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PLATTE RIVER EVAPOTRANSPIRATION: A HISTORICAL PERSPECTIVE IN CENTRAL NEBRASKA*

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A computational model was developed to estimate evapotranspiration (ET) in the Platte River ecosystem of central Nebraska. Data used in the model were mostly derived from the literature, although leaf-temperature data were collected to estimate species transpiration-coefficients.

Preliminary estimates for ET are 35.5 in per yr during the April-to-October growing season. Riparian forest accounted for 30% of the total ET, followed in order of importance by open-water evaporation, forested islands, herbaceous riparian-transpiration, sandbar evaporation, and then herbaceous island-vegetation, which accounted for only 10% of the total ET.

The Platte River has changed markedly during the last 40 years, with reduced flows and narrowed channel-width. Much riparian forest has grown up in that time and vegetated islands occupy a greater percentage of the remaining channel than previously. A comparison of ET rates between the 1930s and 1970s was attempted, using the computational model developed. Total ET rates in the 1930s were about the same as today (37.3 in per yr) but proportion by habitat differed greatly, with open-water evaporation probably accounting for about one-half the total ET then.

The total loss due to evapotranspiration between Kingsley Dam and Duncan, Nebraska, from Platte River ecosystems (except for wet-meadow and cropland) was estimated to be 379,000 acre-feet per year.

† † †

INTRODUCTION

The Platte River in the Big Bend region of Nebraska has changed dramatically in recent history. Changes in the Platte have recently been summarized by Williams (1978).

Present flows at Overton are only about 31% of pristine flows (1976, Unpublished United States Fish and Wildlife Service data, Division of Ecological Survey, Grand Island, Nebraska). This reduced flow has caused channel width to be reduced to 60% to 70% of its 1865 width in the Overton-to-Grand Island reach (Williams, 1978). The areas that were previously channel have become vegetated islands, many of which have become incorporated into the bank. Figure 1 illustrates river change from 1938 to 1969.

The effect of the shift from open-water-sandbar habitat to vegetated islands and riparian habitat upon evapotranspiration (ET) rates has not been studied in the Platte River ecosystem. Dirmeyer (1975) estimated the loss of water by evapotranspiration from Platte River vegetation in Nebraska. He stated:

> Another major river depletion effect that cannot be ignored relates to the heavy (mile-to-two-mile wide) band of trees and brush that has grown up in the river bottom during the past 30 to 40 years. On an annual basis, an acre of heavy cottonwood or willow growth will use water sufficient to irrigate about three acres of corn.
>
> Assuming that the new growth of trees and bushes in the Platte River channel between Kingsley Dam and Duncan in the past 34 years (since completion of Kingsley Dam) is a strip one mile wide and 240 miles long (about 153,600 acres) and that the resultant annual ET rate is assumed to be 72 inches (or 6 feet) per year, then it can be estimated that the increase loss of water is about 921,600 acre feet per year. Assuming that an acre of corn requires about 2 acre feet per year, then it can be seen that the water used annually by this strip of new river bottom vegetation could irrigate about 460,000 acres of corn. Assuming that the 921,600 acre feet is used in a 6-month period between April 1st and October 1st, this works out to about 5120 acre feet per day or a flow of about 2560 cubic feet per second (c.f.s.). The Tri-County Supply Canal has a capacity of about 2200 c.f.s.
>
> The numbers used above are approximate but, in any case, the above estimates put rough dimensions on the problem. Obviously, more accurate numbers should be developed to back-up future water (and fish and wildlife) decisions in Nebraska.

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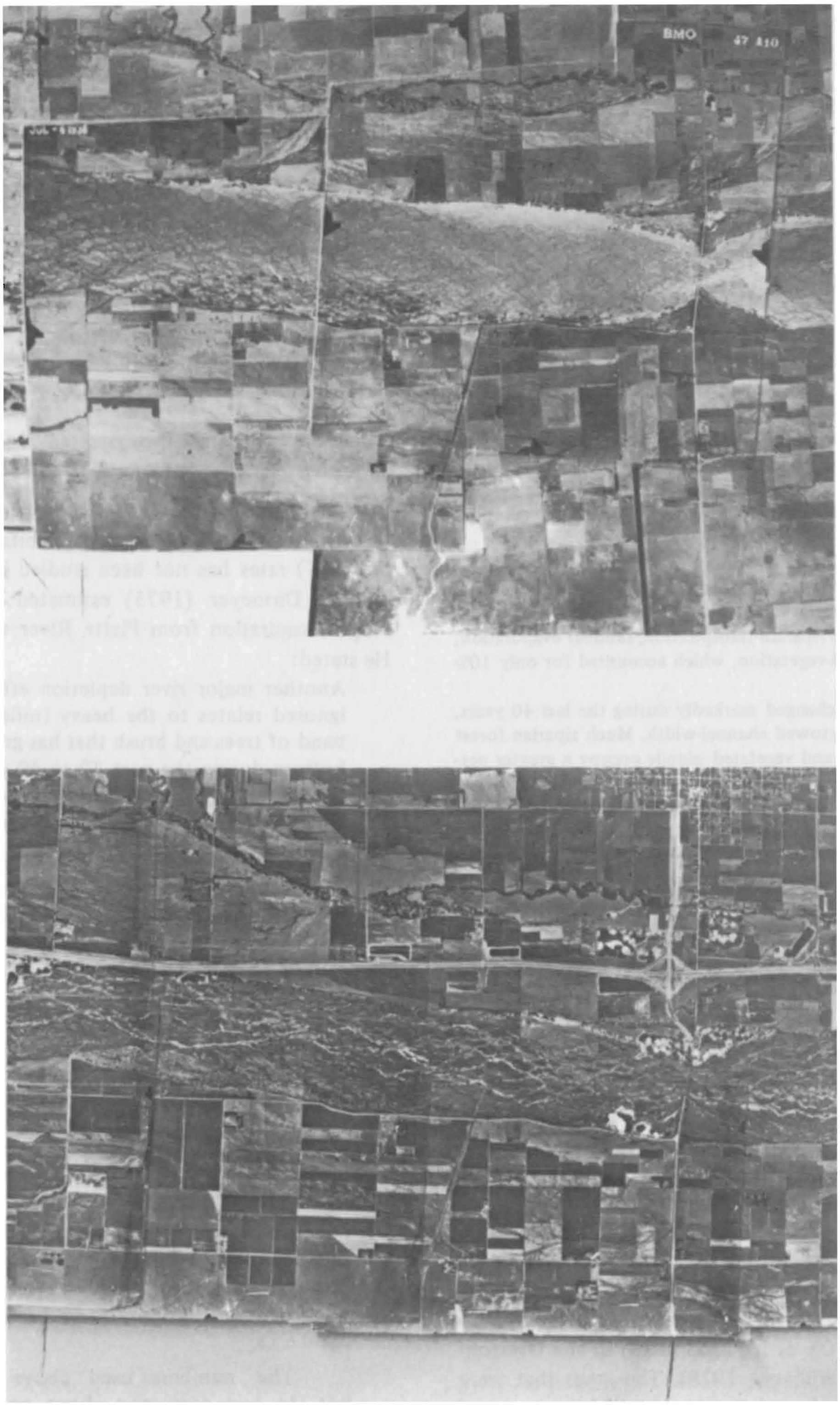

FIGURE 1. Aerial photographs of the Platte River near Kearney, Nebraska, showing change from open-channel in 1938 (above) to braided-channel interspersed with vegetated islands in 1969 (below). Photographs cover about 5 mi of river.

Using the Dirmeyer (1975) evapotranspiration estimates at $10 per acre-foot, the vegetation along the Platte from Kingsley Dam to Duncan would be consuming more than 9 million dollars worth of water per year.

This paper is an attempt to identify areas needing further research, to set up a research model, and to make some preliminary estimates of ET rates in the Big Bend region of the Platte River from Lexington to Grand Island, Nebraska. Only limited field work was done, the methods and data for computations coming primarily from published values. For this reason, units of measure are not metric. The evapotranspiration literature is full of contradictions and controversies, so some interpretation was necessary. The comparisons to be made in this paper are for the period 1938 to 1978. These dates were chosen because of availability of aerial photographs and because 1938 just preceded closing of Kingsley Dam (Lake McConaughy).

METHODS AND DATA SOURCES

Evapotranspiration Rates

The computational flow-chart used to calculate actual ET is given in Table I. Several computational methods based upon meteorological conditions were used to estimate ET, but a modified Blaney-Criddle equation (Blaney and Criddle, 1962; line 3, Table I) produced results which most closely approximated lake evaporation, as estimated in the *Climatic Atlas of the United States* (Anonymous, 1968). Lake evaporation (1946-1955) was about 50 in per yr for the study area and the Blaney-Criddle method estimated 53 in when used with Kearney air temperatures for the period 1940-1969 and percentage of annual sunshine per month, P, from McGuiness (1972). Although some evaporation occurs throughout the year, at least 80% occurs during the April-to-October growing season used in computations.

TABLE I. Platte River evapotranspiration-calculation flow-chart.*

Line		Operation			Comment
1		START			
		↓			
2		READ T_i, P_i			
		↓			
3		CALCULATE: $E_{P_i} = (T_i)(P_i) / 100$			Monthly, Apr.-Oct.
		↓			
4		LIST: Habitat types present in study area.			
		↓			
5		READ: Proportion in habitat types;			From Figure 2
		A_C	A_I	A_R	
		↓	↓	↓	
6	GO TO:	Subprogram 1, Line 7	Subprogram 2, Line 12	Subprogram 3, Line 23	
		↓			
7		READ: Q_i			Mean cfs., Apr.-Oct.
		↓			
8		READ: OW_{P_i}			Figure 4, Apr.-Oct.
		↓			
9		CALCULATE: $A_{OW_i} = OW_{P_i} (A_C)$			
		↓			
10		CALCULATE: $A_{B_i} = (A_C - A_{OW_i}) + (A_{I_B}) (A_I)$			A_{I_B} from Table II
		↓			
11		READ: K_{B_i}			Figure 6, Apr.-Oct.
		↓			
12		SUBPROGRAM 2			Begin with island forest
		↓			

TABLE I. (Continued)

Line	Operation	Comment
13	READ: SC_i ↓	Table III
14	READ: K_i ↓	Table IV
15	CALCULATE: $\sum_{i=l}^{n} (K_i)(SC_i) = K_1$ ↓	N = number of species
16	READ: WL_i ↓	Figure 3, Apr.-Oct.
17	READ: HE ↓	Figure 10
18	CALCULATE: $DW_i = HE - WL_i$ ↓	
19	READ: K_{2_i} ↓	Figure 9, Apr.-Oct.
20	READ: K_3 ↓	Figure 11, no data available; estimated .70 FC for forest, .50 herbaceous
21	CALCULATE: $(K_1)(K_{2_i})(K_3) = K_i$ ↓	
22	REPEAT: Lines 13-22 for herbaceous species ↓	
23	SUBPROGRAM 3 ↓	
24	REPEAT: Lines 13-22 for riparian habitat, woody and herbaceous ↓	
25	READ: A_{R_B} ↓	Table II
26	READ: DW_{i_R} ↓	Line 18, assume HE = 3 ft
27	READ: K_{R_B} for DW_i ↓	Figure 5
28	CALCULATE: $U = \sum_{i=l}^{7} [(RCF) (\sum_{i=l}^{n} (A_{OW_i}) (E_{P_i})) + \sum_{i=l}^{n} (K_{B_i}) (A_{B_i}) (E_{P_i}) + (\sum_{i=l}^{n} (E_{P_i}) (K_{I_{W_i}})) (A_I) (A_{I_F}) + (\sum_{i=l}^{n} (E_{P_i}) (K_{I_{H_i}})) (A_I) (A_{I_H}) + (\sum_{i=l}^{n} (E_{P_i}) (K_{R_{W_i}})) (A_R) (A_{R_F}) + (\sum_{i=l}^{n} (E_{P_i}) (K_{R_{H_i}})) (A_R) (A_{R_H}) + (\sum_{i=l}^{n} (E_{P_i})) (K_{B_R}) (A_R) (A_{R_B})] / 12$	

*Symbol	Definition
A	Proportion of total area in a habitat type. Total area is that part of the historic river channel and flood plain covered by open water (A_C); sandbars and vegetated islands (A_I); and riparian forest (A_R) on 1938 aerial photographs. Areas in 1969 and 1977 were also determined from aerial photographs from one date.
B	Barren (or unvegetated) sandbars or riparian habitat.

*Symbol	Definition
BE	Baseline elevation. The relative elevation of the deepest channel at Overton on May 17, 1978.
C	Channel habitat, including open-water and barren sandbars.
DW	Depth of saturated water-table below soil surface.
Ep	Potential lake evaporation rate (in per yr).
F	Forested habitat, including open-woodland types.
FC	Foliage-cover, that is the proportion of the soil-surface covered with foliage in a vertical plane from soil to top of canopy. (Note: FC_T is total foliage-cover for all species.)
H	Herbaceous plant-cover dominating the habitat, including grasses, sedges, forbs, low shrubs, and other low-growing vegetation.
HE	Height of habitat above baseline channel elevation.
I	Vegetated island-habitat, having water flowing around all sides at average discharges in most years.
K_i	Empirical species-specific consumptive use coefficient.
OW	Area of open-water.
OW_P	Proportion of distance across the channel covered with water at any discharge.
Q	Discharge (cfs) at Overton, Nebraska, gauging station.
Phreatophyte	Plants that tap ground water and habitually depend on this subsurface water-supply.
P_i	Monthly percentage of total daytime hours.
R	Riparian habitat.
RCF	River correction factor (= 1.075), which corrects from lake evaporation-rates.
SC	Species-composition in a habitat. Proportion based upon foliage-cover contributed by each species to the total. (Note: only species contributing more than .05 of foliage cover included.)
T_i	Mean monthly air temperature (F).
U	Total evapotranspiration (ft per yr).
W	Ligneous vegetation, including trees and taller shrubs.
WL	Water-level height (ft) above baseline elevation (BE) of channel.

The approach used to determine ET rates was modified from that of Rantz (1968). The review bibliography by Horton (1973) provided a guide to the literature.

Study Area

The area studied was defined as that covered on the 1938 aerial photographs by open-water, sandbar and wooded islands, and riparian habitat. Riparian wet-meadows and cropland were excluded from the study.

Acreages in the three habitats (Table I, line 5; Fig. 2) were obtained from the Fish and Wildlife Service in Grand Island, Nebraska (1976, unpublished data from Platte River National Wildlife Study, Division of Ecological Services) and Econ Incorporated (Anonymous, 1977). These data (Fig. 2) were obtained by use of a planimeter on 1938 and 1969 black-and-white aerial photographs and false-color infrared color photographs taken in 1976. Transect numbers 10–19 (6 mi E. of Lexington to Grand Island) were used for the 1938 and 1969 data. Transects were 2 mi wide and 6 mi apart. The 1976 data were based on the entire reach of the river from Overton to Chapman.

The proportion of area covered by woody or herbaceous vegetation and barren area within each habitat given on Figure 2 was determined by doing 800 randomly selected point-samples on 1938 and 1977 aerial photographs (Table II).

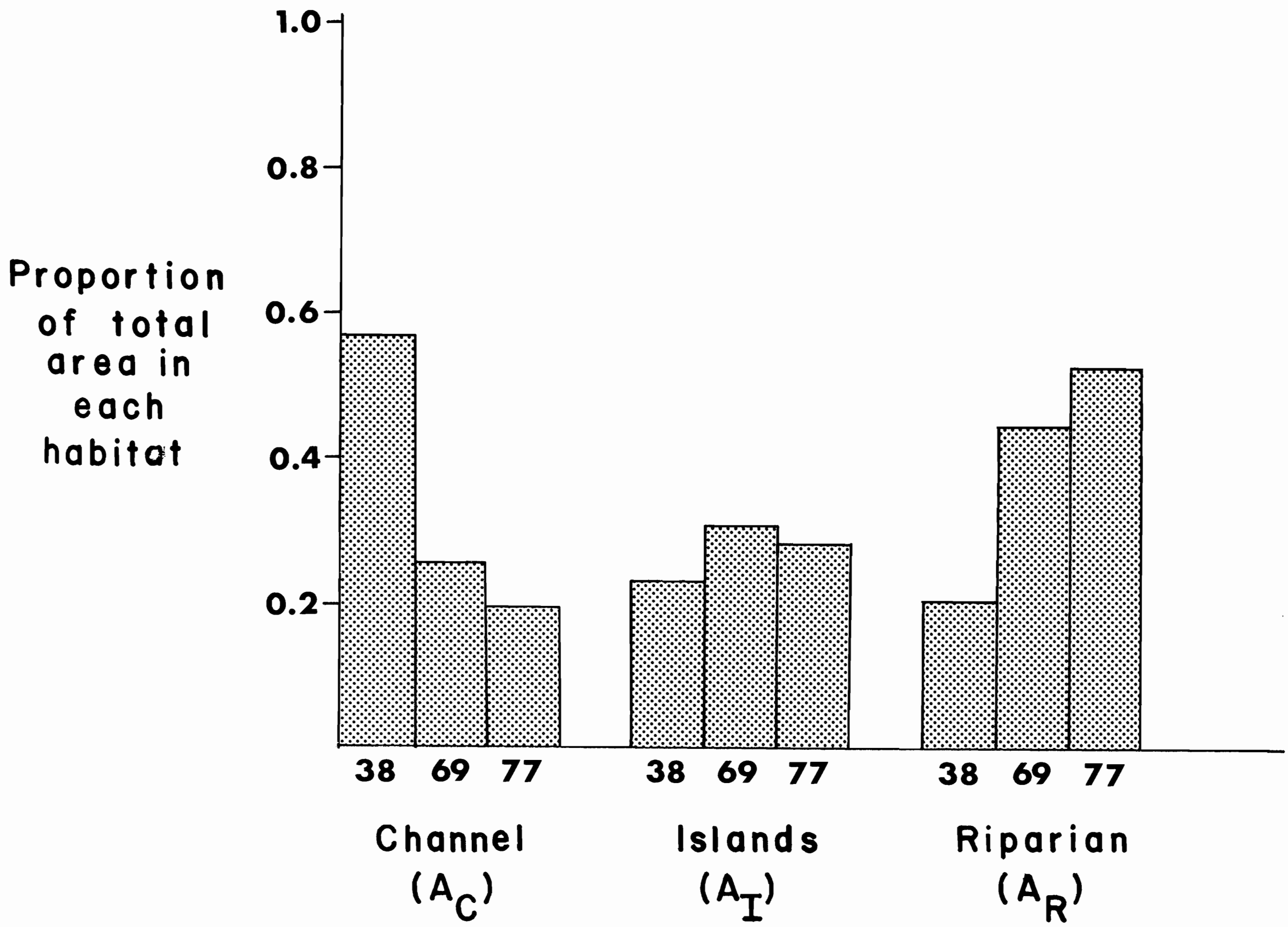

FIGURE 2. Proportion of study area in each of three habitat types in 1938, 1969, and 1977.

Subprogram 1

To estimate evaporation from open-water habitat, the area of water surface at any discharge must be known. Discharge data are available from United States Geological Survey gauging stations within the study area at Overton, Odessa, and Grand Island. Frith (1978, unpublished United States Fish and Wildlife Service data, Grand Island, Nebraska) provided us with an elevation transect across the Platte about 1½ mi upstream from the Overton gauging station. Surveys were done on four dates (March 30, May 17, June 29, and August 23, 1978) and the May and June data were selected as most representative of the evapotranspiration season. This elevational cross-section was considered typical of channel configuration within the study area.

The elevational cross-section (Frith, 1978, unpublished United States Fish and Wildlife Service data, Grand Island, Nebraska) was plotted, wetted perimeters were measured with a planimeter, and cross-sectional area calculated for each of 11 water depths (increments of 0.2 ft). Discharge at each water level was then calculated from the Manning equation (Leopold *et al.*, 1964):

$$Q = A\left(\frac{1.5}{n}\right) R^{2/3} S^{1/2}$$

where: R = A/wp; wp = wetted perimeter
A = cross-sectional area
S = slope of stream = 7 ft per mi
n = Manning roughness coefficient = 0.02
Q = discharge rate (cfs)

Values for each of the six channels present in the cross-section were summed and the results plotted on Figure 3 to produce a rating curve for the transect site.

These data do not explicitly reflect the probable scouring of the channel with increased discharges. However, comparison of this rating curve (Fig. 3) to known, bankfull discharges shows very close agreement between predicted and actual discharges when projected beyond the limits of the curve.

TABLE II. Proportion of major habitats that were barren or covered by woody or herbaceous vegetation.

Habitat	Symbol	1938[a]	1957-65[a]	1977[b]
Riparian Woodland				
Woody cover	A_{R_F}	.29	.38	.51
Herbaceous cover	A_{R_H}	.54	.50	.43
Barren	A_{R_B}	.17	.11	.06
		1938[c]	1957-65[c]	1977[d]
Vegetated Islands				
Woody cover	A_{I_F}	.35	.35	.35
Herbaceous cover	A_{I_H}	.30	.30	.30
Barren	A_{I_B}	.35	.35	.35

a: Based upon point analysis of aerial photographs.

b: Mean of 56% cover (of Gray *et al.*, 1975, unpublished report to National Science Foundation, Kearney State College, Kearney, Nebraska) and point analysis of 1977 aerial photographs which showed 46% woody cover.

c: Foliage-cover is highly variable with season due to high proportion of annual vegetation and barren areas; therefore, assumed same as 1977. Aerial photographs for 1938 and mid-period (1957–1965) were from a different season than the 1977 photograph; so no point analysis was done.

d: Data from Hadenfeldt and Walters (1978, unpublished report to National Science Foundation, Kearney State College, Kearney, Nebraska), verified by visual estimate on 11 islands.

Figure 4 allows linear proportion of open water (line 8, Table I) along the cross-section to be read at any discharge within the range given. Calculations on line 9 (Table I) are necessary because the area of open-water and bare sandbar will vary depending upon discharge when the aerial photograph was taken. Line 10 (Table I) determines the proportion of combined open-water and sandbar habitat which is in sandbar habitat at any discharge.

Line 11 (Table I) reads evaporation rate of sandbars and barren habitat on islands at any discharge from Figure 6. This graph was prepared from the Overton elevation data by drawing 11 equidistant, horizontal lines across the river cross-section, then measuring the depth to water table from surface at 19 equidistant, vertical points across the entire transect from the horizontal lines. Evaporation at any depth under bare sand was read from Figure 5, which was based upon particle-size of bed-material and sandbars (Nickel, 1978, unpublished National Science Foundation Student Originated Studies Report, Kearney State College, Kearney, Nebraska), and evaporation rates were determined by Parshall (1930).

Subprograms 2 and 3

These subprograms estimate evapotranspiration from vegetated-island and riparian habitats. Habitats were split into island and riparian because of different species composition and elevation. The split into woody *versus* herbaceous vegetation was somewhat impractical because of large areas of open-woodland habitat and presence of copious herbaceous vegetation under forest canopy. However, herbaceous vegetation under trees accounts for less than 13% of the total ET there (Van Hylckama, 1970; Kozlowski, 1968) and was ignored where heavy forest-canopy was present. Areas designated herbaceous, therefore, have no woody vegetation present, but woody areas usually do have herbaceous vegetation.

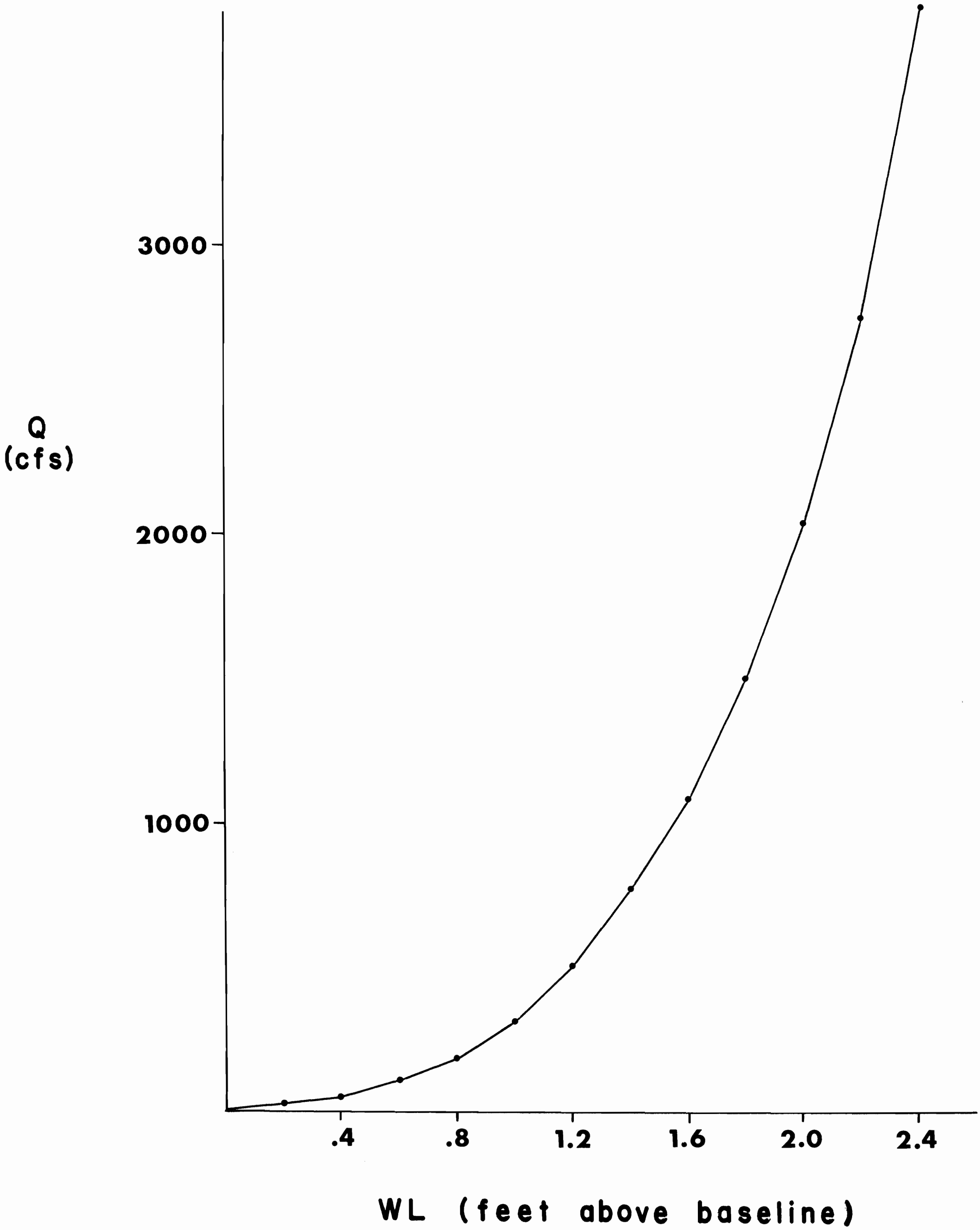

FIGURE 3. Relationship between water level (WL) above baseline elevation and discharge (Q) at Overton, Nebraska.

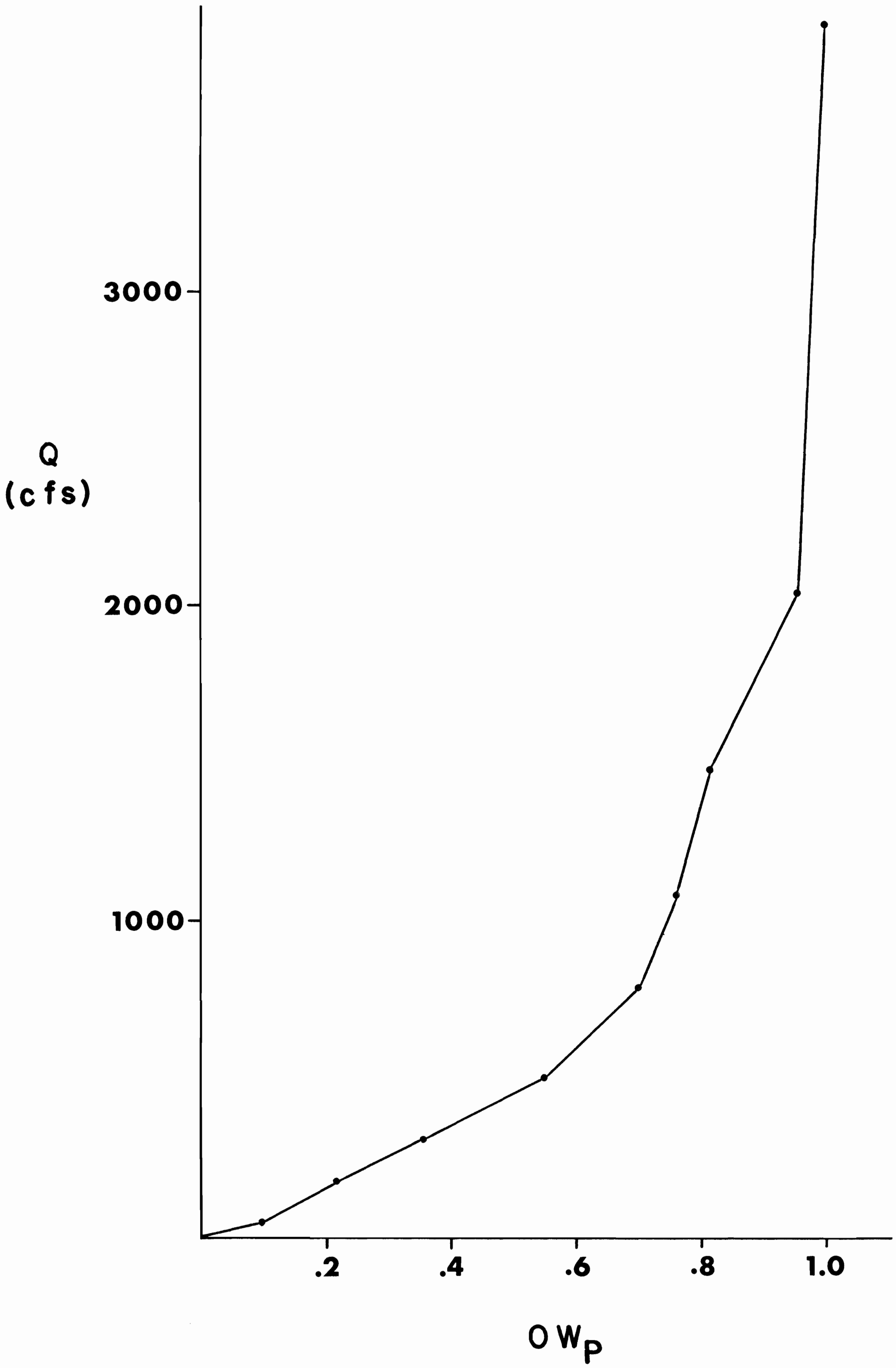

FIGURE 4. Proportion of total channel-width covered with water (OW_p) at any discharge (Q).

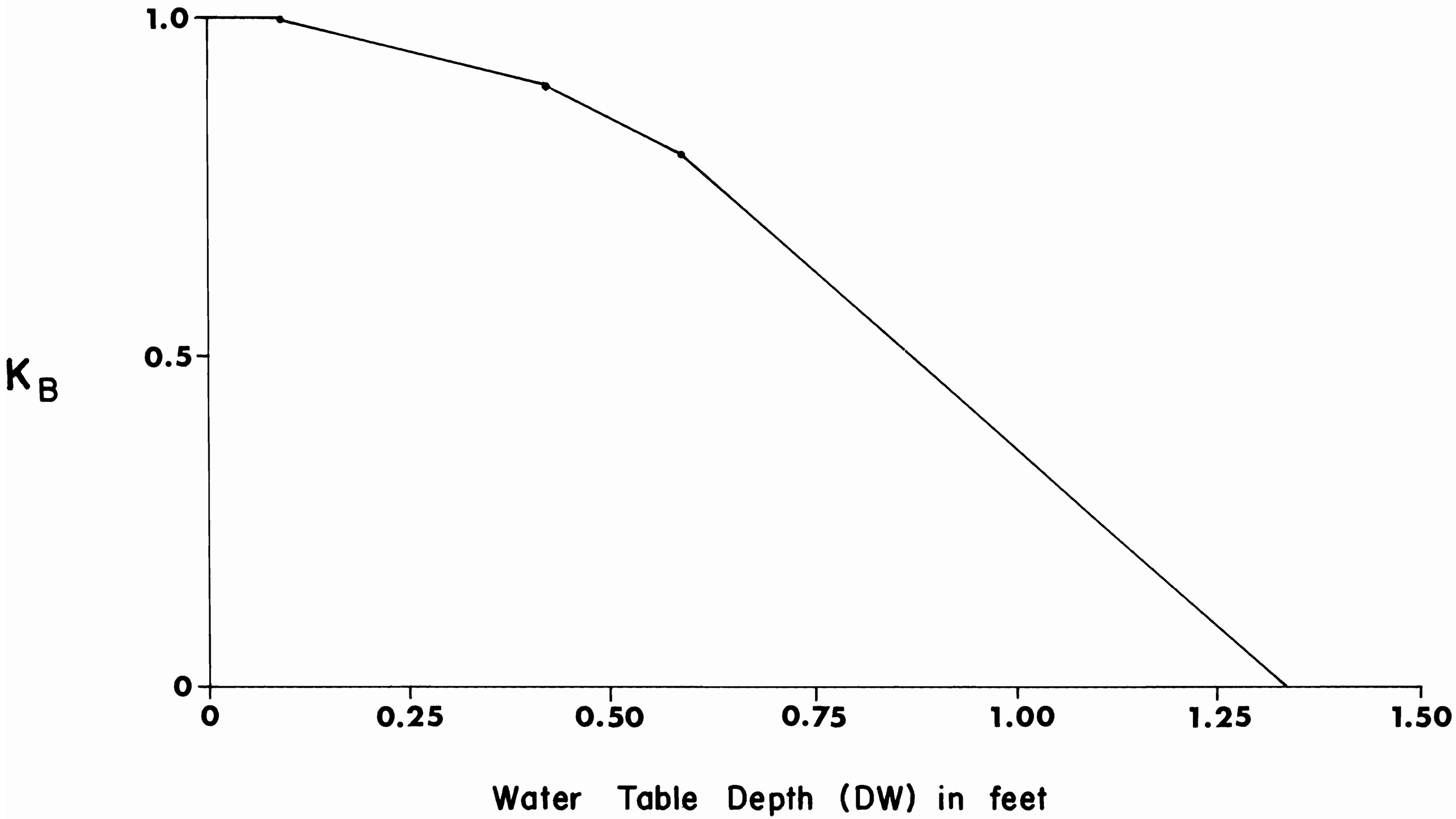

FIGURE 5. Depth of saturated water-table under sandbars and barren islands compared with evaporation rate (K_B).

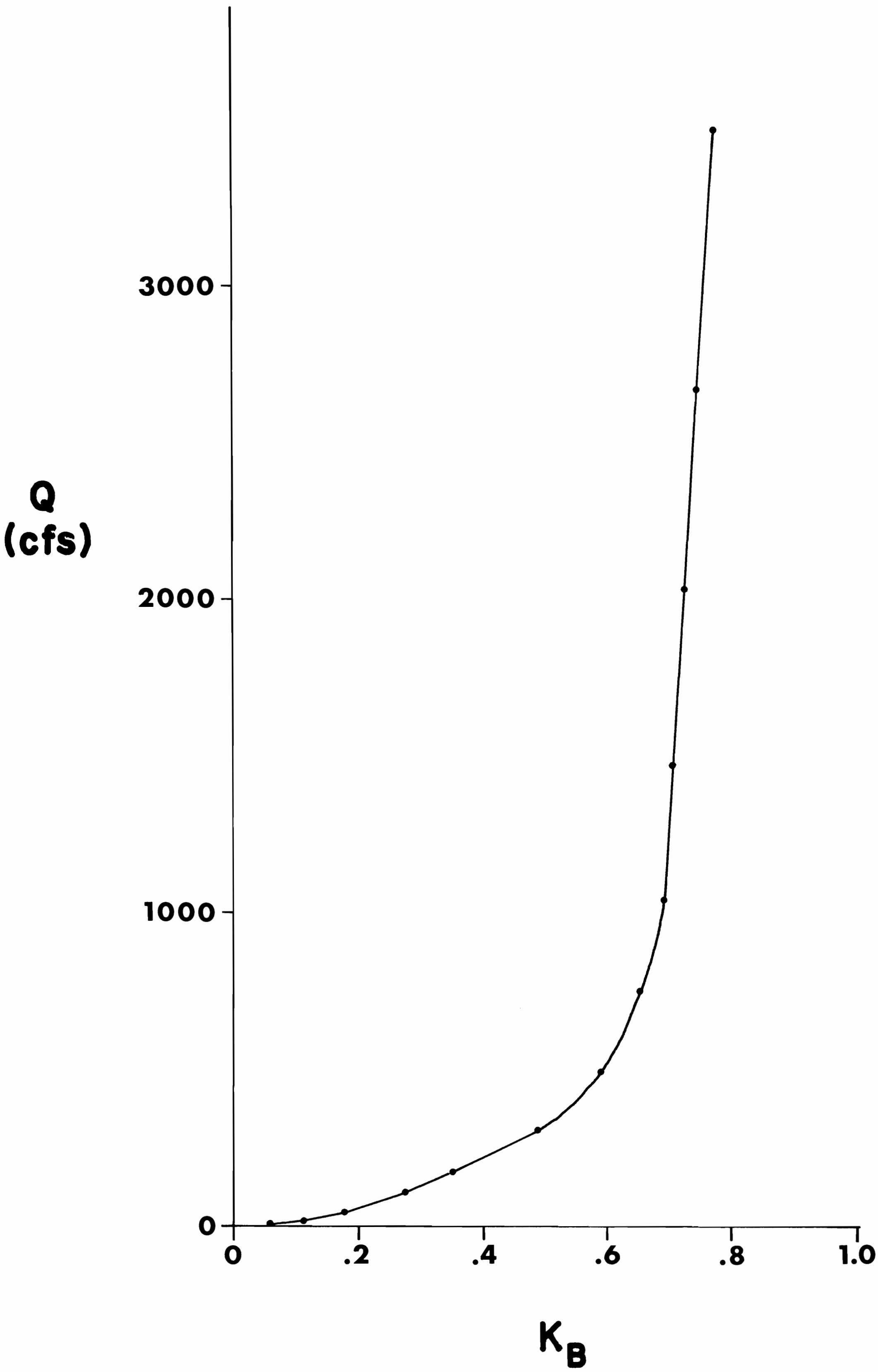

FIGURE 6. Evaporation rate from barren sand surface (K_B) at any discharge (Q).

Present Species-Composition and Foliage-Cover

Riparian species-composition was taken from an unpublished report to the National Science Foundation by Gray, Hertner, Bunde, Deyle, Imel, Stines, Sweeney, and Weiss (1975, Kearney State College, Kearney, Nebraska). They studied five 5-acre sites at 15 mi intervals between Grand Island and Lexington. Each of these sites was sampled intensively at two dates for both woody and herbaceous species-composition and foliage-cover (Table III).

Island vegetation data were obtained from Hadenfeldt and Walters (1978, unpublished National Science Foundation Student Originated Studies Report, Kearney State College, Kearney, Nebraska). They systematically surveyed 22 randomly selected islands between Gibbon and Overton for both species-composition (Table III) and foliage-cover (Table II). Woody species-composition and foliage-cover is an average from results of their study, which covered the western one-half of the study stretch, and from visual mapping by us (11 islands) in the eastern one-half of the study reach.

TABLE III. Platte River riparian and island vegetative-composition from Lexington to Grand Island from Gray *et al.,* 1975 (unpublished report to the National Science Foundation, Kearney State College, Kearney, Nebraska) and Hadenfelt and Walters, 1978 (unpublished report to the National Science Foundation, Kearney State College, Kearney, Nebraska).

Species	Common Name	Species-Composition[a]	
		Riparian	Island
Woody Species			
Amorpha fruticosa	False indigo	.10	.27
Cornus stolonifera	Red dogwood	.26	.08
Fraxinus pennsylvanica	Green ash	.07	T[c]
Parthenocissus quinquefolia	Virginia creeper	.05	T
Populus deltoides	Eastern cottonwood	.22	.22
Salix amygdaloides	Peachleaf willow	–[b]	.11
S. exigua spp. *interior*	Sandbar willow	.06	.29
Ulmus americana	American elm	.06	0
Vitus riparia	Wild grape	.12	T
Woody	Other species	.06	.03
Herbaceous Species			
Cyperus spp.	Flatsedge	0	.09
Ellisia spp.	Ellisia	.15	0
Elymus canadensis	Canada wildrye	.22	0
Juncus spp.	Rush	0	.10
Poa pratensis	Kentucky bluegrass	.08	0
Rhus radicans	Poison ivy	.15	0
Scirpus spp.	Bulrush	0	.22
Xanthium strumarium	Cocklebur	0	.58
Herbaceous	Other species	.40[d]	.01

a: Proportion of total foliage-cover by woody species or herbaceous species.

b: All willow species included in sandbar willow.

c: Less than .05.

d: Includes, in order of importance, *Asparagus, Bromus, Rosa, Galium, Rumex, Erigeron, Hordeum, Apocynum, Scirpus, Equisetum,* and *Smilacina* sp., all contributing between .02 and .05.

Percentage of bare soil (Table II) depended greatly upon when the sample was taken and data used were subject to much variation. The report by Gray *et al.* (*see above*) did not give estimates of bare ground; therefore, data given were derived from point analysis of aerial photographs.

1938 Species-Composition and Foliage-Cover

Species-composition and foliage-cover for islands and banks in 1938 are difficult to estimate as published data seemingly do not exist. Early visitors to the Platte Valley remarked about the absence of trees on the banks, but did note the presence of islands with trees (Williams, 1978) although McKinley (1935), in reviewing early reports, stated that "westward to a point somewhat beyond the junction of the North and South Plattes, there was an ample supply of timber along the banks of the river and on the islands." Early reports noted the prevalence of cottonwoods and willows, similar to what is found today. In their report (*see above*), Hadenfeldt and Walters discussed successional changes in vegetation on the Platte. The most dramatic changes seemed to occur during the first 10 years. One change was a reduction in sandbar willow and an increase in peachleaf willow from very young islands to those 10 years old. Cottonwood gradually increased until an island was 20 years old, then decreased in importance. False indigo, red dogwood, and green ash did not appear on islands less than 10 years old. However, willow species and cottonwood still dominate the vegetation today on many islands which were present on 1938 aerial photographs. Since no clear-cut trend was apparent in Hadenfeldt and Walters' data, we assumed the same species-composition and foliage-cover for vegetated habitats in 1938 as today. There actually were probably more willows and cottonwoods proportionally in 1938, especially on the banks, since these species occur primarily in early seral stages.

We estimated foliage-cover from 1938 aerial photographs for trees and herbaceous vegetation by the point method. These data were proportionately higher for herbaceous cover than shown by the data of Hadenfeldt and Walters (*see above*), probably because 1938 photos were taken from July to October, whereas 1978 data were collected from May to July.

Species Transpiration Coefficients

Line 14 (Table I) reads K_i from Table IV. With the exception of willow, cottonwood, and grape, data on transpiration coefficients for species in Table III were not found in the literature. Therefore, coefficients for the remaining dominant species were estimated.

The method chosen was that of measuring maximum difference between ambient-air and leaf-surface temperatures, as suggested by Tanner (1963). This approach assumes if a plant has an adequate supply of water available to the roots, the difference between the temperature of the leaf and the ambient air around it should be an indication of the magnitude of transpiration. A leaf able to maintain its temperature at or near ambient, when receiving maximum solar-radiation, transpired the most, whereas species whose leaves were warmer than ambient air had lower transpiration rates.

The following standardized conditions were present during taking of leaf temperatures with a Yellow Springs Telethermometer (YSI Model 42 SC, 1 cm diameter banjo probe):

1. Leaf was in full sun, *i.e.*, no clouds or shading;
2. Leaf surface was held perpendicular to sun;
3. All readings were taken between air temperatures of 29 C and 33 C during June and July;
4. Bottom of leaf was used for temperature measurement;
5. If leaf was too small to cover banjo probe, two leaves, just overlapping, were used;
6. Water table was high enough so plant had roots in water;
7. Leaf was not in wilted condition or damaged by insects, pathogens, etc.; and
8. Wind was $\leqslant$ 10 mph.

Gates (1968) stated that size of leaf had a great impact upon leaf temperature. Consequently, leaf size was measured when taking temperatures, in anticipation of the need to develop a correction equation to adjust for leaf size. The results, however, showed very little intraspecific variation (Fig. 7), and no significant correlation between leaf area and temperature difference within species was found. Therefore, a graph (Fig. 8) showing the linear relationship between leaf-temperature difference from ambient air *versus* K_i was prepared, using known values (from the literature) for cottonwood and grape as the end points, then placing data from Figure 7 onto Figure 8.

The resulting slope of the curve (Fig. 8) is $1K_i$ unit = 5 C temperature difference. Konis (1950), using different plants and directly measuring transpiration and temperature of excised leaves, found that $1K_i$ = 4.9 C leaf-temperature difference from ambient, a good correlation with our data.

An assumption was made that phreatophyes were able to extend roots into a receding water-table fast enough to keep ET rates from drooping. Gardner (1965) stated that if a plant had 10% of its roots in water, transpiration rates would not drop. Most researchers also seem now to agree with Holmes (1961) that in sandy soils, transpiration rates proceed at about the same rate until the wilting-point is reached. Thus, although occasional wilting of plants was noted on tall islands, especially of annual plants such as cocklebur, at periods of low flow, no adjustment is made in this model for reduced K's due to lack of water availability to plants.

TABLE IV. Species transpiration-coefficients (K_i) for major plant species found along the Platte River in central Nebraska.[a]

Species	K_i	Source of Data
Woody		
Amorpha fruticosa	1.05	Figure 8
Cornus stolonifera	1.15	Figure 8
Fraxinus pennsylvanicus	1.05	Figure 8
Parthenocissus quinquefolia	1.65	Figure 8
Populus deltoides	1.80	Rantz (1968)
Salix amygdaloides	1.65	Figure 8
S. exigua interior	1.75	Figure 8
Ulmus americana	1.15	Figure 8
Vitus riparia	0.60	Donahue *et al.* (1977) and Dunne and Leopold (1978)[c]
Other	0.75	–[d]
Herbaceous		
Cyperus spp.	1.30	Rantz (1968)
Ellisia spp.	0.75	–[d]
Elymus canadensis	0.75	Penman (1963) and Blaney and Criddle (1962)[b]
Juncus spp.	1.30	Rantz (1968)
Poa pratensis	0.75	Penman (1963), Blaney and Criddle (1962)[b]
Rhus radicans	0.75	–[d]
Scipus spp.	1.30	Rantz (1968)
Xanthium strumarium	1.65	Figure 8
Other	0.75	–[d]

a: Assume water-table near or at surface and not limiting transpiration. These values are probably most representative of peak seasonal K_i for species.

b: K for irrigated pastures.

c: Average of two sources.

d: Estimated.

Figure 9 shows the relationship used between depth to water-table and K. This graph was based upon a straight-line relationship found for several species by Rantz (1968) and by Gatewood *et al.* (1950). This relationship showed a 7% decline in K for each 1 ft drop of water-table. This figure was used in line 19 of Table I. Although the curve may differ for most species of plants, not enough data were available to draw such curves. Additionally, the water-table rarely fell below 3 ft below island surface, and the curves based on on the first several feet from the surface probably do not vary as much.

Depth of water (Table I, line 18) is height above the baseline elevation at the Overton cross-section. This base line was the bottom of the lowest channel in the cross section. A level water-table, although introducing some error into the model, was assumed across the entire river cross section.

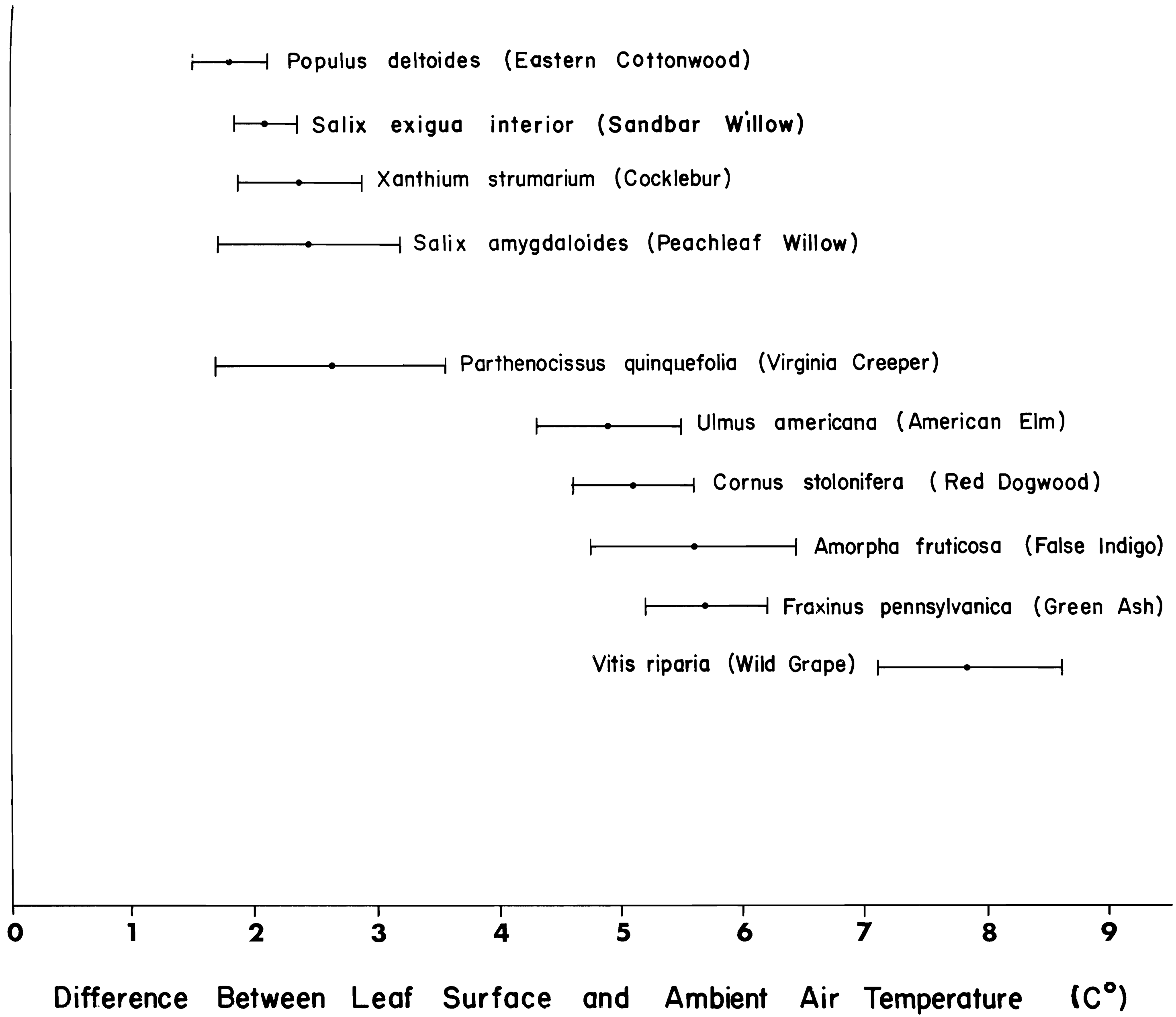

FIGURE 7. Leaf-surface temperature minus ambient-air temperature. (N = 20, dot = mean, bar is 95% confidence limits).

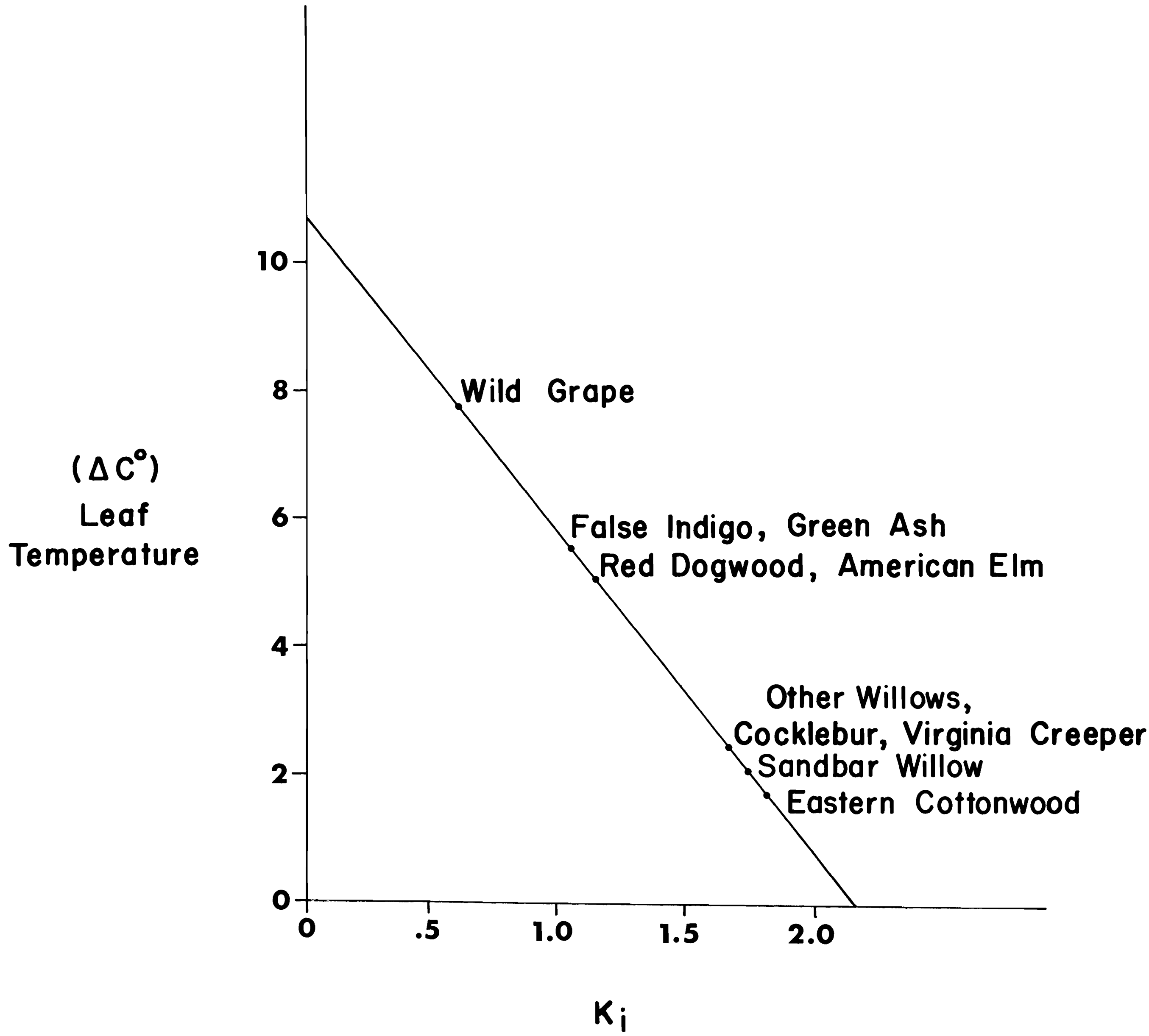

FIGURE 8. Leaf-temperature differences from Figure 7 and corresponding K_i values.

Stec (1978, unpublished National Science Foundation Student Originated Studies Report, Kearney State College, Kearney, Nebraska) reported that islands in the Platte River (within the study area) present before 1938 averaged 2.1 ft above mean channel-height; islands first present on 1957 photos but not on 1938, 1.3 ft tall; 1957-1969, 0.9 ft tall, and islands first present in 1969 were only 0.6 ft above mean channel (Fig. 10).

Figure 11 shows the relationship between foliage-cover and K (Table I, line 20). These data came from Miller (1977) who stated that an increase in surface area of foliage by 0.5 results in an increase in transpiration by about 0.2. Chang (1968) stated ". . . after the canopy is reasonably well developed, large differences in vegetative growth can cause only relatively small differences in evapotranspiration rate. . . ." Foliage-cover data were not available and values of 70% were used in woody habitat and 50% in herbaceous habitats. These covers vary considerably on a seasonal basis, especially in herbaceous areas, and should be estimated monthly.

Lines 25-27 (Table I) read the area and coefficient for barren habitat in riparian habitat. A major source of error here is that elevations above baseline and depth to water-table were not known (Fig. 10, *see* footnote c).

RESULTS AND DISCUSSION

Monthly evaporation, estimated by the Blaney-Criddle method (Blaney and Criddle, 1962), is given in Table V. Flow data (cfs) are also given in Table V for the two periods of estimation. Earlier, higher flows (*e.g.* 1915-1930) were not used in the model because the channel configuration may have differed under high flows, thus invalidating results.

Monthly estimates of actual evapotranspiration calculated for conditions in the 1930s and 1970s are given in Table VI. Annual values are about the same as those found by Van Klaveren *et al.* (1975) on the North Platte in Wyoming. They found an average ET of 31.25 in per yr with cottonwood and willow phreatophytic vegetation along the Platte and three tributaries. Although their estimate is about 4 in less than ours (Table VI) for recent conditions, this difference is easily accounted for by the fact that the mean-annual lake-evaporation rate is about 7 in less than in our study area (Anonymous, 1968). The 3-in differential between the two studies (plus 7-in difference in lake-evaporation rate minus 4-in estimated difference) may be due to the fact that 95% of the Wyoming vegetation was cottonwood and willow, whereas many tree species with lower transpiration coefficients were present in Nebraska.

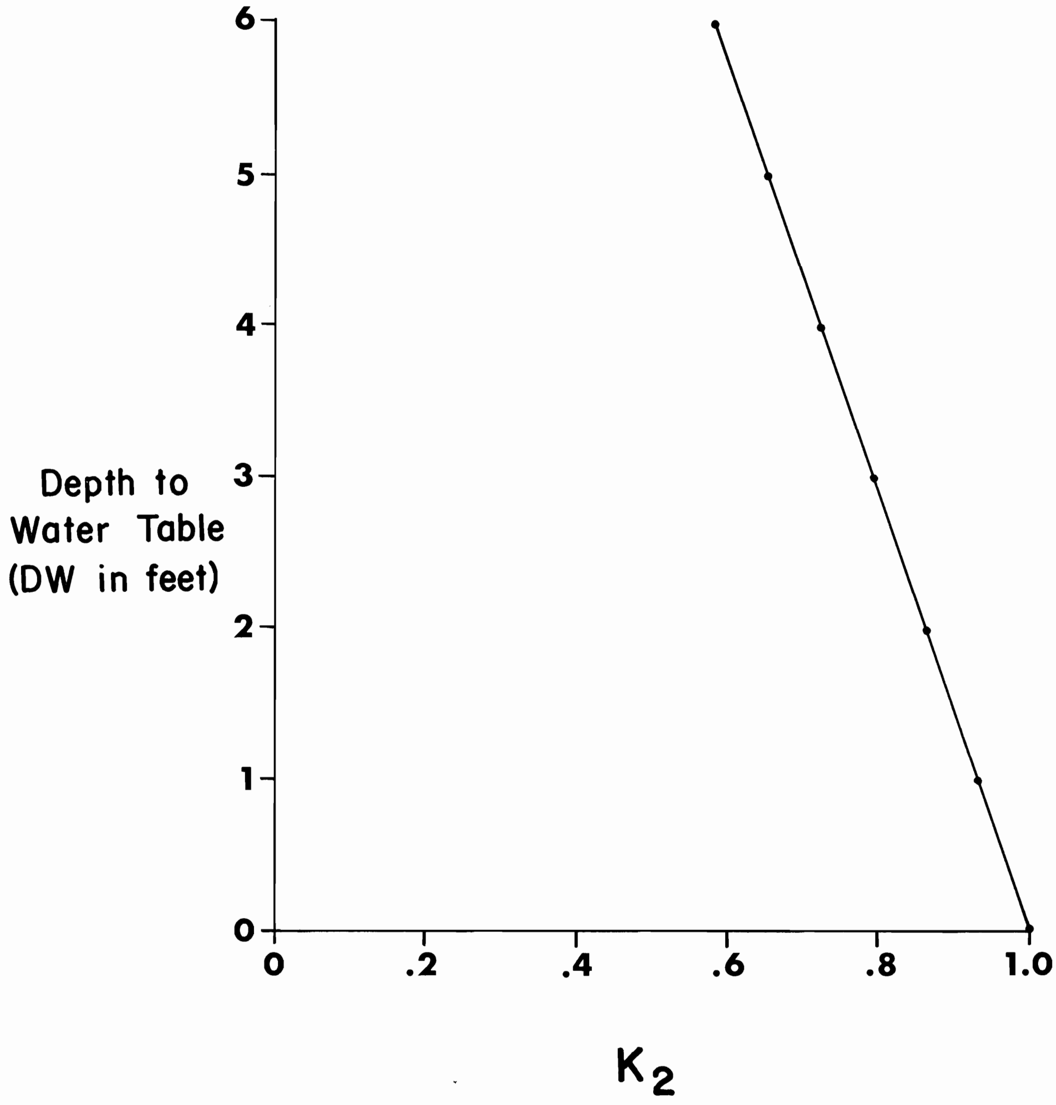

FIGURE 9. Depth to saturated water-table from soil surface as compared to K_2.

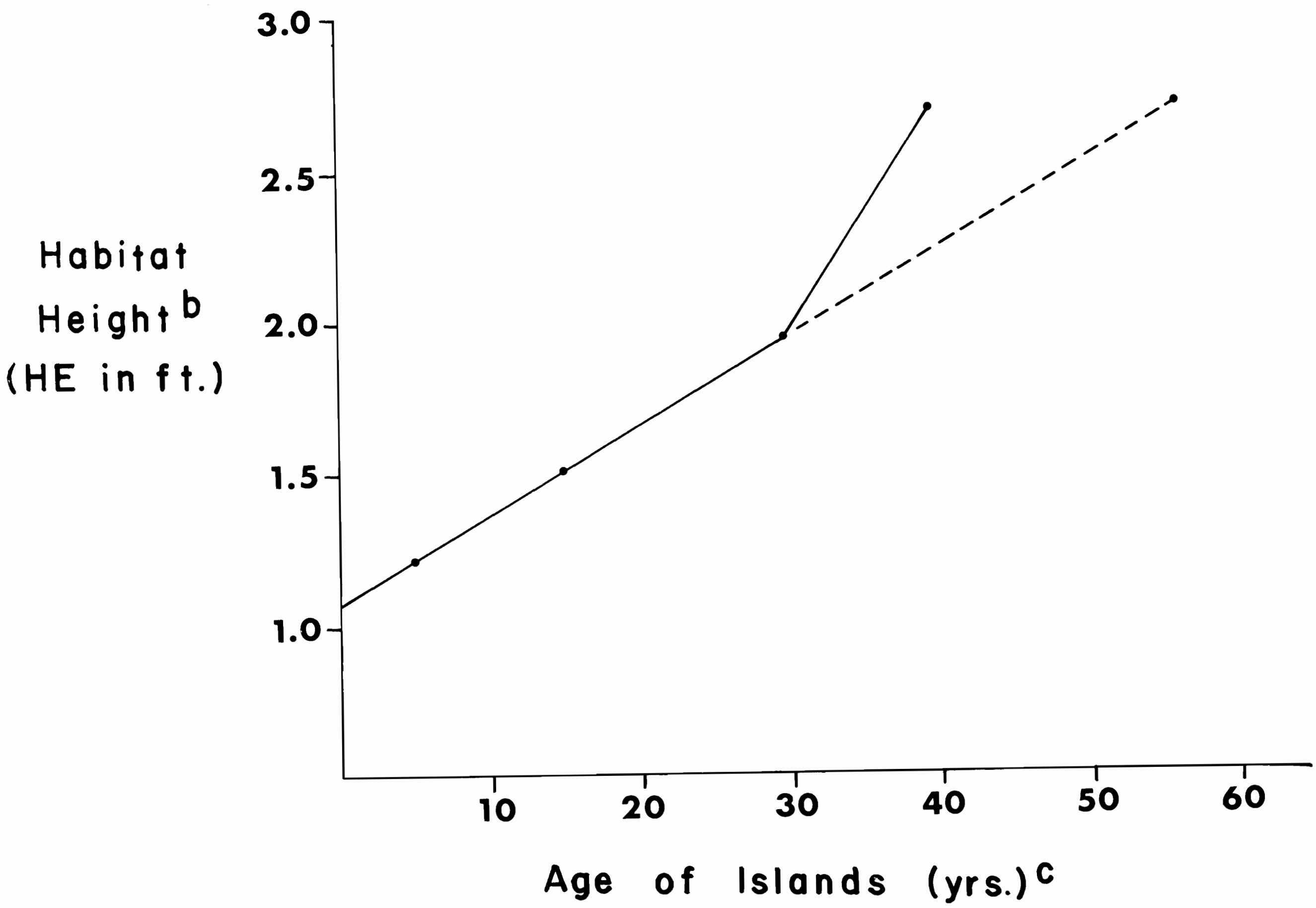

FIGURE 10. Island height above baseline elevation of channel. Data points are averages from Stec (1978, unpublished National Science Foundation Student Originated Studies, Kearney State College, Kearney, Nebraska). Footnotes: **a.** Midpoints of range of known island ages used. The 40-year-old point should be farther to the right, but since 1938 photographs were the oldest used, the mid-point is not known. The dashed line assumes a linear build-up in elevation with age, as demonstrated by the first three data points. **b.** Stec's data on elevation were adjusted upward by 0.6 ft to conform to our baseline elevation. Stec's data were measured in relation to mean channel-elevation, not lowest point. The 0.6 ft correction was the difference between mean channel depth and baseline at the Overton cross-section. **c.** No elevational data were found for riparian habitat. Since much of the riparian habitat now was once island, we assumed that riparian-habitat elevation was that of an old island and given an elevation of 3 ft.

The evaporation-rate calculated from open river (44.8 in, Table VI) may be low due to excluding November through March. However, it compares well with the rate computed by Meyers (1962) for stream-and-canal evaporation on the Platte River in Nebraska below the junction of the North and South Plattes (43.4 in per yr).

The 1977 estimate of ET is probably more accurate than that of 1938 due to most data on species-composition and foliage-cover being of recent origin. Another problem with the 1938 estimate is that the channel configuration used by us was based on a single cross-sectional location done in 1978 and the channel configuration may have been considerably different in the 1930s.

Extrapolating our data (Table VI) to the reach of the Platte from Kingsley Dam to Duncan (*refer to* Dirmeyer quotation in INTRODUCTION), we estimate the wooded and open channel to average 0.83 mi wide in our study area. This equals about 128,000 acres in the 240 mi reach. Our estimated ET for recent conditions is 379,000 acre-feet per year (at an ET of 2.96 ft per yr).

The most surprising result of the calculations is the very slight difference between the ET in 1930s as compared to today. We expected the increasing proportion of the study area in riparian forest since the 1930s (Fig. 2) to result in a much higher ET rate in 1970s than in 1930s. The apparent reason for there being little or no difference is that the riparian

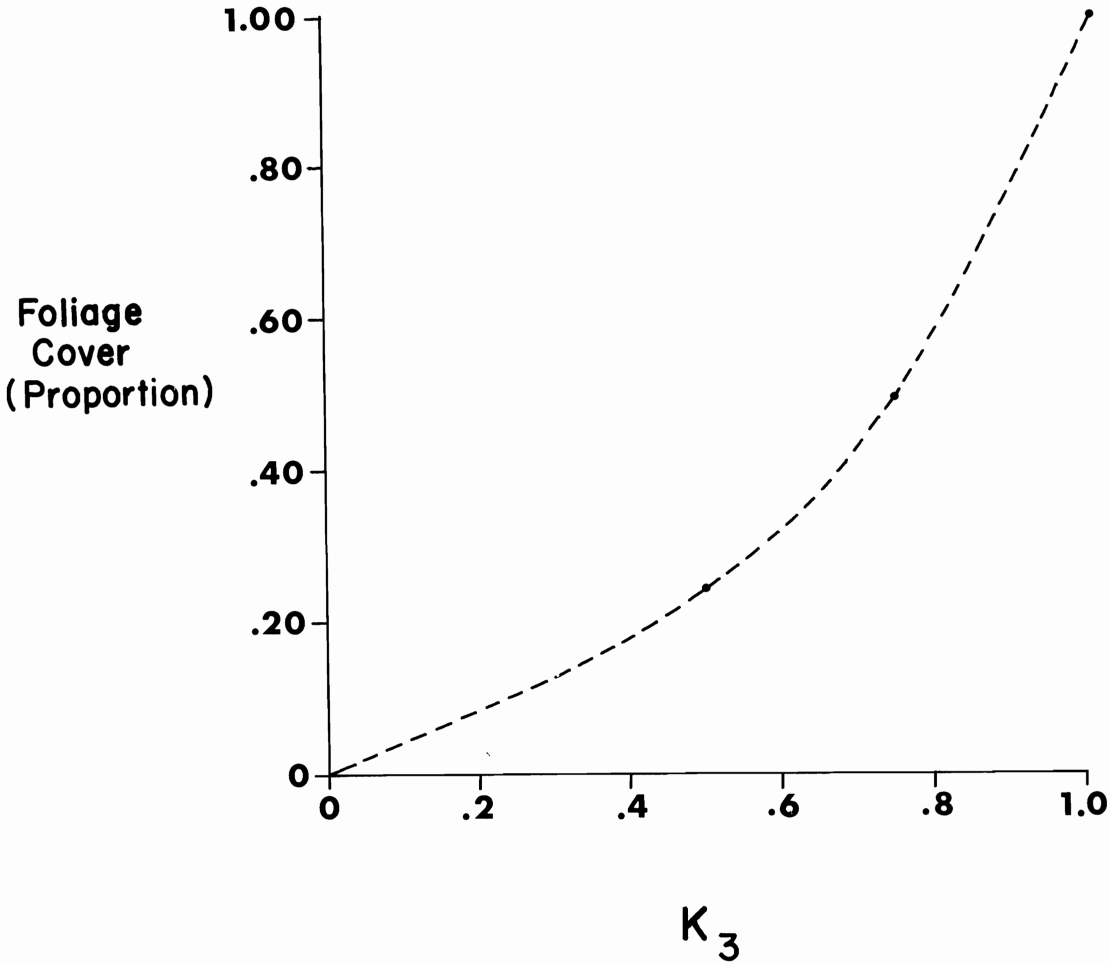

FIGURE 11. Transpiration rates compared to total foliage-cover.

TABLE V. Values used for E_p from Blaney-Criddle equation, and mean Q's for 1970s and 1930s at Overton gauging station.

	April	May	June	July	August	September	October
Evaporation (in)	4.43	6.06	7.14	7.88	7.20	5.46	4.19
Discharge (cfs)							
1970-76[a]	2156	1607	1298	692	481	958	1531
1932-39	1649	1616	1682	692	396	725	1121

a: United States Geological Survey (1973 excluded, due to high flows).

TABLE VI. Monthly computed ET loss from each habitat for 1930s (top) and 1970s (bottom).

	Evapotranspiration Loss (inches)									
Habitat	April	May	June	July	August	September	October	Σ	Area[a]	ET Rate
Open River	2.17	2.97	3.50	2.92	1.80	2.07	1.84	18.57[c]	0.42	44.21
Sandbar and Bare Island	0.50	0.69	0.81	1.39	1.56	0.94	0.90	6.79	0.25	27.16
Forested Island	0.44	0.60	0.71	0.76	0.68	0.52	0.41	4.12	0.08	51.50
Herbaceous Island	0.33	0.41	0.54	0.57	0.51	0.37	0.31	3.04	0.07	43.43
Riparian Forest	0.25	0.35	0.41	0.43	0.38	0.30	0.24	2.36	0.06	39.33
Riparian Herbaceous	0.25	0.34	0.40	0.43	0.38	0.30	0.23	2.33	0.11	21.18
Riparian Barren	0.03	0.04	0.05	0.00	0.00	0.00	0.00	0.12	0.03	4.00
Total								37.33	1.02	
Open-River	0.84	1.02	1.12	1.02	0.77	0.79	0.69	6.72[c]	0.15	44.80
Sandbar and Bare Island	0.36	0.56	0.71	0.84	0.80	0.57	0.39	4.23	0.15	28.20
Forested Island	0.56	0.76	0.88	0.95	0.86	0.67	0.52	5.20	0.10	52.00
Herbaceous Island	0.40	0.54	0.63	0.67	0.61	0.47	0.37	3.69	0.08	46.13
Riparian Forest	1.16	1.57	1.84	1.96	1.76	1.39	1.08	10.76	0.27	39.85
Riparian Herbaceous	0.51	0.69	0.80	0.86	0.77	0.61	0.47	4.71	0.22	21.41
Riparian Barren	0.07	0.03	0.01	0.00	0.00	0.00	0.00	0.12	0.03	4.00
Total								35.48	1.00	

a: In proportion of total study area.

b: ET rate (in per yr) = ΣET loss/area.

c: Σ = 17.27 (RCf) = 18.57, and 6.25 (RCf) = 6.72.

forest does not have any higher average K than does open-water (Tables II, III, IV). Dirmeyer (1975) apparently assumed a solid stand of phreatophytic vegetation with high K's. However, the riparian forest has undergone 40 yrs or more of succession, for the main part, and the higher seres have as dominant plant-species ones with lower K's than early seres. The contrast between species-composition for island forests (younger) and riparian forest (older) in Table III is clear.

As the riparian forest ages, barring serious disturbance, it will trend toward an ash-elm-dogwood-cedar community (Hadenfeldt and Walters, 1978, unpublished National Science Foundation Student Originated Studies, Kearney State College, Kearney, Nebraska), all of which have relatively low K's; thus water loss from the Platte River due to ET should gradually decline.

Although sometimes mentioned as a management possibility, clearing the woody vegetation from islands and riparian forest may have little effect upon water loss. The denuded sandbars would probably quickly grow up in cocklebursand perennial hydrophytes, which have water-loss coefficients almost equal to those of cottonwood and willows.

CONCLUSIONS AND LIMITATIONS

The computational flow-chart for estimating evapotranspiration on the Platte River in central Nebraska seems to work reasonably well. Data are lacking for accurate estimation of ET, but the approximations made correspond well with most published estimates. The flow chart is complex enough to allow fairly sophisticated ET estimation, when adequate data exist.

In order to obtain accurate present estimates of ET, additional research on elevational cross-sections of the channel, on depth to ground-water in the riparian zone, and on verification of species transpiration coefficients is needed. Additional data are needed on foliage-cover of the vegetated habitats on a monthly basis. The 1970s ET estimate is perhaps 10% or more too low, because early spring and late fall evaporation-rates from sand and open-water were not considered. Another factor in underestimation is that evaporation of precipitation from barren sand (both island and riparian) was not considered.

Accurate estimation of historic ET rates on the Platte is improbable, due to the lack of data on vegetation species-composition and channel configuration. However, assumptions made for conditions in the 1930s probably are accurate enough to conclude that ET rates have not changed dramatically during the past 40 years on the Platte River ecosystem in Nebraska.

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