WRC RESEARCH REPORT NO. 19

DEVELOPMENT OF DRAINAGE ASSESSMENT PROCEDURES BASED ON PHYSICAL FEATURES IN ILLINOIS

Benjamin A. Jones Jr., Professor
and
Carroll J.W. Drablos, Assistant Professor
Agricultural Engineering Department
University of Illinois, Urbana-Champaign

F I N A L   R E P O R T

Project No. A-011-ILL
June 1, 1965 - June 30, 1968

The work upon which this publication is based was supported by funds provided by the U.S. Department of the Interior as authorized under the Water Resources Research Act of 1964, P.L. 88-379
Agreement No. 14-01-0001-1081

UNIVERSITY OF ILLINOIS
WATER RESOURCES CENTER
3220 Civil Engineering Building
Urbana, Illinois 61801

May, 1969

ABSTRACT

DEVELOPMENT OF DRAINAGE ASSESSMENT PROCEDURES BASED ON PHYSICAL FEATURES IN ILLINOIS

The objectives of this study were to identify the physical features of the land in a drainage district which influence benefits accruing from drainage improvements, and to formulate a method for distributing assessments based upon the relative importance of these physical features.

The significant physical features discovered in the study were: (1) the distance from the tract of land to the main drain, (2) the distance from the tract of land to the main outlet, and (3) the permeability of the soil on the tract of land. An equation was developed to determine the assessment for any tract: $An = 1.4845 - 0.3476 (Ln/L^*) - 0.4680 (Dn/D^*) - 0.4434 (Kn/K^*)$.

The equation provides a procedure and a computer program to equitably distribute drainage assessments with a savings in labor and time in the preparation of the assessment roll. This unbiased procedure should reduce the present objection of landowners of unfair assessments based upon personal judgment. Although the present equation is limited to the geographic area that supplied the data for the coefficients, the procedure developed may be used to calculate coefficients for other soil and morphological areas.

Jones, Benjamin A., Jr. and Drablos, Carroll J. W.
DEVELOPMENT OF DRAINAGE ASSESSMENT PROCEDURES BASED ON PHYSICAL FEATURES IN ILLINOIS
Completion Report to Office of Water Resources Research, Department of Interior, May 1969, Washington, D.C., 27 p.
KEYWORDS--*drainage/ *assessment/ *physical features/ *benefits/ *drainage districts.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGMENTS

The authors want to express their appreciation to Norman A. Barron, Richard L. Bengtson, and Don D. Jones, Graduate Research Assistants who made a major contribution to the project. We also express our thanks to Mr. Donald M. Tennant, of the firm of Dobbins, Fraker and Tennant, Attorneys at Law, Champaign, Illinois, for his counsel.

INTRODUCTION

As the population in the United States and the world increases, the amount of agricultural products grown each year must also increase to meet the needs. At the same time, however, it is necessary to remove large areas of fertile land from production each year for cities, highways, etc. in many areas of the United States. Therefore, it is necessary to produce more food from a smaller overall land area and from less-productive soils.

One way to improve the productivity of croplands that have an excess of surface and subsurface water is to improve the drainage. The greatest obstacle encountered in draining many areas is the lack of an outlet for the disposal of the drainage water. In such instances, it is often necessary to organize a legal entity, such as a drainage district, in order to secure a community outlet. The objective of the district is to construct and maintain drains and to apportion the cost among the landowners benefited, within the framework of the law.

The amount of money expended by each landowner for construction, improvement, and yearly maintenance of a district is called an assessment. In Illinois, the amount of an assessment is determined on the basis of benefits received; by law, the benefits must be equal to or greater than the cost. The determination of the amount of each drainage assessment often causes a conflict among affected landowners because they feel that the assessments are not proportioned equitably. At the present time, the commissioners of a drainage district, in consultation with their engineer and lawyer, evaluate the benefits the land receives from the project, based upon their experience and personal judgment.

Since people may be prejudiced and since experience and judgment will vary from person to person, it would be beneficial to eliminate, or at least reduce, the personal judgment factors involved in the assessment process. Consequently, an assessment procedure is needed that will objectively analyze the variables affecting the benefits of drainage, so that all landowners will be treated in a fair and impartial manner.

The objectives of this study were: (1) to identify the physical features of the land that may influence the benefits accruing from drainage; (2) to determine those physical features that have a significant effect in influencing the benefits accruing from drainage; and (3) to formulate an assessment procedure based on the correlation between the significant physical features and the benefits accruing from drainage.

REVIEW OF LITERATURE

Benefits From Drainage

If a landowner is going to be able to pay for the installation of a drainage system, the benefits from drainage must be greater than the cost. One of the benefits is increase in crop yields. Several persons have published results of experiments showing a crop increase due to improved drainage. G.O. Schwab, G.S. Taylor, J.L. Fouss, and E. Stibbe[22] showed an average corn yield of 51.4 bu/acre on undrained plots, 81.1 bu/acre on surface drained plots, 89.5 bu/acre on tile drained plots, and 92.1 bu/acre on surface and tile drained plots. This is an increase of 58% for the surface drained plots and 79% for the surface and tile drained plots. In this experiment even a minor improvement in drainage such as a surface drain increased yields and a major improvement such as a combination surface and tile drain increased yields even more. Walter L. Johnson,[13] in a flooding experiment, showed a relationship between crop yield and the stage of plant development when the plants were flooded. The plots of corn flooded June 8 to 14 only produced an average of 95.5 bu/acre while the plots flooded August 12 to 18 produced an average of 124 bu/acre. The plots not flooded at all produced an average of 128 bu/acre. The yields of the plants flooded in August and not flooded at all were 30% and 34% greater respectively than those flooded in June. Johnson showed that there was no doubt that flooding especially in the late spring decreased crop yields.

The Middle Western United States usually has a great amount of rain in the late spring which may cause flooding. To get maximum yields, the flooding must be relieved either by natural or artificial drainage. The increase in crop yields is the most important benefit from drainage since this benefit usually recovers the cost of the drainage system.

Other benefits from drainage are that drainage allows the fields to dry and warm up earlier in the spring. This permits the farmer to till his fields and plant his crops earlier in the season. Drainage also allows the use of more fertilizer and better management which increases yields even more. Also benefits from drainage accrue from increased land value due to greater productiveness, accessibility, and the decreased cost of agricultural operations.[19]

General benefits enjoyed by the public and common to all people of the community also result from drainage. Some benefits are increased healthfulness, convenience, and general prosperity.[4]

Factors Affecting Benefits

One of the first published works on the assessment of drainage projects and the factors affecting benefits from drainage was by L. E. Ashbaugh[2] in 1906. He believed that the persons determining assessments should give a classification percentage to each tract of land. The percentage would be 100% on that tract which received the greatest benefit and proportional percentages on all other tracts. His percentage system was useful not only for the initial apportionment of assessments but also for future assessments. He used the following factors in determining benefits: the land's inherent need for drainage (degree of wetness), the sufficiency of the improvement to drain it, each tract's proximity to the improvement, and each tract's proximity to a natural outlet. Ashbaugh also thought that the drainage of high quality land might yield more benefit than the drainage of low quality land due to a greater increase in productivity on the first.

One of the first attempts at using an equation for distributing drainage assessments was made by S. T. Morse,[16] in 1912. In direct contrast to Ashbaugh he believed that such items as the cost of the improvement, the distance of the tract from the outlet, or the tract's location on the branches or the mains, and the land's assumed present state of wetness did not in any way confer benefits on the lands for agricultural and sanitary purposes. Instead he believed that the basic principles to which benefits must be referred were the relative elevation of the land to the proposed drain and the depth and size, or efficiency of the drain. Finally, he stated that $A = \frac{100\,X^1\,Y}{Y^1\,X}$ was a simple formula for the equitable classification of all tracts of land for assessment purposes. In this equation, A was the classification of a certain tract, X was the additional depth given the outlet of the most benefited tract on the project, Y was the change in elevation from the base of the present outlet to the mean plane of the most benefited tract, X^1 was the additional depth given the outlet of the tract in question, and Y^1 was the change in elevation from the base of the present outlet to the mean plane of the tract in question.

J. W. Lee[14] believed that land should be assessed on the basis of its condition or need for drainage or degree of wetness. He also believed that the best procedure for distributing drainage assessments in use in Iowa in 1914 was one that divided the drainage district into forty acre tracts. Then the tracts were divided into classes by the district commissioners. The four classes used were swamp, wet, low, and high. They were defined as follows: swamp, land that was worthless swamp; wet, wet grass land too wet to till; low, low plowed land that needed tiling; and high, high lands that received little benefit from the drainage improvement. Each respective classification was assessed: 100%, 70%, 30%, and 3%.

Lee also stated that the district commissioners should consider each tract individually for exceptions or conditions which warranted an increased or a decreased assessment. The commissioners should consider the difference in elevation between each tract to the course of the proposed improvement, the course of the overflow water from the existing ditches, the location of the tract in respect to the outlet provided by the new improvement, and the distance from the tract to the drain in their exceptions or conditions.

Guy R. Campbell[5] in 1915 disagreed with Lee. He believed that the distance from the tract to the drain should not affect assessments directly, but only as it affected out-of-pocket cost incurred by the owners to secure drainage equal to that of owners directly on the drain. Campbell also thought that Lee should have considered the depth and the size of the drain in his method.

J. L. Parsons[17] in 1915 stated that the various factors influencing just assessments were:

1. The location of the tract in reference to the main drain.

2. The location of the tract in reference to the outlet of the main drain.

3. The comparative elevation of the tract.

4. The relation of classifications to assessments.

5. The design of the main as affecting the tract.

6. The comparison of the cost in and requirements of different sections of the watershed.

7. The soil fertility of the various tracts.

He also expressed the opinion that an assessment procedure to be successful and acceptable to landowners, attorneys and judges must provide equitability and simplicity. With this in mind he divided the watershed into forty-acre tracts similar to Lee and based his assessment scheme on the class of land, proximity to the drain, and proximity to the outlet. The class of land referred to the condition of the land adjusted by a consideration of the ease and cost of draining. For example, swamp was benefited more than drier land. Proximity to the drain referred to the distance of each tract from the drain. If a tract lies along the drain, it was assumed to accrue benefits from the drain carrying its surface water away and the drain preventing flooding and overflow from above. Tracts distant from the drain were benefited less because expensive lateral ditches or tiles must be constructed to achieve the benefits immediately accrued to more adjacent lands. Proximity to the outlet was the distance of the tract from the main outlet. This considered the differences in benefits accrued from the relative position of the tracts within the district due to elevation and subjection to overflow. Using the above factors, Parsons gave each tract a percentage classification and calculated assessments the same as Ashbaugh.

Within the last few years, Carl M. Anderson[1] has recommended a method for apportioning assessments for an open ditch. It was based on the following factors: the distance from the mouth of the ditch to the tract, the average amount of soil removed from the ditch below the location of the owner's property, the average grade of the ditch bottom, the slope of the land to the ditch, the lateral distance from the ditch to the tract, and the difference in elevation between the ditch and the tract of land. Anderson combined these factors into a complicated procedure.

Assessment Procedures

There are several assessment distribution procedures in existence today. Boyd and Hart[4] listed the Percentage Method, the Classification Method, and the Actual Value of the Benefits Method as the major procedures. According to the Percentage Method, each factor that affected the physical conditions surrounding a tract and its drainage was given a separate value in percentage. From these combined percentages the relative benefit was finally determined. Boyd and Hart thought this method was complicated, so much so that it was confusing to both assessors and landowners, and therefore it was unsatisfactory. The Classification Method provided that the land be divided into five classes and that the ratio of assessments between the five classes be 5, 4, 3, 2, and 1. Boyd and Hart thought this method was far too inflexible to allow the fixing of equitable assessments. They also thought the simplest, the most readily understood, and the best procedure was the Actual Value of the Benefits Method. This method provided that the benefits conferred by the drainage improvement be estimated and the assessments be apportioned accordingly. This is basically the method used in Illinois today.

The True Outlet Cost Method was recommended by Allen D. Hauge[11] for apportioning the cost of mutual drainage systems. This method required each owner to pay for the value of a lateral tile, according to the size commonly used in that particular area, for that portion of the main installed on his property and for the entire group to equally share the cost of the oversize tile and the outlet cost on a per acre basis. The difference between the lateral tile cost and the cost of the main plus the outlet costs divided by either the watershed acreage or wet acreage as determined, gave an outlet cost per acre the same for every landowner in the watershed.

There are several "shortcut" methods for distributing drainage assessments. The first is the Flat Rate Method which presumes that the benefits and therefore, the assessments for all tracts are equal. The Ad Valorem Method makes assessments proportional to the property value of the tracts. Another method assumes the benefits conferred per tract are equal to the difference between the market value after improvement and the market value prior to improvement.[7] These methods do not make any attempt to estimate the actual benefits accrued from drainage and therefore are unsatisfactory.

FORMULATION OF THE METHOD

A method or procedure for distributing drainage assessments must be simple, readily understood, and easy to apply. This is especially true when large numbers of people are involved. The assumption was made that a method expressed in the form of an equation would provide the most equitable procedure. This assumption was based on the premise that an equation would apply the same factors in a similar manner to each tract of land, thus determining each assessment relative to every other assessment.

On the basis of previous work, the physical features that appeared to influence drainage benefits and that should be considered as part of an equation were as follows:

1. Coefficient of permeability of the soil on the tract of land. (Kn)
2. Shortest horizontal distance from the centroid of the tract to the main drain. (Ln)
3. Shortest horizontal distance from the centroid of the tract to the main outlet. (Dn)
4. Relative elevation between the mean plain of the tract to the main outlet. (Yn)
5. Depth of the main drain that corresponds to the tract. (Xn)
6. Productivity of the soil on each tract.

These physical features were combined and expressed in a tentative equation: $\frac{An}{A^*} = C_1 \frac{(XnY^*)}{(YnX^*)} + C_2 \frac{(Ln)}{(L^*)} + C_3 \frac{(Pn)}{(P^*)} + C_4 \frac{(Dn)}{(D^*)} + C_5 \frac{(Kn)}{(K^*)}$ where: An is the classification of tract n, and the * terms represent values for the tract reseiving the maximum benefit. C_1, C_2, C_3, C_4, and C_5 are the assessment-equation coefficients necessary to equate both sides of the equation.

Figure 1 shows the distances in a typical drainage project to be measured for use in the assessment equation. The main drain conveys the excess water, the cost of which is paid by the assessment. The main outlet is the point where the main drain discharges from the project.

The first part of the equation was taken from Morse (16); the depth of the main drain and the relative elevation to the outlet were considered. The other physical features were added to the equation, using Morse's idea of dividing the measurements for each feature by the maximum measurement for the feature on the project. Each tract was classified from zero to one, according to the amount of benefit received and as determined by the formulated equation; the higher the classification, the more benefit the tract of land receives. A* is 1.00, since it represents the tract of land on the project receiving the maximum benefit.

To compute the monetary assessment for each tract, a summation is made of all of the classifications within the project. Then the total cost is divided by this sum to determine a per-unit cost. Next, the per-unit cost is multiplied by the classification for each tract to determine the monetary assessment for that tract. Thus, the assessment represents the tract's share of the total cost, based on the drainage benefits received by that particular tract.

CALCULATING THE EQUATION COEFFICIENTS

The coefficients in the assessment equation relate the weighted influence of each selected physical feature to drainage benefits received from the project. To calculate the coefficients, the physical features of the land were correlated with the benefits of drainage, using multiple-regression analysis. The increase in crop yields as the result of improvements made in a drainage system was chosen to represent the benefits received. However, crop yields may be increased by better varieties, technological

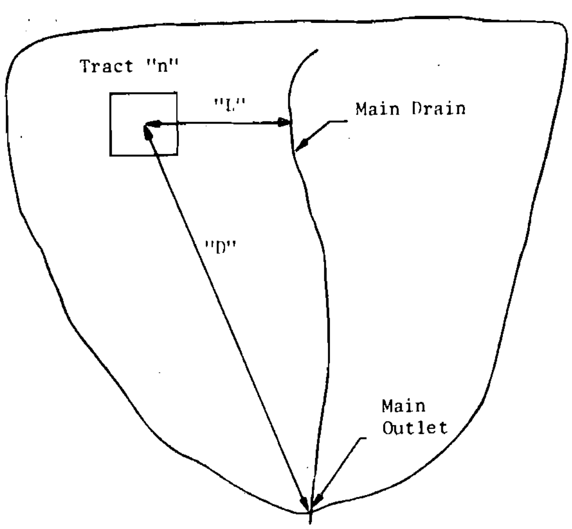

Figure 1. A typical drainage project.

advances, improved management practices, etc. To keep the effect of these extraneous factors to a minimum, the crop yields for two years before and after the installation of a drainage system were obtained, and the difference between the "before-drainage" and "after-drainage" yields was used as the measure of the benefits accruing from drainage. Both tile and open-ditch drainage systems were selected for study.

Corn was used as the crop for yield comparisons. Yields were obtained for each 40-acre tract from the records of farm managers or by interviewing the landowner or operator. The "before-drainage" and "after-drainage" yields were corrected for weather variation by using the Illinois Corn Yield Chart from the publication Weather Variability and the Need for a Food Reserve. (27) The corrected yields were calculated using the following equation: $X = \frac{Y}{1 - \frac{t-c}{c}}$ where: X = corn yields corrected to normal weather, Y = actual corn yields reported by the landowner or operator, t = expected corn yield based upon the technology for the specific year in question and normal weather, and c = expected corn yield based on weather data for the specific year in question using the Illinois Corn Yield Chart. (27) The average corrected "before-drainage" corn yield was subtracted from the average corrected "after-drainage" corn yield to determine the benefit.

The physical features were measured by the following procedures:

1. The shortest distance in feet from the centroid of the tract to the main ditch (Ln) and the shortest distance in feet from the centroid of the tract to the main outlet (Dn), as noted in Figure 1, were measured from the engineering plan of the drainage system.

2. The depth of tile or open ditch was measured in feet from the profile drawing of the drainage system.

3. The mean elevation of the tracts and the elevation of the

main outlets were measured in feet from topographic maps.

The productivity rating and the coefficient of permeability are dependent on the soil type. The area covered by the various soil types in each tract was measured from county soil reports or Soil Conservation Service soil maps. The estimated average yield per acre of corn for each soil type was used as the basis for the productivity factor for each soil type. Three soil reports--"McHenry County Soils",(20) "Wabash County Soils", (31) and "Will County Soils" (32)--were selected for this study, because they contained the latest information on expected average yields; also, because they illustrated the capability of different soil types under modern technology. The data on the coefficients of permeability for each soil type were taken from the "Drainage Guide for Illinois".(6) A weighted average area of each soil type was used to obtain the productivity rating and the coefficient of permeability for each tract.

The assessment equation coefficients were calculated by the IBM 7094 computer, using a multiple-regression program. The input to the computer consisted of the measurements of the physical features of each tract, the maximum measurement of each feature on the project, the increase in corn yield for each tract, and the maximum increase in corn yield on the project. The program output consisted of the equation coefficients, the multiple-correlation coefficient, the analysis-of-variance table for the F test, and the standard partial-regression coefficient.

RESULTS AND DISCUSSION

The equation coefficients using five independent variables and data from 28 tracts were not significant. It was observed, however, that the variables Ln/L*, Dn/D*, and Kn/K* were nearly twice as important as the independent variables XnY*/YnX* and Pn/P*. Therefore, it was decided to calculate the equation coefficients without the two less-important independent variables, in order to determine whether the multiple-correlation coefficient and the F value would become larger.

The equation coefficients with three independent variables (Ln/L*, Dn/D*, and Kn/K*) and 28 tracts were not significant, but the F value and the multiple-correlation coefficient did increase. Also, the three independent variables were nearly equal in importance. Because of this analysis, it was decided to use the independent variables Ln/L*, Dn/D*, and Kn/K* in the formulated equation, and to collect more data.

Additional tracts of land were analyzed until the equation coefficients became significant at a probability of 0.01. After data from 48 tracts were analyzed, the F value for three independent variables was equal to 8.23, and the multiple-correlation coefficient was equal to 0.5996.

The critical F for 3 and 44 degrees of freedom and a probability of 0.01 is 4.31. The standard partial-regression coefficients were the following: Ln/L*, 0.347965; Dn/D*, 0.297158; and Kn/K*, 0.226182. Since the F of 8.23 is greater than 4.31, the equation coefficients were significant at a probability of 0.01. The independent variable, Ln/L*, was 1.17 and 1.46 times more important than the independent variables Dn/D* and Kn/K*. The multiple-correlation coefficient showed that 36 percent of the dependent variable was attributable to the independent variables. This was low, because other factors besides drainage (such as management and technology) had affected the increase in corn yields.

The equation coefficients from the multiple-regression analysis were accepted because of the significant F value and the nearly equal importance of the three independent variables. This resulted in the following formulated equation:

$$An = 1.4845 - 0.3476\ (Ln/L^*) - 0.4680\ (Dn/D^*) - 0.4434\ (Kn/K^*).$$

The assessments obtained by the equation were compared to assessments that had been determined by district commissioners and approved by the courts. The purpose of this comparison was to determine the relationships between the assessments obtained by the equation method and the presently accepted methods.

The assessments calculated for Project No. 1 (see Table 1) were yearly maintenance assessments for the upkeep of an open-ditch and tile system. The assessments from the equation compared favorably with those from the district assessment roll. There was no apparent reason for those assessments that did differ.

The assessments calculated for Project No. 2 (see Table 2) were for the cleaning of an open ditch, the construction of conservation structures, and for tile repairs. In this case, the assessments from the equation were lower than the assessments from the assessment roll near the main drain, and larger for those tracts farther from the main drain and near the edge of the district.

Figure 2 shows that the assessments calculated by the equation for Projects 1 and 2 were not greatly different from the assessments on the assessment roll. Therefore, they appear to be within the present standards.

MECHANICS OF THE METHOD

Figure 3 shows an open drain, selected to illustrate the method. The drain is represented by the arrows extending through six 40-acre units to

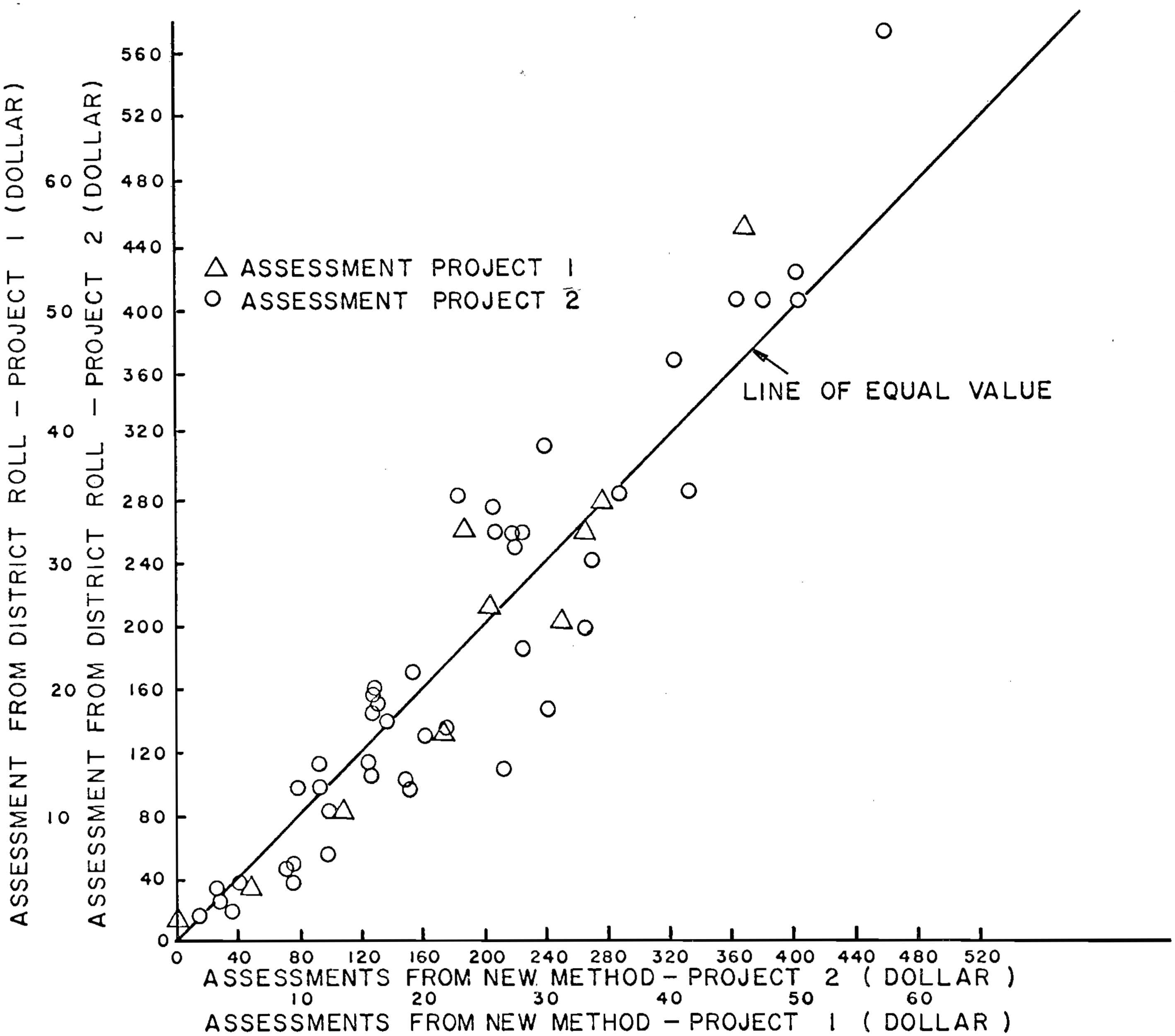

Figure 2. Assessments Calculated by Equation Are Comparable to Those on Assessment Rolls

the outlet and benefiting fifteen 40-acre units.

Table 1. Drainage Assessments From Project No. 1

Landowner	Assessment from District Roll	Assessment from Equation a/
County Roads	$ 1.80	$ 0.00
1.	4.10	3.80
2.	4.10	6.10
3.	6.10	9.50
4.	10.10	13.50
5.	16.30	21.80
6.	25.00	31.40
7.	26.50	25.90
8.	32.10	33.40
9.	32.60	23.80
10.	34.70	34.60
11.	56.60	46.20
Total	$250.00	$250.00

a/ The equation will calculate assessments to the nearest cent. The figures in the column "Assessment from Equation" have been rounded to the nearest 10 cents to make them consistent with those from the district assessment roll.

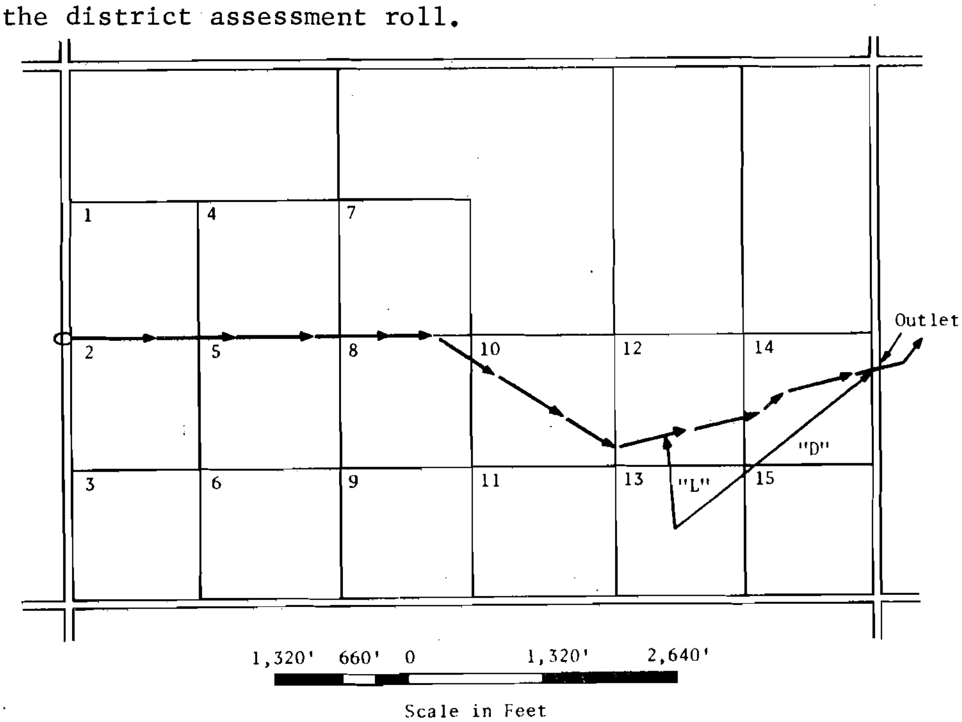

Figure 3. Plan view of group project.

To use the formulated method, the drainage district is divided into 40-acre tracts. Since most districts are irregular in shape, a few odd-

Table 2. Drainage Assessments From Project No. 2

Landowner	Assessment from District Roll	Assessment from Equation
1.	$ 16.20	$ 18.80
2.	19.30	36.40
3.	24.30	28.50
4.	36.50	41.20
5.	36.90	78.10
6.	46.20	72.40
7.	55.30	99.00
8.	81.10	100.90
9.	97.30	79.30
10.	97.30	94.10
11.	97.30	152.20
12.	100.60	150.90
13.	105.40	128.00
14.	109.50	214.00
15.	112.30	94.10
16.	113.50	126.10
17.	129.70	161.20
18.	131.80	176.40
19.	139.90	136.90
20.	146.00	128.00
21.	146.00	241.30
22.	150.00	132.20
23.	156.10	128.50
24.	160.10	129.20
25.	170.30	153.70
26.	184.80	226.80
27.	198.70	266.00
28.	241.20	270.70
29.	251.40	221.00
30.	257.90	225.20
31.	258.30	219.00
32.	259.50	208.40
33.	281.00	183.70
34.	283.80	288.60
35.	283.80	334.40
36.	286.40	193.90
37.	312.20	240.10
38.	367.10	322.90
39.	401.80	402.20
40.	405.40	379.90
41.	407.50	364.90
42.	423.70	402.30
43.	572.30	460.90
44.	a/	43.40
Total	$8,155.70	$8,155.70
Highways b/	186.50	186.50
Public School	8.10	8.10
Total Assessment	$8,350.30	$8,350.30

a/ The assessment for this tract of land was missing from the assessment roll.
b/ Since the equation is good only for agricultural lands, the highways assessment was not changed.

shaped areas will usually be left after the district is subdivided. These may be treated as individual tracts, with the areas recorded in acres.

The physical features that must be measured and entered into the equation are:

a. Distance, expressed in feet, from the centroid of each tract of land to the main drain.

b. Distance, expressed in feet, from the centroid of each tract of land to the main outlet.

c. The permeability of the soil on the tract of land.

The shortest distance from the centroid of each tract to the main drain and the shortest distance from the centroid of each tract to the main outlet are measured from an engineering plan of the drainage project. The coefficients of permeability are determined by measuring the area of each soil type on each tract from a soils map. Then the mean coefficient of permeability is selected for each soil type, from a drainage reference such as the "Drainage Guide for Illinois." (6) A weighted average may be used to compute the average coefficient of permeability for each tract.

In the example, the distances L, L*, D, and D* were measured from the plan view and recorded, as shown in Table 3. Each soil type in this project had the same coefficient of permeability, so the permeability was determined only once and K* was equal to K (Table 3). Using the assessment equation, each assessment classification (A) was calculated, also as shown in Table 3.

Table 3. Physical-Feature Measurements and Assessment Classification for Individual Tracts

Tract	L	D	K	A
1.	660	7,300	1.7	0.4631
2.	660	7,234	1.7	.4673
3.	1,980	7,392	1.7	.2256
4.	660	6,006	1.7	.5450
5.	660	5,940	1.7	.5492
6.	1,980	6,138	1.7	.3050
7.	660	4,726	1.7	.6261
8.	660	4,646	1.7	.6311
9.	1,749	4,884	1.7	.4249
10.	0	3,300	1.7	.8322
11.	1,056	3,670	1.7	.6234
12.	330	1,993	1.7	.8570
13.	924	2,534	1.7	.7185
14.	106	713	1.7	.9774
15.	1,155	1,690	1.7	.7314
	L*	D*	K*	
	1,980	7,392	1.7	8.9772

To obtain the assessment for each tract, the total project cost is divided by the sum of the classifications to determine cost per unit of classification. Then, the cost per unit of classification is multiplied by each tract's classification to determine the tract's dollar assessment.

In this example, the total project cost is $4,800.00, and the summation of the assessment classifications is 8.9772 (Table 3). Therefore, the cost per unit of classification is $534.69. To determine the assessment for each tract, multiply the assessment classification for each tract by the unit cost ($534.69). The assessment for each tract is shown in Table 4.

Table 4. Assessment for Each Tract

Tract no.		Cost per tract
1.		$ 247.62
2.		249.85
3.		120.61
4.		291.42
5.		293.66
6.		163.06
7.		334.75
8.		337.46
9.		227.19
10.		444.97
11.		333.33
12.		458.24
13.		384.18
14.		522.59
15.		391.07
	Total	$4,800.00

As stated earlier, a program was written to do the calculations on the IBM 7094 computer. The following is the calculation for tract 13 in Figure 3 and Tables 3 and 4:

Input Data: $L^* = 1{,}980$ ft. $D^* = 7{,}392$ ft. $K^* = 1.7$

Tract 13: $Ln = 924$ ft. $Dn = 2{,}534$ ft. $Kn = 1.7$

$$An = 1.4845 - 0.3476\,\frac{(Ln)}{(L^*)} - 0.4680\,\frac{(Dn)}{(D^*)} - 0.4434\,\frac{(Kn)}{(K^*)}$$

$$An\ (13) = 1.4845 - 0.3476\,\frac{(924)}{(1{,}980)} - 0.4680\,\frac{(2{,}534)}{(7{,}392)} - 0.4434\,\frac{(1.7)}{(1.7)}$$

$$An\ (13) = 1.4845 - 0.162 - 0.161 - 0.4434$$

$$An\ (13) = 0.7185 \text{ (classification)}$$

$$\Sigma An = 8.9772$$

$$\text{Cost per tract} = \frac{\text{Project cost}}{\Sigma An} \times An.$$

$$\text{Cost per tract (13)} = \frac{\$4{,}800}{8.9772} \times 0.7185$$

$$\text{Cost per tract (13)} = \$384.18$$

CONCLUSIONS

Like all mathematical equations, the proposed assessment equation is restricted by certain assumptions and limitations; therefore, it must be applied with judgment. The main limitation of this method is that it is applicable only for agricultural lands, since the coefficients were calculated using agricultural benefits from drainage. Also, the data for this study were collected from central Illinois; thus, the equation coefficients are only applicable to this area. It is assumed that the significant physical features will be similar in any area. However, further study would be needed to determine the coefficients for different geographic areas.

The formulated method is intended as a guide that will assist the drainage district commissioners and engineers in determining more equitably the benefits accruing from drainage. Therefore, it may be necessary for the monetary assessments calculated by the equation method to be adjusted by the drainage district authorities, so as to compensate for extenuating circumstances not considered by the equation.

It can be concluded from this study that three physical features significantly affect drainage benefits:

1. The distance from the tract of land to the main drain
2. The distance from the tract of land to the main outlet
3. The permeability of the soil on the tract of land.

The equation method offers a procedure and a computer program to equitably distribute drainage assessments, with a savings in labor and time in the preparation of the assessment roll. The results of the study have been discussed with attorneys and consulting engineers who serve drainage districts. Both groups were receptive to testing the equation as soon as appropriate projects are available. At the present time the equation is limited to the area which supplied the data for the coefficients. However, the procedure developed may be used to calculate coefficients for other areas and work will continue to assemble data from other soil and morphological areas so that appropriate coefficients can be determined.

LIST OF REFERENCES

1. Anderson, Carl M. Methods of watershed determination. Personal communication. Boone County Surveyor, Lebanon, Indiana. August 9, 1966.

2. Ashbaugh, L.E. The assessment of drainage districts. Journal of the Western Society of Engineers. 11:433-452. August, 1906.

3. Beer, C.E., Johnson, H.P. and Shrader, W.D. Yield Response of corn in a planosol soil to subsurface drainage with variable tile spacings. Research Bulletin 540, Agricultural and Home Economics Experiment Station, Iowa State University, Ames, Iowa. September, 1965.

4. Boyd, George R. and Hart, R.A. Drainage district assessments. UDSA Bulletin No. 1207. February, 1924.

5. Campbell, Guy R. Methods of levying drainage district assessments. 11th Annual Meeting, Iowa State Drainage Association. 79-84. 1915.

6. Drainage Guide for Illinois. University of Illinois, Cooperative Extension Service, Agricultural Experiment Station and USDA Soil Conservation Service, Urbana, Illinois.

7. Etchevery, B.A. Land Drainage and Flood Protection. McGraw-Hill Book Co. New York. 282-294. 1931.

8. Fly, Claude L. The soil drainability factor in land classification. Journal of the Irrigation and Drainage Division. American Society of Civil Engineers. 87, IR3:47-62. September, 1961.

9. Goodell, W.F. Development and application of a method for estimating the increase in agricultural production resulting from a flood control and drainage project. Unpublished M.S. Thesis, University of Illinois Library, Urbana, Illinois.

10. Hannah, H.W. Illinois farm drainage law. Circular 751, University of Illinois Cooperative Extension Service, Urbana, Illinois. 1965.

11. Hauge, Allen D. Methods of apportioning costs of mutual drainage systems. Rockford Brick and Tile Co., Rockford, Iowa. 1965.

12. Henderson, M.L. Discussion of An investigation into the efficiency and equity of present methods of levying assessments for drainage districts. 10th Annual Meeting, Iowa State Drainage Association. 33-37. 1914.

13. Johnson, Walter L. Some effects of excess water in the soil upon the growth and development of maize. Unpublished Ph.D. Thesis, University of Illinois Library, Urbana, Illinois. 1953.

14. Lee, J.W. An investigation into the efficiency and equity of present methods of levying assessments for drainage districts. 10th Annual Meeting, Iowa State Drainage Association. 26-32. 1914.

15. Menze, J.A. The economic evaluation of a drainage project. Journal of Soil and Water Conservation. 19-1:12-14. January-February, 1964.

16. Morse, S.T. Assessments for benefits from drainage systems for agricultural and sanitary purposes. Engineering and Contracting. 37:222-225. February 12, 1912.

17. Parsons, J.L. Land Drainage. Myron C. Clark Pub. Co. Chicago. 108-117, 251. 1915.

18. Pickels, G.W. Drainage and Flood Control Engineering. McGraw-Hill Book Co. New York. 462. 1924.

19. Powers, W.L. and Teeter, T.A.H. Land Drainage. John Wiley and Sons. New York. 165-171. 1932.

20. Ray, B.W. and Wascher, H.L. McHenry County Soils. Soil Report 81, University of Illinois Agricultural Experiment Station, Urbana, Illinois. 1965.

21. Sauer, E.L. Economics of soil and water conservation: effects of practices followed on farms in selected Illinois areas. Unpublished Ph.D. Thesis, University of Illinois Library, Urbana, Illinois.

22. Schwab, Glenn O., Taylor, George S., Fouss, James L. and Stibbe, Ehud. Crop response from tile and surface drainage. Unpublished paper, No. 65-217, presented at American Society of Agricultural Engineers Summer Meeting, June 1965.

23. Schwab, Glenn O., Kirkham, Don and Johnson, H.P. Effect of tile spacing on crop yield and water table level in a planosol soil. Soil Science of America Proceedings. 21-4:448-452. July-August, 1957.

24. Smith, R.S., DeTurk, E.E., Bauer, F.C. and Smith, L.H. Ford County Soils. Soil Report 54, University of Illinois Agricultural Experiment Station, Urbana, Illinois. 1933.

25. Smurr, Tom W. The Law of Farm Drainage. The Bobbs-Merrill Co. Indianapolis, Indiana. 1909.

26. Steel, Robert G.D. and Torrie, James H. Principals of Procedures of Statistics. McGraw-Hill Book Co. New York. 1960.

27. Thompson, Louis M. Weather variability and the need for a food reserve. CAED Report 26, Center for Agricultural and Economic Development, Iowa State University, Ames, Iowa. 21-47. 1966.

28. Tompkin, J.R. Effect of drainage on crop yields on selected soil types in east central Illinois. Unpublished M.S. Thesis, University of Illinois Library, Urbana, Illinois. 1947.

29. Troeh, F.R. Land form parameters correlated to soil drainage. Soil Science Society of America Proceedings. 28-6:808-812. November-December, 1964.

30. van Schilfgaarde, J. and Williamson, R.E. Studies of crop response to drainage. Transactions of ASAE. 8-1:94-100. 1965.

31. Walker, G.O. and Fehrenbacher, J.B. Soil Survey: Wabash County Illinois. Soil Report 83, University of Illinois Agricultural Experiment Station, Urbana, Illinois. 1964.

32. Wascher, H.L., Veale, P.T. and Odell, R.T. Will County Soils. Soil Report 80, University of Illinois Agricultural Experiment Station, Urbana, Illinois. 1962.

33. Wesseling, J. and Van Wijk, W.R. Land drainage in relation to crops and soils. Drainage of Agricultural Lands. American Society of Agronomy, Madison, Wisconsin. 461-504. 1957.

APPENDIX

Publications which have resulted from this project are:

1. Bengtson, Richard L. A method for distributing drainage assessments. Unpublished M.S. Thesis. University of Illinois at Urbana-Champaign Library. 52 p. 1967.

2. Bengtson, R.L., Drablos, C.J.W. and Jones, B.A. Jr. A method for distributing drainage assessments. Trans. of the ASAE 12-1:114-117.