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# Storage and Retrieval System for Ground Water Quality Data in South Dakota

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# STORAGE AND RETRIEVAL SYSTEM FOR GROUND WATER QUALITY DATA IN SOUTH DAKOTA

BY

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WATER QUALITY DATA IN SOUTH DAKOTA

This thesis is approved as a creditable, independent investigation by a candidate for the degree, Master of Science, and is acceptable as meeting the thesis requirements for this degree, but without implying that the conclusions reached by the candidate are necessarily the conclusions of the major department.

Thesis Advisor Date

Head of Major Department Date

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# INTRODUCTION

Water is a natural resource vital to all men for their general well-being. It is undeniably important in the area of recreation, waste disposal, agriculture, industry and navigation. Man has lived on waterways or near water sources because of his dependence upon water for life.

Man's concern over water quality differs from place to place, often his social and economic growth depends upon the quality maintained. Serious changes in water quality have resulted; its change being dependent upon the nature and extent of the water supply, the number and kind of users, the geographic placement of water users along the waterway, and the degree of pollution control (4). Due to increased water consumption and the lack of concern over prevention of rapid deterioration, a need for annual replenishment has often resulted. This is one reason why work with water has become complicated by many types of jurisdictional disputes (2).

"Water is one of the materials required to sustain life and has long been suspected of being the source of many of the illnesses of man." It is apparent that rivers and other receiving bodies of water have a limited ability to handle waste materials without creating nuisance conditions (9). It is essential to collect, collate, and evaluate all available information relative to the effects of each potential pollutant on each possible beneficial use of water in order to establish the current picture of water quality (10).

The increasing emphasis on improving America's streams, lakes, and coastal waters has created a need to define and to measure the pollution problem. Data available to man are produced both by traditional techniques and by recently developed automatic monitoring systems (6). The electronic computer is a device that aids man in many ways. It has rapidly changed the approach of solving many problems and situations. These might include such things as the design of equipment, storage and retrieval of information, translation of languages, solution of physical problems, and simulation of life situations (8). The electronic digital computer has evidently the speed, capacity, and flexibility necessary to handle adequately most complicated tasks involved in many State programs as well as regional or national oriented water pollution control programs. The need for automatic data processing becomes self-evident when consideration is given to the effort, time, and cost of performing the necessary tasks of considering alternate programs for solving problems of this scope. The application of automatic data processing techniques makes possible a successful analysis to daily complex voluminous and varied problems of water quality control. Automatic processing makes possible the rapid and efficient storage and retrieval of data, thus permitting large volumes of data to be readily accessible to those who wish to use them. The process also provides an efficient means of feeding data into computational programs of many kinds (5).

In order to aid in solving the problems and to meet the needs of all agencies connected and concerned with investigations and research programs in ground water quality, and in particular the Water Resources

Institute of South Dakota State University, a system of storage and retrieval named "SODAK" was designed. Although the design of "SODAK" primarily meets the needs of the State of South Dakota, it has adaptations for many other areas and many types of data which requires storage and retrieval. Basically, the system represents the storage and retrieval system for ground water quality data. Its main purpose is the uniform conversion of data in such a manner that a researcher can find information which is of interest to him or convince himself of the absence of such data. The system consists of the processing of collected data in whatever form it is available and converting it to a stored record which can be searched by an electronic digital computer.

# OBJECTIVES

The three general objectives of this study are as follows: (1) to devise a storage and retrieval system for rapid and efficient retrieval of water quality data such as may be available in the State of South Dakota, (2) to develop a system which would enable the scientist of the Water Resources Institute of South Dakota State University and other agencies interested in water quality management to communicate more effectively with the public. This would aid in obtaining better water quality management practices and thus allow the best use of water, and (3) to develop flexibility in the data system so as to meet varying program needs and conditions.

Specific Objectives of the "SODAK" System:

1. To develop procedures to store ground water quality data so that the origin of the data and the point of collection can be ascertained.
2. To develop procedures to record and store water quality and related parameters.
3. To devise methods of retrieving the data in any one of several forms so as to best meet the needs of the public in general and the users in particular.
4. To develop a system for the uniform conversion of data so that a researcher can find particular information which is of interest to him or convince himself of the absence of such data.

5. To develop a program that consists of collecting data in whatever form it is available and convert it to a stored record which can then be searched by an electronic digital computer.

The study was initiated in the spring of 1966, and its development as a system was completed in the fall of 1967. The study and its development was made on the South Dakota State University Campus. The ground water quality data used in this study was furnished by the U.S. Geological Survey.

# REVIEW OF LITERATURE

A data system is a combination of the steps taken to acquire a desired objective. All data systems contain the four basic elements of input (a piece of information recorded on a sheet of paper, special cards, magnetic or paper tapes, or disks.), storage (where the input or piece of information is housed or filed.), processing (the calculation or deduction made on the data by an individual.), and the output (the results of the processing which is recorded on another sheet of paper, or punched on similar cards as those used for the input.).

Computers constitute one of the comprehensive data processing analysis tools available at the present time; besides their capability of high speed, they can be programmed to perform a wide variety of arithmetic and logical functions. The need of the agency is an important factor to be considered in the design of a computer-oriented system. The need of the agency should not be limited to possible increase in the volume of data to be handled but more so with the need of an over-all speed of processing, capacity for increased computational capabilities, and potential expansion in scope of the design (1).

Literature on this subject is limited. Only a few organizations are actively using a storage and retrieval system; however, many are in the planning stage. Some information is based on "in-house" activities and experiences which are not formally documented (3).

The STORET system (shown in Figure 1) devised and used by the Public Health Service (1, 5, 6, 12), is the only system of storage and retrieval of water quality data for both surface waters and ground waters being

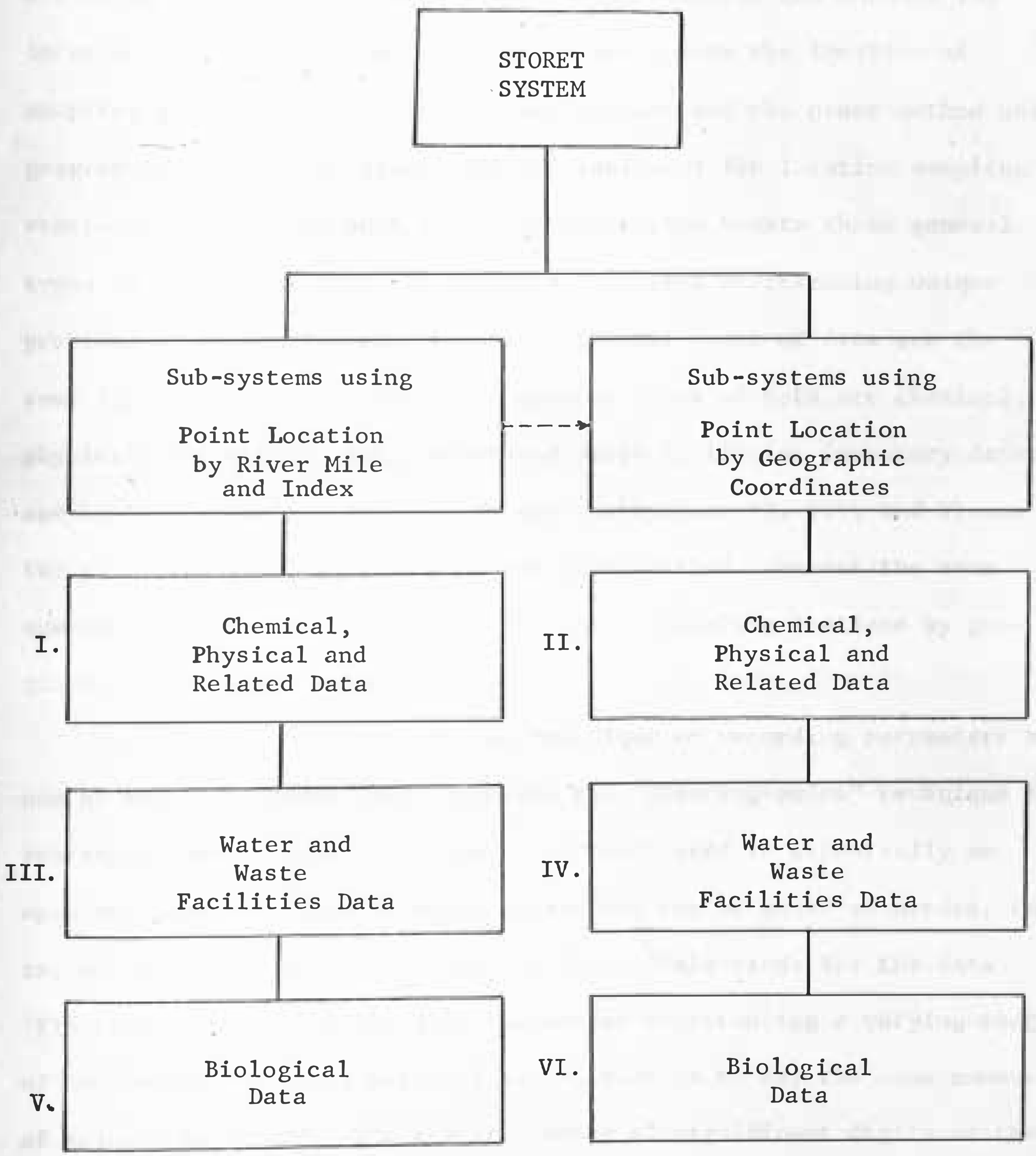


Figure 1. The STORET SYSTEM

used at the present time. Some national, state, and local agencies are utilizing the system. Actually, the system employs two methods for locating sampling stations: one method deals with the location of sampling points by river mileage and indices; and the other method uses geographic coordinates (longitude and latitude) for locating sampling stations. The two methods of the STORET system treats three general types of data, each data type being a subsystem representing unique problems of system design. The three general types of data are the same for both methods. The three general types of data are chemical, physical, and related data; water and waste facilities inventory data; and biological data. The odd numbered subsystems (I, III, and V) use the point location by river mile and index method, whereas the even numbered subsystems (II, IV, and VI) locate sampling stations by geographic coordinates method.

The STORET system employs the technique of recording parameters by use of the "open ended" data card and the "floating-point" technique for storing parameter values. "Open ended" data card is essentially an open-end parameter list to which parameters can be added as needed; that is, not being limited to a series of fixed field cards for the data. "Floating-point" technique is a system for representing a varying range of numbers with a fixed width of field, that is to say the same number of columns in a card. The desired number of significant digits of the value is recorded first, then an exponent is recorded which places the decimal point in its proper location. An illustration of the "floating-point" equivalent of two numbers would be the number 110 and the number

.00011; 110 is represented as .11000000E+03 and .00011 is represented as .11000000E-03. Note that the significant digits are the same for both numbers and that the decimal point location is determined by multiplying the significant digits by the signed power of 10 as indicated by the last two digits.

At the present time, there are two subsystems of the STORET system that are in operation. STORET I or subsystem I went into operation in the spring of 1964, and STORET II or subsystem II went into operation sometime in the fall of 1966. These subsystems are designed to accept data in a variety of formats to facilitate the use of data collected by agencies other than the Public Health Service. The STORET system utilizes the Robert A. Taft Sanitary Engineering Computer Center in Cincinnati. The equipment consists of a Honeywell 400 computer with six magnetic tape drives, 4096 words internal memory, high speed card reader-punch, and a high speed printer.

The STORET subsystems in operation at the present time can be described and summarized as follows:

STORET I (Subsystem I):

This subsystem basically consists of programs to read machine-punched cards containing station location information and water quality data, which in turn are stored on a magnetic tape. There are other programs in this subsystem that retrieves data by printing them out on paper or writing them on another magnetic tape for further statistical or mathematical processing.

Elements of STORET I:

(a) Location Coding

The basic purpose of this coding is to permit retrieval and listing of water quality and related data pertaining to stream systems in the most useful form--the hydrologic sequence. This coding, which is a necessary first step before using this system, is described as follows:

Within a terminal minor basin, a 3-digit terminal stream number is assigned to each stream discharging to the ocean or large lake. This stream then is coded in detail which includes the map measurement of the mileage from the mouth of the stream to each of the tributaries entering the stream. An index number is assigned to each of the tributaries. The index numbers for the streams and its tributaries are such that when facing upstream, all streams entering the terminal stream from the right side are given even numbers, and all streams entering from the left side are given odd numbers. The base written index numbers are preceded by four zeros. All succeeding streams are given index numbers in such a manner that they increase by 20 if they are on the same side of the former stream and increase by 10 if they are on the opposite side of the former stream. An example of this is the location code 2-000020/1.60. This code would indicate a second level stream (designated by the 2) with an index number of 000020, and a distance of 1.60 miles from the mouth of the terminal stream. The even index number (000020) indicates that this stream enters the terminal stream on the right side.

The stream coding for STORET I is in progress in various places of the Southeastern United States, the Ohio River Basin, the Mississippi

River Basin, the Arkansas-Red River Basins, portions of the Great Lakes drainage as well as in the Columbia Basin. Stream coding work has been completed in the Chesapeake Bay and the Colorado River. Plans are underway for the coding of other major drainage basins in the Missouri, the Hudson, and the Delaware River.

(b) Station Location Storage

These are spotted sampling point locations on the coded maps and a six-digit station serial number is assigned to each point. The storage procedure is done by feeding the computer with basin numbers (major and minor basins), terminal stream number, river mileage, stream index information, type of station, agency operating the station, and descriptive material concerning the station. All of these items of information are fed to the computer only once, and thereafter only the six-digit station serial number is needed for any additional data pertaining to that sampling station. The six-digit station serial number is assigned serially by state; the first two digits correspond to the alphabetical order in number of a given state, and the next four digits correspond to the individual code number of the station in that state.

(c) Water Quality Data Storage

Each variable is assigned a 5-digit number and this parameter number allows essentially an "open end" parameter list to which parameters can be added as needed. This allows greater flexibility in the handling of water quality and related data. A major benefit of this system is that the user is not limited to a series of fixed field cards for the data.

The data is entered as a parameter number, a value for this parameter which has four significant digits and a two-digit number, one representing the exponent for decimal place purposes in the printout, and one for remarks purposes. The "floating-point" technique is used for the storage of parameter values. This allows the storage of parameters varying widely in value across the country without limiting the fixed number of columns for a given value. Fixed field cards can also be entered or stored in this system since there are programs that assign parameter numbers to the data after the fixed field cards are read.

(d) Data Retrieval

For retrieval purposes, two methods are used in this system: (1) the specification by the six-digit station serial number of the stations for which data are to be retrieved (six-digit station serial number is assigned serially by state; the first two digits correspond to the alphabetical order in number of a given state, and the next four digits correspond to the individual code number of the station in that state), and (2) the identification of a control point on a river system. For the first method, data retrieved is on the station serial number specified only, which may be in the hydrologic or random sequence. In the second method, data retrieved can be made for a selection of stations above a control point, below a control point, between control points, or combinations of stations based on these control points. The data retrieved by use of the second method is in hydrologic sequence going upstream on the main stem; that is, the first station on the main stem above the control point is retrieved and listed first, the second station on the main stem is listed next, and so on up to the headwaters on the main stem. Then stations on the tributary closest to the mouth of the main stem are listed, followed by the second tributary, etc. The retrieval of stations can be restored in such a manner that they can be limited to certain types, to those operated by certain agencies, or to those stations located in a certain state.

One to fifty parameters can be retrieved in each retrieval run. The data can appear in any desired form of printout. For engineers and the other users not involved in full-time programming, further processing of data retrieved may be done by specifying that the retrieved data be written on a magnetic tape.

The processing speeds on the storage of stations and the storage of parameters are 2400 stations per hour and 45,000 parameters per hour respectively if location and related non-variable information on stations involved have been previously stored. Approximately 150,000 items of variable data per hour can be retrieved.

STORETT II (Subsystem II):

This subsystem utilizes latitude and longitude to identify the location of data collection points. It is used in handling data collected from large open bodies of water and from points on land areas which cannot be associated readily with points on a stream. This is a complementary subsystem designed to serve in areas such as coastal and estuarine waters, groundwaters, areas of large marsh and swamps and where stream systems are interconnected in complex patterns. STORET I will not function effectively under these conditions.

The data storage techniques of this subsystem are similar to that of STORET I with only four fundamental differences: (1) latitude and longitude, which require 15 digits, serve as the station number and the basic station location, (2) all identifying information for sampling points is entered on separate cards, (3) water quality data cards are tied by an arbitrary number to the location cards, and (4) there is less emphasis on the storage of descriptive material such as basin designations.

There are four header cards (I, III, IV, and V) used in STORET II for data storage. They are used for location and identification purposes. Only header card I is required, the other three header cards are optional. The optional cards may be stored anytime, simultaneously, or following the establishment of the station by header card I. The numbering system of these four header cards corresponds to the location cards in STORET I. A water quality data card is used for the data storage in addition to the four header cards. The 5-digit parameter number assigned to each variable in water quality data and the "floating-point" technique of storing parameter values (four significant digits) are retained in STORET II, an approach used in STORET I.

There are three basic types of retrieving data used in STORET II: (1) all stations within a specified rectangular area, (2) all stations within a specified circular area, and (3) all stations falling within a stated distance of a vector. Within the three basic types of retrieving data, three control cards are used: (1) parameter control card, which controls the parameters to be retrieved; (2) station control card, which provides instructions to the retrievel program concerning the areas defined by polygons from which data are to be retrieved, the order of listing the data on the printout, and the state or agency restriction if any; and (3) date control card, which controls the retrieval of data for a specific period of time.

Other information on storage and retrieval systems is now being developed to meet specific needs for specialized fields of technology. For example, the National Aeronautics and Space Administration is developing a system for the large quantity of information gathered by meteorological satellites. The objective of their study is to determine how the information can be acquired, annotated, compacted, distributed, and converted into more appropriate forms from a communication's theory and human engineering points of view. Another example of a development of the electronic retrieval of information is the system being designed by the University of Nebraska for retrieval of material on water law, both State and Federal.

Being that it is the purpose of this research to develop a system of storage and retrieval on ground water quality information suitable for use with modern data processing equipment to process existing and future available information, adaptation of present systems is perhaps a logical solution. The STORET system has the desirable characteristics of having an "open ended" data card for listing variables and uses the "floating-point" technique of recording data. This allows flexibility in a system. However, the manner of searching and retrieving material often obtains much more information than is actually wanted by the researcher or user. Systems which are used for data other than water quality information have routines which are adaptable but cannot be used in their entirety for the purposes desired in this study.

The "SODAK" system allows storage of data from all sources, and although not as fast as other retrieval programs, allows extreme selectivity in its retrieval routine. The system as explained, discussed, and illustrated is not complex and will handle water quality data with ease.

The complex design of the STORET system led the author to design the "SODAK" system, which is explained, discussed, and illustrated in this study.

# SCOPE OF THE "SODAK" SYSTEM

The "SODAK" system was established to provide uniform storage and selective retrieval of ground water data. The water quality information used in this study was obtained from the records compiled by the U.S. Geological Survey; however, the system will work for all forms of available data on ground water quality in South Dakota.

With the establishment of the South Dakota Water Resources Institute, it became a logical home for maintenance of such a retrieval system. Since ground water quality data is available from several sources, the system must serve many types of inputs, and if successful it should also provide flexible output.

From the beginning the goals have remained essentially unchanged, namely:

1. Develop a technique to accept data in raw form without dictating the form of laboratory analysis sheets.
2. Convert data to a uniform format.
3. Provide the capacity for both alphabetic as well as numeric data.
4. Provide the ability to expand and add variables without requiring modification of previously stored data.
5. Develop a selective search routine having a rather broad logical capability to accept or reject data in the retrieval process.

The computing facilities available consisted of a decimally oriented IBM 1620 (7) with card input-output using Fortran II language, and thus causing some restrictions to be placed on the system. These restrictions were limited to items not particularly important to the logical flow of the system. Principal restrictions are:

1. Output data is not edited as well as might be desired.
2. Input data is not packed as densely as possible.
3. Comparisons within the program are limited to numeric data elements.

The first restriction is a concession to the 1620 IBM computer. When other equipment is available, such as the IBM 360, the restriction will no longer be present. The fact that the input data is not densely packed causes the search for errors in a program to be more difficult. The third limitation is a concession to the programmer.

Should the system prove acceptable to water researchers, all of the restrictions may be removed with rather simple extensions to the system. Other improvements in data handling will be quite apparent when the system is converted to third-generation magnetic tape, printer-supported computing facilities.

The design of the overall "SODAK" system is shown in Figure 2. The present stored data is in the U.S. Geological Survey form and is represented as "Lab (A) Water Test Data" in the flow diagram. Other forms of data different from that of the U.S. Geological Survey form are represented as "Lab (B) Water Test Data", "Lab (C) Water Test Data", "Lab (D) Water Test Data", etc. There is no limit to the number of

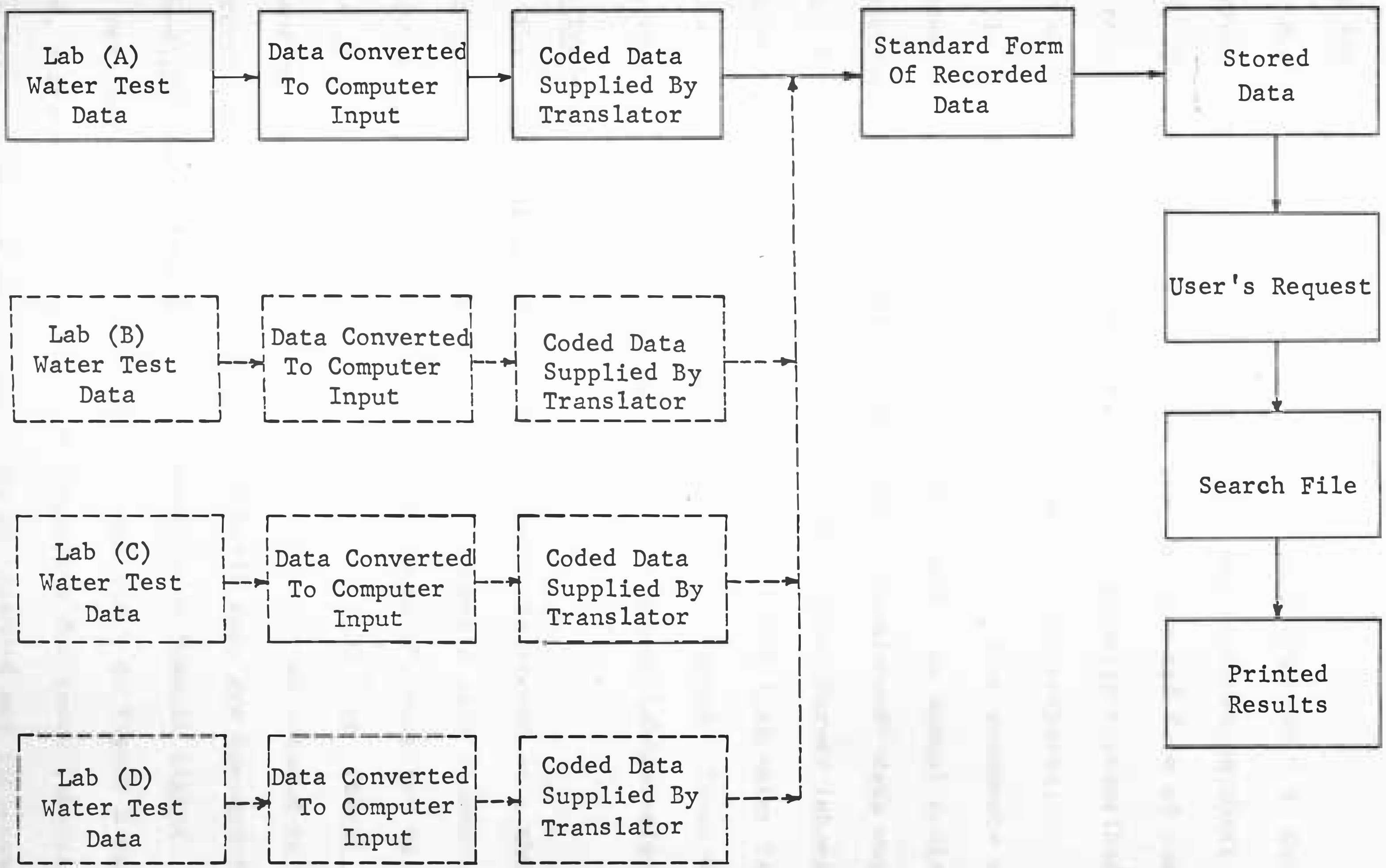


Figure 2. Flow Diagram of the "SODAK" Overall Design System

laboratory forms that can be used.

Data Acquisition

Micro-filmed water quality data obtained from the U.S. Geological Survey, Huron, South Dakota, was scanned and recorded on their report form. Data which did not indicate the location and date of sampling was rejected. The remaining test data was manually transcribed to work sheets from which card input documents were prepared.

It should be pointed out that these card input documents were in a format very similar to the source documents. No manual coding was required and documents which represented "second-hand" data were not used. For example, many standard U.S. Geological Survey laboratory forms were available which contain data collected from water laboratories other than those of the U.S. Geological Survey. These sets of data should logically be collected from the parent laboratories.

Data Translation

Every data element stored in the system is stored as a three-digit code followed by the data element. Numeric data elements are converted to exponential form or "floating-point", that is, 10.0 becomes $.1\ (10)^2$ or .10E+02, 0267 becomes $.267\ (10)^{-1}$ or .267-01, etc. Presently, eight significant digits could easily be reduced to five to provide more compact storage. Alphabetic data are converted to a three-digit code followed by six alphabetic or numeric digits.

Only one translator program was developed. As Figure 2 indicates, a translator program will be necessary for every laboratory input document should this pilot study be expanded and implemented.

## DATA RETRIEVAL OF THE "SODAK" SYSTEM

The approach described and discussed in this system is built around the logic statements "IF", "AND IF", "OR IF", and "SAVE". These statements are contained in the logic program or the user supplied selective search program. This set of statements allows a user to construct his own search routine. He may select or reject any set of data which satisfies the conditions prescribed by his set of instructions. The best way to illustrate the power of this technique can be shown by a few examples:

Logic Program Example #1

```
IF   TOWNSHIP     100.0     110.0
AND IF RANGE       50.0      60.0
SAVE TOWNSHIP
     RANGE
     CALCIUM
     IRON
```

The variables township, range, calcium, and iron will be retrieved on all sets of data that satisfies both the township value of 100.0 to 110.0 and the range value of 50.0 to 60.0 The user or researcher in this example desires to save the variables township, range, calcium, and iron with their corresponding values on all sets of data that satisfies the conditions of both variables in the "IF" and "AND IF" statements. The user or researcher, however, may save variables not included in the "IF" and "AND IF" statements.

Logic Program Example #2

```
IF       IRON                    0.80   10.0
OR IF    MANGANESE               0.70    2.0
SAVE     HARDNESS AS CaCO3
         ALKALINITY AS CaCO3
         SULFATE
         DISSOLVED SOL CALC
         pH
```

The variables listed in the "SAVE" statement with their corresponding values will be retrieved on all sets of stored data that satisfies either the iron value of 0.80 to 10.0 parts per million or the manganese value of 0.070 to 2.0 parts per million. The user or researcher in this example desires to save the variables hardness as calcium carbonate ($CaCO_3$), alkalinity as calcium carbonate ($CaCO_3$), sulfate, dissolved solids calculated, and pH for all sets of stored data that satisfies either conditions of the "IF" or "OR IF" statements.

Logic Program Example #3

```
IF      DATE OF COLLECTION    500000.   650000.
AND IF  DATE DRILLED          450000.   600000.
AND IF  SECTION                  5.0      10.0
AND IF  RANGE                   58.0      60.0
SAVE    SODIUM
        PERCENT SODIUM
        SODIUM ADSORP RATIO
        pH
        SPECIFIC CONDUCTANCE
```

The variables listed in the "SAVE" statement with their corresponding values will be retrieved on all sets of stored data that satisfies the date of collection of the water sample value of 1950 to 1965, date the well was drilled value of 1945 to 1960, section value of 5.0 to 10.0, and range value of 58.0 to 60.0 The user or researcher in this example desires to save the variables sodium, percent sodium, sodium adsorption ratio, pH, and specific conductance with their corresponding values on all sets of stored data that satisfies the conditions of the statement "IF" and the three "AND IF" statements.

Logic Program Example #4

| | | | |
|---|---|---|---|
| IF | DEPTH | 100.0 | 800.0 |
| AND IF | DIAMETER | 0.125 | 0.500 |
| OR IF | NON CARB AS $CaCO_3$ | 250.0 | 500.0 |
| AND IF | MAGNESIUM | 0.07 | 2.0 |
| AND IF | CHLORIDE | 92.0 | 200.0 |
| SAVE | NITRATE | | |
| | CALCIUM | | |
| | POTASSIUM | | |
| | COLOR | | |

The variables listed in the "SAVE" statement with their corresponding values will be retrieved on all sets of stored data that satisfies either both the depth of the well value of 100.0 to 800.0 feet and diameter of the well value of 0.125 to 0.500 feet; or the noncarbonate hardness as calcium carbonate ($CaCO_3$) value of 250.0 to 500 parts per million, the magnesium value of 0.07 to 2.0 parts per million, and the chloride value of 92.0 to 200.0 parts per million. The user or researcher in this example desires to save the variables nitrate, calcium, potassium, and color with their corresponding values on all sets of stored data that satisfies the conditions of both logic statements "IF" and "AND IF", or that satisfies all the conditions of the three logic statements "OR IF", "AND IF", and "AND IF".

Further illustrations of these examples and their retrieved results are shown in the section of this thesis entitled "Tests on the "SODAK" Systems by Use of Examples."

The flow diagram shown in Figure 3 illustrates the logic program of the retrieval system of the "SODAK" program and is explained as follows:

1. The computer starts by reading the user program cards and determining what is asked for in the logic program.
2. A blank card means the end of the user program.
3. If the first logic statement is an "IF", the computer checks the stored data for the variable requested. If what is asked for is present and satisfies the lower and upper limit values, the "IF" statement is satisfied and the computer checks further for the presence of an "AND IF" statement. However, if the "IF" statement is not satisfied by the stored data, then the computer immediately checks for the presence of an "OR IF" statement without checking any intermediate "AND IF" statements.

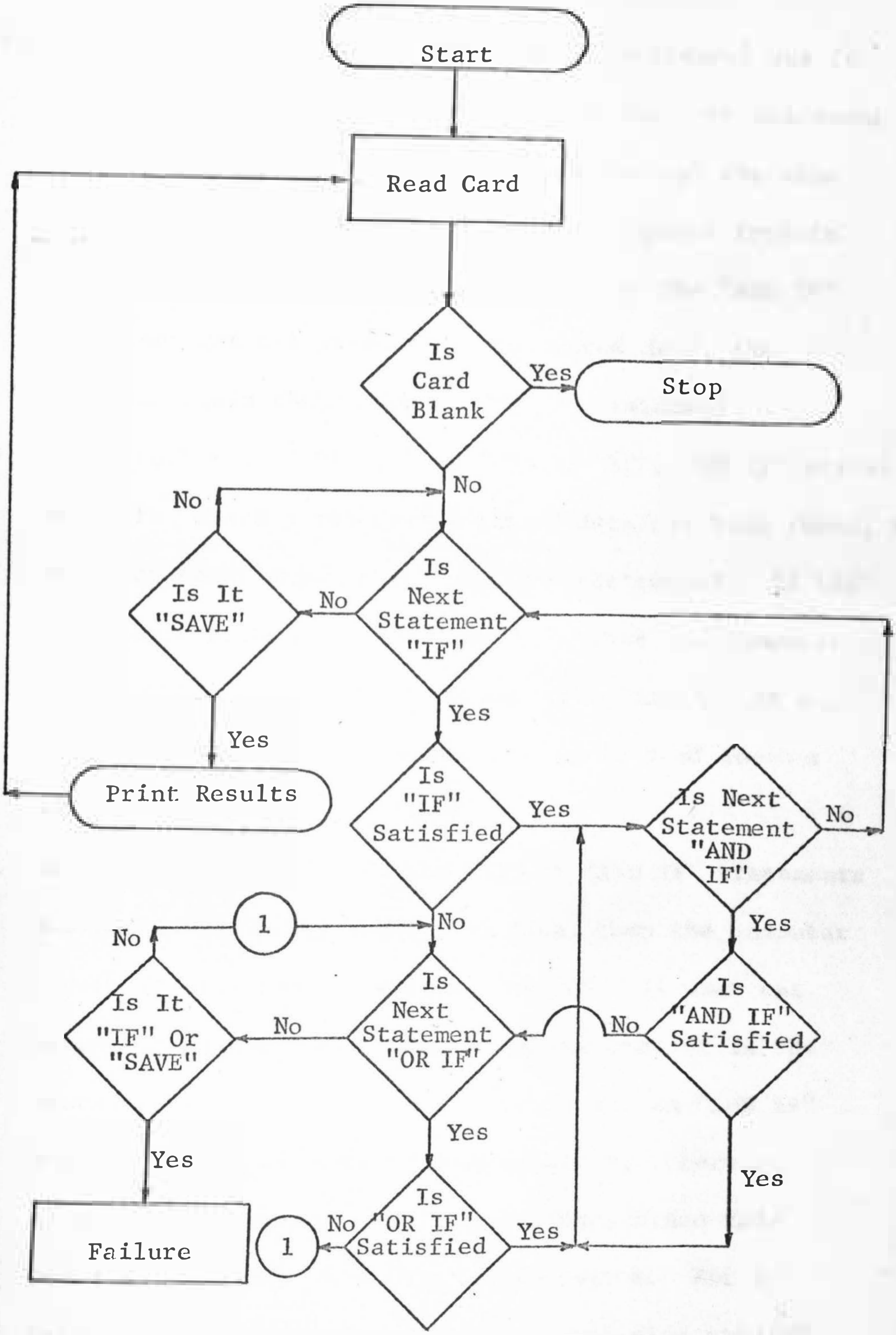


Figure 3. Flow Sheet Diagram of the "SODAK" System

4. If what was asked for in the "AND IF" statement was in the stored data, the computer asks if the next statement is another "AND IF". If so, it goes through the same process in this step; otherwise, the computer repeats step number 3. If what was asked for in the "AND IF" statement was not present in the stored data, the computer again checks for an "OR IF" statement.
5. After each set of "IF", "AND IF", or "IF", "OR IF" statements for which a successful set of data has been found, the computer seeks another set of these statements. If the next logic statement is not an "IF", then the computer checks whether the next statement is a "SAVE". If so, it prints out the results and goes on to read another set of data.
6. If what was asked for in the "IF" or "AND IF" statements was not satisfied by the stored data, then the computer checks for the logic statement "OR IF". If what was asked for in the "OR IF" statement was present in the stored data, then the computer checks for an "AND IF" statement and goes back to step number 4; otherwise, no results can be retrieved or obtained, since this would be a failure condition in the system. For a failure condition, the computer does not give printed results and immediately reads the next set of data.

The user of this system must write the selective search program or logic program to obtain the desired data. The format in writing the logic program is given as follows:

1. The "IF", "AND IF", "OR IF", and "SAVE" statements are punched in columns 1, 2, 3, 4, 5, and 6 of the card.
2. The name of the water quality variable or location variable, such as township, section, calcium, potassium, etc., was punched in columns 7 through 26 of the card.
3. The lower limit value of the variable is punched starting with column 28 of the card. The upper limit value of the variable is punched starting with column 38 of the card.
4. The variable names to be saved or retrieved are punched starting with column 7 of the card. This procedure is identical to that of procedure number 2 above, only the first card contains the logic statement "SAVE".

The logic program or user supplied selective search program is a part of the "SODAK" system which makes it different from the STORET system discussed in the literature review of this thesis. An unlimited number of restrictions can be made on the logic program; it can retrieve from one variable data to the maximum number of variable data elements stored in the system. The user or researcher has the option of choosing the variables he desires to analyze and evaluate.

It is necessary for a user or a researcher to observe the following reminders to allow the "SODAK" system to function properly and effectively:

1. An "IF" and the "SAVE" logic statements must always be the first and the last statements of the logic program.
2. The logic statements must be followed by the correctly spelled variable name and not otherwise; a misspelled variable name or a variable's code number following a logic statement will result in the termination of the program with an appropriate error message.
3. The variable names following the logic statements "IF", "AND IF", and "OR IF", should always have a lower and upper limit value, since the absence of either value will cause the system to assume a zero value.
4. There must be only one "SAVE" statement. An unlimited number of variable names can follow the "SAVE" logic statement.
5. The number of "IF", "AND IF", and "OR IF" logic statements followed by a variable name and their corresponding lower and upper limit value is unlimited. A user or researcher can ask for a large number of "IF", "AND IF", and "OR IF" logic statements. However, more tests applied to the data through the use of these statements will require more computer time to complete the searching process.

STORAGE PROCEDURE OF THE "SODAK" SYSTEM

The format of the stored non-translated data or data converted to computer input is shown in Appendix I. The printed form of the non-translated data is shown in Table 1. The storage of the non-translated data is the second step in the "SODAK" overall design system as shown in Figure 2.

The stored non-translated data is further transformed into a standard form of record. Transformation of the non-translated stored data involved the coding of the variables, changing of the date of collection from an order of day-month-year to an order of year-month-day, and the placing of the 999 code. The changing of the order of the date of collection from day-month-year to an order of year-month-day was to make a single comparison for years alone rather than to make three comparisons in terms of day, month, and year which require more computer time. The form of the translated data (except subsection and sample number) is given as:

3-digit code / 14 digits of data / 3-digit code / 14 digits of data / etc.

The fourteen digits of data consists of nine digits whole numbers and five digits for the fractional part. The format and coding system of the translated or transformed data is shown in Appendix II, and its printed form is shown in Table 2.

A complete set of transformed or translated stored data in the present system has the following characteristics:

1. The first card indicates the number of data cards

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 26011BEAD | 110 58 06 CBBB | | | | 30054. | | 00.040 | |
| 26012BEAD | 013.22 | 006.80 | | | 0278.20 | | 425.90 | 0148.00 |
| 26013BEAD | 2.40 | 003.0 | | 2139.00 | | 0059.33 | 0000.00 | * |
| 26014BEAD | | | | 09.00 | 041.00 | 000029. | 1000. | * 0.500 |
| 26021BEAD | 110 58 06 CBBB | | | | 110051. | | 00.040 | 00.000 |
| 26022BEAD | 007.00 | 002.00 | 0716.00 | 007.80 | 0293.00 | | 1073.00 | 0160.00 |
| 26023BEAD | 2.50 | 002.0 | | 2113.00 | | 0020.0 | 0000.00 | 240. |
| 26024BEAD | | 7.7 | | 98.00 | 061.00 | 000029. | 1008. | * 0.500 |
| 26031BEAD | 110 60 07 DADC | | P-5461 | | 042563. | 12.000 | 00.810 | 00.070 |
| 26032BEAD | 108.00 | 013.00 | 0460.00 | 018.00 | 0164.00 | 00.0 | 1170.00 | 0092.00 |
| 26033BEAD | 1.90 | 000.20 | 00.90 | 1980.00 | 2010.0 | 0406.0 | 0272.00 | * |
| 26034BEAD | 02760. | 7.8 | | 70.00 | 009.90 | 000048. | 0795. | * 0.125 |
| 26041BEAD | 110 60 26 ABBA1 | | P-6925 | | 010964. | 30.000 | 03.800 | 00.080 |
| 26042BEAD | 185.00 | 064.00 | 0596.00 | 014.00 | 0522.00 | 00.0 | 1520.00 | 0029.00 |
| 26043BEAD | 0.40 | 010.00 | 01.70 | 2710.00 | 2770.0 | 0723.0 | 0295.00 | * |
| 26044BEAD | 03150. | 7.8 | | 64.00 | 009.60 | 000045. | 0768. | * 0.125 |

TABLE 1

Form and Appearance of Non-Translated Data

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 001 | | | | | | | |
| 004CBBB | | | | | | | |
| 1 | 110.00 | 2 | 58.00000 | 3 | 6.00000 | 6 | 540300.00000 |
| 8 | .04 | 10 | 13.22000 | 11 | 6.80000 | 14 | 278.20000 |
| 16 | 425.90 | 17 | 148.00000 | 18 | 2.40000 | 19 | 3.00000 |
| 21 | 2139.00 | 23 | 59.33000 | 24 | 0.00000 | 29 | 9.00000 |
| 30 | 41.00 | 31 | 29.00000 | 32 | 1000.00000 | 33 | .50000 |
| 999 | | | | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 001 | | | | | | | |
| 004CBBB | | | | | | | |
| 1 | 110.00 | 2 | 58.00000 | 3 | 6.00000 | 6 | 511100.00000 |
| 8 | .04 | 9 | 0.00000 | 10 | 7.00000 | 11 | 2.00000 |
| 12 | 716.00 | 13 | 7.80000 | 14 | 293.00000 | 16 | 1073.00000 |
| 17 | 160.00 | 18 | 2.50000 | 19 | 2.00000 | 21 | 2113.00000 |
| 23 | 20.00 | 24 | 0.00000 | 25 | 240.00000 | 27 | 7.70000 |
| 29 | 98.00 | 30 | 61.00000 | 31 | 29.00000 | 32 | 1008.00000 |
| 33 | .50000 | 999 | | | | | |

TABLE 2

Form and Appearance of Stored Translated Data

001
004DADC 005P-5461

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | 110.00 | 2 | 60.00000 | 3 | 7.00000 | 6 | 630425.00000 |
| 7 | 12.00 | 8 | .81000 | 9 | .07000 | 10 | 108.00000 |
| 11 | 13.00 | 12 | 460.00000 | 13 | 18.00000 | 14 | 164.00000 |
| 15 | 0.00 | 16 | 1170.00000 | 17 | 92.00000 | 18 | 1.90000 |
| 19 | .20 | 20 | .90000 | 21 | 1980.00000 | 22 | 2010.00000 |
| 23 | 406.00 | 24 | 272.00000 | 26 | 2760.00000 | 27 | 7.80000 |
| 29 | 70.00 | 30 | 9.90000 | 31 | 48.00000 | 32 | 795.00000 |
| 33 | .12500 | 999 | | | | | |

001
004ABBA1 005P-6925

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | 110.00 | 2 | 60.00000 | 3 | 26.00000 | 6 | 640109.00000 |
| 7 | 30.00 | 8 | 3.80000 | 9 | .08000 | 10 | 185.00000 |
| 11 | 64.00 | 12 | 596.00000 | 13 | 14.00000 | 14 | 522.00000 |
| 15 | 0.00 | 16 | 1520.00000 | 17 | 29.00000 | 18 | .40000 |
| 19 | 10.00 | 20 | 1.70000 | 21 | 2710.00000 | 22 | 2770.00000 |
| 23 | 723.00 | 24 | 295.00000 | 26 | 3150.00000 | 27 | 7.80000 |
| 29 | 64.00 | 30 | 9.60000 | 31 | 45.00000 | 32 | 768.00000 |
| 33 | .12500 | 999 | | | | | |

TABLE 2 (Continued)
Form and Appearance of Stored Translated Data

Data Set 1

| Code Number | Variable Value | Variable Name | Real Value | Output as a Floating-Point Value |
|---|---|---|---|---|
| 1 | 110.00 | Township | 110 | .11000000E+03 |
| 2 | 58.00000 | Range | 58 | .58000000E+02 |
| 3 | 6.00000 | Section | 6 | .60000000E+01 |
| 4 | CBBB | Sub-Section | CBBB* | |
| 6 | 540300.00000 | Date of Collection | March, 1954 | .54030000E+06 |
| 8 | .04 | Iron | .04 ppm** | .40000000E-01 |
| 10 | 13.22000 | Calcium | 13.22 ppm | .13220000E+02 |
| 11 | 6.80000 | Magnesium | 6.80 ppm | .68000000E+01 |
| 14 | 278.20000 | Bicarbonate | 278.20 ppm | .27820000E+03 |
| 16 | 425.90 | Sulfate | 425.90 ppm | .42590000E+03 |
| 17 | 148.00000 | Chloride | 148.00 ppm | .14800000E+03 |
| 18 | 2.40000 | Fluoride | 2.40 ppm | .24000000E+01 |
| 19 | 3.00000 | Nitrate | 3.00 ppm | .30000000E+01 |
| 21 | 2139.00 | Dissolved Sol Calc | 2139.00 ppm | .21390000E+04 |
| 23 | 59.33000 | Hardness as CaCO3 | 59.33 ppm | .59330000E+02 |
| 24 | 0.00000 | Non Carb as CaCO3 | 0.00 ppm | .00000000E-99 |
| 29 | 9.00000 | Percent Sodium | 9.00 % | .90000000E+01 |
| 30 | 41.00 | Sodium Adsorp Ratio | 41.00 ppm | .41000000E+02 |
| 31 | 29.00000 | Date Drilled | 1929 | .29000000E+02 |
| 32 | 1000.00000 | Depth | 1000 feet | .10000000E+04 |
| 33 | .50000 | Diameter | .50 feet | .50000000E+00 |
| 999 | | End of Data Set | | |

*Standard United States Geological Survey Designation
**Parts Per Million

Table 3. Identification of Stored Translated Data in Table 2

Data Set 2

| Code Number | Variable Value | Variable Name | Real Value | Output as a Floating-Point Value |
|---|---|---|---|---|
| 1 | 110.00 | Township | 110 | .11000000E+03 |
| 2 | 58.00000 | Range | 58 | .58000000E+02 |
| 3 | 6.00000 | Section | 6 | .60000000E+01 |
| 4 | CBBB | Sub-Section | CBBB | |
| 6 | 511100.00000 | Date of Collection | November, 1951 | .51110000E+06 |
| 8 | .04 | Iron | .04 ppm | .40000000E-01 |
| 9 | 0.00000 | Manganese | 0.00 ppm | .00000000E-99 |
| 10 | 7.00000 | Calcium | 7.00 ppm | .70000000E+01 |
| 11 | 2.00000 | Magnesium | 2.00 ppm | .20000000E+01 |
| 12 | 716.00 | Sodium | 716.00 ppm | .71600000E+03 |
| 13 | 7.80000 | Potassium | 7.80 ppm | .78000000E+01 |
| 14 | 293.00000 | Bicarbonate | 293.00 ppm | .29300000E+03 |
| 16 | 1073.00000 | Sulfate | 1073.00 ppm | .10730000E+04 |
| 17 | 160.00 | Chloride | 160.00 ppm | .16000000E+03 |
| 18 | 2.50000 | Fluoride | 2.50 ppm | .25000000E+01 |
| 19 | 2.00000 | Nitrate | 2.00 ppm | .20000000E+01 |
| 21 | 2113.00000 | Dissolved Sol Calc | 2113.00 ppm | .21130000E+04 |
| 23 | 20.00 | Hardness as $CaCO_3$ | 20.00 ppm | .20000000E+02 |
| 24 | 0.00000 | Non Carb as $CaCO_3$ | 0.00 ppm | .00000000E-99 |
| 25 | 240.00000 | Alkalinity as $CaCO_3$ | 240.00 ppm | .24000000E+03 |
| 27 | 7.70000 | pH | 7.7 | .77000000E+01 |
| 29 | 98.00 | Percent Sodium | 98% | .98000000E+02 |
| 30 | 61.00000 | Sodium Adsorp Ratio | 61.00 ppm | .61000000E+02 |
| 31 | 29.00000 | Date Drilled | 1929 | .29000000E+02 |
| 32 | 1008.00000 | Depth | 1008 feet | .10080000E+04 |
| 33 | .50000 | Diameter | .50 feet | .50000000E+00 |
| 999 | | End of Data Set | | |

Table 3 (Continued). Identification of Stored Translated Data in Table 2

Data Set 3

| Code Number | Variable Value | Variable Name | Real Value | Output as a Floating-Point Value |
|---|---|---|---|---|
| 1 | 110.00 | Township | 110 | .11000000E+03 |
| 2 | 60.00000 | Range | 60 | .60000000E+02 |
| 3 | 7.00000 | Section | 7 | .70000000E+01 |
| 4 | DADC | Sub-Section | DADC | |
| 5 | P-5461 | Sample Number | P-5461 | |
| 6 | 630425.00000 | Date of Collection | April 25, 1963 | .63042500E+06 |
| 7 | 12.00 | Silica | 12.00 ppm | .12000000E+02 |
| 8 | .81000 | Iron | .81 ppm | .81000000E+00 |
| 9 | .07000 | Manganese | .07 ppm | .70000000E-01 |
| 10 | 108.00000 | Calcium | 108.00 ppm | .10800000E+03 |
| 11 | 13.00 | Magnesium | 13.00 ppm | .13000000E+02 |
| 12 | 460.00000 | Sodium | 460.00 ppm | .46000000E+03 |
| 13 | 18.00000 | Potassium | 18.00 ppm | .18000000E+02 |
| 14 | 164.00000 | Bicarbonate | 164.00 ppm | .16400000E+03 |
| 15 | 0.00 | Carbonate | 0.00 ppm | .00000000E-99 |
| 16 | 1170.00000 | Sulfate | 1170.00 ppm | .11700000E+04 |
| 17 | 92.00000 | Chloride | 92.00 ppm | .92000000E+02 |
| 18 | 1.90000 | Fluoride | 1.90 ppm | .19000000E+01 |
| 19 | .20 | Nitrate | .20 ppm | .20000000E+00 |
| 20 | .90000 | Boron | .90 ppm | .90000000E+00 |
| 21 | 1980.00000 | Dissolved Sol Calc | 1980.00 ppm | .19800000E+04 |
| 22 | 2010.00000 | Residue on Evap | 2010.00 ppm | .20100000E+04 |
| 23 | 406.00 | Hardness as $CaCO_3$ | 406.00 ppm | .40600000E+03 |
| 24 | 272.00000 | Non Carb as $CaCO_3$ | 272.00 ppm | .27200000E+03 |

Table 3 (Continued). Identification of Stored Translated Data in Table 2

Data Set 3 (Continued)

| Code Number | Variable Value | Variable Name | Real Value | Output as a Floating-Point Value |
|---|---|---|---|---|
| 26 | 2760.00000 | Specific Conductance | 2760.00 micromhos*** | .27600000E+04 |
| 27 | 7.80000 | pH | 7.8 | .78000000E+01 |
| 29 | 70.00 | Percent Sodium | 70.00 % | .70000000E+02 |
| 30 | 9.90000 | Sodium Adsorp Ratio | 9.90 ppm | .99000000E+01 |
| 31 | 48.00000 | Date Drilled | 1948 | .48000000E+02 |
| 32 | 795.00000 | Depth | 795 feet | .79500000E+03 |
| 33 | .12500 | Diameter | .1250 feet | .12500000E+00 |
| 999 | | End of Data Set | | |

***Micromhos Per Centimeter at 25° Centigrade

Table 3 (Continued). Identification of Stored Translated Data in Table 2

Data Set 4

| Code Number | Variable Value | Variable Name | Real Value | Output as a Floating-Point Value |
|---|---|---|---|---|
| 1 | 110.00 | Township | 110 | .11000000E+03 |
| 2 | 60.00000 | Range | 60 | .60000000E+02 |
| 3 | 26.00000 | Section | 26 | .26000000E+02 |
| 4 | ABBA1 | Sub-Section | ABBA1 | |
| 5 | P-6925 | Sample Number | P-6925 | |
| 6 | 640109.00000 | Date of Collection | January 9, 1964 | .64010900E+06 |
| 7 | 30.00 | Silica | 30.00 ppm | .30000000E+02 |
| 8 | 3.80000 | Iron | 3.80 ppm | .38000000E+01 |
| 9 | .08000 | Manganese | .08 ppm | .80000000E-01 |
| 10 | 185.00000 | Calcium | 185.00 ppm | .18500000E+03 |
| 11 | 64.00 | Magnesium | 64.00 ppm | .64000000E+02 |
| 12 | 596.00000 | Sodium | 596.00 ppm | .59600000E+03 |
| 13 | 14.00000 | Potassium | 14.00 ppm | .14000000E+02 |
| 14 | 522.00000 | Bicarbonate | 522.00 ppm | .52200000E+03 |
| 15 | 0.00 | Carbonate | 0.00 ppm | .00000000E-99 |
| 16 | 1520.00000 | Sulfate | 1520.00 ppm | .15200000E+04 |
| 17 | 29.00000 | Chloride | 29.00 ppm | .29000000E+02 |
| 18 | .40000 | Fluoride | .40 ppm | .40000000E+00 |
| 19 | 10.00 | Nitrate | 10.00 ppm | .10000000E+02 |
| 20 | 1.70000 | Boron | 1.70 ppm | .17000000E+01 |
| 21 | 2710.00000 | Dissolved Sol Calc | 2710.00 ppm | .27100000E+04 |
| 22 | 2770.00000 | Residue on Evap | 2770.00 ppm | .27700000E+04 |
| 23 | 723.00 | Hardness as CaCO3 | 723.00 ppm | .72300000E+03 |
| 24 | 295.00000 | Non Carb as CaCO3 | 295.00 ppm | .29500000E+03 |

Table 3 (Continued). Identification of Stored Translated Data in Table 2

Data Set 4 (Continued)

| Code Number | Variable Value | Variable Name | Real Value | Output as a Floating-Point Value |
|---|---|---|---|---|
| 26 | 3150.00000 | Specific Conductance | 3150.00 micromhos | .31500000E+04 |
| 27 | 7.80000 | pH | 7.8 | .78000000E+01 |
| 29 | 64.00 | Percent Sodium | 64.00 % | .64000000E+02 |
| 30 | 9.60000 | Sodium Adsorp Ratio | 9.60 ppm | .96000000E+01 |
| 31 | 45.00000 | Date Drilled | 1945 | .45000000E+02 |
| 32 | 768.00000 | Depth | 768 feet | .76800000E+03 |
| 33 | .12500 | Diameter | .1250 feet | .12500000E+00 |
| 999 | | End of Data Set | | |

Table 3 (Continued). Identification of Stored Translated Data in Table 2

containing alphameric variables. These alphameric data cards must follow this first card.

2. After this set of data, sufficient cards are provided to contain all the remaining data in the set with four variables per card.
3. The end of each complete set of data is indicated with a 999 code.

The code which indicates the number of alphameric data cards occupies the first three columns of the first card of the translated data, and the remaining columns are left blank. In the second card, the first three columns are used for the code of the first data, and columns 4 through 9 are used for the value of this data. Columns 10 through 18 are left blank. Columns 19 through 21 are used for the code of the second data, and columns 22 through 27 are used for the value of this data. This pattern is repeated for the rest of the card.

For the numeric cards, columns 1 through 3 are used for the code, and columns 4 through 20 are used for the value of its data. Within columns 4 through 18 (a total of 15 columns), one column is used for the decimal point, 9 columns are used for the whole number, and 5 columns are used for the fractional part. The last two columns are left blank for spacing purposes. All variables in the numeric cards have identical formats as illustrated in Appendix II.

Untranslated or non-translated data, that is data without coding and in raw uncondensed form, is shown in Table 1. The translator program deletes all variables for which no data is available and supplies the proper coding information as illustrated in Table 2. As previously explained, this data still contains many blanks which are there to provide better legibility during the development period.

The present translator program of the "SODAK" system can transform or translate only eight sets of non-translated data at a time. The eight sets of data consists of 32 cards. Blank cards are added to sets of data that are less than eight. However, an unlimited number of data sets can be translated or transformed with one reading of the computer on the translator program. The translation of the eight sets of data takes approximately two minutes to accomplish on the IBM 1620 computer. The translator program shown in Appendix VI applies only to the particular form of non-translated data shown in Table 1 and Appendix I.

In the last card of every set of translated data, the three digit code 999 is punched after the field of 20 columns of the last variable. This code number indicates the end of a set of data and also the maximum number of variables that can be stored in the "SODAK" system. At the present time, 999 variables seems to be adequate. However, should it ever be necessary to provide for more than 999 variables, this could be easily accomplished by adding one or more digits to the code.

## RETRIEVAL ROUTINE OF THE "SODAK" SYSTEM

The retrieval system of the "SODAK" is shown in Figure 4. The flow diagram illustrates the following steps: (1) the user supplied selective search program is read by the computer. This program is prepared by the user or researcher; (2) the water sample sorter program analyzes, searches, and evaluates what is desired by the user or researcher in the logic program or user supplied selective search program; (3) in the process of analysis, searching, and evaluation made by the computer based on the water sample sorter program, the data bank or stored data is referred to; and (4) upon final successful analysis, the output for the user or researcher in terms of printed results is obtained.

The card format and coding of the table illustrated in Appendix IV and its printed form shown in Appendix VII was used for the printed results obtained from the retrieval routine. The purpose of the table is to convert input names of the variables in the user supplied selective search program or logic program to three digits codes and to convert the three-digit code number of each variable into the name of its corresponding variable in the information retrieved. The inclusion of the table in the retrieval routine facilitates the analysis and evaluation process made by the user or researcher since the name of the variable is more convenient than digit coding.

There are four card sets in the retrieval routine of the "SODAK" system: (1) water sample sorter program, (2) table, (3) logic program or user supplied selective search program including a final blank card,

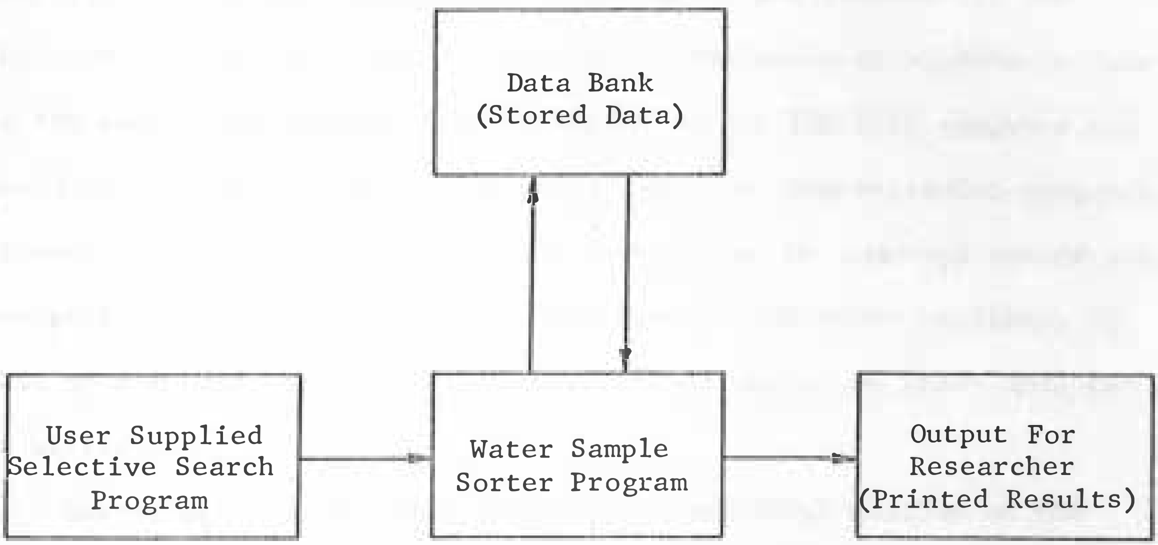


Figure 4. Flow Diagram of "SODAK" Retrieval System

and (4) translated data or standard form of recorded data. The four card sets are read by the digital computer in the order they are listed above. The presence of the blank card in the logic program or user supplied selective search program is to indicate the end of the logic program.

At the present time, subsection and the sample number are the only variables that contain alphameric (alphabets and numbers) data in the stored data. These variables can be stored as shown in Table 2 and Appendix II, but they cannot be retrieved nor included in the logic program at the present time. Since inclusion of alphameric data in the search routine would be difficult on the IBM 1620 computer and would not materially affect the performance for demonstration purposes, it was not included. However, this problem can be remedied should the system be implemented on a state-wide basis. All other variables in this system have numeric data, and thus information on their data can be retrieved.

There were several tests made on the retrieval routine of the "SODAK" system. The results of seven of these tests are illustrated in the section of this thesis entitled "Tests of the "SODAK" System by the Use of Examples." The results indicate the printed form and appearance of the information retrieved from this system. All of the values of the variables are edited in the "floating-point" form with eight significant digits. The "floating-point" technique is a system of recording the number of significant digits of the value first, followed by an exponent which places the decimal point in its proper place. An illustration of the "floating-point" equivalent of the two numbers .21390000E+04 and .21390000E-04 are 2,139 and .00002139 respectively. The decimal point in the first illustration is moved four places to the right, since it has a positive exponent (indicated by E+04); and the decimal point in the second illustration is moved four places to the left, since it has a negative exponent (indicated by E-04).

Retrieved results obtained on the seven tests depended on the information requested in the logic program and the stored translated data or standard form of recorded data. The nonexistence of a variable in the stored translated data is indicated by the large negative number -.99999000E+05. The existence of a variable with a zero data value is indicated by the number .00000000E-99. An illustration of these representations are shown in Figure 5 of "Tests of the "SODAK" System by the Use of Examples": the nonexisting variables in the stored translated data are color and alkalinity as calcium carbonate ($CaCO_3$), and the existing variable in the translated stored data having a zero value is carbonate.

The "floating-point" representation of the present system in its retrieval routine may be refined to the usual procedure of recording numbers with some modifications in the present water sample sorter program. Further refinement of editing the retrieved results can also include the proper units of determination for each variable.

# TESTS ON THE "SODAK" SYSTEM BY USE OF EXAMPLES

The usefulness of the "SODAK" system can be demonstrated by the several tests that were applied to the logic program. (The logic program may be referred to as the user supplied selective search program.) The seven demonstrative tests have various combinations of possible restrictions and conditions that a researcher or user may require of a logic program or selective search program by use of combinations of the logic statements "IF", "AND IF", "OR IF", and "SAVE".

For the sake of brevity, these demonstrative tests use only four sets of stored data rather than all the data stored for the "SODAK" system. The data used are shown in Table 2, page 31. The explanation of the TESTS refers to these four sets of stored data.

TEST I:

The researcher indicates the desire to retrieve data which indicates the amount of dissolved solids in a strip across the State which is included within the limits of all townships between 100 and 120. He wishes to know the location of the water supply by township, range, and section as well as the value for the calculated dissolved solids. The logic program would indicate the following conditions: (1) "IF" the variable township is within the limits of 100.0 to 120.0, then (2) "SAVE" the variables township, range, section, and dissolved solids calculated.

The retrieved results on the stored data as indicated in Figure 5 show the four sets of data that satisfy the user's supplied selective

| | |
|---|---|
| TOWNSHIP | .11000000E+03 |
| RANGE | .58000000E+02 |
| SECTION | .60000000E+01 |
| DISSOLVED SOL CALC | .21390000E+04 |
| | |
| TOWNSHIP | .11000000E+03 |
| RANGE | .58000000E+02 |
| SECTION | .60000000E+01 |
| DISSOLVED SOL CALC | .21130000E+04 |
| | |
| TOWNSHIP | .11000000E+03 |
| RANGE | .60000000E+02 |
| SECTION | .70000000E+01 |
| DISSOLVED SOL CALC | .19800000E+04 |
| | |
| TOWNSHIP | .11000000E+03 |
| RANGE | .60000000E+02 |
| SECTION | .26000000E+02 |
| DISSOLVED SOL CALC | .27100000E+04 |

Figure 5. Retrieved Printed Results for Test I

search program. An interpretation of the retrieved data indicates that in section 6, township 110 and range 58, a water sample had 2,139 parts per million of calculated dissolved solids; in section 6, township 110 and range 58, the water sample had 2,113 parts per million, etc. The value for the calculated dissolved solids is read using the "floating-point" technique. .21390000E+04 and .21130000E+04 represents the numbers 2,139 and 2,113 respectively. The placement of the decimal point is indicated by the last two digits on the printed form of results. E+04 indicates that the placement of the decimal point should be four places to the right, E+01 would indicate one place to the right, E+00 indicates that the decimal point retains its original position. A negative exponent would indicate that the decimal point is to be moved to the left. For instance, the readout in the printed result of .40000000E-02 would indicate a value of 0.004. The exception to the above rule is that the large negative number of -.99999000E+05 indicates that there is no existing value for the variable and the number .00000000E-99 indicates a value of zero.

TEST II:

The user or researcher indicates the desire to retrieve data from an area in the State which includes the first 10 sections of each township in a strip of land which lies within range 60 to 65 inclusive. The user is not interested in any water sample in which the calcium is less than 10 parts per million or greater than 200 parts per million. The water sample must also contain magnesium within the limits of not less than 3 parts per million and not greater than 65 parts per million.

The user wishes to obtain the following information on such samples: location by township, range and section, date of collection of water sample, silica, iron, manganese, calcium, magnesium, sodium potassium bicarbonate, carbonate, sulfate, chloride, fluoride, nitrate, boron, dissolved solids calculated, residue on evaporation, hardness as calcium carbonate ($CaCO_3$), noncarbonate hardness as calcium carbonate ($CaCO_3$), alkalinity as calcium carbonate ($CaCO_3$), specific conductance, pH, color, percent sodium, sodium adsorption ratio, date the well was drilled, depth of the well, and diameter of the well. The logic program would indicate the following conditions: (1) "IF" the variable calcium is within the limits of 10.0 to 200.0 parts per million; "AND IF" the variable range is within the limits of 60.0 to 65.0; "AND IF" the variable section is within the limits of 0.0 to 10.0; "AND IF" magnesium is within the limits of 3.0 to 65.0 parts per million; then (2) "SAVE" the variables township, range, section, date of collection of the water sample, silica, iron, manganese, calcium, magnesium, sodium, potassium, bicarbonate, carbonate, sulfate, chloride, fluoride, nitrate, boron, dissolved solids calculated, residue on evaporation, hardness as calcium carbonate ($CaCO_3$), noncarbonate hardness as calcium carbonate ($CaCO_3$), alkalinity as calcium carbonate ($CaCO_3$), specific conductance, pH, color, percent sodium, sodium adsorption ratio, date the well was drilled, depth of the well, and diameter of the well.

The retrieved results on this test as shown in Figure 6 indicate that only one set of stored data satisfies all the restrictions set forth in condition 1. The retrieved values on the variables saved

| | |
|---|---|
| TOWNSHIP | .11000000E+03 |
| RANGE | .60000000E+02 |
| SECTION | .70000000E+01 |
| DATE OF COLLECTION | .63042500E+06 |
| SILICA | .12000000E+02 |
| IRON | .81000000E+00 |
| MANGANESE | .70000000E-01 |
| CALCIUM | .10800000E+03 |
| MAGNESIUM | .13000000E+02 |
| SODIUM | .46000000E+03 |
| POTASSIUM | .18000000E+02 |
| BICARBONATE | .16400000E+03 |
| CARBONATE | .00000000E-99 |
| SULFATE | .11700000E+04 |
| CHLORIDE | .92000000E+02 |
| FLUORIDE | .19000000E+01 |
| NITRATE | .20000000E+00 |
| BORON | .90000000E+00 |
| DISSOLVED SOL CALC | .19800000E+04 |
| RESIDUE ON EVAP | .20100000E+04 |
| HARDNESS AS $CACO_3$ | .40600000E+03 |
| NON CARB AS $CACO_3$ | .27200000E+03 |
| ALKALINITY AS $CACO_3$ | -.99999000E+05 |
| SPECIFIC CONDUCTANCE | .27600000E+04 |
| PH | .78000000E+01 |
| COLOR | -.99999000E+05 |
| PERCENT SODIUM | .70000000E+02 |
| SODIUM ADSORP RATIO | .99000000E+01 |
| DATE DRILLED | .48000000E+02 |
| DEPTH | .79500000E+03 |
| DIAMETER | .12500000E+00 |

Figure 6. Retrieved Printed Results for Test II

from the set of data indicate that the sample was taken from section 7, township 110, range 60, on April 25, 1963. The "floating-point" technique for various element values are interpreted as indicated in the explanation given for TEST I. It is to be noted that the value of carbonate is zero in this water sample and that no data was available on alkalinity as calcium carbonate and color. The well was drilled in 1948, is 795 feet deep and 0.125 feet in diameter.

TEST III:

The user may desire to have all data where the bicarbonate is within the limits of 160.0 and 525.0 parts per million and the fluoride is within the limits of 0.40 and 2.50 parts per million. The user wants to know the location of such sampling by section number, township and range as well as other variables listed in the "SAVE" statement of the logic program. The logic program would indicate the following conditions: (1) "IF" the variable bicarbonate is within the limits of 160.0 to 525.0 parts per million; "AND IF" the variable fluoride is within the limits of 0.40 to 2.50 parts per million; then (2) "SAVE" the variables township, range, section, date of collection of the water sample, silica, iron, manganese, calcium, magnesium, sodium, potassium, bicarbonate, carbonate, sulfate, chloride, fluoride, nitrate, boron, dissolved solids calculated, residue on evaporation, hardness as calcium carbonate ($CaCO_3$), noncarbonate hardness as calcium carbonate ($CaCO_3$), alkalinity as calcium carbonate ($CaCO_3$), specific conductance, pH, color, percent sodium, sodium adsorption ratio, date the well was drilled, depth, and diameter of the well.

| | |
|---|---|
| TOWNSHIP | .11000000E+03 |
| RANGE | .58000000E+02 |
| SECTION | .60000000E+01 |
| DATE OF COLLECTION | .54030000E+06 |
| SILICA | -.99999000E+05 |
| IRON | .40000000E-01 |
| MANGANESE | -.99999000E+05 |
| CALCIUM | .13220000E+02 |
| MAGNESIUM | .68000000E+01 |
| SODIUM | -.99999000E+05 |
| POTASSIUM | -.99999000E+05 |
| BICARBONATE | .27820000E+03 |
| CARBONATE | -.99999000E+05 |
| SULFATE | .42590000E+03 |
| CHLORIDE | .14800000E+03 |
| FLUORIDE | .24000000E+01 |
| NITRATE | .30000000E+01 |
| BORON | -.99999000E+05 |
| DISSOLVED SOL CALC | .21390000E+04 |
| RESIDUE ON EVAP | -.99999000E+05 |
| HARDNESS AS $CACO_3$ | .59330000E+02 |
| NON CARB AS $CACO_3$ | .00000000E-99 |
| ALKALINITY AS $CACO_3$ | -.99999000E+05 |
| SPECIFIC CONDUCTANCE | -.99999000E+05 |
| PH | -.99999000E+05 |
| COLOR | -.99999000E+05 |
| PERCENT SODIUM | .90000000E+01 |
| SODIUM ADSORP RATIO | .41000000E+02 |
| DATE DRILLED | .29000000E+02 |
| DEPTH | .10000000E+04 |
| DIAMETER | .50000000E+00 |

Figure 7. Retrieved Printed Results for Test III

| | |
|---|---|
| TOWNSHIP | .11000000E+03 |
| RANGE | .58000000E+02 |
| SECTION | .60000000E+01 |
| DATE OF COLLECTION | .51110000E+06 |
| SILICA | -.99999000E+05 |
| IRON | .40000000E-01 |
| MANGANESE | .00000000E-99 |
| CALCIUM | .70000000E+01 |
| MAGNESIUM | .20000000E+01 |
| SODIUM | .71600000E+03 |
| POTASSIUM | .78000000E+01 |
| BICARBONATE | .29300000E+03 |
| CARBONATE | -.99999000E+05 |
| SULFATE | .10730000E+04 |
| CHLORIDE | .16000000E+03 |
| FLUORIDE | .25000000E+01 |
| NITRATE | .20000000E+01 |
| BORON | -.99999000E+05 |
| DISSOLVED SOL CALC | .21130000E+04 |
| RESIDUE ON EVAP | -.99999000E+05 |
| HARDNESS AS $CACO_3$ | .20000000E+02 |
| NON CARB AS $CACO_3$ | .00000000E-99 |
| ALKALINITY AS $CACO_3$ | .24000000E+03 |
| SPECIFIC CONDUCTANCE | -.99999000E+05 |
| PH | .77000000E+01 |
| COLOR | -.99999000E+05 |
| PERCENT SODIUM | .98000000E+02 |
| SODIUM ADSORP RATIO | .61000000E+02 |
| DATE DRILLED | .29000000E+02 |
| DEPTH | .10080000E+04 |
| DIAMETER | .50000000E+00 |

Figure 7 (Continued). Retrieved Printed Results for Test III

| | |
|---|---|
| TOWNSHIP | .11000000E+03 |
| RANGE | .60000000E+02 |
| SECTION | .70000000E+01 |
| DATE OF COLLECTION | .63042500E+06 |
| SILICA | .12000000E+02 |
| IRON | .81000000E+00 |
| MANGANESE | .70000000E-01 |
| CALCIUM | .10800000E+03 |
| MAGNESIUM | .13000000E+02 |
| SODIUM | .46000000E+03 |
| POTASSIUM | .18000000E+02 |
| BICARBONATE | .16400000E+03 |
| CARBONATE | .00000000E-99 |
| SULFATE | .11700000E+04 |
| CHLORIDE | .92000000E+02 |
| FLUORIDE | .19000000E+01 |
| NITRATE | .20000000E+00 |
| BORON | .90000000E+00 |
| DISSOLVED SOL CALC | .19800000E+04 |
| RESIDUE ON EVAP | .20100000E+04 |
| HARDNESS AS $CACO_3$ | .40600000E+03 |
| NON CARB AS $CACO_3$ | .27200000E+03 |
| ALKALINITY AS $CACO_3$ | -.99999000E+05 |
| SPECIFIC CONDUCTANCE | .27600000E+04 |
| PH | .78000000E+01 |
| COLOR | -.99999000E+05 |
| PERCENT SODIUM | .70000000E+02 |
| SODIUM ADSORP RATIO | .99000000E+01 |
| DATE DRILLED | .48000000E+02 |
| DEPTH | .79500000E+03 |
| DIAMETER | .12500000E+00 |

Figure 7 (Continued). Retrieved Printed Results for Test III

| | |
|---|---|
| TOWNSHIP | .11000000E+03 |
| RANGE | .60000000E+02 |
| SECTION | .26000000E+02 |
| DATE OF COLLECTION | .64010900E+06 |
| SILICA | .30000000E+02 |
| IRON | .38000000E+01 |
| MANGANESE | .80000000E-01 |
| CALCIUM | .18500000E+03 |
| MAGNESIUM | .64000000E+02 |
| SODIUM | .59600000E+03 |
| POTASSIUM | .14000000E+02 |
| BICARBONATE | .52200000E+03 |
| CARBONATE | .00000000E-99 |
| SULFATE | .15200000E+04 |
| CHLORIDE | .29000000E+02 |
| FLUORIDE | .40000000E+00 |
| NITRATE | .10000000E+02 |
| BORON | .17000000E+01 |
| DISSOLVED SOL CALC | .27100000E+04 |
| RESIDUE ON EVAP | .27700000E+04 |
| HARDNESS AS CACO3 | .72300000E+03 |
| NON CARB AS CACO3 | .29500000E+03 |
| ALKALINITY AS CACO3 | -.99999000E+05 |
| SPECIFIC CONDUCTANCE | .31500000E+04 |
| PH | .78000000E+01 |
| COLOR | -.99999000E+05 |
| PERCENT SODIUM | .64000000E+02 |
| SODIUM ADSORP RATIO | .96000000E+01 |
| DATE DRILLED | .45000000E+02 |
| DEPTH | .76800000E+03 |
| DIAMETER | .12500000E+00 |

Figure 7 (Continued). Retrieved Printed Results for Test III

The retrieved data are shown in Figure 7. The four sets of data satisfied the conditions. In the first set of data, it is to be noted that no data was obtained for silica, manganese, sodium, potassium, carbonate, residue on evaporation, alkalinity as calcium carbonate, specific conductance, pH, and color. Noncarbonate hardness as calcium carbonate has a zero value. The retrieved data on the second, third, and fourth set of stored data are interpreted in the "floating-point" technique for various element values of the variables in the "SAVE" statement as indicated in the explanation given for TEST I.

TEST IV:

The researcher or user indicates the following conditions: (1) "IF" the variable chloride is within the limits of 29.0 to 35.0 parts per million; "OR IF" the variable potassium is within the limits of 0.40 to 18.0 parts per million; then (2) "SAVE" the variables township, range, section, date of collection of the water sample, silica, iron manganese, calcium, magnesium, sodium, potassium, bicarbonate, carbonate, sulfate, chloride, fluoride, nitrate, boron, dissolved solids calculated, residue on evaporation, hardness as calcium carbonate, noncarbonate hardness as calcium carbonate, alkalinity as calcium carbonate, specific conductance, pH, color, percent sodium, sodium adsorption ratio, date the well was drilled, depth of the well, and diameter of the well.

The retrieved results of this test as shown in Figure 8 indicate that the second set, third set, and the fourth set of stored data

| | |
|---|---|
| TOWNSHIP | .11000000E+03 |
| RANGE | .58000000E+02 |
| SECTION | .60000000E+01 |
| DATE OF COLLECTION | .51110000E+06 |
| SILICA | -.99999000E+05 |
| IRON | .40000000E-01 |
| MANGANESE | .00000000E-99 |
| CALCIUM | .70000000E+01 |
| MAGNESIUM | .20000000E+01 |
| SODIUM | .71600000E+03 |
| POTASSIUM | .78000000E+01 |
| BICARBONATE | .29300000E+03 |
| CARBONATE | -.99999000E+05 |
| SULFATE | .10730000E+04 |
| CHLORIDE | .16000000E+03 |
| FLUORIDE | .25000000E+01 |
| NITRATE | .20000000E+01 |
| BORON | -.99999000E+05 |
| DISSOLVED SOL CALC | .21130000E+04 |
| RESIDUE ON EVAP | -.99999000E+05 |
| HARDNESS AS $CACO_3$ | .20000000E+02 |
| NON CARB AS $CACO_3$ | .00000000E-99 |
| ALKALINITY AS $CACO_3$ | .24000000E+03 |
| SPECIFIC CONDUCTANCE | -.99999000E+05 |
| PH | .77000000E+01 |
| COLOR | -.99999000E+05 |
| PERCENT SODIUM | .98000000E+02 |
| SODIUM ADSORP RATIO | .61000000E+02 |
| DATE DRILLED | .29000000E+02 |
| DEPTH | .10080000E+04 |
| DIAMETER | .50000000E+00 |

Figure 8. Retrieved Printed Results for Test IV

| | |
|---|---|
| TOWNSHIP | .11000000E+03 |
| RANGE | .60000000E+02 |
| SECTION | .70000000E+01 |
| DATE OF COLLECTION | .63042500E+06 |
| SILICA | .12000000E+02 |
| IRON | .81000000E+00 |
| MANGANESE | .70000000E-01 |
| CALCIUM | .10800000E+03 |
| MAGNESIUM | .13000000E+02 |
| SODIUM | .46000000E+03 |
| POTASSIUM | .18000000E+02 |
| BICARBONATE | .16400000E+03 |
| CARBONATE | .00000000E-99 |
| SULFATE | .11700000E+04 |
| CHLORIDE | .92000000E+02 |
| FLUORIDE | .19000000E+01 |
| NITRATE | .20000000E+00 |
| BORON | .90000000E+00 |
| DISSOLVED SOL CALC | .19800000E+04 |
| RESIDUE ON EVAP | .20100000E+04 |
| HARDNESS AS $CACO_3$ | .40600000E+03 |
| NON CARB AS $CACO_3$ | .27200000E+03 |
| ALKALINITY AS $CACO_3$ | -.99999000E+05 |
| SPECIFIC CONDUCTANCE | .27600000E+04 |
| PH | .78000000E+01 |
| COLOR | -.99999000E+05 |
| PERCENT SODIUM | .70000000E+02 |
| SODIUM ADSORP RATIO | .99000000E+01 |
| DATE DRILLED | .48000000E+02 |
| DEPTH | .79500000E+03 |
| DIAMETER | .12500000E+00 |

Figure 8 (Continued). Retrieved Printed Results for Test IV

| | |
|---|---|
| TOWNSHIP | .11000000E+03 |
| RANGE | .60000000E+02 |
| SECTION | .26000000E+02 |
| DATE OF COLLECTION | .64010900E+06 |
| SILICA | .30000000E+02 |
| IRON | .38000000E+01 |
| MANGANESE | .80000000E-01 |
| CALCIUM | .18500000E+03 |
| MAGNESIUM | .64000000E+02 |
| SODIUM | .59600000E+03 |
| POTASSIUM | .14000000E+02 |
| BICARBONATE | .52200000E+03 |
| CARBONATE | .00000000E-99 |
| SULFATE | .15200000E+04 |
| CHLORIDE | .29000000E+02 |
| FLUORIDE | .40000000E+00 |
| NITRATE | .10000000E+02 |
| BORON | .17000000E+01 |
| DISSOLVED SOL CALC | .27100000E+04 |
| RESIDUE ON EVAP | .27700000E+04 |
| HARDNESS AS $CACO_3$ | .72300000E+03 |
| NON CARB AS $CACO_3$ | .29500000E+03 |
| ALKALINITY AS $CACO_3$ | -.99999000E+05 |
| SPECIFIC CONDUCTANCE | .31500000E+04 |
| PH | .78000000E+01 |
| COLOR | -.99999000E+05 |
| PERCENT SODIUM | .64000000E+02 |
| SODIUM ADSORP RATIO | .96000000E+01 |
| DATE DRILLED | .45000000E+02 |
| DEPTH | .76800000E+03 |
| DIAMETER | .12500000E+00 |

Figure 8 (Continued). Retrieved Printed Results for Test IV

satisfy the restrictions set forth in condition 1.

TEST V.

The user of the system may incorporate a combination of "AND IF" statements with "OR IF" statements. The following logic program uses the combination: (1) "IF" the variable township is within the limits of 100.0 to 150.0; "AND IF" the variable range is within the limits of 60.0 to 65.0; "AND IF" the variable section is within the limits of 0.0 to 10.0; "OR IF" the variable sodium is within the limits of 460.0 to 720.0 parts per million; "OR IF" the variable noncarbonate is within the limits of 0.0 to 293.0 parts per million; then (2) "SAVE" the variables township, range, section, date of collection of the water sample, silica, iron, manganese, calcium, magnesium, sodium, potassium, bicarbonate, carbonate, sulfate, chloride, fluoride, nitrate, boron, dissolved solids calculated, residue on evaporation, hardness as calcium carbonate, noncarbonate hardness as calcium carbonate, alkalinity as calcium carbonate, specific conductance, pH, color, percent sodium, sodium adsorption ratio, date the well was drilled, depth of the well and diameter of the well.

The retrieved data of this test are shown in Figure 9. All four sets of stored data satisfy the restrictions set forth in condition 1.

TEST VI.

A user's selective search program can restrict the date on which the water sample was taken as well as a combination of several other restrictions. A user program may indicate the following conditions: (1) "IF" the variable dissolved solids calculated is within the limits

| | |
|---|---|
| TOWNSHIP | .11000000E+03 |
| RANGE | .58000000E+02 |
| SECTION | .60000000E+01 |
| DATE OF COLLECTION | .54030000E+06 |
| SILICA | -.99999000E+05 |
| IRON | .40000000E-01 |
| MANGANESE | -.99999000E+05 |
| CALCIUM | .13220000E+02 |
| MAGNESIUM | .68000000E+01 |
| SODIUM | -.99999000E+05 |
| POTASSIUM | -.99999000E+05 |
| BICARBONATE | .27820000E+03 |
| CARBONATE | -.99999000E+05 |
| SULFATE | .42590000E+03 |
| CHLORIDE | .14800000E+03 |
| FLUORIDE | .24000000E+01 |
| NITRATE | .30000000E+01 |
| BORON | -.99999000E+05 |
| DISSOLVED SOL CALC | .21390000E+04 |
| RESIDUE ON EVAP | -.99999000E+05 |
| HARDNESS AS $CACO_3$ | .59330000E+02 |
| NON CARB AS $CACO_3$ | .00000000E-99 |
| ALKALINITY AS $CACO_3$ | -.99999000E+05 |
| SPECIFIC CONDUCTANCE | -.99999000E+05 |
| PH | -.99999000E+05 |
| COLOR | -.99999000E+05 |
| PERCENT SODIUM | .90000000E+01 |
| SODIUM ADSORP RATIO | .41000000E+02 |
| DATE DRILLED | .29000000E+02 |
| DEPTH | .10000000E+04 |
| DIAMETER | .50000000E+00 |

Figure 9. Retrieved Printed Results for Test V

| | |
|---|---|
| TOWNSHIP | .11000000E+03 |
| RANGE | .58000000E+02 |
| SECTION | .60000000E+01 |
| DATE OF COLLECTION | .51110000E+06 |
| SILICA | -.99999000E+05 |
| IRON | .40000000E-01 |
| MANGANESE | .00000000E-99 |
| CALCIUM | .70000000E+01 |
| MAGNESIUM | .20000000E+01 |
| SODIUM | .71600000E+03 |
| POTASSIUM | .78000000E+01 |
| BICARBONATE | .29300000E+03 |
| CARBONATE | -.99999000E+05 |
| SULFATE | .10730000E+04 |
| CHLORIDE | .16000000E+03 |
| FLUORIDE | .25000000E+01 |
| NITRATE | .20000000E+01 |
| BORON | -.99999000E+05 |
| DISSOLVED SOL CALC | .21130000E+04 |
| RESIDUE ON EVAP | -.99999000E+05 |
| HARDNESS AS $CACO_3$ | .20000000E+02 |
| NON CARB AS $CACO_3$ | .00000000E-99 |
| ALKALINITY AS $CACO_3$ | .24000000E+03 |
| SPECIFIC CONDUCTANCE | -.99999000E+05 |
| PH | .77000000E+01 |
| COLOR | -.99999000E+05 |
| PERCENT SODIUM | .98000000E+02 |
| SODIUM ADSORP RATIO | .61000000E+02 |
| DATE DRILLED | .29000000E+02 |
| DEPTH | .10080000E+04 |
| DIAMETER | .50000000E+00 |

Figure 9 (Continued). Retrieved Printed Results for Test V

| | |
|---|---|
| TOWNSHIP | .11000000E+03 |
| RANGE | .60000000E+02 |
| SECTION | .70000000E+01 |
| DATE OF COLLECTION | .63042500E+06 |
| SILICA | .12000000E+02 |
| IRON | .81000000E+00 |
| MANGANESE | .70000000E-01 |
| CALCIUM | .10800000E+03 |
| MAGNESIUM | .13000000E+02 |
| SODIUM | .46000000E+03 |
| POTASSIUM | .18000000E+02 |
| BICARBONATE | .16400000E+03 |
| CARBONATE | .00000000E-99 |
| SULFATE | .11700000E+04 |
| CHLORIDE | .92000000E+02 |
| FLUORIDE | .19000000E+01 |
| NITRATE | .20000000E+00 |
| BORON | .90000000E+00 |
| DISSOLVED SOL CALC | .19800000E+04 |
| RESIDUE ON EVAP | .20100000E+04 |
| HARDNESS AS $CACO_3$ | .40600000E+03 |
| NON CARB AS $CACO_3$ | .27200000E+03 |
| ALKALINITY AS $CACO_3$ | -.99999000E+05 |
| SPECIFIC CONDUCTANCE | .27600000E+04 |
| PH | .78000000E+01 |
| COLOR | -.99999000E+05 |
| PERCENT SODIUM | .70000000E+02 |
| SODIUM ADSORP RATIO | .99000000E+01 |
| DATE DRILLED | .48000000E+02 |
| DEPTH | .79500000E+03 |
| DIAMETER | .12500000E+00 |

Figure 9 (Continued). Retrieved Printed Results for Test V

| | |
|---|---|
| TOWNSHIP | .11000000E+03 |
| RANGE | .60000000E+02 |
| SECTION | .26000000E+02 |
| DATE OF COLLECTION | .64010900E+06 |
| SILICA | .30000000E+02 |
| IRON | .38000000E+01 |
| MANGANESE | .80000000E-01 |
| CALCIUM | .18500000E+03 |
| MAGNESIUM | .64000000E+02 |
| SODIUM | .59600000E+03 |
| POTASSIUM | .14000000E+02 |
| BICARBONATE | .52200000E+03 |
| CARBONATE | .00000000E-99 |
| SULFATE | .15200000E+04 |
| CHLORIDE | .29000000E+02 |
| FLUORIDE | .40000000E+00 |
| NITRATE | .10000000E+02 |
| BORON | .17000000E+01 |
| DISSOLVED SOL CALC | .27100000E+04 |
| RESIDUE ON EVAP | .27700000E+04 |
| HARDNESS AS $CACO_3$ | .72300000E+03 |
| NON CARB AS $CACO_3$ | .29500000E+03 |
| ALKALINITY AS $CACO_3$ | -.99999000E+05 |
| SPECIFIC CONDUCTANCE | .31500000E+04 |
| PH | .78000000E+01 |
| COLOR | -.99999000E+05 |
| PERCENT SODIUM | .64000000E+02 |
| SODIUM ADSORP RATIO | .96000000E+01 |
| DATE DRILLED | .45000000E+02 |
| DEPTH | .76800000E+03 |
| DIAMETER | .12500000E+00 |

Figure 9 (Continued). Retrieved Printed Results for Test V

of 2,500.0 to 2,715.0 parts per million; "AND IF" the variable date of collection of the water sample is within the limits of 1963 to 1965; "AND IF" the variable specific conductance is within the limits of 2,750.0 to 3,120.0 parts per million; "AND IF" the variable sodium adsorption ratio is within the limits 0.0 to 10.0 parts per million; "AND IF" the variable hardness as calcium carbonate is within the limits 550.0 to 725.0 parts per million; "OR IF" the variable date of collection of the water sample is within the limits 1963 to 1965; "OR IF" the variable dissolved solids calculated is within the limits of 2,500.0 to 2,715.0 parts per million; "OR IF" hardness as calcium carbonate is within the limits of 550.0 to 725.0 parts per million; "OR IF" sodium adsorption ratio is within the limits of 0.0 to 10.0 parts per million; "OR IF" the variable date when the well was drilled is within the limits of 1945 to 1950; then (2) "SAVE" the variables township, range, section, date of collection of the water sample, silica, iron, manganese, calcium, magnesium, sodium, potassium, bicarbonate, carbonate, sulfate, chloride, fluoride, nitrate, boron, dissolved solids calculated, residue on evaporation, hardness as calcium carbonate, noncarbonate hardness as calcium carbonate, alkalinity as calcium carbonate, specific conductance, pH, color, percent sodium, sodium adsorption ratio, date when the well was drilled, depth of the well, and diameter of the well.

The retrieved data for this logic program is shown in Figure 10. Two sets of stored data satisfy the restrictions set forth.

| | |
|---|---|
| TOWNSHIP | .11000000E+03 |
| RANGE | .60000000E+02 |
| SECTION | .70000000E+01 |
| DATE OF COLLECTION | .63042500E+06 |
| SILICA | .12000000E+02 |
| IRON | .81000000E+00 |
| MANGANESE | .70000000E-01 |
| CALCIUM | .10800000E+03 |
| MAGNESIUM | .13000000E+02 |
| SODIUM | .46000000E+03 |
| POTASSIUM | .18000000E+02 |
| BICARBONATE | .16400000E+03 |
| CARBONATE | .00000000E-99 |
| SULFATE | .11700000E+04 |
| CHLORIDE | .92000000E+02 |
| FLUORIDE | .19000000E+01 |
| NITRATE | .20000000E+00 |
| BORON | .90000000E+00 |
| DISSOLVED SOL CALC | .19800000E+04 |
| RESIDUE ON EVAP | .20100000E+04 |
| HARDNESS AS $CACO_3$ | .40600000E+03 |
| NON CARB AS $CACO_3$ | .27200000E+03 |
| ALKALINITY AS $CACO_3$ | -.99999000E+05 |
| SPECIFIC CONDUCTANCE | .27600000E+04 |
| PH | .78000000E+01 |
| COLOR | -.99999000E+05 |
| PERCENT SODIUM | .70000000E+02 |
| SODIUM ADSORP RATIO | .99999000E+01 |
| DATE DRILLED | .48000000E+02 |
| DEPTH | .79500000E+03 |
| DIAMETER | .12500000E+00 |

Figure 10. Retrieved Printed Results for Test VI

| | |
|---|---|
| TOWNSHIP | .11000000E+03 |
| RANGE | .60000000E+02 |
| SECTION | .26000000E+02 |
| DATE OF COLLECTION | .64010900E+06 |
| SILICA | .30000000E+02 |
| IRON | .38000000E+01 |
| MANGANESE | .80000000E-01 |
| CALCIUM | .18500000E+03 |
| MAGNESIUM | .64000000E+02 |
| SODIUM | .59600000E+03 |
| POTASSIUM | .14000000E+02 |
| BICARBONATE | .52200000E+03 |
| CARBONATE | .00000000E-99 |
| SULFATE | .15200000E+04 |
| CHLORIDE | .29000000E+02 |
| FLUORIDE | .40000000E+00 |
| NITRATE | .10000000E+02 |
| BORON | .17000000E+01 |
| DISSOLVED SOL CALC | .27100000E+04 |
| RESIDUE ON EVAP | .27700000E+04 |
| HARDNESS AS $CACO_3$ | .72300000E+03 |
| NON CARB AS $CACO_3$ | .29500000E+03 |
| ALKALINITY AS $CACO_3$ | -.99999000E+05 |
| SPECIFIC CONDUCTANCE | .31500000E+04 |
| PH | .78000000E+01 |
| COLOR | -.99999000E+05 |
| PERCENT SODIUM | .64000000E+02 |
| SODIUM ADSORP RATIO | .96000000E+01 |
| DATE DRILLED | .45000000E+02 |
| DEPTH | .76800000E+03 |
| DIAMETER | .12500000E+00 |

Figure 10 (Continued). Retrieved Printed Results for Test VI

TEST VII.

It is possible to have a logic program with the following conditions: (1) "IF" the variable calcium is within the limits of 50.0 to 100.0 parts per million; "AND IF" the variable date of collection of the water sample is within the limits of January 1, 1955, to January 1, 1960; "OR IF" noncarbonate hardness as calcium carbonate is within the limits of 0.0 to 10.0 parts per million; then (2) "SAVE" the variables township, range, section, date of collection of the water sample, silica, iron, manganese, calcium, magnesium, sodium, potassium, bicarbonate, carbonate, sulfate, chloride, fluoride, nitrate, boron, dissolved solids calculated, residue on evaporation, hardness as calcium carbonate, noncarbonate hardness as calcium carbonate, alkalinity as calcium carbonate, specific conductance, pH, color, percent sodium, sodium adsorption ratio, date when the well was drilled, depth of the well, and diameter of the well.

The retrieved results on this test as shown in Figure 11 indicate that the first and the second set of stored data satisfy the restrictions set forth in condition 1; satisfying the calcium value of 50.0 to 100.0 parts per million, the date of collection of the water sample value of January 1, 1955, to January 1, 1960; or just the noncarbonate hardness as calcium carbonate value of 0.0 to 10.0 parts per million.

| | |
|---|---|
| TOWNSHIP | .11000000E+03 |
| RANGE | .58000000E+02 |
| SECTION | .60000000E+01 |
| DATE OF COLLECTION | .54030000E+06 |
| SILICA | -.99999000E+05 |
| IRON | .40000000E-01 |
| MANGANESE | -.99999000E+05 |
| CALCIUM | .13220000E+02 |
| MAGNESIUM | .68000000E+01 |
| SODIUM | -.99999000E+05 |
| POTASSIUM | -.99999000E+05 |
| BICARBONATE | .27820000E+03 |
| CARBONATE | -.99999000E+05 |
| SULFATE | .42590000E+03 |
| CHLORIDE | .14800000E+03 |
| FLUORIDE | .24000000E+01 |
| NITRATE | .30000000E+01 |
| BORON | -.99999000E+05 |
| DISSOLVED SOL CALC | .21390000E+04 |
| RESIDUE ON EVAP | -.99999000E+05 |
| HARDNESS AS $CACO_3$ | .59330000E+02 |
| NON CARB AS $CACO_3$ | .00000000E-99 |
| ALKALINITY AS $CACO_3$ | -.99999000E+05 |
| SPECIFIC CONDUCTANCE | -.99999000E+05 |
| PH | -.99999000E+05 |
| COLOR | -.99999000E+05 |
| PERCENT SODIUM | .90000000E+01 |
| SODIUM ADSORP RATIO | .41000000E+02 |
| DATE DRILLED | .29000000E+02 |
| DEPTH | .10000000E+04 |
| DIAMETER | .50000000E+00 |

Figure 11. Retrieved Printed Results for Test VII

| | |
|---|---|
| TOWNSHIP | .11000000E+03 |
| RANGE | .58000000E+02 |
| SECTION | .60000000E+01 |
| DATE OF COLLECTION | .51110000E+06 |
| SILICA | -.99999000E+05 |
| IRON | .40000000E-01 |
| MANGANESE | .00000000E-99 |
| CALCIUM | .70000000E+01 |
| MAGNESIUM | .20000000E+01 |
| SODIUM | .71600000E+03 |
| POTASSIUM | .78000000E+01 |
| BICARBONATE | .29300000E+03 |
| CARBONATE | -.99999000E+05 |
| SULFATE | .10730000E+04 |
| CHLORIDE | .16000000E+03 |
| FLUORIDE | .25000000E+01 |
| NITRATE | .20000000E+01 |
| BORON | -.99999000E+05 |
| DISSOLVED SOL CALC | .21130000E+04 |
| RESIDUE ON EVAP | -.99999000E+05 |
| HARDNESS AS $CACO_3$ | .20000000E+02 |
| NON CARB AS $CACO_3$ | .00000000E-99 |
| ALKALINITY AS $CACO_3$ | .24000000E+03 |
| SPECIFIC CONDUCTANCE | -.99999000E+05 |
| PH | .77000000E+01 |
| COLOR | -.99999000E+05 |
| PERCENT SODIUM | .98000000E+02 |
| SODIUM ADSORP RATIO | .61000000E+02 |
| DATE DRILLED | .29000000E+02 |
| DEPTH | .10080000E+04 |
| DIAMETER | .50000000E+00 |

Figure 11 (Continued). Retrieved Printed Results for Test VII

# SUMMARY

The "SODAK" storage and retrieval system was established to provide uniform storage and selective retrieval of ground water quality data. The system, designed primarily for the Water Resources Institute of South Dakota State University, will aid in the study of water problems and will meet the needs of many agencies concerned with ground water quality data in the State of South Dakota.

The system accepts data in raw form without dictating the form of laboratory analysis sheets and converts the data to a uniform format. The flexibility of the system provides the opportunity to expand and to add variables without modification of previously stored data. The selective search routine has a broad logical capability and thereby allows the user to selectively search stored data with an electronic digital computer.

"SODAK" has three programs in its system: (1) the translator program, (2) the water sample sorter program, and (3) the logic or user supplied selective search program. The translator program supplies the proper coding information to the data supplied by a laboratory and deletes all variables for which no data is available. A separate translator program is necessary for each laboratory document. Only one translator program was developed for this study. The water sample sorter program processes the translated stored data as required by the logic program.

The logic or user supplied selective search program, the retrieval portion of the system, is supplied by the researcher or user of the system. The logic or user selective search program is built around the logic statements "IF", "AND IF", "OR IF", and "SAVE", thus allowing the user or researcher to construct a search routine that satisfies his needs by selection or rejection of any data. Several combinations of the logic statements may be made to accomplish the desired search.

The system in its present form can retrieve information on all variables with numeric data, that is data in the numerical form. Alphameric data, that is data in the alphabetic and numerical form, cannot be retrieved and thus eliminates the possibility of retrieving the laboratory number given to a water sample. It also eliminates the possibility of locating by subsection the point at which the sample was taken. These restrictions can be eliminated if necessary. There are other restrictions placed on the "SODAK" system because at the time of initial implementation of the system the computing facilities available consisted of a decimally oriented IBM 1620 (7) with card input-output. These restrictions are limited to items not particularly important to the logical flow of the system. The principal restrictions are:

1. Output data is not edited as well as might be desired.
2. Input data is not packed as densely as possible.
3. Comparisons within the program are limited to numeric data elements.

The first restriction is a concession to the 1620 IBM computer. When other equipment is available, such as the IBM 360, the restriction will no longer be present. The fact that the input data is not densely packed causes the search for errors in the program to be difficult. The third limitation is a concession to the programmer.

Should the system prove acceptable to potential users, all of the restrictions can be removed with simple extensions to the system. Other improvements in data handling will be quite apparent when the system is converted to third-generation magnetic tape, printer-supported computing facilities.

The "SODAK" system with modifications can be adapted to other forms of numeric data in need of storage and retrieval systems such as management systems and operations problems, up-dating stored information, and forms of data dealing with selective search operations. With a particular translator program to conform with the format and coding system of the stored data, the system can also process other forms of compiled information on water quality.

Further refinement of the editing process in the "SODAK" system program can change the "floating-point" technique of recording data into the usual method of recording values of determination for the variables. The inclusion of the proper units of determination for each variable is also possible.

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# APPENDIX I
# CARD FORMAT OF NON-TRANSLATED DATA

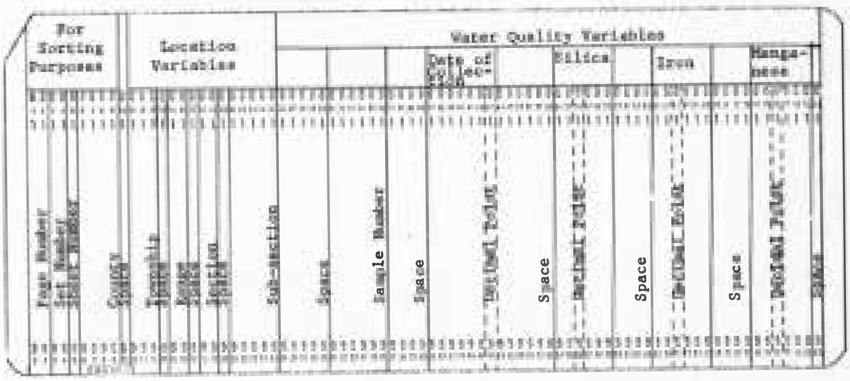


Figure 1.1
Card I

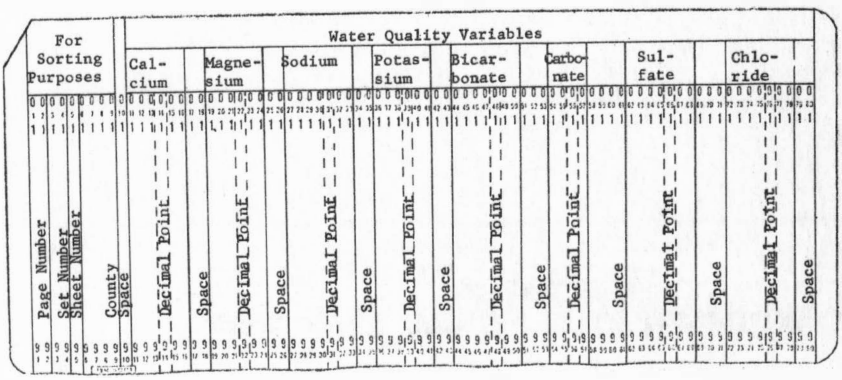


Figure 2.1
Card II

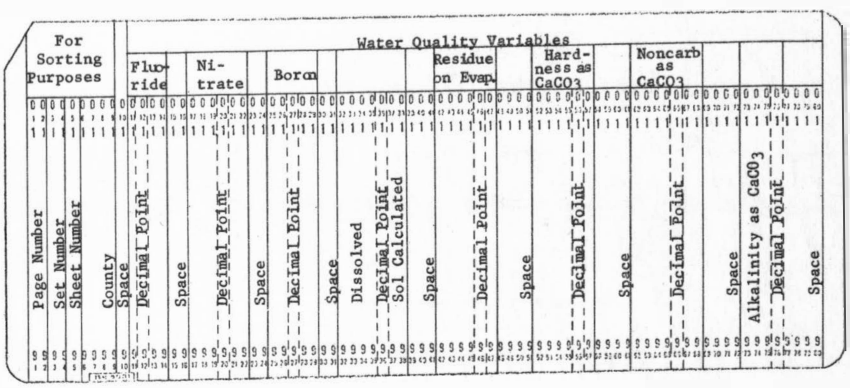


Figure 3.1
Card III

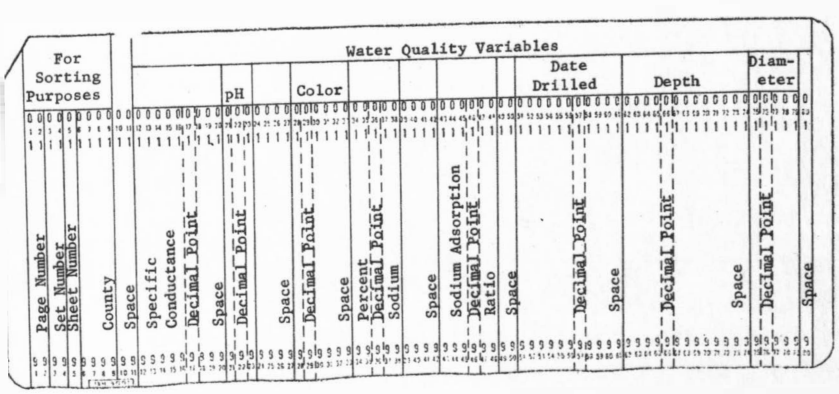


Figure 4.1
Card IV

# APPENDIX II
# CARD FORMAT AND CODING OF TRANSLATED DATA

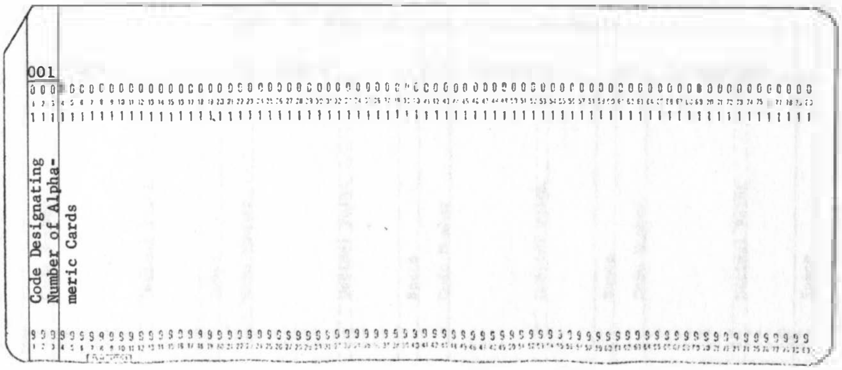


Figure 1.2
Card I

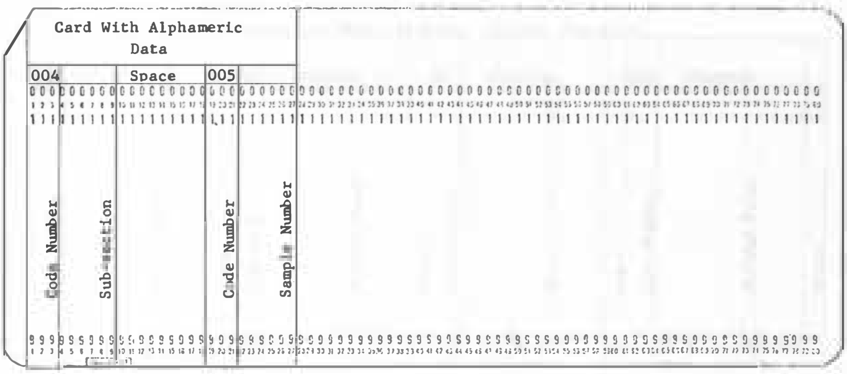


Figure 2.2
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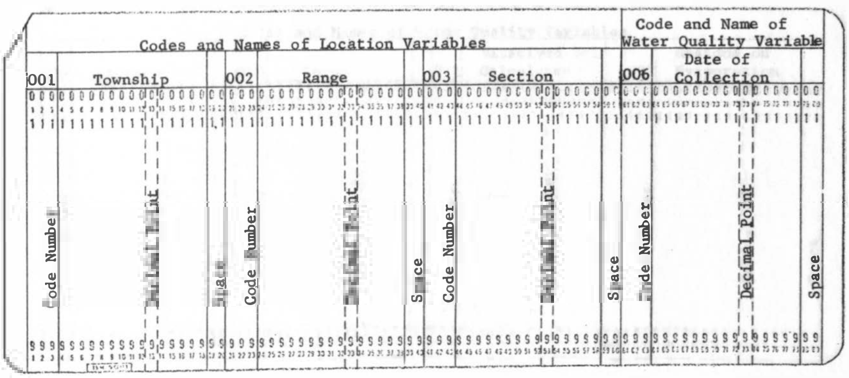


Figure 3.2
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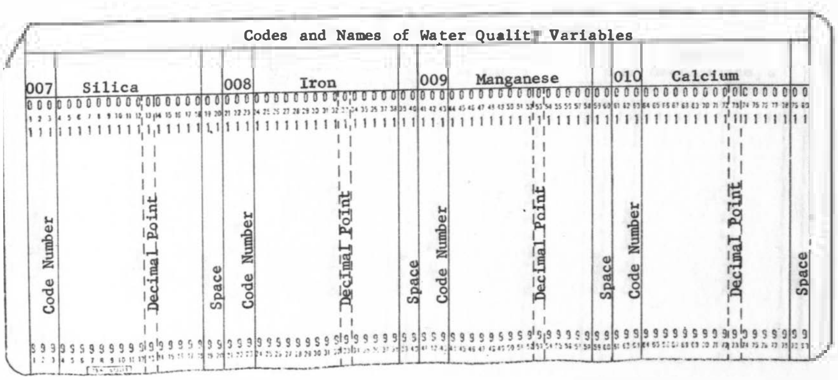


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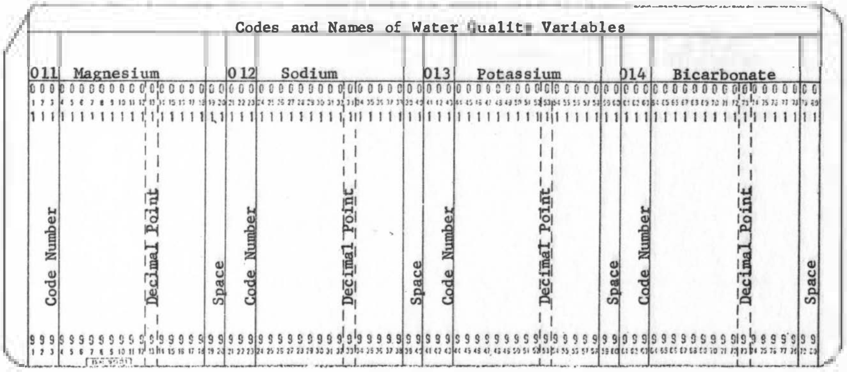



Figure 5.2
Card V

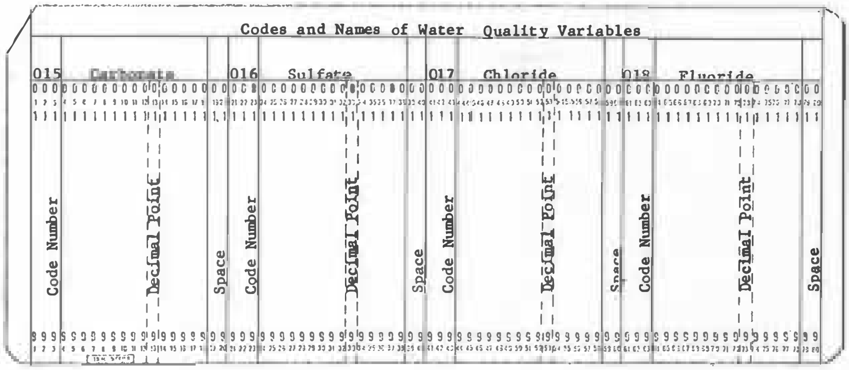



Figure 6.2
Card VI

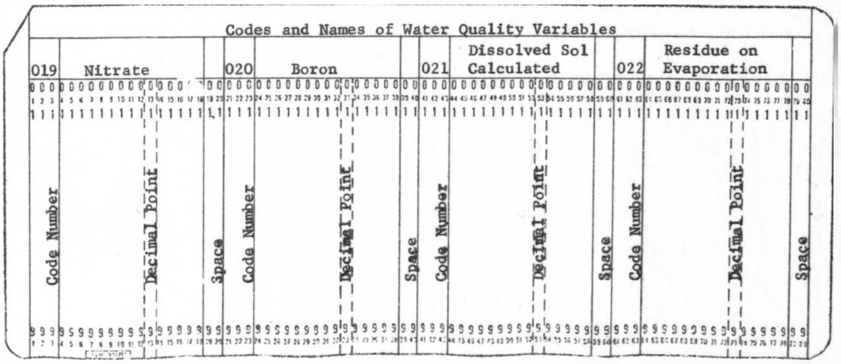



Figure 7.2
Card VII

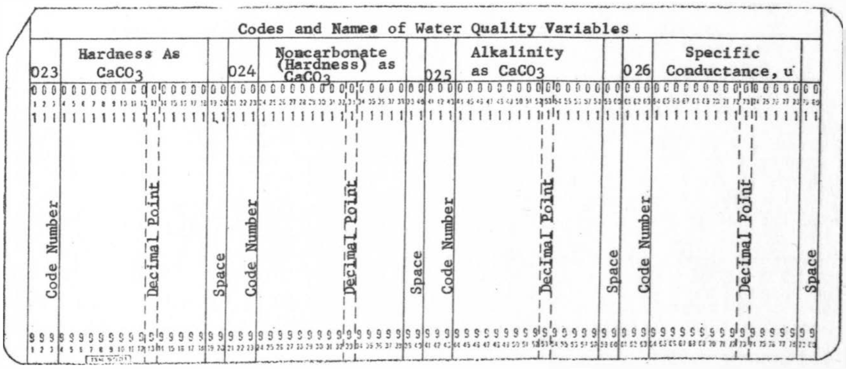



Figure 8.2
Card VIII

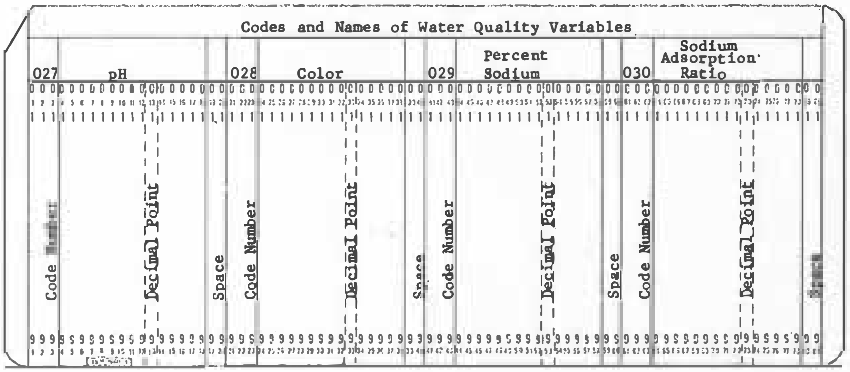



Figure 9.2
Card IX

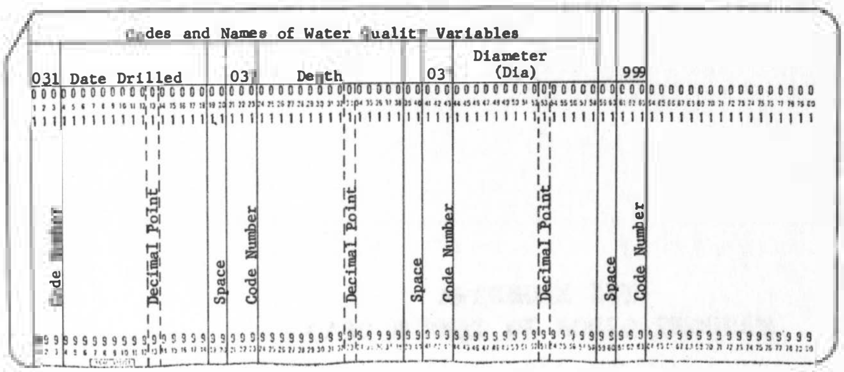



Figure 10.2
Card X

# APPENDIX III
# CARD FORMAT OF LOGIC PROGRAM

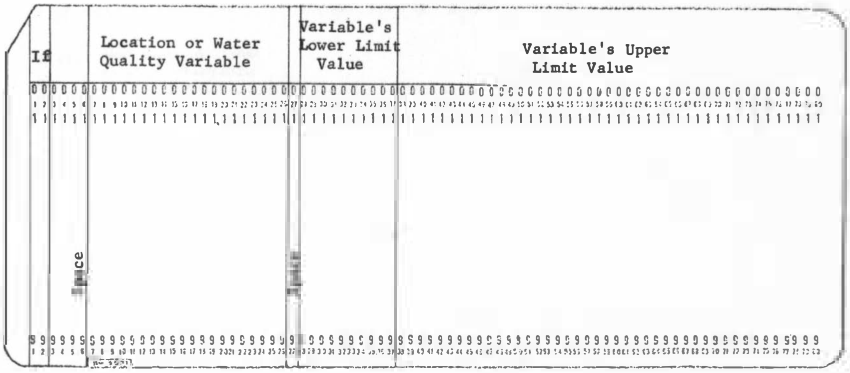
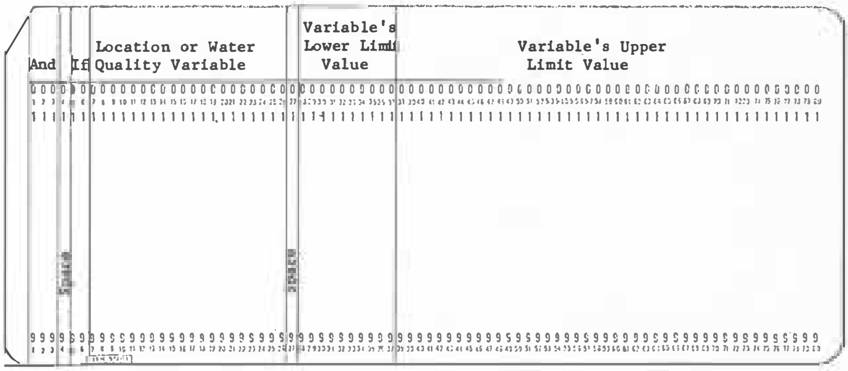



Figure 1.3
Card I

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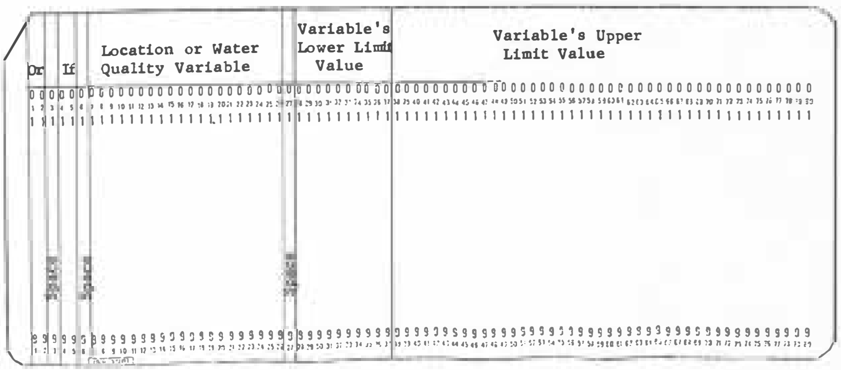
Card II

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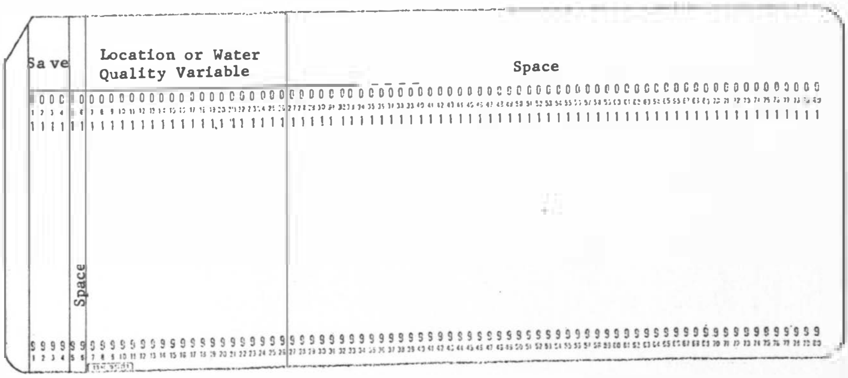


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Card IV

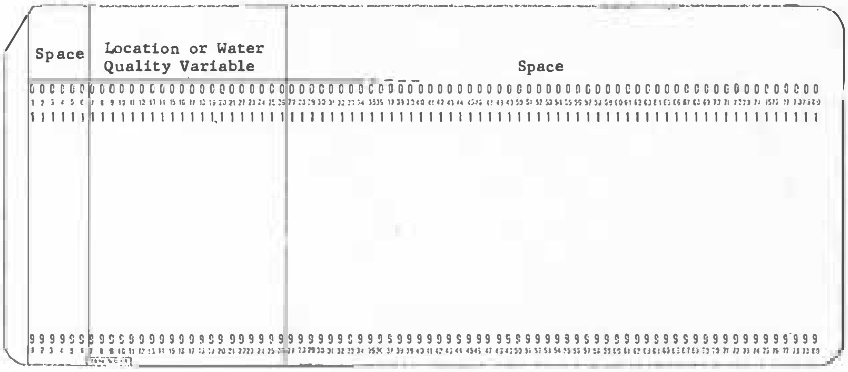


Figure 5.3
Card V

# APPENDIX IV
# CARD FORMAT AND CODING OF TABLE

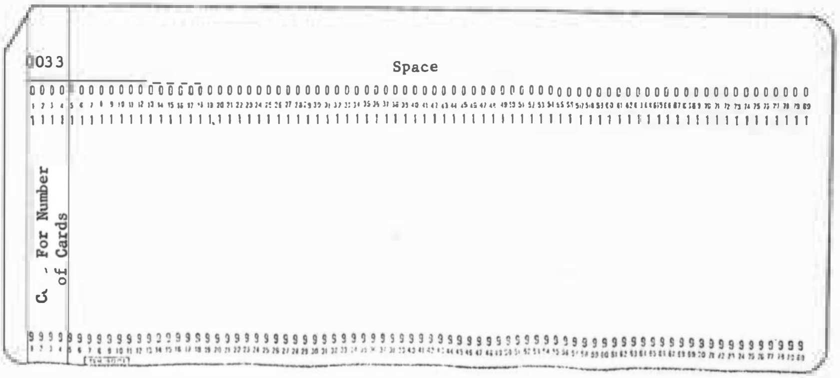


Figure 1.4
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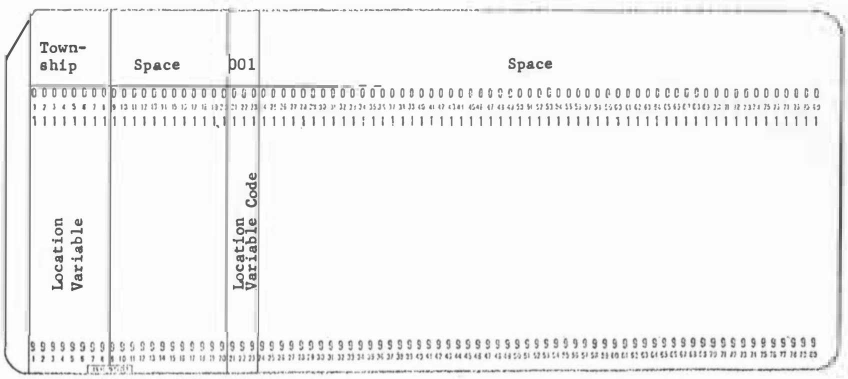


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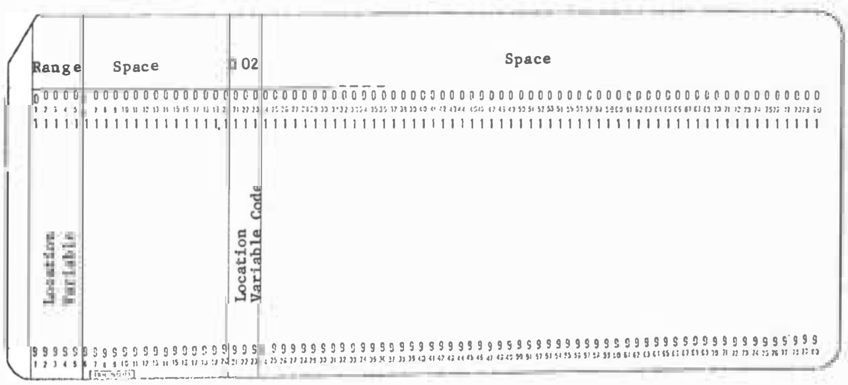
Card II

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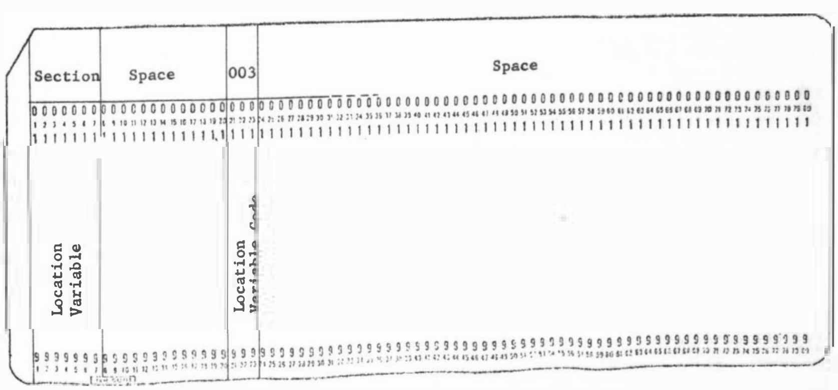


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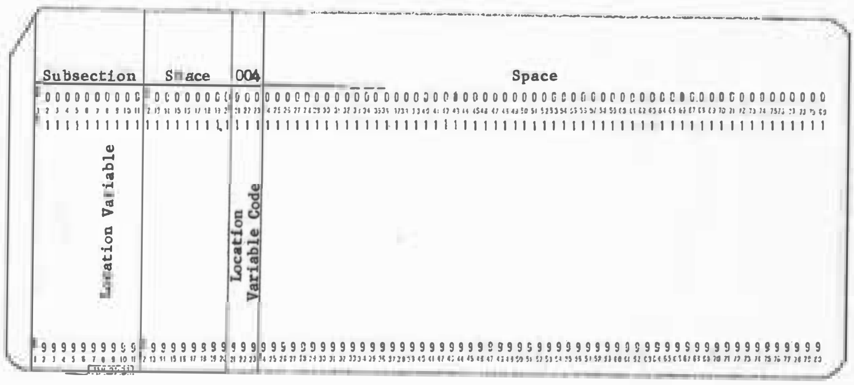


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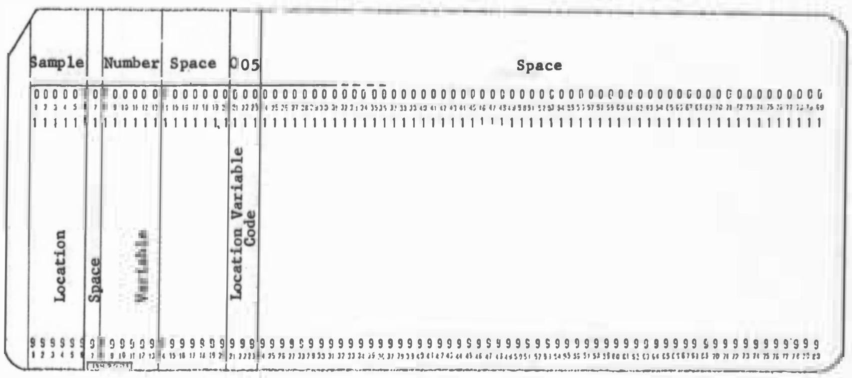


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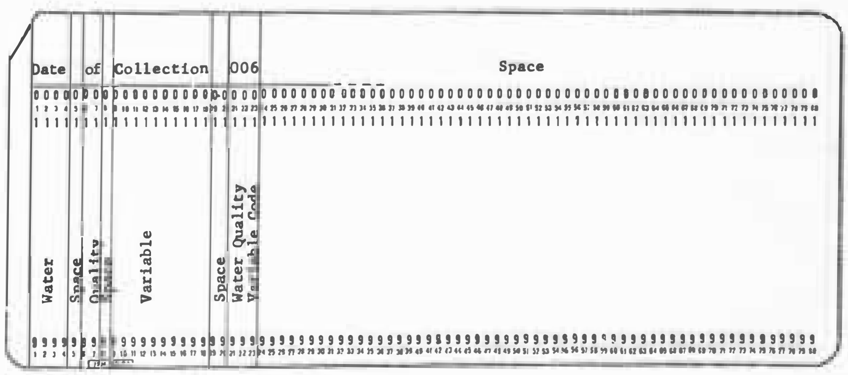


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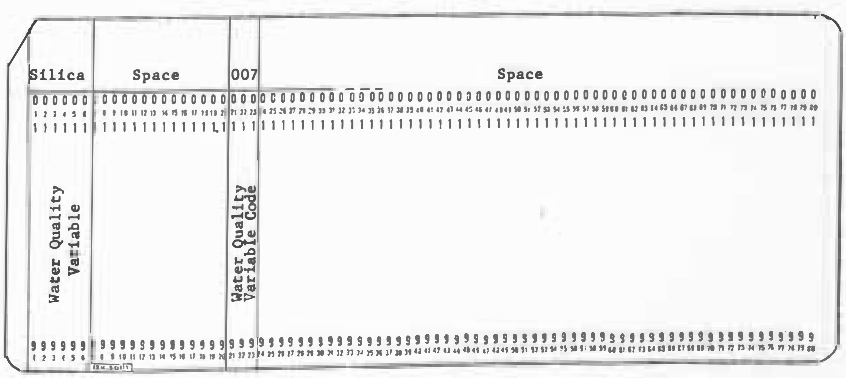


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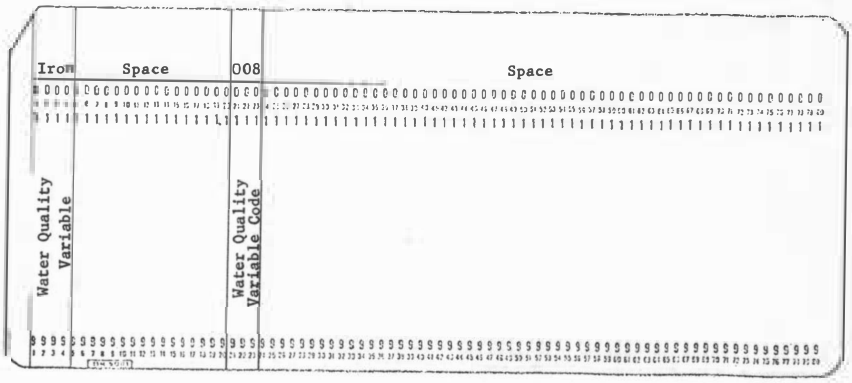
Card VIII

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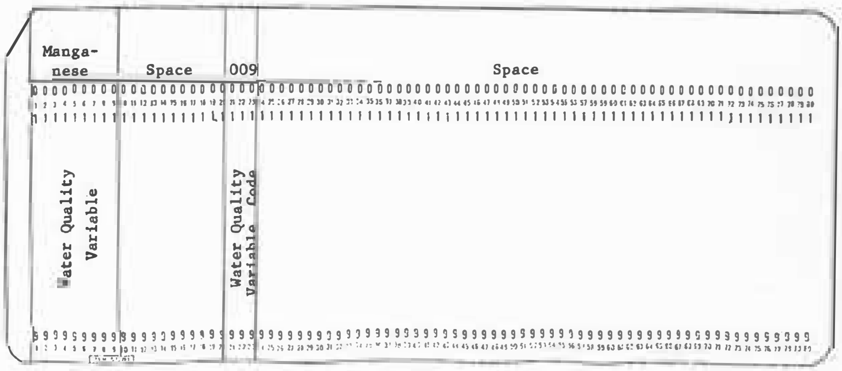


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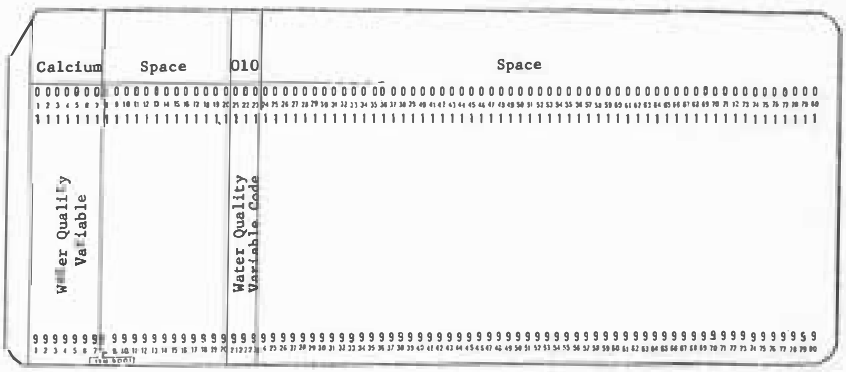


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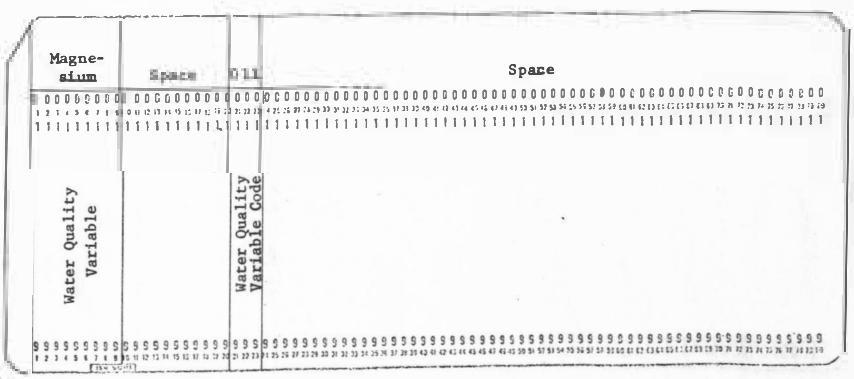
Card XI

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Card XII

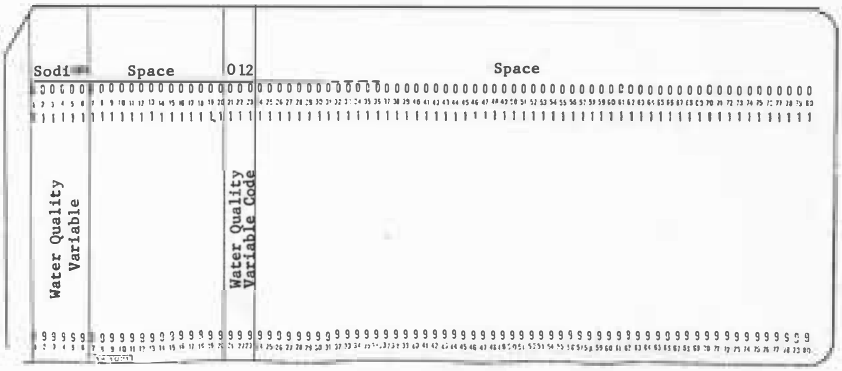


Figure 13.4
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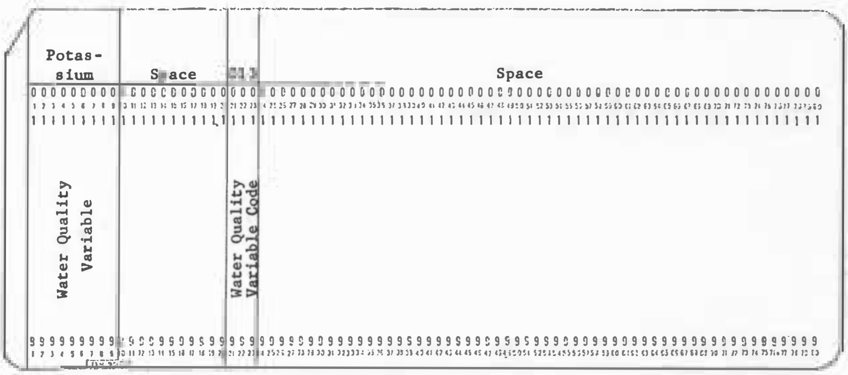


Figure 14.4
Card XIV

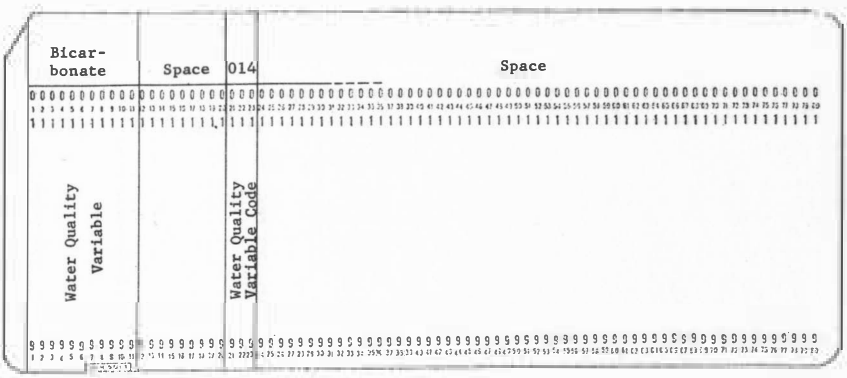


Figure 15.4
Card XV

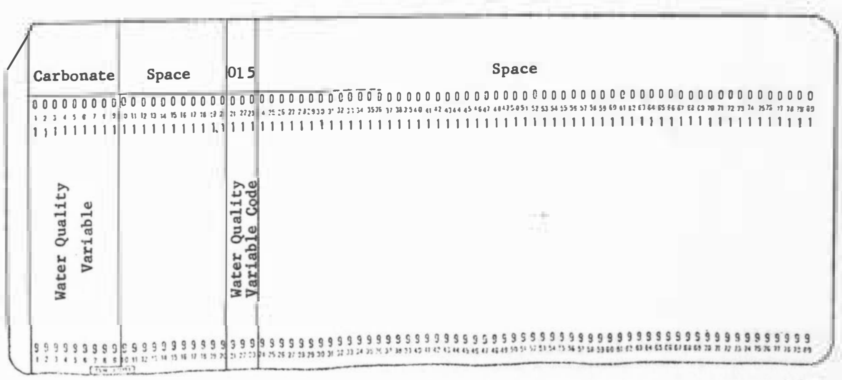


Figure 16.4
Card XVI

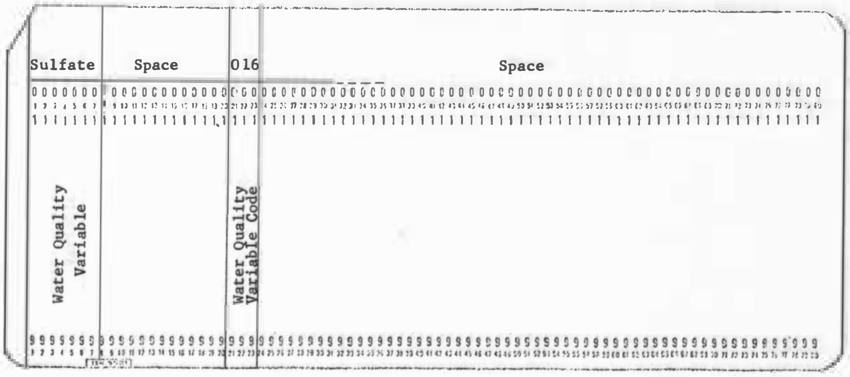


Figure 17.4
Card XVII

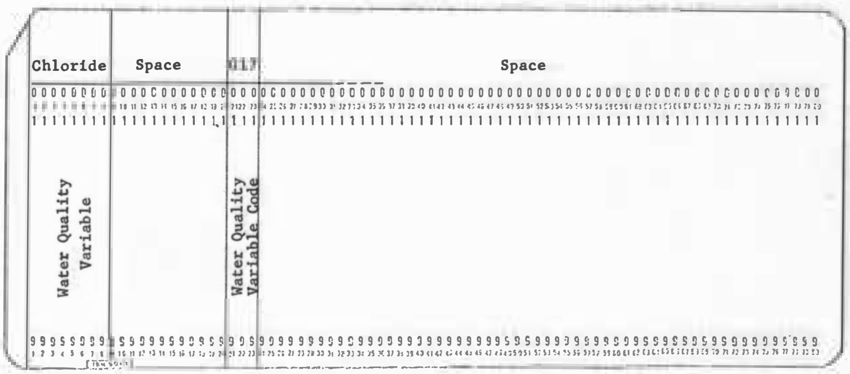


Figure 18.4
Card XVIII

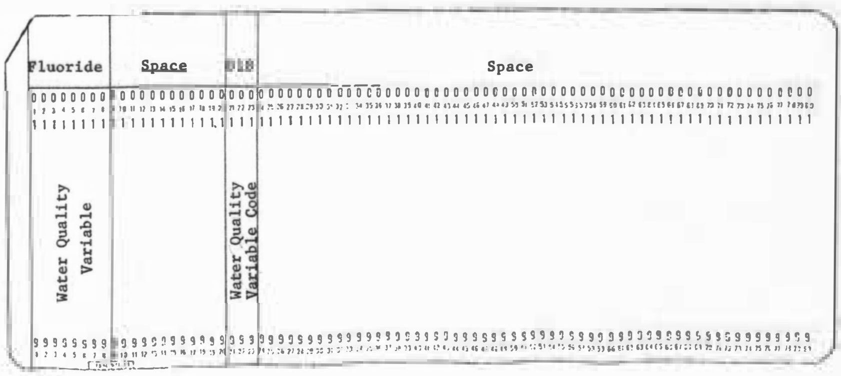


Figure 19.4
Card XIX

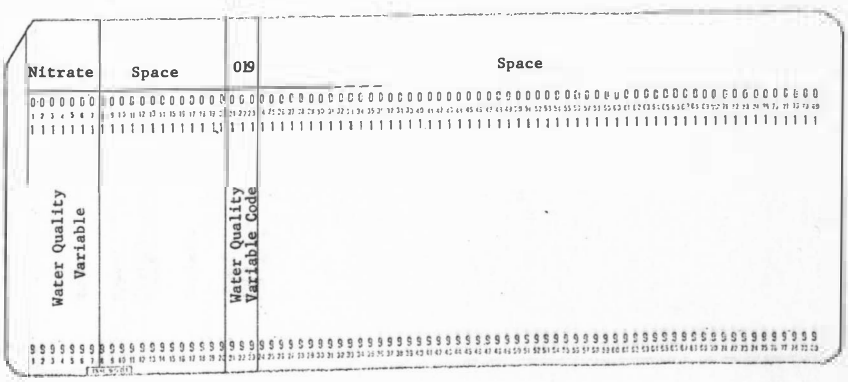


Figure 20.4
Card XX

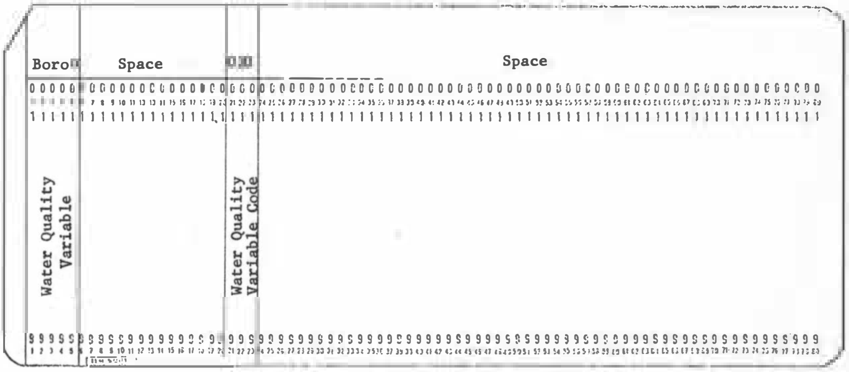


Figure 21.4
Card XXI

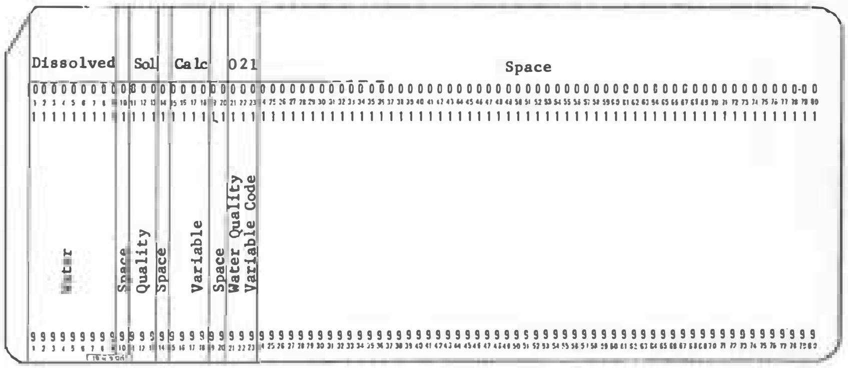


Figure 22.4
Card XXII

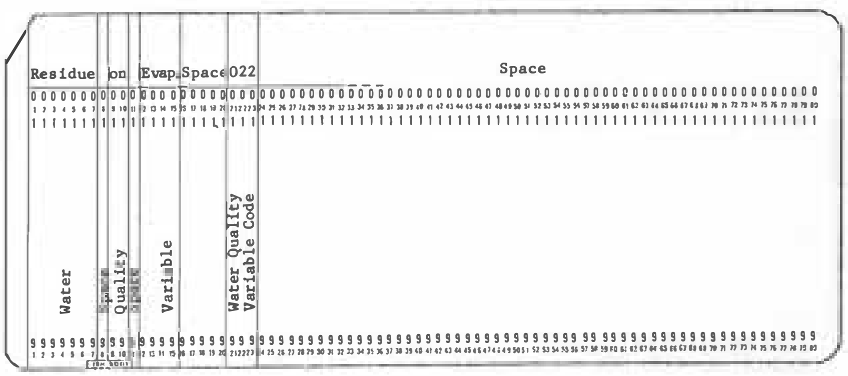


Figure 23.4
Card XXIII

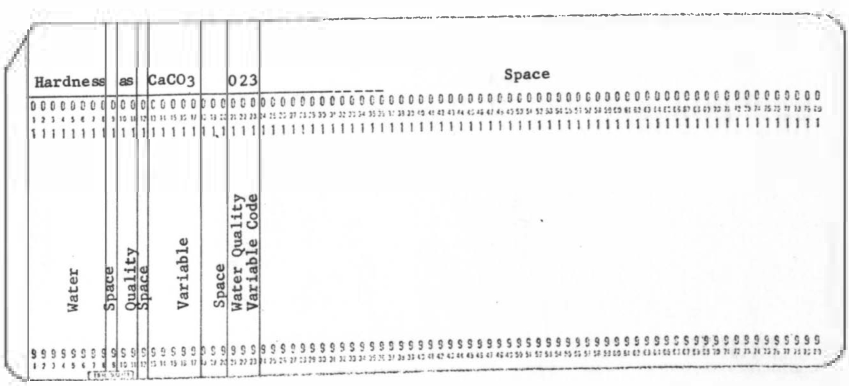


Figure 24.4
Card XXIV

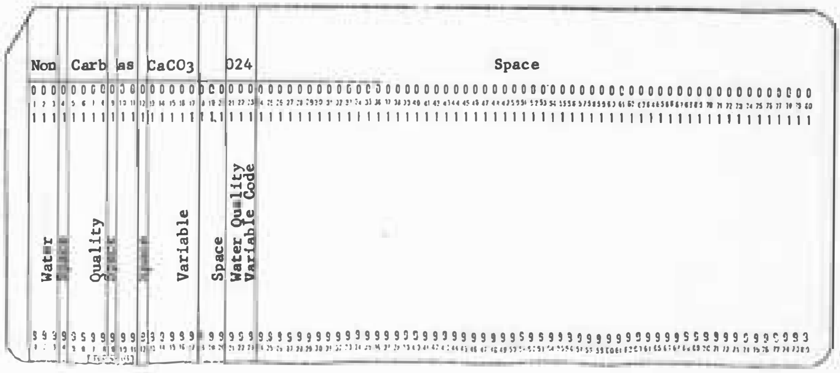


Figure 25.4
Card XXV

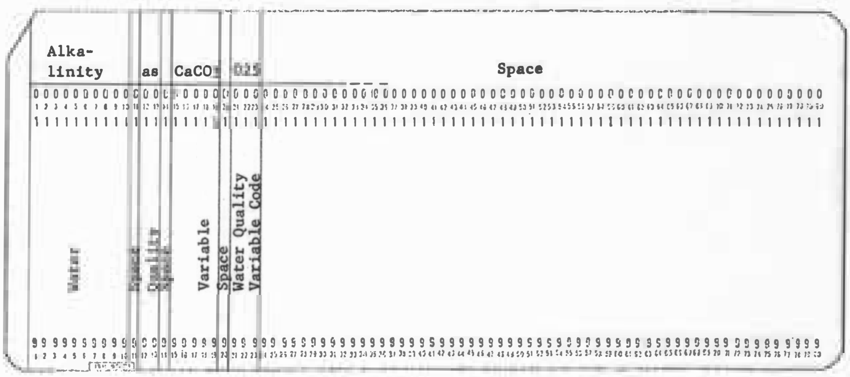


Figure 26.4
Card XXVI

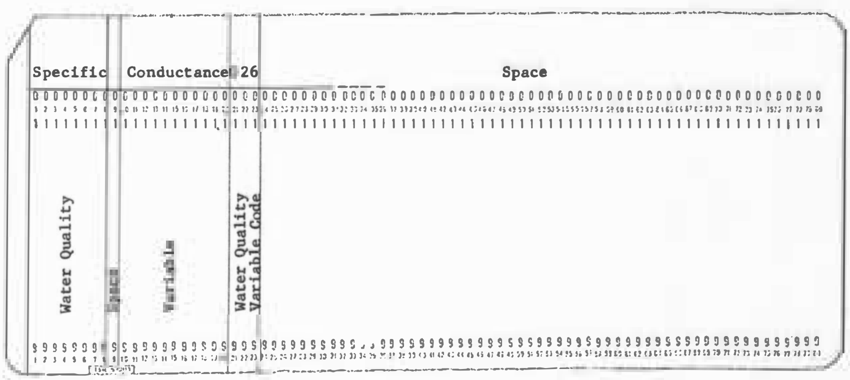


Figure 27.4
Card XXVII

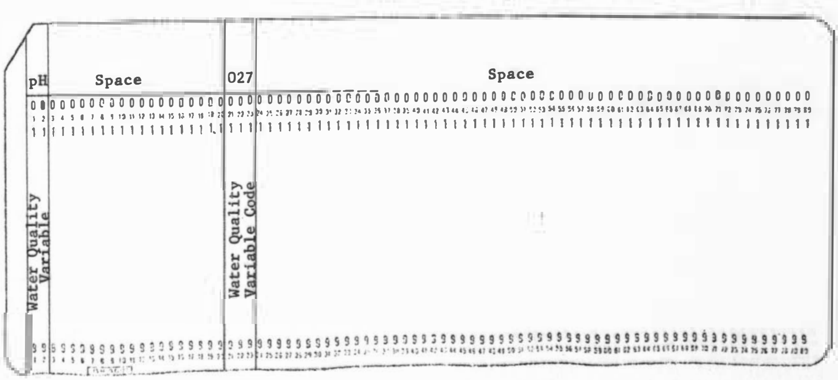


Figure 28.4
Card XXVIII

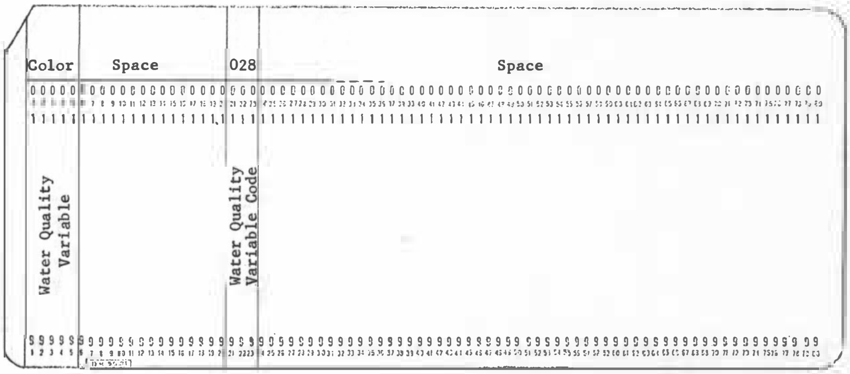


Figure 29.4
Card XXIX

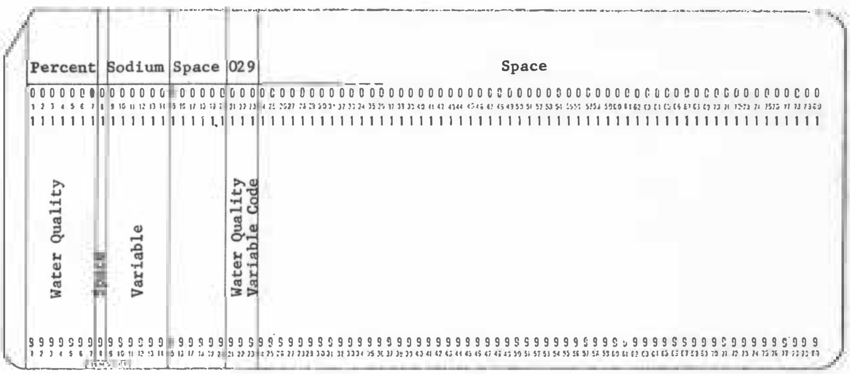


Figure 30.4
Card XXX

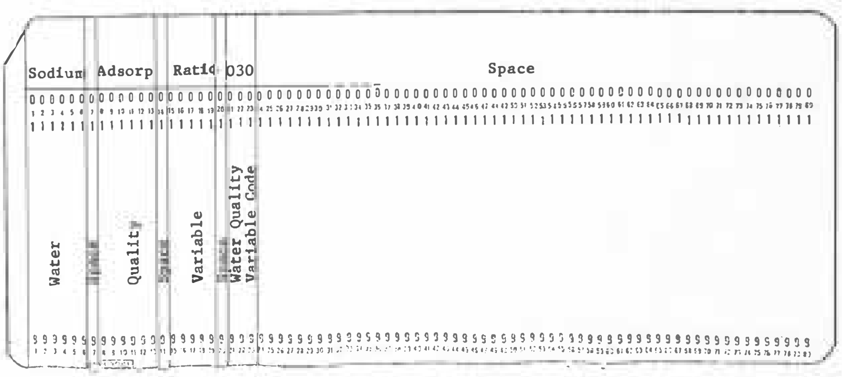


Figure 31.4
Card XXXI

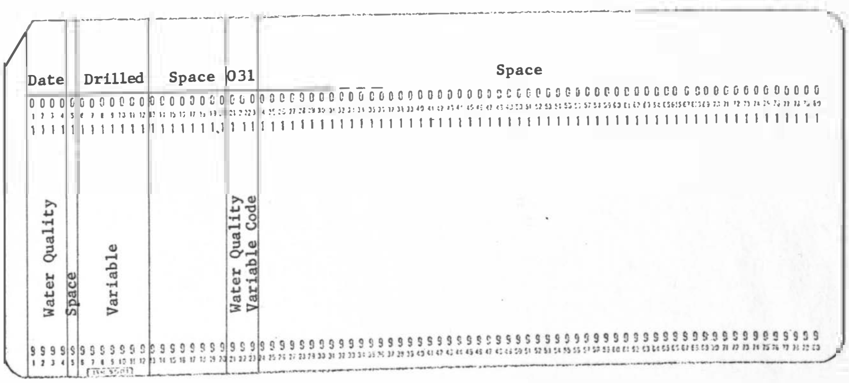


Figure 32.4
Card XXXII

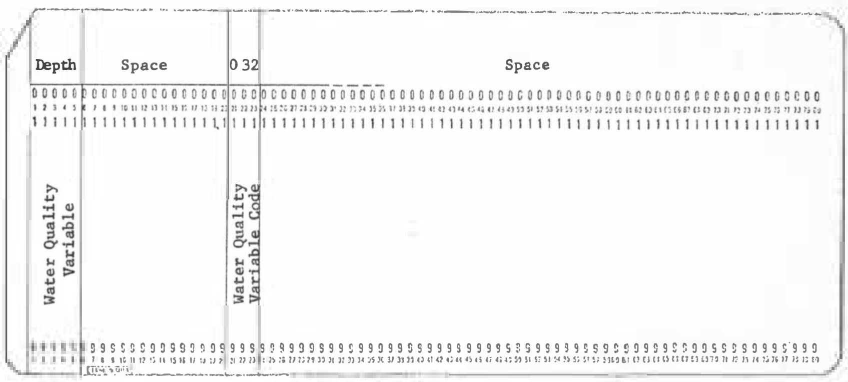


Figure 33.4
Card XXXIII

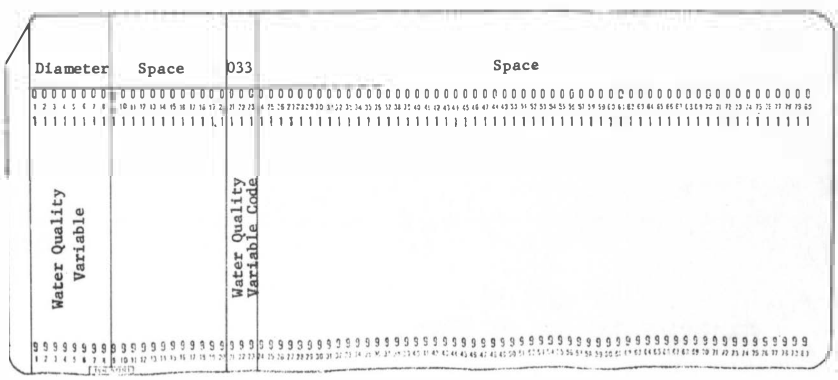


Figure 34.4
Card XXXIV

# APPENDIX V.
# WATER SAMPLE SORTER PROGRAM

```
ZZJOB 5                    WATER SAMPLE SORTER
ZZFORX5
      DIMENSION KODE(50),ITEM(50),BOTOM(50),TABLE(100,5),DATA(50,2)      *
      DIMENSION DAT(4,2),TOP(50),ID(4)
C     BEGIN INITIALIZATION OF TABLES
  500 DO 1 I=1,50
      KODE(I)=0
      ITEM(I)=0
      BOTOM(I)=0.0
   13 TOP(I)=0.
    1 CONTINUE
      DO 38 I=1,50
      DO 38 J=1,5
   38 TABLE (I,J)=0.0
      READ 2,N
      DO 3 I=1,N
    3 READ4,(TABLE(I,J),J=1,5)
    2 FORMAT(I4)
    4 FORMAT(5A4)
      IMIN=0
      K=
      I=1
   20 READ 5,TYPE,VARA,VARB,VARC,VARD,VARE,BOTOM(I),TOP(I)
    5 FORMAT(A4,2X,5A4,2F10.2)
      IF(TYPE-.49460000)7,6,7
    7 IF(TYPE-.56590049)9,8,9
    9 IF(TYPE-.41554400)11,10,11
   11 IF(TYPE-.62416545)203,12,203
  203 TYPE 14
   14 FORMAT(24H IMPROPER STATEMENT TYPE)
      PAUSE
      GO TO 20
    6 KODE(I)=1
      GO TO 30
```

```
 8 KODE(I)=2
   GO TO 30
10 KODE(I)=3
   GO TO 30
12 KODE(I)=4
   IMIN=I
30 DO 31 J=1,100
   IF(VARA-TABLE(J,1))31,32,31
32 IF(VARB-TABLE(J,2))31,33,31
33 IF(VARC-TABLE(J,3))31,34,31
34 IF(VARD-TABLE(J,4))31,35,31
35 IF(VARE-TABLE(J,5))31,36,31
36 ITEM(I)=J
   GO TO 40
31 CONTINUE
   PRINT 37
37 FORMAT(22H VARIABLE NOT IN TABLE)
   PAUSE
   GO TO 20
40 IF(KODE(I)-4)41,42,41
42 K=1
41 IF(K)46,46,43
43 READ 44,VARA,VARB,VARC,VARD,VARE
44 FORMAT(6X,5A4)
   IF(VARA)49,45,49
46 I=I+1
   IF(I-50)20,20,47
47 PRINT 48
48 FORMAT(17H PROGRAM TOO LONG)
   PAUSE
   GO TO 500
49 I=I+1
   IF(I-50)30,30,47
45 IMAX=I
```

```
C      THIS IS WHERE PROGRAM
C      BEGINS STORING A SET OF DATA.
   600 DO 100 I=1,IMAX
       DO 100 J=1,2
   100 DATA(I,J)=-99999.
       READ 101,NUM
   101 FORMAT(I3)
       IF (NUM) 128,128,102
   102 DO 105 I=1,NUM
       READ 104,(ID(J),DAT(J,1),DAT(J,2),J=1,4)
   104 FORMAT(4(I3,2A4,9X))
       DO 105 J=1,4
       IF(ID(J)-999)106,700,106
   106 K=1
   107 IF(ID(J)-ITEM(K))108,109,108
   109 DATA(K,1)=DAT(J,1)
       DATA(K,2)=DAT(J,2)
   108 IF(K-IMAX)110,105,105
   110 K=K+1
       GO TO 107
   105 CONTINUE
   128 READ 121,(ID(I),DAT(I,1),I=1,4)
   121 FORMAT(4(I3,E17.8))
       DO 122 I=1,4
       IF(ID(I)-999)123,700,123
   123 J=1
   124 IF(ID(I)-ITEM(J))126,125,126
   125 DATA(J,1)=DAT(I,1)
   126 IF(J-IMAX)127,122,122
   127 J=J+1
       GO TO 124
   122 CONTINUE
       GO TO 128
```

```
C      BEGIN TEST OF DATA
   700 J=1
   703 IF(KODE(J)-1)702,701,702
   701 IF (DATA(J,1)-BOTOM(J)) 704,705,705
   705 IF(DATA(J,1)-TOP(J))706,706,704
   702 IF (KODE(J)-4) 777,800,777
   777 J=J+1
       IF (J-IMIN) 703,703,805
   706 J=J+1
       IF (J-IMIN) 750,750,805
   750 IF (KODE(J)-3) 703,707,703
   707 IF (DATA(J,1)-BOTOM(J)) 704,708,708
   708 IF(DATA(J,1)-TOP(J))706,706,704
   704 J=J+1
       IF (J-IMIN) 751,751,805
   751 IF (KODE(J)-2) 710,709,71
   709 IF (DATA(J,1)-BOTOM(J)) 704,711,711
   711 IF(DATA(J,1)-TOP(J))706,706,704
   710 IF(KODE(J)-1)712,600,712
   712 IF (KODE(J)-4) 704,600,704
   800 IF (IMIN) 801,805,801
   805 PRINT 806
   806 FORMAT(19HNO SAVE INSTRUCTION)
       PAUSE
       GO TO 500
C      BEGIN PRINTING SAVED VALUES
   801 DO 807 I=IMIN,IMAX
       J=ITEM(I)
   807 PRINT 808,(TABLE(J,K),K=1,5),DATA(I,1)
   808 FORMAT(5A4,E14.8)
       PRINT 809
   809 FORMAT(2H  )
       GO TO 600
       END
```

# APPENDIX VI.
# TRANSLATOR PROGRAM

```
ZZJOB 5                    TRANSLATOR
ZZFORX5
  101 FORMAT (10X,I3,1X,I2,1X,I2,21X,F7.0,6X,F6.3,4X,F6.3,4X,F6.3)      *
  102 FORMAT (10X,F6.2,2X,F6.2,2X,F7.2,2X,F6.2,2X,F7.2,3X,F5.2,3X,F7.2,3*
     1X,F7.2)
  200 FORMAT (10X,A3,1X,A2,1X,A2,1X,A4,6X,A4,6X,A4,9X,A4,6X,A4,6X,A4)   *
  201 FORMAT (10X,A4,4X,A4,4X,A4,5X,A4,4X,A4,6X,A4,4X,A4,6X,A4)         *
  202 FORMAT (10X,A4,2X,A4,4X,A4,3X,A4,6X,A4,6X,A4,6X,A4,7X,A4)         *
  203 FORMAT (12X,A4,4X,A3,4X,A2,4X,A4,5X,A4,4X,A4,7X,A4,9X,A4)         *
  400 FORMAT (20X,A4,A2,4X,A4,A2)
  105 FORMAT (10X,F4.2,2X,F6.2,2X,F5.2,2X,F7.2,3X,F6.1,4X,F7.2,3X,F7.2,4*
     1X,F5.1)
  106 FORMAT (11X,F7.1,2X,F3.1,4X,F2.1,4X,F5.2,4X,F6.2,2X,F7.0,4X,F7.2,6*
     1X,F5.3)
  401 FORMAT (3X,A4)
  402 FORMAT(3X,A3)
  403 FORMAT(18X,A4)
  100 FORMAT (6HRELOAD)
  109 FORMAT(4(I3,F15.5,2X))
  110 FORMAT(3H000)
  111 FORMAT (3H004,A4,A2,9X,3H005,A4,A2)
  112 FORMAT (3H004,A4,A2)
  113 FORMAT (3H005,A4,A2)
  116 FORMAT(3H999)
  117 FORMAT(I3,F15.5,2X,3H999)
  118 FORMAT(I3,F15.5,2X,I3,F15.5,2X,3H999)
  130 FORMAT(3H001)
  505 FORMAT(I3,F15.5,2X,I3,F15.5,2X,I3,F15.5,2X,3H999)
  506 FORMAT(I3,F15.5,2X,I3,F15.5,2X,I3,F15.5,2X,I3,F15.5)
      DIMENSION Z(33)
      DIMENSION QUE(8)
      DIMENSION DATA(33,8)
      DIMENSION TRUE (33,8)
      DIMENSION D(34,8)
```

```
      DIMENSION A(33,8)
      DIMENSION B(7,8)
      DIMENSION THERE(7,8)
    5 DO 11 II=1,8
      READ 400,B(1,II),B(2,II),B(3,II),B(4,II)
      READ 401,B(5,II)
      READ 402,B(6,II)
      READ 403,B(7,II)
   11 CONTINUE
      DO 12 IJ=1,8
      DO 12 IK=1,7
      IF (B(IK,IJ)) 14,15,14
   15 THERE(IK,IJ)=0.
      GO TO 12
   14 THERE(IK,IJ)=1.
   12 CONTINUE
      DO 13 IL=1,8
      IF(THERE(1,IL))26,26,27
   26 IF(THERE(3,IL))28,28,29
   28 QUE(IL)=0.
      GO TO 13
   27 IF(THERE(3,IL))128,128,127
  127 QUE(IL)=4.
      GO TO 13
   29 QUE(IL)=3.
      GO TO 13
  128 QUE(IL)=1.
   13 CONTINUE
      PRINT 100
      PAUSE
      DO 20 N=1,8
      READ 200,(DATA(M,N),M=1,9)
      READ 201,(DATA(M,N),M=10,17)
      READ 202,(DATA(M,N),M=18,25)
```

```
      READ 203,(DATA(M,N),M=26,33)
   20 CONTINUE
      DO 10 N=1,8
      DO 22 M=1,33
      IF(DATA(M,N))24,23,24
   23 TRUE(M,N)=0.
      GO TO 22
   24 TRUE(M,N)=1.
   22 CONTINUE
      TRUE(4,N)=0.
      TRUE(5,N)=0.
   10 CONTINUE
      PRINT 100
      PAUSE
      DO 35 N=1,8
      READ 101,D(1,N),D(2,N),D(3,N),D(6,N),D(7,N),D(8,N),D(9,N)          *
      READ 102,(D(M,N),M=10,17)
      READ 105,(D(M,N),M=18,25)
      READ 106,(D(M,N),M=26,33)
   35 CONTINUE
      IX=6
      DO 40 K=1,8
      Y=D(IX,K)
      W=Y/100.
      I=W
      V=I
      C=V*100.
      X=Y-C
      F=X*10000.
      G=F+V
      IX=6
      D(IX,K)=G
   40 CONTINUE
      DO 9999 I=1,8
      IF(QUE(I)-1.)45,46,46
```

```
   45 PUNCH 110
      GO TO 49
   46 PUNCH 130
   49 IF(QUE(I)-1.)50,51,52
   50 GO TO 55
   51 PUNCH 112,B(1,I),B(2,I)
      GO TO 55
   52 IF(QUE(I)-3.)53,54,56
   56 PUNCH 111,B(1,I),B(2,I),B(3,I),B(4,I)
      GO TO 55
   53 GO TO 55
   54 PUNCH 113,B(3,I),B(4,I)
   55 CONTINUE
      M=1
      DO 9998 K=1,33
      IF(TRUE(K,I))60,60,61
   60 GO TO 9998
   61 CONTINUE
      A(M,I)=D(K,I)
      Z(M)=K
      M=M+1
 9998 CONTINUE
   74 SAVEA1=0.
      K=
   75 K=K+1
      IF (TRUE(K,I)) 77,77,78
   77 GO TO 76
   78 SAVEA1=SAVEA1+1.
   76 IF(K-33)75,80,8
   80 AFNL=SAVEA1/4.
      IL=AFNL
      P=IL*4
      C=SAVEA1-P
      IF(C)81,82,81
   82 HERE=0.
```

```
      GO TO 1
   81 IF(C-1.)83,84,83
   84 HERE=1.
      GO TO 1
   83 IF(C-2.)85,86,85
   86 HERE=2.
      GO TO 1
   85 IF(C-3.)89,88,89
   88 HERE=3.
      GO TO 1
   89 PAUSE
    1 M=1
      DO 90 K=1,IL
      M1=M+1
      M2=M+2
      M3=M+3
      PUNCH 109,Z(M),A(M,I),Z(M1),A(M1,I),Z(M2),A(M2,I),Z(M3),A(M3,I)    *
      M=M+4
   90 CONTINUE
      M1=M+1
      M2=M+2
   92 IF(HERE-1.)  91,93,94
   91 PUNCH 116
      GO TO 9999
   93 PUNCH 117,Z(M),A(M,I)
      GO TO 9999
   94 IF(HERE-3.)98,97,9999
   98 PUNCH 118,Z(M),A(M,I),Z(M1),A(M1,I)
      GO TO 9999
   97 PUNCH 505,Z(M),A(M,I),Z(M1),A(M1,I),Z(M2),A(M2,I)
      GO TO 9999
 9999 CONTINUE
      GO TO 5
      END
```

APPENDIX VII.
PRINTED FORM OF TABLE

| | |
|---|---|
| 0033 | |
| TOWNSHIP | 01 |
| RANGE | 02 |
| SECTION | 03 |
| SUB-SECTION | 04 |
| SAMPLE NUMBER | 05 |
| DATE OF COLLECTION | 006 |
| SILICA | 07 |
| IRON | 08 |
| MANGANESE | 09 |
| CALCIUM | 10 |
| MAGNESIUM | 11 |
| SODIUM | 12 |
| POTASSIUM | 13 |
| BICARBONATE | 14 |
| CARBONATE | 15 |
| SULFATE | 16 |
| CHLORIDE | 17 |
| FLUORIDE | 18 |
| NITRATE | 19 |
| BORON | 20 |
| DISSOLVED SOL CALC | 021 |
| RESIDUE ON EVAP | 22 |
| HARDNESS AS CACO3 | 023 |
| NON CARB AS CACO3 | 024 |
| ALKALINITY AS CACO3 | 025 |
| SPECIFIC CONDUCTANCE | 026 |
| PH | 27 |
| COLOR | 28 |
| PERCENT SODIUM | 29 |
| SODIUM ADSORP RATIO | 030 |
| DATE DRILLED | 31 |
| DEPTH | 32 |
| DIAMETER | 33 |