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RELATIONS BETWEEN CERTAIN VEGETATIONAL CHARACTERS AND GROUND WATER LEVEL IN A MIXED HARDWOOD COMMUNITY IN EAST-CENTRAL MINNESOTA

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INTRODUCTION. This report describes the vegetation of a mixed hardwood community in terms of species composition, frequency, areal cover and height classes in relation to ground water level. An attempt is made to show how known changes in ground water level during the past 25 years have brought about changes in the vegetation.

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The period of investigation was from March through October 1960. The site is in Section 6, Township 32 North, Range 22 West in Anoka County, Minnesota on the Anoka Sand Plain, an extensive area of glacial outwash. The area studied includes approximately four acres of oak-aspen woods surrounding a one acre marsh. A road borders the woods on one side and cultivated grassland adjoins the other three sides.

METHODS. *Vegetation Analysis.* A total of 161 stations were established using a 35 foot diagonal grid system. Elevations were determined at each station. Station 1 was given the arbitrary reference datum of 200 cm and all other stations were leveled from that to the nearest 5 cm. The midpoints of these 5 cm contour intervals are referred to in this report, e.g., 155 represents the 152.5—157.4 interval.

Intensive phytosociological investigations were carried out at 83 stations. These included the habitat from the marsh edge almost to the fringe of the upland grasses. The stations which would have included the transition zone between the woods and grassland were not included in this study because this edge has been mowed each year to prevent the spread of the woody species.

The quadrat method as described by Cain and Castro (1959), Oosting (1956) and others was used with modifications to sample the vegetation. Bormann (1953), Clapham (1932), and Greig-Smith (1957) have reported that rectangular shaped quadrats parallel to natural boundaries such as slope are most efficient. However, in this study square quadrats were used for several reasons. Orientation of the plots parallel to the slope would cause difficulties in laying out the quadrats. A square quadrat tends to cross fewer contours than a rectangular one when laid out on straight transects. It was also necessary to revisit the stations many times and the uniform shape and orientation resulted in less damage to the plants present.

The phytosociological analysis incorporated the nested quadrat method recommended by Oosting (1956) for the various strata of a community. Four strata were chosen as follows:

1. Tree Stratum—Woody vegetation over 250 cm. (16 sq. meters)
2. Tall Shrub Stratum—Woody vegetation between 100 and 250 cm. (8 sq. meters)
3. Short Shrub Stratum—Woody vegetation between 30 and 100 cm. (4 sq. meters)
4. Herbaceous Stratum—Woody vegetation shorter than 30 cm. and all other plants not included in the above groups. (2 sq. meters)

Field data were collected in May for the Tree Stratum; June for the two Shrub Strata, and July for the Herbaceous Stratum. Data were collected and recorded separately for each square meter for each of the stratum plots.

The plot size for the Tree Stratum was established at 16 square meters, measured four meters to the west and to the north of the station stake. Individual plant species and their diameters at breast height (DBH) were recorded in the following two categories:

1. Tree species, e.g., oak (*Quercus sp.*) and aspen (*Populus sp.*), were divided into three groups by DBH, namely, 2.5—7.4 cm, 7.5—14.9 cm, and 15.0 cm and over. In the last group each individual over 15.0 cm was separately recorded to the nearest 2.5 cm.
2. Shrubs, e.g., alder (*Alnus sp.*) and dogwood (*Cornus sp.*), which because of height greater than 250 cm fit into the "tree" category as defined for this study, were grouped as follows: less than 2.5 cm, 2.5—7.5 cm and over 7.5 cm.

The tall shrub data were collected on the south half of the tree stratum plot (eight square meters). The shrubs were divided into three groups determined by height. These height groupings were 100-149 cm, 150-199 cm and 200-249 cm.

The Short Shrub data were collected from the SE ¼ of the Tree Stratum plot which constituted a square 2 × 2 meters. These shrubs were also divided into three groups determined by height. These height groupings were 30-49 cm, 50-74 cm and 75-99 cm.

The Herbaceous Stratum data were obtained from the W ½ of the SE ¼ of the Tree Stratum plot which constituted a quadrat 1 × 2 meters with the long axis north and south. The individuals of each species were recorded by height to the nearest 5 cm. Height was measured to the tallest portion of the plant as found in its natural form. Each plant was placed in one of three phenological categories: vegetative only, in flower, or in fruit.

In addition to the above a visual estimate of the areal cover was made for each of the more important species. The merits of using areal cover to represent the importance of a species in a community have been reviewed by Tester and Marshall (1961).

Observations were made on all plots for leaf development, flowering and fruiting for all of the woody vegetation and ferns. Records of water, snow and frost levels were collected from March through October 1960.

DATA ANALYSIS. *Tree Stratum:* Areal cover was chosen as the phytosociological character which would provide the best measure of each plant species with regard to the plant community. Cain and Castro (1959) state that "... total cover does not bear a direct relationship to total leaf and stem areas." However, for this analysis the assumption was made that total basal area of a tree species is linearly related to areal cover. Values were assigned each species in a contour by multiplying the total basal area of the species in the contour by its frequency of occurrence in the contour. Frequency of occurence as used here is the percent of the total number of plots in which the species occurs and as such gives an indication of the species distribution pattern. The resultant figure is called the Importance Value or IV. The IV should not be confused with that used by Curtis and McIntosh (1951). If the sum of the total basal area for all species in a contour is divided into the IV the result can be called the Relative Importance or RI. This RI can be used for cover comparisons between species in the same stratum of other contours.

Shrub and Herbaceous Strata: In the analysis of the Shrub Strata, all woody stems between 30 and 250 cm in height were grouped for the areal cover estimates. On the basis of this grouping areal cover was worked out for each species in each quadrat. This areal cover value was obtained by use of the following conversion table based upon tests in the field.

Separate Importance Values were obtained for most of the species in the Shrub and Herbaceous Strata by means of the areal cover values given each species. This was done by multiplying the areal cover of each species of a contour by its frequency of occurrence

TABLE 1. Percent Areal Cover Based upon Height and Number of Stems on the 2 × 2 Meter Shrub Quadrats.

	Number of Stems				
Height of Stems (Meters)	1	2	3	4	5
.3-1.0	5	7	8	9	10
1.0-1.5	10	15	17	20	22
1.5-2.0	20	30	35	40	45
2.0-2.5	40	60	70	75	80

in the contour. The Relative Importance value for each species of a contour was then determined by totalling the areal cover of the contour and dividing this sum into the IV.

A third term is necessary to permit comparison of a species among the three strata of any contour. This figure, called the Coefficient of Importance (CI), is derived by dividing the IV of a species in a given strata by the sum of the basal areas of all species in the Tree Stratum plus the total areal cover for all species in the Shrub Stratum and the Herbaceous Stratum. The only figures presented in the tables in this report are the % frequency of occurrence, the Relative Importance and the Coefficient of Importance (CI). The CI has been converted to percent to facilitate comparisons.

The Relative Importance and the Coefficient of Importance terms appear to describe the habitat very well based upon subjective field observations.

RESULTS. *Tree Species:* It appeared from field observations that the tree species were closely linked to contour or ground water level. The tree species most common and closely related to these factors were the trembling aspen (*Populus tremuloides*) and the northern pin oak (*Quercus ellipsoidalis*). The variation in elevation from the lowest to the highest contour of the intensively studied stations was only 110 cm. The most striking change in the species composition of these two trees occurs between the 155 and 160 cm contours (Tables 2—4). The 59 stations below the 155 cm contour contain 97 percent of the CI values for aspen in the Tree Strata. The 25 stations above 160 cm contain 96 percent of the CI values for northern pin oak in the Tree Strata.

At the point of delimitation aspen makes up 83% of the total CI for tree species at the 155 cm contour and only 4% at the 160 cm contour. In like manner the pin oak makes up only 15% of the total CI for tree species at the 155 cm contour and 95% at the 160 cm contour. In the remainder of this paper these two topographic areas will be referred to as the Aspen Contours (120—155 cm) and the Oak Contours (160-230 cm). 59 of the study plots were located in the Aspen Contours and 25 were in the Oak Contours.

Aspen is found throughout the Shrub and Herbaceous Strata at most of the contours. In the Shrub Strata aspen was found in a 6:1 CI ratio favoring the 155 cm and lower contours. Aspen were not found in large enough numbers in the Herbaceous Stratum (30 cm or less) to warrant CI or RI evaluations. Based upon frequency of occurrence in the Herbaceous Stratum aspen was found in almost every contour and averaged 20% frequency.

Prunus and *Quercus* species were not common in the Shrub Strata. In the Herbaceous Stratum seedlings and sprouts of these genera did not show a frequency of occurrence as high as aspen but were concentrated to a much greater degree above the 155 cm contour. *Prunus* species had a 1:4 frequency ratio favoring the Oak Contours. *Quercus* species had approximately a 1:3 frequency ratio favoring the Oak Contours.

TABLE 2. Frequency, Relative Importance and Coefficient of Importance of Species in the Aspen and Oak Contours of the Tree Strata.

	Aspen Contours			Oak Contours		
Species	Frequency	RI	CI	Frequency	RI	CI
Acer rubrum	3	1.0	0.1			
Betula papyrifera	8	1.6	0.2	12	0.7	0.2
Populus tremuloides	59	201.2	25.1	16	2.9	0.7
Prunus pennsylvanica	2	T	T	4	T	T
Prunus serotina	2	0.2	T	4	T	T
Prunus virginiana				8	3.3	0.8
Quercus alba				20	4.2	1.1
Quercus ellipsoidalis	14	10.8	1.3	76	140.2	35.7
Alnus rugosa	46	37.8	4.7	8	1.6	0.4
Amelanchier interior				4	T	T
Cornus racemosa	7	0.4	T	4	T	T
Cornus stolonifera	14	0.2	T			
Corylus americana	10	0.7	0.1	8	0.6	0.2
Ilex verticillata	8	0.4	T			
Salix spp.	12	1.6	0.2			
Total		256.2	31.9		157.7	40.2

TABLE 3. Frequency, Relative Importance and Coefficient of Importance of Species in the Aspen and Oak Contours of the Shrub Strata.

	Aspen Contours			Oak Contours		
Species	Frequency	RI	CI	Frequency	RI	CI
Populus tremuloides	29	21.3	2.7	8	1.6	0.4
Prunus sp.				4	0.5	0.1
Quercus alba				4	0.2	T
Quercus ellipsoidalis	2	0.5	0.1			
Salix amygdaloides	2	0.8	0.1			
Alnus rugosa	22	26.2	3.3			
Cornus racemosa	22	15.9	2.0	28	11.2	2.9
Cornus stolonifera	20	31.4	3.9			
Corylus americana	15	40.0	5.0	24	4.7	1.2
Ilex verticillata	8	7.8	1.0			
Salix discolor	2	0.2	T			
Viburnum lentago				4	0.4	0.1
Parthenocissus inserta				4	0.2	T
Total		144.0	17.9		17.7	4.5

TABLE 4. Frequency, Relative Importance and Coefficient of Importance of Species in the Aspen and Oak Contours of the Herbaceous Strata.

Species	Aspen Contours			Oak Contours		
	Frequency	RI	CI	Frequency	RI	CI
Trees and Shrubs						
Acer rubrum	5			20	0.2	0.1
Alnus rugosa	12	0.3	T	0		
Cornus racemosa	25	1.4	0.2	12		
Cornus stolonifera	10	T	T	4		
Corylus americana	31	10.7	1.3	52	3.5	0.9
Ilex verticillata	10	0.2	T			
Populus tremuloides	20	T	T	20		
Prunus sp.	10			40	0.2	0.1
Quercus sp.	9			24	0.4	0.1
Ferns						
Dryopteris spinulosa	10	5.6	0.7	4		
Dryopteris thelypteris	10	0.2	T			
Onoclea sensibilis	14	9.0	1.1	4		
Osmunda cinnamonea	15	7.5	0.9	8	1.3	0.3
Osmunda claytoniana	32	95.6	11.9	56	98.9	25.2
Osmunda regalis	7	3.5	0.4			
Pteridium aquilinum	15	7.5	0.9	52	9.0	2.3
Grasses and Sedges						
Calamagrostis canadensis	54	67.2	8.4	12	T	T
Carex blanda	3	2.3	0.3	4	T	T
Carex crawfordii	7	0.8	0.1			
Carex debilis	3	T	T			
Carex gracillima	12	T	T			
Carex haydenii	20	23.5	2.9	4	0.7	0.2
Carex intumescens	5	0.2	T			
Carex pennsylvanica	25	3.0	0.4	72	22.9	5.8
Carex projecta	20	7.5	0.9			
Carex tenera	7	0.2	T	4		
Poa palustris	24	6.0	0.1	20	0.2	0.1
Poa pratensis				4	T	T
Herbaceous						
Amphicarpa bracteata	17			32	0.6	0.2
Anemone quinquefolia	2	T	T			
Asclepias incarnata	5	T	T			
Aralia nudicaulis	8	1.4	0.2	40	4.0	1.0
Aster macrophyllus	31	17.7	2.2	96	36.5	9.3
Aster sp.	53	0.7	0.1	12	T	T
Cicuta maculata	14	1.0	0.1			
Clintonia borealis	5	T	T	8	0.2	0.1
Diervilla lonicerca	12	1.0	0.1	32	2.7	0.7
Equisetum sylvaticum	27	2.2	0.3			
Fragaria virginiana	39	0.4	T	16	T	T
Galium boreale	8	T	T	8		
Galeopsis tetrahit	5	0.8	0.1			
Heleanthus sp.				4	T	T
Lycopus uniflorus	14	0.3	T			
Lysimachia ciliata	5	T	T			
Lysimachia terrestris	12	0.3	T			
Maianthemum canadense	44	T	T	52	0.3	0.1
Parthinocissus inserta	49	4.4	0.5	44	4.9	1.3
Rhus radicans	17	0.9	0.1	12	0.4	0.1
Rubus acridens	5			16	0.6	0.2
Rubus flagellaris	31	3.1	0.4	24	0.7	0.2
Rubus pubescens	54	44.3	5.5	8		
Veronicastrum virginicum	2			12	T	T
Viola incognita	32	1.1	0.1	12		
Misc.		72.9	9.1		29.1	7.4
Total		402.8	50.2		217.3	55.3

Shrub Species: Data for all shrubs are presented as parts of Tables 2-4. Alder (*Alnus rugosa*) appears to be the most important shrub in the study area at the present time but the phytosociological data indicate that a regression is impending. Alder is next in importance to aspen in the Aspen Contours in the Tree Stratum. In the Shrub Stratum it is restricted to the Aspen Contours where it places third in importance. The alder which was recorded in the Herbaceous Stratum is again restricted to the lower contours but is found at only 12% of these stations.

Hazel (*Corylus americana*) was recorded at several of the contour groupings in the Tree Stratum but did not reach a high degree of importance. In the Shrub Strata hazel attained its highest concentration at the 145-155 cm contours. This species does not occur in the three lowest contours except in the Herbaceous Stratum where it was represented in all but the lowest contour. In the Herbaceous Stratum 31% of the stations below the 155 cm contour contained the species.

Red Osier dogwood (*Cornus stolonifera*) is restricted to the 155 cm or lower contours. In the Shrub Strata over 93% of the total CI of this species occurs in the lower three contours (120-130 cm).

Panicled dogwood (*Cornus racemosa*) is very widespread in this area. It seems to be a species which does not conform to either of the habitat groupings of the study. This shrub is not important in the Tree Stratum but is second in importance in the shrub level. Approximately 56% of the frequency of this species occurs in the Oak Contours in the Shrub Strata. At the Herbaceous Strata the trend is reversed with 25% of the stations below the 155 cm contour containing the species while only 12% of the stations above the 160 cm contour contain it.

The willows (*Salix spp.*) all occur below the 135 cm contour level in all strata. Virginia winterberry (*Ilex verticillata*) occurs only in the 135 cm to 155 cm contours in the Tree and Shrub Strata and in the 130 cm level in the Herbaceous Stratum.

Herbaceous Species: The CI values for the Herbaceous Stratum (Table 4) are important in the areal cover description, but due to the large number of species at each station the occurrence of a plant may not have been high enough to warrant an areal cover figure. The herbaceous species seem to have a wide range of contours in which they occur but in many cases they do not seem to exhibit their potential importance. It is only when the opportunity presents itself in the form of space or light conditions at the optimum time that a single species can show its potential. For these reasons the percent frequency of occurrence is used as a means of comparison in addition to the available CI and RI figures. A percent frequency figure was computed only for those species which were found at three or more stations. A complete list of all species identified and recorded at the stations is presented in Table 5.

Ferns. Seven species of ferns were recorded at the stations studied. Interrupted fern (*Osmunda claytoniana*) had a CI of 12 in the herbaceous cover in the Aspen Contours and 25 in the Oak Contours. The frequency of occurrence was 32% and 56% for the same contour groupings. Braken fern (*Pteridium aquilinum*) had a CI of 1 in the herbaceous cover in the Aspen Contours and 2 in the Oak Contours. In this case the frequency of occurrence for these two contour groupings was 15% and 52% respectively.

The remaining five species of ferns are represented primarily in the Aspen Contours. Two of the species, *Osmunda regalis* and *Dryopteris thelypteris*, are semi-aquatics as indicated by their occurrence only below the 135 cm. contour.

Grasses and Sedges. Bluejoint (*Calamagrostis canadensis*) is the most important grass in the community. It has a CI of 8 in the Aspen Contours and only a trace in the Oak Contours. This importance is reflected by a 54% frequency of occurrence in the Aspen Contours and only 12% above the 155 cm. contour. The hydrophytic tendencies of this grass are amply demonstrated by the high CI values of 37, 8 and 19 recorded for the lowest three contours. The only other grass present in any large amounts is the bluegrass, *Poa palustris*, another semi-acquatic restricted to the lower contours.

Seven species of sedges were noted at the stations surveyed *Carex haydenii*, a semi- aquatic form, and *Carex pennsylvanica*, an upland form, were the two most important. The CI of *Carex haydenii* for the Aspen and Oak Contours was 2.9 and 0.2 respectively. This species is represented by 20% frequency at stations below the 160 cm. contour and by only 4% above the 160 cm. contour. *Carex pennsylvanica* has a CI figure of 0.4 and 5.8 for the Aspen and Oak Contours, respectively. The frequency of occurrence of this sedge is 25% in the Aspen and 72% in the Oak Contours. The remaining species of *Carex* are restricted primarily to the Aspen Contours.

Forbs. Of the large number of species which occur in this last group, only three are present in large enough concentrations to be rated for RI and CI and with a CI of 1% or higher. These species are woodbine (*Parthenocissus inserta*), large-leaved aster (*Aster macrophyllus*) and blackberry (*Rubus pubescens*). The CI and the percent frequency of occurrence for these three species are shown by contour groupings in Table 4.

DISCUSSION. It seems apparent from the data in Tables 2–4 that two distinct zones of differentiation are present. The most obvious change occurs between the 155-160 cm. contours. A less obvious zone of change, not revealed by the tables, was noted between the 130-135 cm. contours.

A review of the history of land use of the area reveals some of the basis for this differentiation. Prior to 1935 the pond within the study area was maintained at a height of about 140-150 cm. (based upon the estimated age of most of the *Quercus ellipsoidalis*. At this time the road bed was built up and the pond drained. In the fall of 1936 the woven wire fence was erected. The process of building the fence involved the construction of a dike across the pond. A ten inch tile

TABLE 5. Species Identified within Study Area.

Acer rubrum
Alnus rugosa
Amelanchier interior
Amphicarpa bracteata
Anemone quinquifolia
Apocynum androsaemifolium
Aquilegia canadensis
Aralia nudicaulis
Asclepias incarnata
Aster lateriflorus
Aster macrophyllus
Aster simplex
Aster sp.
Aster umbellatus

Betula papyrifera
Brachyelytrum erectrum

Calamagrostis canadensis
Carex blanda
Carex crawfordii
Carex debilis var. rudgei
Carex gracillima
Carex haydenii
Carex intumescens
Carex lacustris
Carex pennsylvanica
Carex projecta
Carex sp.
Carex tenera
Cicuta maculata
Cirsium sp.
Clintonia borealis
Cornus racemosa
Cornus stolonifera
Corylus americana
Cyperus strigosus

Diervilla lonicerca
Dryopteris spinulosa
Dryopteris thelypteris

Epilchium glandulosum var. adenocaulon
Equisetum sylvaticum
Eupatorium perfoliatum

Fragaria virginiana

Galeopsis tetrahit
Galium boreale
Galium tinctorium

Helianthus giganteus
Helianthus hirsutus

Ilex verticillata

Lycopus uniflorus
Lysimachia ciliata
Lysimachia terrestris

Maianthemum canadense
Monarda fistulosa var. mollis

Oenothera parviflora
Onoclea sensibilis
Osmunda cinnamonea
Osmunda claytoniana
Osmunda regalis var. spectabilis
Osmunda sensibilis

Panicum oligosanthes var. scribnerianum
Parthenocissus inserta
Poa palustris
Poa pratensis
Polygonum hydropiper
Polygonum sagittatum
Populus tremuloides
Potentilla simplex
Prenanthes alba
Prunus pennsylvanica
Prunus serotina
Prunus virginiana
Pteridium aquilinum

Quercus alba
Quercus borealis var. rubra
Quercus ellipsoidalis

Rhus radicans
Rubus acridens
Rubus flagellaris
Rubus minnesotainus
Rubus multifer
Rubus pubescens
Rumex orbiculatus

Salix amygdaloides
Salix bebbiana
Salix discolor
Scirpus atrovirens
Scutellaria epilobiifolia
Smilacina stellata
Solidago altissima
Solidago canadensis
Spirea alba
Stachys palustris
Stellaria longifolia

Taraxacum officinale
Trientalis borealis
Trillium cernum

Vaccinium angustifolium
Verbena hastata
Veronicastrum virginicum
Viburnum lentago
Virburnum trilobum
Viola incognita
Vitis riparia

was inserted in the dike which effectively drained the pond to the 115 cm. level. In the next few years the pond became established at the 120 cm. level because vegetation partially plugged the tile. In 1957 the tile was plugged so the dike acted as a dam with an overflow at 155 cm.

Run-off and spring rains usually maintain the water level between 120-130 cm. until July. At this time precipitation decreases and the water level then drops quite rapidly. The area usually is dry by the middle of August. Fall rains then normally raise the level to at least the 110-120 cm. level prior to freezeup.

Aspens have not been able to compete with the much older oak trees in the area studied although the presence of root suckers in most contours demonstrates the pioneering potential of aspen. The distribution of aspen rapidly expanded to fill the available habitat when the water was drained from the pond in 1935.

The effects of the reflooding in 1957 are revealed by a large number of dead aspen in the lower contours (Table 6). Aspen dead due to crowding and wind damage were also recorded in other contours but the number of dead standing trees was much higher at the lowest contours.

TABLE 6. Percent of Dead Standing Aspen in the Tree Stratum Contours.

Contour	120	125	130	135	140	145	150	155
% Dead	23	33	3	20	14	0	0	0

The dead trees in the 135 and 140 contours were of the smaller size classes suggesting overcrowding. The low number of dead aspen in the contours above 130 cm. indicates that prolonged flooding is not common above this point.

The presence of relatively large amounts of bluejoint, Hayden's sedge, red osier dogwood and willow below the 135 cm. contour further attests to the prevailing hydric conditions. Virginia winterberry, hazel, woodbine and other moist-mesic species are found almost entirely above the 130 cm. contour. A careful review of most of the data on tree and shrub species, as well as many of the herbaceous species, reveals a definite difference in distribution and abundance between the 130-135 cm. and/or between the 155-160 cm. contours. A larger sample would probably sharpen the points of transition and might possibly reveal additional zones of change.

It is interesting to note that the points of vegetational change are so sharply defined and so easily demonstrable in relation to such small microtopographic differences in a sample of this size and with the chance of contour error being relatively large. This latter error exists because the contour was read at the corner of the plot and the data were collected from within the 16 square meters. In some plots this could raise or lower the reading on parts of the plot by one or more contour intervals due to the slope within the sample area.

SUMMARY. A forest community has been described in numerical terms by means of the natural relationships which exist between species composition, areal cover, frequency and ground water level. Measurements were taken separately in the three recognized strata, namely the tree stratum, shrub stratum and herbaceous stratum. Two terms used in the vegetation analysis are developed and described. The first term, Relative Importance Value or RI, is best used for comparisons of plant species within a stratum between contours. The second term, Coefficient of Importance or CI, is best used for comparisons of plant species between strata in a given contour. Based upon subjective field observations the habitat appears to be adequately described by means of these two terms.

The ground water level was shown to be a very important factor in the distribution and abundance of many plant species in spite of the fact that the variation in elevation from the lowest to the highest contour of the stations studied was only 110 cm. A review of the past history of the study area is presented as an aid in interpreting the relationships of certain plant species to the ground water level changes as revealed by the phytosociological analysis.

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