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WATER SUPPLIES FOR IRRIGATION IN THE NORTHEAST

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The subject of this paper as given on the program is "Water Supplies for Irrigation in the Northeast." Both surface-water and ground-water resources are discussed, although with somewhat differing approaches. First we discuss the use of streamflow data in estimating the surface-water supplies available for irrigation use. Then we treat some of the hydrologic factors that bear on the use of ground water for irrigation in the New England-New York region.

Streamflow in the Northeast

The supply of surface water in the Northeast is ample but is not always available at the right time or place. The average annual runoff ranges from 15 inches for Delaware to 25 inches for northern New England. In general, streamflow in the Northeast is less variable than in most other parts of the country -- that is, there is less range between high and low flows. Maximum flows and average flows although important for many purposes, are of little interest to irrigators unless storage projects are contemplated and are notdiscussed further in this paper; minimum flows are likely to be of greater interest to irrigators in the Northeast.

On unregulated streams having drainage areas of 10 to 100 square miles the minimum flow at gaging stations in the North Atlantic States ranges from zero to 0.34 cfs (cubic feet per second) per square mile. About one-half of these streams have minimum flows in excess of 0.05 cfs per square mile and about three-fourths have minimum flows in excess of 0.025 cfs per square mile. A flow of 0.025 cfs per square mile from a drainage area of 100 square miles is equivalent to 1100 gpm (gallons per minute).

Stream-Gaging Records

At the present time the U. S. Geological Survey operates about 800 gaging stations on streams in the North Atlantic Slope basins. Records for these stations are published annually in Geological Survey Water Supply Papers as parts in the series entitled "Surface Water Supply of the United States." The use of these data in the design of hydroelectric plants, water-supply systems, and flood-control work is well known, but how can they be used to assist the farmer who wants to use streamflow for supplemental irrigation?

If there is a stream-gaging station on the stream he wishes to use, the farmer can look at the most recently published streamflow data for the minimum flow of record. If that amount is several times what he and his neighbors upstream and downstream are likely to use he can feel confident of his supply. But what if this doesn't appear to be an adequate supply? In that case he should not overlook the possibility that this low flow may have been cuased by regulation upstream that lasted only a day or two. By consulting records of discharge for the year in which the low flow occurred he may find that the daily discharge for a few days before and after the low day was considerably higher and that the average of the minimum 3 days or minimum 7 days is a better basis of comparison than is the instantaneous minimum or minimum day. Even if the flow for the minimum 7 days of record is not an adequate supply he can think in terms of possible benefit from the water that is available rather than in terms of a guaranteed adequate supply every day of every year. If the supply of surface water during the low-flow period each year is adequate four years out of five, the benefit from irrigation during the four years may be great enough to offset the loss caused by insufficient water the fifth year. I have heard it said that farmers are really gamblers; that is, they are willing to take an occasional loss if the odds are favorable that a certain crop or agricultural practice will pay off in the long run. If this is true, the farmers can use streamflow records to help in estimating the odds that a surface-water supply will be sufficient in any one year.

Discharge records published by the Geological Survey are usually expressed in cubic feet per second (cfs), but the user often finds it more convenient to convert flow to other units. For example, 1 acre-foot of water will cover 1 acre to a depth of 1 foot or 12 acres to a depth of 1 inch. Therefore, it is sometimes convenient to convert cfs-days to acre-feet by multiplying by 2 (a more precise factor is 1.98). However, if the water is to be pumped, the gallons-per-minute (gpm) unit is convenient and can be obtained by multiplying the cfs figure by 450 (a more precise conversion factor is 448.8). Furthermore, 1 cfs is practically equivalent to 1 acre-inch per hour so that the discharge in cfs shows the number of acres that could be irrigated at the rate of 1 inch per hour. Thus, discharge expressed in cfs, as in the water-supply papers of the U. S. Geological Survey, is a convenient starting point for hydraulic computation.

In the use of streamflow records, the compilation report for Part 1-A recently issued by the Geological Survey will prove valuable. This report, Water-Supply Paper 1301, is entitled "Compilation of Records of Surface Waters of the United States through September 1950; Part 1-A, North Atlantic Slope Basins, Maine to Connecticut." Copies are available for your inspection here and may be purchased from the Superintendent of Documents, Government Printing Office, Washington 25, D. C., for $1.75. A similar report, Part 1-B, covering stream basins from New York through the York River in Virginia is in preparation and will be available in two or three years. These reports contain a compilation of streamflow by months for the period of record at each stream-gaging station and also the maximum and minimum discharge during each water year ending September 30. In using the table of minimum daily discharge, this September date should be kept in mind for it is possible that one low-flow condition may affect the minimum flow shown for two water years--the one ending September 30 and the one starting October 1 of the same calendar year.

These compilation reports are not intended to be the final word in low-flow analysis. Eventually we expect to present the low-flow data that have been collected over many years in a form that will be more meaningful to the general public and the engineering profession. For example, we hope to use the longest records available in anarea to help define the frequency of occurrence of low flow at all gaging stations, whether the record is long or short. When this is done, the curve or table for a particular station will give information that would require weeks of time for the user to compute. However, it will be several years before much work can be done on a low-flow study because the compilation reports and a flood-frequency-analysis project have higher priority.

Ungaged Areas

But what if there is no gaging station on the stream the farmer hopes to use for irrigation? In the past, two methods have been used to estimate what he could expect. One method was by talking with local residents, and the other was by transposing data from a gaged stream on the basis of a drainage-area relationship. Both of these methods are rather unreliable. The first is weak because man's memory plays tricks on him when he tries to remember hydrologic conditions, and also because of the difficulty of estimating streamflow. Even experienced stream gagers would likely not be able to estimate within 50 percent of the amount of water in a stream by looking at it, and an untrained observer would probably do much worse.

The use of drainage-area relationships to transpose low-flow data on small streams is unreliable because base flow is affected by geologic conditions that are not readily apparent. It is not uncommon for the flow in cfs per square mile on adjacent streams in the Northeast to vary severalfold; that is, the flow per square mile on one stream may be several times greater than on the other. For example, the minimum daily discharge in cfs per square mile on South Branch Raritan River near High Bridge, N. J., is over 5 times that on the adjacent drainage, Black River near Pottersville, N. J. The minimum flow on Schoharie Creek at Prattsville, N. Y., is 0.12 cfs per square mile while Catskill Creek at Oak Hill, N. Y., a nearby drainage basin, practically goes dry. On streams of several hundred square miles, various upstream conditions tend to average out and result in a fairly uniform low-water yield per square mile.

If we can't trust what we hear from the local residents and we can't transpose data from another stream, what are we to do? We believe the answer is "to relate" -- relate the observed flow at an ungaged stream to that at a gaged stream. If the observation of flow at the ungaged stream is made under base-flow conditions--not affected by runoff from recent rains--comparison with the flow at nearby stream-gaging stations will indicate whether the flow per square mile is greater or less than at the gaging station. It has been found that if several base-flow measurements a year can be made for several years the average relationship line shown by these measurements is a fairly reliable indication of the long-term average relationship, and that this relationship can be used to transpose streamflow characteristics from one stream to another. Thus, for an investment of a few hundred dollars, a reliable estimate of the long-term flow characteristics of an ungaged stream can be obtained. If time is short, a few measurements in the same year, or even a single measurement, usually give a more reliable indication of the flow characteristics of the ungaged stream than either of the other two methods.

Records of Water Use

Although supplemental irrigation benefits the farmer it adds to the difficulties of the hydrologists. The relations between the flows of adjacent streams, discussed above, are valid only so long as the measured flow represents natural conditions. When the natural flow has been depleted by irrigation upstream a misleading figure will be obtained unless allowance is made for the amount of water being withdrawn. This is where we hope agricultural engineers can assist us. Records of the amount of land irrigated, the size of pump and motor, the average height to which the water is pumped, and the hours operated would be of value when an appraisal of the supply of water in a drainage basin is undertaken. Many farmers may think records of this kind are an unnecessary bother, but if they understand the use to which these data can be put, they will be more willing to keep records. It will be of great benefit if data of this kind can be filed in the County Agent's office or some other place equally accessible. They may prove of direct value in the event that proof of claims of beneficial use (may) become necessary.

Supply to Ponds

Another aspect of the use of surface water for irrigation is the use of ponds to store runoff from drainage areas of less than 1 square mile. In the design of these ponds the agricultural engineer must estimate the amount of water that will flow into the pond during a dry year. Unfortunately, there is little information regarding the annual yield of these small areas. Extrapolating from gaged areas of 10 to 25 square miles down to areas of less than 1 square mile is unreliable. However, by using only storm runoff at the gaging station (as distinct from base flow) we can make a rough calculation of runoff into the pond.

For example, streamflow records on unregulated streams in the Northeast indicate that in an area where the average annual runoff is 20 inches the annual runoff may be as low as 13 inches once in every 10 years, on the average. If 30 percent of this total runoff occurs as storm runoff, the annual yield of storm runoff on small areas will be as low as 4 inches per year (one-third of an acre-foot per acre) once every 10 years on the average.

If the leakage and evaporation from the pond are neglected, this same 4 inches of water can be put back on the same amount of land during the irrigation season, or if the area irrigated were only half the drainage area 8 inches of irrigation water would be available.

The figure of 30 percent for direct runoff is based on an analysis of Brandywine Creek at Chadds Ford, Pa., where during 2 of the past 22 years the direct runoff has been as low as 30 percent of the total runoff. Analysis of records on other streams would indicate the possible range in such a figure and whether it truly represents the yearly runoff to be expected from field-sized areas.

Further Analysis

Obviously, there are many types of analyses that can be made of streamflow data to make them more usable. If such analyses are made and published by one agency all users will benefit. Therefore, the Geological Survey is undertaking such a program as part of its regular work, but many years will elapse before all the analyses can be completed.

Ground Water

The use of ground water for irrigation depends mainly on: (1) the availability of ground water; (2) the dependability of the supply; (3) the quality of the water; and (4) farm economics as related to the cost of installing and operating an irrigation system. This article will review briefly three of these elements--availability, dependability, and quality--with respect to ground-water supplies for the New England-New York region. By availability is meant the occurrence, in any particular area, of saturated deposits that are thick enough and permeable enough to yield water in adequate amounts to properly constructed wells. By dependability is meant the capacity of such deposits to supply the amounts required on a sustained basis throughout summer dry spells, and from year to year. By quality is meant the effect of dissolved chemical constituents.

The New England-New York region as used in this talk (see pl. 1) includes all the New England States and most of New York except the drainage basins of the Allegheny, Susquehanna, and Delaware Rivers and the New York metropolitan area.

Before discussing "availability" and "dependability," let us first consider what constitutes an adequate amount of water for irrigation use. The term "adequate" is elastic. In the western part of the United States, where acreages are large and irrigation is the principal means of supplying water for crops, a yield of less than a few hundred gallons per minute from a well or battery of wells is generally inadequate. Yields of 1,000 gpm or more from a single well are common. In the northeastern part of the United States acreages generally are relatively small. Also, in most years irrigation is only supplemental. Accordingly, a yield of as little as 100 gpm from a single well may be an adequate amount of water for a small farm during most years. On the other hand, at times and in some parts of the Northeast, irrigation may be the primary source of water for crops, especially during extended droughts such as that in the summer of 1949. Ideally, an adequate irrigation supply must therefore be capable of satisfying the full crop requirement for intervals of at least several weeks.

Availability

The physical availability of ground water is governed mainly by the extent, thickness, and permeability of the rock materials that contain the water. These materials should be sufficiently thick and permeable to yield water to individual wells at the required rate. Plate 1, a generalized map of the New England-New York region including most of Long Island, shows areas underlain by rock materials that are most likely to yield water to wells at sufficient rates for at least supplemental irrigation. The shaded parts of the map represent areas underlain by coarse-grained unconsolidated deposits, chiefly sand and gravel, which are relatively permeable and in many places are 50 feet or more thick. The unshaded parts of the map represent areas immediately underlain by either bedrock or fine-grained unconsolidated deposits, chiefly till, or by thin sand and gravel deposits of local extent. Admittedly some wells in the area of thick and extensive deposits will not yield enough water for irrigation use, and many wells may yield only enough water to irrigate small acreages. Conversely, some wells in the low-yield areas will yield enough water for some irrigation use. Indeed, some wells that penetrate bedrock, especially where the bedrock is limestone, yield as much as 1,000 gpm, but such large yields are not common.

The map shows that the more extensive bodies of coarse-grained deposits are those that underlie Long Island, Cape Cod, the nearby off-shore islands, including Marthas Vineyard and Nantucket, and the Connecticut Valley in Connecticut and Massachusetts.

Only on Long Island has ground water been developed extensively for irrigation. In 1953, according to estimates of the New York State Water Power and Control Commission, about 19,000 acre-feet (6,200 million gallons) of water was pumped for irrigation in Suffolk County (about two-thirds of the area of the Island). This water was applied to about 21,000 acres of crops. Pumpage during the 107-day growing season averaged about

55 mgd, or about 0.1 inch per day on each acre. It is of interest to note that the yields of most individual irrigation wells on Long Island are between 200 and 500 gpm. In contrast, according to estimates made for reports of the New England-New York Inter-Agency Committee, during a recent year only 17,000 acre-feet (5,500 million gallons) of water, including both surface and ground water, was used for irrigation in the New England-New York region exclusive of Long Island. About 30,000 acres of crops were irrigated, an average of about 7 inches of water per acre. Less than 10 percent of the water was from wells; however, of the remaining 90 percent, some was pumped from groundwater ponds.

The availability of ground water for irrigation on Cape Cod, Marthas Vineyard, and Nantucket is promising, perhaps approaching that on Long Island, but few supplies have been developed.

The unconsolidated deposits of the Connecticut Valley are not nearly so excellent a source of ground water as those of Long Island and Cape Cod. The thicker deposits of sand and gravel in the Connecticut Valley are essentially restricted to the margins of the valley. Elsewhere a thin blanket of sand, at most places capable of yielding only enough water for small acreages, overlies relatively impermeable deposits of silt and clay. These impermeable deposits occupy most of the saturated zone. In contrast, the permeable deposits of Long Island and Cape Cod are several hundred to more than 1,000 feet thick, and nearly everywhere yield moderate to large volumes of water.

Elsewhere in the New England-New York region, ground-water reservoirs favorable to the development of irrigation supplies occur along stream courses or occupy buried preglacial valleys, some of which no longer have main streams. Except for a few places, little detailed information is available on the thickness and character of the materials that compose these reservoirs. Therefore their potential as sources of irrigation water is largely undetermined. Reconnaissance data suggest that only in scattered places will the rock materials yield as much as 1,000 gpm to individual wells, and in many places yields may be sufficient for only a few acres of crops.

Even where ground water may be physically available for irrigation use, other factors may limit its availability. Two principal limiting factors are the competition of other uses and the relation of ground water to streamflow. Many of the region's industrial cities are in the areas of substantial ground-water yield. Accordingly, municipalities and industries may compete locally with agriculture for the use of ground water. Furthermore, throughout much of the region ground water and surface water are hydraulically interconnected so that uses of both are, to some extent, inherently competitive. The existing water-use pattern is based largely on the development of surface-water resources. Obviously, extensive ground-water development that would alter the pattern of streamflow might result in a need for determination of legal rights to water use.

<u>Dependability</u>

Fundamentally, the dependability of a ground-water reservoir is governed by the amount and rate of replenishment in relation to withdrawals. However, the size of the reservoir is an important subsidiary factor. For instance, a reservoir with a large storage capacity can sustain some withdrawal for a limited period without any replenishment at all. Conversely, a very small reservoir must have a more or less continuous replenishment at a rate equal to that of the withdrawal, at least during the period of withdrawal. Assuming that the size factor is satisfactory, replenishment determines dependability.

All ground-water reservoirs in the New England-New York region receive some replenishment from precipitation, and, as indicated in the foregoing, many of them are situated along streams so that under proper conditions they can receive replenishment by infiltration of streamflow. Precipitation, the ultimate source, averages from 35 to 50 inches annually in most parts of the area and is rather evenly distributed throughout the year. This precipitation is so reliable that, despite occasional seasonal deficiencies, year-long droughts seldom occur. Under natural conditions, therefore, most ground-water reservoirs are re lenished annually to their approximate capacity. These features are illustrated by hydrographs of four representative wells in New England.

The hydrographs show a marked seasonal fluctuation. As would be expected, the ground-water reservoirs are ordinarily replenished in the nongrowing season, when water is not used by plants. During the growing season water levels usually decline, and withdrawals from small ground-water reservoirs may not always be sustained—especially if the amount withdrawn is relatively large. However, during the 10-year period 1945-54, the water level in each well reached nearly the same peak level for that well each year. No long-term trends either up or down are discernible.

It must be recognized that withdrawals from the reservoirs whose fluctuations are represented in plate 2 are not large. If the yearly peak water level showed a progressive decline, it would then be suspected that the average rate of withdrawal exceeded the average rate of replenishment. The average rate of replenishment for ground-water reservoirs in the New England-New York region is not known in general, and doubtless differs considerably from one reservoir to another. However, it has been found that water losses--evapotranspiration--in New England _/ average about half the amount of the precipitation. Thus, if roughly half the precipitation

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_/ Knox, C. E., and Nordenson, T.J., Average Annual Runoff and Precipitation in the New England-New York area: U. S. Geol. Survey Hydr. Atlas No. 7, in preparation.

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is available for runoff and for percolation underground, the possible replenishment to ground-water reservoirs from precipitation would average in the order of 20 inches in those areas where topography and soil would not favor much overland runoff. In some areas there is considerable potential replenishment from surface water where streams cross ground-water reservoirs. Despite seasonal fluctuations in ground-water storage, ground-water supplies for irrigation in the New England-New York region are probably generally dependable in those areas shown on plate 1--certainly unless future withdrawals greatly increase.

<u>Quality</u>

Regardless of the availability and dependability in an area, unless water is of suitable chemical quality it may be relatively useless for irrigation. The suitability of water for irrigation depends mainly on the amount and kinds of dissolved salts in the water, and to a lesser extent on a combination of related factors, which include type of soil, climate, type and age of crops, and irrigation practices.

In most parts of the New England-New York region water from the unconsolidated deposits, which are most likely to be the source of irrigation water, contains few harmful salts and is suitable for irrigation use. Chemical analyses from typical wells follow.

Chemical analyses [a] of ground water from representative wells in the New England-New York area
(In parts per million, except specific conductance and pH)

	Suffolk Co., N.Y. Depth 75 feet Sampled May 27, 1948	Windsor Locks, Conn. Depth 68 feet Sampled July 20,1954	Falmouth, Mass. Depth 90 feet Sampled March 18, 1953
Silica (SiO_2)	9.7	9.5	9.4
Iron (Fe)	.33	.01	.06
Manganese (Mn)		.03	
Calcium (Ca)	1.8	15	6.3
Magnesium (Mg)	1.4	6.8	3.5
Sodium (Na)	6.3	2.0	
Potassium (K)	.6	.5	11
Bicarbonate (HCO_3)	9	61	10
Sulfate (SO_4)	10	13	6.6
Chloride (Cl)	4.8	2.8	20
Fluoride (F)	.0		.0
Nitrate (NO_3)	2.3	5.0	13
Dissolved solids	41	88	86
Specific conductance (micromhos at 25°C)	56.1	138	138
pH	6.8	7.5	6.1

a/ Analysis by U. S. Geological Survey

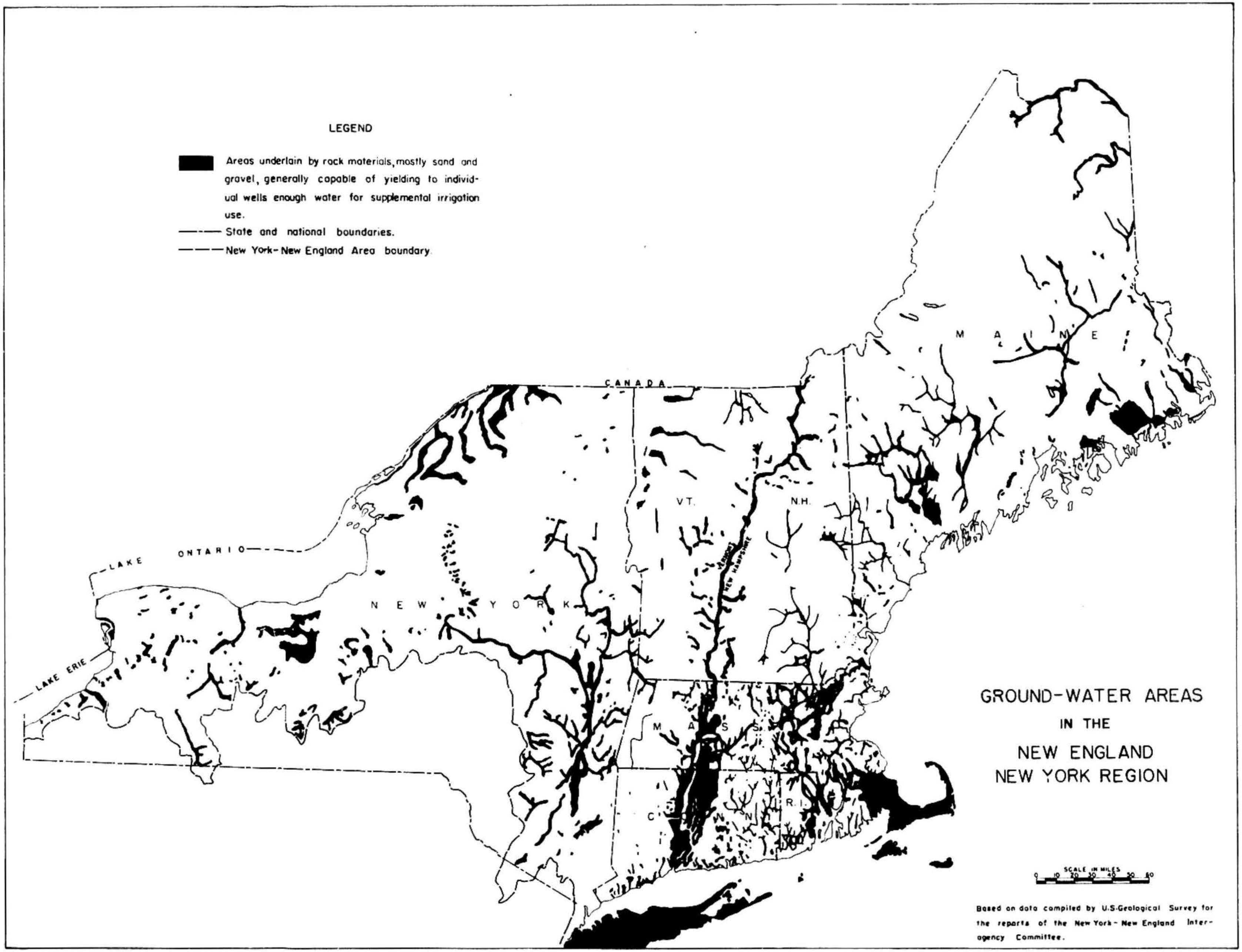
In the coastal areas contamination of ground water by sea water may locally render the ground water unsuitable for irrigation use. Sea-water encroachment is already a problem in some parts of Long Island.

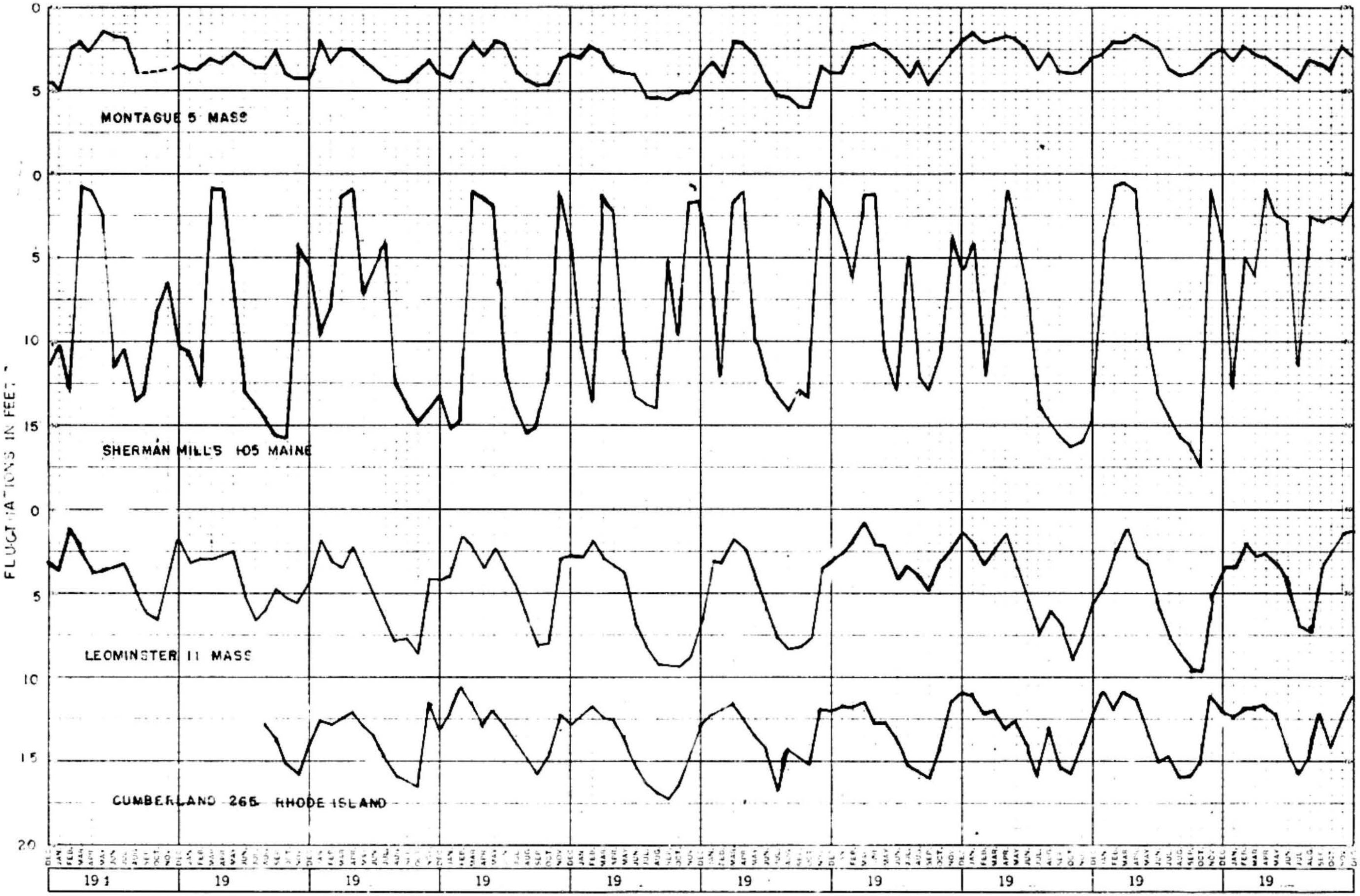
Summary

Streamflow records published by the U. S. Geological Survey can be used to determine the frequency of occurrence of low flows of various magnitudes for gaged streams. For ungaged streams low flow should be measured and related to that at a stream-gaging station on the same day. Further investigation is needed before we can determine the amount of direct runoff that might be used to supply irrigation ponds.

Records of the use of surface water and ground water should be obtained and consolidated for use in future analysis of potential water supply.

Extensive unconsolidated deposits, chiefly of sand and gravel, are the main potential source of ground water for irrigation in many parts of the New England-New York region. Although the general distribution of these deposits is known, in most places little detailed information on the extent, thickness, and water-yielding characteristics of these deposits is presently available. Only on Long Island have ground-water supplies been developed intensively for irrigation use. The quality of the water from the most likely sources is generally good, and these sources are fairly dependable.


LEGEND
Areas underlain by rock materials, mostly sand and gravel, generally capable of yielding to individual wells enough water for supplemental irrigation use.
State and national boundaries.
New York-New England Area boundary.
CANADA
LAKE ONTARIO
LAKE ERIE
NEW YORK
VT.
N.H.
MAINE
MASS.
CONN.
R.I.
GROUND-WATER AREAS
IN THE
NEW ENGLAND
NEW YORK REGION
SCALE IN MILES
0 10 20 30 40 50 60
Based on data compiled by U.S. Geological Survey for the reports of the New York-New England Inter-agency Committee.



REPRESENTATIVE HYDROGRAPHS SHOWING WATER-LEVEL FLUCTUATIONS IN NEW ENGLAND