A NUMERICAL MODEL TO EVALUATE PROPOSED GROUND-WATER ALLOCATIONS IN SOUTHWEST KANSAS

By

D. G. Jorgensen, H. F. Grubb, C. H. Baker, Jr.,

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SOUTHWEST KANSAS GROUNDWATER

MANAGEMENT DISTRICT NO. 3

Lawrence, Kansas

1982

UNITED STATES DEPARTMENT OF THE INTERIOR

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GEOLOGICAL SURVEY

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CONVERSION FACTORS

For those readers who would prefer to use the International System of Units (SI) rather than the inch-pound units given in this report, the following conversion factors are presented:

Multiply inch-pound unit	By	To obtain SI unit
inch	25.40	millimeter
foot	0.3048	meter
mile	1.609	kilometer
acre	0.4047	square hectometer
square mile	2.590	square kilometer
acre-foot	1,233	cubic meter
foot per second	30.48	centimeter per second
gallon per minute (gal/min)	0.06309	liter per second
gallon per day per square foot [(gal/d)/ft^2]	0.04074	meter per day

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By

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ABSTRACT

A computer model was developed to calculate the drawdown, due to a proposed well, at all existing wells in the section of the proposed well and at all wells in the adjacent eight sections. The depletion expected in the 9-square-mile area due to all existing wells and the proposed well is computed and compared with allowable limits defined by the Southwest Kansas Groundwater Management District No. 3. An optional program permits the evaluation of allowable depletion for one or more townships. All options are designed to run interactively, thus allowing for immediate evaluation of proposed ground-water withdrawals.

INTRODUCTION

The Ogallala aquifer in the Ogallala Formation of late Tertiary age is the principal source of water for much of western Kansas. Irrigation from wells in Kansas was practiced on a limited scale until about 1960. During the 1960's, rapid development of ground water resulted in the significant lowering of the water table in the Ogallala. By 1970, the saturated thickness of the aquifer at some sites had been decreased to the extent that some wells would not yield water at an adequate rate for irrigation.

Concern by many residents in western Kansas was expressed through Kansas legislative action in 1972 when a bill was enacted that allowed the creation of ground-water management districts. Between 1972 and 1978, five ground-water management districts were formed. The Southwest Kansas Groundwater Management District No. 3 manages the ground water in the area shown in figure 1.

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[1] U.S. Geological Survey, Lawrence, Kansas.
[2] U.S. Geological Survey, Austin, Texas.
[3] Kansas State Board of Agriculture, Topeka, Kansas.
[4] Southwest Kansas Groundwater Management District No. 3, Garden City, Kansas.

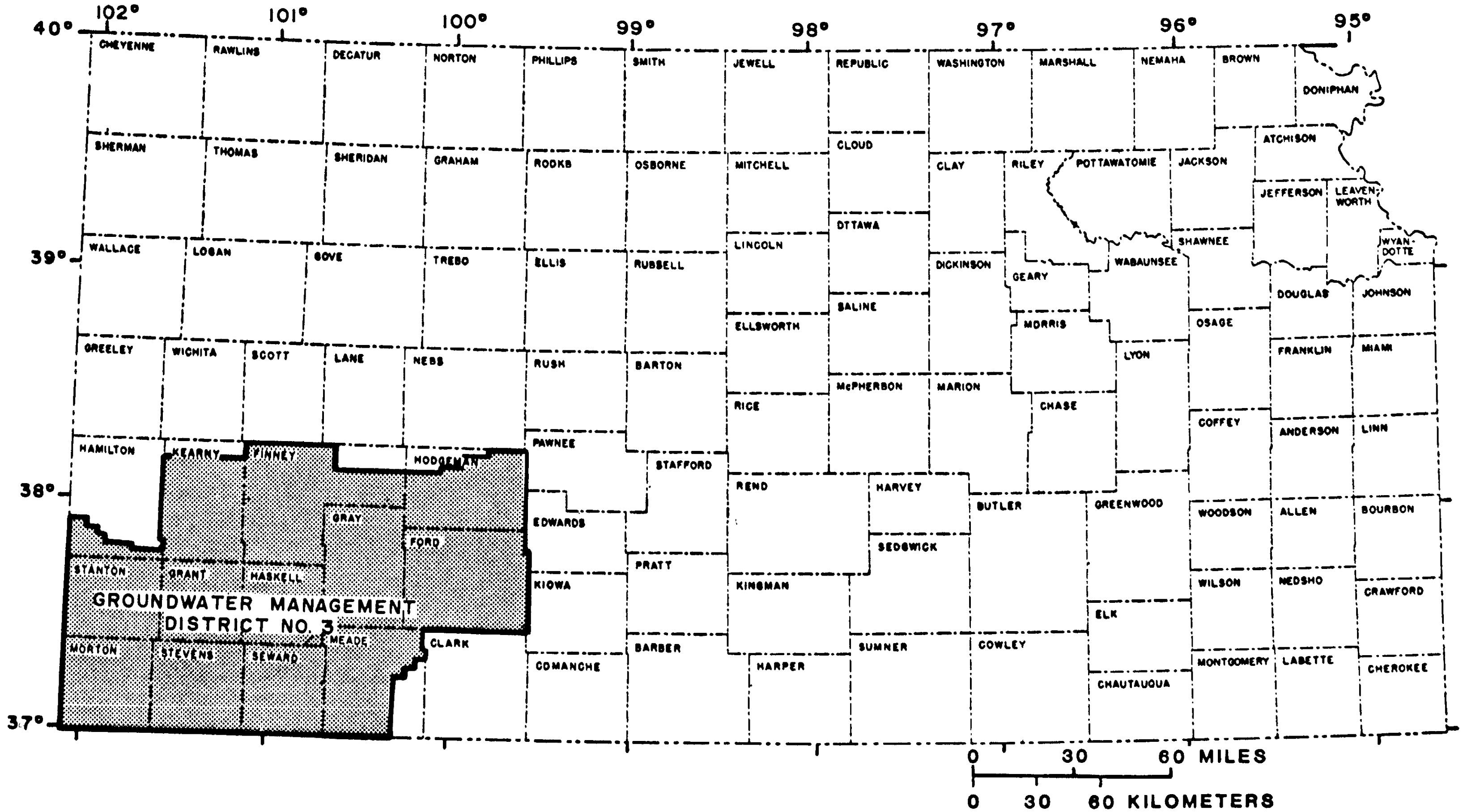

Figure 1.--Location of Southwest Kansas Groundwater Management District No. 3.

Regulations for the appropriation of ground water in Management District No. 3 are the joint responsibility of the management district and the Chief Engineer of the Division of Water Resources, Kansas State Board of Agriculture. Regulations written by the district are approved by the Chief Engineer, who then administers the appropriation of water rights. The Chief Engineer must decide if a proposed ground-water appropriation would interfere with a prior ground-water or surface-water appropriation. The Chief Engineer also must determine whether a new appropriation would cause a significant decrease in saturated thickness at existing well sites. Frequently, an appropriation may be proposed at a diversion rate greater than the aquifer can sustain.

The regulations adopted by the management district and approved by the Chief Engineer include:

"1. Well spacing -- All wells included on an application for permit to appropriate water for beneficial use, except those for domestic uses and wells for which the maximum diversion rate is to be less than fifty (50) gallons per minute, shall meet the following criteria unless approval is authorized in accordance with exceptions defined in the management program.

(a) The minimum spacing of wells with a diversion rate of from fifty-one (51) to four hundred (400) gallons per minute and a maximum pump column diameter of six (6) inches shall be thirteen hundred (1,300) feet. The maximum diversion rate shall not exceed eight hundred (800) gallons per minute when combined with the authorized rate of any other wells within a standard legal one-quarter section of land containing approximately one hundred sixty (160) acres. Larger or smaller tracts shall be considered on an individual basis.

(b) The minimum spacing of wells with a diversion rate in excess of four hundred (400) gallons per minute or a pump column diameter in excess of six (6) inches shall be twenty-three hundred (2,300) feet.

(c) The location of a well or wells on an application for approval to change the point of diversion under an existing water right shall be no more than thirteen hundred twenty (1,320) feet from the authorized point of diversion and shall not decrease the existing spacing to other wells by more than three hundred (300) feet, unless the minimum spacing requirements for new applications are met or authorization is given in accordance with the exceptions defined by the management program. The three-hundred- (300-) foot limit shall not apply to proposed changes in points of diversion under an approved application for which the well has not been drilled.

2. Aquifer depletion--The approval of all applications for permit to appropriate water for beneficial use, except as noted below, shall be subject to the following criteria. The proposed appropriation, when added to the vested rights and prior rights, shall not cause more than forty- (40-) percent depletion in twenty-five (25) years of the saturated materials underlying the area included within a nominal nine- (9-) square-mile area about the location of the proposed well or wells. It shall be assumed, for the purpose of analysis, that all water rights are being fully exercised. The area of consideration shall include the legal section of land, referred to as one (1) square mile, nominally six hundred forty (640) acres, of the proposed well or wells and the eight (8) adjacent sections. If the boundary of the aquifer or of the district falls within the nine- (9-) square-mile area, the area of consideration shall include only the area overlying the aquifer or within the district.

Saturated thickness shall be determined from logs of test holes and wells within the area and from maps available from the U.S. Geological Survey and the Kansas Geological Survey and such refinements as have been accomplished by the district.

The coefficient of storage (specific yield) used in the analysis shall be assumed to be twenty (20) percent, unless hydrological information indicates a smaller value. A value of two (2) inches per year shall be assumed for recharge from natural sources and irrigation return flow."

In general, the procedure used by Groundwater Management District No. 3 for approving an allocation for a new water right is to determine if the new well meets all the existing criteria with respect to diversion rate, pump-column diameter, and minimum spacing to wells under vested or approved appropriation rights. The proposed well site also must meet the depletion criteria. To determine whether aquifer-depletion criteria are met, it is necessary to search the files for all ground-water rights (appropriations) in the 9-square-mile area (fig. 2). This procedure is lengthy and tedious and, therefore, subject to error. If the proposed well site and appropriation meet both the well-spacing and aquifer-depletion criteria, the question of impairment to existing water rights and to surface-water flow is evaluated by the Chief Engineer.

Groundwater Management District No. 3 has proposed that a management model be developed to determine if the proposed well site and appropriation meet the required spacing and depletion criteria and to calculate the drawdown at existing wells caused by pumping the proposed well. The model would use information from other programs now being used in relation to hydrology and water rights of the management district.

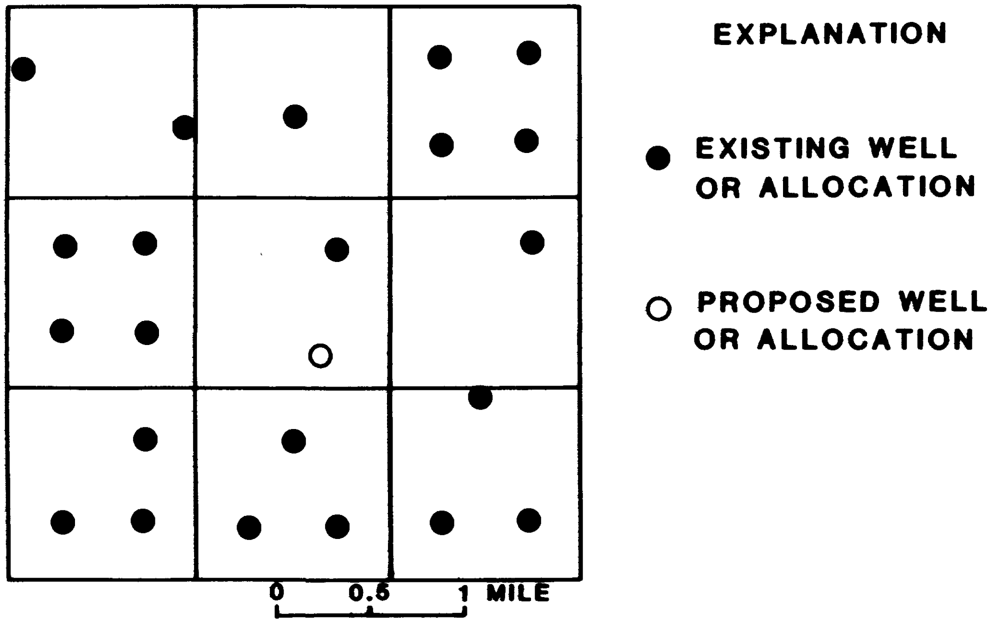

Figure 2.--Existing and proposed wells in 9-square-mile area.

The Southwest Kansas Groundwater Management District, in cooperation with the U.S. Geological Survey, periodically prepares and publishes maps showing the saturated thickness of the Ogallala aquifer in and near the boundaries of the district. These maps are used to determine the saturated thickness at a proposed well site. Values for saturated thickness, area, and specific yield are used to calculate the volume of water in storage. A value of 0.2 is assigned to specific yield, as designated in the regulations adopted by the management district.

The Division of Water Resources of the Kansas State Board of Agriculture is currently (1982) converting its existing "water-rights" file to a computer-managed data base. The U.S. Geological Survey is assisting the Division in this effort because the water-rights file contains valuable information on water use.

GROUND-WATER MODEL

The U.S. Geological Survey, in cooperation with Southwest Kansas Groundwater Management District No. 3, designed a ground-water model that will use the automated water-rights file on the computer to evaluate well-spacing and depletion requirements and to calculate the drawdown in all nearby wells.

Numerical Method for Calculating Drawdown

The drawdown resulting from pumping a well is calculated by numerical techniques. The Ogallala aquifer is treated as an isotropic aquifer under unconfined (water-table) conditions. It is recognized that the aquifer is not truly isotropic and that drawdowns resulting from a very short pumping period may be more representative of confined (artesian) conditions. However, for pumping periods ranging from 2 weeks to 1 year or more, the aquifer will respond in the manner of an unconfined aquifer; thus, unconfined formulation is appropriate for the problem to be solved.

Radial flow to a fully penetrating well in an unconfined isotropic aquifer of infinite extent using the Dupuit-Forcheimer assumption is expressed mathematically as

$$\frac{1}{r}\frac{\partial}{\partial r}\left(\frac{rK}{2}\frac{\partial h^2}{\partial r}\right) = S'\frac{\partial h}{\partial t}\ , \qquad (1)$$

where

- r = radial distance from pumping well, in units of length;
- K = hydraulic conductivity, in units of length per time;
- h = altitude of the water table above the base of the aquifer (saturated thickness), in units of length;
- S' = specific yield, dimensionless; and
- t = pumping time, in units of time.

The relationship between transmissivity (T), hydraulic conductivity (K), and saturated thickness (h) is

$$T = Kh\ . \qquad (2)$$

A schematic of a well pumping in an unconfined system is shown in figure 3.

Examining the differential within the parentheses of equation 1:

$$\frac{\partial h^2}{\partial r} = 2h\frac{\partial h}{\partial r}\ . \qquad (3)$$

Substituting equation 3 into equation 1 and simplifying results in

$$\frac{1}{r}\frac{\partial}{\partial r}\left(rKh\frac{\partial h}{\partial r}\right) = S'\frac{\partial h}{\partial t}\ . \qquad (4)$$

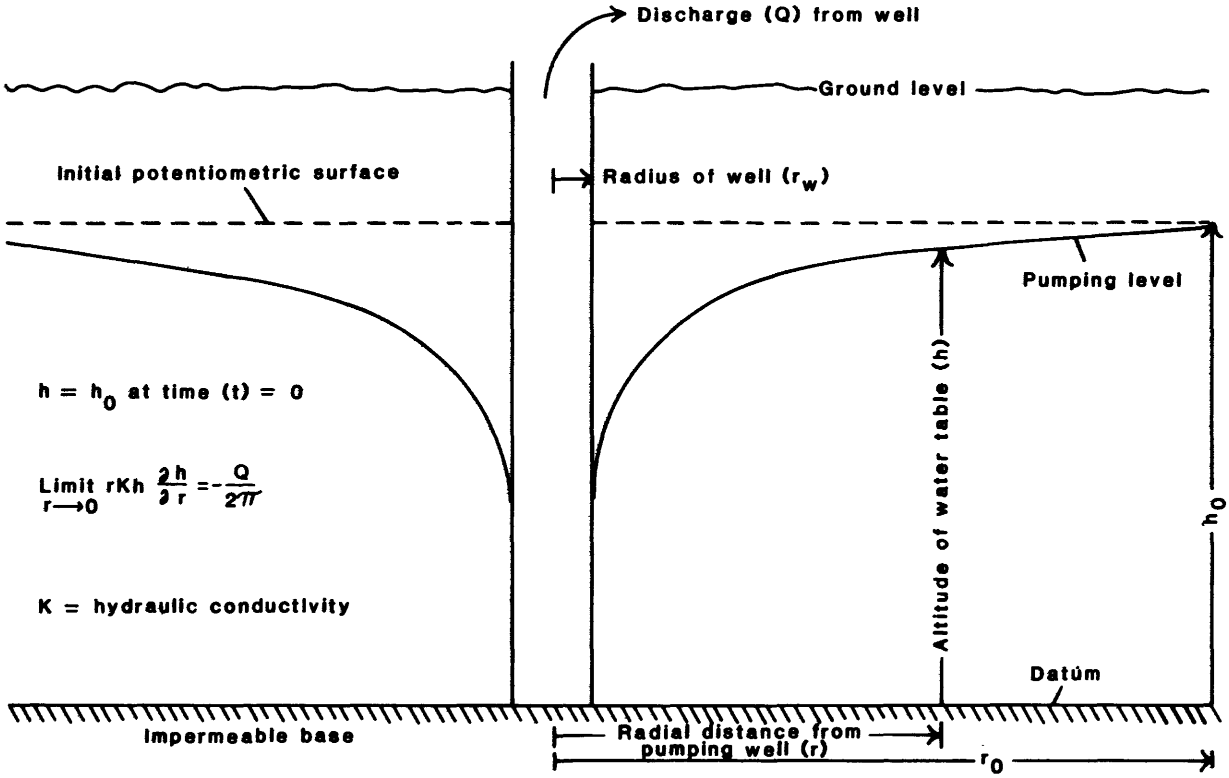

Figure 3.--Effects of pumping a well completed in an unconfined aquifer.

Equation 4 describes radial flow to a well in an unconfined aquifer. To obtain an equation for one-dimensional flow, equation 4 can be transformed using finite-difference approximations (see Supplemental Information, p. 30. The solution of the finite-difference equations was programmed into a numerical model. A flow diagram for the numerical-model program is shown in figure 4.

A comparison of the analytical solution, assuming a constant transmissivity, with the numerical solution to conditions where the drawdown is large (more than 5 percent of the saturated thickness) indicates the need for modeling the unconfined condition. However, the two solutions yielded nearly identical results when the drawdown was less than 5 percent of the original saturated thickness (fig. 5).

Additionally, the model was tested against the analytical steady-state solution of

$$h = \left(\frac{Q}{\pi K} \ln \frac{r}{r_n} + h_n^2\right)^{1/2}, \qquad (5)$$

where

Q is negative for a pumping well.

Equation 5 is similar to an equation derived by Jacob (1950, p. 79) or DeWeist

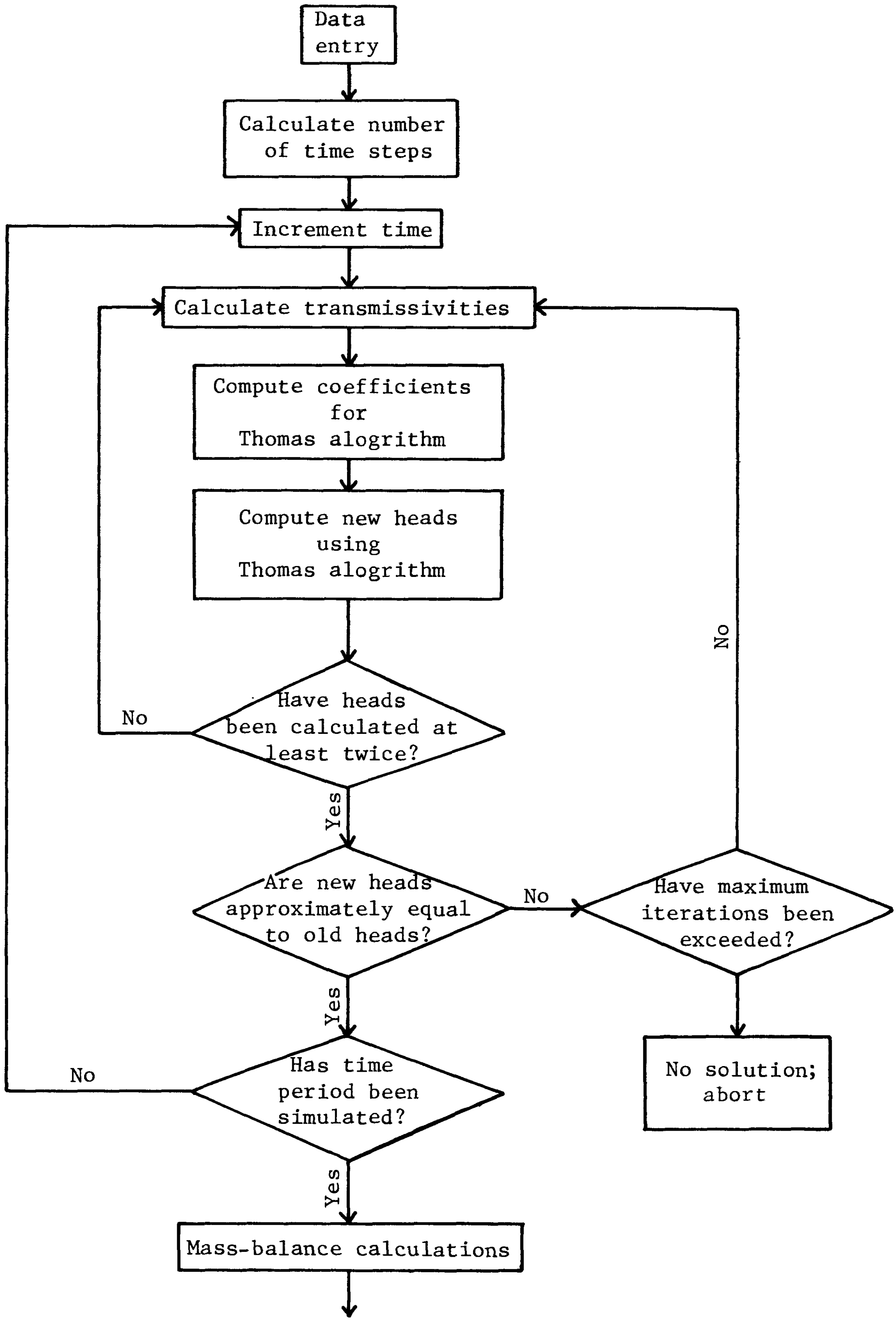

Figure 4.--Flow diagram for numerical-model program.

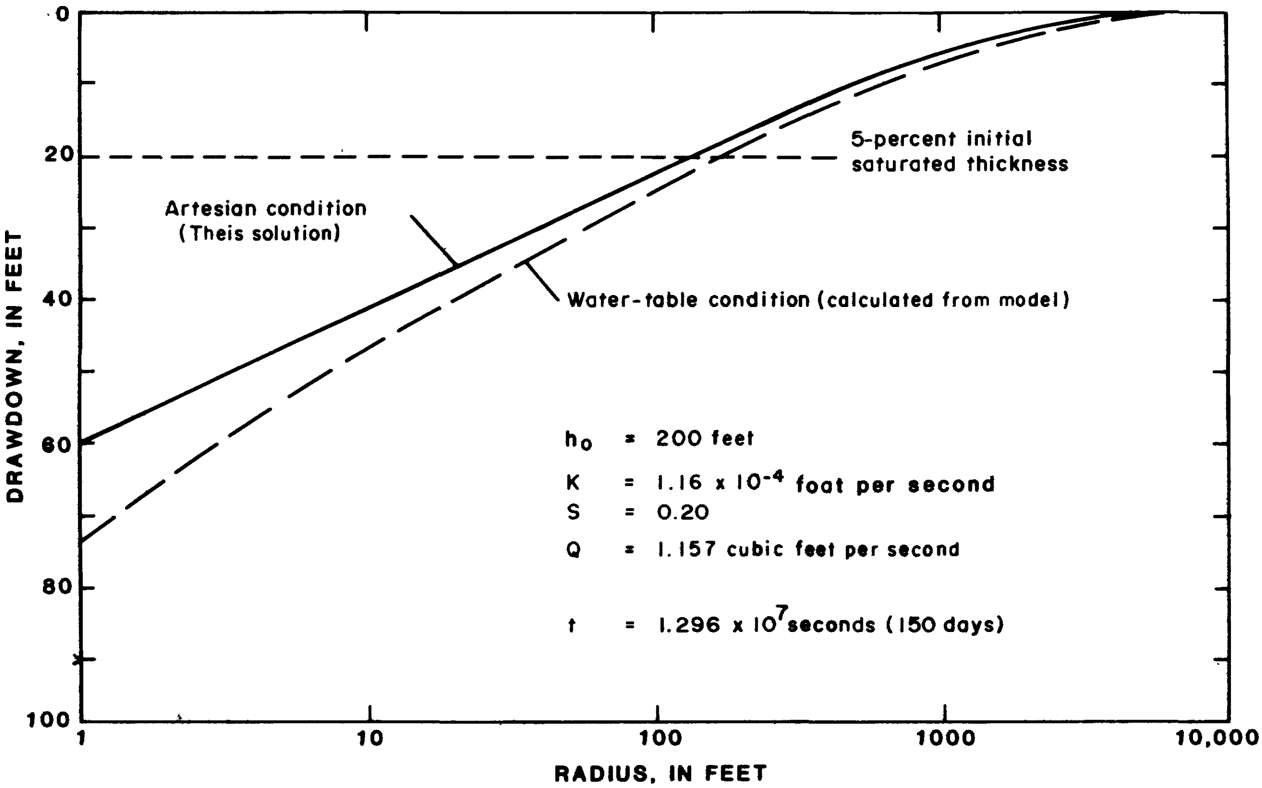

Figure 5.--Drawdown versus distance for transient conditions.

(1965, p. 243). (See figure 6.) The numerical technique was stable if a small Δt was used. An algorithm similar to that used by Trescott, Pinder, and Larson (1976, p. 85-86) was modified to calculate Δt. The modified algorithm calculates the correct Δt and number of time steps required to reach a designated pumping period. To decrease the number of time steps required, an acceleration factor (A) was used in the form $\Delta t_{new} = A \, \Delta t_{old}$. Generally, an acceleration factor of 1.5 was used. The model solutions were stable with an acceleration factor of 3; however, acceleration factors greater than 2 resulted in " hard starts." Hard-start oscillation occurred only for simulation of pumping of a few seconds. Actual problems required simulation of pumping durations greater than 1 week.

The program also contains a mass balance algorithm that calculates the water removed from the cone of depression and compares this to the product Q times the duration of pumping. The model does not solve the combined water-table-artesian problem, as was treated by Moench and Prickett (1972), or the delayed yield and vertical leakage, as treated by Ehlig and Halepaska (1976). The model calculates drawdown at any given radius; thus, knowing drawdown, impairment can be evaluated at the existing wells.

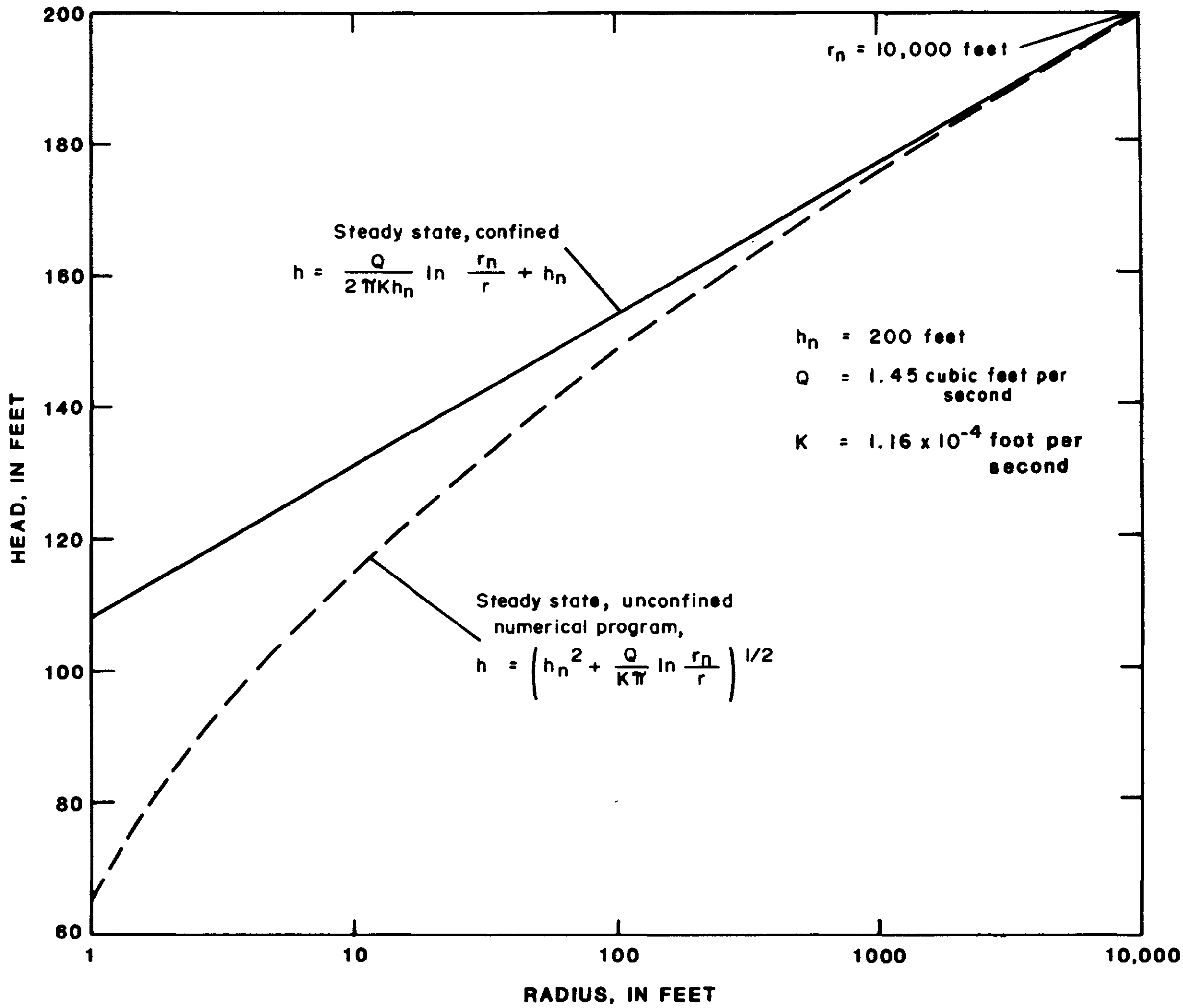

Figure 6.--Head versus distance for steady-state conditions.

Depletion Calculations

One option for evaluation of ground-water depletion was adopted by the management district on July 12, 1978. It allows an evaluation of the depletion due to the addition of a single new well to all existing ground-water rights in the section of the proposed new well and the eight adjacent sections and commonly is described as within a 9-square-mile area. Another option for use in examining larger areas, although not adopted by the management district, allows an evaluation of depletion due to all existing water rights in a township, or a 36-square-mile area. The equations used to make depletion calculations are presented first, followed by examples of both the single-well option and the township option. Options identifying computers, program languages, data requirements, and summaries of possible results are shown by the flow diagram in figure 7.

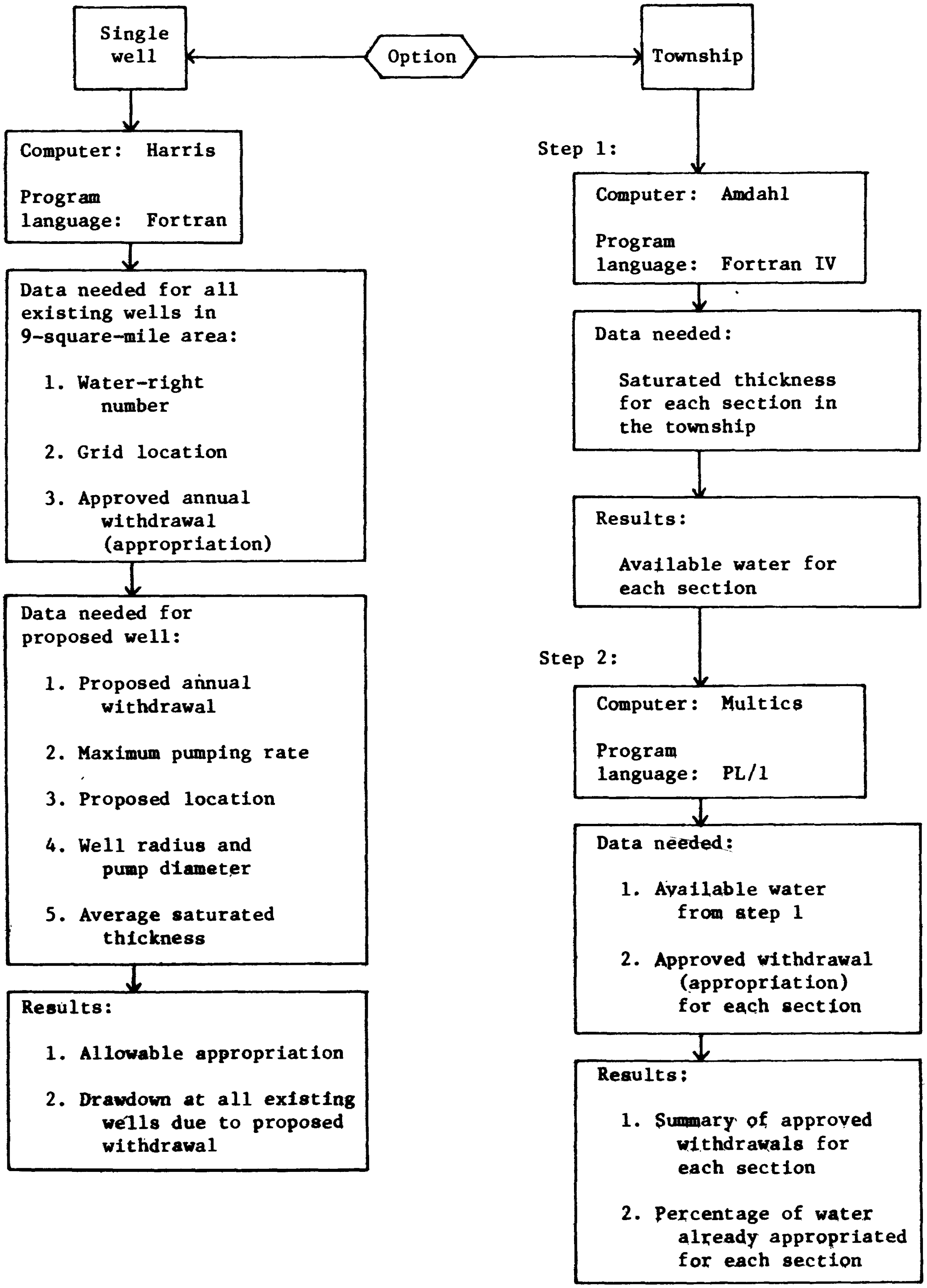

Figure 7.--Options identifying computers, program languages, principal data requirements, and program results.

The volume of ground-water available for appropriation (V_{av}) is limited to 40 percent of that volume of water in ground-water storage plus that volume of water recharged to the aquifer from precipitation and irrigation return flow and is given by:

$$V_{av} = (V_{gws} + V_{rchg})\ (0.40), \tag{6}$$

where

V_{av} = volume of ground water available for appropriation;

V_{gws} = volume of ground water in storage at time of analysis (specific yield assumed to be 20 percent); and

V_{rchg} = volume of recharge for 25 years (assumed to be 2 inches per year).

The total volume appropriated in 25 years is computed by adding all of the approved appropriations in the 9-square-mile area:

$$V_{app} = V_1 + V_2 + V_3 \ldots V_n\ , \tag{7}$$

where

V_{app} = total volume appropriated in 9 square miles in 25 years; and

$V_{1,2,\ldots n}$ = volume appropriated for an individual well in 25 years.

The volume of ground water appropriated must not exceed the allowable volume of depletion:

$$V_{app} \leq V_{av}. \tag{8}$$

If $V_{app}/V_{av} > 1$, then no further development of the aquifer is allowed.

Single-Well Option

Upon receipt of an application for a new well, the Southwest Kansas Groundwater Management District can use this option to evaluate the impact of the proposed ground-water withdrawal on the aquifer. The Fortran program (listed in Supplemental Information, p. 34) is designed for use in an interactive mode. The user provides necessary information about the proposed new well, existing wells, and aquifer properties. This program is written using Fortran IV (1966 ANSI) on a Harris S125[1/] computer system.

1/ The use of brand names in this report is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

Data Requirements

Required information for the single-well option includes county name, land-line location, proposed annual appropriation, maximum pumping rate, well radius, and pump diameter. The location of the proposed well also is indicated by a row and column designation (fig. 8) representing one of the 10-acre tracts of the section in which the proposed well is to be drilled.

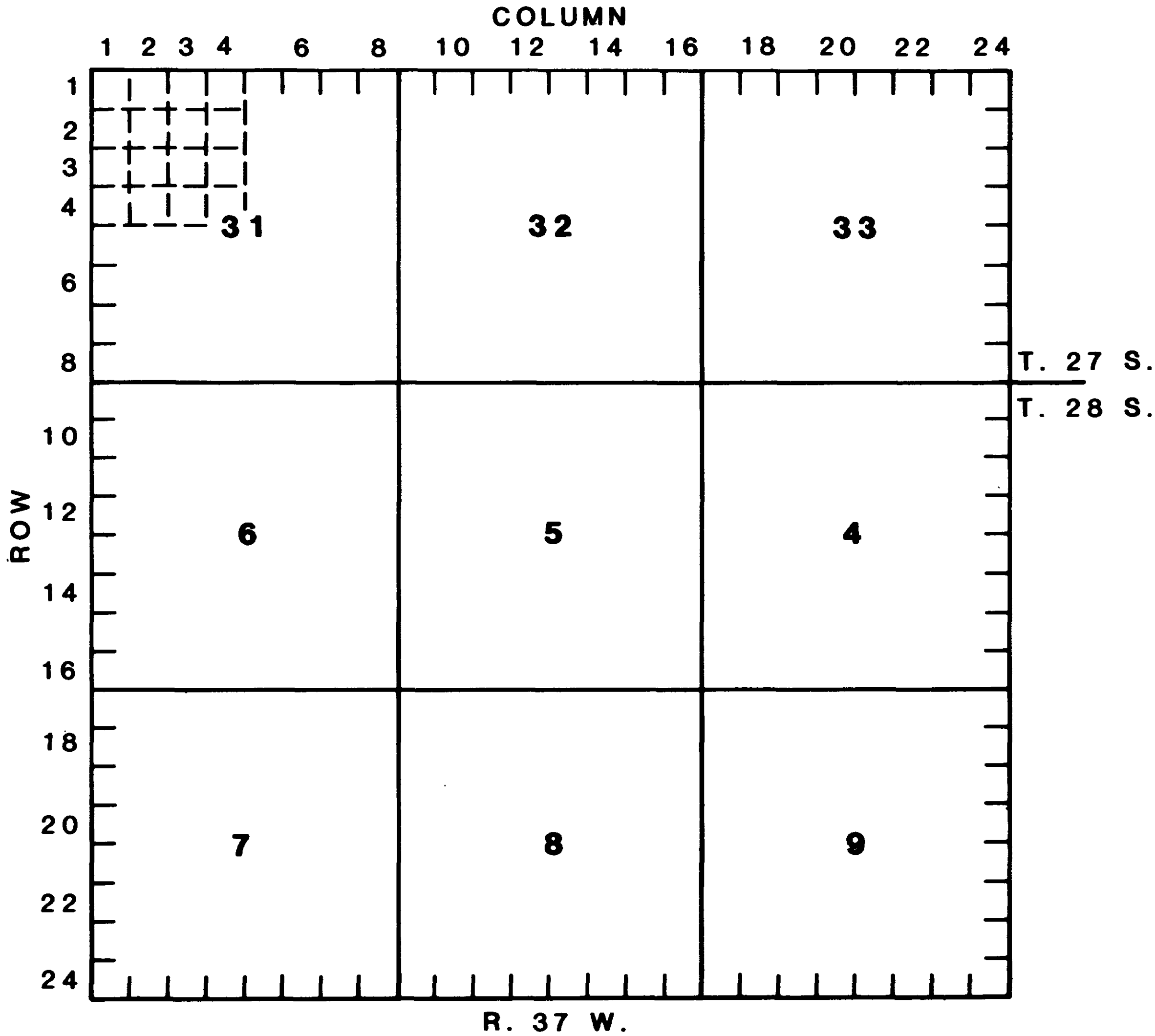

Figure 8.--Indexing system used to compute distance from proposed well to existing wells.

Information required for all existing wells in the section where the new well is proposed and in the adjacent eight sections include: (1) The water-right number, (2) the row and column location in the 9-square-mile area, and (3) the quantity of ground-water withdrawal approved for appropriation on an annual basis. The row and column location represents the 10-acre tract in which the well is located, based on the division of the 9-square-mile area shown in figure 8. This location is used to approximate the distance between the existing wells and the proposed well. The error introduced by this approximation can be as great as 933 feet if two wells are located in the opposite corners of their respective 10-acre tracts. This accuracy suffices for the purpose of this model because the location of an existing well generally is not specified in the historical record to an accuracy greater than the 10-acre tract. If this degree of accuracy is inadequate to ascertain if well-spacing requirements are being met, an onsite investigation by the proposed water appropriator or management district personnel is necessary.

In some instances two or more water rights have been approved for the same parcel of land. This is called overlapping of water rights. It will be necessary, for management district personnel and those who use this program, to review such appropriations for limitations or corrections.

The aquifer properties necessary for the depletion calculation are saturated thickness and specific yield. The average saturated thickness for the 9-square-mile area is determined from the latest published saturated-thickness map, which recently has been prepared every third year (Pabst and Jenkins, 1976; Pabst, 1978). The specific yield is assumed to be 20 percent if other information for the 9 square miles in question is not available. An average aquifer hydraulic conductivity for the 9 square miles is needed for the drawdown computations and is determined by dividing the transmissivity by the saturated thickness.

Results

The printed output for the single-well option includes a summary of the data plus the results of the depletion calculations and the computed drawdown in the aquifer due to the proposed well. The volume of water available considering all existing wells in the 9-square-mile area is printed for both 25 years and 1 year as the last two lines of the depletion information.

There are two basic forms of printed results depending upon the percentage of ground-water depletion with the proposed well. An example of the first form, where the percentage appropriation is equal to or less than the 40-percent allowable depletion for 25 years, is given in figure 9. However, the proposed diversion rate of 810 gal/min exceeded the maximum allowable diversion rate as defined by regulation. Thus, a message "MAXIMUM DIVERSION RATE EXCEEDED" was written.

The second form is characterized by a printed warning that depletion will exceed the 40-percent limit, and, if water is available, the volume requested for the proposed well will be adjusted downward to meet the maximum depletion limit. For the example problem shown in figure 10, a proposed annual appropriation of 500 acre-feet was requested. As this request for appropriation exceeded the allowable depletion, the proposed annual appropriation was reduced to 110 acre-feet. Because the requested appropriation exceeded the volume of water available for appropriation, the message "WITH PROPOSED WELL APPROPRIATION WILL EXCEED 40%" was printed.

SOUTHWEST KANSAS GROUND WATER MANAGEMENT DISTRICT
GROUND WATER APPROPRIATION ANALYSIS
WELL PROPOSED FOR
HODGMAN COUNTY
T 22S. R.22E. SEC 22
SE,SE,SE

DIVISION OF WATER RESOURCES NUMBER, 12345
LOCATION OF 10 ACRE TRACT IN NINE SQUARE MILE AREA
ROW,12 COLUMN,12

PROPOSED ANN APPROP.,	500.ACRE-FEET
PROPOSED DIVERSION RATE,	810. GALLONS PER MINUTE
PUMP DIAMETER,	8. INCHES
PROPOSED WELL RADIUS,	24. INCHES

AQUIFER PROPERTIES
HYDRAULIC CONDUCTIVITY, 390 GAL/DAY/SQ FT
SATURARED THICKNESS, 175 FEET

NUMBER OF EXISTING WELLS IN NINE SQUARE MILE AREA= 1

DWR NO.	LOCATION ROW	LOCATION COLUMN	ANNUAL APPROPRIATION ACRE FEET	DISTANCE FROM PROPOSED WELL, IN FEET
23456	13	20	600.	5,321.

****

MAXIMUM DIVERSION RATE EXCEEDED

****

	WITHOUT PROPOSED WELL	WITH PROPOSED WELL
ACRE-FEET IN STORAGE,	225,600.	
ACRE-FEET APPROPRIATED,	15,000.	27,500.
PERCENT APPROPRIATED,	7.	12.
ACRE-FEET AVAILABLE FOR APPROPRIATION,	78,240.	62,740.
ACRE-FEET AVAILABLE FOR APPROPRIATION ANNUALLY,	3,010.	2,510.

```
DRAWDOWN AFTER ONE YEAR DUE TO PUMPING PROPOSED WELL CONTINUOUSLY AT ANNUAL APPROPRIATION RATE

    DISTANCE        DRAWDOWN
        2.00          10.35
        3.61           9.70
        6.52           9.05
       11.77           8.40
       21.25           7.75
       38.37           7.11
       69.27           6.47
      125.06           5.83
      225.78           5.20
      407.63           4.57
      735.96           3.94
     1328.72           3.31
     2398.92           2.68
     4331.10           2.06
     7819.53           1.45
    14117.66           0.87
    25488.53           0.37
    46017.92           0.07
    83082.42           0.00
   150000.01           0.00

            EXISTING WELLS
     5321.09           1.85
CALCULATED DELT AND NUMT,      0.9606E-05   66


DRAWDOWN DUE TO PUMPING ANNUAL APPROPRIATION FROM PROPOSED WELL CONTINUOUSLY AT PROPOSED DIVERSION RATE

    DISTANCE        DRAWDOWN
        2.00          21.92
        3.61          20.09
        6.52          18.29
       11.77          16.50
       21.25          14.74
       38.37          12.99
       69.27          11.27
      125.06           9.56
      225.78           7.87
      407.63           6.20
      735.96           4.56
     1328.72           2.98
     2398.92           1.53
     4331.10           0.45
     7819.53           0.04
    14117.66           0.00
    25488.53           0.00
    46017.92           0.00
    83082.42           0.00
   150000.01           0.00

            EXISTING WELLS
     5321.09           0.30
139.69DAYS PUMP AT DIV.RATE;SHOULD NOT EXCEED 365

 MASS BALANCE,
VOLUME OF CONE = 105810407.5000
VOL. PUMPED=      0.2178E+08  VOL. WATER FROM CONE=      0.2116E+08
IT,NUMDT,TIME,     3    66     0.12E+08
```

Figure 9.--Example of depletion and drawdown calculations when depletion is equal to or less than maximum allowed.

SOUTHWEST KANSAS GROUND WATER MANAGEMENT DISTRICT
GROUND WATER APPROPRIATION ANALYSIS
WELL PROPOSED FOR
STEVENS COUNTY
T.34S. R.10E. SEC.24
SE.SE.SE

DIVISION OF WATER RESOURCES NUMBER, 20000
LOCATION OF 10 ACRE TRACT IN NINE SQUARE MILE AREA
ROW,12 COLUMN,13

PROPOSED ANN. APPROP.,	110.ACRE-FEET ,
PROPOSED DIVERSION RATE,	600. GALLONS PER MINUTE
PUMP DIAMETER,	8. INCHES
PROPOSED WELL RADIUS,	24. INCHES

AQUIFER PROPERTIES
HYDRAULIC CONDUCTIVITY, 390 GAL/DAY/SQ FT
SATURARED THICKNESS, 175 FEET

NUMBER OF EXISTING WELLS IN NINE SQUARE MILE AREA= 7

DWR NO.	LOCATION ROW	LOCATION COLUMN	ANNUAL APPROPRIATION ACRE-FEET	DISTANCE FROM PROPOSED WELL, IN FEET
100	8	17	500.	3734.
200	9	8	500.	3848.
300	11	17	500.	2721.
400	18	17	500.	4759.
500	20	17	500.	5903.
600	21	8	500.	6795.
700	24	17	500.	8348.

****

WITH PROPOSED WELL APPROPRIATION WILL EXCEED 40%

****

	WITHOUT PROPOSED WELL	WITH PROPOSED WELL
ACRE-FEET IN STORAGE,	225600.	
ACRE-FEET APPROPRIATED,	87500.	92500.
PERCENT APPROPRIATED,	39.	41.
ACRE-FEET AVAILABLE FOR APPROPRIATION,	2740	-2260.
ACRE-FEET AVAILABLE FOR APPROPRIATION ANNUALLY,	110.	-90.

APPROPRIATION ADJUSTED TO, 110 ACRE FEET

DRAWDOWN AFTER ONE YEAR DUE TO PUMPING PROPOSED WELL CONTINUOUSLY AT ANNUAL APPROPRIATION RATE

DISTANCE	DRAWDOWN
2.00	2.22
3.61	2.08
6.52	1.94
11.77	1.81
21.25	1.67
38.37	1.53
69.27	1.40
125.06	1.26
225.78	1.13
407.63	0.99
735.96	0.86
1328.72	0.72
2398.92	0.59
4331.10	0.45
7819.53	0.32
14117.66	0.19
25488.53	0.08
46017.92	0.01
83082.42	0.00
150000.01	0.00

```
           EXISTING WELLS
    3733.52             0.48
    3848.43             0.48
    2721.25             0.56
    4759.33             0.43
    5903.22             0.38
    6795.12             0.35
    8348.41             0.30
CALCULATED DELT AND NUMT,      0.9594E-05   63


 DRAWDOWN DUE TO PUMPING ANNUAL APPROPRIATION FROM PROPOSED WELL CONTINUOUSLY AT PROPOSED DIVERSION RATE

     DISTANCE        DRAWDOWN
         2.00           14.61
         3.61           13.31
         6.52           12.03
        11.77           10.76
        21.25            9.49
        38.37            8.24
        69.27            6.99
       125.06            5.76
       225.78            4.54
       407.63            3.33
       735.96            2.17
      1328.72            1.11
      2398.92            0.31
      4331.10            0.03
      7819.53            0.00
     14117.66            0.00
     25488.53            0.00
     46017.92            0.00
     83082.42            0.00
    150000.01            0.00

           EXISTING WELLS
    3733.52             0.10
    3848.43             0.09
    2721.25             0.25
    4759.33             0.02
    5903.22             0.01
    6795.12             0.01
    8348.41             0.00
 41 34DAYS PUMP AT DIV.RATE;SHOULD NOT EXCEED 365

 MASS BALANCE,
VOLUME OF CONE =   23195224.5520
VOL. PUMPED=       0.4774E+07  VOL. WATER FROM CONE=      0.4639E+07
IT,NUMDT,TIME,      3    63     0.36E+07
```

Figure 10.--Example of depletion and drawdown calculations when depletion exceeds maximum allowed.

Township Option

Data Requirements

Evaluation of ground-water depletion for an entire township was accomplished in an interactive mode by using a remote terminal and programs and data on disk files of a Honeywell Multics Computer in Reston, Virginia. Although the computations are the same as the single-well evaluation for any given section, the method of data entry is different. First, equation 6 was solved using a FORTRAN computer program (Supplemental Information, p. 40) and the average saturated thickness in each square mile of the township. This program is written in Fortran IV (IBM "G" Compiler) and runs on an Amdahl V7 computer. An area of as many as four townships on a side can be analyzed in a single run of the program. This program calculates the volume of ground water available for appropriation on an annual basis in the 9-square-mile area centered around each section in the township (table 1). The ground water available for appropriation on an annual basis must be written on a disk file, which becomes one part of the data required by the PL/1 computer program used to determine V_{app}/V_{av}. The other part of the data required by this PL/1 interactive program is a file of water rights that was prepared from a tape file of the Kansas Water Office containing applications for water rights in Kansas up through 1974. Because this PL/1 program is primarily a file-management routine written specifically for Kansas water-rights data and has little or no general application, a listing is not included in this report.

Results

Results from the computer program used to evaluate ground-water depletion on a township basis are a summary of the water rights for each section and the eight adjacent sections (fig. 11) and a tabular listing of the percentage of ground water appropriated for each section in the township, considering all available water and water rights in each 9-square-mile area (fig. 12). A withdrawal is "certified" (fig. 11) if the volume of water withdrawn has been certified by onsite measurements.

The procedure was tested using the 16 townships in northwestern Finney County. The available water in each 9-square-mile area, based on the management district's rules and regulations for 1978-2003, ranges from less than 1,000 to more than 5,000 acre-feet per year. The two areas where the available water generally is less than 1,000 acre-feet per year are located in the northeastern and northwestern townships where the January 1978 saturated thickness was less than 50 feet (fig. 13). The two southwestern townships have the most available water (fig. 13), with a few 9-square-mile areas averaging as much as 7,000 acre-feet of ground water available annually for 1978-2003.

Table 1.--Example of ground-water-availability calculations for an entire township

GROUND WATER AVAILABILITY
BASED ON NINE SQUARE MILE DEPLETION MODEL

SOUTHWESTERN KANSAS GROUNDWATER MANAGEMENT DISTRICT NO. 3

U.S. GEOLOGICAL SURVEY

TOWNSHIP 24W RANGE 31S

SECTION	AVERAGE SATURATED THICKNESS (FEET)	VOLUME IN STORAGE (ACRE-FEET)	VOLUME AVAILABLE IN 25 YEARS (ACRE-FEET)	ANNUAL VOLUME AVAILABLE (ACRE-FEET)
1	94.3	108671.9	53068.7	2122.7
2	100.7	115967.9	55987.1	2239.5
3	112.9	130047.9	61619.2	2464.8
4	122.2	140799.9	65919.9	2636.8
5	133.3	153599.9	71039.9	2841.6
6	145.0	167039.9	76415.9	3056.6
7	159.4	183679.9	83071.9	3322.9
8	146.7	168959.9	77183.9	3087.4
9	135.6	156159.9	72063.9	2882.6
10	126.8	146047.9	68019.1	2720.8
11	116.2	133887.9	63155.1	2526.2
12	111.0	127871.9	60748.8	2430.0
13	130.2	149951.9	69580.7	2783.2
14	134.6	155007.9	71603.1	2864.1
15	143.4	165247.9	75699.1	3028.0
16	148.9	171519.9	78207.9	3128.3
17	157.2	181119.9	82047.9	3281.9
18	167.8	193279.9	86911.9	3476.5
19	177.2	204159.9	91263.9	3650.6
20	168.3	193919.9	87167.9	3486.7
21	162.8	187519.9	84607.9	3384.3
22	157.8	181759.9	82303.9	3292.2
23	150.6	173439.9	78975.9	3159.0
24	146.7	168959.9	77183.9	3087.4
25	155.8	179519.9	81407.9	3256.3
26	157.8	181759.9	82303.9	3292.2
27	162.2	186879.9	84351.9	3374.1
28	166.7	191999.9	86399.9	3456.0
29	173.3	199679.9	89471.9	3578.9
30	183.9	211839.9	94335.9	3773.4
31	188.3	216959.9	96383.9	3855.4
32	175.8	202559.9	90623.9	3625.0
33	167.5	192959.9	86783.9	3471.4
34	161.7	186239.9	84095.9	3363.8
35	159.2	183359.9	82943.9	3317.8
36	158.7	182879.9	82751.9	3310.1

Section 31 Twp 14S Ran 42W

Total withdrawal approved 6361 acre-feet
Total withdrawal certified 1516 acre-feet
9 Water rights in or near section 31

Section 32 Twp 14S Ran 42W

Total withdrawal approved 5516 acre-feet
Total withdrawal certified 1516 acre-feet
7 Water rights in or near section 32

Section 33 Twp 14S Ran 42W

Total withdrawal approved 7828 acre-feet
Total withdrawal certified 1280 acre-feet
10 Water rights in or near section 33

Figure 11.--Example of water-rights summary for a section and eight adjacent sections within an entire township.

Percentage of water already appropriated in

Township 14S Range 42W

156	176	137	181	193	140
166	236	212	272	259	177
236	309	316	329	324	235
240	289	377	365	367	219
204	203	319	307	362	240
165	148	237	197	254	135

Figure 12.--Ground-water depletion evaluation for an entire township. Values for each section are in the same position as they would be found on a map, with section 1 being the top value on the right side.

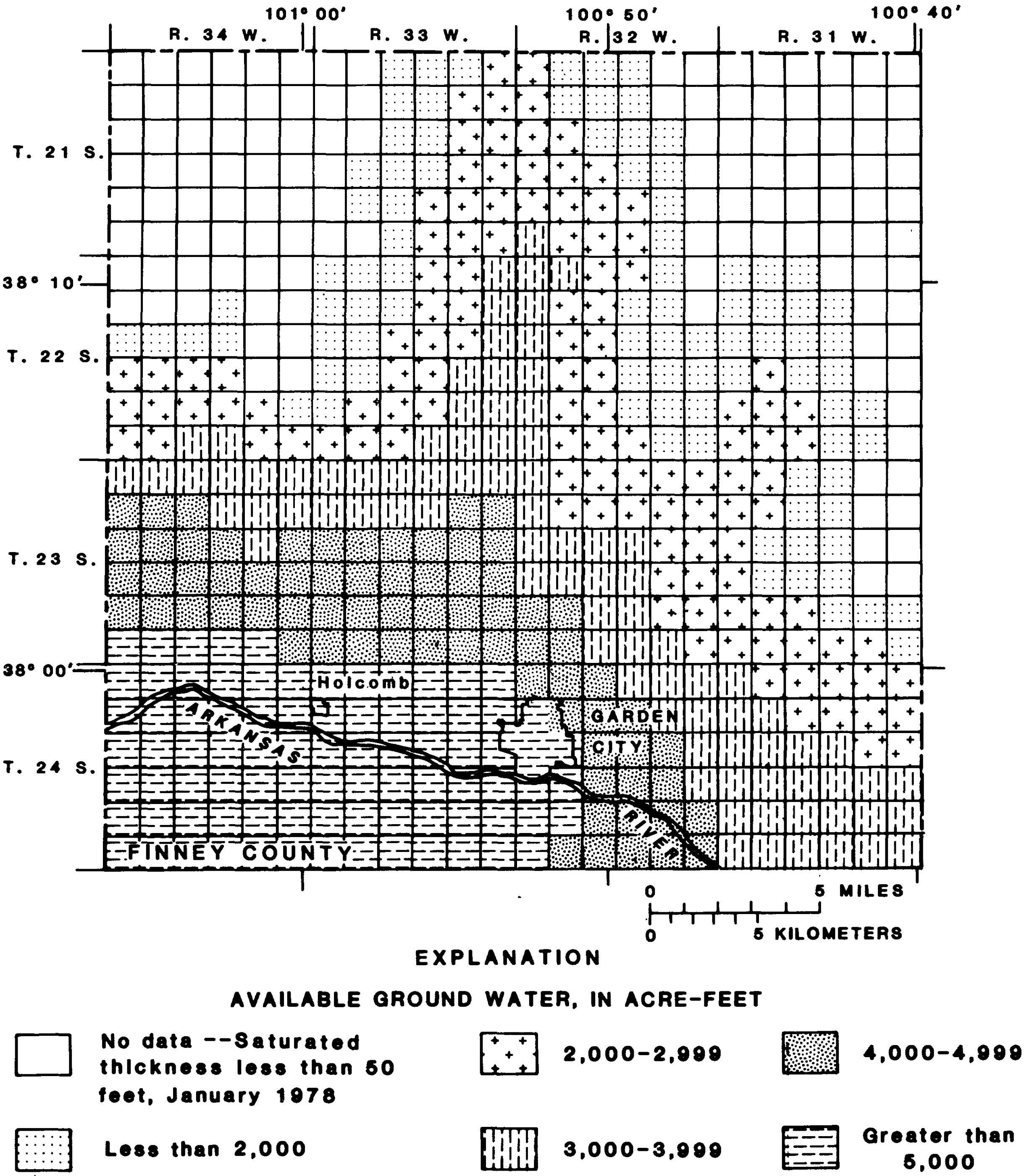

Figure 13.--Volume of ground water available for appropriation annually for each section and the adjacent eight sections, 1978-2003.

The percentage of water available during 1978, which was already appropriated during 1974, is shown in figure 14. There were only about 6 square miles in the southern part of the area where the percentage of ground water available for appropriation was less than the 40-percent limit set by the management district for new development. More than 100 percent of the ground water available during 1978, as defined by the management district's regulations, has been appropriated in all but 61 square miles of the 16 townships evaluated.

CONCLUSIONS

A computer model was developed to calculate the drawdown, due to a proposed well, at all existing wells in the section of the proposed well and at all wells in the adjacent eight sections. The depletion expected in the 9-square-mile area due to all existing wells and the proposed well is computed and compared with allowable limits defined by the Southwest Kansas Groundwater Management District No. 3. An optional program permits the evaluation of allowable depletion for one or more townships. All options are designed to run interactively, thus allowing for immediate evaluation of proposed ground-water withdrawals.

ACKNOWLEDGMENTS

The assistance of the staff of the Southwest Kansas Groundwater Management District No. 3 in collating allocation data, and the advice and assistance of Dr. Carl McElwee of the Kansas Geological Survey in developing the finite-difference approximations used in the model are appreciated.

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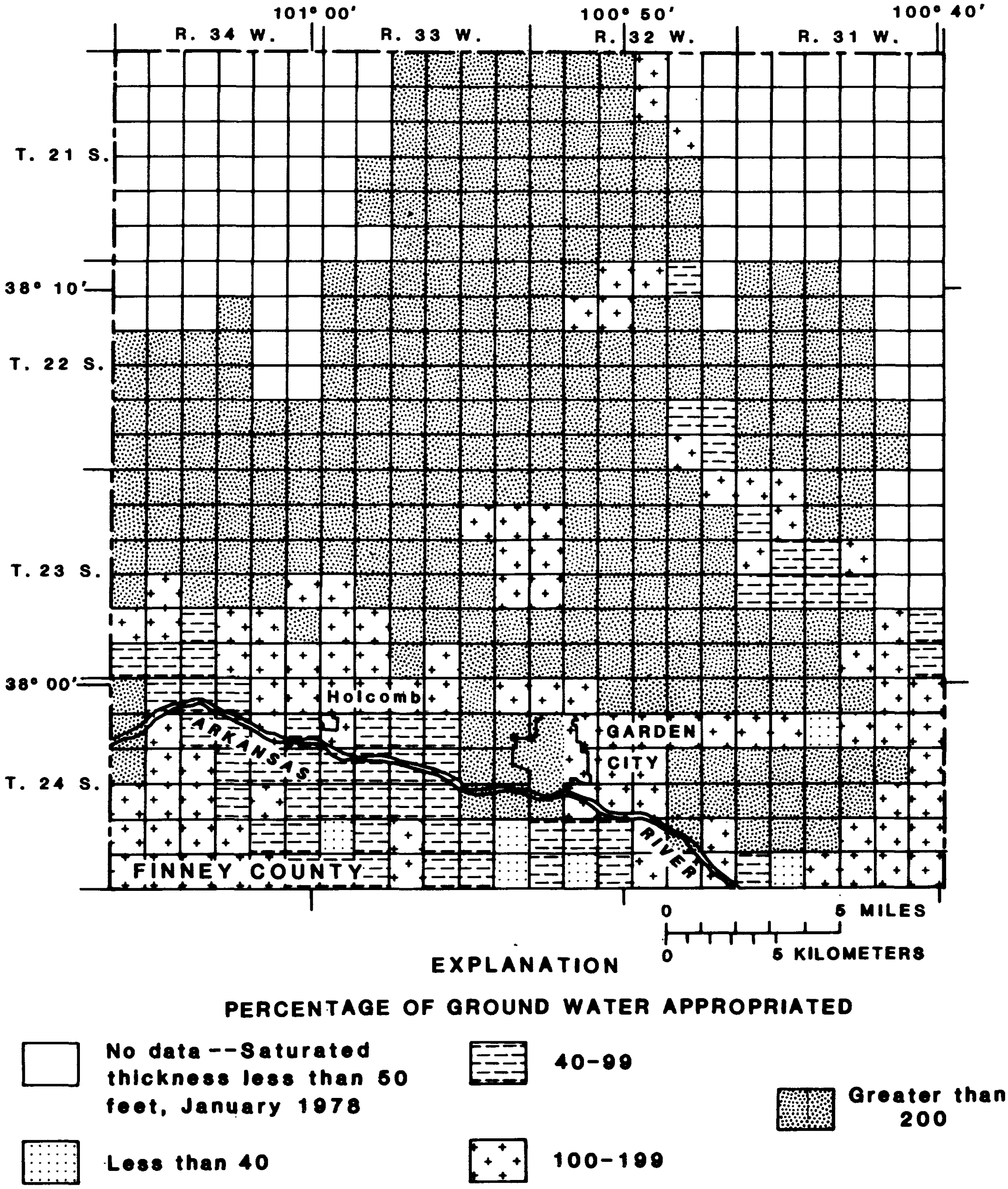

Figure 14.--Percentage of ground water available for appropriation during 1978 that was already appropriated during 1974.

Pabst, M. E., and Jenkins, E. D., 1976, Water-level changes in southwestern Kansas, 1940-75: Kansas Geological Survey Journal, May 1976, 26 p.

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SUPPLEMENTAL INFORMATION

Finite-Difference Approximations of Radial-Flow Equation

$$\frac{1}{r} \frac{\partial}{\partial r} \left(rKh \frac{\partial h}{\partial r} \right) = S' \frac{\partial h}{\partial t} \quad . \tag{1}$$

Equation 1 in radial coordinates can be transformed to cartesian coordinates by a change of variables. Let

$$x = \ln \left(\frac{r}{r_w} \right) , \tag{a}$$

where $0 \leq x \leq R$.

R is a very large distance from the origin, and r_w is the radius of the well. From equation a, it can be stated

$$r = r_w e^x \quad . \tag{b}$$

Differentiating equation a yields

$$\frac{\partial x}{\partial r} = \frac{1}{r} \quad . \tag{c}$$

Substituting equations b and c into equation 1 yields

$$\frac{1}{(r_w e^x)^2} \frac{\partial}{\partial x} \left(rKh \frac{\partial h}{\partial r} \right) = S' \frac{\partial h}{\partial r} \quad . \tag{d}$$

Applying the "chain rule" of differentiation to equation d results in

$$\frac{1}{r_w{}^2 e^{2x}} \frac{\partial}{\partial x} \left(Kh \frac{\partial h}{\partial x} \right) = S' \frac{\partial h}{\partial t} \quad . \tag{e}$$

Equation e is a nonlinear differential equation and can be solved numerically using finite-difference techniques.

Let x = i x, where i indexes the nodes at which equation e is to be evaluated. The finite-difference equation has a constant spacing. At the radius of the well where $r = r_w$:

$$x = \ln \frac{r}{r_w} = 0 \quad , \text{at } i = 1 .$$

Using a numerical method, noting equation 1, and using a technique similar to that used by Von Rosenburg (1969, p. 63), equation e has the form

$$T^{m+\frac{1}{2}}_{i+\frac{1}{2}} h^{m+1}_{i+1} - T^{m+\frac{1}{2}}_{i+\frac{1}{2}} h^{m+1}_{i} - T^{m+\frac{1}{2}}_{i-\frac{1}{2}} h^{m+1}_{i} + T^{m+\frac{1}{2}}_{i-\frac{1}{2}} h^{m+1}_{i-1} - F h^{m+1}_{i} =$$
$$-F h^{m}_{i} - T^{m+\frac{1}{2}}_{i+\frac{1}{2}} h^{m}_{i+1} + T^{m+\frac{1}{2}}_{i+\frac{1}{2}} h^{m}_{i} + T^{m+\frac{1}{2}}_{i-\frac{1}{2}} h^{m}_{i} - T^{m+\frac{1}{2}}_{i-\frac{1}{2}} h^{m}_{i-1} \quad , \qquad \text{(f)}$$

where m is a superscript indicating time level, and

$$F = \frac{S' \quad 2r_w^2 \quad \Delta x^2}{e^{2i} \quad \Delta x \quad \Delta t} .$$

F is an arbitrary variable created to simplify equation f and others. Equation f is for the interior nodes.

At the well face (r_w), at i = 1, is a constant-flux boundary

$$\frac{-Q}{2\pi} = rhK \left.\frac{\partial h}{\partial r}\right|_{r=r_w} \qquad \text{(g)}$$

Noting that $r\frac{\partial h}{\partial r} = \frac{\partial h}{\partial x}$, equation g changes to

$$\frac{-Q}{2\pi} = hk \left.\frac{\partial h}{\partial x}\right|_{r=r_w} \qquad \text{(h)}$$

At an imaginary node inside the well at i = 0, let

$$\frac{\partial h}{\partial x} \approx \frac{h_2 - h_0}{2 \Delta x}, \text{ then} \qquad \text{(i)}$$

$$h^m_0 = h_2^m + \frac{\Delta x \ Q}{\pi T_1} .$$

Evaluating at i = 1, using equation i yields

$$-1 -\left(\frac{T_{\frac{1}{2}}^{m+\frac{1}{2}} + F}{T_{3/2}^{m+\frac{1}{2}}}\right) h_1^{m+1} + \left(1 + \frac{T_{\frac{1}{2}}^{m+\frac{1}{2}}}{T_{3/2}^{m+\frac{1}{2}}}\right) h_2^{m+\frac{1}{2}} = \tag{j}$$

$$\frac{-Fh_1^m}{T_{3/2}^{m+\frac{1}{2}}} + (h_1^m - h_2^m) + \frac{T_{\frac{1}{2}}^{m+\frac{1}{2}}}{T_{3/2}^{m+\frac{1}{2}}} \left(h_1^m - h_2^m - \frac{\Delta xQ}{\pi T_1^m} - \frac{\Delta xQ}{\pi T_1^{m+1}}\right).$$

At the outside boundary, i = n, a constant head is chosen, or $h_n^{m+1} = h_n^m$. The equation at n becomes

$$\frac{T_{n-3/2}^{m+\frac{1}{2}}}{T_{n-\frac{1}{2}}^{m+\frac{1}{2}}} h_{n-2}^{m+1} + \left\{-1 -\left(\frac{T_{n-\frac{1}{2}}^{m+\frac{1}{2}} + F}{T_{n-\frac{1}{2}}^{m+\frac{1}{2}}}\right) h_n^{m+1}\right\} =$$

$$\frac{F\, h_{n-1}^m}{T_{n-\frac{1}{2}}^{m+\frac{1}{2}}} + h_{n-1}^m - 2h_n^m + \left(\frac{T_{n-3/2}^{m+\frac{1}{2}}}{T_{n-\frac{1}{2}}^{m+\frac{1}{2}}}\right)(h_{n-1}^m - h_{n-2}^m). \tag{k}$$

The various forms of T can be reduced by using the following relations:

$$T_1^m = K\, h_1^m \quad ; \tag{l}$$

$$T_1^{m+1} = K\, h_1^{m+1} \quad ; \tag{m}$$

$$T_{i+\frac{1}{2}}^{m+\frac{1}{2}} = \tfrac{1}{2}\,(T_i^{m+\frac{1}{2}} + T_{i+1}^{m+\frac{1}{2}}) \quad ; \tag{n}$$

$$T_{i-\frac{1}{2}}^{m+\frac{1}{2}} = \tfrac{1}{2}\,(T_i^{m+\frac{1}{2}} + T_{i-1}^{m+\frac{1}{2}}) \quad ; \tag{o}$$

$$T_{3/2}^{m+\frac{1}{2}} = \tfrac{1}{2}\,(T_1^{m+\frac{1}{2}} + T_2^{m+\frac{1}{2}}) \quad ; \tag{p}$$

$$T_{\frac{1}{2}}^{m+\frac{1}{2}} = \tfrac{1}{2}\,\left(T_1^{m+\frac{1}{2}} + T_2^{m+\frac{1}{2}} + \frac{\Delta x\ Q}{\pi h_1^{m+\frac{1}{2}}}\right) \quad ; \text{ and} \tag{q}$$

$$h_1^{m+\frac{1}{2}} = \tfrac{1}{2}\,(h_1^{m+1} + h_1^m). \tag{r}$$

Equations f, j, and k are of the form that can be solved using the Thomas algorithm. The procedure for solution is to iterate the head values until little change occurs between h^m and h^{m+1}. This is accomplished by updating the T values after each iteration using

$$T_1^{m+\frac{1}{2}} = \tfrac{1}{2}K \left(h_i^{m+1} + h_i^m\right) \ . \qquad (s)$$

The first estimate of T at a new time step assumes

$$T_1^{m+1} = K\ h_i^{m+1} \approx K\ h_i^m \ . \qquad (t)$$

Program Listing for Single-Well Option

```
27 OCT 81 10 21 01        MODULE:  *MAIN*   OPTIONS: SE SU WA LO                                        PAGE    1
61516-02 ENHANCED SAU FORTRAN COMPILER        REVISION LEVEL 08.01 PRE     SOURCE INPUT:   SAPP:S

C       GWMD NO 3--APPROPRIATION OF GROUND WATER                                            00000
C                                                                                           00000
C                 POLICY-REGULATIONS                                                        00000
C                        AND                                                                00000
C       PREDICTION  OF WATERTABLE DRAWDOWNS                                                 00000
C ------------------------------------------------------------------                        00000
        INTEGER DWRNO                                                                       00000
        DIMENSION BETA(20),HO(20),HN(20),T(20),GAMMA(20),R(20),                             00000
       $ DWRNO(20),RTONWL(20),IR(20),IC(20),APPROP(20),CO(8),A(20),BB(1),                   00000
       & C(1)                                                                               00000
C       CALL FPARAM (1,131)                                                                 00000
        IPRNT=0                                                                             00000
        PRINT 1000                                                                          00006
   1000 FORMAT('COUNTY?')                                                                   00013
        READ (33,1001) CO                                                                   00024
   1001 FORMAT (8A1)                                                                        00034
        PRINT 1002                                                                          00043
   1002 FORMAT ('TOWNSHIP,RANGE,SECTION?')                                                  00050
        READ(33,-)ITNS,IRNG,ISEC                                                            00066
        PRINT 1111                                                                          00103
   1111 FORMAT ('1/4,1/4,1/4?')                                                             00110
        READ (33,1112) A                                                                    00122
   1112 FORMAT (20A1)                                                                       00132
C             INPUT WELL DATA                                                               00132
        PRINT 650                                                                           00141
    650 FORMAT('DIVISION OF WATER RESOURCES NUMBER?')                                       00146
        READ (33,655)NDWRNO                                                                 00170
    655 FORMAT (I8)                                                                         00200
        PRINT 660                                                                           00206
    660 FORMAT('ROW,COLLUMN, AND APPROPRIATION IN AC FT./YR ?')                             00213
        READ(33,-) IRPW,ICPW,PROPAP                                                         00240
        WRITE(44,665) NDWRNO, IRPW,ICPW,PROPAP                                              00253
    665 FORMAT('DWR NO  ROW,COL,& APPROPRIATION,',I8,I4,I4,F9.2)                            00276
        PRINT 670                                                                           00323
    670 FORMAT('DIV  RATE IN GPM &PUMP COL  DIAM  IN INCHES ARE?')                          00330
        READ(33,-)QINST,PUMDIA                                                              00356
        RMIN=1300                                                                           00370
        IF(QINST GT 400 ) RMIN=2300                                                         00373
        IF(PUMDIA GT 6.)  RMIN=2300                                                         00402
        PRINT 680                                                                           00411
    680 FORMAT('RADIUS OF NEW WELL IN FEET ?')                                              00416
        READ(33,-)RW                                                                        00436
        PRINT 700                                                                           00445
        RWI=RW*12 0                                                                         00452
    700 FORMAT('NUMBER OF EXISTING WELLS ?')                                                00456
        READ(33,-)NW                                                                        00475
        IF(NW EQ 0)  GO TO 22                                                               00504
        APPR=0                                                                              00511
        PRINT 710                                                                           00515
    710 FORMAT('DWR NO  ON 1ST LINE  ROW, COL ,& APPROP  ON 2ND LINE')                      00522
        DO 20 IW=1,NW                                                                       00552
        READ(33,655) DWRNO(IW)                                                              00562
        READ(33,-)IROWWL,ICOLWL,APPROP                                                      00576
        APPR=APPR+APPROP                                                                    00613
        IR(IW)=IROWWL                                                                       00617
        IC(IW)=ICOLWL                                                                       00623
        APROP(IW)=APPROP                                                                    00626
```

```
          ASQ=((660.)*(IRPW-IROWWL))**2                                        00633
          BSQ=((660.)*(ICPW-ICOLWL))**2                                        00642
          RTONWL(IW)=SQRT(ASQ+BSQ)                                             00651
          WRITE(44,730)DWRNO(IW),IROWWL,ICOLWL,APPROP,RTONWL(IW)               00664
      730 FORMAT('DWR NO,ROW,COL ,APPROP ,&RADIUS,',I8,2I4,F6.0,F8.0)          00720
       20 CONTINUE                                                             00746
          WRITE(44,740) RMIN                                                   00755
      740 FORMAT('DISTANCE BETWEEN WELLS SHOULD EXCEED',F7.0,' FT ')           00765
    C               HYDROLOGIC DATA                                            00765
       22 PRINT 760                                                            01013
      760 FORMAT('HYDRAULIC CONDUCTIVITY IN GAL/DAY/SQ FT  IS ?')              01021
          READ(33,-)P                                                          01046
          PM=P                                                                 01055
          P=P/(7.481*86400.)                                                   01060
          S=0.20                                                               01067
          RECHAR=(2./12.)*9.*640.*25                                           01072
          PRINT 765                                                            01101
     765  FORMAT('SATURATED THICKNESS IN FEET ?')                              01106
          READ(33,-)H                                                          01126
          VOLSTR=S*H*9.*640.+RECHAR                                            01135
          VOLAPR=APPR*25.                                                      01144
          VOLLFT=(.4*VOLSTR)-VOLAPR                                            01150
          PERCNT=(VOLAPR/VOLSTR)*100                                           01155
          WRITE(44,770)VOLSTR,VOLAPR,PERCNT,VOLLFT                             01162
      770 FORMAT('VOL STORED,VOL APPROP ,% APPROP ,VOL LEFT',4F12.0)           01203
          TOTVAP=VOLAPR+PROPAP*25.                                             01231
          PERCT=(TOTVAP/VOLSTR)*100                                            01236
          WRITE(44,800)PERCT,VOLFT                                             01243
          VOLFT=(.4*VOLSTR)-TOTVAP                                             01256
          WRITE(44,800)PERCNT,VOLLFT                                           01263
          AVLLFT=VOLLFT/25                                                     01276
          AVLFT=VOLFT/25                                                       01302
      800 FORMAT('% APPROP  INCLUDING NEW WELL AND VOL LEFT',2F12.2)           01306
          IF(PERCT.LT.40.) GO TO 50                                            01334
          ADJAPR=((VOLSTR*.4)-VOLAPR)/25                                       01340
          WRITE(44,810)ADJAPR                                                  01347
      810 FORMAT('THE ADJUSTED APPROPRIATION IS',F12.0,' IN AC.FT /YR')        01357
          PROPAP=ADJAPR                                                        01406
          GO TO 50                                                             01411
      815 FORMAT('OVERAPPROP OR MAX DIV  RATE EXCEEDED,CALC  CONT ')           01412
    C               DATA FOR SOLUTION SCHEME                                   01412
       50 JCNT=0                                                               01441
          RO=150000                                                            01444
          N=20                                                                 01447
          Q=(-1.)*(PROPAP*43560.)/(365.*86400.)                                01452
          TMAX=7.89E08                                                         01464
       53 DELT=0.00001                                                         01467
          IPRNT=IPRNT + 1                                                      01473
          NUMT=150                                                             01477
          CDLT=1.5                                                             01502
          JCNT=JCNT+1                                                          01505
          HDIFF=0.01                                                           01511
          ITMAX=20                                                             01514
          DX=ALOG(RO/RW)/(N-1)                                                 01517
    C     COMPUTE ACTUAL DELT AND NUMT                                         01517
          FACT=1                                                               01533
          IF(DELT.LT.1.) FACT=1./DELT                                          01536
```

```
27 OCT 81 10:21:01        MODULE   *MAIN*    OPTIONS  SE SU WA LO                                   PAGE    3
61516-02 ENHANCED SAU FORTRAN COMPILER         REVISION LEVEL 08.01 PRE       SOURCE INPUT:   SAPP:S

          DELT=DELT*FACT                                                              01546
          DT=DELT                                                                     01552
          TMAX=TMAX*FACT                                                              01555
          TM=0                                                                        01561
          DO 131 I=1,NUMT                                                             01564
          DT=CDLT*DT                                                                  01574
          TM=TM+DT                                                                    01600
          IF(TM.GE.TMAX) GO TO 132                                                    01604
      131 CONTINUE                                                                    01610
          GO TO 133                                                                   01620
      132 DELT=TMAX/(TM*DELT)                                                         01621
          NUMT=I                                                                      01632
      133 DELT=DELT/FACT                                                              01635
          TMAX=TMAX/FACT                                                              01642
          WRITE(44,530) DELT,NUMT                                                     01646
      530 FORMAT(1X,'CALCULATED DELT AND NUMT,',E15.4,I4)                             01661
    C INITIALIZATION                                                                  01661
          TIME=0                                                                      01703
          NUMDT=0                                                                     01706
          PI=3.1416                                                                   01710
          HO(N)=H                                                                     01713
          T(N)=H*P                                                                    01720
          DO 140 I=1,N                                                                01724
          HN(I)=H                                                                     01734
      140 CONTINUE                                                                    01741
      145 IT=0                                                                        01750
          NUMDT=NUMDT+1                                                               01753
          DELT=DELT*CDLT                                                              01757
          TIME=TIME+DELT                                                              01763
          DO 150 I=1,N-1                                                              01767
      150 HO(I)=HN(I)                                                                 02002
    C COMPUTING COEFFICIENTS FOR 1ST EQUATION                                         02002
          AI= 0                                                                       02015
      151 RI=0.0                                                                      02020
    C COMPUTING T(1) THRU T(N-1) AT TIME M+1/2                                        02020
          DO 155 I=1,N-1                                                              02024
      155 T(I)=.5*P*(HO(I)+HN(I))                                                     02037
          IT=IT+1                                                                     02061
          ARG=2.*RI*DX                                                                02065
          COEF2=1./(2.*RW*RW*DX*DX*EXP(ARG))                                          02074
          COEF2=S/(COEF2*DELT)                                                        02114
          T1HAF=.5*(T(1)+T(2)+(DX*Q)/(PI*.5*(HO(1)+HN(1))))                           02123
          T3HAFS=.5*(T(1)+T(2))                                                       02150
          T1M=P*HO(1)                                                                 02157
          T1MPL=P*HN(1)                                                               02163
          B1=(-1.-(T1HAF+COEF2)/T3HAFS)                                               02167
          C1=1.+T1HAF/T3HAFS                                                          02177
          D1=-COEF2*HO(1)/T3HAFS+HO(1)-HO(2)+T1HAF/T3HAFS*                            02204
         &(HO(1)-HO(2)-(DX*Q)/(PI*T1M)-(DX*Q)/(PI*T1MPL))                             02204
          BETA(1)=B1                                                                  02245
          GAMMA(1)=D1/BETA(1)                                                         02250
    C COMPUTING COEF FOR INTERIOR AND LAST EQUATIONS                                  02250
          DO 160 I=2,N-1                                                              02254
          TIMIN=(T(I-1)+T(I))/2                                                       02267
          TIPLUS=(T(I)+T(I+1))/2                                                      02276
    C ALL CI FROM C2 TO CN-1 ARE 1                                                    02276
          RI=I-1                                                                      02303
```

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 27 OCT 81 10:21:01      MODULE  *MAIN*   OPTIONS  SE SU WA LO                                              PAGE   4
 61516-02 ENHANCED SAU FORTRAN COMPILER        REVISION LEVEL 08 01 PRE      SOURCE INPUT   SAPP:S

        ARG=2.*RI*DX                                                                              02310
        COEF2=1./(2.*RW*RW*DX*DX*EXP(ARG))                                                        02317
        COEF2=S/(COEF2*DELT)                                                                      02337
        AI=TIMIN/TIPLUS                                                                           02346
        BI=(-1.-(TIMIN+COEF2)/TIPLUS)                                                             02352
        DI=(-COEF2*HO(I))/TIPLUS+HO(I)-HO(I+1)+AI*(HO(I)-HO(I-1))                                 02362
        IF(I.EQ.(N-1)) DI=DI-HN(N)                                                                02402
        BETA(I)=BI-AI/BETA(I-1)                                                                   02417
        IF(I.EQ.2) BETA(2)=BI-AI*C1/BETA(1)                                                       02426
    160 GAMMA(I)=(DI-AI*GAMMA(I-1))/BETA(I)                                                       02444
  C TEMPORARILY STORING HEAD VALUES IN T MATRIX                                                   02444
        DO 170 I=1,N-1                                                                            02464
    170 T(I)=HN(I)                                                                                02477
        HN(N-1)=GAMMA(N-1)                                                                        02512
        DO 180 J=1,N-3                                                                            02517
        I=(N-1)-J                                                                                 02532
    180 HN(I)=GAMMA(I)-HN(I+1)/BETA(I)                                                            02537
        HN(1)=GAMMA(1)-(C1*HN(2))/BETA(1)                                                         02556
        HMAXDF=0                                                                                  02566
        DO 190 I=1,N-1                                                                            02571
        DIFF=ABS(T(I)-HN(I))                                                                      02604
        IF(DIFF.GT.HMAXDF) HMAXDF=DIFF                                                            02614
    190 CONTINUE                                                                                  02623
        IF(IT.LT.3) GO TO 151                                                                     02632
        IF(HMAXDF.LT.HDIFF) GO TO 210                                                             02640
        IF(IT.LT.ITMAX) GO TO 151                                                                 02645
    210 CONTINUE                                                                                  02654
        IF(HN(1).LT.0.) GO TO 215  ,                                                              02657
        IF(NUMDT.LT.NUMT)  GO TO 145                                                              02662
        GO TO 220                                                                                 02671
    215 WRITE(44,597)                                                                             02673
    597 FORMAT(' WELL GOES DRY')                                                                  02702
    220 CONTINUE                                                                                  02715
  C CALCULATING RADII                                                                             02715
        DO 240 I=1,N                                                                              02717
        Z=I-1                                                                                     02727
        X=Z*DX                                                                                    02734
        R(I)=RW*EXP(X)                                                                            02740
    240 CONTINUE                                                                                  02751
        VOLCO=0.                                                                                  02760
        DO 245 I=1,N-1                                                                            02763
        RAD=2.*R(I+1)*R(I)/(R(I+1)+R(I))                                                          02776
        DELH=HN(I+1)-HN(I)                                                                        03013
        IF(DELH.LT.0.00001) DELH=0.0                                                              03017
    245 VOLCO=VOLCO+PI*RAD*RAD*DELH                                                               03026
        IF (IPRNT.GT.1) GO TO 1120                                                                03043
        WRITE (44,1008)                                                                           03051
   1008 FORMAT(1H1)                                                                               03057
        WRITE(44,1003) CO, ITNS,IRNG,ISEC,A,NOWRNO,IRPW,ICPW                                      03066
   1003 FORMAT ("1",39X,"SOUTHWEST KANSAS GROUND WATER MANAGEMENT DISTRICT                        03123
       &"/46X,"GROUND WATER APPROPRIATION ANALYSIS"/55X,"WELL PROPOSED                            03123
       & FOR"/56X,8A1,"COUNTY"/57X,"T ",I2,"S  R ",I2,"E "," SEC ",I2,/,                          03123
       &58X,20A1,/,1H0,1X,"DIVISION OF WATER RESOURCES NUMBER,",I8,/,1X,                          03123
       &"LOCATION OF 10 ACRE TRACT IN NINE SQUARE MILE AREA"/8X,"ROW,",I2,                        03123
       &5X,"COLUMN,",I2)                                                                          03123
        WRITE (44,1004) PROPAP,QINST,FUMDIA,RWI                                                   03322
   1004 FORMAT (1H0,2X,'PROPOSED ANN. APPROP.,' ,F9.0,'ACRE FEET'/1X,                             03343
```

```
          &'PROPOSED DIVERSION RATE,',F9 0,' GALLONS PER MINUTE'/11X,'PUMP DI         03343
          &AMETER,',F9 0,' INCHES'/3X,'PROPOSED WELL RADIUS,',F9.0,' INCHES')        03343
           WRITE (44,1005) PM,H,NW                                                   03451
     1005 FORMAT (1H0,10('-')/4X,'AQUIFER PROPERTIES'/6X     ,'HYDRAULIC COND      03467
          &UCTIVITY,',F5 0,'GAL/DAY/SQ.FT '/6X,'SATURARED THICKNESS,',F5 0,'F        03467
          &EET'/10('-')/1H0/20X,'NUMBER OF EXISTING WELLS IN NINE SQUARE MILE        03467
          & AREA=',I2/14X,'DWR NO.',7X,'LOCATION',7X,'ANNUAL APPROPRIATION',         03467
          &4X,'DISTANCE FROM PROPOSED '/25X,'ROW',2X,'COLUMN',10X,'ACRE FEET'        03467
          &,15X,'WELL, IN FEET')                                                     03467
           DO 1007 I=1,NW                                                            03670
           WRITE (44,1006) DWRNO(I),IR(I),IC(I),AFROP(I),RTONWL(I)                   03700
     1007 CONTINUE                                                                   03746
     1006 FORMAT (13X,I8,5X,I2,5X,I2,12X,F6 0,20X,F8 0)                              03755
           IF (QINST GT 800.) WRITE (44,8816)                                        03774
     8816 FORMAT(1H0,100("*"),/1H0,10X,"MAXIMUM DIVERSION RATE EXCEEDED")           04005
           IF (PERCT  GT  40.) WRITE (44,8815)                                       04037
     8815 FORMAT(1H0,100("*"),/1H0,10X,"WITH PROPOSED WELL APPROPRIATION WIL        04050
          &L EXCEED 40%")                                                            04050
           WRITE (44,1010) VOLSTR,VOLAPR,TOTVAP,PERCNT,PERCT,VOLLFT,VOLFT,           04107
          &AVLLFT,AVLFT                                                              04107
     1010 FORMAT(1H0,100("*"),                                                       04147
          &/1H0,45X,'WITHOUT PROPOSED WELL',                                         04147
          &12X,'WITH PROPOSED WELL'/18X,'ACRE FEET IN STORAGE,',10X,F12.0/           04147
          &16X,'ACRE FEET APPROPRIATED,',10X,F12 0,20X,F12.0/18X,                    04147
          &'PERCENT APPROPRIATED,',10X,F12 0,20X,F12.0/1X,                           04147
          &"ACRE FEET AVAILABLE FOR APPROPRIATION,"                                  04147
          &,10X,F12.0,20X,F12.0/1X,"ACRE FEET AVAILABLE FOR APPROPRIATION",          04147
          &/30X,'ANNUALLY,',10X,F12 0,20X,F12 0)                                     04147
           IF (PERCT GT  40.) WRITE (44,8817) ADJAPR                                 04334
     8817 FORMAT(1H0,20X,'APPROPRIATION ADJUSTED TO,',F12.0,'ACRE FEET')            04350
     1120 IF (IPRNT EQ 1) WRITE (44,1131)                                            04377
           IF (IPRNT GT 1) WRITE(44,1130)                                            04413
     1131 FORMAT (1H1,2X,'DRAWDOWN AFTER ONE YEAR DUE TO PUMPING PROPOSED WE        04426
          &LL CONTINUOUSLY AT ANNUAL APPROPRIATION RATE')                            04426
     1130 FORMAT (1H1,2X,'DRAWDOWN DUE TO PUMPING ANNUAL APPROPRIATION FROM         04477
          &PROPOSED WELL CONTINUOUSLY AT PROPOSED DIVERSION RATE')                   04477
           WRITE (44,1121)                                                           04553
     1121 FORMAT (1H0,6X,'DISTANCE',7X,'DRAWDOWN')                                   04560
           DO 242 I=1,N                                                              04601
           DD=H-HN(I)                                                                04611
           WRITE(44,620) R(I),DD                                                     04617
      620 FORMAT(2F13 2)                                                             04636
      242 CONTINUE                                                                   04645
           WRITE(44,653)                                                             04654
      653 FORMAT (1H0,13X,'EXISTING WELLS')                                          04661
           DO 259 J=1,NW                                                             04677
           DO 255 I=2,N                                                              04707
           IF(R(I).GT RTONWL(J)) GO TO 257                                           04717
      255 CONTINUE                                                                   04727
      257 B=(HN(I)-HN(I-1))/ALOG(R(I)/R(I 1))                                        04737
           DD=H-(HN(I)-B*ALOG(R(I)/RTONWL(J)))                                       04764
           WRITE(44,620) RTONWL(J),DD                                                05002
      259 CONTINUE                                                                   05021
           Q=-QINST/(60 *7 481)                                                      05030
           TMAX=PROPAP*43560 /(-Q)                                                   05041
           TMAXDA=TMAX/86400                                                         05050
           IF (IPRNT GT 1) WRITE (44,840) TMAXDA                                     05054
```

Program Listing for Single-Well Option--Continued

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27 OCT 81 10.21.01       MODULE:  *MAIN*   OPTIONS: SE SU WA LO                              PAGE    6
61516-02 ENHANCED SAU FORTRAN COMPILER       REVISION LEVEL 08.01 PRE     SOURCE INPUT:   SAPP:S

  840 FORMAT(F7.2,'DAYS PUMP AT DIV RATE;SHOULD NOT EXCEED 365')                  05072
      IF (IPRNT.EQ.1) GO TO 8888                                                  05120
      WRITE (44,1122)                                                             05126
 1122 FORMAT (1H0,1X,'MASS BALANCE,')                                             05134
      WRITE(44,610) VOLCO                                                         05152
  610 FORMAT(' VOLUME OF CONE =',F15.4)                                           05162
      VOLWEL=PI*RW*RW*(H-HN(1))                                                   05177
      VWATCO=S*(VOLCO-VOLWEL)                                                     05210
      VOLWAT=VWATCO+VOLWEL                                                        05215
      VOLPUM=-Q*TIME                                                              05221
      WRITE(44,625) VOLPUM, VOLWAT                                                05227
  625 FORMAT(' VOL. PUMPED=',E15.4,'  VOL. WATER FROM CONE=',E15.4)               05242
      WRITE (44,600) IT,NUMDT,TIME                                                05270
  600 FORMAT (' IT,NUMDT,TIME,',2I5,E12.2)                                        05306
      WRITE(44,8899)                                                              05324
 8899 FORMAT (1H1)                                                                05331
 8888 CONTINUE                                                                    05340
      IF(JCNT.GT.1) GO TO 270                                                     05342
      IF(TMAXDA.GT.365.) GO TO 270                                                05350
      GO TO 53                                                                    05355
  270 STOP                                                                        05357
      END                                                                         05365
```

Program Listing for Township Option

```
//* ***********************************************
//STEP1  EXEC   FTG1CG
//FORT.SYSIN DD *
       DOUBLE PRECISION TITLE
      DIMENSION AVSTK(24,24), VINST(24,24), VALAPP(24,24),
     1 AVAAP(24,24),SATHK(24,24), DELX(24), DELY(24), TITLE(16)
      DATA DELX/24*5280./,DELY/24*5280./
      DATA TITLE/'AVERAGE ', 'SATURATE', 'D THICKN', 'ESS,FEET','VOLUME
     1A','VAILABLE', ' FOR APP', 'ROPRIATI', 'ON-25YRS', ', AC-FT ',
     2'ANNUAL V', 'OLUME AV', 'AILABLE ', 'FOR APPR', 'OPRIATIO',
     3 'N, AC-FT'/
C******
C                NUMBER OF COLUMNS IN INPUT ARRAY - JMX    (I2)
C                   NUMBER OF ROWS IN INPUT ARRAY - IMX    (I2)
C                         NORTHWEST MOST TOWNSHIP - IT     (I2)
C                            NORTHWEST MOST RANGE - IR     (I2)
C         INITIALIZE MATRICES AND READ IN CONSTANTS FOR:
C                                  SPECIFIC YIELD - SY     (F5.0)
C                           AREA IN NINE SQ MILES - A9SQMI (F5.0)
C                      NUMBER YEARS FOR DEPLETION - TIME   (F5.0)
C              NO. YRS TIMES ANNUAL RECHARGE RATE - RCHGV  (F5.0)
C            OPTIONAL PRINT OF OUTPUT IN MAP FORM - IOP    (I2)
C******
C
      READ (5,100) IMX,JMX, IT, IR, SY, A9SQMI, TIME, RCHGV,IOP
      DO 10 I=1, IMX
      DO 11 J=1, JMX
      SATHK(I,J) = 0.0
      AVSTK(I,J) = 0.0
      VINST(I,J) = 0.0
      VALAPP(I,J) = 0.0
   11 AVAAP(I,J)  = 0.0
   10 CONTINUE
      IMAP = 0
      DO 12 K=1, IMX
      READ (5,101) (SATHK(K,L), L=1,JMX)
   12 CONTINUE
C******   COMPUTE SATURATED THICKNESS(AVE 9SQ.MI.) AND WATER AVAILABLE
      DO 13 I=1, IMX
      DO 14 J=1, JMX
      IF (I .EQ. 1  .OR. J.EQ.1 .OR. I.EQ.IMX .OR. J.EQ.JMX) GO TO 200
C******   AVERAGE SATURATED THICKNESS  9 SQ. MILES
      AVSTK(I,J) = (SATHK(I,J) + SATHK(I-1,J) + SATHK(I+1,J) +
     1 SATHK(I-1,J-1) + SATHK(I,J-1) + SATHK(I+1,J-1) + SATHK(I-1,J+1) +
     2 SATHK(I,J+1) + SATHK(I+1,J+1))/ 9.0
      GO TO 220
C
C
C******
C
  200 IF (I.EQ.1 .AND. J.EQ.1) GO TO 401
      IF (I.EQ.1 .AND. J.EQ.JMX) GO TO 402
      IF (I.EQ.IMX .AND. J.EQ.1) GO TO 403
      IF (I.EQ.IMX .AND. J.EQ.JMX) GO TO 404
```

```
      GO TO 445
C***        COMPUTATION FOR NW CORNER
C
  401 AVSTK(I,J)=(SATHK(I,J) + SATHK(I,J+1) + SATHK(I+1,J) +
     1 SATHK(I+1,J+1))/4.0
      GO TO 220
C
C**         COMPUTATION FOR NE CORNER
C
  402 AVSTK(I,J) = (SATHK(I,J) + SATHK(I,J-1) + SATHK(I+1,J-1) +
     1 SATHK(I+1,J))/4.0
      GO TO 220
C
C**         COMPUTATION FOR SW CORNER
C
  403 AVSTK(I,J) = (SATHK(I,J) + SATHK(I-1,J) + SATHK(I-1,J+1) +
     1 SATHK(I,J+1))/4.0
      GO TO 220
C
C***        COMPUTATION OF SE CORNER
C
  404 AVSTK(I,J) = (SATHK(I,J) + SATHK(I,J-1) + SATHK(I-1,J-1) +
     1 SATHK(I-1,J))/4.0
      GO TO 220
C
  445 IF (I.EQ.1) GO TO 301
      IF (I.EQ.IMX) GO TO 302
      IF (J.EQ.1) GO TO 303
      IF (J.EQ.JMX) GO TO 304
      GO TO 444
C           COMPUTATION FOR NORTH SIDE OF MATRIX
  301 AVSTK(I,J) = (SATHK(I,J) + SATHK(I,J-1) + SATHK(I,J+1) +
     1 SATHK(I+1,J-1) + SATHK(I+1,J) + SATHK(I+1,J+1))/6.0
      GO TO 220
C           COMPUTATION FOR EAST SIDE OF MATRIX
  304 AVSTK(I,J) = (SATHK(I,J) + SATHK(I-1,J) + SATHK(I+1,J) +
     1 SATHK(I-1,J-1) + SATHK(I,J-1) + SATHK(I+1,J-1))/6.0
      GO TO 220
C           COMPUTATION FOR WEST SIDE OF MATRIX
  303 AVSTK(I,J) = (SATHK(I,J) + SATHK(I-1,J) + SATHK(I+1,J) +
     1 SATHK(I-1,J+1) + SATHK(I,J+1) + SATHK(I+1,J+1))/6.0
      GO TO 220
C
C********
C
C           COMPUTATION FOR SOUTH SIDE OF MATRIX
  302 AVSTK(I,J)=(SATHK(I,J) + SATHK(I-1,J) + SATHK(I,J-1) +
     1 SATHK(I-1,J+1) + SATHK(I,J+1) + SATHK(I-1,J-1)) / 6.0
C
      GO TO 220
  210 AVSTK(I,J) = (SATHK(I,J) + SATHK(I+1,J) + SATHK(I,J+1) +
     1 SATHK(I+1,J+1)) / 4.0
C***        WATER AVAILABLE
  220 VINST(I,J) = AVSTK(I,J) * SY * A9SQMI
      VAVLB = VINST(I,J) + RCHGV
```

```
      VALAPP(I,J) = VAVLB * 0.40
   14 AVAAP(I,J) = VALAPP(I,J) / TIME
   13 CONTINUE
C******   MAP OUTPUT OPTION
      IF (IOP) 15,15,16
   16 WRITE (6,102) IT,IR
C      DO 333  I=1,IMX
C      WRITE(6,335)  (AVAAP(I,J), J=1,JMX)
CD 333 CONTINUE
C  335 FORMAT (1H0,6(3X,F6.0)/6(3X,F6.0)/6(3X,F6.0)/6(3X,F6.0))
      IMAP=IMAP + 1
      WRITE   (6,102) IT,IR
      CALL VGMAP (AVSTK,IMX,JMX,DELX,DELY, 5280., TITLE,IMAP)
      IMAP=IMAP + 1
      WRITE (6, 102) IT, IR
      CALL VGMAP (VALAPP, IMX, JMX, DELX, DELY, 5280., TITLE, IMAP)
      WRITE (6, 102) IT, IR
      IMAP=IMAP + 1
      CALL VGMAP (AVAAP, IMX, JMX, DELX, DELY, 5280., TITLE, IMAP)
   15 CONTINUE
      CALL REORD (AVSTK,VINST,VALAPP,AVAAP,IMX,JMX,IT,IR)
       GO TO  443
  444 WRITE(6,103) I,J
  443 CONTINUE
      STOP
  100 FORMAT (4I2,4F5.0, I2)
  101 FORMAT (20F4.0)
  102 FORMAT (1H1, 'NORTHWEST MOST TOWNSHIP ',I2,1X,I2,'W')
  103 FORMAT (1H1, 'MATRIX SELETION ERROR ', 2I2)
      END
      SUBROUTINE VGMAP(A,IMAX,JMAX,DELX,DELY,BASE,TITLE,IMAP)
C
C THIS SUBROUTINE PRINTS A VARIABLE GRID MAP
C
C
C ARGUMENTS:
C     A     -  ARRAY TO BE PLOTTED
C     IMAX  -  Y DIMENSION
C     JMAX  -  X DIMENSION
C     DELY  -  ARRAY OF DELTA Y'S
C     DELX  -  ARRAY OF DELTA X'S
C     BASE  -  DISTANCE WHICH CORRESPONDS TO 5X3 BOX ON PRINTER
C              (UNITS PER HALF INCH)
      DOUBLE PRECISION TITLE
      DIMENSION A(IMAX,JMAX),IA(25)
      DIMENSION DELX(JMAX),DELY(IMAX),TITLE(16)
      DIMENSION FMTO(9)
      DIMENSION FMT1(127),FMT2(11),FMT3(53),FMT4( 9),FMT5(104)
      DIMENSION LX1(25),LX2 (25),LX3 (25),LX4 (25)
      DATA FMTO/4H(4H(,4H4X ,,4H  25,4H(2H,,4HI,I4,4H,1H,,4H,I4,,4H1HX),
     .          4H1H))/
      DATA FMT2/4H(4H(,4H 4X,,4H4H1H,4H+ , ,4H  25,4H(1H,,4H,I2,,4H1HX,,
     .          4H4H,1,4HH+),,4H1H))/
      DATA FMT4/4H(4H(,4H1XI,,4H4H2,,4H1X, ,4H  25,4H(2H,,4HI,I4,4H),1H,
     .          4H))  /
```

```
      DATA BLNK/'    '/
C
      CALL JULDAT(NYR,MO,NDA)
C
C SCALE ARRAY VALUES TO 4 SIGNIFICANT DIGITS
C
      Z=0.
      DO 10 I=1,IMAX
      DO 10 J=1,JMAX
   10 Z = AMAX1(Z,ABS(A(I,J)))
      S=1.
      IF(Z.EQ.0.) GO TO 70
   30 IF(Z-1000.) 40,70,50
   40 S=S*10.
      Z=Z*10.
      GO TO 30
   50 IF(10000.-Z) 60,60,70
   60 S=S/10.
      Z=Z/10.
      GO TO 50
   70 CONTINUE
C
C COMPUTE NODE SPACING PARAMETERS
C
      KDX=0
  200 CONTINUE
      SUMDX=0.
      LENGTH=5
      LX=0
      N=0
      JL=KDX+1
  210 CONTINUE
      SUMDX=SUMDX+DELX(KDX+1)
      LDX  =5.*SUMDX/BASE + 5.5 - LENGTH
      LENGTH=LENGTH+LDX
      IF(LENGTH.GT.130) GO TO 220
      KDX=KDX+1
      N=N+1
      LX1(N)=LDX-1
      LX3(N)=(LDX-2)/2
      LX2(N)=LDX-LX3(N)
      LX4(N)=(LDX+6)/2+LX
      LX=(LDX-5)/2
      IF(KDX.LT.JMAX) GO TO 210
  220 CONTINUE
C
C CONSTRUCT FORMAT STATEMENTS
C
      CALL CORE(FMT0(3),4)
      WRITE(1,1010)N
 1010 FORMAT(I4)
      CALL CORE(FMT1,508)
      WRITE(1,FMT0)(LX2(J),LX3(J),J=1,N)
      CALL CORE(FMT2(5),4)
      WRITE(1,1010)N
```

```
      CALL CORE(FMT3,212)
      WRITE(1,FMT2)(LX1(J),J=1,N)
      CALL CORE(FMT4(5),4)
      WRITE(1,1010)N
      CALL CORE(FMT5,416)
      WRITE(1,FMT4)(LX4(J),J=1,N)
C
C PRINT ONE PAGE WIDTH OF MAP
C
      SUMDY=0.
      LENGTH=0
      IF (IMAP .EQ.1) GO TO 9000
      IF (IMAP .EQ.2) GO TO 9001
      IF (IMAP .EQ.3) GO TO 9002
 9000 WRITE(6,9010) (TITLE(I),I=1,4),S,MO,NDA,NYR
      GO TO 9003
 9001 WRITE(6,9011) (TITLE(I),I=5,10),S,MO,NDA,NYR
      GO TO 9003
 9002 WRITE(6,9011) (TITLE(I),I=11,16),S,MO,NDA,NYR
 9010 FORMAT ( 5X, 4A8,5X,'(VALUES HAVE BEEN MULTIPLIED BY',1PE8.1,')',
     .10X,2(I2,' - '),I2//)
 9011 FORMAT ( 5X, 6A8,5X,'(VALUES HAVE BEEN MULTIPLIED BY',1PE8.1,')',
     .10X,2(I2,' - '),I2//)
 9003 WRITE(6,FMT1)(J,J=JL,KDX)
      WRITE(6,FMT3)
      DO 270 I=1,IMAX
      SUMDY=SUMDY+DELY(I)
      LDY  =3.*SUMDY/BASE +.5 - LENGTH
      LENGTH=LENGTH+LDY
      ISP1=(LDY-1)/2
      ISP2=LDY-2-ISP1
      DO 240 K=1,ISP1
  240 WRITE(6,6010)
 6010 FORMAT()
      L=0
      DO 250 J=JL,KDX
      L=L+1
  250 IA(L)=A(I,J)*S+SIGN(.5,A(I,J))
      WRITE(6,FMT5) I,(IA(J),J=1,L)
      IF(ISP2.EQ.0) GO TO 270
      DO 260 K=1,ISP2
  260 WRITE(6,6010)
  270 WRITE(6,FMT3)
      WRITE(6,FMT1) (J,J=JL,KDX)
      IF(KDX.LT.JMAX) GO TO 200
      RETURN
      END
      SUBROUTINE REORD (BMRO,CMRO,DMRO,AMRO,IMX,JMX,IT,IR)
C
C******     THIS SUBROUTINE REORDERS A MATRIX OF COMPLETE TOWNSHIPS
C           IN THE STANDARD GW DIGITAL MODEL FORMAT TO TOWNSHIP, RANGE
C           AND SECTION ORDER
      DIMENSION BMRO(24,24),CMRO(24,24),DMRO(24,24),AMRO(24,24),
     1  RORDMX(5,5,36),BORDMX(5,5,36),CORDMX(5,5,36),DORDMX(5,5,36)
      IRL = IMX/6
```

```
      ITL = JMX/6
      N=1
      DO 10 IRR=1, IRL
      L=0
      J=6
      DO 11 JR = 1, ITL
      L=L+1
      IF(JR.NE.1)J=L*6
      M=0
    5 I=(N*6-6+1)
      DO 12 KR =1, 36
      RORDMX(IRR,JR,KR) = AMRO(I,J)
      BORDMX(IRR,JR,KR)=BMRO(I,J)
      CORDMX(IRR,JR,KR)=CMRO(I,J)
      DORDMX(IRR,JR,KR)=DMRO(I,J)
      M = M + 1
C----------------------------------------ADDED 8-22-79-------
      IF(KR.EQ.1 .OR. KR .EQ. 13 .OR. KR .EQ. 25) GO TO 23
      IF(KR.EQ.7 .OR. KR.EQ.19 .OR. KR.EQ.31) GO TO 24
C-------------------------
      IF(J.EQ. 1 .OR. J.EQ.6)GO TO 22
      IF(MOD(J,6).EQ.0)GO TO 22
      IF(MOD(J-1,6) .EQ.0)GO TO 22
C----------------------------------------LABLED 8-23-79------
   23 IF (MOD (I,2).NE.0) J=J-1
C------------------------------
   24   IF(MOD (I,2).EQ.0)J=J+1
   22 IF(M.EQ.6 .OR.M .EQ.12 .OR. M .EQ.18 .OR. M.EQ.24 .OR. M.EQ.30)
     1 I=I+1
   12 CONTINUE
   11 CONTINUE
   10 N=N+1
C
C    *     WRITE REORDERED MATRIX
      IRH= IR
      DO 50 I=1, IRL
      IR= IRH
      IF (I.NE.1) IT= IT+1
      DO 51 J=1, ITL
      IF (J.NE.1) IR= IR-1
      WRITE (6,40) IT,IR
      DO 52 K=1,36
      WRITE(6,41) K,BORDMX(I,J,K),CORDMX(I,J,K),DORDMX(I,J,K),
     1  RORDMX(I,J,K)
      IF(MOD(K,6).EQ.0)WRITE(6,43)
C     WRITE(7,42) IRORD
   52 CONTINUE
   51 CONTINUE
   50 CONTINUE
   40 FORMAT (1H1,54X,'GROUND WATER AVAILABILITY'/46X,'BASED ON NINE SQU
     1ARE MILE DEPLETION MODEL'/1H0,10X,'SOUTHWESTERN KANSAS GROUNDWATER
     2',54X,'U.S.GEOLOGICAL SURVEY'/12X,'MANAGEMENT DISTRICT NO.3'///11X
     3,'TOWNSHIP ',I2,'S',' RANGE ',I2,'W'/49X,'AVERAGE',11X,'VOLUME IN',
     4,7X,'VOLUME AVAILABLE',4X,'ANNUAL VOLUME'/42X,          'SATURAT
     5ED THICKNESS',6X,'STORAGE',9X,'IN 25 YEARS',10X,'AVAILABLE'/30X,
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     6'SECTION',11X,'(FEET)',11X,'(ACRE-FEET)',9X,'(ACRE-FEET)',
     77X,'(ACRE-FEET)'/)
  41 FORMAT (33X,I2,14X,F5.1,13X,F10.1,8X,F10.1,12X,F6.1)
  42 FORMAT (13I6)
  43 FORMAT  (1H )
     RETURN
     END
/*
```

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