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Open-file Report

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RGS  
OF  
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A STUDY OF REGIONAL  
UNIT VALUES FOR MINERALS

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## Foreword

Several purposes are served by circulation of the results of the Regional Unit Value study, participated in jointly by Bureau of Mines personnel and personnel of the Kansas Geological Survey.

1. An indication is given of the sophisticated work engaged in at the jointly sponsored seminar.

2. Knowledge of the method of grid spacing may be useful in and of itself for application to Bureau of Mines problems.

3. From the method of grid spacing comes the application of trend surface charts, where the layout of the mathematical or freehand curves has geographic significance.

4. Contour charts have come of increasing use as tools of analysis of trends, which may have application to particular resource problems.

5. The concept of regional unit value is a useful one and may furnish a basis of judgment of what returns will be obtained for a given investment in a particular region. In terms of Bureau of Mines projects, the concept of regional unit value may aid in consideration of mineral uses of land, as compared with use for dwellings or for recreation. It may be useful in estimation of the value of minerals lost if a given area is proposed to be flooded by a dam. In terms of program planning, it may be possible to estimate what increase in value of output will result from a given expenditure of Bureau of Mines funds for a particular mineral resource project.

6. In terms of exploration policy, the regional unit value maps have important significance. The Pennsylvania State University has become so much interested in regional unit value maps that Dr. John C. Griffiths, who headed the study group at the joint seminar, has been granted special funds to prepare a similar analysis for Pennsylvania. It is the opinion of Dr. Griffiths that exploration programs

are in part held up for want of knowledge of the worth of any particular region so that if we had value maps for the United States we could make a good guess on any area which resembled, in geologic terms, some specific area in the United States of known value.

7. In terms of national interests, Dr. Griffiths believes that a thorough knowledge of the natural resources of the United States is essential to national mineral planning policy and that the regional unit value maps on presently produced resources would be the first step. As time goes by, this point of view may become accepted federal policy and the Bureau of Mines could have substantial funds devoted to the project of determining regional unit values for all of the United States. The data for determining regional unit values would be available from the accumulated files of the Bureau of Mines. Thus potentially, the determination of regional unit values could become a big endeavor for the Bureau of Mines.

The explanation which I have prepared and the "bare bones" outline report prepared by the Kansas Geological Seminar are mostly all on methodology. For those who may at present or constructively may have interest in regional unit values, the detailed explanation of methodology may be of some interest and utility. I for one believe that the concept of regional unit values will become increasingly important not only for national mineral resource planning policy, and for planning exploration programs but also an analytical tool in consideration of the alternative use of land.

This particular study, as well as the others comprising the seminar, did not result from any set program at the seminar. Rather it arose from a general discussion held at the beginning of the seminar, which determined what study groups were to be formed. The services of Dr. Griffiths, as well as of the other professors working with the seminar groups, were all provided by the Kansas Geological Survey,

through the interest and broad vision of the Associate Director of the Kansas Survey, Dr. William Hambleton.

If there are any questions about methodology, please communicate with me.

Arthur Berger

Division of Statistics  
Washington, D. C.  
April 18, 1966

## REGIONAL UNIT VALUES

### Introduction

The Kansas Geological Survey and the Bureau of Mines participated in a joint seminar on mineral resource problems during the period June 14-25, 1965. One of the study groups formed under the leadership of Professor John C. Griffiths, head of the Department of Geochemistry and Mineralogy of the College of Mineral Industries, Pennsylvania State University, concerned the estimation of regional unit values, both on a unit area basis and on a unit volume basis.

The study was purely exploratory. The results of the study group with respect to the charts were issued exactly as done by the study group, rather than after polishing after the seminar was finished. A general summary only of the procedures of the study was prepared as part of the results of the study group. Because the methods employed are complicated, it was believed that an elaboration of them would give more meaning to the results of the study group.

The method of dividing the State into approximately equal areas by the use of grid coordinates is applicable to other states, as are the other methods employed. Because of the relatively uniform composition of the counties of Kansas, the grid coordinates method of apportioning the State may be relatively less troublesome than for other states where the counties are irregular in shape. For many states, the counties, as political subdivisions, vary considerably in areas covered. The study group indicates a method of utilizing county data to obtain a basis for values of minerals per unit of area and per unit of volume.

ESTIMATION OF THE VALUE OF A UNIT OF LAND FOR MINERALS AND  
AGRICULTURAL PRODUCTS PRODUCED

One of the topics which was covered in a study group of the joint seminar of the Kansas Geological Survey and the Bureau of Mines during 1965 was the estimation of the mineral value of a unit area of land of the state of Kansas. The study group was led by Professor John Griffiths, Head, Department of Geochemistry and Mineralogy, College of Mineral Industries, Pennsylvania State University. The methods developed are generally applicable to problems of this nature. A copy of the report is enclosed after explanatory text.

Because the methodology employed may not be fully comprehensible through a reading of the report, an exposition of the methods is offered herein. The analysis consisted of two parts, with the second being more interesting than the first. An estimate was made of the average mineral value of a square mile of Kansas. The mineral value estimated was the value based upon accumulated production in dollars to some specified date. This turned out to be \$100,000 per square mile. Then a projection was made for a 20-year period and an estimated value of \$120,000 per square mile was obtained.

The more interesting part of the analysis is that portion of the study concerning the variability of mineral values on a county basis. The 105 counties of Kansas were arranged on a symmetrical grid of seven (7) tiers (rows) of counties from north to south and in 14 columns from east to west. Some counties were grouped together to make the cells of approximately equal size. The value per county was assigned to each grid intersection. See map of Kansas attached. In terms of mathematical computation, there were a total of 98 points into which Kansas was divided. Seven different sets of data were obtained for each of these 98 points, and from these data a sixth degree equation was derived on the computer on a program already available at the University of Kansas.



If the map of Kansas is examined, it will be found that, except for a few cases, the intersection of the grid lines define the coordinates of a given county and may be used in mathematical analysis in place of the county. An illustration of an exception is the grid coordinates, 5, 1. By reference to Appendix Table 1 (explained in detail later), it will be found that Johnson and Wyandotte counties are listed for these grid coordinates. This is a case where two small counties are grouped together. This occurs for eleven sets of grid coordinates. If a county was large, it would have been assigned to more than one set of grid coordinates in order to have approximately equal areas assigned to each grid coordinate. Where a county would have to be broken into segments, some estimation would of course be required. In the case of Kansas, all that was needed was the adding together of the data for the two counties grouped for each set of grid coordinates. In all cases except the eleven, there was a one to one correspondence between counties and one set of grid coordinates with the result that the data for each county are assigned mathematically to the appropriate set of grid coordinates.

This type of analysis produces a contour map of mineral value for the State of Kansas. The fitted trend is thus a representation of the variation in mineral value for the different counties. The method is called trend surface analysis.

The effort in this regard was purely exploratory to determine the feasibility of establishing value maps per unit area (and per unit volume). The conclusion was reached that the approach is feasible. Certain recommendations are made by the study group for the refinement of the methodology.

The study group selected seven (7) county variables for the equation to determine the variation in value per county. The report indicates eleven county variables. However, some of the eleven variables were derived from other variables: 1. Total square miles of area was translated to thousand square miles and is not a separate variable, 2. Thickness of sedimentary crust was obtained by subtracting

depth of basement below sea level feet from elevation of surface above sea level in feet and dividing the result by 5280 to translate the figure to miles. The report counted the two items of basement and elevation as two additional variables, 3. The data on square miles of irrigated land is not a variable used in the equation, although counted as a variable in the report. However, it was used in the calculations of the value of products from irrigated land. The total value of products due to irrigation has to be calculated upon the basis of available agricultural data. Thus the area of irrigated land has to be obtained for the State as basic data, but it does not appear directly in the equation for estimation of variation of mineral values per county.

The county variables actually used in the analysis were:

1. Total Value of all Minerals in Million Dollars
2. Value of Products from Irrigated Land in Million Dollars
3. Crude Oil Production in Million Barrels
4. Natural Gas Production in Million Cubic Feet
5. Liquid Petroleum Gas Production in Million Barrels
6. Area in Thousand Square Miles
7. Thickness of Sedimentary Crust (explained above) in Miles

These seven variables were utilized in a particular way for the trend surface analysis. The variables used in the mathematical analysis for the 98 points were as follows:

- I. County total value of all mineral products per 1000 square miles (Item 1 divided by Item 6)
- II. County value of the total of all minerals and of agricultural products due to irrigation per 1000 square miles (Sum of Item 1 and 2 above divided by Item 6)
- III. County value of oil, natural gas, and liquified petroleum gas per 1000 square miles (Sum of value of Item 3, 4, and 5 divided by Item 6)

IV. County value of all minerals and of agricultural products from irrigated land less value of oil, natural gas and LPG production per 1000 square miles. (Sum of Item 1 and 2 above less sum of value of Items 3, 4, and 5 divided by Item 6)

V. County agricultural products value due to irrigation per 1000 square miles (Item 2 divided by Item 6)

VI. County value of minerals and agricultural products due to irrigation per 1000 cubic miles (Item II (already in area units) divided by Item 7 to translate numbers to unit volume basis).

The value of products from irrigated land is included by the study group because water is regarded as a mineral resource. This value of products from irrigated land is a derived figure, and was calculated from the available statistics on agriculture. The calculation of the wealth added to the land because of the use of water is an interesting and sophisticated facet in the derivation of the mineral worth of land by county.

As indicated above, Kansas was divided into 98 grid intersections. The six derived value figures for each county was assigned to each appropriate intersection of the map of Kansas, and was the basic data which were fed into the computer for the mathematical derivations.

The partitioning of Kansas into grids which gave an x and y ordinate for each county (or county group) is a key device of the study group in obtaining a mathematical formula for the variation in mineral values by county. This technique is applicable to other states. The data for the seven variables for each county were obtained from different sources. After the data for each county are obtained and are translated into the form for use in the calculations (Items I through VI above) the values are assigned each of the grid coordinates by use of the appropriate grid numbers for each county. The first two columns of Appendix

Table 1 are the x and y grid coordinates. The basic data are shown for each grid coordinate in Appendix Table 1 and the notation used is A, B, C, D, and G.

Appendix Table 2 is the same data as Appendix Table 1, only organized alphabetically.

Because of the sequence of work, the explanation herein given jumps to Appendix Table 5. Appendix Table 3 is explained as part of the explanation for Appendix Table 7 for which the thickness of the sedimentary crust is calculated for obtaining data on a cubic mile basis. Appendix Tables 3 and 4 are related to Appendix Tables 1 and 2 in that they represent basic data for each county or county group.

The value of minerals per 1000 square miles is derived as follows, using the basic data in Appendix Table 1. The values are shown in Appendix Table 5. Thus for Cheyenne County, which is the county in the upper right hand corner of the State, the grid coordinates (see map) are 7 and 14. (See columns x and y of Appendix Table 1 for Cheyenne County). The total value of minerals for the chosen year (1960) was .055 million dollars (Column B of Appendix Table 1) and the area in thousands of square miles 1.008. (Column A of Appendix Table 1 in square miles divided by 1000). Division of .055 million dollars by 1.008 gives the value of minerals for Cheyenne county as 0.054563 million dollars per 1000 square miles. Rawlins is to the right of Cheyenne. Rawlins county has the grid intersection of 7 and 13 (See map and columns x and y for Rawlins County of Appendix Table 1). For Rawlins county, the value of minerals was 1.569 million dollars (Column B, Appendix Table 1) and the county has 1.064 thousand square miles of area (Column A, Appendix Table 1 divided by 1000). The value in million dollars of all mineral production per 1000 square miles is 1.569 divided

by 1.064 or 1.474624 million dollars per 1000 square miles. This same procedure was followed for all counties or groups of counties prepared. As indicated, under the procedure no more than two counties were grouped together. In the report the value for minerals per 1000 square miles is shown in Appendix Table 5. The notation for the computer was Z (1). See the Z(1) column for x and y coordinates of 7, 14 and 7, 13, in Appendix Table 5 for Cheyenne and Rawlins Counties.

Cheyenne and Rawlins Counties are the first two counties listed in Appendix Table 5. They are indicated by reference numbers 1 and 2 of which there will be an explanation below.

In Appendix Table 5 as well as for the succeeding Appendix table through 11 the study report shows the values per square mile rather than per 1000 square miles. The interpretation was made that the area was scaled down by taking .001 of the area. Thus the data in Appendix Tables 5 through 11 may be viewed as either the values per 1000 square miles or cubic miles, or in square miles or cubic miles (scaled). Had the division of the values in millions of dollars been by square miles, the data would of course have shown more zeros after the decimal point. Alternatively to expressing the data in millions of dollars, another approach could have been to have expressed the data in thousand of dollars per square mile.

The explanation for each of the appendix tables will be in terms of division by thousand of miles, for ease in reference. However, it should be understood that the translation has to be made to view the area as scaled by a factor of .001, in the notation for the Appendix Tables 5 through 11.

The next step in the analysis is to obtain the values for each county or county group with its appropriate grid notation for the combined value of minerals and value of agricultural products due to irrigation per 1000 square miles. These

numbers are shown in Appendix Table 6. The computer notation is Z(2). For Cheyenne County in Appendix Table 1, we find that the value of agricultural products due to irrigation in millions of dollars (Column D on Appendix Table 1) is .138. The mineral product value as indicated above (Column B of Appendix Table 1) is .055 million dollars. This gives a total of .193 million dollars for both combined. If this is divided by 1.008 (Column A of Appendix Table 1, divided by 1000 or multiplied by .001 as explained above) the value per square mile in millions of dollars is .191468. This number is found in Appendix Table 6 for the first item in the table for the coordinates 7 and 14, which are the coordinates for the grid for Cheyenne County. For Rawlins county, with the grid coordinates of 7 and 13, Appendix Table 1 shows .040 million dollars of agricultural products from irrigated land, (Column D) and 1.569 million dollars for mineral products (Column B) or a combined total of 1.609 million dollars. The square miles of area is 1064 (Column A) of 1.064 thousand square miles. The result of dividing 1.609 million dollars by 1.064 is 1.512218 million dollars per 1000 square miles or per square miles (scaled). This result is shown as the second item for the coordinates 7, 13 coordinates in Appendix Table 6.

Column C is also on Appendix Table 1 but it was not used directly for the computer analysis; it was required to obtain the total value of agricultural products due to irrigation. The numbers in Column C are the square miles of irrigated land by county for Kansas thus no reference is made above to Column C for Appendix Tables 1 and 2.

Appendix Table 3 contains additional basic data for each county, the quantity of production of crude oil, natural gas and liquid petroleum gas. Crude oil production is labeled Column E, natural gas production is labeled Column F, and LPG production is labeled Column G in Appendix Table 3.

The values of oil and gas and LPG production are calculated from the basic data for Appendix Table 3 and are given in Appendix Table 7. In computer notation the value of oil, gas and LPG production is given the symbol Z(3). Let us take the same two counties again, Cheyenne and Rawlins, and trace how the numbers were derived by use of Appendix Table 3 for Appendix Table 7. The last column of the Appendix Tables 3 and 7 contains the numbers indicating the order of the counties.

In Appendix Table 1, which is in the same reference order number, it will be found that Cheyenne County (grid coordinates of 7, 14) was given reference number 1, and is listed first. See last column of Appendix Table 1. Rawlins County was given the reference number 2 and is second on Appendix Table 1. Thus, although the grid coordinates are not shown on Appendix Tables 3 and 7, they are there by implication through the reference number column, the last column on Appendix Table 3 and 7. By reference to Appendix Table 3, it is seen that Cheyenne County has no oil production (Column E) and no liquified petroleum gas production (Column G). Its production of natural gas in 1960 (Column F) in millions of cubic feet was 0.014. (See Column F, Reference number 1, on Appendix Table 3). This was valued at a price of \$0.11 per cubic feet. The multiplication of 0.014 by 0.11 gives .00154 million dollars and this divided by the area of 1.008 thousand square miles gives the value in millions of dollars per 1000 square miles (or per square miles (scaled ) of 0.001528). See Appendix Table 7 for value of production for reference number 1 for Cheyenne County.

According to Appendix Table 3 for reference Number 2, Rawlins County had no natural gas (Column F) or liquified petroleum gas production (Column G), but 0.545 million barrels of crude oil (Column E) was produced in 1960. (See Column E in Appendix Table 3 for reference number 2). This production is valued at \$2.85 a barrel. When 0.545 million barrels is multiplied by \$2.85 and divided by 1.064 (area in thousand square miles), the value in millions of dollars per 1000 square miles or per square mile ( scaled) is 1.459821. (See Appendix Table 7 for reference number 2

for Rawlins County).

Column G of Appendix Table 3 is the 1960 production of liquified petroleum gases in millions of barrels. (The unit of production for this product is different from that used in the Mineral Year Book which is in thousands of gallons). Only certain counties have LPG production. By reference to Appendix Table 3, it is noted that the county with reference number 47 has LPG production. This county also has crude oil and natural gas production. By reference to Appendix Tables 1 and 2 it is found that this is Rush County, reference number 47, with the grid coordinates 4,10. The price per barrel of LPG at which the production was valued, was \$1.85. Rush County has 719 square miles of area (Column A of Appendix Table 1), or .719 thousand square miles. The Rush County production of crude oil in millions of barrels is .301; the production of natural gas in millions of cubic feet is 1.681 and the production of LPG in millions of barrels is .010. If these productions are multiplied by \$2.85, \$0.11 and \$1.85 respectively, and then the sum of the products is divided by .719, the resultant value in millions dollars per 1000 square miles or per square mile (scaled) is \$1.476022. This is the number shown in the Z column for reference number 47, Appendix Table 7.

Kearney County, reference number 58, grid coordinates 3, 13, is worked the same way. It will be noted that Appendix Table 7 shows 9.924935 for this county. This high value for the fuels results from a very large quantity of the natural gas production for this county.

In Appendix Table 5, 6, and 7, the value of mineral products per 1000 square miles, the combined value of mineral products and value of agricultural products resulting from the use of irrigation water per 1000 square miles, and the value of the fuels per 1000 square miles are stated for each set of grid coordinates which thus covers all the counties of Kansas. All of the data for each county in these tables are derived as explained above.

Appendix Table 8 is derived from Appendix Tables 6 and 7. For each grid coordinates the value of the oil, gas and LPG production shown in Appendix Table 7 is subtracted from the value of all mineral products, including the value of products coming from the use of irrigation water, shown for the grid coordinates in Appendix Table 6.

For Cheyenne County, the total value of minerals and agricultural products due to irrigation is 0.191468 million dollars per 1000 square miles (Appendix Table 6 reference number 1). The value of the fuels production is 0.001538 (Appendix Table 7, reference number 1). If the fuel value is subtracted from the total mineral value the result is .189940, the first figure shown in Appendix Table 8 for reference number 1. The computer symbol for these values is Z(4).

Appendix Table 9 comes from Appendix Table 1. The value of agricultural products due to irrigation shown in Column D in Appendix Table 1 is divided by the area shown in Column A of Appendix Table 1, expressed in thousands of square miles. Thus for Cheyenne County, .138 (reference number 1, Column D of Appendix Table 1) is divided by 1.008 (Column A of Appendix Table 1 divided by 1000) to obtain the value of agricultural products per 1000 square miles. This value has been given the symbol Z(5) for the computer. In Appendix Table 9, the result 0.136905 is shown as the first item, reference number 1 for grid coordinates 7,14.

As indicated before, the variable Z(6) failed to run on the computer and was subsequently omitted. Only Z(7) was used by the computer in terms of a cubic miles value variable. The numbers for Z(6) are in Appendix Table 10 and for Z(7) in Appendix Table 11. Both tables are expressed in terms millions of dollars per 1000 cubic mile or per cubic mile (scaled). Appendix Table 10 gives the value of minerals (not including the value of agricultural products due to irrigation) in million of dollars per 1000 cubic miles or per cubic mile

scaled). Appendix 11 includes both the value of minerals and the value of agricultural products due to irrigation per 1000 cubic miles (or per cubic mile (scaled)).

The technique for cubic mile analysis is derived very interestingly. The values per 1000 square miles (or square mile (scaled)) are divided by the thickness of the sedimentary crust for each of the grid coordinate intersections (county or county group) into which the State was divided. For each county, figures were obtained on the elevation of surface above sea level in feet and the depth of the basement below sea level in feet. The difference between the two is then divided by 5280 to get the thickness of sedimentary crust in miles. It will be recalled that figures had already been obtained on the square mileage of each county or county group.

The numbers for the calculation of the thickness of sedimentary crust are shown in Appendix Table 4.

Again for Appendix Table 4, the reference to the grids is obtained by the reference number shown in the last column of Appendix Table 4. The elevation above sea level is the column marked "E" and the Depth of Basement is the column marked "F". Although the notation "H" and "I" are used on page 4 of the report to refer to these two sets of data, the appendix table does not use this notation.

Since the depth of basement numbers are negative, the effect of the formula of subtracting the basement number from the elevation number is to add the two numbers together to get the thickness of the sedimentary crust.

The source of these numbers is of course, from the geological information on the structure of Kansas. The study thus welds together geologic data with minerals data as well as agricultural data. Again the numbers are assigned to each set of grid coordinates representing all the counties of the State.

For Cheyenne County the average elevation is 3400 feet (column E, Reference No. 1 Appendix Table 4) and the basement depth is minus 2050 feet (Column F, Reference No. 1 Appendix Table 4) or a total thickness of crust of 5450 feet. If this is divided by 5280 feet, the thickness in miles is 1.032197. From Appendix Table 5, the value of minerals in millions of dollars per 1000 square miles or per square mile (scaled) is 0.054563 for Cheyenne County, (reference number 1, grid coordinates 7, and 14). This number, divided by 1.032197, gives a value in millions of dollars per 1000 cubic miles or per cubic mile (scaled) of .052861. (Appendix Table 10 shows the number as .052862).

For Rawlins County, reference Number 2, grid coordinates 7, 13, Appendix Table 4 shows elevation 3000 feet and basement depth of minus 2000 feet. The thickness of the sedimentary crust is therefore 5000 feet. In terms of mileage, the thickness is .94696966. Appendix Table 5 showed, for Rawlins County, the value of minerals to be 1.474624 million dollars per 1000 square miles or per square mile (scaled) (Reference No. 2, grid coordinates 7,13). If this number is divided by the thickness factor, the value of minerals in millions of dollars per 1000 cubic miles or per cubic mile (scaled) is 1.557203, which is the number shown in Appendix Table 10 for reference Number 2, grid coordinates 7, 13. The computer symbol for this factor is Z(6).

The total value of minerals and of agricultural products due to irrigation per 1000 cubic miles is computed in the same way. For Cheyenne County, reference Number 1, Appendix Table 6 shows .191468 million dollars per 1000 square miles. If this is divided by the thickness factor, 1.032197 (see above), the result is .185496 million dollars per 1000 cubic miles or cubic mile (scaled). This is the figure shown for reference Number 1 for Appendix Table 11. For Rawlins County, the value per 1000 square miles shown in Appendix Table 6 is 1.512218. If this is

divided by the thickness factor, .94696966 (see above), the value in millions of dollars per 1000 cubic miles or per cubic mile (scaled) is 1.596902, which is shown for reference Number 2 in Appendix Table 11.

The computer symbol for this factor is Z(7). Appendix Table 12 shows the computer program written for this trend surface analysis.

After the Z variables have been obtained for each grid coordinates, the 98 grid values can be changed in order by having all the data for 1,14; 2,14; 3,14; 4,14; 5,14; 6,14 and 7,14 arranged together. The numbers for the Z(1) variable are shown in this way on Figure 1. Figure 1 has seven sets of numbers horizontally opposite particular values of Y. The Y scales have been interpolated. Across the paper against 14 on the Y scale are shown the numbers 1693, 350, 53, 1, 7, 35, and 5. These numbers all come from Appendix Table 5. For a y of 14 and an x of 1, the Z value shown is 16.938718. The figures on the table have been multiplied by 100 from millions to hundred millions. Therefore the plotted figure for  $x$  y for 1,14 (Morton County) is 1693. For an x of 2 and a y of 14, Stanton County, the Z value shown on Appendix Table 5 is 3.502190 or if multiplied by 100, the result is 350. For an x of 3 and a y of 14, Appendix Table 5 shows 0.536585, or multiplied by 100, the result is 53. Other values for this y line of 14 are obtained in this way.

Other lines of values are found the same way. The 12 line is not posted exactly against the quantity 12.00 on the y scale. For the 12 line of Figure 1, the values are obtained for an x of 1,2,3, etc, with a y value of the grid coordinates of 12. For example, from Appendix Table 5 it will be found for an x of 1 and a y of 12, the value of Z(1) is 9.395023, or multiplied by 100, the result is 939. This is the number posted as the first item on the 12 y line on Figure 1.

The numbers for Figures 4,7,9,11, and 14 are derived the same way. The source of the numbers for Z(2) in Figure 4 is Appendix Table 6. The numbers for Figure 7, for Z(3) come from Appendix Table 7. The numbers for Figure 9 for Z(4) come from Appendix Table 8. The numbers for Figure 11 for Z(5) come from Appendix Table 9. The numbers for Figure 14 for Z(7) come from Appendix Table 11.

All the numbers on each of these figures comes from these appendix tables and are raised by multiplication by 100 to get rid of the decimal, except figure 11 for which the numbers from the Appendix Table 9 are multiplied by 1000.

Thus all the above indicated six charts, 1, 4, 7, 9, 11 and 14, have the original data raised by 100 or 1000 on the charts. Figures 1, 4, and 14 as well as Figure 6 (and Figure 16 explained below) also have some free hand contours drawn on the charts. These will be explained below.

For easier understanding, the numbers on Figures 3, 6, 13, and 16, are explained next. These charts all have a listing of residuals, based upon the mathematical curves shown in the remaining figures. The trend surface charts and the free-hand contour lines will be explained as one unit after the explanation of the residuals.

Figure 3 is the listing of the deviations of the mathematical curve from the actual mineral values. There are a string of plus and minus numbers across the page at the y ordinates of 14, 13, 12, etc. In place of the scale above the numbers, the x ordinates of 1, 2, 3, 4, 5, 6, and 7 may be substituted. Thus, plus 71 applies to grid coordinates  $\begin{matrix} x & y \\ & 1,14 \end{matrix}$ ; minus 989 applies to grid coordinates  $\begin{matrix} x & y \\ & 2,14 \end{matrix}$ ; minus 237 applies to grid coordinates  $\begin{matrix} x & y \\ & 3,14 \end{matrix}$ ; ..... and minus 142 applies to grid coordinates  $\begin{matrix} x & y \\ & 7,14 \end{matrix}$ . With the grid identification of the residuals, the counties involved are clearly defined. As explained below these residuals represent numbers to the  $10^4$  power (except for chart 14 which has numbers to the  $10^3$  power). Thus 989 represents \$9,890,000; 142 represents a residual of \$1,420,000.

The arrangement of the residuals is on the same basis as the numbers on Figures 1, 4, 7, 9, 11 and 14. The mathematical value was obtained for each set of grid coordinates and the residuals for each set of grid coordinates were arranged in the same way as the above indicated charts. Thus the residuals were lined up for each x ordinate applying to the same y ordinate. The chart thus has the different x ordinates 1, 2, 3, 4, 5, 6, and 7, on one line against a specific y ordinate such as 14, 13, 12, 11, etc. The highest y ordinate is thus as the top of the chart.

As indicated above, the grid coordinates 1, 14, refers to Morton County. This may be verified by checking the map and also referring to Appendix Table 2, where the counties are arranged alphabetically. For Morton County, (grid coordinates 1, 14), the actual mineral value was 1693, as explained above. The mathematically determined value was 1622 or a difference between the actual and the computed of plus 71. For Stanton County (grid coordinates 2,14), the computed was considerably in the excess of the actual. The subtraction of the computed from the actual resulted in a large negative difference, indicating that the actual was 989 less than the computed.

For Hamilton County (grid coordinates 3,14), the actual was 53. It should be noted that the trend surface chart Figure 2 shows that the G cross-hatch and the "H" cross-hatch (explained below), come into this grid area. However, the mathematical value for the 3,14 coordinate is in the 300 range. The result is that the actual is less than the computed by 237.

There was a large underestimate of the mineral values by the mathematical equation for some counties. Take Ellis County, (grid coordinate 5,10). The actual is 3591 (See Appendix Table 5). The deviation or residual is an excess of the actual over the computed of 2078. In dollars this represents an excess of actual over the computed of \$20,780,000, (See explanation of values below).

The residuals for all counties in Figure 3 are calculated this way and the residuals are calculated this way for Figures 6, 13, and 16. The contour lines on

Figures 6 and 16 will be explained later, along with the contour lines on Figures 1, 4, and 14, mentioned above.

To explain the geographical significance of the values as placed on the Figures 1, 4, 7, 9, 11 and 14, and Figures 3, 6, 13, and 16, the effect of going from 1 to 7 across the page for the given y coordinate is to go from south to north up the State of Kansas and from west to east. For example, for the y coordinate 14, the counties for the x ordinate 1, 2, 3, 4, 5, 6, and 7 are as follows:

See map and Appendix Table 2

<u>Name of County</u>	<u>Grid Coordinates</u>
Morton	1,14
Stanton	2,14
Hamilton	3,14
Greeley	4,14
Wallace	5,14
Sherman	6,14
Cheyenne	7,14

In Appendix Table 2, the counties are arranged alphabetically and it will be seen that these counties have the indicated grid coordinates.

Figures 2, 5, 8, 10, 12 and 15 are charts of the mathematically derived trend surfaces. If each of these figures is turned on its side, the relationship to the map of Kansas is as above that one is going from south to north and from west to east. It will be recalled that the charts with the numbers across the page at each coordinate such as Figure 1, 3, etc. were explained as arranging the x coordinates for any particular y coordinates from 1 to 7, and that furthermore the effect of this arrangement is go from south to north and from west to east, geographically. The mathematically derived trend surface have the same geographic reference as the source charts, figures 1, 4, 7, 9, 11 and 14, and the residual charts, figures 3, 6, 13, and 16.

Thus for any trend surface chart a line drawn from the upper right hand corner to the lower left hand corner is to go geographically from the northwest corner of the state to the southeast corner of the state. For the trend surface chart, the use of the grid coordinates has a geographical meaning as well as a mathematical meaning. This arose because the counties were assigned grid numbers and each value was taken mathematically as the intersection of particular grid coordinates which had geographic significance.

The trend surface charts have significance with respect to the trend of comparable mineral values. A belt of a particular value level is traced mathematically (geographically) across the State, in accordance with the facts obtained for all the counties.

The value levels are indicated by the different cross-hatchings of the trend surface charts.

Figure 2 is the first of the trend surface charts attached to the report of the study group. As indicated above, the chart, to be read properly, should be turned on its side. The various cross-hatching legend indicate different value levels. North is at the top of the chart, the west is to the left. The cross-hatching for this chart shows "D", "E", "F", "G", "H", "I", "J" and "K". This chart is the trend surface mathematically determined for the value of minerals (not including the value of agricultural products due to irrigation) per 1000 square miles. The source of Figure 2 is Appendix Table 5. It has already been indicated that the data on Appendix Table were rearranged so that one would have all the values pertaining to a particular y ordinate of the grid coordinates in one line going across the page, or if the chart is turned on its side, going from the x ordinate 1 at the bottom and proceeding to 7 at the top. It will be recalled that this was the arrangement for Figure 1 where the numbers were shown across the page. The deviations were shown across the page in the same manner for Figure 3.

The mathematically derived chart is arranged the same way. The geographic interpretation given above stems from this arrangement of the data for the various grid coordinates. This principle of arrangement applies to all the mathematically derived trend surface charts, which are, in addition to Figure 2, Figures 5, 8, 10, 12, and 15.

One final note of recall about Figure 2 is that it was stated above that the numbers for Figure 1 derived from Appendix Table 5 were multiplied by 100 to get rid of the decimals. Figure 2 follows the same procedure. The values on the chart are to interpreted as numbers to the  $10^4$  power or in ten thousand of dollars rather than millions of dollars. The resultant dollar figure is the same--i.e., .43 times  $10^6$  is the same as 43 times  $10^4$  or \$430,000.

It will be noticed that Figure 2, a mathematical trend surface chart, has numbers along side each set of cross-hatching. The numbers are not shown on any other contour chart but apply the same way to all the mathematically derived contour charts. All numbers are therefore in  $10^4$  power. The chart is read by adding the numbers for the cross-hatch to \$350,000 (.35 times  $10^6$  or  $35 \times 10^4$ ). The dollar figure \$350,000 represents the base or 0 contour.

To procede up the scale, 23 plus 35 equals 58 times  $10^4$  or .58 times  $10^6$  dollars or 580,000. Twenty-five plus 35 equals 60 or \$600,000. It is noted that the range for the intervals is \$20,000. The average for this particular range is thus \$590,000. This represents the maximum average value to which the fitted sixth degree polynomial reached. Thus the cross-hatch "D" is the maximum range obtained from the fitted data.

The value meaning of the cross-hatches are as follows:

Type of cross-hatch

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Range of values indicated on  
 Figures 2

---

LEGEND

As marked on chart

Actual dollar  
 represented

D	23 to 25	\$580,000 to \$600,000
E	15 to 17	\$500,000 to \$520,000
F	11 to 13	\$460,000 to \$480,000
G	7 to 9	\$420,000 to \$440,000
H	3 to 5	\$380,000 to \$400,000
I	-1 to 1	\$340,000 to \$360,000
J	-3 to -5	\$300,000 to \$320,000
K	-7 to -9	\$260,000 to \$280,000

As stated above \$350,000 was the mathematical base for the charts. It is noted that for cross-hatch "I", the average of the interval range is zero and the average dollar value for the interval range is \$350,000. The width of each interval is 2 times  $10^4$  or \$20,000. Although the legend for each cross-hatch is not shown on the mathematically derived trend surface charts other than Figure 2 the meaning of the trend surfaces is indicated by the cross-hatch letter used. At the top of each mathematical legend chart, 35 is shown at the top of the page as the reference contour and 2 is shown as the contour interval.

Figure 2 as well as all the other mathematically derived charts is based upon a sixth degree polynomial. By reference to Figure 3, it is clear from the residuals from the mathematical trend surface that the sixth degree surface does not go high enough for some county values. Ellis county, reference number 33, grid coordinates  $\begin{matrix} x & y \\ 5, & 10 \end{matrix}$  had a value of minerals of almost \$36,000,000 per 1000 square miles. Barton County, reference number 48, grid coordinates  $\begin{matrix} x & y \\ 4, & 9 \end{matrix}$  had a mineral value of \$34,000,000 per 1000 square miles. These high mineral values were reflected in large excess of the actual over the computed. If reference is made to Figure 3, it will be found that at the 10 y coordinate line, counting over 5 (x coordinate), the residual was 2078 times  $10^4$  per \$20,780,000. For Barton County at the 9 y coordinate counting over 4 (x coordinate), the residual was \$20,000,000.

It is clear that for Kansas, the surface is more complex than can be fitted by a sixth-degree polynomial. The large residuals show this. Accordingly, the

study group had recommendations for changing the procedure in order to reduce the deviations from the computed, or to state it differently to reduce the unexplained variation in the county unit values.

Figures 2, 5, 8, 10, 12, and 15 were all prepared the same way.

Figure 5 is mathematically derived from Appendix Table 6 which is the combined value of minerals and value of agricultural products due to irrigation per 1000 square miles, Z(2). Figure 8 is mathematically derived from Appendix Table 7 on the value of crude oil, natural gas and liquified petroleum gas per 1000 square miles, Z(3). Figure 10 is derived from Appendix Table 8 on the value of mineral products less the value of oil, gas and LPG production, Z(4). Figure 12 is derived from Appendix Table 9 on the value of agricultural products due to irrigation per 1000 cubic miles, Z(5). Figure 15 is derived from Appendix Table 11 on the value of mineral products and the agricultural products due to irrigation per 1000 cubic miles, Z(7). No chart is given for Appendix Table 10 which is for the Z(6) variable, (the value of minerals per unit volume) which did not run on the computer and was dropped. In other words Figures 2, 5, 8, 10, 12, and 15 are the mathematically derived trend surface charts for Z(1), Z(2), Z(3), Z(4), Z(5), and Z(7) variables obtained from the indicated appendix tables. Figures 5 and 15 are for the same combined values of mineral products and agricultural products due to irrigation. Figure 5 is on a unit area basis and Figure 15 is on a unit volume basis, and the two charts have some differences in the mathematical trend surface patterns.

Figures 2, 3, and 15 include the value of the crude oil, natural gas, and liquified petroleum gas. Figure 8 is the trend surface pattern of the value of crude oil, natural gas and liquified petroleum gas. It will be noted from a comparison of Figures 2, 3, and 15 with Figure 8 that the trend surface pattern of the three charts tend to follow the pattern for the value of crude oil, natural gas and liquified petroleum gas for the state of Kansas. As entirely different

pattern is found when the value of minerals and agricultural products is shown exclusive of the value of the fuels. See Figure 10 as compared to Figures 2, 5, 8, and 15. Figure 12 is the trend surface pattern for the value of agricultural products due to irrigation per unit of area, and is completely different.

The conclusion about the effect of the petroleum resources is highlighted by the study group, as it is a predominant effect for the state of Kansas.

The areas that have produced least in terms of mineral resources and are indicated in the trend surface charts are:

- (1) The northwest region
- (2) A north central and north eastern region
- (3) A region in south-central Kansas

Figure 10 is the contour chart for the value of minerals and agricultural products deducting the value of petroleum, gas and LPG. By reference to Appendix Table 8, the source of the data, it is seen that the data vary from .01 to 12 (in terms of millions of dollars). By contrast the range for the value of minerals and agricultural products including the value of petroleum, gas and LPG as seen from Appendix Table 6 varies from .01 to 35.9 (in terms of millions of dollars). The result is that the contours on Chart 10 spread apart and the changes in values are much less steep. The contour interval of \$20,000 is perhaps too large for resolving detail.

Figure 12 is the mathematical derived trend for the value of agricultural products, with the basic data coming from Appendix Table 9. The variation in the data is only from 0 to 2.8. In plotting the data on a geographic basis, as for the other variables, the numbers were multiplied by  $10^3$  rather than  $10^2$  as for the other charts. These numbers are shown on Figure 11. Figure 12 is the mathematically derived trend from these data as organized on Figure 11. The chart is to be interpreted as having only one contour line, with all the other area of the state having no contour. The zero contour cross-hatch or "I" is shown for the rest of the state. The blank space on the chart indicates the portion of the state where the value of agricultural products due to irrigation was more than 2 million dollars. By reference to Appendix Table 9, it is found that the grid coordinates for these counties were 2,14; 2,13; 3,12; and 4,13. These grid coordinates place the counties represented in approximately the indicated position on the mathematically derived trend-surface chart.

Charts 1, 4, 6, 14, and 16 have previously been referred to and contain numbers which are either the original data or the residual from the mathematically determined trend surfaces. On these charts are freehand contour lines. These lines represent approximately equal values as are indicated approximately by the data from the appendix tables (or the residuals) which are shown across the page. The contour lines, just as the mathematically determined trend surfaces come from the values which were found as the basic data (or residuals from the computed numbers) for each county or county groups. As was indicated previously, the numbers on these charts have geographical significance as well as magnitude. The geographical significance comes from the grid coordinates which are related to the map of Kansas. It has already been indicated that by arranging the magnitudes in such a way that the 1, 2, 3, 4, 5, 6, and 7 x ordinate of each number is on the same line as the y ordinate one is going diagonally from the northwest corner of Kansas to the southeast corner, if the chart is turned on its side.

The freehand contour chart for Figure 14 is incomplete. The study group found the freehand contours on a cubic mile basis sufficiently similar to the freehand contours on a unit area basis and therefore discontinued the contouring.

As was indicated above, a sixth degree polynomial fitted to the data was used for the charts. As part of the mathematical work, polynomials of the first, second, third, fourth and fifth orders were fitted for each of the variables, as well as the sixth order polynomial. The mathematical measure of the percentage of explained variance is given in Table 5. The first column, unlabeled in Table 5, is the degree of the polynomial. The other column headings indicate the Z factor and the percentage of variance explained is thus given for each Z factor for each degree of the equation. A first degree equation explains only 7% of the variance for the combined value

of minerals and agricultural products per unit volume (Z(7)). However, a sixth degree equation for that factor explains 41% of the variance. The same values on a unit area basis (Z(2)) have 45% of the variance explained by a sixth degree polynomial. The percentage of variance explained climbs with the degree of the equation, but as indicated previously, there are some wide differences between the trend surface value, mathematically derived, and the actual, even with a sixth degree equation.

In the recommendation for the future work, the suggestion was made that the grids should be more carefully designed to follow the parallels of latitude. It was also suggested that two tiers of counties in the adjoining states should be added to insure that the mathematical boundary effect does not distort the trends for Kansas.

Another recommendation was that one new variable should be added, a measure of the intensity of exploration effort. If this recommendation is practical for other states, then eight sets of variables would be available for each set of grid coordinates representing the counties.

Other recommendations concerned the possibility of performing the analysis at two-year intervals, the possibility of obtaining data for a long term period for more commodities, and a determination of whether the transformation of the data to logarithms aids the mathematical fit, and whether the computation of trend surface are necessary for all the variables.

Problem III

ESTIMATING REGIONAL UNIT VALUE

Participants

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## ESTIMATING REGIONAL UNIT VALUE

Since one of the most important items in determining the orderly development of a region is its estimated worth, it was considered pertinent to estimate the value of a unit volume of the earth's crust underlying the state of Kansas. When this is known, appropriate limits for investment in exploration and development may be set.

It is, at present, impossible to determine that any region is completely depleted so that the value estimated in this research represents the value based on the accumulated production in dollars to some specified date.

As a first approximation an estimate of the value per unit area, e. g. , per square mile, may be obtained from data based on the whole State for the period 1880-1963 by dividing the accumulated dollar value of all mineral industries resources to date ( $=\$8,838.8 \times 10^6$ ) by the total area of the State (82,276 square miles). This procedure yields the estimated average value per square mile of Kansas to be \$100,000.

As a second step the value of the production from 1880 to 1960 was projected on the basis of resources which could be produced at present rate of production in the 20 year period 1960-1980, and this yields a figure of value per square mile of Kansas for the period 1960-1980 of \$120,000.

The third step was to examine the variability of value per square mile for the state of Kansas; this step was carried out on a county basis. The 105 counties of Kansas were arranged on a symmetrical orthogonal grid of 7 tiers (rows) of counties from north to south in 14 columns from east to west (see Fig. 6) and the value per county was assigned to each point. Some counties, the smaller ones, were grouped together and others, the larger ones, were subdivided into halves to make the "cells" approximately of equal size. There are 98 (7 x 14) such cells.

This grid was used as a basis for contouring the values at each grid point and for fitting the surface trend map by computer. The fitted trend (up to six-degree polynomial) was used as a representation of the variation in value per square mile. It is clear that the fitted surface is a smoothed approximation to the "real" surface, and measured degree of fit of computed to observed are listed in Table 5.

### Data Gathering

The initial data were classified in terms of eleven original variables, A to J, as shown in Table 6. These eleven variables were then transformed into seven "value variables" ( $Z_1$  to  $Z_7$ , see Table 3) and the subsequent analysis was performed on the seven variables.

Information was collected from the following sources:

Economic Development for Kansas Mineral and Water Resources (a sector report), 1962: State Geological Survey of Kansas Special Distribution Publication 2.

Goebel, A.M., Heffelfinger, J.B., Gammon, D., 1952, Kansas...Our State. A Geography of Kansas: State of Kansas Board of Education.

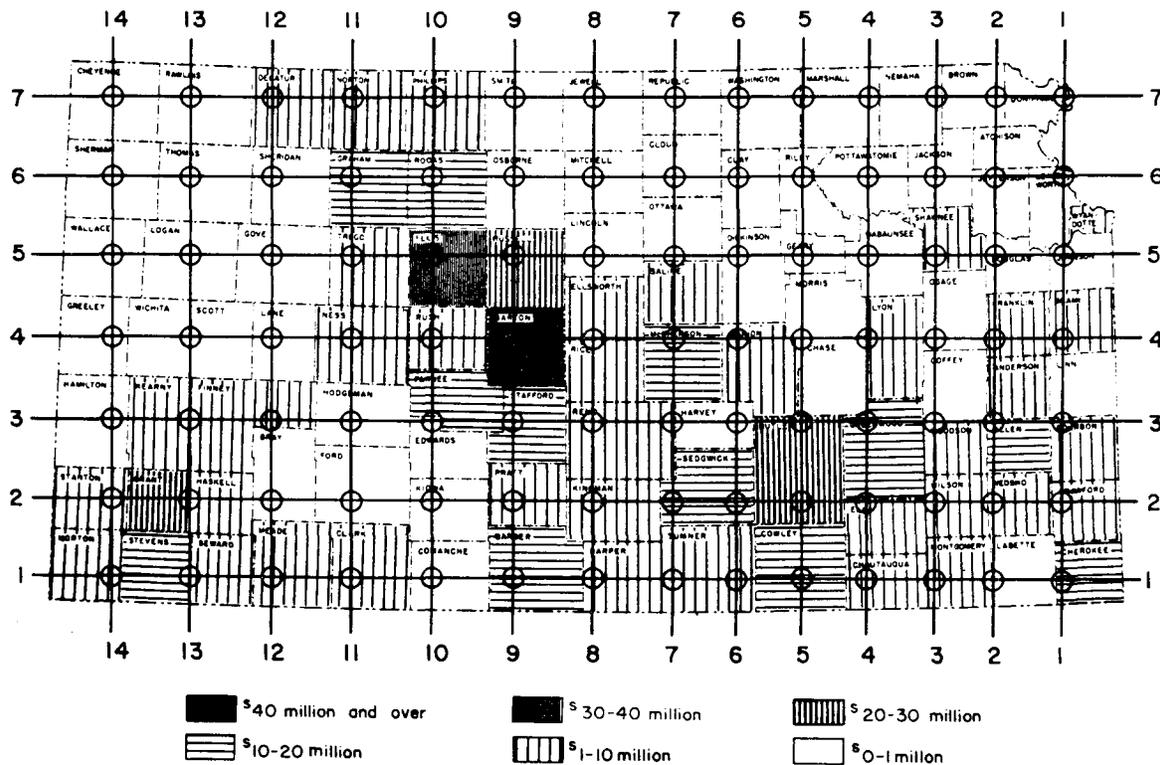


Figure 6 - Map of Kansas Showing Range of Annual Value of Mineral Production Per County Since 1950 with Super-Imposed Grid for Trend-Surface Analysis

Hilpman, P.L., Oros, M.O., Beene, D.L., and Goebel, E.D., 1964, Oil and Gas Developments in Kansas During 1963: State Geological Survey of Kansas Bulletin 172.

Hornbaker, A.L., Hardy, R.G., 1965, The Kansas Mineral Industry - 1964: State Geological Survey of Kansas Special Distribution Publication 17.

Kansas Agriculture 1963-1964 (47th Report), 1964: Kansas State Board of Agriculture.

Minerals Yearbook, 1961, Volumes I, II, III: U.S. Department of the Interior.

Minerals Yearbook, 1962, Volumes I, II, III: U.S. Department of the Interior.

Minerals Yearbook, 1963, Volumes I, II, III: U.S. Department of the Interior.

Notes on Ellsworth County, Gerhard, R. and Hardy, R.G. (not published).

Schoewe, W.H., 1956, The Mineral Industry in Kansas 1950 to 1954: State Geological Survey of Kansas Bulletin 119, Part 4.

\_\_\_\_\_, 1956, The Mineral Industry in Kansas in 1955: State Geological Survey of Kansas Bulletin 119, Part 8.

\_\_\_\_\_, 1957, The Mineral Industry in Kansas in 1956: State Geological Survey of Kansas Bulletin 127, Part 6.

\_\_\_\_\_, 1958, The Mineral Industry in Kansas in 1957: State Geological Survey of Kansas Bulletin 30, Part 6.

\_\_\_\_\_, 1959, The Mineral Industry in Kansas in 1958: State Geological Survey of Kansas Bulletin 134, Part 7.

\_\_\_\_\_, 1960, The Mineral Industry in Kansas in 1959: State Geological Survey of Kansas Bulletin 142, Part 6.

\_\_\_\_\_, 1961, The Mineral Industry in Kansas in 1960: State Geological Survey of Kansas Bulletin 152, Part 3.

\_\_\_\_\_, 1958, The Geography of Kansas: Transactions of the Kansas Academy of Science, Winter 1958, Vol. 61, No. 4.

Water in Kansas 1955 - Report to the 1955 State Legislature, 1955: Kansas Water Resources Fact-Finding and Research Committee.

Appendix to Water in Kansas 1955 - Report to the Kansas State Legislature, 1955: Kansas Water Resources Fact-Finding and Research Committee.

Table 5. Coefficients of determination =  $R_{ij}^2$  = Multiple Correlation Coefficient Squared.

Degree of Polynomial	Variable					
	Z <sub>1</sub>	Z <sub>2</sub>	Z <sub>3</sub>	Z <sub>4</sub>	Z <sub>5</sub>	Z <sub>7</sub>
	<b>Percentage of Total Variability for Z variable accounted for by degree of polynomial</b>					
1	10.2	11.9	11.4	14.3	28.2	7.3
2	16.0	17.1	18.7	19.1	47.9	14.7
3	18.9	20.1	20.7	23.3	55.9	18.3
4	32.8	33.3	33.2	27.9	62.9	29.4
5	36.5	36.8	36.6	32.4	71.9	33.0
6	44.7	45.5	43.6	46.2	79.4	41.0

Table 6. Basic variables measured

- A = Area (sq. mi.)
- B = Total value of minerals \$ x 10<sup>6</sup>
- C = Square miles of irrigated land
- D = Value of products from irrigated land in \$ x 10<sup>6</sup>
- E = Crude oil (Bbl.)
- F = Natural gas (M cu. ft.)
- G = Liquid petroleum gas (Bbl.)
- AA = A. \* .001 (Scaled)
- H = Elevation of surface (above sea level), in feet
- I = Depth of basement (below sea level), in feet
- J = ( (H-I) /5280) = thickness of sedimentary crust for Kansas, in miles

Table 7. Variables contoured, with legend

- Z (7) County total mineral value + agricultural products value due to irrig. per cubic mile
- Z (5) County agricultural products value due to irrig. per square mile
- Z (4a) = Z (2) - Z (3a) County value of mineral plus irrig. products less oil, gas and LPG
- Z (2) = County total mineral value + agricultural products value due to irrig. per square mile
- Z (3a) County oil, gas and LPG value per square mile
- Z (6) County total mineral value per cubic mile
- Z (1) County total mineral value per square mile

Legend for Variables for Trend Surface Fitting

- (1) ~~Z~~ (1) = B/AA
- Z (2) = (B + D)/AA
- Z (3a) = ( (E\*2.85 + (F\*0.11) + (G\*1.85) )/AA \*\*
- Z (4a) = Z (2) - Z (3a) \*\*
- Z (5) = D/AA
- Z (6) = B/AA.J = Z<sub>1</sub>/J
- Z (7) = (B + D)/(AA\*J) = Z(2)/J

   \*\* Corrected from Z (3) = ( (E\*3.0) + (F\* 0.11) + (G\*2.1) )/AA

### Surface Fitting

The data from the orthogonal grid were processed using the Trend 6 Program on the IBM 7074 computer at Kansas University. The output consisted of:

- (1) The raw data on the variables in Appendix Tables 1-11.
- (2) The Fortran program used to prepare the data for analysis by Trend 6 Program.
- (3) Contour maps of the raw data figures.
- (4) Trend surface maps of sixth degree for each of the six variables  $Z_1$  to  $Z_7$ .
- (5) Maps of residual values for sixth degree surface of variables  $Z_1$  to  $Z_7$  ( $Z_6$  omitted<sup>3/</sup>.)

### Summary of Conclusions

Examples of the variation in value per unit area and unit volume per county are:

(1) The value ( $Z_1$ ) of mineral resources for 1960 varies from about 36 thousand dollars per square mile for Ellis County to 6.76 dollars per square mile for Smith County.

(2) The value ( $Z$ ) of mineral resources plus agricultural products from irrigated water varies from 47.6 million dollars per cubic mile for Barton County to 14,000 dollars per cubic mile for Brown County.

In all the maps that contain information on the petroleum resources they dominate the picture and the value of the central uplift of Kansas is emphasized as a trend across the center of the state moving from northwest to southeast.

Similarly, the three areas that have produced least in terms of value of mineral resources are three, namely:

- (1) The northwest region.
- (2) A north-central and northeastern region (exclusive of Kansas City).
- (3) A small region in south-central Kansas.

If the value produced represents potentially depleted areas then these three are the most potentially promising for future exploration and development; the intensity of exploration efforts in these areas should be checked in order to decide whether in fact they are devoid of resources or whether they are really underdeveloped.

### Recommendations

This investigation was performed in order to decide the feasibility of establishing value maps per unit area and per unit volume of Kansas; this research indicates that this approach is not only feasible but desirable. The following procedure is recommended:

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<sup>3/</sup>  $Z_6$  program failed to run on computer and was subsequently omitted.

(1) The grid should be more carefully designed to follow the parallels of latitude. Two tiers of counties in the adjoining states should be added to insure that the mathematical boundary effect does not distort the trends for Kansas.

(2) The same variables may be used and one new one should be added, namely, a measure of the intensity of exploration effort such as dollars spent on exploration by drilled wells per cubic mile of sediments (i. e. , above Pre-Cambrian basement). It should be calculated as follows: appropriate cost function per foot of wildcat wells per county divided by volume (i. e. , cubic miles).

(3) The variables should also be transformed to logarithms and surface trends fitted.

(4) This analysis should be performed for each two-year interval for 1947-1965. An estimate of variance per two year period should be included.

(5) The feasibility of constructing a data matrix classified in terms of 105 counties by 65 years by a number of commodities (for example, the 13 commodities listed on p. 5 of Kansas Geological Survey Special Distribution Publication 17) should be explored. If feasible this data may be used as the basis for recommendation 4. There is also the possibility of fitting three-dimensional regression surfaces to such data through a computer program available at Denver Mining Research Center. These data would be used to project future trends.

(6) If the recommendations are implemented, careful planning and editing of computer programs should be undertaken to reduce the amount of computing effort, e. g. , not all the surface trend maps of 1 to 6 degree are necessary and some choice should be made of those that are required.

APPENDIX TABLE 1.

LIST OF ORIGINAL DATA USED FOR VALUE OF KANSAS STUDY

THIS LIST IS IN ORDER BY ROW AND COLUMN ON GRID

COUNTY OR COUNTIES	X	Y	A	B	C	D	NO.
CHEYENNE	07.	14.	1008.	.055	6.0	.138	1
RAWLINS	07.	13.	1064.	1.569	2.7	.040	2
DECATUR	07.	12.	891.	1.083	2.5	.043	3
NORTON	07.	11.	876.	2.547	2.5	.047	4
PHILLIPS	07.	10.	887.	5.531	1.2	.022	5
SMITH	07.	9.	888.	.006	1.2	.026	6
JEWEL	07.	8.	900.	.817	1.2	.014	7
REPUBLIC	07.	7.	704.	.207	2.2	.032	8
WASHINGTON	07.	6.	902.	.078	1.1	.016	9
MARSHALL	07.	5.	905.	.494	0.0	0.000	10
NEMAHA	07.	4.	716.	.039	0.0	0.000	11
BROWN	07.	3.	571.	.006	0.0	0.000	12
BROWN + DONIPHAN	07.	2.	475.	.380	0.0	0.000	13
DONIPHAN	07.	1.	378.	.377	0.0	0.000	14
SHERMAN	06.	14.	1049.	.371	4.7	.087	15
THOMAS	06.	13.	1065.	.102	5.5	.090	16
SHERIDAN	06.	12.	896.	1.296	6.2	.112	17
GRAHAM	06.	11.	895.	17.595	1.5	.010	18
ROOKS	06.	10.	890.	16.210	0.0	0.000	19
OSBORNE	06.	9.	894.	.224	5.6	.131	20
MITCHELL	06.	8.	713.	.026	3.0	.047	21
CLOUD	06.	7.	702.	.298	4.2	.061	22
CLAY	06.	6.	538.	.367	1.4	.028	23
RILEY	06.	5.	604.	.791	0.0	0.000	24
POYTAWATOMIE	06.	4.	829.	.220	0.0	0.000	25
JACKSON	06.	3.	675.	.090	0.0	0.000	26
JEFFERSON + ATCHISON	06.	2.	955.	1.276	0.0	0.000	27
LEAVENWORTH	06.	1.	440.	.497	0.0	0.000	28
WALLACE	05.	14.	921.	.067	11.2	.272	29
LOGAN	05.	13.	1082.	.011	1.9	.047	30
GOVE	05.	12.	1080.	.034	2.7	.049	31
TREGO	05.	11.	899.	4.838	0.0	0.000	32
ELLIS	05.	10.	901.	32.360	0.0	0.000	33
RUSSELL	05.	9.	895.	25.234	0.0	0.000	34
LINCOLN	05.	8.	721.	.941	0.0	0.000	35
OTTAWA + SALINE	05.	7.	1432.	2.405	0.9	.018	36
DICKINSON	05.	6.	838.	1.254	0.0	0.000	37
MORRIS + GEARY	05.	5.	1086.	1.999	0.0	0.000	38
WABAUWSEE	05.	4.	795.	.895	0.0	0.000	39
SHAWNEE	05.	3.	544.	1.075	0.0	0.000	40
DOUGLAS	05.	2.	469.	.293	0.0	0.000	41
JOHNSON + WYANDOTTE	05.	1.	629.	7.737	0.0	0.000	42
GREILEY	04.	14.	776.	.011	5.6	.144	43
WICHITA + SCOTT	04.	13.	1435.	.175	115.0	3.152	44
LANE	04.	12.	715.	.046	6.2	.153	45
KESS	04.	11.	1079.	1.760	4.1	.108	46
RUSH	04.	10.	719.	1.463	6.6	.157	47
BARTON	04.	9.	892.	30.455	4.7	.106	48
ELLSWORTH + RICE	04.	8.	1431.	21.991	3.6	.039	49
MCPHERSON	04.	7.	900.	10.601	2.7	.055	50
MARION	04.	6.	696.	10.515	0.0	0.000	51
CHASE	04.	5.	769.	.324	0.0	0.000	52
LYON	04.	4.	845.	.653	0.0	0.000	53
OSAGE	04.	3.	718.	.037	2.0	0.000	54
FRANKLIN	04.	2.	585.	1.212	0.0	0.000	55
LINN + JAMI	04.	1.	1215.	1.903	0.0	0.000	56
HAMILTON	03.	14.	984.	.528	13.7	.384	57
KEARNY	03.	13.	853.	8.467	47.2	1.263	58
FINNEY	03.	12.	1276.	7.075	95.8	2.670	59
HODGEMAN	03.	11.	856.	1.169	7.0	.177	60
PAWNEE + EDWARDS	03.	10.	1343.	7.102	20.9	.309	61
STAFFORD	03.	9.	796.	17.445	2.2	.035	62
RENO	03.	8.	621.	6.017	3.9	.054	63
RENO	03.	7.	621.	6.017	1.1	.022	64
HARVEY	03.	6.	560.	2.040	0.0	0.000	65
RUTLER	03.	5.	717.	11.448	0.0	0.000	66
GREENWOOD	03.	4.	1158.	13.837	0.0	0.000	67
COFFEY + WOODSON	03.	3.	1147.	2.863	0.0	0.000	68
ALLEN + ANDERSON	03.	2.	1285.	12.736	0.0	0.000	69
BOURBON	03.	1.	656.	.605	0.0	0.000	70
STANTON	02.	14.	685.	2.399	66.0	1.920	71
GRANT	02.	13.	578.	16.174	51.6	1.388	72
GRAY + HASKELL	02.	12.	1434.	11.940	102.0	2.375	73
FORD	02.	11.	1086.	.200	7.8	.113	74
IOWA	02.	10.	723.	2.884	5.9	.047	75
PRATT	02.	9.	726.	5.739	3.7	.056	76
KINGMAN	02.	8.	867.	12.910	0.0	0.000	77
SEDGWICK	02.	7.	497.	5.557	1.2	.021	78
SEDGWICK	02.	6.	497.	5.557	0.0	0.000	79
RUTLER	02.	5.	717.	11.448	0.0	0.000	80
ELK	02.	4.	652.	1.397	0.0	0.000	81
WILSON	02.	3.	581.	4.849	0.0	0.000	82
NEOSHO	02.	2.	580.	7.590	0.0	0.000	83
CRAWFORD	02.	1.	605.	1.768	0.0	0.000	84
MORTON	01.	14.	718.	12.162	10.3	.297	85
STEVENS	01.	13.	729.	12.900	35.5	1.037	86
SEWARDS	01.	12.	643.	6.041	30.8	.752	87
MADE	01.	11.	984.	4.587	18.3	.429	88
CLARK	01.	10.	974.	1.333	0.0	0.000	89
COMANCHE	01.	9.	788.	.076	0.0	0.000	90
BARBER	01.	8.	1134.	10.924	0.5	.007	91
HARPER	01.	7.	799.	4.217	0.0	0.000	92
SUMNER	01.	6.	1179.	9.332	0.0	0.000	93
COWLEY	01.	5.	1133.	11.557	0.0	0.000	94
CHAUTAQUA	01.	4.	652.	2.567	0.0	0.000	95
MONTGOMERY	01.	3.	644.	4.806	0.0	0.000	96
LARETTE	01.	2.	643.	.449	0.0	0.000	97
CHEROKEERY	01.	1.	605.	3.613	0.0	0.000	98

APPENDIX TABLE 2.

## LIST OF ORIGINAL DATA USED FOR VALUE OF KANSAS STUDY

THIS LIST IS IN ALPHABETICAL ORDER BY COUNTIES

COUNTY OR COUNTIES	X	Y	A	B	C	D	NO.
ALLEN + ANDERSON	09	2	1285	12.736	0.0	0.000	69
BARBER	01	8	1134	10.924	0.5	.007	91
BARTON	04	9	892	30.455	4.7	.108	48
BOURBON	03	1	656	.605	0.0	0.000	70
BROWN	07	3	571	.006	0.0	0.000	12
BROWN + DONIPHAN	07	2	475	.380	0.0	0.000	13
BUTLER	09	5	717	11.448	0.0	0.000	66
BUTLER	02	5	717	11.448	0.0	0.000	80
CHASE	04	5	769	.122	0.0	0.000	52
CHAUTAQUA	01	4	652	2.567	0.0	0.000	95
CHEROKEERY	01	1	605	3.613	0.0	0.000	98
CHEYENNE	07	14	1008	.055	6.0	.138	1
CLARK	01	10	974	1.335	0.0	0.000	89
CLAY	06	6	638	.367	1.4	.028	23
CLOUD	06	7	702	.298	4.2	.081	22
COFFEY + WOODSON	09	3	1147	2.663	0.0	0.000	68
COMANCHE	01	9	788	.076	0.0	0.000	90
COWLEY	01	5	1133	11.557	0.0	0.000	94
CRAWFORD	02	1	605	1.768	0.0	0.000	84
DECATUR	07	12	891	1.083	2.5	.043	3
DICKINSON	05	6	838	1.254	0.0	0.000	37
DONIPHAN	07	1	378	.377	0.0	0.000	14
DOUGLAS	05	2	469	.293	0.0	0.000	41
ELK	02	4	652	1.397	0.0	0.000	81
ELLIS	05	10	901	32.360	0.0	0.000	33
ELLSWORTH + RICE	04	8	1431	21.991	3.6	.039	49
FINNEY	03	12	1276	7.075	95.8	2.670	59
FORD	02	11	1086	.200	7.8	.113	74
FRANKLIN	04	2	585	1.212	0.0	0.000	55
GOVE	05	12	1080	.034	2.7	.049	31
GRAHAM	06	11	895	17.595	1.5	.010	18
GRANT	02	13	578	16.174	51.6	1.388	72
GRAY + HASKELL	02	12	1434	11.940	102.0	2.375	73
GREENEY	04	14	776	.011	5.6	.144	43
GREENWOOD	03	4	1158	13.837	0.0	0.000	67
HAMILTON	03	14	984	.528	13.7	.384	57
HARPER	01	7	799	4.217	0.0	0.000	92
HARVEY	03	6	540	2.040	0.0	0.000	65
HODGEMAN	03	11	858	1.169	7.0	.177	60
JACKSON	06	3	675	.090	0.0	0.000	26
JEFFERSON + ATCHISON	06	2	955	1.276	0.0	0.000	27
JEWEL	07	8	900	.817	1.2	.014	7
JOHNSON + WYANDOTTE	05	1	629	7.737	0.0	0.000	42
KEARNY	03	13	853	8.467	47.2	1.263	58
KINGMAN	02	8	867	12.910	0.0	0.000	77
KIOWA	02	10	723	2.884	5.9	.047	75
LABETTE	01	2	643	.449	0.0	0.000	97
LANE	04	12	715	.046	6.2	.153	45
LEAVENWORTH	06	1	440	.497	0.0	0.000	28
LINCOLN	05	8	721	.941	0.0	0.000	35
LINN + MIAMI	04	1	1215	1.903	0.0	0.000	56
LOGAN	05	13	1082	.011	1.9	.047	30
LYON	04	4	845	.653	0.0	0.000	53
MARION	04	6	696	10.515	0.0	0.000	51
MARSHALL	07	5	905	.494	0.0	0.000	10
MCPHERSON	04	7	900	10.601	2.7	.055	50
MEADE	01	11	984	4.587	18.3	.429	88
MITCHELL	06	8	713	.026	3.0	.047	21
MONTGOMERY	01	3	644	4.806	0.0	0.000	96
MORRIS + GEARY	05	5	1086	1.999	0.0	0.000	38
MORTON	01	14	718	12.162	10.3	.297	85
NEMAHA	07	4	716	.039	0.0	0.000	11
NEOSHO	02	2	580	7.590	0.0	0.000	83
NESS	04	11	1079	1.760	4.1	.108	46
NORTON	07	11	876	2.547	2.5	.047	4
OSAGE	04	3	718	.037	0.0	0.000	54
OSBORNE	06	9	894	.224	5.6	.131	20
OTTAWA + SALINE	05	7	1432	2.409	0.9	.018	36
PAWNEE + EDWARDS	03	10	1343	7.102	20.9	.309	61
PHILLIPS	07	10	887	5.531	1.2	.022	5
POTTAWATOMIE	06	4	829	.220	0.0	0.000	25
PRATT	02	9	726	5.739	3.7	.056	76
RAWLINS	07	13	1064	1.569	2.7	.040	2
RENO	03	8	621	6.017	3.9	.054	63
RENO	03	7	621	6.017	1.1	.022	64
REPUBLIC	07	7	704	.207	2.2	.032	8
RILEY	06	5	604	.791	0.0	0.000	24
ROOKS	06	10	890	16.210	0.0	0.000	19
RUSH	04	10	719	1.463	6.6	.157	47
RUSSELL	05	9	895	25.234	0.0	0.000	34
SEDGWICK	02	7	497	5.557	1.2	.021	78
SEDGWICK	02	6	497	5.557	0.0	0.000	79
SEWARDS	01	12	643	6.041	30.8	.752	87
SHAWNEE	05	3	544	1.075	0.0	0.000	40
SHERMAN	06	14	1049	.371	4.7	.087	15
SHERIDAN	06	12	896	1.296	6.2	.112	17
SMITH	07	9	888	.006	1.2	.026	6
STAFFORD	03	9	796	17.445	2.2	.035	62
STANTON	02	14	685	2.399	66.0	1.920	71
STEVENS	01	13	729	12.900	35.5	1.037	86
SUMNER	01	6	1179	9.332	0.0	0.000	93
THOMAS	06	13	1065	.102	5.5	.090	16
TREGO	05	11	899	4.838	0.0	0.000	32
WABAUNSEE	05	4	795	.895	0.0	0.000	39
WALLACE	05	14	921	.067	11.2	.272	29
WASHINGTON	07	6	902	.078	1.1	.016	9
WICHITA + SCOTT	04	13	1435	.175	115.0	3.152	44
WILSON	02	3	581	4.849	0.0	0.000	82

APPENDIX TABLE 3.  
LIST OF ORIGINAL DATA USED FOR VALUE OF KANSAS STUDY

E	F	G	NO.
0.000	0.014		1
0.545	0.000		2
0.377	0.000		3
0.882	0.000		4
1.913	0.000		5
			6
			7
			8
			9
			10
0.010	0.000		11
			12
			13
			14
			15
0.002	0.000		16
0.448	0.000		17
6.116	0.000		18
5.635	0.000		19
0.067	0.000		20
			21
			22
0.010	0.000		23
0.212	0.000		24
			25
			26
			27
0.000	0.004		28
			29
0.000	0.004		30
0.010	0.000		31
1.584	0.000		32
11.231	0.000		33
8.337	0.280		34
			35
0.648	0.000		36
0.062	0.000		37
0.425	0.429		38
0.280	0.000		39
			40
0.043	0.000		41
0.005	0.077		42
			43
0.049	0.000		44
			45
0.595	0.000		46
0.301	1.681	0.010	47
10.246	0.720		48
6.230	0.497		49
3.503	0.260		50
3.297	0.989		51
0.104	0.035		52
0.157	0.000		53
			54
0.334	0.000		55
0.474	0.000		56
0.013	4.549		57
0.076	69.932	0.301	58
0.361	53.961	0.106	59
0.407	0.000		60
2.080	4.649		61
5.737	1.150		62
0.778	3.963	.019	63
			64
0.677	0.339		65
			66
4.759	0.000		67
0.904	0.008		68
1.445	0.084		69
0.028	0.000		70
0.031	21.848		71
0.010	91.749	2.436	72
2.427	35.945	0.206	73
0.008	0.390		74
0.828	3.384		75
1.843	1.364		76
3.174	18.982	0.496	77
1.141	0.008	0.001	78
1.141	0.008		79
7.800	0.000		80
0.226	0.151		81
0.197	0.153		82
0.488	0.118		83
0.041	0.029		84
1.341	76.950		85
0.009	122.005		86
0.056	33.010	0.888	87
1.019	14.313		88
0.197	6.811		89
0.023	0.000		90
1.400	53.315	0.206	91
1.212	4.861		92
3.070	0.339		93
3.672	1.413		94
0.866	0.102		95
0.494	0.339		96
0.110	0.071		97
0.000	0.002		98
			99

APPENDIX TABLE 4.

LIST OF ORIGINAL DATA USED FOR VALUE OF KANSAS STUDY

THESE CARDS ARE FOR THE SECOND SET OF VARIABLES USED TO GET CUBIC MILE  
RESULTS FOR VARIABLES Z(6) AND Z(7)

E	F	G	NO.
3400	-2050.		1
3000	-2000.		2
2700	-1500.		3
2400	-1500.		4
2000	-2000.		5
1800	-2750.		6
1700	-3500.		7
1500	-2500.		8
1400	-1750.		9
1200	-1000.		10
1200	+ 500.		11
1000	-3000.		12
1000	-2750.		13
1000	-2500.		14
3700	-2250.		15
3100	-2200.		16
2600	-2000.		17
2200	-1800.		18
2000	-1750.		19
1800	-2500.		20
1600	-3500.		21
1600	-3000.		22
1200	-2000.		23
1000	-1000.		24
1200	- 500.		25
1000	-2500.		26
1000	-2250.		27
1000	-1800.		28
3400	-2350.		29
3000	-2500.		30
2800	-2500.		31
2400	-2500.		32
2100	-2000.		33
1800	-2200.		34
1400	-3000.		35
1300	-3000.		36
1150	-2000.		37
1500	-1500.		38
1000	-2000.		39
950	-2000.		40
800	-1500.		41
1000	-1500.		42
3600	-2500.		43
3100	-2750.		44
2800	-2750.		45
2250	-2500.		46
2050	-2000.		47
1800	-2000.		48
1650	-2500.		49
1500	-2500.		50
1300	-2000.		51
1200	- 500.		52
1150	-2000.		53
1100	-1750.		54
900	-1400.		55
1000	-1200.		56
3250	-3000.		57
3000	-3250.		58
2850	-3500.		59
2250	-2600.		60
2100	-2200.		61
1900	-2500.		62
1500	-3000.		63
1500	-3000.		64
1450	-2500.		65
1300	-2100.		66
1150	-2000.		67
1000	-1500.		68
1000	-1250.		69
900	- 950.		70
3350	-3500.		71
3050	-3800.		72
2800	-4000.		73
2500	-3200.		74
2200	-2800.		75
1900	-3000.		76
1600	-3800.		77
1400	-3000.		78
1300	-3000.		79
1400	-3000.		80
1000	-2000.		81
900	-1500.		82
900	-1050.		83
1000	- 900.		84
3400	-4100.		85
3100	-4500.		86
2800	-5000.		87
2400	-5000.		88
2000	-4500.		89
2000	-4000.		90
1600	-4000.		91
1400	-4200.		92
1250	-3500.		93
1300	-3000.		94
1000	-2100.		95
800	-1500.		96
900	-1200.		97
900	- 950.		98

APPENDIX TABLE 5.

C Z(1) = COUNTY TOTAL MINERAL VALUE/SQUARE MILE

X	Y	Z(1)	I	NO.
7.000000	14.000000	0.054563	1	1
7.000000	13.000000	1.474624	1	2
7.000000	12.000000	1.215488	1	3
7.000000	11.000000	2.907534	1	4
7.000000	10.000000	6.235626	1	5
7.000000	9.000000	0.006757	1	6
7.000000	8.000000	0.907778	1	7
7.000000	7.000000	0.294034	1	8
7.000000	6.000000	0.086474	1	9
7.000000	5.000000	0.545856	1	10
7.000000	4.000000	0.054469	1	11
7.000000	3.000000	0.010508	1	12
7.000000	2.000000	0.800000	1	13
7.000000	1.000000	0.997354	1	14
6.000000	14.000000	0.353670	1	15
6.000000	13.000000	0.095775	1	16
6.000000	12.000000	1.446429	1	17
6.000000	11.000000	19.659218	1	18
6.000000	10.000000	18.213483	1	19
6.000000	9.000000	0.250559	1	20
6.000000	8.000000	0.036466	1	21
6.000000	7.000000	0.424501	1	22
6.000000	6.000000	0.575235	1	23
6.000000	5.000000	1.309603	1	24
6.000000	4.000000	0.265380	1	25
6.000000	3.000000	0.133333	1	26
6.000000	2.000000	1.336126	1	27
6.000000	1.000000	1.129545	1	28
5.000000	14.000000	0.072747	1	29
5.000000	13.000000	0.010166	1	30
5.000000	12.000000	0.031481	1	31
5.000000	11.000000	5.381535	1	32
5.000000	10.000000	35.915649	1	33
5.000000	9.000000	28.194413	1	34
5.000000	8.000000	1.305132	1	35
5.000000	7.000000	1.682263	1	36
5.000000	6.000000	1.496420	1	37
5.000000	5.000000	1.840700	1	38
5.000000	4.000000	1.125786	1	39
5.000000	3.000000	1.976103	1	40
5.000000	2.000000	0.624733	1	41
5.000000	1.000000	12.300477	1	42
4.000000	14.000000	0.014175	1	43
4.000000	13.000000	0.121951	1	44
4.000000	12.000000	0.064336	1	45
4.000000	11.000000	1.631140	1	46
4.000000	10.000000	2.034771	1	47
4.000000	9.000000	34.142376	1	48
4.000000	8.000000	15.367575	1	49
4.000000	7.000000	11.778889	1	50
4.000000	6.000000	15.107759	1	51
4.000000	5.000000	0.421326	1	52
4.000000	4.000000	0.772781	1	53
4.000000	3.000000	0.051532	1	54
4.000000	2.000000	2.071795	1	55
4.000000	1.000000	1.566255	1	56
3.000000	14.000000	0.536585	1	57
3.000000	13.000000	9.926143	1	58
3.000000	12.000000	5.544671	1	59
3.000000	11.000000	1.362471	1	60
3.000000	10.000000	5.288161	1	61
3.000000	9.000000	21.915829	1	62
3.000000	8.000000	9.689211	1	63
3.000000	7.000000	9.689211	1	64
3.000000	6.000000	3.777778	1	65
3.000000	5.000000	15.966527	1	66
3.000000	4.000000	11.949050	1	67
3.000000	3.000000	2.321709	1	68
3.000000	2.000000	9.911284	1	69
3.000000	1.000000	0.922256	1	70
2.000000	14.000000	3.502190	1	71
2.000000	13.000000	27.982699	1	72
2.000000	12.000000	8.326360	1	73
2.000000	11.000000	0.184162	1	74
2.000000	10.000000	3.988935	1	75
2.000000	9.000000	7.904959	1	76
2.000000	8.000000	14.890427	1	77
2.000000	7.000000	11.181086	1	78
2.000000	6.000000	11.181086	1	79
2.000000	5.000000	15.966527	1	80
2.000000	4.000000	2.142638	1	81
2.000000	3.000000	8.345955	1	82
2.000000	2.000000	13.086207	1	83
2.000000	1.000000	2.922314	1	84
1.000000	14.000000	16.938718	1	85
1.000000	13.000000	17.695473	1	86
1.000000	12.000000	9.395023	1	87
1.000000	11.000000	4.661585	1	88
1.000000	10.000000	1.368583	1	89
1.000000	9.000000	0.096447	1	90
1.000000	8.000000	9.633157	1	91
1.000000	7.000000	5.277847	1	92
1.000000	6.000000	7.915182	1	93
1.000000	5.000000	10.200353	1	94
1.000000	4.000000	3.937117	1	95
1.000000	3.000000	7.462733	1	96
1.000000	2.000000	0.698289	1	97
1.000000	1.000000	5.971901	1	98

APPENDIX TABLE 6.

C Z(1) = COUNTY TOTAL MINERAL VALUE + AGRICULTURAL PRODUCTS VALUE DUE TO  
 C IRRIGATION/SQUARE MILE

X	Y	Z(1)	I	NO.
7.000000	14.000000	0.191468	2	1
7.000000	13.000000	1.512218	2	2
7.000000	12.000000	1.263749	2	3
7.000000	11.000000	2.961187	2	4
7.000000	10.000000	6.263429	2	5
7.000000	9.000000	0.036036	2	6
7.000000	8.000000	0.923333	2	7
7.000000	7.000000	0.339489	2	8
7.000000	6.000000	0.104213	2	9
7.000000	5.000000	0.545856	2	10
7.000000	4.000000	0.054469	2	11
7.000000	3.000000	0.010508	2	12
7.000000	2.000000	0.800000	2	13
7.000000	1.000000	0.997354	2	14
6.000000	14.000000	0.436606	2	15
6.000000	13.000000	0.180282	2	16
6.000000	12.000000	1.571429	2	17
6.000000	11.000000	19.670391	2	18
6.000000	10.000000	18.213483	2	19
6.000000	9.000000	0.397092	2	20
6.000000	8.000000	0.102384	2	21
6.000000	7.000000	0.511396	2	22
6.000000	6.000000	0.619122	2	23
6.000000	5.000000	1.309603	2	24
6.000000	4.000000	0.265380	2	25
6.000000	3.000000	0.133333	2	26
6.000000	2.000000	1.336126	2	27
6.000000	1.000000	1.129545	2	28
5.000000	14.000000	0.368778	2	29
5.000000	13.000000	0.053604	2	30
5.000000	12.000000	0.076852	2	31
5.000000	11.000000	5.381535	2	32
5.000000	10.000000	35.915649	2	33
5.000000	9.000000	28.194413	2	34
5.000000	8.000000	1.305132	2	35
5.000000	7.000000	1.694832	2	36
5.000000	6.000000	1.496420	2	37
5.000000	5.000000	1.840700	2	38
5.000000	4.000000	1.125786	2	39
5.000000	3.000000	1.976103	2	40
5.000000	2.000000	0.624733	2	41
5.000000	1.000000	12.300477	2	42
4.000000	14.000000	0.199742	2	43
4.000000	13.000000	2.318467	2	44
4.000000	12.000000	0.278322	2	45
4.000000	11.000000	1.731233	2	46
4.000000	10.000000	2.253129	2	47
4.000000	9.000000	34.261210	2	48
4.000000	8.000000	15.394829	2	49
4.000000	7.000000	11.840000	2	50
4.000000	6.000000	15.107759	2	51
4.000000	5.000000	0.421326	2	52
4.000000	4.000000	0.772781	2	53
4.000000	3.000000	0.051532	2	54
4.000000	2.000000	2.071795	2	55
4.000000	1.000000	1.566255	2	56
3.000000	14.000000	0.926829	2	57
3.000000	13.000000	11.406799	2	58
3.000000	12.000000	7.637147	2	59
3.000000	11.000000	1.568765	2	60
3.000000	10.000000	5.518243	2	61
3.000000	9.000000	21.959799	2	62
3.000000	8.000000	9.776167	2	63
3.000000	7.000000	9.724638	2	64
3.000000	6.000000	3.777778	2	65
3.000000	5.000000	15.966527	2	66
3.000000	4.000000	11.949050	2	67
3.000000	3.000000	2.321709	2	68
3.000000	2.000000	9.911284	2	69
3.000000	1.000000	0.922256	2	70
2.000000	14.000000	6.305109	2	71
2.000000	13.000000	30.384083	2	72
2.000000	12.000000	9.982566	2	73
2.000000	11.000000	0.288214	2	74
2.000000	10.000000	4.053942	2	75
2.000000	9.000000	7.982094	2	76
2.000000	8.000000	14.890427	2	77
2.000000	7.000000	11.223340	2	78
2.000000	6.000000	11.181086	2	79
2.000000	5.000000	15.966527	2	80
2.000000	4.000000	2.142638	2	81
2.000000	3.000000	8.345955	2	82
2.000000	2.000000	13.086207	2	83
2.000000	1.000000	2.922314	2	84
1.000000	14.000000	17.352367	2	85
1.000000	13.000000	19.117970	2	86
1.000000	12.000000	10.564541	2	87
1.000000	11.000000	5.097561	2	88
1.000000	10.000000	1.368583	2	89
1.000000	9.000000	0.096447	2	90
1.000000	8.000000	9.639330	2	91
1.000000	7.000000	5.277847	2	92
1.000000	6.000000	7.915182	2	93
1.000000	5.000000	10.200353	2	94
1.000000	4.000000	3.937117	2	95
1.000000	3.000000	7.462733	2	96
1.000000	2.000000	0.698289	2	97
1.000000	1.000000	5.971901	2	98

APPENDIX TABLE 7.

C Z(3) = COUNTY OIL, GAS, AND LPG VALUE/SQUARE MILE

X	Y	Z(I)	I	NO.
7.000000	14.000000	0.001528	3	1
7.000000	13.000000	1.459821	3	2
7.000000	12.000000	1.205892	3	3
7.000000	11.000000	2.869521	3	4
7.000000	10.000000	6.146618	3	5
7.000000	9.000000	-0.	3	6
7.000000	8.000000	-0.	3	7
7.000000	7.000000	-0.	3	8
7.000000	6.000000	-0.	3	9
7.000000	5.000000	-0.	3	10
7.000000	4.000000	0.039804	3	11
7.000000	3.000000	-0.	3	12
7.000000	2.000000	-0.	3	13
7.000000	1.000000	-0.	3	14
6.000000	14.000000	-0.	3	15
6.000000	13.000000	0.005352	3	16
6.000000	12.000000	1.425000	3	17
6.000000	11.000000	19.475530	3	18
6.000000	10.000000	18.044663	3	19
6.000000	9.000000	0.213591	3	20
6.000000	8.000000	-0.	3	21
6.000000	7.000000	-0.	3	22
6.000000	6.000000	0.044671	3	23
6.000000	5.000000	1.000331	3	24
6.000000	4.000000	-0.	3	25
6.000000	3.000000	-0.	3	26
6.000000	2.000000	-0.	3	27
6.000000	1.000000	0.001000	3	28
5.000000	14.000000	0.000478	3	29
5.000000	13.000000	0.010536	3	30
5.000000	12.000000	0.026389	3	31
5.000000	11.000000	5.021580	3	32
5.000000	10.000000	35.525360	3	33
5.000000	9.000000	26.582402	3	34
5.000000	8.000000	-0.	3	35
5.000000	7.000000	1.289665	3	36
5.000000	6.000000	0.210859	3	37
5.000000	5.000000	1.158785	3	38
5.000000	4.000000	1.003774	3	39
5.000000	3.000000	-0.	3	40
5.000000	2.000000	0.261301	3	41
5.000000	1.000000	0.036121	3	42
4.000000	14.000000	-0.	3	43
4.000000	13.000000	0.097317	3	44
4.000000	12.000000	-0.	3	45
4.000000	11.000000	1.571594	3	46
4.000000	10.000000	1.476022	3	47
4.000000	9.000000	32.825448	3	48
4.000000	8.000000	12.445961	3	49
4.000000	7.000000	11.124611	3	50
4.000000	6.000000	13.656954	3	51
4.000000	5.000000	0.390442	3	52
4.000000	4.000000	0.529527	3	53
4.000000	3.000000	-0.	3	54
4.000000	2.000000	1.627179	3	55
4.000000	1.000000	1.111852	3	56
3.000000	14.000000	0.546179	3	57
3.000000	13.000000	9.924935	3	58
3.000000	12.000000	5.611802	3	59
3.000000	11.000000	1.351923	3	60
3.000000	10.000000	4.794780	3	61
3.000000	9.000000	20.699686	3	62
3.000000	8.000000	4.329114	3	63
3.000000	7.000000	-0.	3	64
3.000000	6.000000	3.642111	3	65
3.000000	5.000000	15.502092	3	66
3.000000	4.000000	11.712565	3	67
3.000000	3.000000	2.246975	3	68
3.000000	2.000000	3.212054	3	69
3.000000	1.000000	0.121646	3	70
2.000000	14.000000	3.637416	3	71
2.000000	13.000000	25.307076	3	72
2.000000	12.000000	7.846583	3	73
2.000000	11.000000	0.060497	3	74
2.000000	10.000000	3.778755	3	75
2.000000	9.000000	7.441584	3	76
2.000000	8.000000	13.900253	3	77
2.000000	7.000000	6.548451	3	78
2.000000	6.000000	6.544728	3	79
2.000000	5.000000	15.502092	3	80
2.000000	4.000000	1.013359	3	81
2.000000	3.000000	0.995318	3	82
2.000000	2.000000	2.420310	3	83
2.000000	1.000000	0.198413	3	84
1.000000	14.000000	17.111908	3	85
1.000000	13.000000	18.444718	3	86
1.000000	12.000000	8.450233	3	87
1.000000	11.000000	4.551402	3	88
1.000000	10.000000	1.345647	3	89
1.000000	9.000000	0.083185	3	90
1.000000	8.000000	9.026234	3	91
1.000000	7.000000	4.992378	3	92
1.000000	6.000000	7.452748	3	93
1.000000	5.000000	9.373901	3	94
1.000000	4.000000	3.802638	3	95
1.000000	3.000000	2.244084	3	96
1.000000	2.000000	0.499705	3	97
1.000000	1.000000	0.000364	3	98

APPENDIX TABLE 8.

C Z(4) = COUNTY VALUE OF MINERAL PRODUCTS LESS OIL, GAS, AND

C LPG/SQUARE MILE

X	Y	Z(1)	I	NO.
7.000000	14.000000	0.189940	4	1
7.000000	13.000000	0.052397	4	2
7.000000	12.000000	0.057856	4	3
7.000000	11.000000	0.091667	4	4
7.000000	10.000000	0.113811	4	5
7.000000	9.000000	0.036036	4	6
7.000000	8.000000	0.023333	4	7
7.000000	7.000000	0.339489	4	8
7.000000	6.000000	0.104213	4	9
7.000000	5.000000	0.545856	4	10
7.000000	4.000000	0.014665	4	11
7.000000	3.000000	0.010508	4	12
7.000000	2.000000	0.800000	4	13
7.000000	1.000000	0.997354	4	14
6.000000	14.000000	0.436606	4	15
6.000000	13.000000	0.174930	4	16
6.000000	12.000000	0.146429	4	17
6.000000	11.000000	0.194860	4	18
6.000000	10.000000	0.168820	4	19
6.000000	9.000000	0.183501	4	20
6.000000	8.000000	0.102384	4	21
6.000000	7.000000	0.511396	4	22
6.000000	6.000000	0.574451	4	23
6.000000	5.000000	0.309272	4	24
6.000000	4.000000	0.265380	4	25
6.000000	3.000000	0.133333	4	26
6.000000	2.000000	1.336126	4	27
6.000000	1.000000	1.128545	4	28
5.000000	14.000000	0.367600	4	29
5.000000	13.000000	0.043068	4	30
5.000000	12.000000	0.050463	4	31
5.000000	11.000000	0.359956	4	32
5.000000	10.000000	0.390289	4	33
5.000000	9.000000	1.612011	4	34
5.000000	8.000000	1.305132	4	35
5.000000	7.000000	0.405168	4	36
5.000000	6.000000	1.285561	4	37
5.000000	5.000000	0.681915	4	38
5.000000	4.000000	0.122013	4	39
5.000000	3.000000	1.976103	4	40
5.000000	2.000000	0.363433	4	41
5.000000	1.000000	12.264356	4	42
4.000000	14.000000	0.199742	4	43
4.000000	13.000000	2.221150	4	44
4.000000	12.000000	0.278322	4	45
4.000000	11.000000	0.159639	4	46
4.000000	10.000000	0.777107	4	47
4.000000	9.000000	1.435762	4	48
4.000000	8.000000	2.948868	4	49
4.000000	7.000000	0.715389	4	50
4.000000	6.000000	1.450805	4	51
4.000000	5.000000	0.030884	4	52
4.000000	4.000000	0.243254	4	53
4.000000	3.000000	0.051532	4	54
4.000000	2.000000	0.444615	4	55
4.000000	1.000000	0.454403	4	56
3.000000	14.000000	0.380650	4	57
3.000000	13.000000	1.481864	4	58
3.000000	12.000000	2.025345	4	59
3.000000	11.000000	0.216841	4	60
3.000000	10.000000	0.723462	4	61
3.000000	9.000000	1.260113	4	62
3.000000	8.000000	5.447053	4	63
3.000000	7.000000	9.724638	4	64
3.000000	6.000000	0.135667	4	65
3.000000	5.000000	0.464435	4	66
3.000000	4.000000	0.236485	4	67
3.000000	3.000000	0.074734	4	68
3.000000	2.000000	6.699230	4	69
3.000000	1.000000	0.800610	4	70
2.000000	14.000000	2.667693	4	71
2.000000	13.000000	5.077007	4	72
2.000000	12.000000	2.135983	4	73
2.000000	11.000000	0.227716	4	74
2.000000	10.000000	0.275187	4	75
2.000000	9.000000	0.540510	4	76
2.000000	8.000000	0.990173	4	77
2.000000	7.000000	4.674889	4	78
2.000000	6.000000	4.636358	4	79
2.000000	5.000000	0.464435	4	80
2.000000	4.000000	1.129279	4	81
2.000000	3.000000	7.350637	4	82
2.000000	2.000000	10.665896	4	83
2.000000	1.000000	2.723901	4	84
1.000000	14.000000	0.240460	4	85
1.000000	13.000000	0.673251	4	86
1.000000	12.000000	2.114308	4	87
1.000000	11.000000	0.546159	4	88
1.000000	10.000000	0.022936	4	89
1.000000	9.000000	0.013261	4	90
1.000000	8.000000	7.613095	4	91
1.000000	7.000000	0.285469	4	92
1.000000	6.000000	0.462434	4	93
1.000000	5.000000	0.826452	4	94
1.000000	4.000000	0.134479	4	95
1.000000	3.000000	5.218649	4	96
1.000000	2.000000	0.198585	4	97
1.000000	1.000000	5.971537	4	98

APPENDIX TABLE 9.

C Z(5) = COUNTY AGRICULTURAL PRODUCTS VALUE DUE TO IRRIGATION/SQUARE MILE

X	Y	Z(I)	I	NO.
7.000000	14.000000	0.136905	5	1
7.000000	13.000000	0.037594	5	2
7.000000	12.000000	0.048260	5	3
7.000000	11.000000	0.053653	5	4
7.000000	10.000000	0.024803	5	5
7.000000	9.000000	0.029279	5	6
7.000000	8.000000	0.015556	5	7
7.000000	7.000000	0.045455	5	8
7.000000	6.000000	0.017738	5	9
7.000000	5.000000	0.	5	10
7.000000	4.000000	0.	5	11
7.000000	3.000000	0.	5	12
7.000000	2.000000	0.	5	13
7.000000	1.000000	0.	5	14
6.000000	14.000000	0.082936	5	15
6.000000	13.000000	0.084577	5	16
6.000000	12.000000	0.125000	5	17
6.000000	11.000000	0.011173	5	18
6.000000	10.000000	0.	5	19
6.000000	9.000000	0.146532	5	20
6.000000	8.000000	0.065919	5	21
6.000000	7.000000	0.086895	5	22
6.000000	6.000000	0.043887	5	23
6.000000	5.000000	0.	5	24
6.000000	4.000000	0.	5	25
6.000000	3.000000	0.	5	26
6.000000	2.000000	0.	5	27
6.000000	1.000000	0.	5	28
5.000000	14.000000	2.295331	5	29
5.000000	13.000000	0.043438	5	30
5.000000	12.000000	0.045370	5	31
5.000000	11.000000	0.	5	32
5.000000	10.000000	0.	5	33
5.000000	9.000000	0.	5	34
5.000000	8.000000	0.	5	35
5.000000	7.000000	0.012570	5	36
5.000000	6.000000	0.	5	37
5.000000	5.000000	0.	5	38
5.000000	4.000000	0.	5	39
5.000000	3.000000	0.	5	40
5.000000	2.000000	0.	5	41
5.000000	1.000000	0.	5	42
4.000000	14.000000	0.185567	5	43
4.000000	13.000000	2.196516	5	44
4.000000	12.000000	0.213986	5	45
4.000000	11.000000	0.100093	5	46
4.000000	10.000000	0.218359	5	47
4.000000	9.000000	0.118834	5	48
4.000000	8.000000	0.027254	5	49
4.000000	7.000000	0.061111	5	50
4.000000	6.000000	0.	5	51
4.000000	5.000000	0.	5	52
4.000000	4.000000	0.	5	53
4.000000	3.000000	0.	5	54
4.000000	2.000000	0.	5	55
4.000000	1.000000	0.	5	56
3.000000	14.000000	0.390244	5	57
3.000000	13.000000	1.480656	5	58
3.000000	12.000000	2.092476	5	59
3.000000	11.000000	0.206294	5	60
3.000000	10.000000	0.230082	5	61
3.000000	9.000000	0.043970	5	62
3.000000	8.000000	0.086957	5	63
3.000000	7.000000	0.035427	5	64
3.000000	6.000000	0.	5	65
3.000000	5.000000	0.	5	66
3.000000	4.000000	0.	5	67
3.000000	3.000000	0.	5	68
3.000000	2.000000	0.	5	69
3.000000	1.000000	0.	5	70
2.000000	14.000000	2.802920	5	71
2.000000	13.000000	2.401384	5	72
2.000000	12.000000	1.656206	5	73
2.000000	11.000000	0.104052	5	74
2.000000	10.000000	0.065007	5	75
2.000000	9.000000	0.077135	5	76
2.000000	8.000000	0.	5	77
2.000000	7.000000	0.042254	5	78
2.000000	6.000000	0.	5	79
2.000000	5.000000	0.	5	80
2.000000	4.000000	0.	5	81
2.000000	3.000000	0.	5	82
2.000000	2.000000	0.	5	83
2.000000	1.000000	0.	5	84
1.000000	14.000000	0.413649	5	85
1.000000	13.000000	1.422497	5	86
1.000000	12.000000	1.169518	5	87
1.000000	11.000000	0.435976	5	88
1.000000	10.000000	0.	5	89
1.000000	9.000000	0.	5	90
1.000000	8.000000	0.006173	5	91
1.000000	7.000000	0.	5	92
1.000000	6.000000	0.	5	93
1.000000	5.000000	0.	5	94
1.000000	4.000000	0.	5	95
1.000000	3.000000	0.	5	96
1.000000	2.000000	0.	5	97
1.000000	1.000000	0.	5	98

APPENDIX TABLE 10.

C Z(6) = COUNTY TOTAL MINERAL VALUE/CUBIC MILE

X	Y	Z(1)	I-3	NO.
7.000000	14.000000	0.052862	3	1
7.000000	13.000000	1.557203	3	2
7.000000	12.000000	1.528042	3	3
7.000000	11.000000	3.936354	3	4
7.000000	10.000000	8.231026	3	5
7.000000	9.000000	0.007841	3	6
7.000000	8.000000	0.921744	3	7
7.000000	7.000000	0.388125	3	8
7.000000	6.000000	0.144948	3	9
7.000000	5.000000	1.310055	3	10
7.000000	4.000000	0.410854	3	11
7.000000	3.000000	0.013870	3	12
7.000000	2.000000	1.126400	3	13
7.000000	1.000000	1.504580	3	14
6.000000	14.000000	0.313845	3	15
6.000000	13.000000	0.095413	3	16
6.000000	12.000000	1.660748	3	17
6.000000	11.000000	25.950167	3	18
6.000000	10.000000	25.644584	3	19
6.000000	9.000000	0.307663	3	20
6.000000	8.000000	0.037753	3	21
6.000000	7.000000	0.487254	3	22
6.000000	6.000000	0.949138	3	23
6.000000	5.000000	3.457351	3	24
6.000000	4.000000	0.824239	3	25
6.000000	3.000000	2.170690	3	26
6.000000	2.000000	2.130000	3	27
6.000000	1.000000	0.066801	3	28
5.000000	14.000000	0.009760	3	29
5.000000	13.000000	0.031363	3	30
5.000000	12.000000	5.798878	3	31
5.000000	11.000000	46.252347	3	32
5.000000	10.000000	37.216625	3	33
5.000000	9.000000	1.566158	3	34
5.000000	8.000000	2.065662	3	35
5.000000	7.000000	2.508285	3	36
5.000000	6.000000	3.239632	3	37
5.000000	5.000000	1.981384	3	38
5.000000	4.000000	3.536889	3	39
5.000000	3.000000	1.434171	3	40
5.000000	2.000000	25.978607	3	41
5.000000	1.000000	0.012720	3	42
4.000000	14.000000	0.110069	3	43
4.000000	13.000000	0.061206	3	44
4.000000	12.000000	1.813141	3	45
4.000000	11.000000	2.652738	3	46
4.000000	10.000000	47.439933	3	47
4.000000	9.000000	19.651999	3	48
4.000000	8.000000	15.548133	3	49
4.000000	7.000000	24.172413	3	50
4.000000	6.000000	1.308592	3	51
4.000000	5.000000	1.295328	3	52
4.000000	4.000000	0.095470	3	53
4.000000	3.000000	4.756120	3	54
4.000000	2.000000	3.759012	3	55
4.000000	1.000000	0.453307	3	56
3.000000	14.000000	8.385605	3	57
3.000000	13.000000	4.610372	3	58
3.000000	12.000000	1.483267	3	59
3.000000	11.000000	6.493369	3	60
3.000000	10.000000	26.298994	3	61
3.000000	9.000000	11.368674	3	62
3.000000	8.000000	11.368674	3	63
3.000000	7.000000	5.049789	3	64
3.000000	6.000000	24.795177	3	65
3.000000	5.000000	20.028884	3	66
3.000000	4.000000	4.903449	3	67
3.000000	3.000000	23.258480	3	68
3.000000	2.000000	2.632169	3	69
3.000000	1.000000	2.699498	3	70
2.000000	14.000000	21.569146	3	71
2.000000	13.000000	6.465173	3	72
2.000000	12.000000	0.170592	3	73
2.000000	11.000000	4.212315	3	74
2.000000	10.000000	8.517996	3	75
2.000000	9.000000	14.559528	3	76
2.000000	8.000000	13.417304	3	77
2.000000	7.000000	13.729334	3	78
2.000000	6.000000	19.159832	3	79
2.000000	5.000000	3.771043	3	80
2.000000	4.000000	18.361101	3	81
2.000000	3.000000	35.433421	3	82
2.000000	2.000000	8.120957	3	83
1.000000	14.000000	11.924857	3	84
1.000000	13.000000	12.293697	3	85
1.000000	12.000000	6.359708	3	86
1.000000	11.000000	3.326104	3	87
1.000000	10.000000	1.111711	3	88
1.000000	9.000000	0.084873	3	89
1.000000	8.000000	9.082691	3	90
1.000000	7.000000	4.976256	3	91
1.000000	6.000000	8.798350	3	92
1.000000	5.000000	12.525084	3	93
1.000000	4.000000	6.705799	3	94
1.000000	3.000000	17.131839	3	95
1.000000	2.000000	1.755699	3	96
1.000000	1.000000	17.044127	3	97
			3	98

APPENDIX TABLE 11.

C Z(7) = COUNTY TOTAL MINERAL VALUE + AGRICULTURAL PRODUCTS VALUE  
 C DUE TO IRRIGATION/CUBIC MILE

X	Y	Z(1)	I-3	NO.
7.000000	14.000000	0.185496	4	1
7.000000	13.000000	1.596902	4	2
7.000000	12.000000	1.588712	4	3
7.000000	11.000000	4.008992	4	4
7.000000	10.000000	8.263765	4	5
7.000000	9.000000	0.041818	4	6
7.000000	8.000000	0.937538	4	7
7.000000	7.000000	0.448125	4	8
7.000000	6.000000	0.174681	4	9
7.000000	5.000000	1.310055	4	10
7.000000	4.000000	0.410854	4	11
7.000000	3.000000	0.013870	4	12
7.000000	2.000000	1.126400	4	13
7.000000	1.000000	1.504580	4	14
6.000000	14.000000	0.387442	4	15
6.000000	13.000000	0.179601	4	16
6.000000	12.000000	1.803727	4	17
6.000000	11.000000	25.964916	4	18
6.000000	10.000000	25.644584	4	19
6.000000	9.000000	0.407592	4	20
6.000000	8.000000	0.105998	4	21
6.000000	7.000000	0.586994	4	22
6.000000	6.000000	1.021552	4	23
6.000000	5.000000	3.457351	4	24
6.000000	4.000000	0.824239	4	25
6.000000	3.000000	0.201143	4	26
6.000000	2.000000	2.170690	4	27
6.000000	1.000000	2.130000	4	28
5.000000	14.000000	0.337992	4	29
5.000000	13.000000	0.051460	4	30
5.000000	12.000000	0.076562	4	31
5.000000	11.000000	5.798878	4	32
5.000000	10.000000	46.252347	4	33
5.000000	9.000000	37.216625	4	34
5.000000	8.000000	1.566158	4	35
5.000000	7.000000	2.081096	4	36
5.000000	6.000000	2.508285	4	37
5.000000	5.000000	3.239632	4	38
5.000000	4.000000	1.981384	4	39
5.000000	3.000000	3.536889	4	40
5.000000	2.000000	1.434171	4	41
5.000000	1.000000	25.978607	4	42
4.000000	14.000000	0.172892	4	43
4.000000	13.000000	2.092565	4	44
4.000000	12.000000	0.264782	4	45
4.000000	11.000000	1.924402	4	46
4.000000	10.000000	2.937413	4	47
4.000000	9.000000	47.605050	4	48
4.000000	8.000000	19.586673	4	49
4.000000	7.000000	15.628800	4	50
4.000000	6.000000	24.172413	4	51
4.000000	5.000000	1.308590	4	52
4.000000	4.000000	1.295328	4	53
4.000000	3.000000	0.095470	4	54
4.000000	2.000000	4.756120	4	55
4.000000	1.000000	3.759012	4	56
3.000000	14.000000	0.782285	4	57
3.000000	13.000000	9.636464	4	58
3.000000	12.000000	6.350258	4	59
3.000000	11.000000	1.707851	4	60
3.000000	10.000000	6.775889	4	61
3.000000	9.000000	26.351758	4	62
3.000000	8.000000	11.470703	4	63
3.000000	7.000000	11.410241	4	64
3.000000	6.000000	5.049789	4	65
3.000000	5.000000	24.795077	4	66
3.000000	4.000000	20.028884	4	67
3.000000	3.000000	4.903449	4	68
3.000000	2.000000	23.258480	4	69
3.000000	1.000000	2.632169	4	70
2.000000	14.000000	4.859997	4	71
2.000000	13.000000	23.420139	4	72
2.000000	12.000000	7.751169	4	73
2.000000	11.000000	0.266977	4	74
2.000000	10.000000	4.280963	4	75
2.000000	9.000000	8.601113	4	76
2.000000	8.000000	14.559528	4	77
2.000000	7.000000	13.468008	4	78
2.000000	6.000000	13.729334	4	79
2.000000	5.000000	19.159832	4	80
2.000000	4.000000	3.771043	4	81
2.000000	3.000000	18.361101	4	82
2.000000	2.000000	35.433421	4	83
2.000000	1.000000	8.120957	4	84
1.000000	14.000000	12.216066	4	85
1.000000	13.000000	13.281958	4	86
1.000000	12.000000	7.151382	4	87
1.000000	11.000000	3.637179	4	88
1.000000	10.000000	1.111711	4	89
1.000000	9.000000	0.084873	4	90
1.000000	8.000000	9.088511	4	91
1.000000	7.000000	4.976256	4	92
1.000000	6.000000	8.798350	4	93
1.000000	5.000000	12.525084	4	94
1.000000	4.000000	6.705799	4	95
1.000000	3.000000	17.131839	4	96
1.000000	2.000000	1.755699	4	97
1.000000	1.000000	17.044127	4	98

Figure 1. Plot of Original Data Z(1) Coordinates

Value Per Square Mile (Scaled) of Kansas for 1960 for the County total mineral value per square mile

Plotting Limits

Maximum x = 7.000000 Minimum x = 1.000000

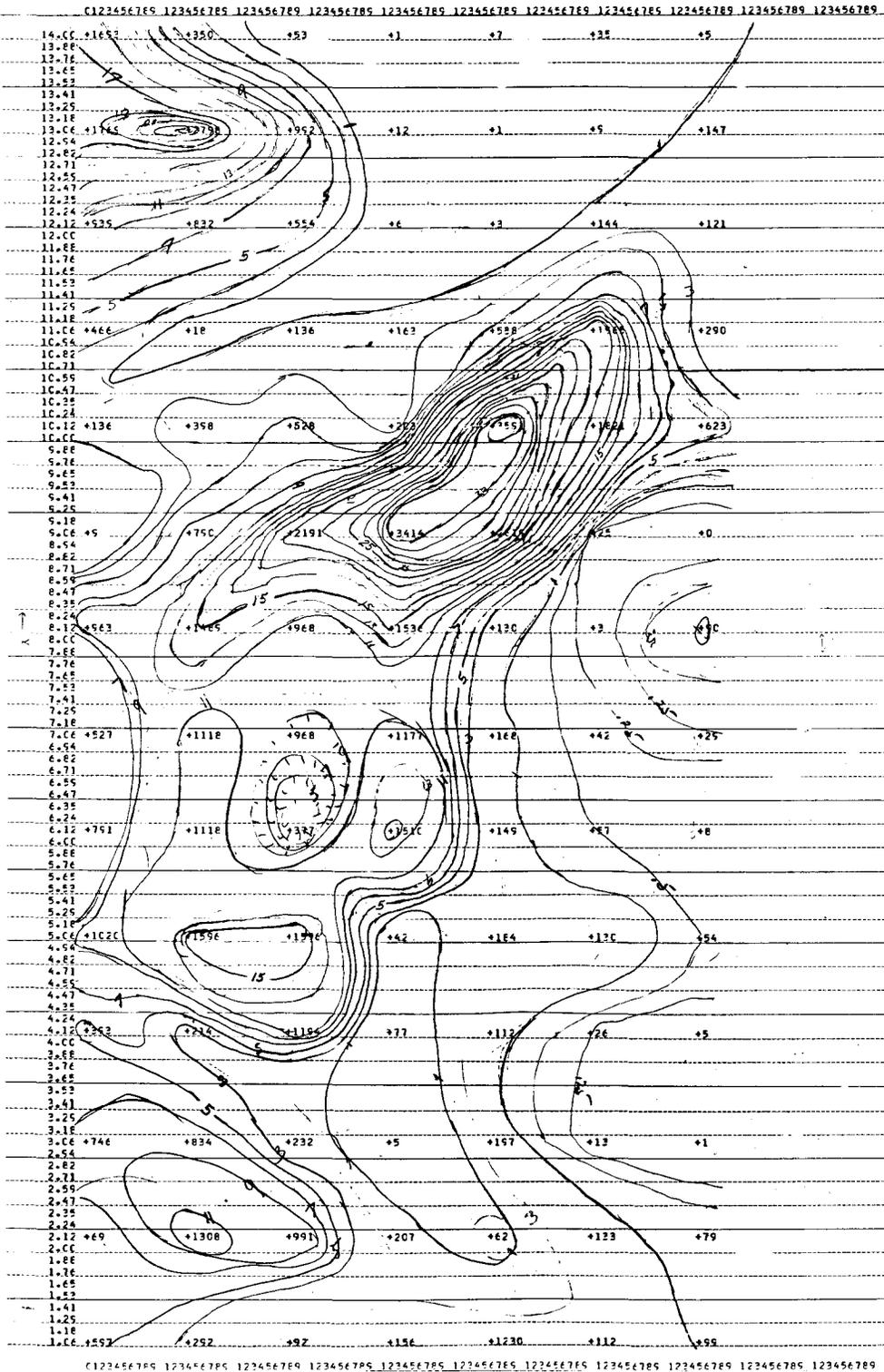
Maximum y = 14.000000 Minimum y = 1.000000

Plotted Values have been multiplied by a Factor of 10 to the 2 power

x-Scale is Horizontal x-Value = 1.00 + 0.0706 x (Scale Value)

y-Scale is Vertical

X →



**Figure 2. Contoured Sixth-Degree Surface Z(1)**

**Value Per Square Mile (Scaled) of Kansas for 1960 for the County total mineral value per square mile**

**Plotting Limits**

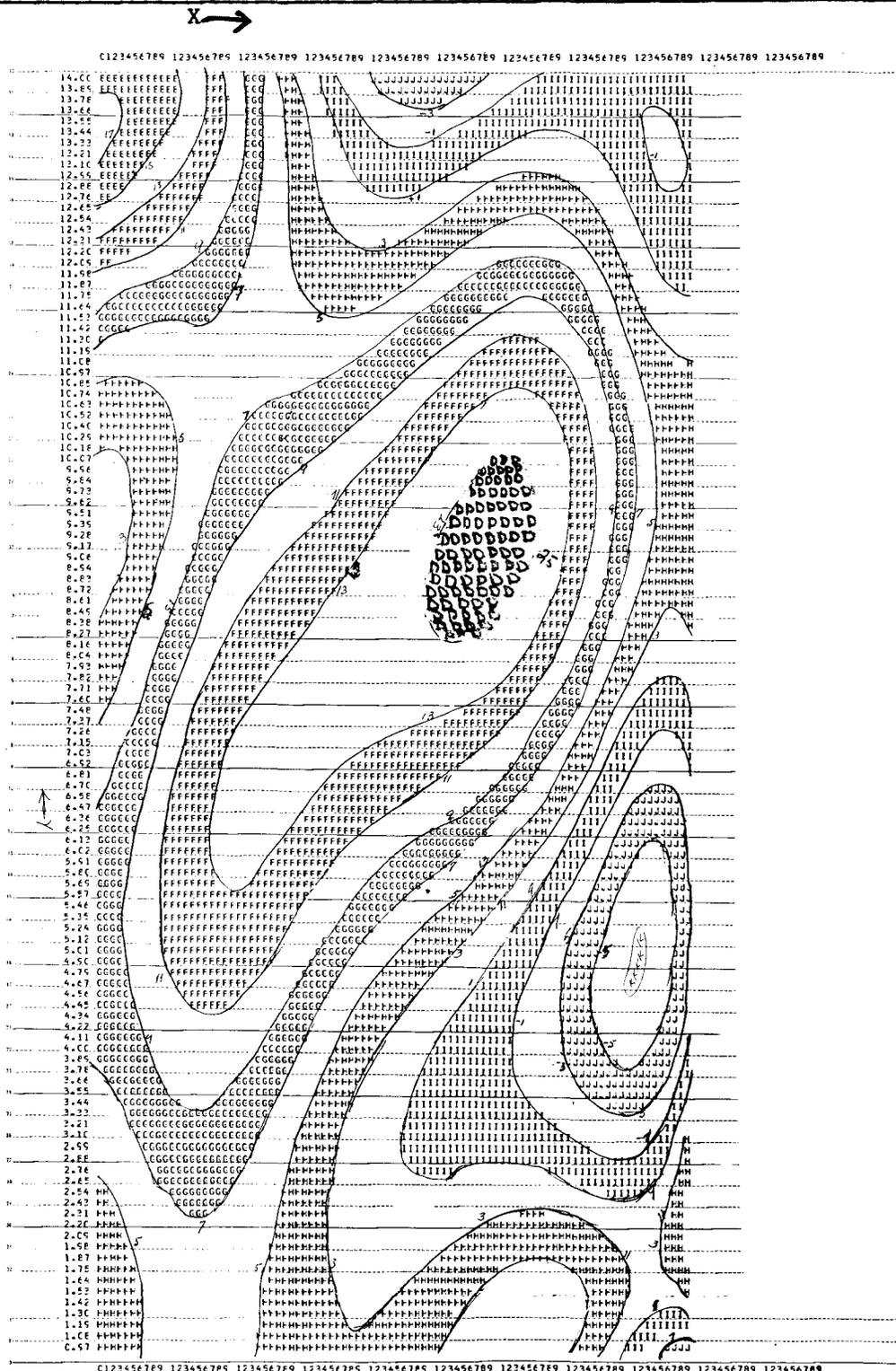
**Maximum x - 7.000000 Minimum x - 1.000000**

**Maximum y - 14.000000 Minimum y - 1.000000**

**x-Scale is Horizontal x-Value = 1.00 + 0.0674 x (Scale Value) - y-Scale is Vertical**

**Contour Interval = 2.00 = .02x10<sup>6</sup> = \$20,000**

**Reference Contour = 35.00 = 0.35 x 10<sup>6</sup> = \$350,000**



**Figure 3. Plot of Sixth-Degree Residuals Z(1)**

**Value Per Square Mile (Scaled) of Kansas for 1960 County total mineral value per square mile**

**Plotting Limits**

**Maximum x = 7.000000 Minimum x = 1.000000**

**Maximum y = 14.000000 Minimum y = 1.000000**

**Plotted Values have been multiplied by a Factor of 10 to the 2 power**

**x-Scale is Horizontal x-Value = 1.00 + 0.0706 x (Scale Value)**

**y-Scale is Vertical**

	C123456789	123456789	123456789	123456789	123456789	123456789	123456789	123456789	123456789
14.00	+71	-985	-237	+404	+256	+64	-142		
13.96									
13.94									
13.65									
13.53									
13.41									
13.25									
13.18									
13.06	+126	+1608	+574	-6	-223	-157	+219		
12.54									
12.82									
12.71									
12.55									
12.47									
12.35									
12.24									
12.12	-112	-11	+65	-422	-746	-444	+41		
12.00									
11.88									
11.76									
11.65									
11.53									
11.41									
11.25									
11.18									
11.06	-110	-602	-514	-680	-672	+1027	-34		
10.54									
10.82									
10.71									
10.55									
10.47									
10.35									
10.24									
10.12	-137	-213	-369	-555	+2078	+708	+145		
10.00									
9.88									
9.76									
9.65									
9.53									
9.41									
9.25									
9.18									
9.06	-225	+14	+1034	+2000	+1237	-1014	-426		
8.54									
8.82									
8.71									
8.55									
8.47									
8.35									
8.24									
8.12	+572	+482	-366	+106	-1268	-727	-136		
8.00									
7.88									
7.76									
7.65									
7.53									
7.41									
7.25									
7.18									
7.06	-77	-77	-359	-65	-847	-233	+85		
6.54									
6.82									
6.71									
6.55									
6.47									
6.35									
6.24									
6.12	+23	-150	-865	+602	-356	+231	+275		
6.00									
5.88									
5.76									
5.65									
5.53									
5.41									
5.25									
5.18									
5.06	+205	+355	+596	-486	+41	+563	+224		
4.54									
4.82									
4.71									
4.55									
4.47									
4.35									
4.24									
4.12	-328	-814	+472	-153	+161	+456	+31		
4.00									
3.88									
3.76									
3.65									
3.53									
3.41									
3.25									
3.18									
3.06	+188	+11	-273	-112	+143	+106	-375		
2.54									
2.82									
2.71									
2.55									
2.47									
2.35									
2.24									
2.12	-343	+643	+581	+0	-327	-223	-457		
2.00									
1.88									
1.76									
1.65									
1.53									
1.41									
1.25									
1.18									
1.06	+207	-257	-257	-151	+573	-326	+441		

C123456789 123456789 123456789 123456789 123456789 123456789 123456789 123456789 123456789 123456789

Figure 4. Plot of Original Data Z(2) Coordinates

Value Per Square Mile (Scaled) of Kansas for 1960 of the County total value of all minerals and of agricultural products due to irrigation

Plotting Limits

Maximum x = 7.000000 Minimum x = 1.000000

Maximum y = 14.000000 Minimum y = 1.000000

Plotted Values have been multiplied by a Factor of 10 to the 2 power

x-Scale is Horizontal x-Value = 1.00 + 0.0706 x (Scale Value)

y-Scale is Vertical

X →

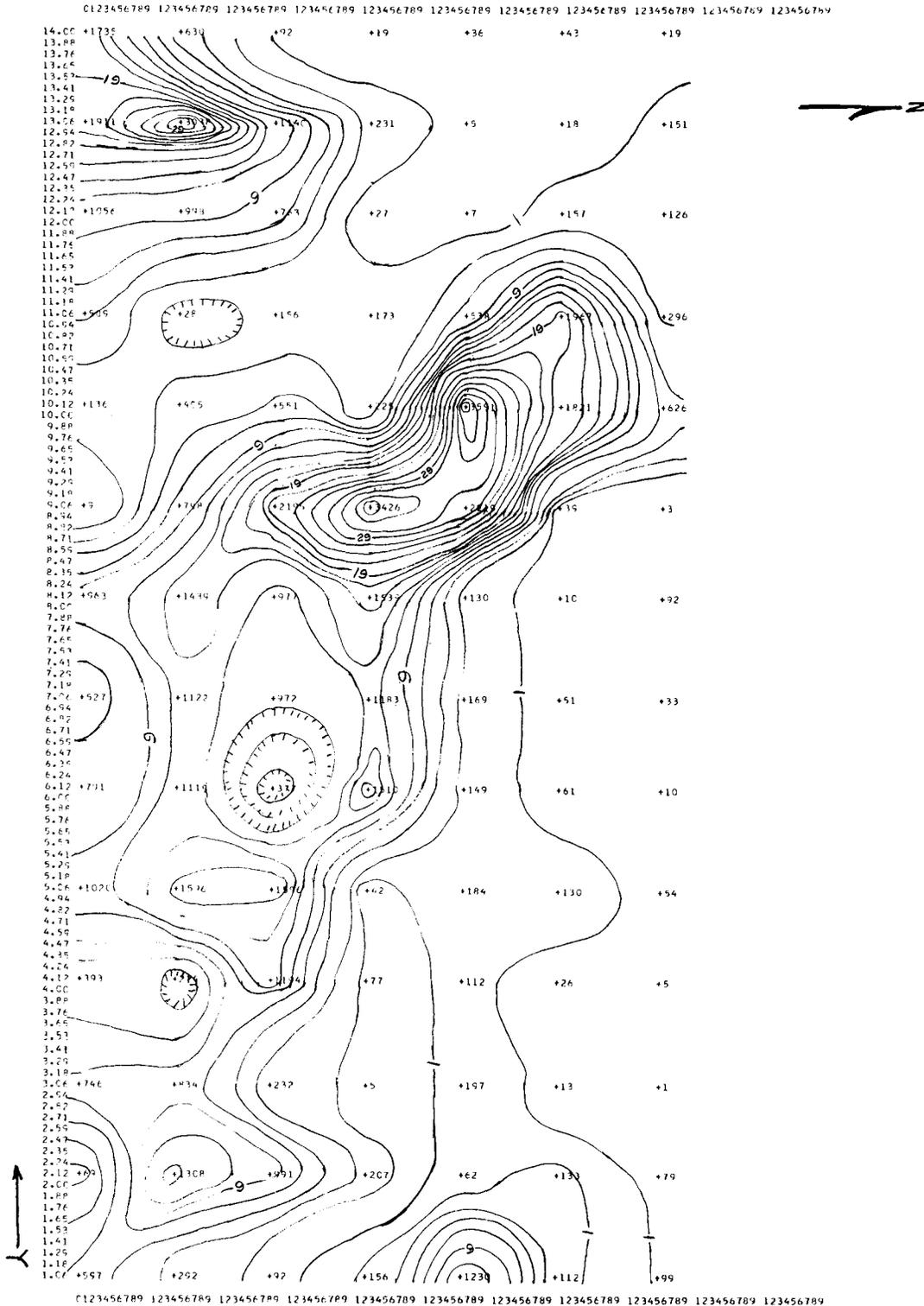






Figure 7. Plot of Original Data Z(3) Coordinates

Value Per Square Mile (Scaled) of Kansas for 1960 for County oil, gas and LPG value per square mile

Plotting Limits

Maximum x = 7.000000 Minimum x = 1.000000

Maximum y = 14.000000 Minimum y = 1.000000

Plotted Values have been multiplied by a Factor of 10 to the 2 power

x-Scale is Horizontal x-Value = 1.00 + 0.0706 x (Scale Value)

y-Scale is Vertical

X →

	123456789	123456789	123456789	123456789	123456789	123456789	123456789
14.00	+1711	+761	+56	+0	+0	+0	+0
13.99							
13.74							
13.65							
13.53							
13.41							
13.26							
13.19							
12.54	+1844	+2530	+992	+9	+1	+0	+145
12.02							
12.71							
12.55							
12.41							
12.35							
12.24							
12.12	+845	+786	+961	+0	+2	+142	+120
12.00							
11.88							
11.76							
11.65							
11.53							
11.41							
11.25							
11.15							
11.06	+455	+6	+135	+157	+502	+1547	+286
10.54							
10.02							
10.71							
10.55							
10.47							
10.35							
10.24							
10.12	+134	+377	+479	+147	+3552	+1804	+614
10.00							
9.88							
9.76							
9.65							
9.53							
9.41							
9.25							
9.15							
9.06	+8	+744	+2060	+3282	+2658	+21	+0
8.54							
8.02							
8.71							
8.55							
8.47							
8.35							
8.24							
8.12	+902	+1390	+432	+1244	+0	+0	+0
8.00							
7.88							
7.76							
7.65							
7.53							
7.41							
7.25							
7.15							
7.06	+495	+654	+0	+1112	+128	+0	+0
6.54							
6.02							
6.71							
6.55							
6.47							
6.35							
6.24							
6.12	+745	+654	+364	+1365	+21	+6	+0
6.00							
5.88							
5.76							
5.65							
5.53							
5.41							
5.25							
5.15							
5.06	+937	+1550	+1550	+35	+115	+100	+0
4.54							
4.02							
4.71							
4.55							
4.47							
4.35							
4.24							
4.12	+380	+101	+1171	+52	+100	+0	+3
4.00							
3.88							
3.76							
3.65							
3.53							
3.41							
3.25							
3.15							
3.06	+224	+99	+224	+0	+0	+0	+0
2.54							
2.02							
2.71							
2.55							
2.47							
2.35							
2.24							
2.12	+49	+242	+321	+162	+26	+0	+0
2.00							
1.88							
1.76							
1.65							
1.53							
1.41							
1.25							
1.15							
1.06	+0	+19	+12	+111	+3	+0	+0

**Figure 8. Contoured Sixth-Degree Surface Z(3)**

**Value Per Square Mile (Scaled) of Kansas for 1960 for County oil, gas and LPG value**

**Plotting Limits**

**Maximum x = 7.000000 Minimum x = 1.000000**

**Maximum y = 14.000000 Minimum y = 1.000000**

**x-Scale is Horizontal x-Value = 1.00 + 0.0674 x (Scale Value) - y-Scale is Vertical**

**Contour Interval = 2.00 = .02x10<sup>6</sup> = \$20,000**

**Reference Contour = 35.00 = 0 = 35 x 10<sup>6</sup> = \$350,000**

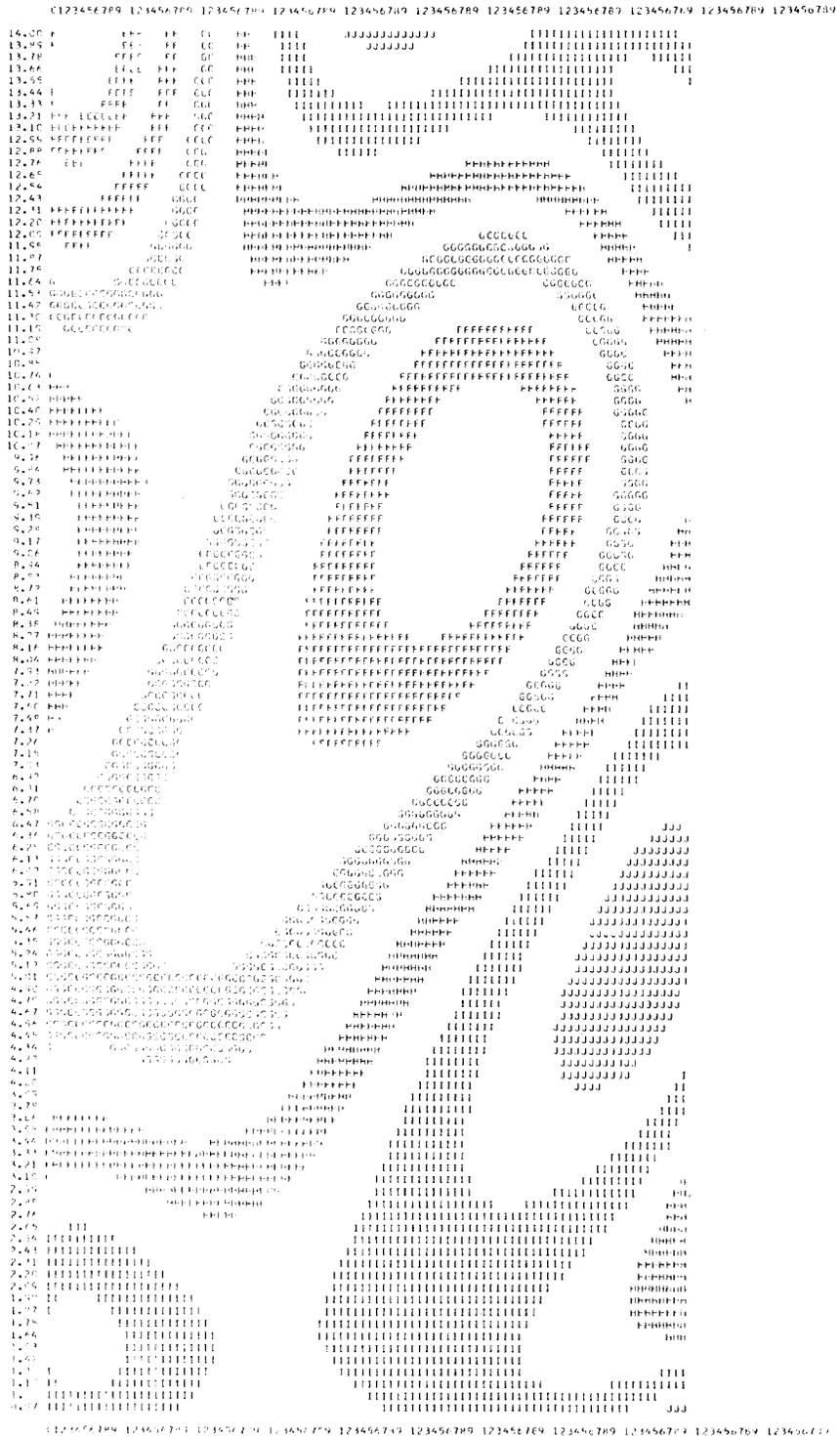


Figure 9. Plot of Original Data Z(4) Coordinates

Value Per Square Mile (Scaled) of Kansas for 1960 for County value of mineral plus irrigation products less oil, gas and LPG

Plotting Limits

Maximum x = 7.000000 Minimum x = 1.000000

Maximum y = 14.000000 Minimum y = 1.000000

Plotted Values have been multiplied by a Factor of 10 to the 2 power

x-Scale is Horizontal x-Value = 1.00 + 0.0706 x (Scale Value)

y-Scale is Vertical

X →

	0123456789	123456789	123456789	123456789	123456789	123456789	123456789	123456789	123456789	123456789			
14.00	+24		+266		+38		+19		+36		+43		+18
13.88													
13.76													
13.65													
13.53													
13.41													
13.29													
13.18													
13.06	+67		+507		+148		+222		+4		+17		+5
12.94													
12.82													
12.71													
12.59													
12.47													
12.35													
12.24													
12.12	+211		+213		+202		+27		+5		+14		+5
12.00													
11.88													
11.76													
11.65													
11.53													
11.41													
11.29													
11.18													
11.06	+54		+22		+21		+15		+35		+19		+9
10.94													
10.82													
10.71													
10.59													
10.47													
10.35													
10.24													
10.12	+2		+27		+72		+77		+39		+16		+11
10.00													
9.88													
9.76													
9.65													
9.53													
9.41													
9.29													
9.18													
9.06	+1		+54		+126		+143		+161		+18		+3
8.94													
8.82													
8.71													
8.59													
8.47													
8.35													
8.24													
8.12	+61		+99		+544		+294		+130		+10		+92
8.00													
7.88													
7.76													
7.65													
7.53													
7.41													
7.29													
7.18													
7.06	+28		+467		+972		+71		+40		+51		+33
6.94													
6.82													
6.71													
6.59													
6.47													
6.35													
6.24													
6.12	+46		+463		+13		+145		+128		+57		+10
6.00													
5.88													
5.76													
5.65													
5.53													
5.41													
5.29													
5.18													
5.06	+82		+46		+46		+3		+68		+30		+54
4.94													
4.82													
4.71													
4.59													
4.47													
4.35													
4.24													
4.12	+13		+112		+23		+24		+12		+26		+1
4.00													
3.88													
3.76													
3.65													
3.53													
3.41													
3.29													
3.18													
3.06	+521		+735		+7		+5		+197		+13		+1
2.94													
2.82													
2.71													
2.59													
2.47													
2.35													
2.24													
2.12	+19		+1066		+669		+44		+36		+133		+79
2.00													
1.88													
1.76													
1.65													
1.53													
1.41													
1.29													
1.18													
1.06	+597		+772		+0		+45		+1226		+112		+99



Figure 11. Plot of Original Data Z(5) Coordinates

Value Per Square Mile (Scaled) of Kansas for 1960 of County agricultural products value due to irrigation per square mile

Plotting Limits

Maximum x = 7.000000 Minimum x = 1.000000

Maximum y = 14.000000 Minimum y = 1.000000

Plotted Values have been multiplied by a Factor of 10 to the 2 power

x-Scale is Horizontal x-Value = 1.00 + 0.0706 x (Scale Value)

y-Scale is Vertical

X →

	123456789	123456789	123456789	123456789	123456789	123456789	123456789	123456789
14.00	+412	+2902	+390	+185	+255	+82	+136	
13.96								
13.76								
13.66								
13.53								
13.41								
13.23								
13.19								
13.06	+1422	+2401	+1480	+2196	+43	+84	+37	
12.94								
12.52								
12.31								
12.55								
12.47								
12.35								
12.24								
12.17	+1105	+1656	+2092	+213	+45	+125	+48	
12.50								
11.95								
11.76								
11.65								
11.52								
11.41								
11.25								
11.18								
11.06	+435	+104	+206	+100	+0	+11	+53	
10.94								
10.92								
10.71								
10.45								
10.47								
10.35								
10.24								
10.12	+0	+63	+231	+218	+0	+0	+24	
10.50								
9.69								
9.76								
9.65								
9.53								
9.41								
9.25								
9.15								
9.04	+0	+77	+41	+118	+0	+146	+29	
8.94								
8.92								
8.71								
8.45								
8.47								
8.35								
8.24								
8.12	+6	+0	+6	+27	+0	+65	+15	
8.00								
7.89								
7.76								
7.65								
7.53								
7.41								
7.25								
7.18								
7.06	+0	+42	+35	+61	+12	+86	+45	
6.94								
6.92								
6.71								
6.55								
6.47								
6.35								
6.24								
6.12	+0	+0	+0	+0	+0	+43	+17	
6.00								
5.89								
5.76								
5.65								
5.53								
5.41								
5.25								
5.18								
5.06	+0	+0	+0	+0	+0	+0	+0	
4.94								
4.92								
4.71								
4.55								
4.47								
4.35								
4.24								
4.12	+0	+0	+0	+0	+0	+0	+0	
4.00								
3.89								
3.76								
3.65								
3.53								
3.41								
3.25								
3.18								
3.06	+0	+0	+0	+0	+0	+0	+0	
2.94								
2.92								
2.71								
2.55								
2.47								
2.35								
2.24								
2.12	+0	+0	+0	+0	+0	+0	+0	
2.00								
1.89								
1.76								
1.65								
1.53								
1.41								
1.25								
1.18								
1.06	+0	+0	+0	+0	+0	+0	+0	

Figure 12. Contoured Sixth-Degree Surface Z(5)

Value Per Square Mile (Scaled) of Kansas for 1960 for County agricultural products value due to irrigation per square mile

Plotting Limits

Maximum x = 7.000000 Minimum x = 1.000000

Maximum y = 14.000000 Minimum y = 1.000000

x-Scale is Horizontal x-Value = 1.00 + 0.0674 x (Scale Value) - y-Scale is Vertical

Contour Interval = 2.00 = .02x106 = \$20,000

Reference Contour = 35.00 = 0 = 35 x 10^6 = \$350,000

X →

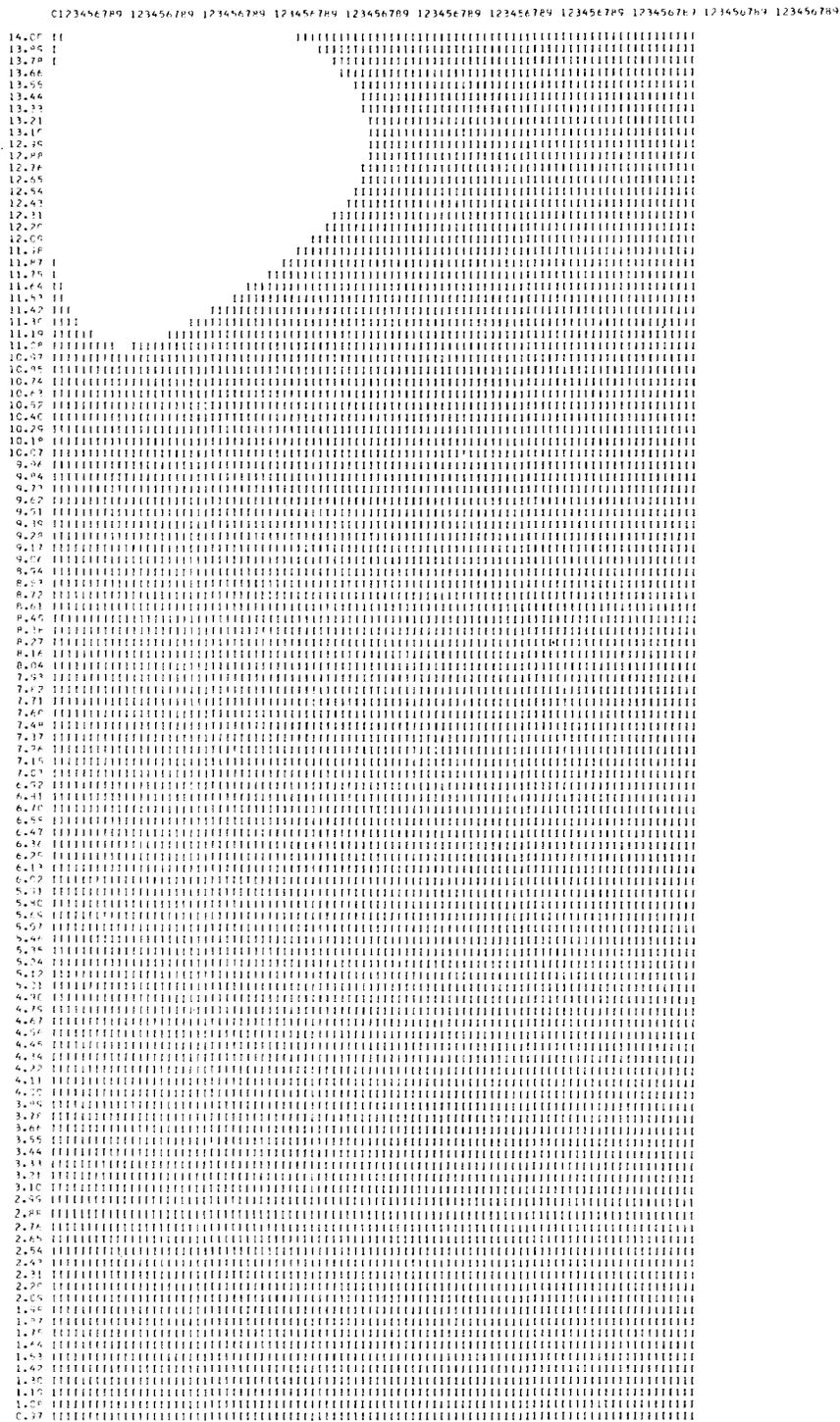


Figure 13. Plot of Sixth-Degree Residuals Z(5)

Value Per Square Mile (Scaled) of Kansas for 1960 for County agricultural products  
value due to irrigation per square mile

Plotting Limits

Maximum x = 7.000000 Minimum x = 1.000000

Maximum y = 14.000000 Minimum y = 1.000000

Plotted Values have been multiplied by a Factor of 10 to the 2 power

x-Scale is Horizontal x-Value = 1.00 + 0.0706 x (Scale Value)

y-Scale is Vertical X →

	0123456789	123456789	123456789	123456789	123456789	123456789	123456789	123456789	123456789
14.00	-173	+721	-876	-244	+356	+99	+14		
13.88									
13.76									
13.65									
13.53									
13.41									
13.29									
13.18									
13.06	-28	-21	-191	+1229	-407	-217	-141		
12.94									
12.92									
12.71									
12.59									
12.47									
12.35									
12.24									
12.12	+110	-60	+939	-474	-244	-10	+66		
12.00									
11.88									
11.76									
11.65									
11.53									
11.41									
11.29									
11.18									
11.06	+22	-761	-305	-197	-49	+46	+173		
10.94									
10.82									
10.71									
10.59									
10.47									
10.35									
10.24									
10.12	+31	-195	+145	+148	+55	+68	+87		
10.00									
9.88									
9.76									
9.65									
9.53									
9.41									
9.29									
9.18									
9.06	+173	+99	+122	+86	+25	+143	-43		
8.94									
8.82									
8.71									
8.59									
8.47									
8.35									
8.24									
8.12	+101	+65	+152	-70	-48	-15	-159		
8.00									
7.88									
7.76									
7.65									
7.53									
7.41									
7.29									
7.18									
7.06	-51	+66	+76	-98	-66	-4	-126		
6.94									
6.82									
6.71									
6.59									
6.47									
6.35									
6.24									
6.12	-143	-6	-27	-157	-31	+23	-49		
6.00									
5.88									
5.76									
5.65									
5.53									
5.41									
5.29									
5.18									
5.06	-124	+20	-2	-98	+60	+74	+64		
4.94									
4.82									
4.71									
4.59									
4.47									
4.35									
4.24									
4.12	-25	+70	+34	-40	+119	+97	+114		
4.00									
3.88									
3.76									
3.65									
3.53									
3.41									
3.29									
3.18									
3.06	+64	+74	+19	-47	+81	-16	+20		
2.94									
2.82									
2.71									
2.59									
2.47									
2.35									
2.24									
2.12	+60	-6	-49	-93	-5	-197	-121		
2.00									
1.88									
1.76									
1.65									
1.53									
1.41									
1.29									
1.18									
1.06	-16	-65	+0	+58	+154	-93	+98		

0123456789 123456789 123456789 123456789 123456789 123456789 123456789 123456789 123456789 123456789

Figure 14. Plot of Original Data Z(7) Coordinates

Value Per Square Mile (Scaled) of Kansas for 1960 County total mineral value + agricultural products value due to irrigation per cubic mile

Plotting Limits

Maximum x = 7.000000 Minimum x = 1.000000

Maximum y = 14.000000 Minimum y = 1.000000

Plotted Values have been multiplied by a Factor of 10 to the 2 power

x-Scale is Horizontal x-Value = 1.00 + 0.0706 x (Scale Value)

y-Scale is Vertical

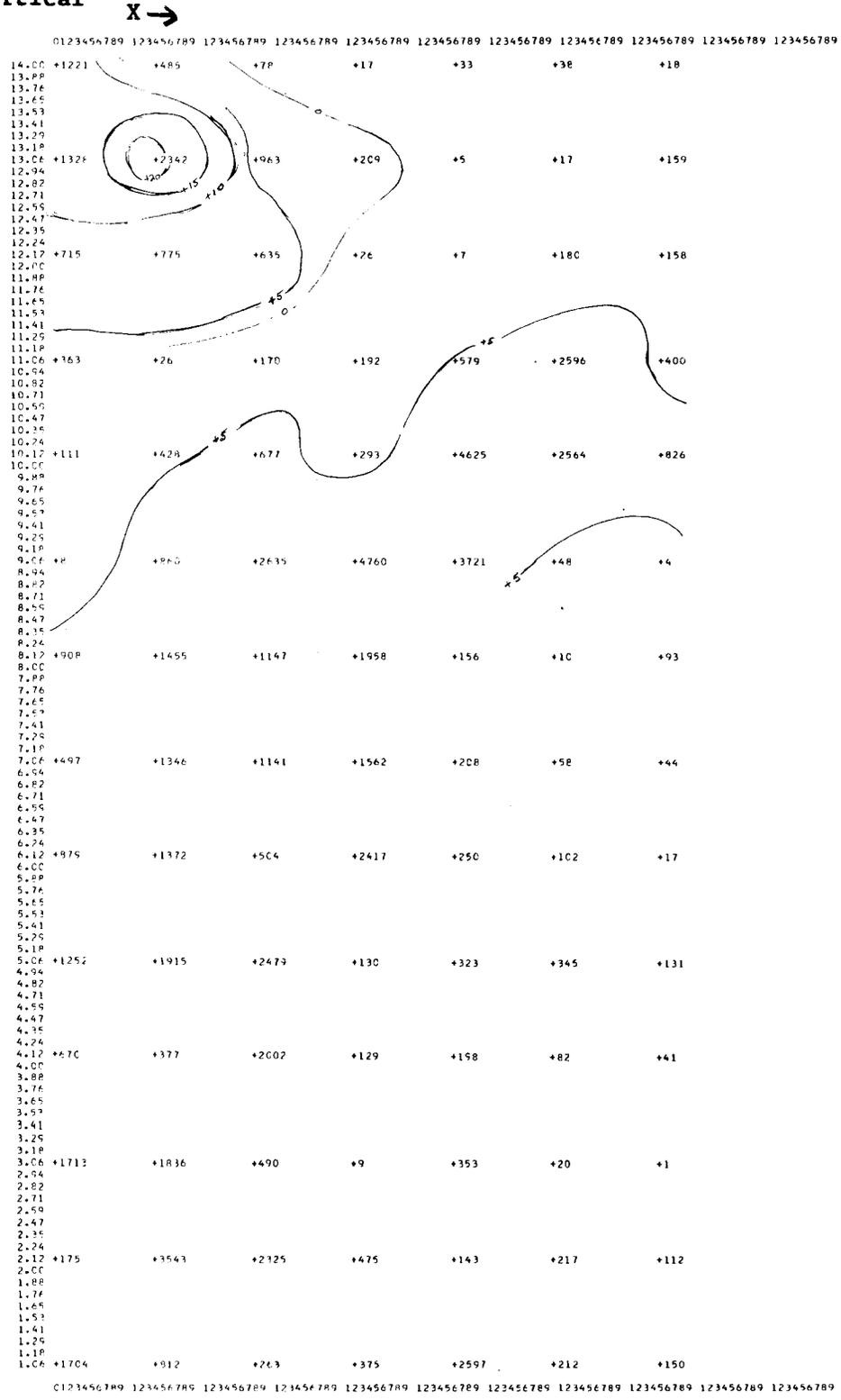


Figure 15. Contoured Sixth-Degree Surface Z(7)

Value Per Square Mile (Scaled) of Kansas for 1960 for County total mineral value + agricultural products value due to irrigation per cubic mile

Plotting Limits

Maximum x = 7.000000 Minimum x = 1.000000

Maximum y = 14.000000 Minimum y = 1.000000

x-Scale is Horizontal x-Value = 1.00 + 0.0674 x (Scale Value) - y-Scale is Vertical

Contour Interval = 2.00 = .02x10<sup>6</sup> = \$20,000

Reference Contour = 35.00 = 0 = 35 x 10<sup>6</sup> = \$350,000

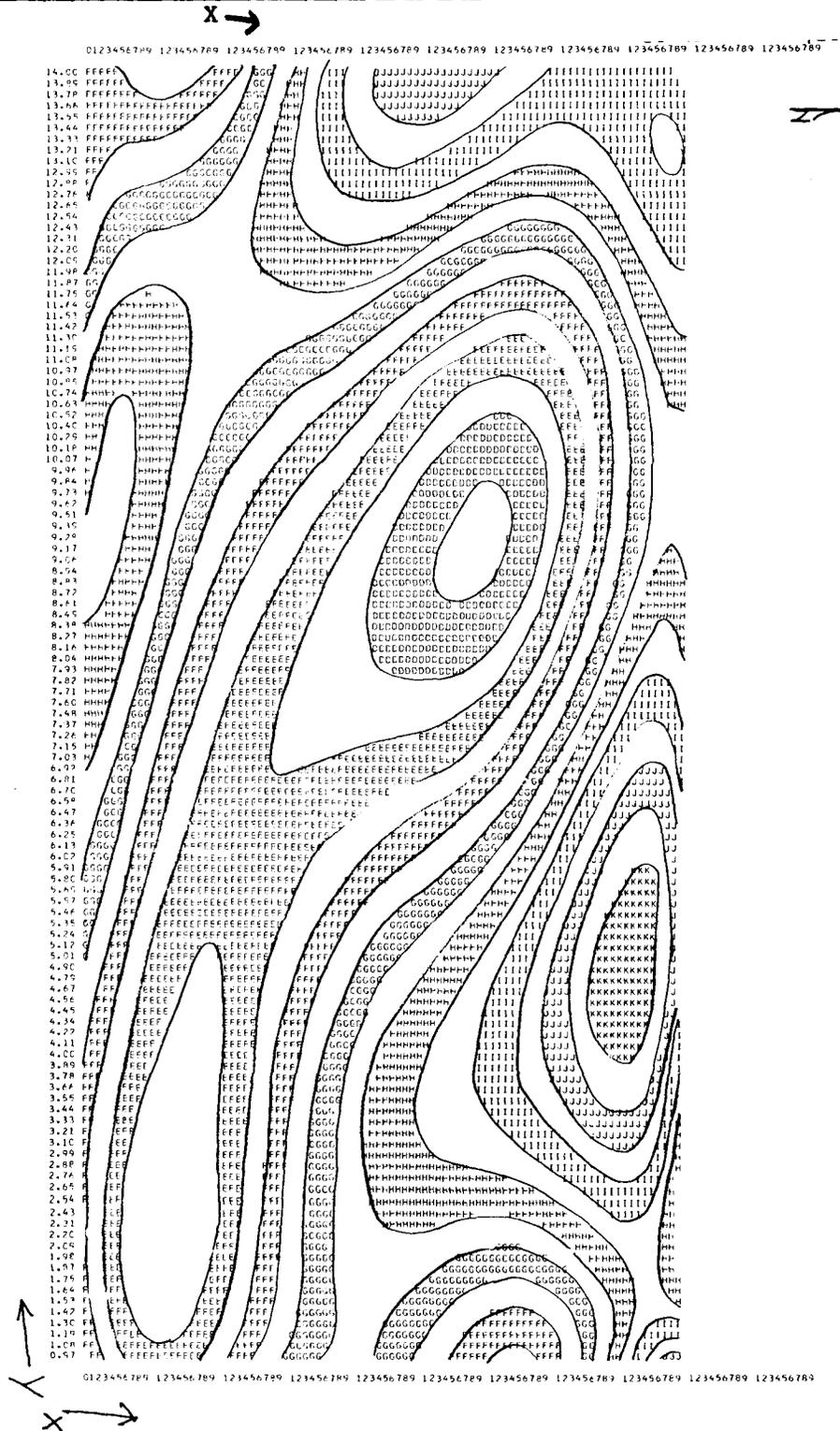


Figure 16. Plot of Sixth-Degree Residuals Z(7)

Value Per Square Mile (Scaled) of Kansas for 1960 of County total mineral value + agricultural products value due to irrigation per cubic mile

Plotting Limits

Maximum x = 7.000000 Minimum x = 1.000000

Maximum y = 14.000000 Minimum y = 1.000000

Plotted Values have been multiplied by a Factor of 10 to the 2 power

x-Scale is Horizontal x-Value = 1.00 + 0.0706 x (Scale Value)

y-Scale is Vertical

