation Sampling

Species Richness/Structure— Fifty one vascular plant species were identified in the study. Of those, 33 species were identified in the ground cover stratum, 21 in the shrub stratum, and 13 in the tree stratum. There were 32 species identified in both the cedar/giant rhododendron and the cedar community. In the northern and southern black gum communities there were 28 and 18 species identified, respectively. Nineteen species were identified in the red maple community. This data is summarized in table 3.

Dominant ground cover species were identified for each of the plant communities. In the cedar/giant rhododendron community dominant species included *Pteridium aquilinum* (bracken fern), *Trientalis borealis* (starflower), *Osmunda cinnamomea* (cinnamon fern), and *Coptis groenlandica* (goldthread). In the cedar community dominant species included *C. groenlandica*, *O. cinnamomea*, and *Kalmia latifolia* (mountain laurel). In the northern black gum community dominant species included *O. cinnamomea* and *Symplocarpus foetidus* (skunk cabbage) *C. groenlandica*, *Gaultheria hispidula* (creeping snowberry) and *Thelypteris simulata* (Massachusetts fern). In the southern black gum community dominant species included *O. cinnamomea* and *Vaccinium vacillans*. In the red maple community dominant species included *O. cinnamomea*, *C. groenlandica*, and *T. simulata*.

Dominant shrub species were identified for each of the plant communities. In the cedar/giant rhododendron community, dominant species included *Vaccinium corymbosum* (common highbush blueberry), *Gaylussacia baccata* (black huckleberry), *Rhododendron maximum* (Giant rhododendron) and *Lyonia ligustrina* (maleberry). In the cedar community dominant species included *K. latifolia*, *Acer rubrum* (red maple), and *Betula alleghaniensis* (yellow birch). In the northern black gum community dominant species included *V. corymbosum* and *G. frondosa*. In the southern black gum community dominant species included *V. corymbosum* and *A. rubrum*. In the red maple community dominant species included *V. corymbosum* and *Kalmia angustifolia* (sheep laurel).

Dominant tree species were identified for each of the plant communities. In the cedar/giant rhododendron community dominant species included *C. thyoides* and *A. rubrum*. In the cedar community dominant species included *C. thyoides*. In the northern black gum community dominant species included *Nyssa sylvatica* (black gum), *A. rubrum*, *Pinus strobus* (Eastern white pine), and *Tsuga Canadensis* (Eastern hemlock). In the southern black gum community dominant species included *N. sylvatica* and *P. strobus*. In the red maple community dominant species included *A. rubrum* and *P.strobus*.

Complete results of vegetation sampling are shown in table 4.

Plant Communities and Water Level

Linear regression analyses were performed for the ground cover and shrub strata to determine if a relationship exists between the WSI and mean water level. The tree stratum was not included in the analyses since basal area was used to determine dominance instead of percent areal cover. Both r^2 values indicate that there is not a strong correlation between the WSI and the mean water level: ground cover $r^2 = 0.0062$, and shrub $r^2 = 0.0737$. The r^2 for the ground cover strata is slightly stronger, but is not statistically significant ($P = 0.002106$). The low r^2 values suggest that there is a great deal of variability in water table preference. It is notable that each vegetative stratum has a different level of correlation with the water table. Many of the shrubs sampled in the study had a lower R1IND Status than much of the ground cover sampled. This is apparent in the linear regression model, as the WSI was not higher at piezometers with higher mean water levels for the shrub stratum. In contrast the WSI was higher at piezometers with a higher mean water level for the ground cover stratum. Therefore, the notion that the wettest plots would have the highest WSI values does not hold true. The weakness of these correlations indicates that as a method, the Routine on-site method, the most widely practiced standardized method for wetland delineation, may be inadequate in yielding a determination of "wetlandness" in terms of vegetation analysis. Linear regression results are shown as figures 8 and 9.

CONCLUSIONS

These wetland basins support a broad vegetative assemblage of species with highly variable water requirements. Species were identified with R1IND Status assignments ranging from Obligate to Facultative Upland. Although, topography was not measured as part of this study, it seems that topography plays a role in enabling such a wide variety of species to colonize these wetlands by providing an elevational gradient (from wet to dry) upon which to colonize.

Lowry's (1984) study showed a wide disparity in water level data between years and among wetland types emphasizing the need for long-term hydrologic monitoring. The monitoring plan set forth in this study and the data collected now serves as the foundation upon which long-term hydrologic and ecological monitoring of the Manchester Cedar Swamp has been based. Continuance of this study is an ongoing effort of The Nature Conservancy. This study will make it possible to observe the long-term effects of development on hydrology and plant community composition and subsequently, strategies can be implemented to minimize adverse effects resulting from future development in the surrounding upland. Maintaining a stable hydrologic regime should be integral to any protection plan if the goal of protecting the cedar community is to succeed.

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Figure 1—Project area map showing plant communities and piezometer locations.

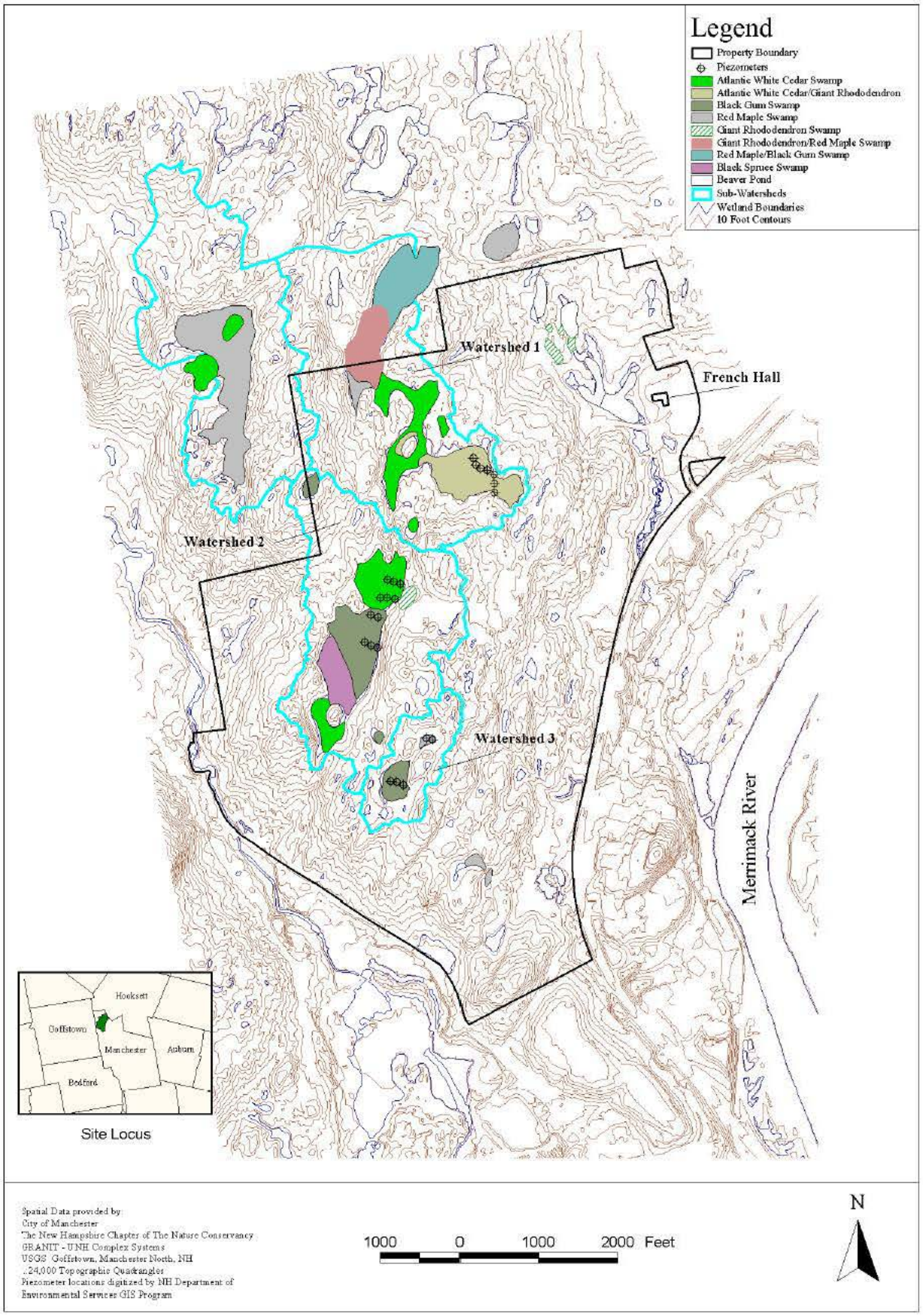

Table 1— P Value Analysis of Mean Water Level between Plant Communities.

Plant Community	AWC/GR	AWC	NBG	SBG	RM
AWC/GR	--	7.85E-14	1.22E-05	0.668	1.33E-11
AWC	7.85E-14	--	4.67E-08	2.47E-09	0.983
NBG	1.22E-05	4.67E-08	--	3.45E-04	3.18E-07
SBG	0.668	2.47E-09	3.45E-04	--	4.79E-11
RM	1.33E-11	0.983	3.18E-07	4.79E-11	--

Table 2—P Value Analysis of Water Table Fluctuation between Plant Communities.

Plant Community	AWC/GR	AWC	NBG	SBG	RM
AWC/GR	--	0.43	0.24	0.55	0.63
AWC	0.43	--	0.84	0.51	0.59
NBG	0.24	0.84	--	0.30	0.38
SBG	0.55	0.51	0.30	--	0.86
RM	0.63	0.59	0.38	0.86	--

Table 3—Summary of Species Richness/Structure for each Plant Community.

Plant Community	Ground Cover	Shrub	Tree	Species Richness /Plant Community
AWC/GR	20	7	11	32
AWC	21	12	6	32
NBG	16	8	9	28
SBG	11	11	4	18
RM	11	4	4	19
Species Richness/Strata	33	21	13	51

Table 4—Results of vegetation sampling for each plant community.

Genus/Species	Common Name	AWC	AWC/GR	RM	NBG	SBG
GROUND COVER						
Chamaecyparis thyoides	Atlantic white cedar	1	--	--	--	--
Nyssa sylvatica	Black gum	2	--	--	--	--
Gaylussacia baccata	Black huckleberry	2	--	--	--	--
Pteridium aquilinum	Bracken fern	4	--	--	--	--
Cornus canadensis	Bunchberry	--	1	--	--	--
Maianthemum canadense	Canada mayflower	--	1	--	--	--
Osmunda cinnamomea	Cinnamon fern	--	1	--	--	--
Ilex verticillata	Common winterberry holly	--	1	--	--	--
Gaultheria hispidula	Creeping snowberry	1	1	--	--	--
Dalibarda repens	Dewdrop	2	1	--	--	--
Vaccinium vacillans	Early low blueberry	2	1	--	--	--
Glyceria striata	Fowl manna grass	1	5	--	--	--
Coptis groenlandica	Goldthread	--	--	1	--	--
Vaccinium angustifolium	Late low blueberry	--	--	--	1	--
Thelypteris simulata	Massachusetts fern	1	--	--	1	--
Kalmia latifolia	Mountain laurel	--	1	--	1	--
Trillium undulatum	Painted trillium	--	1	--	1	--
Aster lanceolatus	Pancled aster	1	1	--	1	--
Acer rubrum	Red maple	2	--	1	1	--
Quercus rubra	Red oak	--	1	1	1	--
Kalmia angustifolia	Sheep laurel	1	1	2	3	--
Symplocarpus foetidus	Skunk cabbage	1	--	--	4	--
Trientalis borealis	Starflower	--	--	--	--	1
Lysimachia terrestris	Swamp candles	1	--	--	--	1
Rubus hispidus	Swamp dewberry	--	1	1	--	1
Carex trisperma	Three seed sedge	1	--	--	1	1
Lycopodium obscurum L.	Tree clubmoss	5	2	1	1	1
Aster acuminatus	Whorled aster	3	1	1	2	1
Uvularia sessifolia	Wild oats	5	2	2	2	1
Aralia nudicaulis	Wild sarsaparilla	--	--	1	--	2
Gaultheria procumbens	Wintergreen	2	5	2	4	2
Betula alleganiensis	Yellow birch	1	2	1	1	3
Clintonia borealis	Yellow clintonia	5	6	--	3	3
SHRUBS						
Nyssa sylvatica	Black gum	--	--	1	--	1
Gaylussacia baccata	Black huckleberry	--	2	--	1	--
Amelanchier canadensis	Canada shadbush serviceberry	--	--	1	--	--
Vaccinium corymbosum	Common highbush blueberry	2	5	2	3	3
Ilex verticillata	Common winterberry holly	1	1	--	2	2
Amelachier arborea	Downy serviceberry	--	--	--	--	1
Vaccinium angustifolium	Early low blueberry	1	--	--	--	1
Rhamnus frangula	European buckthorn	1	--	--	--	--
Rhododendron maximum	Giant rhododendron	--	3	--	--	--
Vaccinium angustifolium	Late low blueberry	1	--	--	1	1
Lyonia ligustrina	Maleberry	--	2	--	--	--
Nemopanthus mucronata	Mountain holly	1	--	--	--	--

Kalmia latifolia	Mountain laurel	1	--	–	–	–
Rhododendron nudiflorum	Pink azalea	–	--	–	1	--
Acer rubrum	Red maple	3	1	–	1	2
Quercus rubra	Red oak	1	--	–	–	1
Kalmia angustifolia	Sheep laurel	1	--	1	–	1
Gaylussacia frondosa	Tall huckleberry	–	--	–	1	--
Pinus strobus	White pine	–	--	–	–	1
Hammamalis virginiana	Witch hazel	1	--	–	–	–
Betula alleganiensis	Yellow birch	2	1	–	1	1
TREES						
Chamaecyparis thyoides	Atlantic white cedar	78	56	–	1	–
Betula lenta	Black birch	–	1	–	–	–
Nyssa sylvatica	Black gum	–	10	–	9	12
Quercus velutina	Black oak	–	1	–	–	–
Picea mariana	Black spruce	–	--	–	5	–
Tsuga canadensis	Eastern hemlock	–	4	–	15	–
Pinus rigida	Pitch pine	2	--	–	–	–
Acer rubrum	Red maple	11	60	17	21	12
Quercus rubra	Red oak	10	5	–	3	–
Betula papyrifera	White birch	–	3	1	–	--
Quercus alba	White oak	–	1	1	4	–
Pinus strobus	White pine	18	7	6	18	11
Betula allegheniensis	Yellow birch	1	2	–	4	3

Figure 2—Hydroperiod for the Atlantic White Cedar/Giant Rhododendron Community by transects A and B.

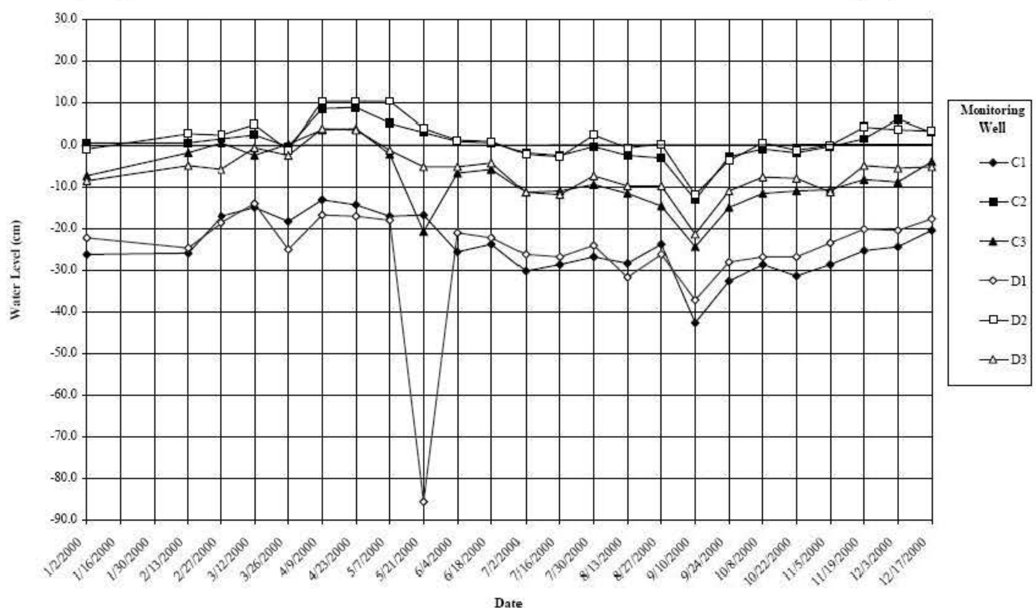

Figure 3—Hydroperiod for the Atlantic White Cedar Community represented by transects C and D.

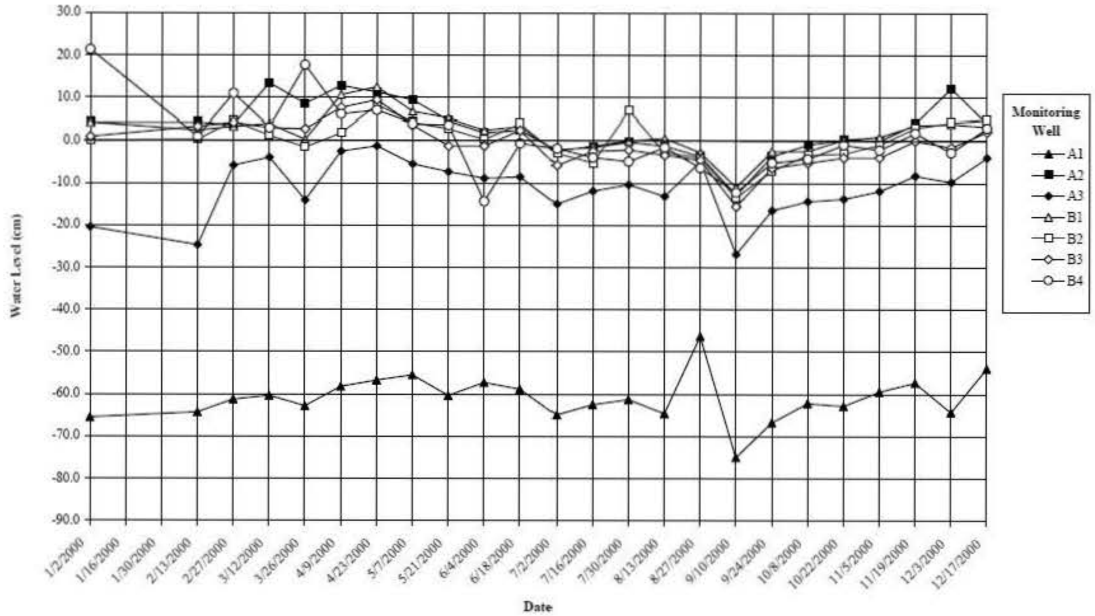

Figure 4—Hydroperiod for the Northern Black Gum Community represented by transects E and F.

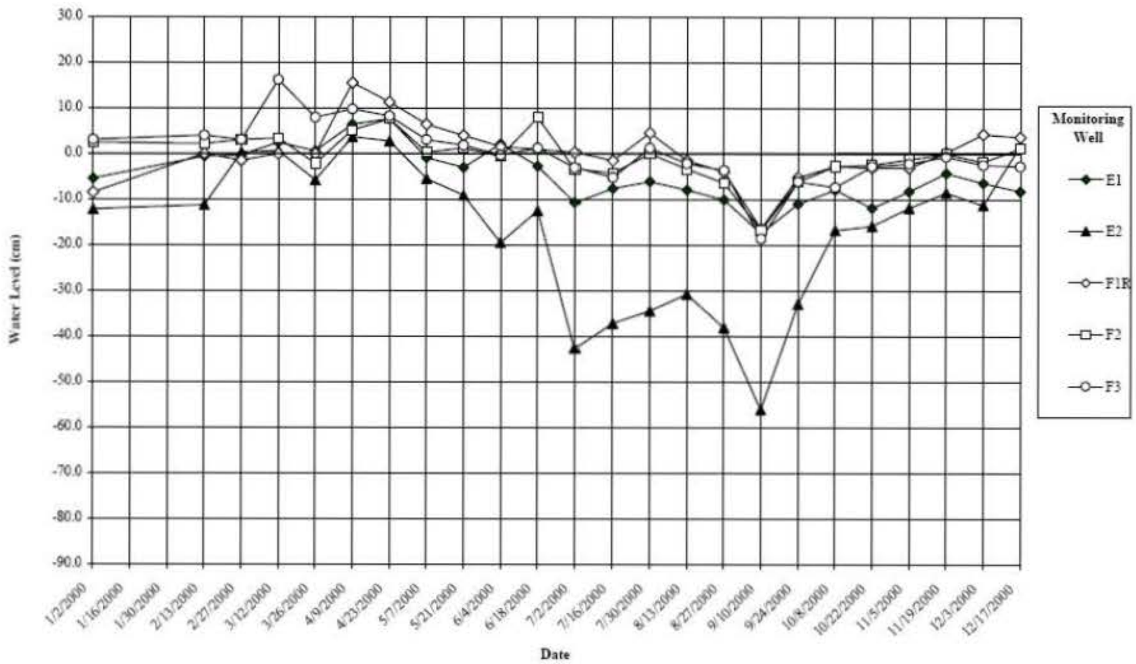

Figure 5— Hydroperiod for the Southern Black Gum Community represented by transect G.

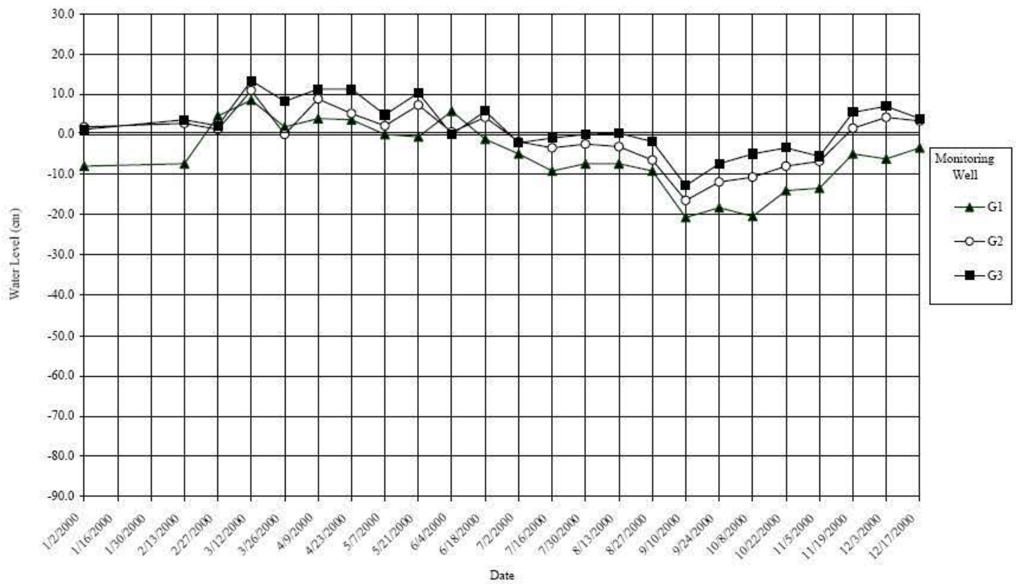

Figure 6— Hydroperiod for the Red Maple Community represented by transect H.

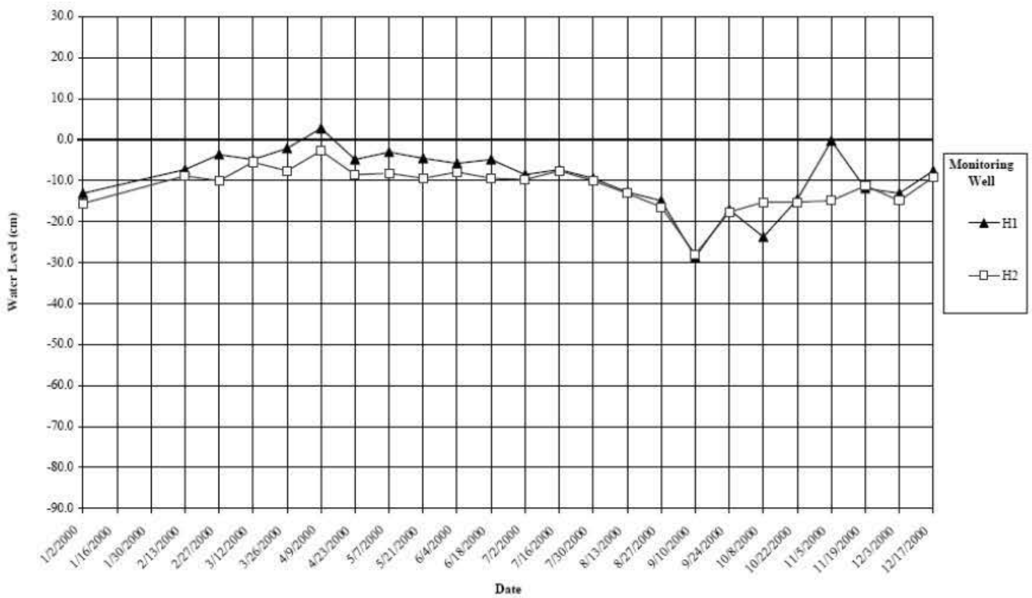

Figure 7—Mean, maximum, and minimum water levels for all piezometers.

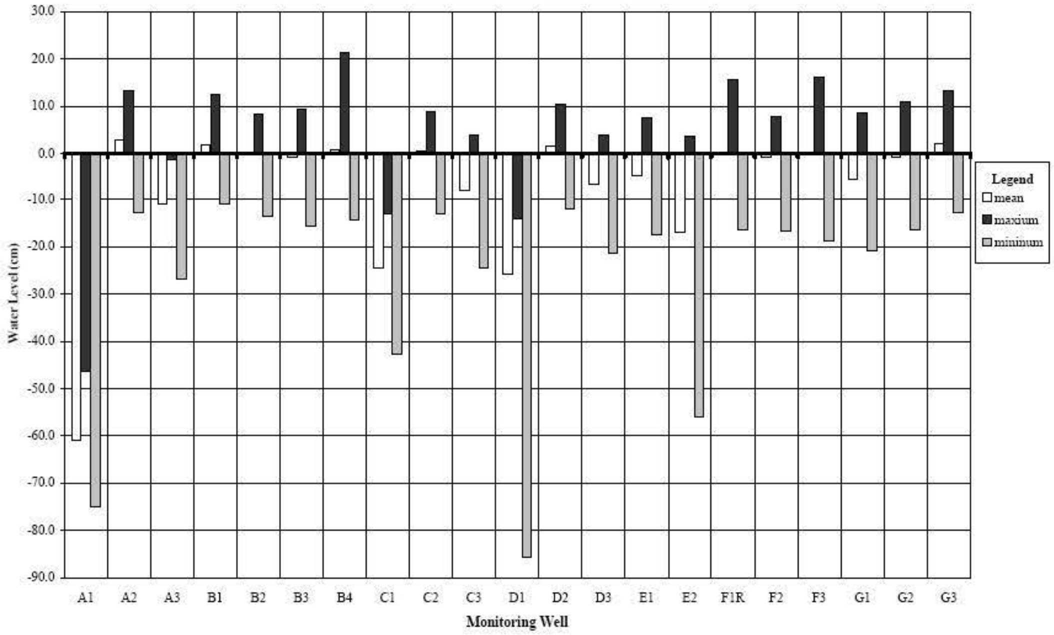

Figure 8—Results of regression analysis for the ground cover stratum.

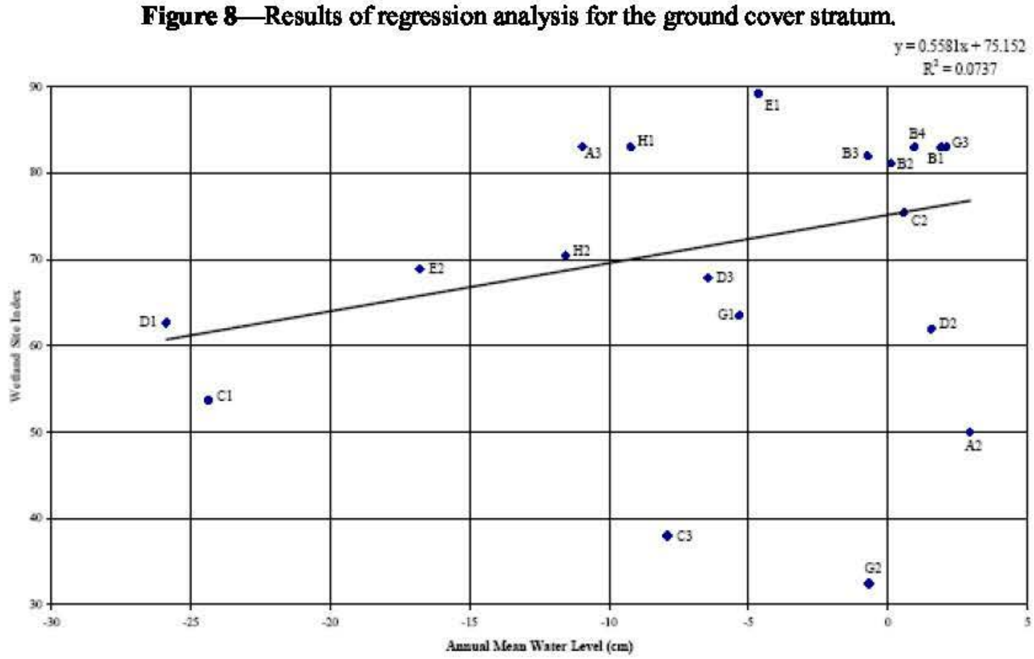

Figure 9—Results of regression analysis for the shrub stratum.