

**SECOND  
REPORT**

of the

**NEW JERSEY**

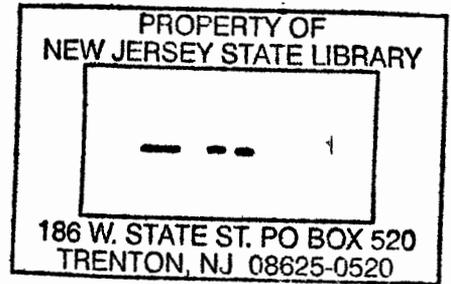
**WATER RESOURCES**

**ADVISORY COMMITTEE.**

**MAY 14, 1958**

PROPERTY OF  
RECEIVED  
JAN 24 1961  
Division of State Library,  
Archives and History  
TRENTON

**DEPOSITORY COPY**  
Do Not Remove From Library





May 14, 1958

Hon. Joseph E. McLean, Commissioner  
Department of Conservation and Economic Development  
State House Annex  
Trenton 7, New Jersey

Dear Commissioner McLean:

The Water Resources Advisory Committee appointed by you in September, 1956, is glad to submit this Second Report. It represents the Committee's survey of what needs to be done by the State to obtain data on which to develop a program for profitable use and protection of ground-water resources.

This Second Report includes a statement by the Committee and a detailed program for investigation of ground-water resources by Leggette, Brashears & Graham, our ground water consultants on this phase of our work.

The Advisory Committee in its First Report on surface water resources in April, 1957, recognized the considerable underground water resources throughout the State and particularly in southern New Jersey. Any long-range program to meet New Jersey's expanding needs for new water supplies must necessarily include development of both surface and underground water resources.

The Committee appreciates the assistance and cooperation of Administration officials, members of the Legislature and many public-spirited persons who have helped in this ground-water resources program. We are pleased to see that the main points in the report have been written into legislative acts that have been adopted by the Legislature and signed by the Governor.

FOR THE WATER RESOURCES ADVISORY COMMITTEE

George F. Smith, Chairman



# NEW JERSEY WATER RESOURCES ADVISORY COMMITTEE

## SECOND REPORT

### TABLE OF CONTENTS

	Page
I. COMMITTEE REPORT AND RECOMMENDATIONS .....	1
II. EXHIBITS	
A. Membership List of Committee .....	3
B. Financial Contributors to the Committee .....	4
C. Proposed Program of Investigation submitted by Leggette, Brashears & Graham .....	5
III. MAP AND FIGURE	
Map Showing Ground-Water Provinces of New Jersey....	6
Figure Showing Generalized Geologic Cross Section from Philadelphia to Atlantic City .....	7





## **SECOND REPORT OF NEW JERSEY'S WATER RESOURCES**

**by the**

### **NEW JERSEY WATER RESOURCES ADVISORY COMMITTEE**

#### **New Jersey's Water Resources**

The New Jersey Water Resources Advisory Committee in its earlier study of surface water resources of the State, recognized the considerable underground water resources available throughout the State, particularly in southern New Jersey. Any long-range program to meet New Jersey's expanding needs for new water supplies must necessarily include development of both surface and underground water supplies.

The Committee's First Report, April 25, 1957, included a preliminary account of New Jersey's ground-water resources. This Second Report outlines what must be done if the State is to obtain the basic hydrologic and geologic data on which to develop a program for profitable use and protection of these ground-water resources.

#### **The Underground Water Situation**

No comprehensive program to guide the safe development of New Jersey's underground water resources is in existence. A limited amount of information on underground water supplies has been collected over the past 30 years by the U. S. Geological Survey and by the New Jersey Division of Water Policy and Supply of the Department of Conservation and Economic Development. Because of shortage of funds and personnel, investigations have been limited to critical areas where wells have been subject to heavy pumpage or where salt water intrusion has endangered or threatened to endanger the aquifers. An expanded program of ground-water investigation initiated in 1956 by the two government agencies has been confined thus far to critical areas in southern New Jersey and to studies to determine the potential of the underground water resources in the huge Wharton Tract purchased by the State in 1952.

The need for ground-water study and for development of supplies exists in many parts of the State. Well supplies might supplement surface water resources in areas of great demand and thus make possible more rapid residential, industrial and farm irrigation growth.

The attached report by Leggette, Brashears & Graham considered these problems and proposed a solution to New Jersey's lack of information and slow development of underground water resources. In effect, the report proposes that the State get the facts county-by-county on current use of underground water, estimate future needs, and point the way in which each county can obtain sound development of its underground water resources.

## **Administration and Cost of a Ground-Water Development Program**

The Advisory Committee approved the geologist's recommendation that control of the 10-year program on underground water investigation be placed in the State Division of Water Policy and Supply. The Committee recommends that a Citizen Board also be established to give advice, review and promote the program. Such duties might be added to those of any other Water Board or Commission established for administration of surface water development in the State.

The Committee accepted the estimate that the annual cost of the 10-year program would be \$225,000, and that up to half the amount annually might be made available under the present cooperative agreement with the U. S. Geological Survey. The New Jersey Senate Committee has included in its 1958 legislation (Senate Bills No. 145 and 146) the sum of \$1,250,000 to meet the State's anticipated portion of the 10-year ground-water program.

If for any reason matching Federal funds are not made available in ensuing years, the Committee recommends that the State make up the difference in the \$225,000 annual estimated cost so that the 10-year program of studies can be completed.

## **Long-Range Water Development**

A continuing part of a long-range water development plan for New Jersey is the integration of surface and underground water supplies. There is a community of interest by all parts of the State in making certain that water resources are developed both above and below ground. Availability, cost, and nearness to areas of need are all determining factors in water resource development.

→ The Advisory Committee's series of three reports is dedicated to this state-wide community of interest in water development. The reports, of which the first was issued in April, 1957, include surface and ground-water potentialities. Following this second report, a third will deal with other surface water resources that may be developed for the benefit of the State.

Intrastate water resources within New Jersey are of great magnitude. It is for the citizens, the government of the State and its counties and municipalities, and private water companies to seek the most efficient and economical methods of meeting our expanding needs for new water supplies.

As a result of its water studies the Advisory Committee believes that with the facts on both surface and underground water resources available, development can be made in a businesslike way.

The report of Leggette, Brashears & Graham is contained in pages 5 to 16.

**NEW JERSEY WATER RESOURCES ADVISORY COMMITTEE**

Mr. George F. Smith, President (Chairman)  
Johnson & Johnson  
New Brunswick, New Jersey

Mr. James Kerney, Jr., Editor, (Vice-Chairman)  
The Trenton Times  
Trenton, New Jersey

Mr. Bernard Hellring (Secretary)  
1180 Raymond Boulevard  
Newark, New Jersey

Mr. V. E. Atkins, General Manager (Treasurer)  
Manufacturing Services Division  
American Cyanamid Company  
New York, New York

Mr. John T. Connor, President  
Merck & Co.  
Rahway, New Jersey

Mr. Oliver G. Willits  
Chairman of the Board  
Campbell Soup Company  
Camden, New Jersey

Mr. Frank J. Valgenti, Former Chairman  
New Jersey State Fish & Game Council  
1 Waverly Place  
Madison, New Jersey

Mr. Louis P. Marciante, President  
N. J. Federation of Labor  
790 Broad Street  
Newark 2, New Jersey

Mr. Paul Krebs, President  
New Jersey State CIO Council  
772 High Street  
Newark, New Jersey

Mr. W. Grant Parry, General Sales Manager  
Jersey Central Power & Light Company  
New Jersey Power & Light Company  
9 West Blackwell Street  
Dover, New Jersey

Mr. Clarence Alles, Overseer  
New Jersey State Grange  
R. D. #1  
Flemington, New Jersey

Mr. Edward A. Curtis, Vice-President  
New Jersey Bell Telephone Company  
540 Broad Street  
Newark 2, New Jersey

Mr. Bayard L. England, President  
Atlantic City Electric Company  
1600 Pacific Avenue  
Atlantic City, New Jersey

Mr. Ernest Lass, Publisher  
The Asbury Park Press  
Asbury Park, New Jersey

Miss Jane Stretch, Editor  
The Camden Courier Post  
Camden, New Jersey

## FINANCIAL CONTRIBUTORS

to the

## New Jersey Water Resources Advisory Committee

(AS OF APRIL 30, 1958)

The Water Resources Advisory Committee is indebted to the following for contributions of \$62,325 in support of its surveys. The funds were used solely for engineering, legal and printing expenses.

Allied Chemical & Dye Corp.	Kieckhefer Container Co.
Aluminum Corp. of America	Koppers Co., Inc.
American Cyanamid Company	Mack Trucks, Inc.
Anheuser-Busch, Inc.	Mengel Company, The
Atlantic City Electric Co.	Merck & Company
Bakelite Company	Mutual Benefit Life Insurance Co.
Baker & Company, Inc.	National State Bank of Newark
Ballantine, P. & Sons	New Jersey Bell Telephone Co.
Belleville Manufacturers Association	New Jersey State C.I.O. Council
Benzol Products Company	North Jersey Quarry Co.
Blanchard Bros. & Lane, Inc.	Okonite Company, The
Campbell Soup Company	Pennsylvania Railroad Co.
Celanese Corp. of America	Public Service Electric & Gas Company
Cities Service Oil Co.	Prudential Insurance Co. of America
Colgate Palmolive Co.	Revlon Company
Continental Can Company	Roebbling's Sons, John A. Corporation
Curtiss-Wright Corp.	Ruberoid Company
Daystrom, Inc.	Shell Oil Company
Driver, Wilbur B. Co.	Sherwin-Williams Co.
Duhernal Water System	Shulton, Inc.
Edison, Thomas A., Inc.	Singer Manufacturing Co.
Elizabeth Daily Journal	E. R. Squibb & Sons
Ford Motor Company	Standard Oil Company (N. J.)
Grand Union Company	Suburban Propane Gas Corp.
Helme, George W. Co.	Texas Company
Interchemical Corp.	Triangle Conduit & Cable Co.
Jersey Central Power & Light Co.	Warner-Lambert Pharmaceutical Co.
Johnson & Johnson	Western Electric Co., Inc.
Johns-Manville Corporation	Westinghouse Electric Corp.
Walter Kidde & Co., Inc.	Worthington Corp.
Walter Kidde Constructors, Inc.	

TOTAL CONTRIBUTIONS (Through April 30, 1958) .....	\$62,325
AVERAGE CONTRIBUTION .....	\$ 1,017
LARGEST INDIVIDUAL CONTRIBUTION .....	\$ 5,000

**LEGGETTE, BRASHEARS & GRAHAM**  
CONSULTING GROUND-WATER GEOLOGISTS  
551 FIFTH AVENUE

R. M. LEGGETTE  
M. L. BRASHEARS  
JACK B. GRAHAM

**NEW YORK**  
MURRAY HILL 2-5989  
CABLE ADDRESS-LEBRAGRA

WATER SUPPLY  
INVESTIGATIONS  
REPORTS

**NEW JERSEY GROUND-WATER RESOURCES**  
**Proposed Program of Investigation**

**INTRODUCTION**

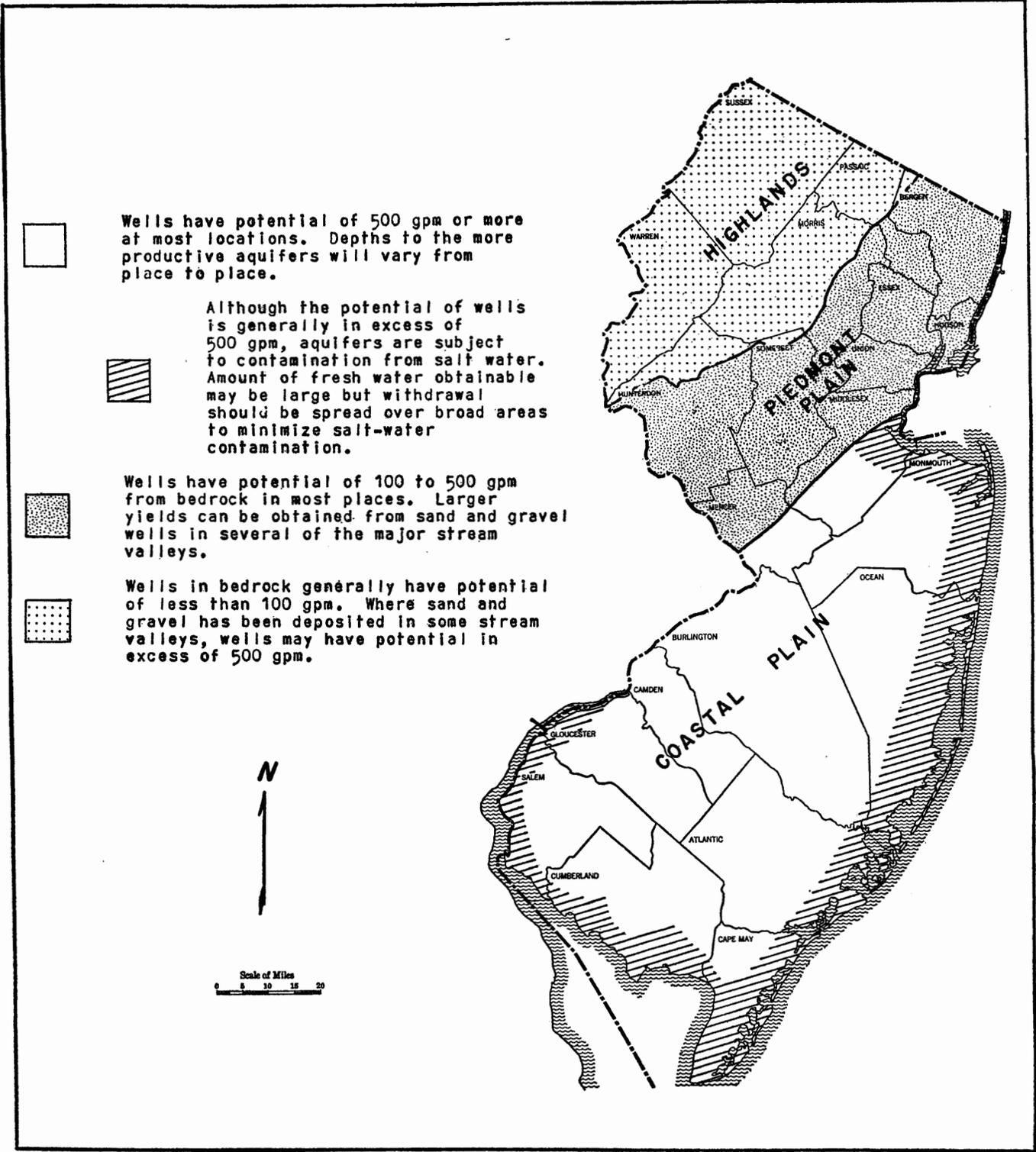
The quantity of ground water stored in the natural sand and rock reservoirs beneath New Jersey's land surface is very large. Most of this great volume of water, much larger than all the water contained at any particular time in the rivers, lakes and storage reservoirs on the land surface, is slowly percolating to areas of natural discharge such as springs and seeps in the beds of surface streams, and to the ocean and bays. Only a very small part, probably less than 10 percent, of the total quantity of water that moves through these underground reservoirs each year is now being utilized by wells and springs.

Contrary to legend, there are no underground rivers fed by New England streams, the Great Lakes or any other distant sources, which if located and tapped by wells, would solve all of New Jersey's water problems. Essentially all ground water in New Jersey has its source in precipitation that falls within the State, but even though the average rainfall is distributed fairly evenly over the State, there is a pronounced difference between geologic formations as to the amount of water they receive as recharge from the infiltration of rainfall. Similarly, there is a pronounced difference between formations as to the amount of water they contain and the rate at which this water can move through these formations. As a consequence, some areas of New Jersey are very favorable for the development of large quantities of ground water, whereas other areas are capable of supporting only small to moderate developments.

Broad areas of the State are of sufficient similarity in kind of rock and land topography to permit them to be grouped into ground-water provinces. (See figure 1, page 6). There are three such regional ground-water provinces in New Jersey. These are essentially equivalent to the geographic areas known as:

1. The Highlands and Appalachian Valley
2. The Piedmont Plain
3. The Atlantic Coastal Plain.

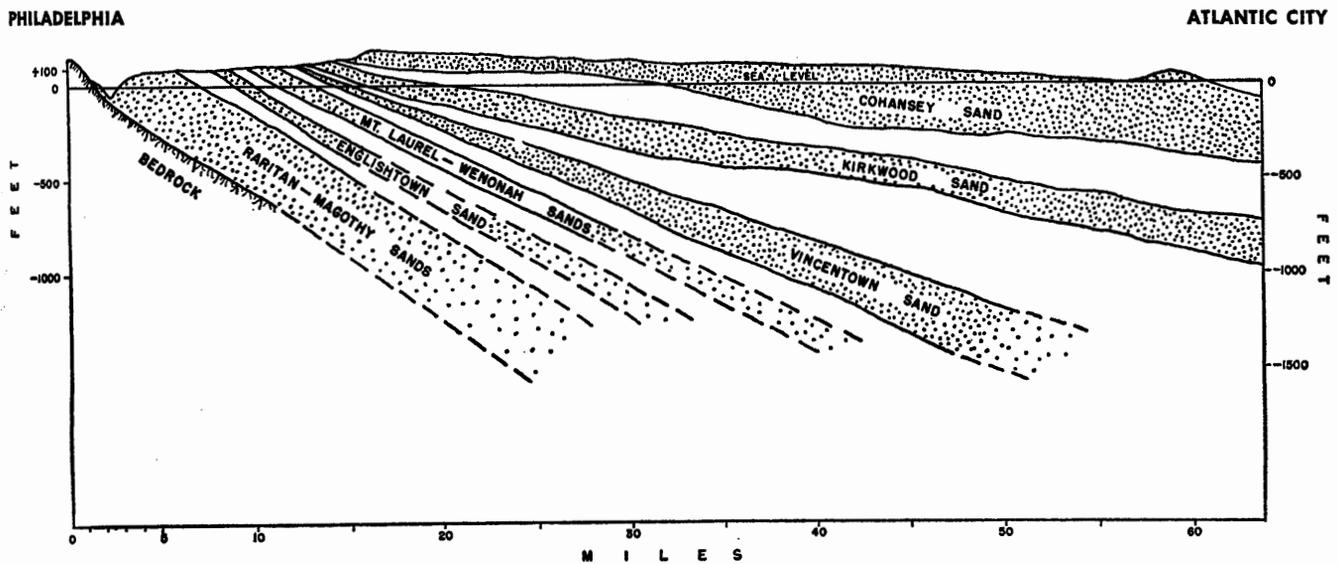
FIGURE 1



GROUND-WATER PROVINCES OF NEW JERSEY

The Highlands and Appalachian Valley region in the northwestern portion of the State contains consolidated rocks that are generally unfavorable for the production of large supplies of ground water. However, in a few localities, where sands and gravels have been deposited in some of the larger valleys of streams that were fed by melting glaciers in the geologic past, wells of high capacity have been constructed. The Piedmont Plain province in the north central part of the State is somewhat more favorable for the development of ground-water supplies, but in this province also the larger supplies are obtained from the sand and gravel deposits in some of the major stream valleys. The Atlantic Coastal Plain is not only the largest but possesses by far the most favorable characteristics for the development of ground-water supplies.

All of the Atlantic Coastal Plain province is underlain by layers of sands, gravels and clays which dip gently to the southeast (see figure 2, below). The coarser beds in these deposits are very favorable for the storage and movement of ground water. A large percentage of the regional precipitation enters the soil in this province and a considerable part of it is transmitted through the permeable formations to the ocean and to the banks and beds of nearby streams. Not only is there a



NOTE:  
 MODIFIED FROM SPECIAL REPORT NO. 6  
 N.J. STATE WATER POLICY COMMISSION.

GENERALIZED GEOLOGIC CROSS SECTION FROM PHILADELPHIA TO ATLANTIC CITY, SHOWING PRINCIPAL WATER-BEARING BEDS

FIGURE 2

very large amount of water moving through these formations, but the total quantity stored in the sediments of the Coastal Plain is vast, totaling many hundreds of billions of gallons.

Most of the interior portion of this region lies essentially undeveloped and unchanged from its original natural condition, with reference to its ground-water resources. Nearly all of its area of approximately 2,000 square miles is underlain by highly permeable sands, the Cohansey formation, which has a very high infiltration capacity. For the magnitude of water in storage, the availability and directness of recharge and for the ease and economy with which large quantities of ground water may be developed, this formation has no equal in northeastern United States. Properly constructed large-diameter wells, perhaps 100 to 200 feet deep, may be expected to have yields averaging 500 to 1,000 gallons per minute (gpm) or more.

Thus, while New Jersey's total ground-water resources are very large, they are by no means evenly distributed and, in general, the largest supplies occur in southern New Jersey where the local water-supply requirements are not large. The more highly-industrialized and developed regions of central and northern New Jersey have much less favorable conditions for the development of ground-water supplies. It is apparent from this broad pattern of the occurrence of ground water in the State that the major problem is not one of a deficiency in overall supply but one of unequal distribution within the State.

The total use of ground water in 1955 was on the order of 500 to 600 million gallons per day (mgd). While this quantity is only a small fraction of the total amount of water used for all purposes in New Jersey, (industry alone uses over three billions gallons per day), it is an extremely valuable asset to the State. Among the more obvious advantages of ground water is its widespread occurrence, thereby making long pipelines unnecessary for most developments, and its general dependability during drought periods as compared to most surface-water supplies. Its relatively constant, cool temperature and chemical quality make it highly advantageous for cooling purposes. For most uses, ground-water supplies generally require much less treatment than surface water. Although in central and northern New Jersey ground water does not generally occur in quantities suitable for large municipal and industrial needs, it is highly important as a supplementary source and its utilization for such purposes is often much more economical than the additional development of available surface water. Ground-water supplies, where available, are particularly well-suited for meeting large-scale future needs because they can often be developed well by well until the maximum potential of an aquifer is utilized. This can be done without the high initial costs that characterize surface-water developments where diversion works or reservoirs generally are constructed with capacities far in excess of the immediate need.

The future importance of the ground-water resources will increase as the competition for remaining surface-water supplies increases. Without question, there

will not only be a need to expand greatly the development of this resource for requirements within its area of occurrence, but it may become necessary to export ground water from regions of ground-water abundance to more distant water-short areas. The present imbalance occasioned by the ground-water abundance in South Jersey, where existing needs are small, and the large water requirements of North Jersey, where ground-water supplies are far less favorable, will gradually be overcome in part by long distance distribution.

More than 30 years ago, the State of New Jersey, recognizing the need for reliable information concerning some of its ground-water problems, began a study of the ground-water resources of the State in cooperation with the U. S. Geological Survey. This program of investigation was quite limited at the start and although the scope of the work has gradually enlarged, the results obtained have only partly met the State's need for adequate technical information in many parts of the State.

Most of the excellent work that has been done pertained to areas where ground-water problems had already arisen at the time of the investigation. The funds and personnel available for the work were not adequate to undertake studies in parts of the State before the critical problems developed.

For many years it has been apparent that the orderly development of the State's available ground-water resources could be made only if sound and reliable technical information were obtained by investigation before critical problems arose, rather than after they arose. Thus, from the long-term point of view, the most urgent need at the present time is to plan and implement an intelligent program of state-wide ground-water investigation to provide a basis for making wise decisions as future ground-water problems arise.

## **TYPICAL PROBLEMS**

The possession of a valuable commodity such as New Jersey's abundant ground-water resources, does not automatically eliminate all problems related to its use. Even in southern New Jersey, where the prospects for large-scale ground-water developments are perhaps the best to be found anywhere in the East, considerable investigation and research will be required to determine the most favorable areas and best methods of development, to avoid salt-water contamination and to properly space well fields so as to avoid excessive interference between wells.

In Cape May County, recent investigations have disclosed that brackish water in the principal aquifer is fairly widespread. In the Atlantic City area, the effect of increasing the ground-water withdrawal on the encroachment of salt water is so little understood that further development is being retarded.

Along the Lower Delaware River from Paulsboro south, the water-bearing sands and gravels are in hydraulic connection with river water that increases in salt

content during periods of low flow. River water, which at times is brackish, can enter the producing aquifer whenever cones of depression caused by pumping have extended to the river. There is some salt-water contamination now apparent at some localities along this stretch of the river and more contamination will doubtless occur if the shallow aquifers bordering the river are drawn on more heavily in the future.

Near the mouth of the South River in Middlesex County, salt water from Raritan Bay and the lower portion of the Raritan River has permeated the sand and gravel aquifers. It is becoming increasingly difficult and expensive to provide adequate supplies of fresh water for the expanding population and industrial development of the area. Consideration is being given to the feasibility of constructing tide gates on the South River to prevent the upstream movement of salt water. If further salt-water contamination of the shallow sands and gravels of this area can be prevented by means of tide gates, additional fresh ground water can eventually be developed.

There are numerous tidal streams in the coastal areas in which upstream movement of salt water could be controlled by tide gates. Installations of this kind would materially increase the amount of fresh ground water available in these areas. The use of tide gates for this purpose is not new. The method has been used with striking success in the Miami, Florida area.

In the Wharton Tract, which is representative of the interior portion of the Coastal Plain, studies are now in progress to determine the most feasible method of developing the water potential of the region. It is believed that large ground-water infiltration systems, relying upon the major streams for continuous recharge by downward percolation through their beds, may be far more practical than surface reservoirs, or even conventional wells dispersed throughout the Pine Barrens.

Very few of the larger streams near water-short areas in northern New Jersey have suitable sites for additional surface reservoirs, either because of poor topographic and geologic conditions or because of the high cost of land acquisition in developed areas. However, the valleys of some of these streams contain deposits of sand and gravel which may have large ground-water-supply potentials, even though the deposits may be quite local in occurrence. Recent water shortages, particularly in the northeastern metropolitan area, have focused attention on these small but prolific aquifers, especially as supplemental sources for some of the larger municipal and industrial water users. At present, however, the location and extent of such aquifers is very inadequately known, and as a consequence, progress in their development, though greatly needed, has not been rapid.

## **PROPOSED TEN-YEAR PROGRAM OF INVESTIGATION**

The effective utilization of the ground-water resources of the State requires a detailed understanding of the occurrence, movement, recharge and chemical character of the water in each formation in all provinces of the State. Such an objective

will probably not be completely realized for many years, but the great importance of the resource dictates that its development should be based on the soundest possible technical information. At present, such information falls far short of that needed to avoid overdevelopment on the one hand, or on the other, to avoid limiting development needlessly, in the fear of exhausting or contaminating the resource. The program here proposed is therefore not a plan for direct water-supply development but rather one to provide the information required to assure the sound and orderly development of the ground-water resources of the State.

It is probable in this age of technical progress that the wisdom of the scientific approach to resources development is widely appreciated. It is not so widely recognized that knowledge of natural phenomena such as the circulation of water, from atmospheric moisture to the land surface, from the land surface to underground reservoirs, and from the underground back to rivers, seas and the sky, is an ever-changing process that varies even more greatly from place to place than it does from time to time. Because of the variation in geologic conditions, the occurrence and, therefore, the opportunity to develop ground water will differ, often in great degree, from town to town and from county to county. It follows, therefore, that an adequate program of hydrologic and geologic study preparatory to the best development of the State's ground-water resources must cover every county in considerable detail, and must span a sufficient interval of time so that annual variations in recharge, and long-term effects of ground-water withdrawal may be observed and evaluated.

For these reasons, it is recommended that New Jersey establish a program of study to identify the present status and future ultimate potential of its ground-water resources in every county of the State, and as far as possible, to schedule the accomplishment of this broad program in a ten-year period.

As proposed, the state-wide study is directed toward five objectives. These are (1) preliminary descriptive county reports, (2) the enlargement of a state-wide network of wells to observe variations in ground-water storage, (3) the enlargement of a state-wide network of wells for observing changes in the chemical quality of ground water, (4) detailed reports for those counties in which ground-water problems are currently pressing or in which large scale future development is imminent, and (5) special studies, largely of a research nature, in areas of the State where more intensive study than county-wide activity, or special hydrologic studies may be required.

## **1. Preliminary county investigations**

Preliminary county investigations are basic to all other phases of the program with the possible exception of some special projects. Such field studies, in addition to identifying the general hydrology and geology of an area, would include mapping the principal water-bearing formations, identification of existing ground-water prob-

lems and the collection of basic data such as the present utilization of ground water, the yield characteristics of typical water-supply wells, current water-level conditions and the chemical quality of the ground water. Reports for all 21 counties should be completed within approximately the first half of the ten-year program, as they should serve as the foundation for more specific studies. In the field work required for the preparation of such reports, an evaluation would be made of wells considered suitable for inclusion in the state-wide network of wells for long-term analysis of water level and quality of water data.

## **2. State-wide network of water level observation wells.**

The enlargement of the pattern of wells for observing changes in water level throughout the State would gradually be accomplished at the same time as the preliminary county investigations were being carried on. At the present time, there are approximately 275 wells in New Jersey in which measurements of fluctuation of water level are being made. An additional 300 or so wells will need to be added during the ten-year period in order to properly determine the effects of increasing development and to permit evaluation of natural changes in the overall quantity of water stored beneath the ground. It is probable that most of these additional wells can be made available for this purpose by arrangements with owners of unused wells. In areas where few wells have penetrated some of the more important water-bearing formations, new wells should be drilled specifically for this purpose. Because of the necessity for closely observing the changes in underground water storage that occur in critical coastal areas and in some centers of industrial concentration, the pattern of observation wells throughout the State will be unevenly distributed with greatest concentration in and near problem areas.

## **3. State-wide network of quality of water observation wells.**

This phase is similar to that of establishing water-level observation wells throughout the State but differs in that most of the wells to be added for quality observation will be in and along the coastal areas. The minimum coverage for the State will require approximately 75 wells in addition to those now available. Because of the necessity for precise information as to the depth of screens and construction of the wells, it is probable that a considerable number of these wells will have to be drilled specifically for this purpose. A number of such wells should be scheduled for the latter part of the ten-year period, at which time the need for specific information on water quality will have become more apparent. It should be noted that wells established for quality of water observation can also be effectively used for water-level measurements. Conversely, some water-level observation wells, particularly in coastal areas, may serve for observation of water quality.

#### **4. Detailed county investigations.**

The principal objective of a program of ground-water study in any locality is to achieve a detailed understanding of the sources of ground water, the properties of its underground reservoirs, the direction and the rate of ground-water movement, the chemical characteristics of the ground water and the maximum amount that can be economically withdrawn without exceeding the sources of supply and without adversely affecting water quality. Such an objective requires a thorough knowledge of the local geology and of the hydraulic properties of the local aquifers.

Among the methods used in such studies are pumping tests, computations of the yield characteristics of wells, the proper spacing of adjacent wells and similar features. Existing ground-water developments would be studied and estimates made of additional ground-water supplies that could be safely developed. The study required for preparing reports of such scope will involve approximately two years for each report. Their completion will therefore not be accomplished until the middle and latter part of the ten-year program. There is need for such studies throughout the Coastal Plain and in some of the moderately favorable ground-water areas in the northeastern metropolitan area. It is believed that only about half of the counties in New Jersey are in need of coverage to this degree during the proposed ten-year program. Subsequently, as development in the other counties progresses, they will doubtless need similar detailed studies.

#### **5. Special studies.**

Without doubt there will be need for a number of special ground-water studies in New Jersey that can be best undertaken by treating them as research projects apart from the county investigations. For example, the present project in the Wharton Tract for determining the feasibility of inducing large-scale river infiltration to supply wells or galleries along the streams, is of great importance to the State in the eventual design of water-supply developments throughout the Pine Barrens. Local salt-water intrusion studies, such as that in progress on Cape May Peninsula, are also projects that may best be undertaken as special studies.

Most special studies of this kind can be fitted into the ten-year program as dictated by need. No special schedule, or in fact, no list of such problems need be prepared at this time. Such studies will become apparent as the ten-year program progresses. Infiltration studies will be needed along the Delaware River and these should be considered special studies that could perhaps be coordinated with detailed county reports in that region. The mapping and testing of glacial outwash deposits in northern New Jersey counties perhaps could also be integrated with county studies. In parts of the State it may be desirable to carry on studies at existing irrigation ponds which draw on local ground-water reservoirs, so as to indicate the feasibility of using large excavations for developing dependable ground-water supplies.

Most of these research projects should be undertaken in the latter part of the ten-year period after the preliminary studies have been completed and when field personnel can be shifted from basic data collection to interpretive work. Some of the new observation wells to be installed will probably form a part of these special research studies.

The execution of this proposed ten-year study should be accomplished by expanding the existing cooperative Federal-State ground-water program in New Jersey. This recommendation is based on the need for personnel trained in ground-water investigations, such as that of the U. S. Geological Survey. Moreover, such Federal-State programs in the past have been supported by Federal funds by as much as 50 percent of the investigational costs. Unified direction of the overall State ground-water program is essential, and is best placed in the present cooperative and joint supervision of the District Geologist of the U. S. Geological Survey and the Chief Engineer of the Division of Water Policy and Supply, State of New Jersey. It may be found desirable to establish a Board, Committee or other advisory group, qualified to provide program review and advice to the State during the progress of the ten-year investigative program.

Because ground-water resources are largely controlled by geologic conditions, the technical group undertaking the proposed program should be composed largely of geologists trained in ground-water hydrology, aided by engineers with training or experience in hydrology. The number of people with ground-water experience is not large, and one of the major difficulties in accomplishing the proposed program will be in developing an adequate and well-trained staff. It is estimated that approximately 12 ground-water geologists and engineers, in addition to the existing personnel of the U. S. Geological Survey in New Jersey, will be required. This additional staff can be added to the program at the rate of a few each year during the first four years so that thereafter, the total of present and new technical personnel engaged in the ten-year study would number about 18.

The information to be included in the preliminary descriptive reports for all counties in the State is basic to the other phases of the program. Hence, these reports should have first priority in accomplishment and should be completed for all of the State by the sixth or seventh year of the program. Each of the more detailed reports recommended for about half the counties in the State will probably require about two years to complete. They will be completed during the middle and late part of the program. The establishment of observation wells in the program of expansion of both the water level and quality of water observation well networks will proceed more or less uniformly during the ten-year period. The drilling of new observation wells will be undertaken largely in the second half of the period.

The special studies, perhaps numbering five or so, should be undertaken after most of the State has been covered by preliminary county investigations, with the exception of the completion of studies now in progress, such as in the Wharton Tract and in Cape May County.

It is recommended that the present activities of the cooperative ground-water program being carried on in New Jersey by the Department of Conservation & Economic Development, Division of Water Policy and Supply and the U. S. Geological Survey, be continued and integrated into the proposed ten-year program. In essence, this will enlarge and accelerate objectives that long have been recognized by State officials as necessary for proper long-range development of the ground-water resources.

It is estimated that the annual cost of the recommended study, including the continuing functions of the existing cooperative ground-water program, will be on the order of \$225,000. In addition to the cost of field investigation and preparation of reports for both county and special reports, this estimate includes \$50,000 for the drilling of new wells, chiefly for water-level and water-quality observations. Except for national trends in costs, it is unlikely that this annual sum will need to be changed greatly from year to year during the ten-year period, unless a scarcity of trained personnel should make it necessary to alter the proposed schedule.

Publication by the State of all reports resulting from the program will permit a relatively quick dissemination of the information obtained. Preliminary descriptive reports on the ground-water resources of all 21 counties in the State could probably be issued within a year after field work in each county has been completed. The preparation of the more detailed reports on about half of the counties will require somewhat longer time. Some of these reports, involving the study of pumping test data and an evaluation of the maximum dependable yield of several aquifers may also require more than two years of field study. Reports giving the results of research projects will be few in number and will probably be completed during the second half of the ten-year program.

The primary responsibility for establishing the order in which the different areas are investigated should lie with the State and Federal officials directing the ground-water program, because of their intimate knowledge of the status of water problems throughout the State. However, there are other factors that should be considered along with known water problems. Among these are areas in which rapid expansion of population or industry is anticipated, source areas of ground water for exportation to water-short localities in the near future, and the degree to which local communities press for early attention to their areas.

It is generally recognized that among the areas in the State that merit high priority are some localities along the Delaware River and along the Jersey Coast. Perhaps equally important will be portions of some central and northern counties,

particularly along streams underlain by permeable deposits of sand and gravel which may provide supplemental ground-water supplies.

In accomplishing the proposed program of investigation of New Jersey's ground-water resources, the orderly expansion of population and industry will be facilitated, the State's ground-water laws can be more appropriately and effectively applied, and the foundation of technical data needed for the long-range planning of ground-water developments can be realized. New Jersey has attained a position of eminence in the technological advances of its people in business, industry and agriculture. A sound program for advancing the understanding of its ground-water resources will be in keeping with this history of progress.

