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Presidential Address: Present Geological Research on Ground-Water Resources in Iowa

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Present Geological Research on Ground-Water Resources in Iowa*

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In the presidential address of 1938 before this Academy and in the presence of many of you, A. C. Trowbridge outlined our water problems with the thought that generally such problems can best be solved after they have been brought out into the open. He was correct in his thinking and many of the problems that he recognized are now on the way to solution.

Our water situation has changed so vastly in the intervening 16 years that it is apropos again to examine it. However, the mass of data is now so great that I shall attempt to discuss only one phase—ground water.

In Iowa, as elsewhere, geological research on ground-water has expanded at a greatly increased rate during the past two decades because of the ever increasing demands for water by industry and agriculture, a growing awareness of its importance in economic development, and the successful and sometimes dramatic application of techniques and skills in the solution of problems.

Inasmuch as ground water occurs in rocks and its quality and availability are controlled largely by the rocks, research in ground-water resources is pre-eminently a geologic problem. This research involves most phases of geology although much is adapted from the related fields of engineering, chemistry, physics, mathematics and soil science in such a way that these adaptations must be considered to be a part of geological research. As a result, ground-water geology has developed specialized techniques, instruments, prinicples, and personnel to meet the need and demand that was early recognized in this State.

Geology

The purely geological phases of ground-water research are the determination of thickness, areal extent, lithology and mineralogy, geologic history, correlation, structural relations, and facies changes of rock formations. These are determined by application

*The presidential address delivered at the first general session of the 1954 meeting of the Iowa Academy of Science.

of well-known techniques of surface and subsurface stratigraphy, sedimentology, petrology, and structural geology, supplemented by some aspects of geomorphology, geochemistry, geophysics, and pedology.

Methods and values of surface geologic mapping are so well known that they will not be given more than passing notice here. Commonly, the ground-water geologist has only to add to the prior geologic mapping, but in cases where no adequate maps have been made he must start from scratch. In either event, the ground-water geologist follows normal procedures except that he pays more attention to and gathers more data on the water-bearing and transmission possibilities of the rocks, their potential ability to stand uncased in a drill hole, and the presence or evidence of the more soluble minerals and other features important to the finding and development of usable ground water.

Although a knowledge of the surface geology is valuable, subsurface geological data are more important to the ground-water geologist. Samples of well cuttings and cores are the chief sources of subsurface geologic information and are supplemented by geophysical data. These samples are studied principally with the binocular microscope, and the results plotted on graphic strip logs with a rather detailed description of each rock unit or individual sample, including type of rock, texture, composition, and fossil content.

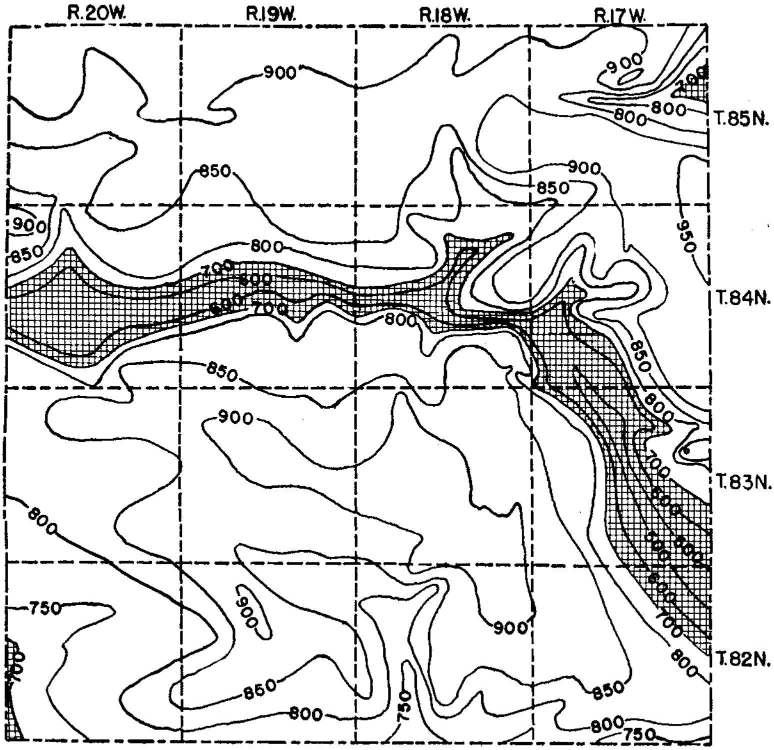
There are no governmentally owned or operated standard drilling rigs in Iowa, and well cutting samples are derived entirely from other sources. These cuttings may come from holes drilled for water, oil, coal, tests for metals, and in fact, from almost any drilling, excavation or mining project. By necessity, they are obtained whenever and wherever available and not always do they fill an immediate need. It would be more efficient if the State owned well drilling equipment. This would permit the geologist or engineer to plan a drilling campaign at the time and place and for the information required at the moment.

Well-cutting and core studies yield information as to the thickness, texture, lithology and mineralogy of individual beds at the well site. From these facts, along with the driller's log and his report on the behavior of water levels during drilling, there can be obtained some indication of the water-bearing characteristics of such aquifers (water-bearing beds) as may be present. When the plotted information is compared and correlated with that from other holes and exposures, the areal extent, structural relations, facies changes, and commonly some features of the geologic history are ascertainable for the bed or beds penetrated.

The ultimate aim of such studies is to identify and map the water-yielding and non-water-yielding beds and to accumulate data whereby the occurrence, quality, and yield over a period of time can be estimated for the area being investigated.

There is a vast difference between the water-bearing and the water-yielding ability of rock formations. Shales often contain as much water as sandstones or limestones, but shales transmit and yield water to wells in only negligible quantities; whereas limestones, sandstones, sands and gravels may transmit rapidly and yield large quantities of water to wells.

It is standard practice to plot as many of the foregoing features as possible on maps or charts. Thus in glaciated country, for example, one aim is to prepare a map or maps of the area under



MARSHALL COUNTY
ALTITUDE OF BEDROCK SURFACE
Contour Interval 50 Feet

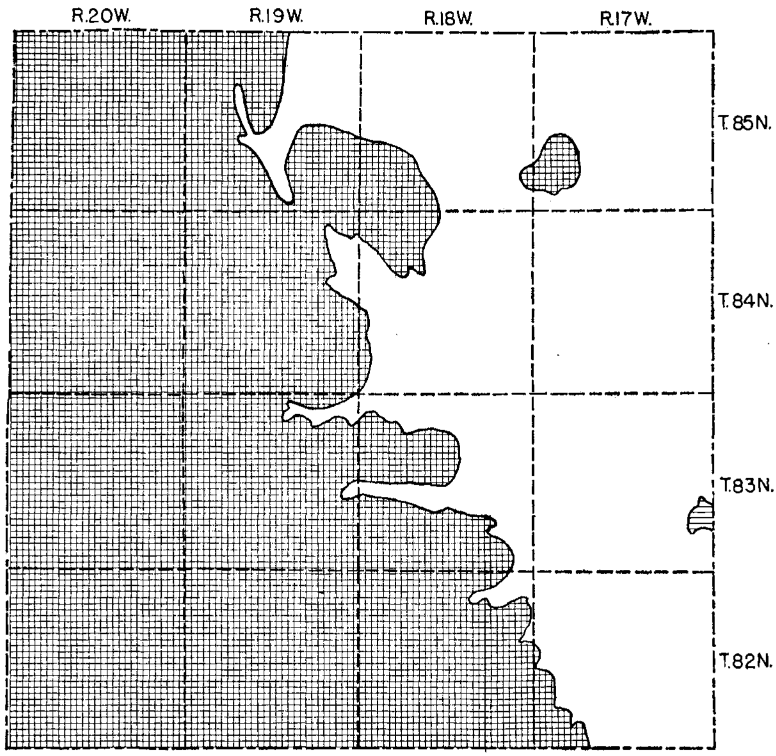
Figure 1.

study showing the thickness of unconsolidated material above bedrock and a surface contour map of the bedrock surface.

A contour map of the bedrock surface in Marshall County is shown by figure 1. The thickness of the glacial drift ranges from 375 feet in the sub-surface glacial valley to a feather edge at surface exposures of bedrock. Desirable and useful also are structure or surface contour maps on key beds and isopachous or thickness maps of important units.

These purely geologic data serve as an essential basis for further hydrologic study and interpretation of the ground-water conditions; and moreover, they commonly constitute a major part of general geologic knowledge in an area.

For example, a subareal geologic map of Marshall County was published in 1934 (fig. 2). It was based on the 20 rock exposures



MARSHALL COUNTY
AREAL GEOLOGIC MAP, 1931
PENNSYLVANIAN
MISSISSIPPIAN
Hampton Maple Mill

Figure 2.

and 10 drill holes then available. Recently a new map was prepared based on the original 20 rock exposures and more than three hundred newly acquired drill holes (fig 3).
This new map (fig. 4) made available in usable form considerably more detailed information for those who utilize such data, including well drillers, quarrymen, construction contractors and pipeliners, as well as geologists.

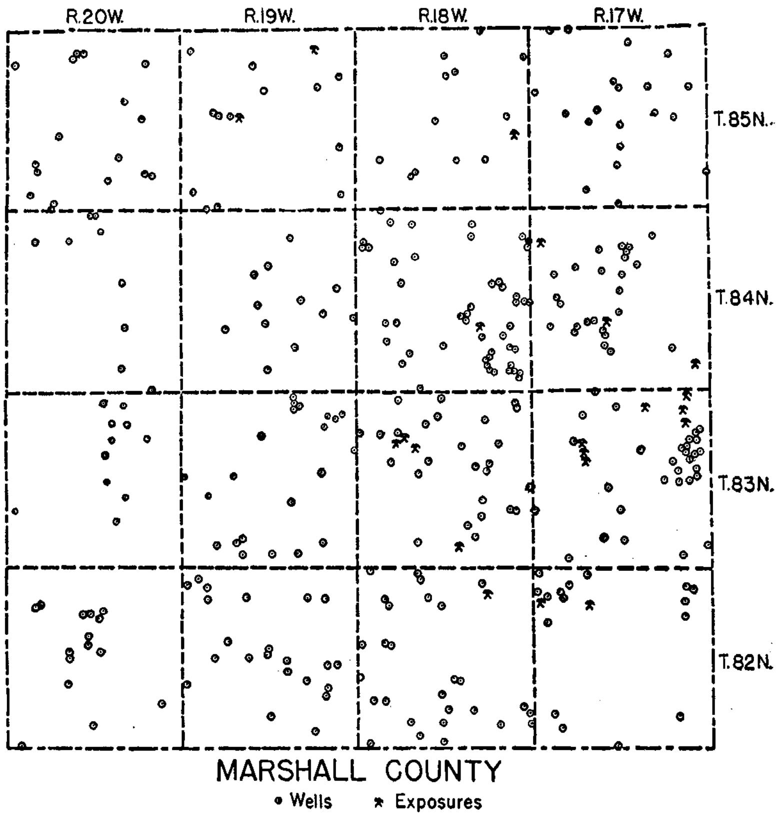
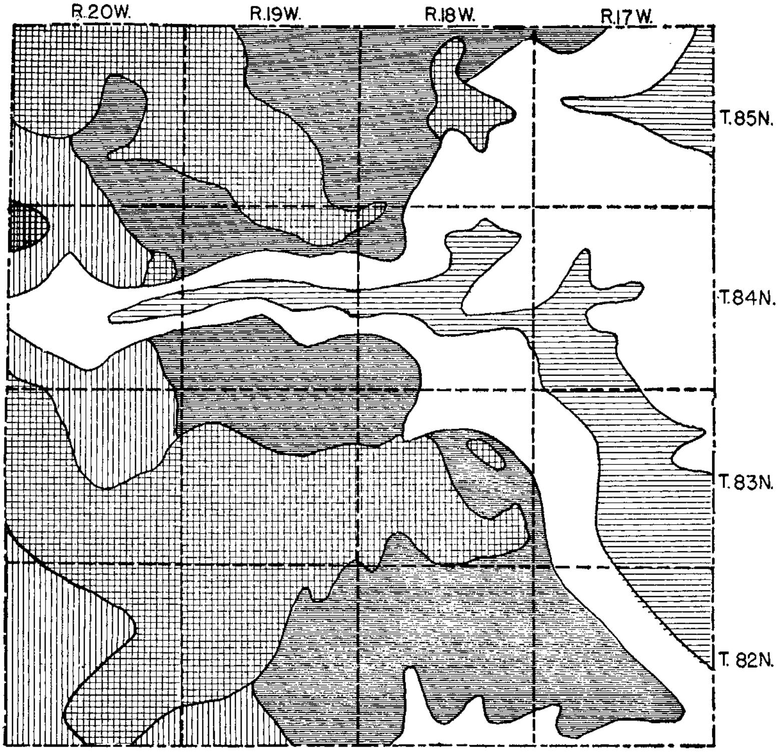


Figure 3.

Hydrology

The movement of water underground and into wells is relatively simple in broad outline but highly complex to determine in detail. Pumping tests on wells have become increasingly important in recent years in advancing our knowledge of these movements and in matters of recharge, storage, and discharge of aquifers. In this phase of ground-water research, engineering and mathematics play a leading role.



MARSHALL COUNTY
AREAL GEOLOGIC MAP, 1954

PENNSYLVANIAN
MISSISSIPPIAN

St. Louis
Gilmore City-Hampton
Warsaw-Keokuk-Burlington
Maple Mill

Figure 4.

For intelligent planning of an underground water supply, particularly where large volumes are concerned, it is desirable to know how much water can be pumped or withdrawn over a short period of time and how much is available over a period of years or a long indefinite period. The hydrologic characteristics of aquifers that are critical to this problem are the water-transmitting ability or "transmissibility" and the storage capacity or "specific yield" and "coefficient of storage" for water table and artesian conditions respectively. Other factors such as extent, recharge, and discharge are also important.

Formulas developed since 1935 are now available to answer these questions from information on local geology and pumping-test data, involving drawdown, rate of discharge, time of pumping, and well construction. In addition the "hydrologic constants" obtainable through these formulas afford a means of making estimates of the extent and amount of drawdown, as well as the degree of interference with other wells. The yield and drawdown after selected periods of pumping can be estimated by substituting appropriate values in the equations, which are further useful in solving still other well, ground-water and drainage problems. These quantitative techniques are adaptable to the many varying conditions encountered in nature if they are applied with adequate regard for the local geologic conditions and the assumptions and limitations inherent in the formulas.

The philosophies behind the development of thinking and research on ground-water hydrology in modern times are interesting. Early in this century, wells were drilled almost without exception on a hit-or-miss basis. Later, inventories were made of existing wells for such features as depth, log, static water level, and production. Assumptions were then made that new wells drilled to the same depth or to the same aquifer as existing wells would produce approximately the same quantity of water of similar quality. Full consideration was not given to several important factors including maximum safe yield of the aquifer or aquifers and other critical features. After about 1935, the practice prevailed of making quantitative studies on individual wells such as mathematical approximations to obtain quantitative determination of interrelations between storage capacity, discharge and recharge. This collection and interpretation of quantitative data expanded first to more than one well as for example those within a well field then to those within larger areas as a town or city and its environs, until now the ultimate aim is to obtain the necessary data to understand the hydrology of entire large aquifers. Furthermore, it is now recognized that we must carry on our investigations so that we understand and evaluate our water resources on a state and national as well as a local basis.

Geophysics

Geophysical instruments and techniques are being used as added tools in ground-water research. Resistivity methods have been widely employed nationally for some years; more recently seismic methods and electrical well logging have come into considerable use with reasonable success.

In Iowa, surface resistivity has been employed in locating top of bedrock and buried channels, but it is limited as to the depth to which it is effective. For this and other reasons, the resistivity methods has been discontinued. The well-known seismic methods are too expensive for use in Iowa at the present time for both the Federal and State Geological Surveys. Commercial electrical well logging is also too costly for general use, but the Iowa Geological Survey is operating its own well logging unit.

This mobile unit is housed in a 1½-ton vanette type truck (fig 5). The four-conductor cable, (fig 6), 3,000 feet in length,

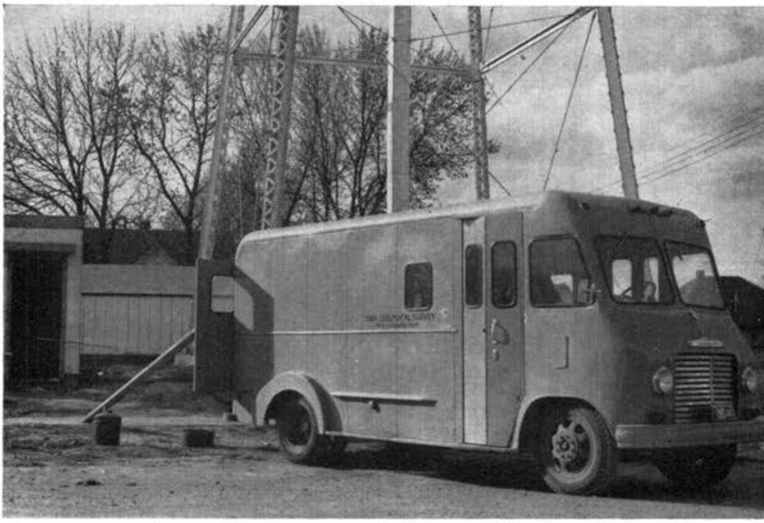


Figure 5. Vanette type truck housing well logging unit.

is powered in and out of the bore hole by means of a power take-off on the truck. A generator supplies 110-volt alternating current for locations where electrical power is not available. "Down-the-hole instruments" being used at present consist of a caliper, current meter, fluid resistivity meter, resistance thermometer, and electrical-logging electrodes (fig. 7). A recording meter permits making permanent records, and the chart can be operated on either a time or a depth basis (fig. 8).

This equipment is used chiefly to determine the depth to water-bearing and non-water-bearing beds, depth, temperature, approximate mineralogical quality of water, and in multi-aquifer wells the direction and amount of underground flow where the water in separate aquifers is under different heads. It is also used to find caved points, casing, and the position and amount of leaks in wells.

Observation Wells

Observation-well programs, when properly executed, are of

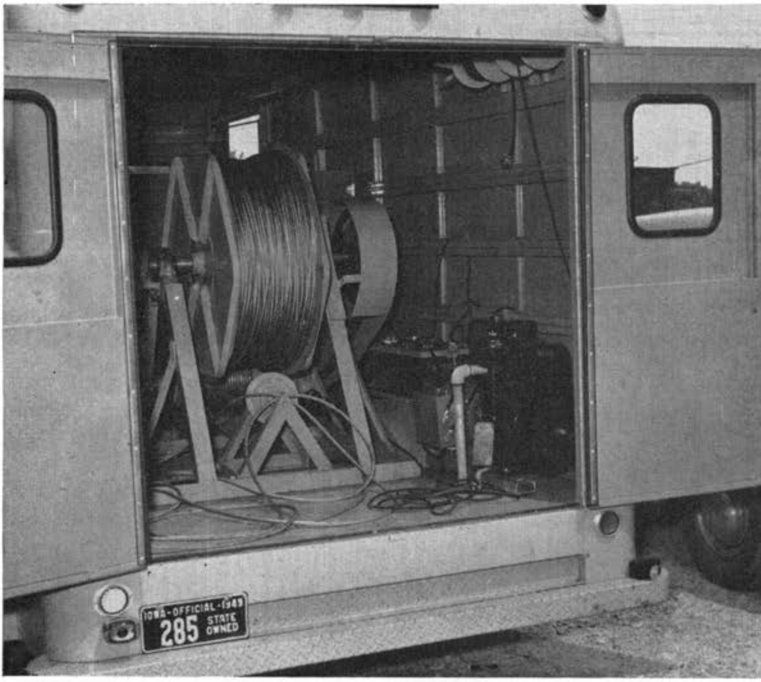


Figure 6. Four conductor cable, mounting and 110-volt a.c. generating equipment.

fundamental importance in the over-all research on ground water. The Iowa program consists of measuring, recording and reporting the fluctuations of water levels in 150 relatively shallow wells penetrating the water table, and 20 deeper wells penetrating artesian aquifers. Some measurements are made continuously, others periodically; some instrumentally, others manually. The data obtained are useful in a number of ways, for example; they may, 1. provide a day-to-day evaluation of available water supply. 2. facilitate the prediction of trends in ground-water levels and the future availability of ground water, 3. delineate the present or potential areas

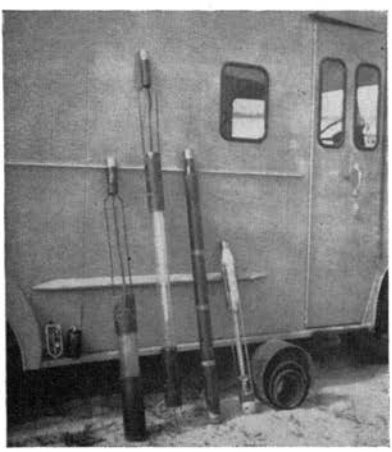


Figure 7. "Down-the-hole instruments used in electrical well logging, including flow meter, flow meter housing, fluid conductivity electrode, electric logging electrode, and caliper. Temperature electrode not shown.

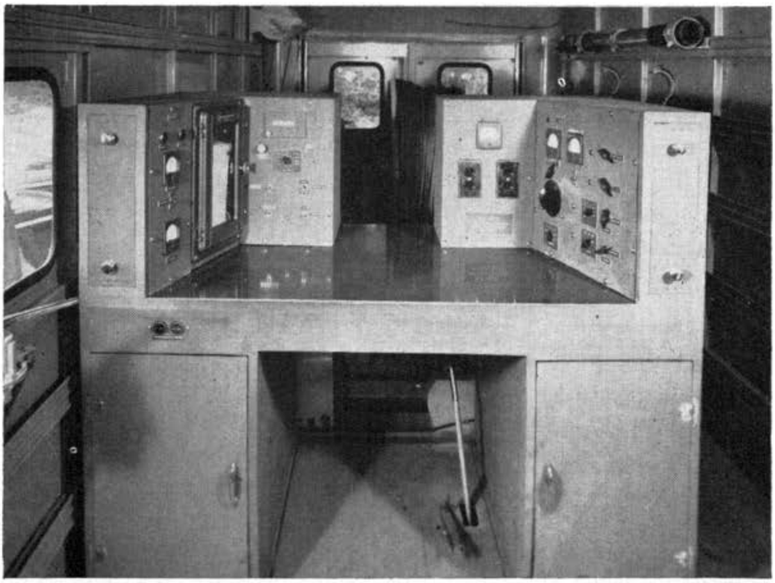


Figure 8. Instrument panel including continuous automatic recorder at right.

of detrimentally high or low water, and 4. aid in the determination of base flow and other features of streams.

Important relationships between rainfall, evaporation and transpiration, infiltration and recharge can be determined from observation-well, stream flow and precipitation data. Similarly, badly needed information on several phases of the effects of soil erosion prevention and water run-off retardation (now so important in our national economy) can be ascertained when correlated with records of precipitation and stream flow. Cooperative efforts along these lines are just getting under way.

Temperature

Temperature is an important property of ground water. The role that it plays in air conditioning and cooling is well known. In natural and artificial recharging, temperature is a vital factor in that it affects water viscosity about 1.5 percent per degree Fahrenheit. A rise of one degree in temperature decreases the viscosity 1.5 percent. Temperature has been used in tracing effects of recharge and in locating leaks in wells, and it is also a factor in the mineral content of water.

Mineral Quality

The mineral quality of ground waters affects importantly their suitability for domestic, industrial, and other uses. Considerable attention is directed toward this phase of ground-water research in Iowa, and an inventory of the mineral content of available waters has been published. Comparatively little has been done as yet to interpret these chemical analyses nor have comprehensive state-wide studies been made to devise the best ways and means of beneficiating ground waters with objectionably high mineral content.

Acknowledgments and Conclusions

By law, the Iowa Geological Survey is charged with the collection and dissemination of basic geologic and water resources data for the State. In ground water, much of this work has been carried on since 1937 in formal cooperation with the U. S. Geological Survey. The State Department of Health, the State Conservation Commission, and the State Hygienic Laboratory have cooperated formally and informally. Other State and Federal agencies have taken part on an informal basis, notably the Iowa Natural Resources Council, the Soil Conservation Service, the Extension Service of Iowa State College, and the State Highway Commission.

Solution of our ground-water problems today depends primarily on careful geological work and the determination of the hydrologic characteristics of water-bearing rock formations. In this endeavor, geology and hydrology are undivorceably related.

It is evident not only that geologic research is fundamental in ground-water investigations, but that adequately planned and executed ground-water studies contribute importantly to fundamental geologic knowledge.

Some techniques in ground-water hydrology, as pumping tests and geochemical studies for example, constitute methods of solving geologic problems that are not resolved readily by older established techniques.

In my opinion, continuation and expansion of all phases of ground-water research is economically justifiable and will be scientifically rewarding. Such a research program must have the full cooperation of all interested groups if Iowa is to maintain the necessary leadership in the water resources and allied fields which almost daily are growing more vital to the State.

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