Stiff Diagrams of Water-Quality Data Programmed for the Digital Computer

By

Charles O. Morgan

Jesse M. McNellis


```
          1 9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8 9 1
                              0
      CA  --------------------0------              HCO3+CO3
                              0
                              0
                              0
                              0
                              0
      MG              --------0---                 SO4
                              0
                              0
                              0
                              0
                              0
    NA+K                  ----0---------           CL
                              0
                              0
                              0
                              0
                              0
      FE                     -0-------------       NO3
                              0
                              0
          1 9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8 9 1
```

State Geological Survey
The University of Kansas
Lawrence, Kansas

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STATE GEOLOGICAL SURVEY OF KANSAS

Frank C. Foley, Director

STIFF DIAGRAMS OF WATER-QUALITY DATA
PROGRAMMED FOR THE DIGITAL COMPUTER

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Prepared by the United States Geological Survey and the State Geological Survey of Kansas, with the cooperation of the Environmental Health Services of the Kansas State Department of Health and the Division of Water Resources of the Kansas State Board of Agriculture.

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STIFF DIAGRAMS OF WATER-QUALITY DATA PROGRAMMED FOR THE DIGITAL COMPUTER

by

Charles O. Morgan[1/] and Jesse M. McNellis[1/]

ABSTRACT

Stiff diagrams, pattern diagrams used in interpretation of quality-of-water data, are calculated and printed with the aid of the GE 625 digital computer at the rate of approximately 170 per minute. A range of scales for the diagrams is specified for each group of data. Each complete analysis is diagrammed if the cations and anions balance within 2, 3, or 5 percent, depending upon the amount of dissolved solids.

INTRODUCTION

Interpretation of quality-of-water data is aided by use of pattern diagrams, one of which is the Stiff diagram. This diagram was developed by H. A. Stiff, Jr. (1951), as a method for visually comparing a series of analyses of oil-field waters and for conveniently illustrating the individual analyses. Stiff gave examples of other uses for the diagram, including comparison of uncontaminated fresh ground waters, contaminated ground waters, and the contaminators. The Stiff diagram has become one of the standard methods for interpreting and comparing ground-water analyses.

The authors developed the program to write Stiff diagrams as part of the cooperative program of the U.S. Geological Survey and the State Geological Survey of Kansas. The IBM 7040 and GE 625 at The University of Kansas Computation Center, Richard G. Hetherington, Director, were used to test the program.

1/ Water Resources Division, U.S. Geological Survey

Chemical analyses of water that, at a minimum, has had Ca, Mg, Na, HCO_3, SO_4, and Cl determined are called completes, and analyses lacking any of these ions are called partials. The program, as written, will print modified Stiff diagrams for the complete analyses in which the cations and anions balance within the following limits: dissolved solids 100 mg/l (milligrams per liter) or less, 5 percent; dissolved solids 101-250 mg/l, 3 percent; dissolved solids greater than 250 mg/l, 2 percent. The diagrams do not have the ends of the horizontal cation and anion lines connected as do the original Stiff diagrams.

The time involved to produce Stiff diagrams by the computer can be demonstrated by 10,500 quality-of-water data sets from the 105 counties in Kansas. In a regional investigation, data from 15 counties were requested from the tape and nearly 1,200 Stiff diagrams were made from these data. The tape search, the check for complete analyses, the check for balanced analyses, and the calculation of the Stiff diagrams took approximately 7 minutes of GE 625 computer time. Thus, by use of data-tape input, where data are selected from a large tape file, approximately 2.8 Stiff diagrams are output per second of computer time. With card input instead of tape, approximately five Stiff diagrams are output per second of computer time. These examples of computer times were taken from the Kansas version of the Stiff program and the Kansas water-quality-data format. The computer at The University of Kansas Computation Center has been upgraded to a GE 635 since these data were processed. Processor time now is approximately three-fourths that of the GE 625.

DESCRIPTION OF PROGRAM

The basic purposes of the program are: (1) to print diagrams suitable for the interpretation and illustration of water types, and (2) to compare a series of analyses. The program is written in FORTRAN IV. Within the listing of the program (app. I) are comments that explain the logical processes. The generalized flow chart of the program is shown in figure 1. Two versions of the program are available. The version listed in appendix I uses the Kansas water-quality data cards (app. II). The unlisted version uses U.S. Geological Survey data cards, ABCQRS, described by Lang and Leonard (1967). However, the segment of the program from card STF 2060 through card STF 2140 (app. I) can be modified to accept the format of other data cards.

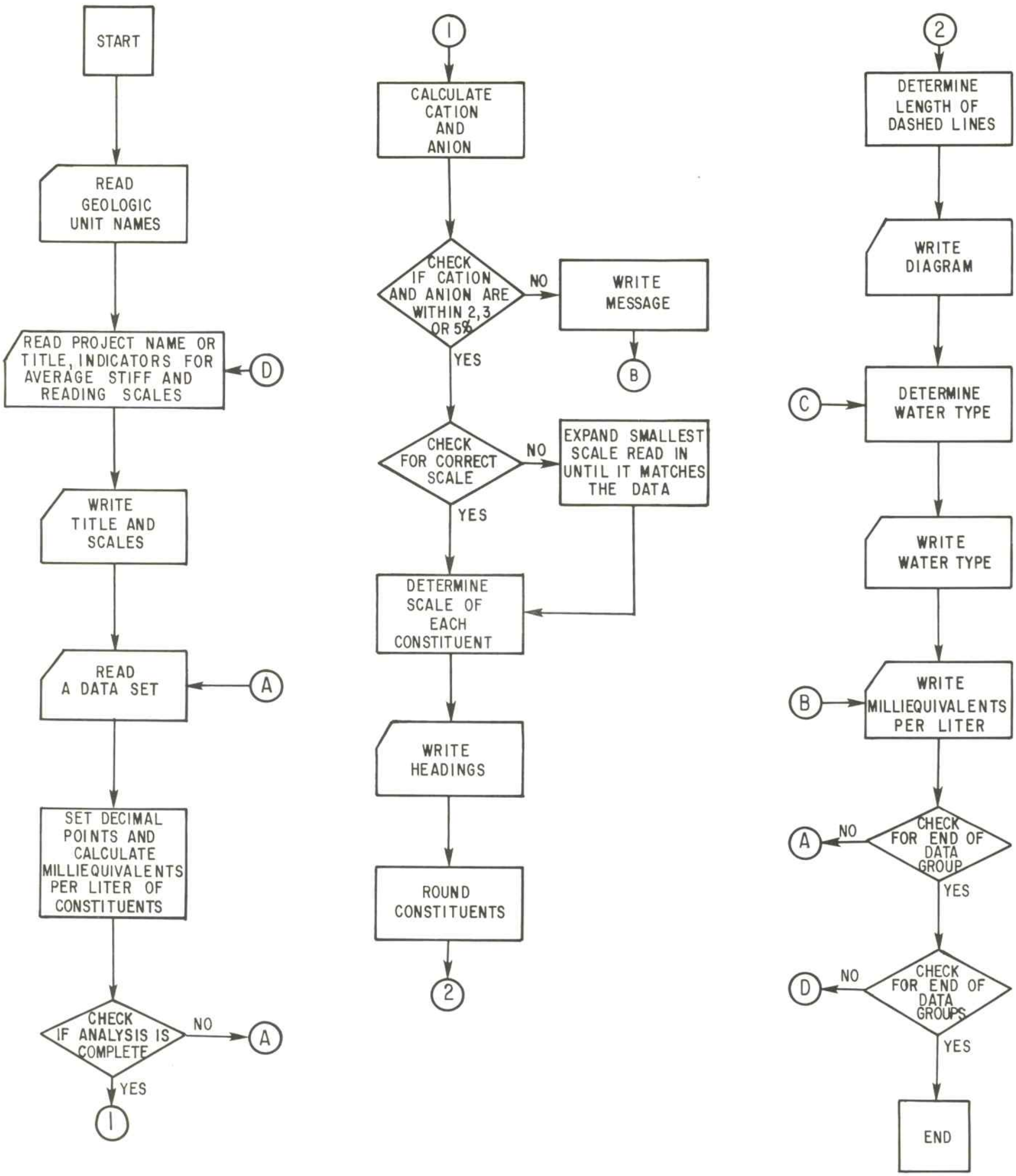

Figure 1.--Flow chart for FORTRAN IV STIFF program.

Four control data cards or sets of cards (app. III) are used in the program. The first and last do not change but the second and third can vary with data groups. The cards contain the following information:

Cards 1-150, Array AQUNT (app. I, card STF 1270) contain geologic unit names, formal and informal, used in Kansas;

Card 151, (app. I, card STF 1680) has the data identification (ACO), a number requesting an average Stiff diagram for each aquifer (IAVER), and a number indicating that either the scales will be read or the program will use the built-in scales (ISC). This card changes with each data group;

Card 152, (app. I, card STF 1780) contains the scales at which the diagrams will be plotted (SCAL). This card changes with each data group and will be read or inserted in the control data if ISC above equals 1 or more;

Card 153 has a Z punched in column 1 and terminates program operation on a data group.

The control cards are read in the order specified in appendix III. Cards 1 through 152 follow the FORTRAN program but precede the quality-of-water data; card 153 follows the last data set. After the Z card (card 153) ends one data group, another data group may be entered with control cards 151 and 152 preceding the data and the Z card again following the last data set in the group.

Following the reading of the control cards, the title for the group of diagrams is printed. The title usually consists of the name of the project and the type of diagrams, such as "Allen County, Kansas ....Stiff diagrams." The scales to be used in printing the diagrams are written immediately below the title.

Immediately after a set of data is read, decimal points are placed in the proper position. The constituent values, read in milligrams per liter, are converted to milliequivalents per liter (me/l)--the unit used for output--and are rounded to the nearest whole number.

The constituents present in the analysis are checked. If the analysis is a complete, the program advances to the next step. If the analysis is a partial, the program reads a new data set. Each time a data set is processed, a check is made for the end of a data group (Z card). If there is no Z card, the next data set is read. When a Z card is encountered, the average Stiff diagram for each aquifer is plotted if requested; then the program checks for control cards 151 and 152 which indicate a new data group. If no new group is encountered, the program is terminated.

After a data set is read and found to be complete, the set is checked for cation and anion balance within an accuracy of 2, 3, or 5 percent depending on the amount of dissolved solids. If the constituents do not balance, the message "cations and anions do not balance" is written along with the local well number or latitude and longitude, the date of the sample collection, and a list of the constituents in milliequivalents per liter (table 1).

Table 1.--Typical message for complete chemical analyses in which the cations and anions do not balance within 2, 3, or 5 percent.

```
CATIONS AND ANIONS DO NOT BALANCE
WELL NUMBER--14 13W 12CB
DATE--5  4 42


CONSTITUENTS IN MILLIEQUIVALENTS PER LITER

      CA=  6.2874      MG=  1.1514      NA=  3.1320      K= -1.         FE=  1.4324

    HCO3=  3.1960     CO3= -1.         SO4=  4.8927     CL=  2.3970    NO3=  0.0242
```

The scale for printing a diagram is determined by comparing the input scales (SCAL) with the concentrations, in milliequivalents per liter, of each constituent. If the constituents are too large for the scales, the last scale punched on control card 152 or built in the program is doubled until the constituents fall within the range of the scale.

For clarity and as a means of reference, a heading is printed for each diagram. The heading consists of the local well number, the sampling date, the well depth, the geologic unit(s), and the cation-anion scales.

Once a scale is chosen, the constituents are multiplied by a factor (20 divided by the scale) to calculate the number of dashes that each constituent will require on the diagram. The maximum number of dashes on the print of the diagram that can represent a constituent (Ca, Mg, Fe, SO_4, Cl, NO_3) or combination of constituents (Na + K and HCO_3 + CO_3) is 20. The program calculates the dashes to represent each constituent and prints them within the basic framework of the Stiff diagram (fig. 2). After calculations are

WELL NO. 12 6W 32AA

DATE SAMPLED 9-15-47

WELL DEPTH 31 FEET

GEOLOGIC UNIT DAKOTA FM

TOTAL SCALE = 10 MILLIEQUIVALENTS PER LITER   EACH DASH = 0.50

```
                  MILLIEQUIVALENTS PER LITER

        1 9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8 9 1
                            0
CA      --------------------0------               HCO3+CO3
                            0
                            0
                            0
                            0
                            0
MG                  --------0---                  SO4
                            0
                            0
                            0
                            0
                            0
NA+K                    ----0---------            CL
                            0
                            0
                            0
                            0
                            0
FE                         -0-------------        NO3
                            0
                            0
        1 9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8 9 1
```

WATER TYPE---CALCIUM NITRATE

CONSTITUENTS IN MILLIEQUIVALENTS PER LITER

CA= 9.9800	MG= 4.0298	NA= 1.6965	K= 0.1023	FE= 0.2575
HCO3= 3.1960	CO3= -1.	SO4= 1.5199	CL= 4.6630	NO3= 6.5410

Figure 2.--Stiff diagram, identification data, water-type message, and cations and anions printed from the digital computer.

completed for a data group, the average Stiff diagram for each aquifer in the group may be calculated and printed (fig. 3), if it has been requested.

```
GEOLOGIC UNIT  DAKOTA FM
     TOTAL SCALE =  20 MILLIEQUIVALENTS PER LITER        EACH DASH =  1.00
     NUMBER OF ANALYSES AVERAGED  32.


                            MILLIEQUIVALENTS PER LITER
                   1 9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8 9
                                       0
                                       0
              CA                      -0-----                    HCO3+CO3
                                       0
                                       0
                                       0
                                       0
                                       0
              MG                      -0----                     SO4
                                       0
                                       0
                                       0
                                       0
                                       0
            NA+K    -------------------0-----------              CL
                                       0
                                       0
                                       0
                                       0
                                       0
              FE                       0                         NO3
                                       0
                                       0
                   1 9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8 9 1


WATER TYPE---SODIUM CHLORIDE

CONSTITUENTS IN MILLIEQUIVALENTS PER LITER
  CA=  0.9799      MG=  1.0087      NA=  18.9918     K=  0.         FE=  0.0241
HCO3=  5.4947     CO3=  0.         SO4=   4.0358    CL= 11.2148   NO3=  0.0345
```

Figure 3.--Average Stiff diagram.

The water type is designated by determining the cation and anion with the highest concentration, in milliequivalents per liter. The type is printed beneath the Stiff diagram with the concentrations of all the constituents used on the diagram.

REFERENCES

Hem, J. D., 1959, Study and interpretation of the chemical characteristics of natural water: U.S. Geol. Survey Water-Supply Paper 1473, 269 p.

Lang, S. M., and Leonard, A. R., 1967, Instructions for using the punchcard system for the storage and retrieval of ground-water data: U.S. Geol. Survey, Techniques of Water-Resources Inv., book 7, sec. A, open-file report, 93 p.

Stiff, H. A., Jr., 1951, Technical Note 84--The interpretation of chemical water analysis by means of patterns: Jour. Petroleum Tech., October, p. 15-16.

APPENDIXES

Appendix I.--Listing of FORTRAN IV statements in STIFF program

```
C       STIFF000     PROGRAM TO PRINT STIFF DIAGRAMS
C       STIFF---PROGRAM TO WRITE STIFF DIAGRAMS (STIFF, H.A., JR., 1951,
C               TECHNICAL NOTE 84--THE INTERPRETATION OF CHEMICAL WATER
C               ANALYSIS BY MEANS OF PATTERNS. JOUR. PETROLEUM TECHNOLOGY,
C               OCTOBER, P. 15-16 AND HEM, J.D., 1959, STUDY AND
C               INTERPRETATION OF THE CHEMICAL CHARACTERISTICS OF
C               NATURAL WATER, U.S. GEOL. SURVEY WATER-SUPPLY PAPER
C               1473, P. 173-174).
C       ----------------------------------------------------------------
C       PROGRAMMED BY CHARLES O. MORGAN AND JESSE M. MCNELLIS
C       KANSAS DISTRICT, WRD, USGS, LAWRENCE, KANSAS
C       DATE COMPLETED - JULY 1965.
C       LANGUAGE - FORTRAN IV.
C       ----------------------------------------------------------------
C       PROGRAM INCLUDES MAINLINE (STIFF) AND SIX SUBROUTINES (SCALE, EPM,
C       ROUND, PLOT1, TYPE, AND EQUIV)
C       ----------------------------------------------------------------
C       INPUT DATA ARE KANSAS WATER-QUALITY CARDS, OUTPUT IS A TABLE OF
C           DIAGRAM SCALES AND THE STIFF DIAGRAMS
C       ----------------------------------------------------------------
C       ----------------------------------------------------------------
C       EXPLANATION OF OUTPUT
C       ----------------------------------------------------------------
C
C               ONE TABLE IS PRINTED -- IDENTIFIES DATA GROUP (SEE ACD
C                                       BELOW) AND SCALES READ-IN FOR
C                                       PLOTTING.
C
C               STIFF DIAGRAM FOR EACH COMPLETE, BALANCED ANALYSIS.
C
C                                       THE DIAGRAM INCLUDES CONSTITUENT
C                                       VALUES (CONVERTED TO ME/L) CA,MG,
C                                       NA + K, FE ON THE CATION SIDE OF
C                                       PLOT AND HCO3 + CO3, SO4, CL,
C                                       NO3 ON THE ANION SIDE.
C
C                                       THE ANALYSIS IDENTIFICATION IS
C                                       PRINTED ABOVE THE DIAGRAM AND
C                                       INCLUDES THE WELL NUMBER, DATE
C                                       SAMPLED, WELL DEPTH, GEOLOGIC
C                                       UNIT(S), AND SCALES USED ON THE
C                                       DIAGRAM
C
C                                       BELOW THE DIAGRAM ARE THE WATER
C                                       TYPE (BASED ONLY ON THE MAXIMUM
C                                       CATION AND ANION) AND THE
C                                       CONSTITUENT ME/L VALUES.
C
C               ANALYSES THAT DO NOT BALANCE ARE IDENTIFIED BY WELL
C               NUMBER AND SAMPLING DATE. THE CONSTITUENT ME/L VALUES
C               ARE INCLUDED.
C
C               THE ANALYSES MUST BALANCE WITHIN 5 PERCENT (DISSOLVED
C               SOLIDS (D.S.) 100 MG/L OR LESS), 3 PERCENT (D.S. 101-250
C               MG/L), AND 2 PERCENT (D.S. GREATER THAN 250 MG/L).
C
C               AVERAGE STIFF DIAGRAMS SEPARATED BY AQUIFER MAY BE
C               OBTAINED (SEE IAVER BELOW).
C
```

```
C                                  THESE DIAGRAMS ARE IDENTIFIED          STF 600
C                                  BY GEOLOGIC UNIT(S). INCLUDED          STF 610
C                                  ARE SCALE, NUMBER OF ANALYSES          STF 620
C                                  USED TO COMPILE THE DIAGRAM,           STF 630
C                                  WATER TYPE, AND CONSTITUENT ME/L       STF 640
C                                  VALUES.                                STF 650
C                                                                         STF 660
C     ------------------------------------------------------------------STF 670
C     ------------------------------------------------------------------STF 680
C     EXPLANATION OF INPUT CONTROL CARDS                                  STF 690
C     ------------------------------------------------------------------STF 700
C          CARDS THAT ARE NOT CHANGED TO MATCH THE DATA                   STF 710
C     ------------------------------------------------------------------STF 720
C                                                                         STF 730
C             150 CARDS - AQUNT                                           STF 740
C                           CONTAINS THE STRATIGRAPHIC NAMES, FORMAL      STF 750
C                           AND INFORMAL, OF GEOLOGIC UNITS IN KANSAS     STF 760
C                                                                         STF 770
C                           PUNCHED IN A 4(3A6,2X) FORMAT                 STF 780
C                                                                         STF 790
C     ------------------------------------------------------------------STF 800
C          CARDS THAT ARE CHANGED TO MATCH THE DATA                       STF 810
C     ------------------------------------------------------------------STF 820
C                                                                         STF 830
C               1 CARD - ACO, IAVER, ISC                                  STF 840
C                           ACO =TITLE OF PROJECT (E.G. DOUGLAS           STF 850
C                                   COUNTY) LEFT-HAND JUSTIFIED IN        STF 860
C                                   COLUMNS 1 THROUGH 36.                 STF 870
C                                                                         STF 880
C                           IAVER = IF 1 IS PUNCHED IN COLUMN 45,         STF 890
C                                   AVERAGE STIFF DIAGRAMS BY AQUIFERS    STF 900
C                                   WILL BE PRINTED.                      STF 910
C                                                                         STF 920
C                           ISC = IF 1 IS PUNCHED IN COLUMN 50, SCALE     STF 930
C                           (SCAL) CARD WILL BE READ, IF BLANK OR 0,      STF 940
C                           SCALES DESIGNATED IN PROGRAM ARE USED TO      STF 950
C                           PLOT DIAGRAMS                                 STF 960
C                                                                         STF 970
C               1 CARD - SCAL = SCALES USED IN PRINTING OF DIAGRAM.       STF 980
C                             PUNCHED RIGHT-HAND JUSTIFIED IN EVERY 5     STF 990
C                             COLUMNS (1-5, 6-10, 11-15, 16-20,ETC.)      STF1000
C                             THE LARGEST SCALE MUST BE FIRST (E.G. 5)    STF1010
C                             THE REMAINING SCALES ARRANGED               STF1020
C                             PROGRESSIVELY SMALLER (E.G. 10, 20, 50,     STF1030
C                             100) THE PROGRAM CHECKS FOR THE LARGEST     STF1040
C                             SCALE THAT WILL FIT THE DATA. IF THE LASTSTF1050
C                             SCALE IS NOT SMALL ENOUGH IT WILL BE        STF1060
C                             DOUBLED UNTIL IT WILL FIT THE DATA.         STF1070
C                                                                         STF1080
C     ------------------------------------------------------------------STF1090
C                                                                         STF1100
C     A CARD WITH A Z PUNCHED IN THE FIRST COLUMN MUST FOLLOW             STF1110
C         EACH DATA GROUP.                                                STF1120
C     ------------------------------------------------------------------STF1130
      DIMENSION NOAQ(200), DCA(100), DMG(100), DNAK(100), DFE(100), DHCOSTF1140
     1(100), DSO(100), DCL(100), DNO(100), DKOUNT(100), ACO(6), NA(38)    STF1150
      COMMON K(60),SCAL(16),AQUNT(1800)                                   STF1160
      DATA NA/1H0,1H1,1H2,1H3,1H4,1H5,1H6,1H7,1H8,1H9,1HA,1HB,1HC,1HD,1HSTF1170
     1E,1HF,1HG,1HH,1HI,1HJ,1HK,1HL,1HM,1HN,1HO,1HP,1HQ,1HR,1HS,1HT,1HU,STF1180
     21HV,1HW,1HX,1HY,1HZ,1H ,1H-/                                        STF1190
```

```
C
C     ------------------------------------------------------------------
C
C     READ GEOLOGIC UNIT NAMES-AQUNT
C
C     ------------------------------------------------------------------
C
      READ (5,1) (AQUNT(I),I=1,1800)
    1 FORMAT (4(3A6,2X))
      DO 2 I=1,20
    2 K(I)=NA(37)
      DO 3 I=21,40
    3 K(I)=NA(38)
      DO 4 I=41,60
    4 K(I)=NA(37)
    5 ITZ=1
      DO 6 I=8,16
    6 SCAL(I)=0.0
      SCAL(1)=5.0
      SCAL(2)=10.0
      SCAL(3)=20.0
      SCAL(4)=50.0
      SCAL(5)=100.0
      SCAL(6)=500.0
      SCAL(7)=1000.0
      IK=0
      DO 7 I=1,100
      NOAQ(I)=0
      NOAQ(I+100)=0
      DCA(I)=0.
      DMG(I)=0.
      DNAK(I)=0.
      DFE(I)=0.
      DHCO(I)=0.
      DSO(I)=0.
      DCL(I)=0.
      DNO(I)=0.
    7 DKOUNT(I)=0.
      WRITE (6,8)
    8 FORMAT (1H1)
C
C     ------------------------------------------------------------------
C
C     READ PROJECT NAME OR TITLE, INDICATOR FOR AQUIFER AVERAGE STIFF
C     DIAGRAMS, AND INDICATOR FOR READING IN SCALES
C
C     ------------------------------------------------------------------
C
      READ (5,9) (ACO(I),I=1,6),IAVER,ISC
    9 FORMAT (6A6,4X,2I5)
      IF (ISC.LT.1) GO TO 11
C
C     ------------------------------------------------------------------
C
C     READ SCALES FOR PRINTING OF DIAGRAMS
C
C     ------------------------------------------------------------------
C
      READ (5,10) (SCAL(I),I=1,16)
   10 FORMAT (16F5.0)
```

```
C
C     -----------------------------------------------------------------------
C
C     WRITE TITLE
C
C     -----------------------------------------------------------------------
C
   11 WRITE (6,12) (ACO(I),I=1,6)
   12 FORMAT (10X,6A6,//)
C
C     -----------------------------------------------------------------------
C
C     WRITE SCALES USED IN PRINTING OF DIAGRAMS
C
C     -----------------------------------------------------------------------
C
      WRITE (6,13) (SCAL(I),I=1,16)
   13 FORMAT (10X,16HINPUT SCALES ARE,16F6.0)
      WRITE (6,8)
C
C     -----------------------------------------------------------------------
C
C     READ A DATA SET
C
C     -----------------------------------------------------------------------
C
   14 READ (5,15) IKC,LST,LCO1,LCO2,LTP,LRG,LWE,LSC,L11,L12,L13,L14,KMO,
     1KDA,KYR,KWD,KTY,SIO,AL,FE,AMN,CA,AMG,ANA,AK,HCO,CO,SO,CL,ICN1
   15 FORMAT (4A1,2A2,A1,A2,4A1,3A2,A4,A1,2F3.0,F5.0,F3.0,F6.0,F5.0,F6.0
     1,F3.0,F4.0,F2.0,F5.0,F7.0,1X,I1)
      IF (IKC.EQ.NA(36)) GO TO 31
      READ (5,16) LX1,LX2,FL,ANO,PO,BO,DS,HD,ANC,ALK,FCO,SAR,RSC,AK10,PH
     1,ICOL,IEMP,ITY,ISOUR,ICN2
   16 FORMAT (15X,2I3,F3.0,F5.0,2F3.0,F6.0,F5.0,2F4.0,3F3.0,F6.0,F3.0,I2
     1,I3,I1,A1,I1)
      IF (KTY.EQ.NA(12)) AMG=AMG*10.
      IF (KTY.EQ.NA(12)) ANA=ANA*10.
      IF (KTY.EQ.NA(12)) SO=SO*10.
C     CONVERT MG/L TO ME/L AND SET DECIMAL POINTS
      CALL EPM (SIO,AL,FE,AMN,CA,AMG,ANA,AK,HCO,CO,SO,CL,FL,ANO,PO,BO,PH
     1,BAL,BFE,BMN,BCA,BMG,BNA,BK,BHCO,BCO,BSO,BCL,BFL,BNO,BPO)
C
C     -----------------------------------------------------------------------
C
C     CHECK FOR PARTIAL OR COMPLETE ANALYSIS
C
C     -----------------------------------------------------------------------
C
      IF (BCA.GT.0..AND.BMG.GT.0..AND.BNA.GT.0..AND.BHCO.GT.0..AND.BSO.G
     1T.0..AND.BCL.GT.0.) GO TO 17
      GO TO 14
C
C     -----------------------------------------------------------------------
C
C     CALCULATE TOTAL CATIONS AND ANIONS AND CHECK FOR BALANCE
C
C     -----------------------------------------------------------------------
C
   17 CATION=BK+BMN+BCA+BMG+BNA
      ANION=BHCO+BCO+BSO+BCL+BFL+BNO
```

```
      IF (DS.GT.100.) GO TO 18
      AN1=.475
      AN2=.525
      GO TO 20
   18 IF (DS.GT.250.) GO TO 19
      AN1=.485
      AN2=.515
      GO TO 20
   19 AN1=.49
      AN2=.51
   20 IF ((ANION/(ANION+CATION)).GE.AN1.AND.(ANION/(ANION+CATION)).LE.AN
     12) GO TO 22
      CATION=CATION+BFE
      IF ((ANION/(ANION+CATION)).GE.AN1.AND.(ANION/(ANION+CATION)).LE.AN
     12) GO TO 22
C
C     ------------------------------------------------------------------
C
C     WRITE MESSAGE IF ANALYSIS DOES NOT BALANCE
C
C     ------------------------------------------------------------------
C
      WRITE (6,21) LTP,LRG,LWE,LSC,L11,L12,L13,L14,KMO,KDA,KYR
   21 FORMAT (10X,34HCATIONS AND ANIONS DO NOT BALANCE /10X,13HWELL NUMB
     1ER--,A2,1X,A2,A1,1X,A2,4A1/10X,6HDATE--,A2,1X,A2,1X,A2)
      GO TO 29
C
C     ------------------------------------------------------------------
C
C     DETERMINE POSITION OF GEOLOGIC UNIT NAMES
C
C     ------------------------------------------------------------------
C
   22 LF1=LX1
      LF2=LX2
      IF (LF1.LE.0) LF1=599
      LFM1=(LF1*3)-2
      LFM2=LFM1+2
      IF (LF2.LE.0) LF2=599
      LFM3=(LF2*3)-2
      LFM4=LFM3+2
      LX1=LF1
      LX2=LF2
C
C     ------------------------------------------------------------------
C
C     DETERMINE SCALE OF DIAGRAM
C
C     ------------------------------------------------------------------
C
      CALL SCALE (BCA,BMG,BNA,BK,BFE,BHCO,BCO,BSO,BCL,BNO,CCA,CMG,CNAK,C
     1FE,CHCO,CSO,CCL,CNO,IN)
C
C     ------------------------------------------------------------------
C
C     WRITE HEADINGS
C
C     ------------------------------------------------------------------
C
      N=SCAL(IN)
```

```
      EN=SCAL(IN)/20.
      WRITE (6,23) LTP,LRG,LWE,LSC,L11,L12,L13,L14,KMO,KDA,KYR,KWD,(AQUN
     1T(I),I=LFM1,LFM2),(AQUNT(I),I=LFM3,LFM4),N,EN
   23 FORMAT (10X,8HWELL NO.,2X,A2,1X,A2,A1,1X,A2,4A1//15X,12HDATE SAMPL
     1ED,2X,A2,1H-,A2,1H-,A2,//15X,10HWELL DEPTH,1X,A4,5H FEET,//15X,13H
     2GEOLOGIC UNIT,2X,3A6,5X,3A6,//15X,13HTOTAL SCALE =,I4,27H MILLIEQU
     3IVALENTS PER LITER,10X,11HEACH DASH =,F6.2)
      WRITE (6,24)
   24 FORMAT (////)
      IF (LX1.GE.599) GO TO 28
      DO 25 IT=1,100
      IF (LX1.EQ.NOAQ(IT).AND.LX2.EQ.NOAQ(IT+100)) GO TO 26
   25 CONTINUE
      IK=IK+1
      NOAQ(IK)=LX1
      NOAQ(IK+100)=LX2
      IJ=IK
      GO TO 27
   26 IJ=IT
   27 DCA(IJ)=DCA(IJ)+BCA
      DMG(IJ)=DMG(IJ)+BMG
      DNAK(IJ)=DNAK(IJ)+BNA+BK
      DFE(IJ)=DFE(IJ)+BFE
      DHCO(IJ)=DHCO(IJ)+BHCO+BCO
      DSO(IJ)=DSO(IJ)+BSO
      DCL(IJ)=DCL(IJ)+BCL
      DNO(IJ)=DNO(IJ)+BNO
      DKOUNT(IJ)=DKOUNT(IJ)+1.
   28 CONTINUE
C     ROUND CONSTITUENT ME/L VALUES TO NEAREST WHOLE NUMBER
      CALL ROUND (CCA,CMG,CNAK,CFE,CHCO,CSO,CCL,CNO,ICA,IMG,INAK,IFE,IHC
     1O,ISO,ICL,INO)
C     PLOT A STIFF DIAGRAM
      CALL PLOT1 (ICA,IMG,INAK,IFE,IHCO,ISO,ICL,INO)
C     DETERMINE AND WRITE THE WATER TYPE
      CALL TYPE (BCA,BMG,BNA,BK,BFE,BHCO,BCO,BCL,BSO,BNO)
   29 WRITE (6,30)
   30 FORMAT (/)
C     WRITE THE ME/L VALUES
      CALL EQUIV (BCA,BMG,BNA,BK,BFE,BHCO,BCO,BSO,BCL,BNO)
      WRITE (6,8)
      GO TO 14
C     CALCULATE AQUIFER AVERAGE STIFF IF REQUESTED
   31 IF (IAVER.LT.1) GO TO 35
      IF (IK.LT.1) GO TO 35
      WRITE (6,32)
   32 FORMAT (1X,30HAVERAGE STIFF PLOTS BY AQUIFER)
      WRITE (6,8)
      DO 34 IP=1,IK
      FCA=DCA(IP)/DKOUNT(IP)
      FMG=DMG(IP)/DKOUNT(IP)
      FNAK=DNAK(IP)/DKOUNT(IP)
      FFE=DFE(IP)/DKOUNT(IP)
      FHCO=DHCO(IP)/DKOUNT(IP)
      FSO=DSO(IP)/DKOUNT(IP)
      FCL=DCL(IP)/DKOUNT(IP)
      FNO=DNO(IP)/DKOUNT(IP)
      CALL SCALE (FCA,FMG,FNAK,0.,FFE,FHCO,0.,FSO,FCL,FNO,CCA,CMG,CNAK,C
     1FE,CHCO,CSO,CCL,CNO,IN)
      N=SCAL(IN)
```

```
      EN=SCAL(IN)/20.
      LFM1=(NOAQ(IP)*3)-2
      LFM2=LFM1+2
      LFM3=(NOAQ(IP+100)*3)-2
      LFM4=LFM3+2
      WRITE (6,33) (AQUNT(I),I=LFM1,LFM2),(AQUNT(I),I=LFM3,LFM4),N,EN,DK
     1OUNT(IP)
   33 FORMAT (10X,16HGEOLOGIC UNIT(S),2X,3A6,5X,3A6//13HTOTAL SCALE =,I4
     1,27H MILLIEQUIVALENTS PER LITER,10X,11HEACH DASH =,F6.2//15X,27HNU
     2MBER OF ANALYSES AVERAGED,F5.0/////)
      CALL ROUND (CCA,CMG,CNAK,CFE,CHCO,CSO,CCL,CNO,ICA,IMG,INAK,IFE,IHC
     1O,ISO,ICL,INO)
      CALL PLOT1 (ICA,IMG,INAK,IFE,IHCO,ISO,ICL,INO)
      FK=0.
      FCO=0.
      CALL TYPE (FCA,FMG,FNAK,FK,FFE,FHCO,FCO,FCL,FSO,FNO)
      WRITE (6,30)
      CALL EQUIV (FCA,FMG,FNAK,FK,FFE,FHCO,FCO,FSO,FCL,FNO)
      WRITE (6,8)
   34 CONTINUE
   35 GO TO 5
      END
```

```
C     SCALE000     SUBROUTINE SCALE
      SUBROUTINE SCALE (BCA,BMG,BNA,BK,BFE,BHCO,BCO,BSO,BCL,BNO,CCA,CMG,
     1CNAK,CFE,CHCO,CSO,CCL,CNO,IN)
      COMMON K(60),SCAL(16),AQUNT(1800)
      IN=1
    1 IF (BCA.LT.SCAL(IN).AND.BMG.LT.SCAL(IN).AND.(BNA+BK).LT.SCAL(IN).A
     1ND.BFE.LT.SCAL(IN).AND.(BHCO+BCO).LT.SCAL(IN).AND.BSO.LT.SCAL(IN).
     2AND.BCL.LT.SCAL(IN).AND.BNO.LT.SCAL(IN)) GO TO 2
      IN=IN+1
      IF (SCAL(IN).GE.0.1) GO TO 1
      SCAL(IN)=SCAL(IN-1)*2.
      GO TO 1
    2 DN=20./SCAL(IN)
      CCA=BCA*DN
      CMG=BMG*DN
      CNAK=(BNA+BK)*DN
      CFE=BFE*DN
      CHCO=(BHCO+BCO)*DN
      CSO=BSO*DN
      CCL=BCL*DN
      CNO=BNO*DN
      RETURN
      END
```

```
C     ROUND000     SUBROUTINE ROUND
      SUBROUTINE ROUND (CCA,CMG,CNAK,CFE,CHCO,CSO,CCL,CNO,ICA,IMG,INAK,I
     1FE,IHCO,ISO,ICL,INO)
      ICA=CCA+.5
      IMG=CMG+.5
      INAK=CNAK+.5
      IFE=CFE+.5
```

```
      IHCO=CHCO
      ISO=CSO+.5
      ICL=CCL+.5
      INO=CNO+.5
      RETURN
      END
```

```
C     PLOT1000    SUBROUTINE PLOT1
      SUBROUTINE PLOT1 (ICA,IMG,INAK,IFE,IHCO,ISO,ICL,INO)
      COMMON K(60)
C
C     -----------------------------------------------------------------
C
C     DETERMINE LENGTH OF DASHED LINES
C
C     -----------------------------------------------------------------
C
      J1=ICA+1
      J2=IMG+1
      J3=INAK+1
      J4=IFE+1
      J5=60-IHCO
      J6=60-ISO
      J7=60-ICL
      J8=60-INO
      ICA=ICA+20
      IMG=IMG+20
      INAK=INAK+20
      IFE=IFE+20
      IHCO=41-IHCO
      ISO=41-ISO
      ICL=41-ICL
      INO=41-INO
C
C     -----------------------------------------------------------------
C
C     WRITE DIAGRAM
C
C     -----------------------------------------------------------------
C
      WRITE (6,1)
    1 FORMAT (53X,26HMILLIEQUIVALENTS PER LITER,/)
      WRITE (6,2)
    2 FORMAT (44X,41H1 9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8 9 1)
      WRITE (6,3)
    3 FORMAT (44X,41H                    0                    )
      WRITE (6,3)
      WRITE (6,4) (K(I),I=J1,ICA),(K(I),I=IHCO,J5)
    4 FORMAT (41X,3HCA ,20A1,1H0,20A1,9H HCO3+CO3)
      LINKT=0
    5 WRITE (6,3)
      LINKT=LINKT+1
      IF (LINKT.LT.5) GO TO 5
      WRITE (6,6) (K(I),I=J2,IMG),(K(I),I=ISO,J6)
    6 FORMAT (41X,3HMG ,20A1,1H0,20A1,4H SO4)
      LINKT=0
    7 WRITE (6,3)
```

```
      LINKT=LINKT+1
      IF (LINKT.LT.5) GO TO 7
      WRITE (6,8) (K(I),I=J3,INAK),(K(I), I=ICL,J7)
    8 FORMAT (39X,5HNA+K ,20A1,1HO,20A1,3H CL)
      LINKT=0
    9 WRITE (6,3)
      LINKT=LINKT+1
      IF (LINKT.LT.5) GO TO 9
      WRITE (6,10) (K(I),I=J4,IFE),(K(I), I=INO,J8)
   10 FORMAT (41X,3HFE ,20A1,1HO,20A1,4H NO3)
      WRITE (6,3)
      WRITE (6,3)
      WRITE (6,2)
      WRITE (6,11)
   11 FORMAT (/////)
      RETURN
      END
```

```
C     TYPE0000     SUBROUTINE TYPE
      SUBROUTINE TYPE (BCA,BMG,BNA,BK,BFE,BHCO,BCO,BCL,BSO,BNO)
C
C     ---------------------------------------------------------------------
C
C     DETERMINE AND WRITE WATER TYPE
C
C     ---------------------------------------------------------------------
C
    1 IF (BCA.GT.BMG.AND.BCA.GT.(BNA+BK).AND.BCA.GT.BFE) GO TO 2
      IF ((BNA+BK).GT.BCA.AND.(BNA+BK).GT.BMG.AND.(BNA+BK).GT.BFE) GO TO
     1 3
      IF (BMG.GT.BCA.AND.BMG.GT.(BNA+BK).AND.BMG.GT.BFE) GO TO 4
    2 IF ((BHCO+BCO).GT.BSO.AND.(BHCO+BCO).GT.BCL.AND.(BHCO+BCO).GT.BNO)
     1 GO TO 5
      IF (BSO.GT.(BHCO+BCO).AND.BSO.GT.BCL.AND.BSO.GT.BNO) GO TO 7
      IF (BCL.GT.(BHCO+BCO).AND.BCL.GT.BSO.AND.BCL.GT.BNO) GO TO 9
      IF (BNO.GT.(BHCO+BCO).AND.BNO.GT.BSO.AND.BNO.GT.BCL) GO TO 11
      GO TO 29
    3 IF ((BHCO+BCO).GT.BSO.AND.(BHCO+BCO).GT.BCL.AND.(BHCO+BCO).GT.BNO)
     1 GO TO 13
      IF (BSO.GT.(BHCO+BCO).AND.BSO.GT.BCL.AND.BSO.GT.BNO) GO TO 15
      IF (BCL.GT.(BHCO+BCO).AND.BCL.GT.BSO.AND.BCL.GT.BNO) GO TO 17
      IF (BNO.GT.(BHCO+BCO).AND.BNO.GT.BSO.AND.BNO.GT.BCL) GO TO 19
      GO TO 29
    4 IF ((BHCO+BCO).GT.BSO.AND.(BHCO+BCO).GT.BCL.AND.(BHCO+BCO).GT.BNO)
     1 GO TO 21
      IF (BSO.GT.(BHCO+BCO).AND.BSO.GT.BCL.AND.BSO.GT.BNO) GO TO 23
      IF (BCL.GT.(BHCO+BCO).AND.BCL.GT.BSC.AND.BCL.GT.BNO) GO TO 25
      IF (BNO.GT.(BHCO+BCO).AND.BNO.GT.BSO.AND.BNO.GT.BCL) GO TO 27
      GO TO 29
    5 WRITE (6,6)
    6 FORMAT (10X,32HWATER TYPE---CALCIUM BICARBONATE)
      GO TO 29
    7 WRITE (6,8)
    8 FORMAT (10X,28HWATER TYPE---CALCIUM SULFATE)
      GO TO 29
    9 WRITE (6,10)
   10 FORMAT (10X,29HWATER TYPE---CALCIUM CHLORIDE)
```

```
      GO TO 29
   11 WRITE (6,12)
   12 FORMAT (10X,28HWATER TYPE---CALCIUM NITRATE)
      GO TO 29
   13 WRITE (6,14)
   14 FORMAT (10X,31HWATER TYPE---SODIUM BICARBONATE)
      GO TO 29
   15 WRITE (6,16)
   16 FORMAT (10X,27HWATER TYPE---SODIUM SULFATE)
      GO TO 29
   17 WRITE (6,18)
   18 FORMAT (10X,28HWATER TYPE---SODIUM CHLORIDE)
      GO TO 29
   19 WRITE (6,20)
   20 FORMAT (10X,27HWATER TYPE---SODIUM NITRATE)
      GO TO 29
   21 WRITE (6,22)
   22 FORMAT (10X,34HWATER TYPE---MAGNESIUM BICARBONATE)
      GO TO 29
   23 WRITE (6,24)
   24 FORMAT (10X,30HWATER TYPE---MAGNESIUM SULFATE)
      GO TO 29
   25 WRITE (6,26)
   26 FORMAT (10X,31HWATER TYPE---MAGNESIUM CHLORIDE)
      GO TO 29
   27 WRITE (6,28)
   28 FORMAT (10X,30HWATER TYPE---MAGNESIUM NITRATE)
   29 RETURN
      END
```

```
C     EQUIV000    SUBROUTINE EQUIV
      SUBROUTINE EQUIV (BCA,BMG,BNA,BK,BFE,BHCO,BCO,BSO,BCL,BNO)
C
C     ------------------------------------------------------------------
C     ------------------------------------------------------------------
C     WRITE MILLIEQUIVALENTS PER LITER OF CONSTITUENTS USED ON DIAGRAM
C
C     ------------------------------------------------------------------
C
      WRITE (6,1)
    1 FORMAT (10X,42HCONSTITUENTS IN MILLIEQUIVALENTS PER LITER/)
      WRITE (6,2) BCA,BMG,BNA,BK,BFE,BHCO,BCO,BSO,BCL,BNO
    2 FORMAT (17X,3HCA=,F12.4,6X,3HMG=,F12.4,6X,3HNA=,F12.4,6X,2HK=,F12.
     14,6X,3HFE=,F12.4//15X,5HHCO3=,F12.4,5X,4HCO3=,F12.4,5X,4HSO4=,F12.
     24,5X,3HCL=,F12.4,5X,4HNO3=,F12.4)
      RETURN
      END
```

```
C     EPM00000    SUBROUTINE EPM
      SUBROUTINE EPM (SIO,AL,FE,AMN,CA,AMG,ANA,AK,HCO,CO,SO,CL,FL,ANO,PO
     1,BO,PH,BAL,BFE,BMN,BCA,BMG,BNA,BK,BHCO,BCO,BSO,BCL,BFL,BNO,BPO)
C
```

```
C     -----------------------------------------------------------------
C
C     SET DECIMAL POINTS OF CONSTITUENTS IN PROPER POSITIONS AND
C     CALCULATE MILLIEQUIVALENTS PER LITER
C
C     -----------------------------------------------------------------
C
      SIO=SIO*0.1
      AL=AL*0.1
      BAL=AL*.11119
      FE=FE*0.01
      BFE=FE*.05372
      AMN=AMN*0.01
      BMN=AMN*.03640
      CA=CA*0.1
      BCA=CA*.04990
      AMG=AMG*0.1
      BMG=AMG*.08224
      ANA=ANA*0.1
      BNA=ANA*.04350
      AK=AK*0.1
      BK=AK*.02558
      BHCO=HCO*.01639
      BCO=CO*.03333
      SO=SO*0.1
      BSO=SO*.02082
      CL=CL*0.1
      BCL=CL*.02820
      FL=FL*0.1
      BFL=FL*.05263
      ANO=ANO*0.1
      BNO=ANO*.01613
      PO=PO*0.01
      BPO=PO*.03159
      BO=BO*0.01
      PH=PH*0.01
      RETURN
      END
```

Appendix II.--Coding of Kansas water-quality cards

1. Code for state, K in field 2 cards 1 and 2

2. Codes for county number, in fields 3-4 cards 1 and 2

Code	County	Code	County	Code	County
01	Allen	36	Greeley	71	Osborne
02	Anderson	37	Greenwood	72	Ottawa
03	Atchison	38	Hamilton	73	Pawnee
04	Barber	39	Harper	74	Phillips
05	Barton	40	Harvey	75	Pottawatomie
06	Bourbon	41	Haskell	76	Pratt
07	Brown	41	Hodgeman	77	Rawlins
08	Butler	43	Jackson	78	Reno
09	Chase	44	Jefferson	79	Republic
10	Chautauqua	45	Jewell	80	Rice
11	Cherokee	46	Johnson	81	Riley
12	Cheyenne	47	Kearny	82	Rooks
13	Clark	48	Kingman	83	Rush
14	Clay	49	Kiowa	84	Russell
15	Cloud	50	Labette	85	Saline
16	Coffey	51	Lane	86	Scott
17	Comanche	52	Leavenworth	87	Sedgwick
18	Cowley	53	Lincoln	88	Seward
19	Crawford	54	Linn	89	Shawnee
20	Decatur	55	Logan	90	Sheridan
21	Dickinson	56	Lyon	91	Sherman
22	Doniphan	57	Marion	92	Smith
23	Douglas	58	Marshall	93	Stafford
24	Edwards	59	McPherson	94	Stanton
25	Elk	60	Meade	95	Stevens
26	Ellis	61	Miami	96	Sumner
27	Ellsworth	62	Mitchell	97	Thomas
28	Finney	63	Montgomery	98	Trego
29	Ford	64	Morris	99	Wabaunsee
30	Franklin	65	Morton	A0	Wallace
31	Geary	66	Nemaha	A1	Washington
32	Gove	67	Neosho	A2	Wichita
33	Graham	68	Ness	A3	Wilson
34	Grant	69	Norton	A4	Woodson
35	Gray	70	Osage	A5	Wyandotte

3. Codes for well depth, in fields 22-25 (in addition to actual depths) card 1
RIGHT HAND JUSTIFIED

CODE		
SINK	=	Sink
R	=	River
S	=	Spring
COMP	=	Composite
SEEP	=	Seep
TAP	=	Tap
PIT	=	Pit
POND	=	Pond
PUMP	=	Pump
TRET	=	Treated

4. Codes for type analysis, in field 26 card 1

C	=	Complete
P	=	Partial

5. Codes for analyst, in field 79 card 1

1	=	State Dept. of Health
2	=	U.S.G.S.
3	=	Your lab, etc.

6. Codes for geologic units, in fields 16-21 card 2

See Appendix III

7. Codes for type, in field 78 card 2

1	=	Pumped
2	=	Bucket
3	=	Forest
4	=	Spigot
5	=	Bailer
6	=	Special

8. Codes for source of data, in field 79 card 2

1	=	USGS
2	=	USPHS
3	=	State Health
4	=	State
5	=	Industrial
6	=	Private
7	=	Educational
8	=	Municipal

KANSAS GROUND WATER
Chemical Analysis Schedule

State	1 2
County	3 4
Well Number: T R E-W Sec. 1/4 1/4 1/4 No.	5 6 7 8 9 10 11 12 13 14 15
Date: M.	16 17
Date: D.	18 19
Date: Y.	20 21
Well or Sampling Depth	22 23 24 25
Type Analysis	26
SiO_2	27 28 29
AL	30 31 32
Fe	33 34 35 36 37
Mn	38 39 40
Ca	41 42 43 44 45 46
Mg	47 48 49 50 51
Na	52 53 54 55 56 57
K	58 59 60
HCO_3	61 62 63 64
CO_3	65 66
SO_4	67 68 69 70 71
Cl	72 73 74 75 76 77 78
Analyst	79
Card No. [1]	80

Geologic Unit	16 17 18
Geologic Unit	19 20 21
F	22 23 24
NO_3	25 26 27 28 29
PO_4	30 31 32
B	33 34 35
Dissolved Solids	36 37 38 39 40 41
Hardness	42 43 44 45 46
Non-Carbonate	47 48 49 50
ALK. as $CaCO_3$	51 52 53 54
Free CO_2	55 56 57
SAR	58 59 60
RSC	61 62 63
$K \times 10^6$	64 65 66 67 68 69
pH	70 71 72
Color	73 74
°F	75 76 77
Type	78
Source of Data	79
Card No. [2]	80

Appendix III.--Listing of input control data

AQUNT ARRAY

CENOZOIC ROCKS	NEOGENE SYS	QUATERNARY SYS	PLEISTOCENE SER
U PLEISTOCENE SSER	RECENT ST	EOLIAN-FLUV DEP	EOLIAN DEP
FLUVIAL DEP	WISCONSINAN ST	MANKATOAN SST	BIGNELL FM
CARYAN SST	TERRACE DEP	BRADYAN SST	BRADY SOIL
PEORIA FM	TAZEWELLIAN SST	IOWAN SST	GLACIAL DRIFT
SANGAMONIAN ST	SANGAMON SOIL	ILLINOISAN ST	LOVELAND FM
CRETE FM	REC-ILL ST	SANBORN GP	VANHEM FM
KINGSDOWN FM	L PLEISTOCENE SSER	YARMOUTHIAN ST	YARMOUTH SOIL
KANSAN ST	SAPPA FM	PEARLETTE ASH B	GRAND ISLAND FM
KANSAS TILL	ATCHISON FM	AFTONIAN ST	AFTON SOIL
NEBRASKAN ST	BLANCO FM	FULLERTON FM	HOLDREGE FM
NEBRASKA TILL	DAVID CITY FM	YARMOUTH-NEBRAS ST	MEADE GP
CROOKED CREEK FM	ATWATER ME	STUMP ARROYO ME	BALLARD FM
ANGELL ME	QUAT OR TERT	PLIO-PLEIST SER	UPLAND CHERT GRAV
TERTIARY SYS	PLIOCENE SER	REXROAD FM	OGALLALA FM
KIMBALL ME	ASH HOLLOW ME	VALENTINE ME	DELMORE FM
LAVERNE FM	CALVERT ASH B	DELLVALE ASH B	FORT WALLACE ASH B
RAWLINS ASH B	REAGER ASH B	REAMSVILLE ASH B	MESOZOIC ROCKS
CRETACEOUS SYS	GULFIAN SER	U CRETACEOUS SER	MONTANA GP
PIERRE SH	BEECHER IS SH ME	MISSLER ME	SALT GRASS SH ME
LAKE CREEK SH ME	WESKAN SH ME	SHARON SP SH ME	COLORADO GP
NIOBRARA CHALK	SMOKY HILL CHK ME	FORT HAYS LS ME	CARLILE SH
CODELL SS ME	BLUE HILL SH ME	FAIRPORT CHALK ME	GREENHORN LS
BRIDGE CREEK LS ME	PFEIFER SH ME	FENCEPOST LS B	JETMORE CHALK ME
HARTLAND SH ME	LINCOLN LS ME	GRANEROS SH	L(?) CRET SER
COCKRUM SS	DAKOTA FM	JANSSEN CLAY ME	TERRA COTTA CL ME
OMADI FM	CRUISE SS ME	HUNTSMAN SH ME	GURLEY SS ME
COMANCHEAN SER	L CRETACEOUS SER	KIOWA SH	CHAMPION SHELL B
CHEYENNE SS	JURASSIC SYS	U JURASSIC SER	MORRISON FM
TRIASSIC SYS	U TRIASSIC SER	DOCKUM GP	X I ME
PALEOZOIC ROCKS	PERMIAN SYS	GUADALUPIAN SER	U PERMIAN SERIES
QUARTERMASTER GP	TALOGA FM	BIG BASIN FM	DAY CREEK DOL
WHITEHORSE FM	KIGER SH ME	HOLOCENE	RELAY CREEK DOL ME
MARLOW SS ME	L PERMIAN SER	LEONARDIAN SER	CIMARRONIAN ST
NIPPEWALLA GP	DOG CREEK FM	BLAINE GYP	HASKEW GYP ME
SHIMER GYP ME	NESCATUNGA GYP ME	MED LODGE GYP ME	FLOWERPOT SH
CEDAR HILLS SS	SALT PLAIN STS	CRISFIELD SS B	HARPER STS
KINGMAN STS ME	CHIKASKIA STS ME	SUMNER GP	STONE CORRAL FM
NINNESCAH SH	RUNNYMEDE STS ME	KAN GLAC-FLUV DEP	WELLINGTON FM
MILAN DOL ME	NICKERSON TILL	HUTCHINSON SALT ME	BUCK CREEK TER DEP
CARLTON LS ME	IOWA POINT TILL	HOLLENBERG LS ME	CEDAR BLUFFS TILL
WOLFCAMPIAN SER	GEARYAN ST	CHASE GP	NOLANS LS
HERINGTON LS ME	PADDOCK SH ME	KRIDER LS ME	ODELL SH
WINFIELD LS	CRESSWELL LS ME	GRANT SH ME	STOVALL LS ME
DOYLE SH	GAGE SH ME	TOWANDA LS ME	HOLMESVILLE SH ME
BARNESTON LS	FORT RILEY LS ME	OKETA SH ME	FLORENCE LS ME
MATFIELD SH	BLUE SPRINGS SH ME	KINNEY LS ME	WYMORE SH ME
WREFORD LS	SCHROYER LS ME	HAVENSVILLE SH ME	THREEMILE LS ME
COUNCIL GROVE GP	SPEISER SH	FUNSTON LS	BLUE RAPIDS SH
CROUSE LS	EASLY CREEK SH	BADER LS	MIDDLEBURG LS ME
HOOSER SH ME	EISS LS ME	STEARNS SH	BEATTIE LS
MORRILL LS ME	FLORENA SH ME	COTTONWOOD LS ME	ESKRIDGE SH
GRENOLA LS	NEVA LS ME	SALEM POINT SH ME	BURR LS ME
LEGION SH ME	SALLYARDS LS ME	ROCA SH	RED EAGLE LS
HOWE LS ME	BENNETT SH ME	GLENROCK LS ME	JOHNSON SH
FORAKER LS	LONG CREEK LS ME	HUGHES CREEK SH ME	AMERICUS LS ME
ADMIRE GP	JANESVILLE SH	HAMLIN SH ME	OAKS SH ME

HOUCHEN CR LS ME
FALLS CITY LS
TOWLE SH ME
U PENN SER
WOOD SIDING FM
PLUMB SH ME
FRENCH CREEK SH ME
GRANDHAVEN LS ME
LANGDON SH
PIERSON POINT SH
EMPORIA LS
AUBURN SH
BURLINGAME LS ME
RULO LS ME
WHITE CLOUD SH ME
CHURCH LS ME
SEVERY SH
HOLT SH ME
JONES POINT SH ME
CALHOUN SH
ROCK BLUFF LS ME
QUEEN HILL SH ME
LECOMPTON LS
ELGIN SS
JACKSON PARK SH ME
PLATTSMOUTH LS ME
TORONTO LS ME
AMAZONIA LS ME
ROBBINS SH ME
WESTPHALIA LS ME
PEDEE GP
LANSING GP
STONER LS ME
PLATTSBURG LS
KANSAS CITY GP
FARLEY LS ME
FRISBIE LS ME
LINN SGP
PAOLA LS ME
OUTWASH DEPOSITS
DEWEY LS ME
WESTERVILLE LS ME
WEA-QUIVIRA SH ME
STARK SH ME
DODDS CREEK SS ME
MIDDLE CREEK LS ME
MOUND CITY SH ME
TACKET FM
SOUTH MOUND SH ME
DESMOINESIAN ST
LENAPAH LS
NOWATA SH
ALTAMONT LS
TINA LS
BANDERA QUAR SS ME
MINE CREEK SH ME
WARRENSBURG SS
HIGGINSVILLE LS ME
BLACKJACK CR LS ME
MULKY COAL
STINE SH ME
ONAGA SH
INDIAN CAVE SS B
VIRGILIAN ST
BROWNVILLE LS ME
NEBRAS CITY LS ME
JIM CREEK LS ME
DRY SH ME
ZEANDALE LS
TARKIO LS ME
ELMONT LS ME
BERN LS
SACFOX SGP
CEDAR VALE SH ME
HOWARD LS
AARDE SH ME
SHAWNEE GP
DU BOIS LS ME
CURZON LS ME
DEER CREEK LS
OSKALOOSA SH ME
BIG SPRINGS LS ME
AVOCA LS ME
KANWAKA SH
OREAD LS
HEEBNER SH ME
DOUGLAS GP
WILLIAMSBURG COAL
HASKELL LS ME
TONGANOXIE SS ME
IATAN LS ME
STANTON LS
EUDORA SH ME
SPRING HILL LS ME
ZARAH SGP
ISLAND CREEK SH ME
LANE SH
IOLA LS
CHANUTE SH
NOXIE SS ME
CEMENT CITY LS ME
WEA SH ME
BRONSON SGP
CANVILLE LS ME
SWOPE LS
LADORE SH
CRITZER LS ME
KNOBTOWN SS ME
HEPLER SS ME
MARMATON GP
IDENBRO LS ME
NEB GLAC-FLUV DEP
WORLAND LS ME
BANDERA SH
UNNAMED
MYRICK STAT LS ME
UNNAMED
LITTLE OSAGE SH ME
CHEROKEE GP
BREEZY HILL LS ME
FIVE POINT LS ME
HAWXBY SH ME
PENNSYLVANIAN SYS
WABAUNSEE GP
PONY CREEK SH ME
CANEYVILLE LS
FRIEDRICH SH ME
DOVER LS ME
MAPLE HILL LS ME
NEMAHA SGP
HARVEYVILLE SH ME
WAKARUSA LS ME
SCRANTON SH
ELMO COAL
UTOPIA LS ME
NODAWAY COAL
TOPEKA LS
TURNER CREEK SH ME
IOWA POINT SH ME
ERVINE CREEK LS ME
OZAWKIE LS ME
DONIPHAN SH ME
KING HILL SH ME
STULL SH ME
KEREFORD LS ME
LEAVENWORTH LS ME
LAWRENCE FM
GILMAN CANYON FM
STRANGER FM
U SIBLEY COAL
WESTON SH ME
SOUTH BEND LS ME
CAPTAIN CR LS ME
HICKORY CR SH ME
BONNER SPRINGS SH
ARGENTINE LS ME
LANE-BONNER SP SH
RAYTOWN LS ME
COTTAGE GRO SS ME
DRUM LS
CHERRYVALE SH
BLOCK LS ME
DENNIS LS
GALESBURG SH
BETHANY FALS LS ME
HERTHA LS
COFFEYVILLE FM
CHECKERBOARD LS
DESMOINESIAN SER
MEMORIAL SH
PERRY FARM SH ME
WALT JOHNSON SS ME
LAKE NEOSHO SH ME
MULBERRY COAL
PAWNEE LS
ANNA SH ME
ENGLEVALE SS ME
HOUX LS B
CABANISS FM
IRON POST COAL
WEST BRANCH SH ME
ASPINWALL LS ME
VIRGILIAN SER
RICHARDSON SGP
GRAYHORSE LS ME
ROOT SH
STOTLER LS
PILLSBURY SH
WAMEGO SH ME
WILLARD SH
READING LS ME
SOLDIER CR SH ME
SILVER LAKE SH ME
HAPPY HOLLOW LS ME
WINZELER SH ME
BACHELOR CR LS ME
COAL CREEK LS ME
SHELDON LS ME
HARTFORD LS ME
LARSH-BURR SH ME
TECUMSEH SH
SPRING BR LS ME
BEIL LS ME
CLAY CREEK LS ME
HEUMADER SH ME
SNYDERVILLE SH ME
WATHENA SH ME
IRELAND SS ME
VINLAND SH ME
L SIBLEY COAL
MISSOURIAN ST
ROCK LAKE SH ME
VILAS SH
MERRIAM LS ME
WYANDOTTE LS
QUINDARO SH ME
LANE-VILAS SH
MUNCIE CREEK SH ME
THAYER COAL
CORBIN CITY LS ME
QUIVIRA SH ME
FONTANA SH ME
WINTERSET LS ME
NORTONVILLE CLAY
HUSHPUCKNEY SH ME
SNIABAR LS ME
PLEASANTON GP
SEMINOLE FM
M PENN SER
HOLDENVILLE SH
NORFLEET LS ME
UNNAMED
AMORET LS ME
UNNAMED
LABERDIE LS ME
LABETTE SH
FORT SCOTT LS
SUMMIT COAL
EXCELLO SH
UNNAMED

UNNAMED	STICE COAL	WHEELER COAL(?)	BEVIER COAL
UNNAMED	VERDIGRIS LS ME	ARDMORE LS ME	CROWEBURG COAL
BROKEN ARROW COAL	UNNAMED	FLEMING COAL	UNNAMED
MINERAL COAL	UNNAMED	SCAMMON COAL	CHELSEA SS ME
PILOT COAL	TIAWAH LS	TEBO COAL	UNNAMED
WIER PITTS COAL	KREBS FM	SEVILLE LS ME	KNIFETON COAL
UNNAMED	BLUEJACKET SS ME	DRYWOOD COAL	UNNAMED
COLUMBUS COAL	ROWE COAL	UNNAMED	NEUTRAL COAL
UNNAMED	LITTLE CABIN SS ME	WARNER SS ME	RIVERTON COAL
UNNAMED	ATOKAN SER	ATOKAN(BENDIAN) ST	ATOKAN ST
CHAT	UNNAMED	MORROWAN SER	L PENN SER
MORROWAN ST	KEARNY FM	PENN BS CON	MISSISSIPPIAN SYS
CHESTERAN SER	U MISS SER	CHESTERAN ST	UNNAMED
MERAMECIAN SER	MERAMECIAN ST	STE. GENEVIEVE LS	ST. LOUIS LS
SPERGEN LS	SALEM LS	WARSAW LS	COWLEY FM
L MISS SER	OSAGIAN SER	OSAGIAN ST	KEOKUK LS
BURLINGTON LS	REEDS SPRING LS	ST. JOE LS	KINDERHOOKIAN SER
KINDERHOOKIAN ST	GILMORE CITY LS	SEDALIA DOL	NORTHVIEW SH
CHOUTEAU LS	COMPTON LS	BOICE SH	DEV OR MISS SYS
CHATTANOOGA SH	DEVONIAN SYS	M DEVONIAN SER	L SIL-M DEV SER
SILURIAN SYS	L SILURIAN SER	HUNTON GP	UNNAMED
UNNAMED	CHIMNEY HILL DOL	ORDOVICIAN SYS	U ORDOVICIAN SER
MAQUOKETA(SYL) SH	M ORDOVICIAN SER	VIOLA (KIMM) LS	SIMPSON GP
PLATTEVILLE FM	ST. PETER SS	UNNAMED	L ORDOVICIAN SER
ARBUCKLE GP	COTTER DOL	JEFFERSON CITY DOL	COTTER-JEFF CY DOL
ROUBIDOUX FM	GASCONADE DOL	VAN BUREN FM	GUNTER SS ME
L ORD-U CAM SER	EMINENCE DOL	CAMBRIAN SYS	U CAMBRIAN SER
BONNETERRE DOL	HONEY CREEK LS	LAMOTTE(REAGAN) SS	LAMOTTE SS
REAGAN SS	PENN-CAM	GRANITE WASH	PRECAMBRIAN ROCKS
PRECAMBRIAN SYS	UNDIFFERENTIATED	NEWMAN TERRACE DEP	ALLUVIUM
HILLS POND PERIDOT	NEOGENE-CRET SYS	L(?)CRET-L CRET SER	JUR-TRI SYS
L PERM-U PENN SER	PENN-MISS SYS	MISS-DEV SYS	DEV-SIL SYS
ORD-CAM SYS	COLLUVIUM		NOT DETERMINED

ACO ARRAY, IAVER, AND ISC

RUSH COUNTY, KANSAS 1 1

SCAL ARRAY

5 10 25 100 500

DATA GROUP

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K831817W22DAD   3 456      C32      37000  103    95   22       33700   47      13 11
K831817W22DAD 004009 01     08        403  296   20 276                   77      432
K831817W22DAD  11460       C33     015000  105    83   24       329 0   52      16 11
K831817W22DAD 004009 01     04        401  296   26 270              64575      432
K831817W27ABA  82460   59C43       020000   93    88   18       288 0   40      15 11
K831817W27ABA 004009 03     93        369  268   32 236              590      54132
K831817W28BCC  81160   63C41       22 031  105   10     31      300 0   85      22 11
K831817W28BCC 004009 02     42        446  303   57 246              720      54132
K831817W30ABB  72165   75C28        02 22  134   14     57   78 403 0 109      53 11
K831817W30ABB 004009  3     53    ι6  607  392   62 330              94076      132
K831817W34BCA 101160 175C 80       038000   18    95  221       407 0 119      70 11
K831817W34BCA 102      26   19        650   84    0 334             1160        132
K831818W 9AAB 101260 265C 80       11 000   14    56  482       298 0 226     435 11
K831818W 9AAB 102      42   18       1323   58    0 244             2470        132
K831818W25BCB  82260   67C35       15 047  122   11     62      378 0   99      46 11
K831818W25BCB 004009 04     62        568  350   40 310              930      54132
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K831818W26DDA 101260 187C 80      036000   29    10    153      329 0  52      84 11
K831818W26DDA 102    16   04         500  114     0 270            920          432
K831818W27CCB  72665  67C26        01 22  128    15     86  93 376 0 176      60 11
K831818W27CCB 004009  6   44     19  690  381    73 308           106075        132
K831818W28AAC  13161  83C33        24000  109    12     32    35400  57       29 11
K831818W28AAC 004009  3    4  2      447  322    32 290            78078        432
K831818W28AAC  62061  83C24       036002  113    12     20    35400  53       20 11
K831818W28AAC 004009  2    4 03      417  332    42 290            70075        432
K831818W28AAC  7  61  83C26       062012  114    11     19      351 0  53      19 11
K831818W28AAC 004009 02   04 02      415  330    42 288            63078        432
K831818W30DDC  81160  70C35       018042  105    73     28      300 0  47      27 11
K831818W30DDC 004009 03  23          420  292    46 246            700        54132
K831818W31DDA 101160 150C 90      11  00   10    27    238      354 0  95     110 11
K831818W31DDA 102    28   18         644   36     0 290           1160        58432
K831818W34BBB  82260  59C33       018000  142    12     66    34000 177       49 11
K831818W34BBB 004009  5  18          665  404   125 279           1050        54132
K831818W36DCA  81960  54C31       018000  115    90     13    31500  40       17 11
K831818W36DCA 004007 02  34          414  324    66 258            710        54132
K831819W21CDB  81160  58C45       018000  119    11     29    33400  90       23 11
K831819W21CDB 004009 02   62         488  342    68 274            740        55132
K831819W22CBB  72165  54C30        05 08  149    18     23  95 400 0 133      23 11
K831819W22CBB 004009  2    8     13  584  446   118 328            87077        132
K831819W27AAA  81160  64C36       029000  135    10     32    29300 135       34 11
K831819W27AAA 004009 02  23          549  378   138 240            850        54132
K831820W14CCB  81160  44C52       020000  118    11     19    32200  63       21 11
K831820W14CCB 004009 03  15          463  340    68 272            710        54132
K831820W15CCB  81160  63C50       020000  115    12     20    31000  79       22 11
K831820W15CCB 004009 03  14          465  336    82 254            730        55132
K831820W19ACC  81160  54C50       020035  114    13     28    35600  79       14 11
K831820W19ACC 004009 03   58         479  338    46 292            780        54132
K831820W19CCB  82260    RC33      14 000   89    12     36      277 0  83      22 11
K831820W19CCB         05   58         418  272    45 227            680        70 32
K831820W20ACC  72165  52C41        01 00  216    28     74 13   381 0 416      46 11
K831820W20ACC 004009  3  17      13 1039  654   342 312           138076        132
K831820W20DCA  2 661  48C33       010000  153    10     20    42500  89       14 11
K831820W20DCA 004009 02   71 04      535  422    74 348            92075        432
K831820W20DCA  32762  48C33       004000  142    16     13      417 0  76      15 11
K831820W20DCA 004009      80 04      508  420    50 342            83072        432
K831820W36ABB 101160 214C 80      055000   13    48    448      361 0 225     340 11
K831820W36ABB 102    56   10        1223   52     0 296           2220        57132
K831916W23DDB 10 760  80C20       053000  168    16     32      315 0  74     104 11
K831916W23DDB 004102 01  88          657  485   227 258           1170        54132
K831917W27ADD  51760 185C11       006000   37    17     59      292 0  19      20 11
K831917W27ADD 102    06   19         309  162     0 240            570        60432
K831918W 3ACA  81560 140C33       018000  124    11     21    31200  77       40 11
K831918W 3ACA 007102 02   97         469  354    98 256            790        54132
K831918W27CCB  51660 390C 80      071000   20    13    139      299 0  28      90 11
K831918W27CCB 102    09   17         448  104     0 245            800        61132
K831919W24CCB  51660 290C11       071000   19    89    191      278 0 125      93 11
K831919W24CCB 102    30   27         591   84     0 228           1050        61 32
K831920W 4BBB 101160 284C 70      015000   10    51    310      327 0 199     163 11
K831920W 4BBB 102    54   08         861   46     0 268           1550        56132
K831920W17DDC  51360 360C14       022000   66    72    415      442 0 205     253 11
K831920W17DDC 102    52   44        1128   46     0 362           1970        58132
K831920W26BAA  51360 410C 95      30 000   66    77    265      317 0 174     118 11
K831920W26BAA 102    49   36         745   48     0 260           1190        66132
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Appendix IV.--Program abstract

KANSAS GEOLOGICAL SURVEY COMPUTER PROGRAM
THE UNIVERSITY OF KANSAS, LAWRENCE

PROGRAM ABSTRACT

Title (If subroutine state in title): Stiff Diagrams of Water-Quality Data Programmed for the Digital Computer

Date: July 1965

Author, organization: Charles O. Morgan and Jesse M. McNellis
U.S. Geological Survey, Water Resources Division

Direct inquiries to: Charles O. Morgan or Jesse M. McNellis

Name: Address: U.S.G.S., WRD
Box 768, Lawrence, Kansas, 66044

Purpose/description: To produce Stiff diagrams of water-quality data.

Mathematical method: See program listing.

Restrictions, range: Analyses must include major anions and cations.

Computer manufacturer: GE, IBM Model: GE 635, IBM 7040, IBM 360/65

Programming language: FORTRAN IV

Memory required: 16 K Approximate running time:

Special peripheral equipment required: None

Remarks (special compilers or operating systems, required word lengths, number of successful runs, other machine versions, additional information useful for operation or modification of program)