

NORTHEASTERN UNITED STATES WATER SUPPLY STUDY

**FURTHER DEVELOPMENT OF
REGIONAL WATER SUPPLY ALTERNATIVES:
NORTHERN NEW JERSEY - NEW YORK CITY - WESTERN CONNECTICUT
METROPOLITAN AREA**



JUNE 1973



DEPARTMENT OF THE ARMY
NORTH ATLANTIC DIVISION, CORPS OF ENGINEERS
90 CHURCH STREET
NEW YORK, N. Y. 10007

IN REPLY REFER TO
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NOTICE

This report is one in a series of studies to be undertaken in connection with the Northeastern United States Water Supply (NEWS) Study authorized under Public Law 89-298, and assigned for accomplishment to the Division Engineer, North Atlantic Division, U.S. Army Corps of Engineers. The reports concerning the Northern New Jersey-New York City-Western Connecticut Metropolitan Area, concentrate on presenting and evaluating alternative means of solving regional water supply problems. Public review and evaluation of these alternatives will provide a starting point for selecting the most promising alternatives for more detailed study.

Additional projects and regional water supply program alternatives are developed in this report. The projects and programs are intended to supplement those alternatives described in the Engineering Feasibility Report on Alternative Regional Water Supply Plans for the Northern New Jersey-New York City-Western Connecticut Metropolitan Area prepared as part of the NEWS Study by Metcalf & Eddy, Inc. - Hazen and Sawyer, November 1971. Projects and programs were developed primarily from an engineering viewpoint, consequently no specific evaluations are made based on considerations other than engineering feasibility. The analysis and evaluation of additional considerations are being presented in other reports in this series.

Specifically this report presents for initial evaluation: a Hudson to Ramapo River diversion with storage in the Ramapo Basin; a Hudson River diversion to Ashokan Reservoir; five projects in the upper Hudson River Basin with direct transmission to the metropolitan region; an exchange of water between the New York City and Long Island water supply systems which utilizes the Long Island groundwater resource as a storage reservoir; and eight possible regional programs utilizing the Hudson River diversions at West Park and Hyde Park as a major supply source. In addition, the study presents for evaluation a universal metering demonstration project for New York City.

NORTH ATLANTIC DIVISION
U.S. ARMY CORPS OF ENGINEERS
CONTRACT NO. DACW-52-73-C-0007

FURTHER DEVELOPMENT OF
REGIONAL WATER SUPPLY DEVELOPMENT ALTERNATIVES
FOR THE
NORTHERN NEW JERSEY-NEW YORK CITY-WESTERN CONNECTICUT
METROPOLITAN AREA

JUNE, 1973

PARSONS, BRINCKERHOFF, QUADE & DOUGLAS, INC.

CONTRACT NO. DACW-33-71-C-0007
U.S. ARMY CORPS OF ENGINEERS
NORTH ATLANTIC DIVISION

METROPOLITAN AREA
NORTHERN NEW JERSEY-NEW YORK CITY-WESTERN CONNECTICUT
FOR THE
REGIONAL WATER SUPPLY DEVELOPMENT ALTERNATIVES
FURTHER DEVELOPMENT OF

JUNE, 1973

PARSONS, BRINCKERHOFF, SMITH & BODDARD, INC.

PARSONS, BRINCKERHOFF, QUADE & DOUGLAS, INC
111 JOHN STREET, NEW YORK, N. Y. 10038
CABLE: PARKLAP NEW YORK • TELEX WU 1-2403 • RCA 222 117



ENGINEERS

June 28, 1973

The Division Engineer
North Atlantic Division
Corps of Engineers
Department of the Army
90 Church Street
New York, New York

Attention: Major General R. H. Groves

Ref.: Contract No. DACW-52-73-C-0007

Gentlemen:

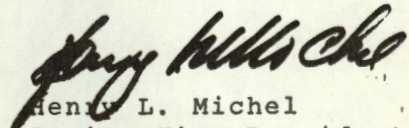
In accordance with the provisions of the referenced contract, we have conducted feasibility level investigations of several projects and Regional Programs which develop water supplies above the level of existing sources for northern New Jersey-New York City-western Connecticut Metropolitan Area.

The investigations included an analysis of an exchange of water with Long Island; diversions of Hudson River water to the Ramapo River; use of Ashokan Reservoir as a balancing reservoir; and development of upper Hudson River Basin storage with new conduits to the study area. Guidelines were developed for use in designing a demonstration project to test the effects of universal metering on water consumption in New York City.

Regional Programs designed to meet excess water demands in the New York Study area through the year 2020 were developed to display the impact of the Long Island groundwater exchange project and assumed metering in New York City on promising Hudson River diversions studied previously, and the results of our study are transmitted herewith.

We wish to express our appreciation to your staff, and in particular the NEWS study group, for their excellent cooperation and assistance. Without their participation, it would not have been possible to complete this assignment within the limited period of time available.

PARSONS, BRINCKERHOFF, QUADE & DOUGLAS, INC.


Henry L. Michel
Senior Vice President

HLM:ml

ENGINEERS



PARSONS BRINCKERHOFF, QUADE & DODGE, INC.
NEW YORK OFFICE
300 WEST 57th STREET, NEW YORK 19, N.Y.
TELEPHONE (212) 512-2000
CABLE: PARSONS NEW YORK • TELETYPE UNIT: 91-2542-171

June 28, 1973

The Division Engineer
North Atlantic Division
Corps of Engineers
Department of the Army
33 Church Street
New York, New York

Attention: Major General R. H. Groves

Re: Contract No. DACW-82-71-C-0007

Gentlemen:

In accordance with the provisions of the referenced contract, we have conducted feasibility level investigations of several projects and National Programs which develop water supplies above the level of existing sources for northern New Jersey-New York City-Waterways Connecticut Metropolitan Area.

The investigations included an analysis of an exchange of water with Long Island, divisions of Hudson River water to the Ramapo River, use of Ashokan Reservoir as a balancing reservoir and development of a new Hudson River Basin. Along with new conduits to the study area, embankments were developed for use in carrying a demonstration project to test the effects of universal metering on water consumption in New York City.

National Program designed to meet excess water demands in the New York City area through the year 2020 was developed to display the impact of the Long Island Sound water exchange project and assumed metering in New York City on providing Hudson River diversions studied previously, and the results of our study are transmitted herewith.

We wish to express our appreciation to your staff and in particular the NEWS study group, for their excellent cooperation and assistance. Without their participation it would not have been possible to complete this assignment within the limited period of time available.

PARSONS BRINCKERHOFF, QUADE & DODGE, INC.

[Handwritten signature]
Director, New York City

Blm:gd

PREFACE

NORTHEASTERN UNITED STATES WATER SUPPLY STUDY (NEWS)

During the major drought in the northeastern part of the United States in the early 1960's, the Congress recognized that the Federal Government had a major role to play in the solution of water supply problems.

The Eighty-Ninth Congress enacted Public Law 89-298 on October 27, 1965 and Title I thereof authorized the Secretary of the Army, acting through the Chief of the Army Corps of Engineers, to cooperate with the various Federal, state and local agencies in the preparation of plans to meet the long-term water needs of the northeastern United States. (A copy of the Title I legislation is shown in Exhibit 1, following this section.)

Specific features of the legislation related to this study include the provision that the plans developed "may provide for the construction, operation and maintenance by the United States of a system of major reservoirs..." and that "such plans shall provide for appropriate financial participation by the states, political subdivisions thereof, and other local interests."

Under authorization of this Act, the Corps of Engineers, North Atlantic Division, has established a NEWS Study Group which has conducted a series of studies to determine the water supply needs of the area, to identify alternative water supply projects to meet these needs, and to identify institutional and cost-sharing options relative to Federal, state, and local efforts required for the implementation of the water supply projects.

In the following report, additional projects and regional programs applicable to the Northern New Jersey - New York City - Western Connecticut portion of the NEWS Study Area are developed.

This report supplements a previous report prepared for the NEWS Study, titled Engineering Feasibility Report on Alternative Regional Water Supply Plans for Northern New Jersey - New York City - Western Connecticut Metropolitan Area, November 1971 by Metcalf and Eddy, Inc. and Hazen and Sawyer (Contract No. DACW-52-69-C-0001). Some materials in this report are drawn from the previous report and the reader is advised to refer to the previous report for details when noted.

The Fifty-Ninth Congress enacted Public Law 59-123 on October 27, 1906 and Title I thereof authorized the Secretary of the Army, acting through the Chief of the Army Corps of Engineers, to cooperate with the various Federal, State and local agencies in the preparation of plans to meet the long-term water needs of the northeastern United States. A copy of the Title I legislation is shown in Exhibit I, following this section.

Specific features of the legislation related to this study include the provision that the plans developed "may provide for the construction, operation and maintenance by the United States of a system of major reservoirs..." and that "such plans shall provide for appropriate financial participation by the States, political subdivisions thereof, and other local interests."

Under authorization of this Act, the Corps of Engineers, North Atlantic Division, has established a NEWS Study Group which has conducted a series of studies to determine the water supply needs of the area, to identify alternative water supply projects to meet these needs, and to identify institutional and cost-sharing options relative to Federal, State, and local efforts required for the implementation of the water supply projects.

In the following report, additional projects and regional programs applicable to the Northern New Jersey - New York City - Western Connecticut portion of the NEWS Study Area are developed.



Public Law 89-298
89th Congress, S. 2300
October 27, 1965

An Act

Authorizing the construction, repair, and preservation of certain public works on rivers and harbors for navigation, flood control, and for other purposes.

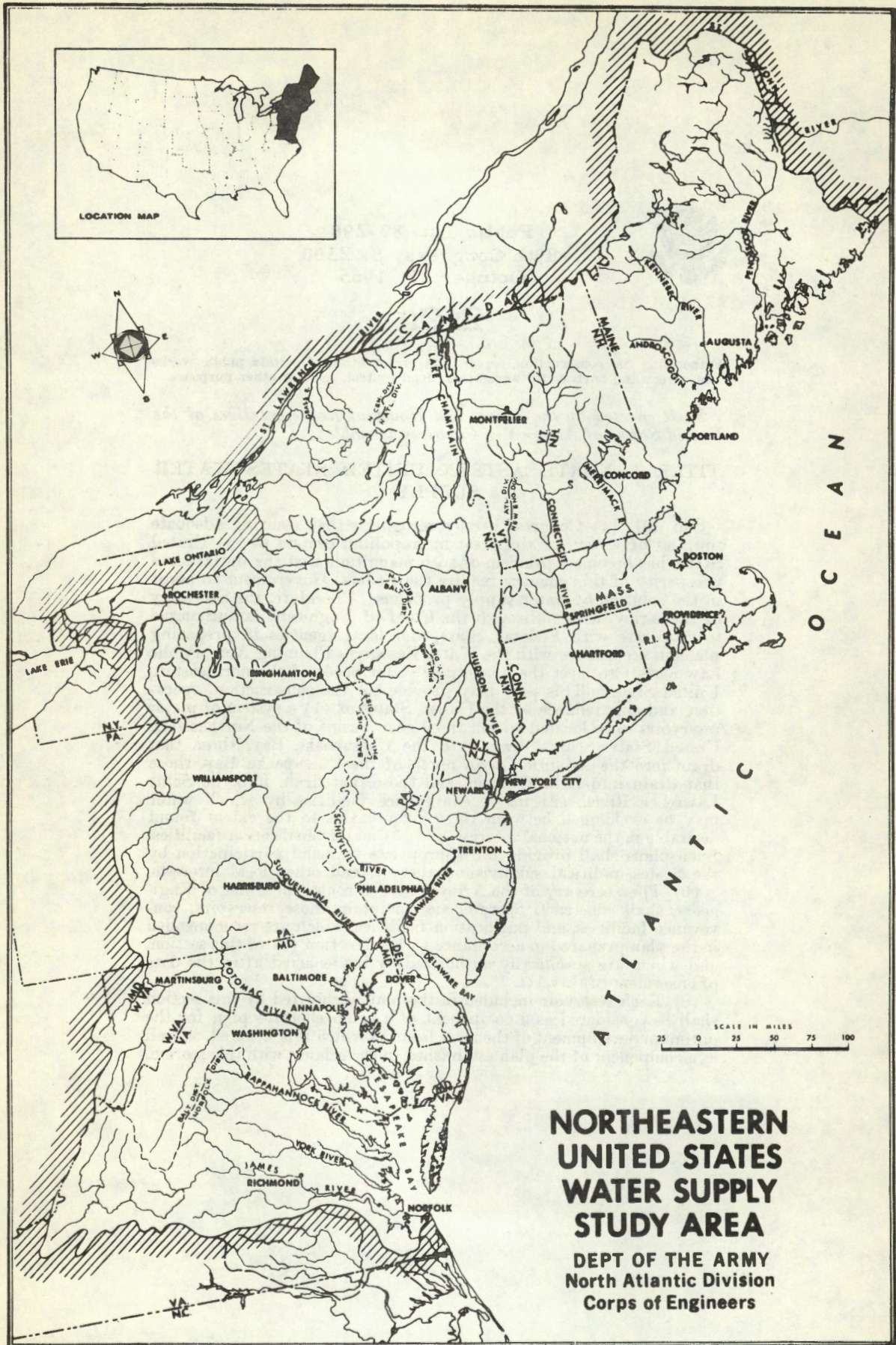
Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

TITLE I—NORTHEASTERN UNITED STATES WATER SUPPLY

SEC. 101. (a) Congress hereby recognizes that assuring adequate supplies of water for the great metropolitan centers of the United States has become a problem of such magnitude that the welfare and prosperity of this country require the Federal Government to assist in the solution of water supply problems. Therefore, the Secretary of the Army, acting through the Chief of Engineers, is authorized to cooperate with Federal, State, and local agencies in preparing plans in accordance with the Water Resources Planning Act (Public Law 89-80) to meet the long-range water needs of the northeastern United States. This plan may provide for the construction, operation, and maintenance by the United States of (1) a system of major reservoirs to be located within those river basins of the Northeastern United States which drain into the Chesapeake Bay, those that drain into the Atlantic Ocean north of the Chesapeake Bay, those that drain into Lake Ontario, and those that drain into the Saint Lawrence River, (2) major conveyance facilities by which water may be exchanged between these river basins to the extent found desirable in the national interest, and (3) major purification facilities. Such plans shall provide for appropriate financial participation by the States, political subdivisions thereof, and other local interests.

(b) The Secretary of the Army, acting through the Chief of Engineers, shall construct, operate, and maintain those reservoirs, conveyance facilities, and purification facilities, which are recommended in the plan prepared in accordance with subsection (a) of this section, and which are specifically authorized by law enacted after the date of enactment of this Act.

(c) Each reservoir included in the plan authorized by this section shall be considered as a component of a comprehensive plan for the optimum development of the river basin in which it is situated, as well as a component of the plan established in accordance with this section.



June 1969 - US Army, Corps of Engineers

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I. INTRODUCTION AND SCOPE OF STUDY

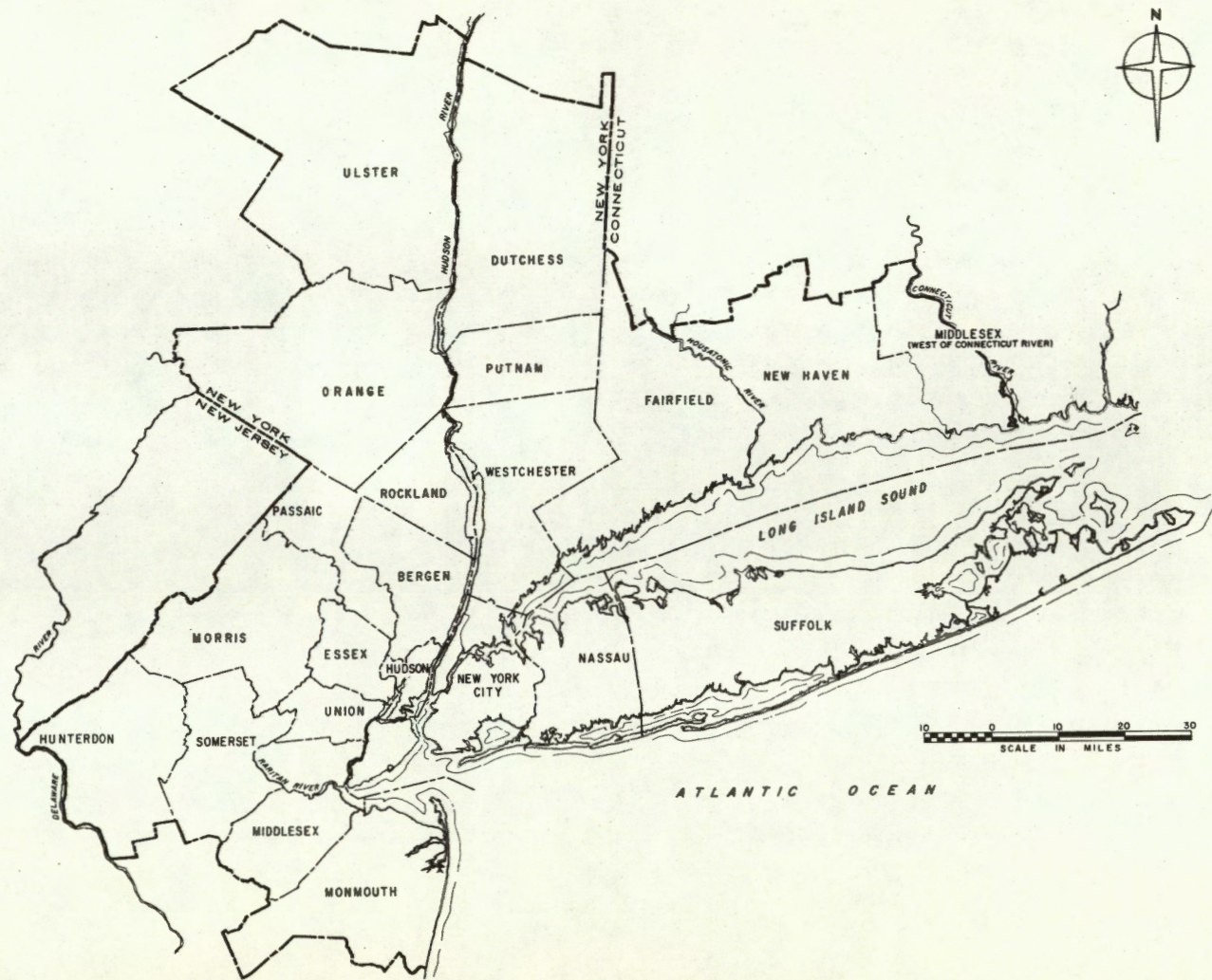
The North Atlantic Division, Corps of Engineers, has been authorized and directed under the Northeastern U.S. Water Supply (NEWS) Study to develop alternative sources of water to meet severe drought demands in the Northern New Jersey-New York City-Western Connecticut Metropolitan Area, hereafter known as the New York Study Area. The study area is shown on Figure 1. Under this authorization, a study entitled "Engineering Feasibility Report on Alternative Regional Water Supply Plans for Northern New Jersey-New York City-Western Connecticut Metropolitan Area", was accomplished by Metcalf & Eddy, Inc. and Hazen & Sawyer under a Joint Venture. The study was completed in November 1971, and is referred to hereinafter as the Joint Venture Report. The Joint Venture Report developed some 100 alternative projects for meeting future water requirements of the New York Study Area, in excess of the requirements being met by existing systems and short-term expansions to those systems.

In order to study further alternatives at the feasibility level, Contract No. DACW-52-73-C-0007 was let to Parsons, Brinckerhoff, Quade & Douglas, Inc. To provide consistency and comparability between previously published reports and this report, it was decided that similar baseline conditions would apply. Wherever possible, anticipated project yields and features would be the same or similar to those selected for use in similar projects in the Joint Venture Report. Further, data used to compute project costs and to develop the cost of regional programs would be taken to the same base, that is, to the Engineering News-Record base of 1400, and unit costs used in the Joint Venture Report would be used for this study.

In order to avoid excessive duplication and to allow for the publication of a document which would not be unwieldy, there are extensive references in this report to the Joint Venture Report.

Specifically, the scope of work for this study is summarized as follows:

1. Develop a project to supply water from the Hudson River to Great Notch, New Jersey for distribution through the existing northern New Jersey water system. The water would be diverted from the Hudson River at West Park similar to Project P-6 in the Joint Venture Report, but with storage within the Ramapo River Basin and high-flow skimming of waters from the Hudson River. The objective of the study is to determine the largest practical yield for New Jersey without resorting to development of upper New York State impoundments.
2. Utilize the existing Ashokan Reservoir as a balancing reservoir for diversion of Hudson River high flows. A two-way exchange with the Ashokan Reservoir would be studied which would permit pumping to Ashokan during periods of high-flows in the Hudson River and the use of Ashokan Reservoir to supply New York Study Area demands during periods of low flows. This project would allow release of additional water to the metropolitan area through the Catskill Aqueduct and also release through Hyde Park or West Park to Kensico Reservoir via tunnels as developed in Projects HU-1 or HU-6 described in the Joint Venture Report.
3. Develop high level supplies in the Upper Hudson River Basin with gravity flow to Kensico Reservoir and/or Great Notch, New Jersey. This analysis is to include five variations of possible projects as follows:
 - a. upper Hudson storage and diversion to Great Sacandaga Lake with a tunnel to Kensico Reservoir in Westchester County, New York;
 - b. the same project as a. above, with flow distributed to Kensico Reservoir and to Great Notch, New Jersey;
 - c. similar to b., above, plus enlarging the Hinckley Reservoir, constructing a new reservoir at Forestport and a diversion at McKeever with tunnels to the Sacandaga-Kensico tunnel;
 - d. similar to c. above with the provision that the tunnel directly from Hinckley Reservoir to the aqueduct from Sacandaga would be eliminated and raw water from Hinckley would be released into West Canada Creek and diverted, treated and pumped to the Sacandaga-Kensico tunnel at a point further downstream; and

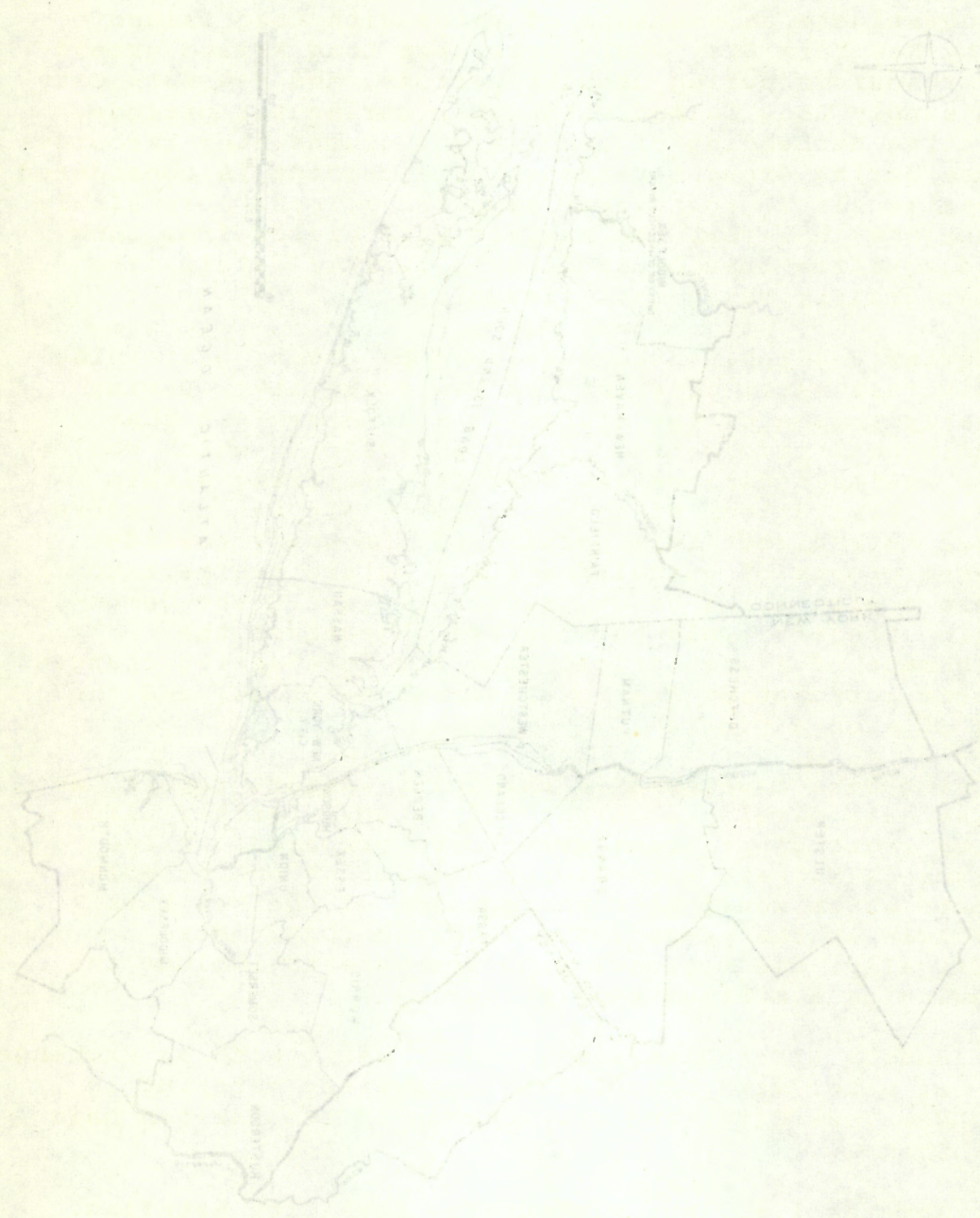


NEW YORK STUDY AREA

Figure 1

AREA YOUTH PROJ. WEA

Figure 1



- e. enlargement of Hinckley Reservoir and a new reservoir at Forestport with a diversion at McKeever all providing additional yield from Hinckley directly to Kensico Reservoir.
4. Investigate an exchange of water with Long Island whereby New York City would draw upon Long Island groundwater resources during drought periods, and New York City would supply Long Island with water during wet periods, permitting husbanding of Long Island groundwater resources for use during drought periods. The concept is considered reasonable since groundwater supplies respond more slowly to droughts; however, the maximum safe yields from Long Island aquifers must be studied in further detail from a water quality management viewpoint.
 5. Review available data developed by others pertaining to universal water metering for New York City. During the early phases of the study, it was determined that no additional information could be developed which would supply reliable data on New York City metering within the time limitations of this contract. It was therefore decided to redirect this portion of the study towards the development of guidelines for a future contract to prepare a plan for a demonstration project. The demonstration project would have as its objectives the development of a statistical base for forecasting changes in water consumption due to universal metering, and the costs of such a program.
 6. Using data developed in the Joint Venture report, as well as data developed during this study, further illustrative regional programs were to be prepared. These programs illustrate methods for developing one or more projects which would meet the demands of the New York Study Area in the years 1980, 2000 and 2020. More specifically, the regional programs were to include the following as a minimum supply source:
 - 1.a. Hudson River diversion at West Park, with an exchange of water with Long Island, universal metering in New York City, and development of the Raritan Main Stem.
 - 1.b. Same as 1.a., but without New York City metering.

- 1.c. Same as 1.a., but without Long Island groundwater exchange.
- 1.d. Hudson River diversion at West Park, plus development of the Raritan Main Stem without universal metering of New York City and without a Long Island groundwater exchange project.
- 2.a. Hudson River diversion at Hyde Park, with an exchange of water with Long Island, universal metering in New York City, and development of the Raritan Main Stem.
- 2.b. Same as 2.a., without New York City metering.
- 2.c. Same as 2.a., without a Long Island groundwater exchange.
- 2.d. Hudson River diversion at Hyde Park and development of the Raritan Main Stem, but without consideration of Long Island groundwater exchange or New York City metering.

One objective of developing the programs was to test the effect of metering in New York City, and tapping Long Island groundwater sources, on the cost of developing a regional supply system.

For purposes of developing regional programs, it was assumed that the program would provide for demands beyond those which could be met by current supplies or by presently planned expansions to current supplies. The total excess demands as developed previously in the Joint-Venture Report is contained in Table 1, following.

Table 1 - Regional Demands

	<u>Million Gallons Per Day in Year</u>		
	<u>1980</u>	<u>2000</u>	<u>2020</u>
New Jersey	120	400	820
New York	150	450	840
Connecticut	<u>40</u>	<u>100</u>	<u>240</u>
Total Study Area	310	950	1,900

In accordance with instructions governing the work on this project, the report includes no recommendations as to specific projects since it is recognized that there are additional considerations which must be studied beyond the economic and engineering feasibility aspects for developing any of the projects or programs. However, the Joint Venture Report, and other work, has indicated clearly that upstream storage in the Hudson Basin provides the most effective source of additional water for the New York Study Area. The most efficient transport system utilizes the Hudson River with a withdrawal and treatment in the Hyde Park-West Park area.

In accordance with instructions governing the work on this project, the report includes no recommendations as to specific projects since it is recognized that there are additional considerations which must be studied beyond the economic and engineering feasibility aspects for developing any of the projects or programs. However, the Joint Venture Report, and other work, has indicated clearly that upstream storage in the Hudson Basin provides the most effective source of additional water for the New York Study Area. The most efficient transport system utilizes the Hudson River with a withdrawal and treatment in the Hyde Park-West Park area.

II. ALTERNATIVE PROJECTS

The future water demands, over and above demands to be met by current or pending local projects, are summarized in Table 1. Numerous projects to satisfy the demands were developed in the previously referenced Joint Venture Report, and a careful review of these projects has led to suggestions for the investigation of further alternatives.

In analyzing the alternative projects during this study, consideration was given to previously developed hydrologic data, minimum downstream low flow releases for prior water demands, and channel and reservoir capacity. The project designations are consistent with the designation selected for similar projects in the Joint Venture Report.

A summary of alternative project cost and yield data is contained in Table 2, following this page.

II.A. HUDSON RIVER DIVERSION TO THE UPPER RAMAPO PROJECT PA-6

Project PA-6 involves high flow skimming from the Hudson River at West Park with diversion to the upper Ramapo River in the Passaic River Basin as shown on Figure 2. The project produces a yield of 250 MGD for use in Northern New Jersey without the necessity of developing impoundments in upper New York State for regulation of flows in the Hudson River. Diverted water would be pumped to off-stream storage near the headwaters of the Ramapo for release during low-flow periods in the Hudson River. The balance of the water would flow down the Ramapo to a pumping station at Pompton Lakes for delivery via a force main to the Wanaque Reservoir, and thence transmitted in conduit to Great Notch. A diversion from the upper Ramapo River could also be used to serve Orange and Rockland Counties. However, a definitive scheme for this diversion would require a more detailed study.

Table 2

PROJECT COST & YIELD DATA

NO.	PROJECT	TERMINAL POINT	YIELD (MGD)	PROJECT COST (Million \$)	PER MGD	UNIT WATER COST PER MILLION GALLONS
PA-6	Hudson River-Upper Ramapo Basin	Great Notch	250	611.9	\$ 2.45	\$ 449
HUA-1	Two-Way Exchange with Ashokan Reservoir	Kensico	530	888.0	1.68	367
UH-1	Upper Hudson River Basin Project UH-1	Kensico	600	2,535.6	2.82	445
UH-2	Upper Hudson River Basin Project UH-2	Kensico - Great Notch	600	2,746.8	3.05	478
UH-3	Upper Hudson River Basin Project UH-3	Kensico - Great Notch	1,500	4,120.3	2.75	421
UH-4A	Upper Hudson River Basin Project UH-4A	Kensico - Great Notch	1,500	3,612.9	2.41	390
UH-4B	Upper Hudson River Basin Project UH-4B	Kensico - Great Notch	1,500	3,498.6	2.33	378
UH-5	Upper Hudson River Basin Project UH-5	Kensico	600	4,427.2	7.38	1,082
LIX	Long Island Exchange	City Tunnels 2 & 3	150	215.8	3.94	282
M-1	Metering*	New York City	125	100.0	0.80	223

*Assumed data for purposes of developing Regional Programs

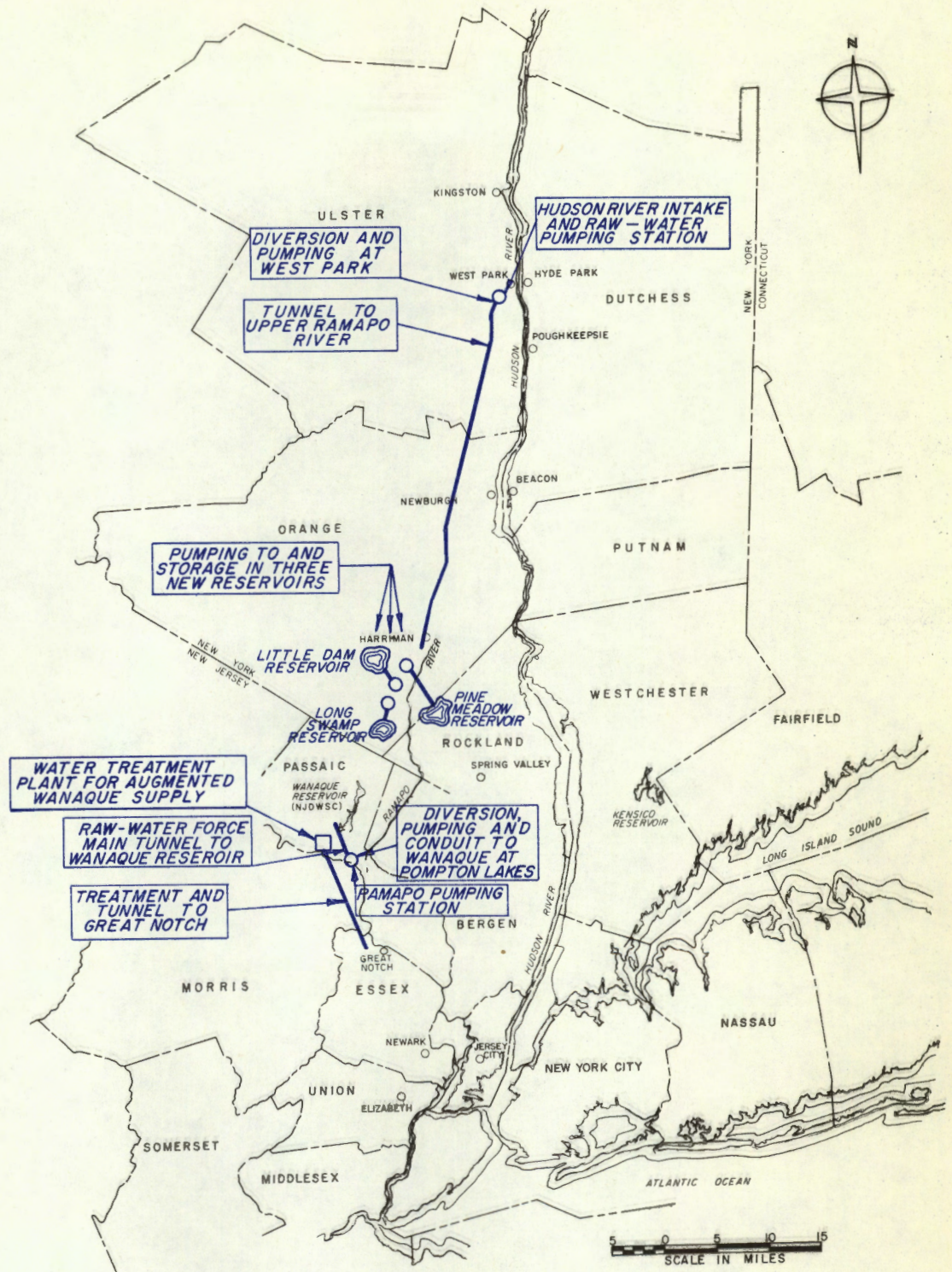
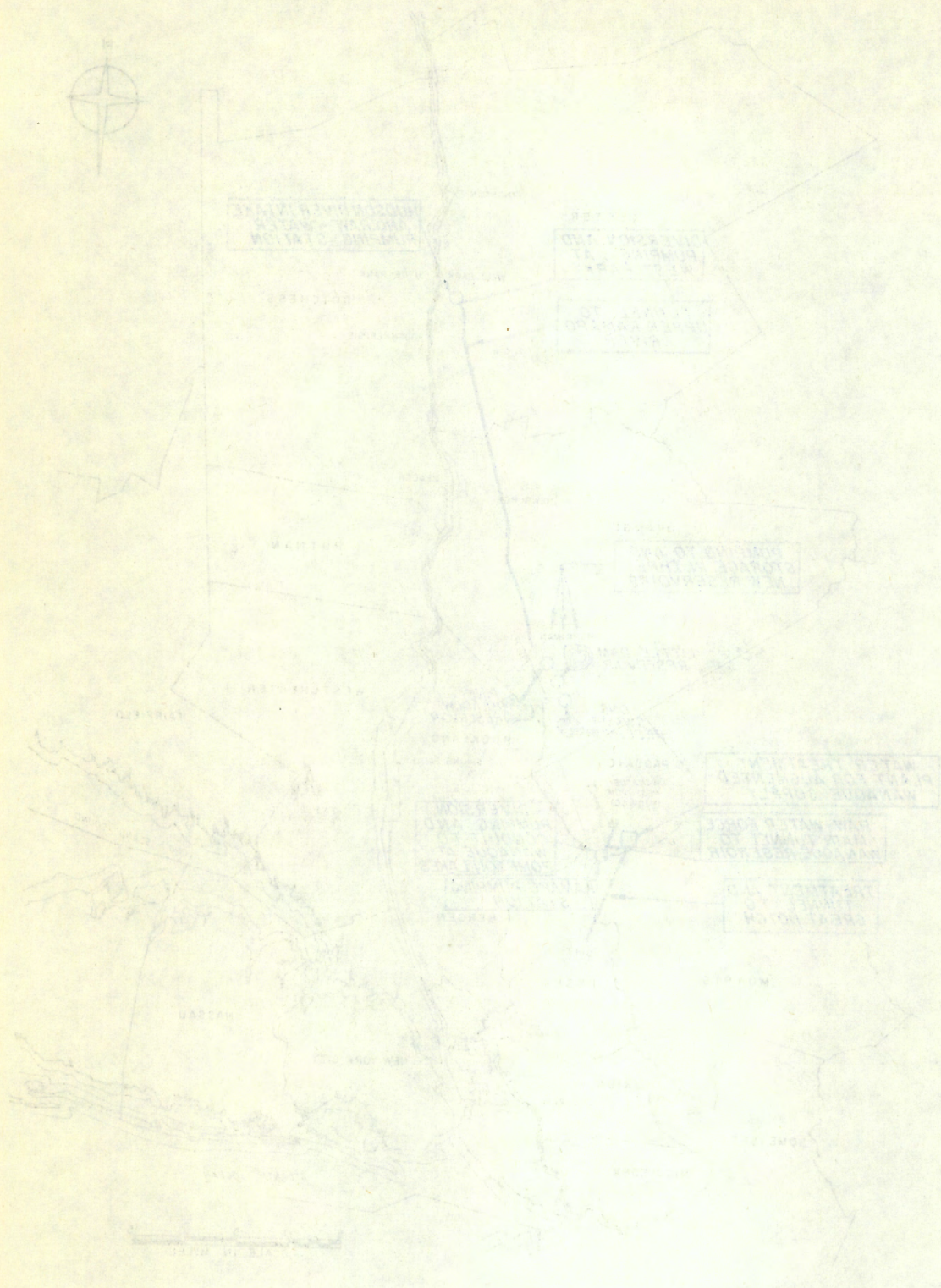


Figure 2 HUDSON RIVER DIVERSION TO UPPER RAMAPO RIVER - PROJECT PA-6



UPPER RAMAPO RIVER - PROJECT PA 6
 Figure 2 - HUDSON RIVER DIVERSION TO

In order to utilize diversions from the Hudson River, it is necessary to maintain flows in the river sufficient to maintain the salt front well below West Park and Poughkeepsie. These requirements are discussed in the Hudson River Basin section of the Joint Venture Report, and the analysis indicates that flows in excess of this minimum requirement are available in all but two or three months of the most severe drought years.

This flood-skimming project would divert water from the Hudson River during high flows and draw on off-stream storage reservoirs in the upper Ramapo basin when water is available on a limited and sporadic basis from the Hudson River. The storage reservoirs would be filled by high-flow diversions from the Hudson River as well.

On-stream storage was investigated; however, the density and proximity of development and the existence of pending flood control projects on the river rendered selection of a practical storage site infeasible at present.

Off-stream storage sites were therefore investigated, and three reasonable reservoir sites were selected during this analysis. The facilities are: a reservoir at Pine Meadow with a dam height of 130', a reservoir at Little Dam with a dam height of 110', and a reservoir at Long Swamp with a dam height of 140'. Together, the reservoirs can store 24 billion gallons and provide most of the flow during those months when high-flow skimming from the Hudson River is limited. Although further refinements may demonstrate that the selected reservoirs could be larger, or that additional or alternative sites could be utilized, the above total storage appears to be the maximum reasonable limiting development based on available information.

During eight months of a drought year, 350 MGD would be skimmed from the Hudson River and delivered through a 13'-diameter, 41.4-mile long reinforced concrete-lined tunnel to the vicinity of Tuxedo, New York, on the upper Ramapo. From there, 30 MGD, 40 MGD, and 30 MGD would be pumped into Pine Meadow, Little Dam and Long Swamp Reservoirs, respectively, and 250 MGD would be released downstream for diversion at Pompton Lakes into Wanaque Reservoir, and thence via conduit to Great Notch.

During the four dry months (of the drought year), an average of 50 MGD would be skimmed from the Hudson River, as available, and the remaining average of 200 MGD would be released from the three small reservoirs, to the diversion at Pompton Lakes. A review of Hudson River flow during the 1960's drought indicates that such diversions are practicable, based on available data.

The pertinent features of the system are shown on the following table.

Table 3
HUDSON RIVER-UPPER RAMAPO PROJECT FEATURES

<u>Feature</u>	<u>Description</u>
Diversion and Pumping at West Park	64,900 HP - 350 MGD
Tunnel to Tuxedo	13'Ø, 41.4-mi. long, S=0.5%- Reinforced concrete liner tunnel
Pump to Pine Meadow	6,080 HP - 30 MGD
Pipe to Pine Meadow	66"Ø, 3.3-mi. long, S=.5% pressure pipe
Pine Meadow Reservoir	130' high dam, HW el. 1060' USGS
Pump to Little Dam	4,510 HP - 40 MGD
Pipe to Little Dam	72"Ø, 3.2-mi. long, S=0.5% pressure pipe
Little Dam Reservoir	110' high, HW el. 780' USGS
Pump to Long Swamp	1,780 HP, 30 MGD
Pipe to Long Swamp	66"Ø, 1.8-mi. long, S=0.5% pressure pipe
Long Swamp Reservoir	140' high, HW el. 620' USGS
Three Reservoirs Storage	24 billion gallons
Diversion & Pumping at Pompton Lakes	11,600 HP - 250 MGD

<u>Feature</u>	<u>Description</u>
Tunnel to Wanaque Reservoir	12'Ø, 4.2-mi. long, S=0.5% reinforced concrete lined tunnel
Tunnel to Great Notch	12'Ø, 13-mi. long, S=1.17% reinforced concrete lined tunnel
Treatment at Wanaque	350 MGD, including existing flows

The use of Wanaque Reservoir and Great Notch is intended to serve as an example of how water may be provided to Northern New Jersey water supply systems. Alternatively this water may be diverted anywhere along the Ramapo and as far downstream as Little Falls on the Passaic River.

Additional yields are possible by providing additional storage near the Ramapo River headwaters, or by providing upstream regulation of the Hudson River and diverting to the upper Ramapo or directly to Wanaque Reservoir. Basic project costs are contained in Appendix A, together with a table describing reservoir features in detail.

II-B. TWO-WAY EXCHANGE WITH ASHOKAN RESERVOIR
PROJECT HUA-1

Project HUA-1 utilizes the skimming of high flows in the Hudson River as outlined in the Joint Venture Report, and as described previously in Project PA-6. The work involves supplying about 530 MGD of water to Kensico Reservoir by utilizing available storage and capacity in the Ashokan Reservoir and the Catskill Aqueduct of the New York City water supply system and constructing a new aqueduct from Hyde Park or West Park to Kensico with a return connection from Ashokan Reservoir, as shown on Figure 3. A feature of this project is that it can be used in combination with Projects HU-1 or HU-6, as described in the Joint Venture Report. The project would be implemented after the construction of aqueducts to Kensico developed for Projects HU-1 or HU-6, and would have the benefit of using existing spare capacity together with taking advantage of Hudson River high-flow skimming.

Specifically, the project develops additional yield from the Hudson River while minimizing upstream regulation by high-flow skimming the river, and provides redundancy for the Catskill Aqueduct for the purpose of permitting major maintenance of the aqueduct.

During the estimated eight high-flow months of a drought year, about 930 MGD of water would be diverted from the Hudson River, of which 530 MGD would be pumped to treatment facilities and released into the Ashokan Reservoir. Concurrently, the present 470 MGD would enter the Ashokan Reservoir from its own basin for storage, and 600 MGD would be released to Kensico reservoir, utilizing the full capacity of the Catskill Aqueduct. It was assumed that the Catskill Aqueduct and Ashokan system deliver approximately 470 MGD during the design year due to limitations in the Ashokan basin and other calls upon the supplies. This project would permit filling of the Ashokan Reservoir and Schoharie Reservoir to full capacity during the eight high-flow months of the year.

Concurrently, 400 MGD would be diverted from the Hudson River at West Park or Hyde Park for treatment and be pumped to Kensico directly through a new aqueduct,

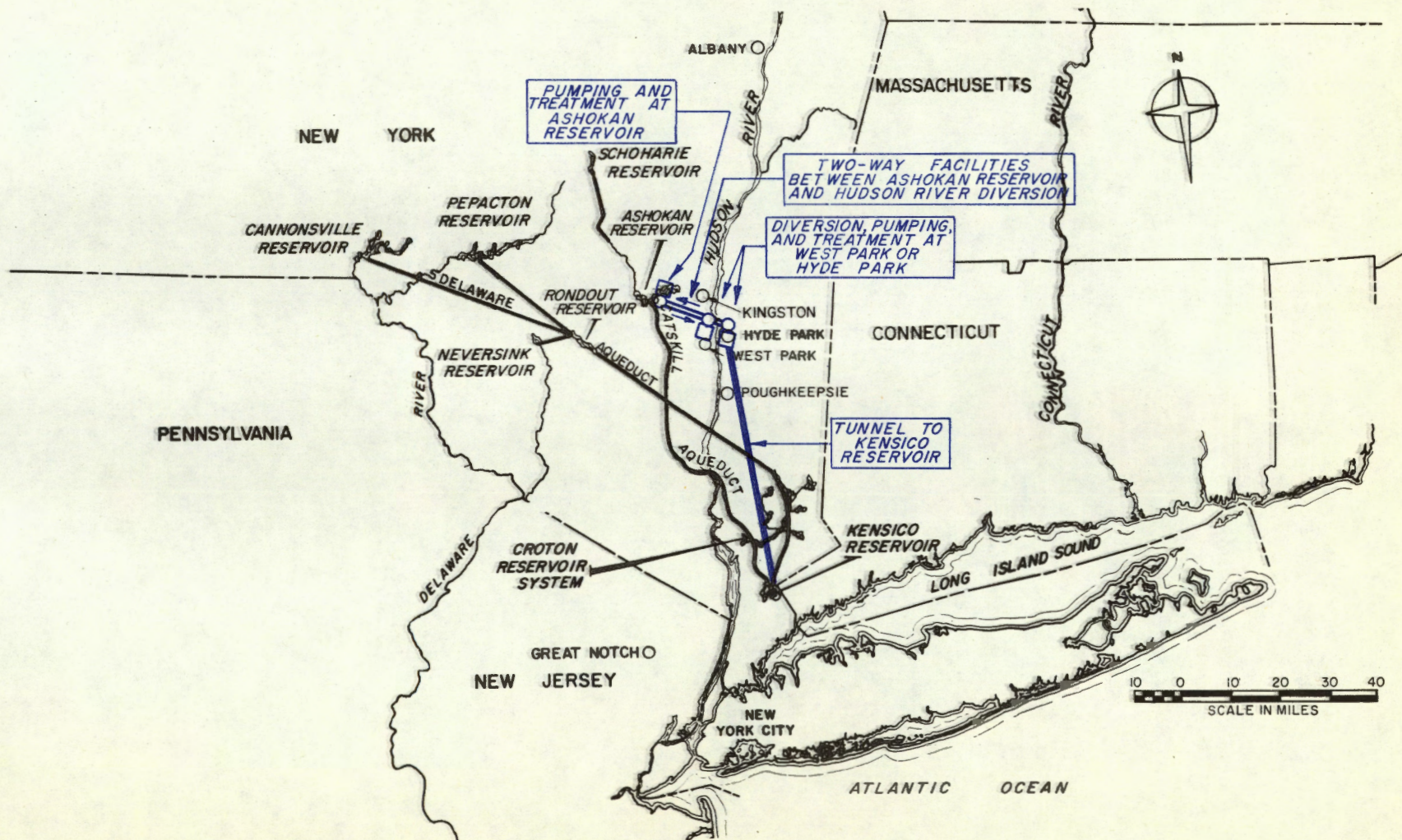
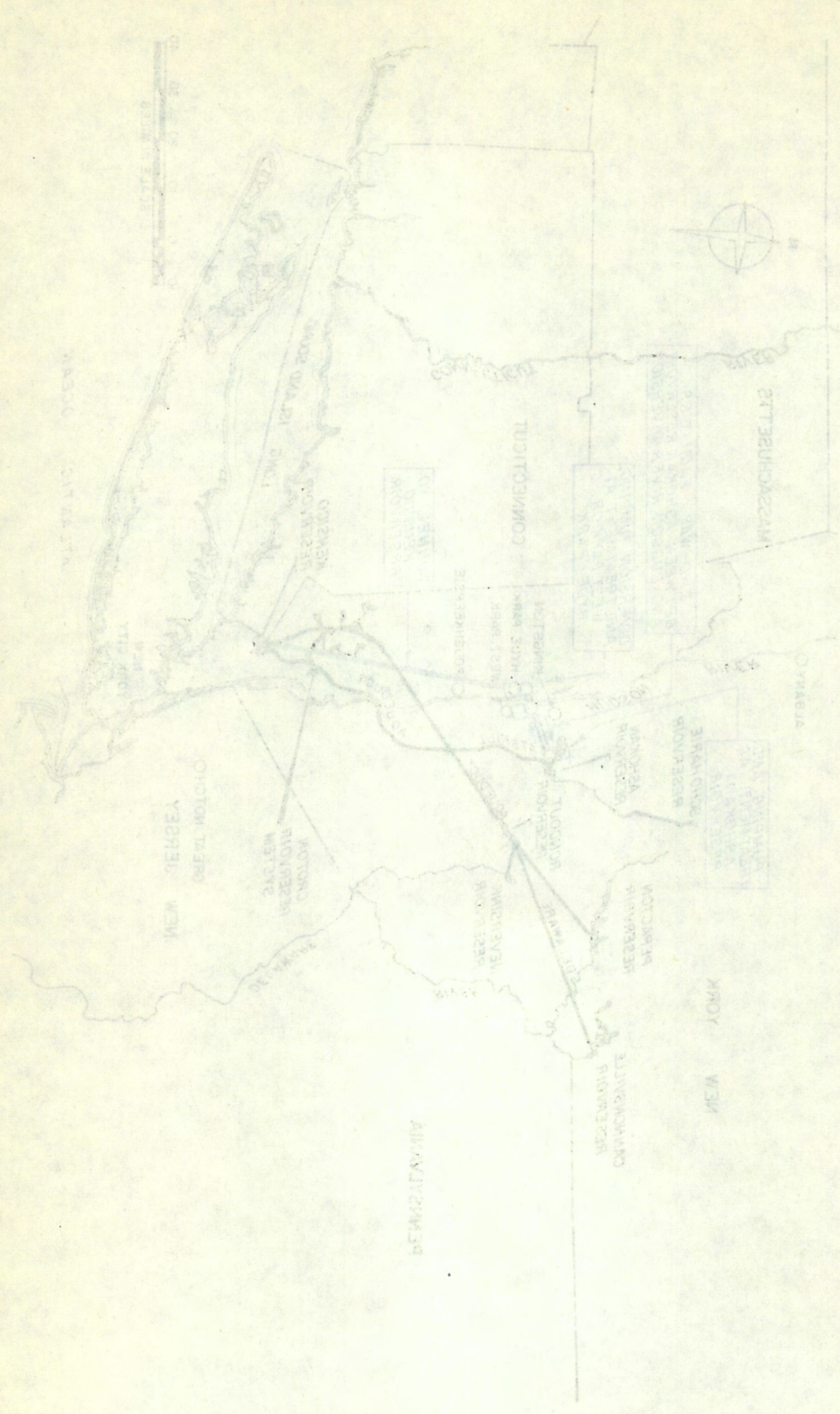


Figure 3 TWO-WAY EXCHANGE WITH ASHOKAN RESERVOIR - PROJECT HUA-1

WATER RESOURCES - BOSTON - MA - WMT
LAW - MA - EXCHANGE



possibly constructed during implementation of Project HU-1 or HU-6 in the Joint Venture Report. The features of this portion of the project, and alternative features, are identical to those described under Project HU-1 in the Joint Venture Report.

During the four low-flow months of the drought year, withdrawals from the Hudson River would be variable and New York City supplies would be delivered from Schoharie-Ashokan. During those estimated four months, 600 MGD would continue to be released to Kensico via the existing Catskill Aqueduct, and an additional 400 MGD would be released to Kensico in the reverse direction through the supply tunnel from the Hudson, and thence via the new aqueduct from Hyde Park or West Park directly to Kensico. The total increased yield from this project is estimated to be 530 MGD.

Varying flows of over 1,000 MGD are estimated to be available from the Hudson River during eight months of the drought year. A portion of this additional yield could be obtained on a year-round basis if upper Hudson storage and regulation is provided. Accordingly, the cost of the new aqueduct from West Park or Hyde Park to Kensico is based on a construction of a tunnel adequate to transmit a total of 1,000 MGD. This assumption would be refined during a detailed study of overall regional requirements and consideration would be given to making a portion of the water available to the northern New Jersey distribution system.

If the Catskill Aqueduct is closed for extended maintenance, the Ashokan Reservoir would release 400 MGD to Kensico via the reverse flow feature and the new aqueduct, thus supplying a yield nearly equal to the present yield. This supply could be augmented by additional Hudson River diversions by selecting portions of the wet season for maintenance operations, or by providing upper Hudson River storage and regulation for releases during the dry season.

Used with Project HU-1, the Ashokan exchange would reduce upstream storage reservoir requirements by making use of Ashokan Reservoir as a pumped storage system.

When used with Project HU-6, the project would share and therefore reduce the yield of the basic Project HU-6 by the 130-MGD excess capacity of the Catskill Aqueduct. However, by providing the additional transmission capacity from Ashokan Reservoir, the total yield available by high-flow skimming is increased by 400 MGD without upper Hudson impoundment construction when the Ashokan-Schoharie system is made available for pumped storage.

Initially, the project could use over 300 MGD excess capacity available in the Delaware Aqueduct as described in HU-6 in the Joint Venture Report. It is important to note, however, that all of the above assumptions require validation by a thorough analysis of the New York City water supply system, which is beyond the scope of this study. Another area to be further analyzed is the water available for high-flow skimming in the Hudson River in the vicinity of Hyde Park-West Park which requires an extensive hydrologic analysis of the Hudson River basin above this point.

Although this project has many attractive features, it was not included in the regional programs developed in Chapter IV, since the purpose of the programs was to test groundwater and metering variables against a fixed baseline. Development of additional programs, after a thorough analysis of Hudson River hydrology and present operation of the New York City supply system, is suggested.

Pertinent features of the project are shown in Table 4, and the basic project cost is contained in Appendix A.

Table 4
TWO-WAY ASHOKAN PROJECT FEATURES

<u>Feature</u>	<u>Description</u>
Hudson River Diversion	1,000 MGD, at West Park or Hyde Park - see Project HU-1 or HU-6 Joint Venture Report
Tunnel to Ashokan Reservoir	19'Ø, 14.2 mile long reinforced concrete tunnel for 600 MGD, capable of reverse gravity flow of 400 MGD

<u>Feature</u>	<u>Description</u>
Pumping and Treatment at Ashokan	Draws 600 MGD of Hudson Water via 120,000 HP pumps and treats for release to Ashokan 8 months of operation per year
Treatment and Pumping at Hudson River Diversion	Treats and pumps 400 MGD to Kensico 8 months per year
Aqueduct from Hudson River Diversion to Kensico	16'Ø, 50 mile long, reinforced concrete tunnel from West Park or Hyde Park

II-C. UPPER HUDSON RIVER ANALYSIS

Additional yields for the New York City Metropolitan Area can be developed by constructing storage and regulation facilities in the upper Hudson River watershed. Tapping of these yields by releasing the water into the Hudson River for diversion at West Park or Hyde Park has been discussed extensively in the Joint Venture Report and elsewhere. Further, feasibility level analysis has been given to tapping the upper Hudson River water resources directly at the source, with gravity tunnels from upstate New York to Kensico Reservoir and Great Notch, New Jersey. The main water conduits are all located such that future connection to the Ashokan Reservoir could be accomplished easily. These conduits would also be interconnected at Shaft 4, which is the intersection of the Catskill and Delaware Aqueducts, to permit discharges from and into any of the three aqueducts.

The reservoir sites that have been considered for these projects are all outside of Adirondack State Park except for the Hinckley Reservoir enlargement, the McKeever Diversion to the Forestport site, and the existing Sacandaga Reservoir. In enlarging Hinckley Reservoir, portions of the northern and eastern shorelines would be extended into the park. The McKeever Diversion structure would flood skim the Moose River for storage in the Forestport Reservoir site outside of the park boundary. Sacandaga Reservoir is located within the park and there would be no change in its storage capacity. The additional yield would be obtained by possibly re-regulating the Indian Lake and Sacandaga Reservoirs while accommodating or, if necessary, reimbursing existing users.

It is noted that there are many alternative reservoir sites in the park which can be readily substituted or added to these projects to regulate dry season flows in the Hudson River Basin. These sites are discussed in the Joint Venture Report.

The results of this analysis are presented in the following sections, and reservoir features are described in detail in Appendix A and in the Joint Venture Report.

C-1. Upper Hudson River Basin - Project UH-1

The Schaghticoke Reservoir discussed in the Joint Venture Report would be developed to regulate flow for diversion into existing Sacandaga Reservoir, with releases from Sacandaga and Fort Hunter Reservoirs being conveyed by a tunnel to Kensico Reservoir, as shown on Figure 4. The Schaghticoke Reservoir provides a year round yield of 400 MGD in addition to downstream requirements. The 400 MGD is treated and pumped into existing Sacandaga Reservoir via a 16'Ø reinforced concrete tunnel. By using Sacandaga Reservoir to its full capacity, an additional 200 MGD can be developed from the Sacandaga River Basin, and combined with the Schaghticoke water to yield a total of 600 MGD. The 600 MGD can be conveyed via a 19'Ø reinforced concrete lined tunnel towards the New York City area.

When required, a new reservoir would be developed at Fort Hunter on Schoharie Creek, a tributary to the Mohawk River, to develop an additional 300 MGD. This additional yield would be treated, then pumped approximately 3.9 miles through a 12'-Ø tunnel to join the main 19'Ø tunnel from Sacandaga at Glen, New York, some 16 1/2 miles below Sacandaga. The total of 900 MGD would then flow south through 135.7 miles of 21'Ø reinforced concrete lined tunnel through Shaft 4 of the New York City water supply system to Kensico Reservoir.

Pertinent features of the Upper Hudson River UH-1 project are shown in the following Table 5, and basic project costs are contained in Appendix A.

Table 5

UPPER HUDSON RIVER PROJECT UH-1 FEATURES

<u>Feature</u>	<u>Description</u>
1. Schaghticoke Reservoir	Impoundment to provide 400 MGD as described in the Joint Venture Report
2a. Raw water pump, tunnel, and treatment from Schaghticoke Reservoir	Treatment for 400 MGD, 2.5-mile long, 11'Ø reinforced concrete-lined tunnel, 34,000 HP pumps

Table 5 (Continued)

Feature	Description
2b. Finished water treatment, pumps and tunnel to Sacandaga	50 miles long, 16'Ø reinforced concrete-lined tunnel, 39,000 HP pumps
3. Tunnel from Sacandaga to Glen	19'Ø, 16.4 miles long, 0.44% slope
4. Fort Hunter Reservoir	Impoundment on Schoharie Creek, 300 MGD yield as described in the Joint Venture Report
5. Pumping and Treatment, at Fort Hunter Reservoir	Treatment for 300 MGD and 38,900 HP in pumping plant to deliver 300 MGD to Glen, New York
6. Tunnel, Fort Hunter to Glen, New York	12'Ø, 3.9 mile long reinforced concrete-lined tunnel on slope S=0.63%
7. Tunnel from Glen, New York to Kensico Reservoir	21'Ø, 135.7-mile long reinforced concrete tunnel on slope of S=0.48%

C-2. Upper Hudson River Basin Project UH-2

The features and operation of Project UH-2 are identical in all respects to Upper Hudson River Basin Project UH-1A upstream of the main delivery aqueduct connection with New York City water supply system Shaft 4, as shown on Figure 5. This connection occurs approximately 89.6 miles downstream of Glen, New York.

At Shaft 4, diversion of a portion of the flow to New Jersey is considered in order to permit more flexibility in serving diverse needs, and to produce a project serving a larger portion of the regional needs. For purposes of developing a relative construction cost estimate, the flow was assumed to be divided as follows:

- a. Flow of 355 MGD delivered to Great Notch, New Jersey, via a 12'Ø, 54-mile long reinforced concrete-lined tunnel on a slope of S=1.1%.
- b. The remaining 545 MGD delivered to Kensico Reservoir via an 18'Ø, 46.1-mile long reinforced concrete-lined tunnel on a slope of S=0.5% from Shaft 4.

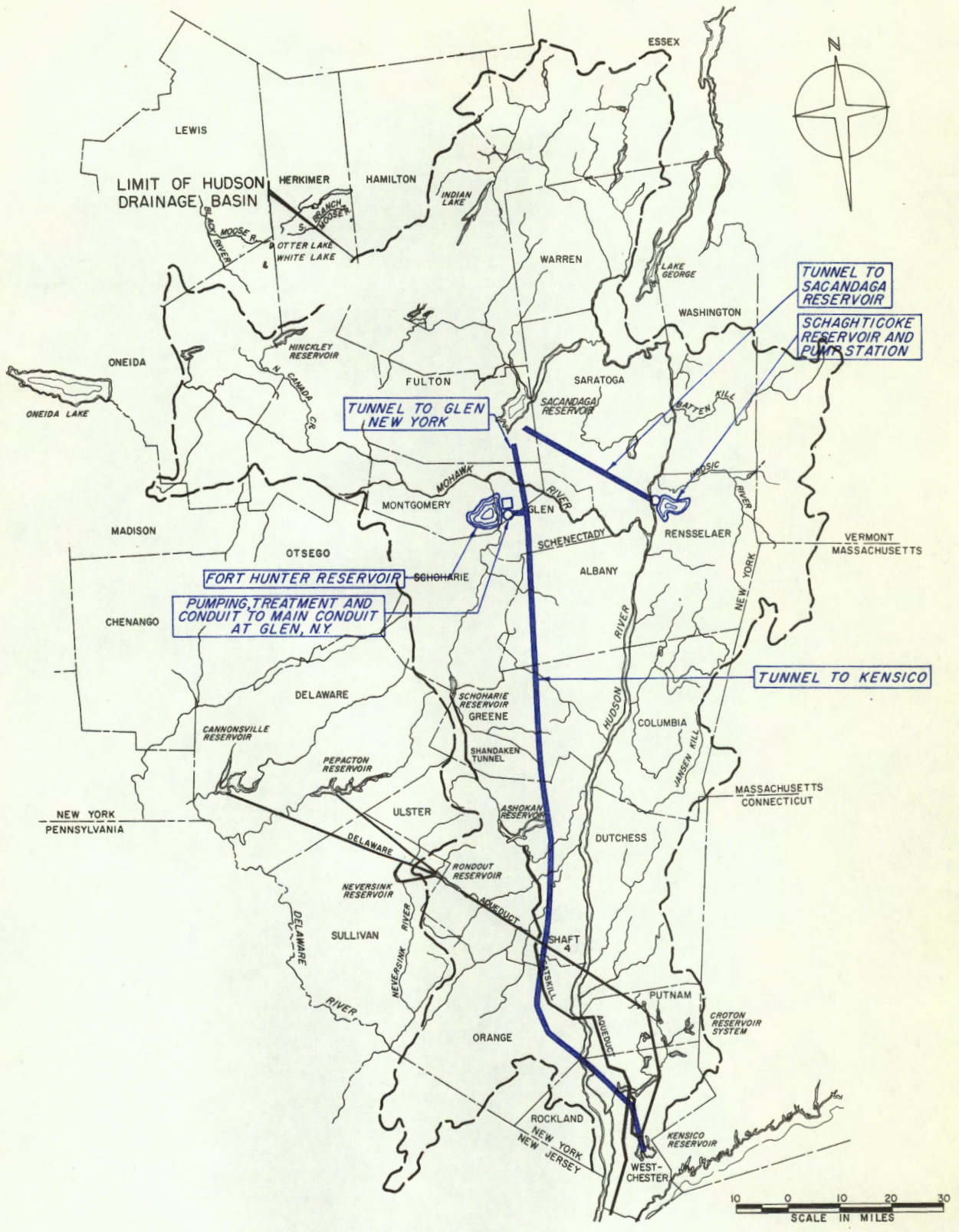


Figure 4 UPPER HUDSON RIVER
BASIN-PROJECT UH - I

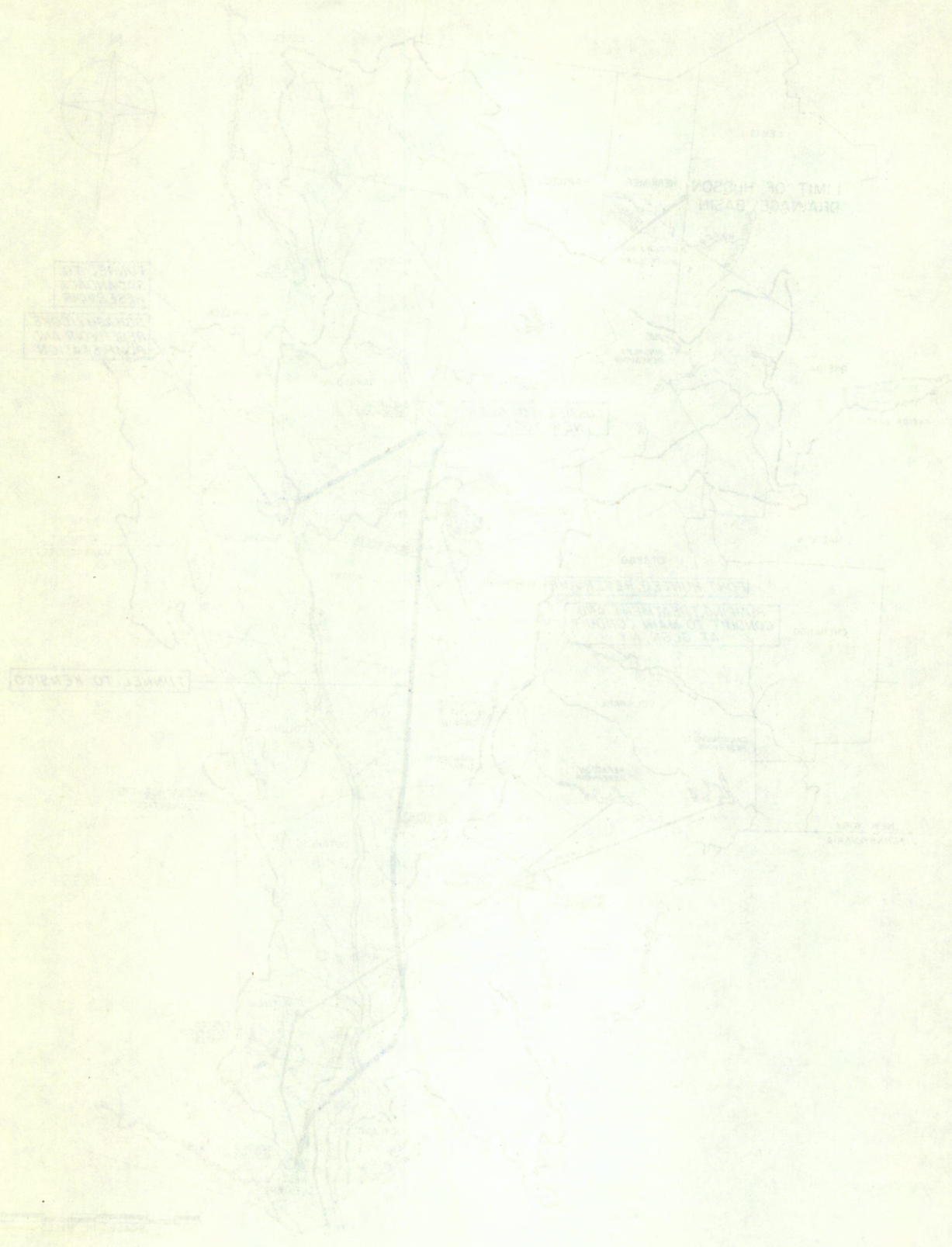


Figure 4. UPPER HUDSON RIVER
 BASIN-PROJECT UNIT

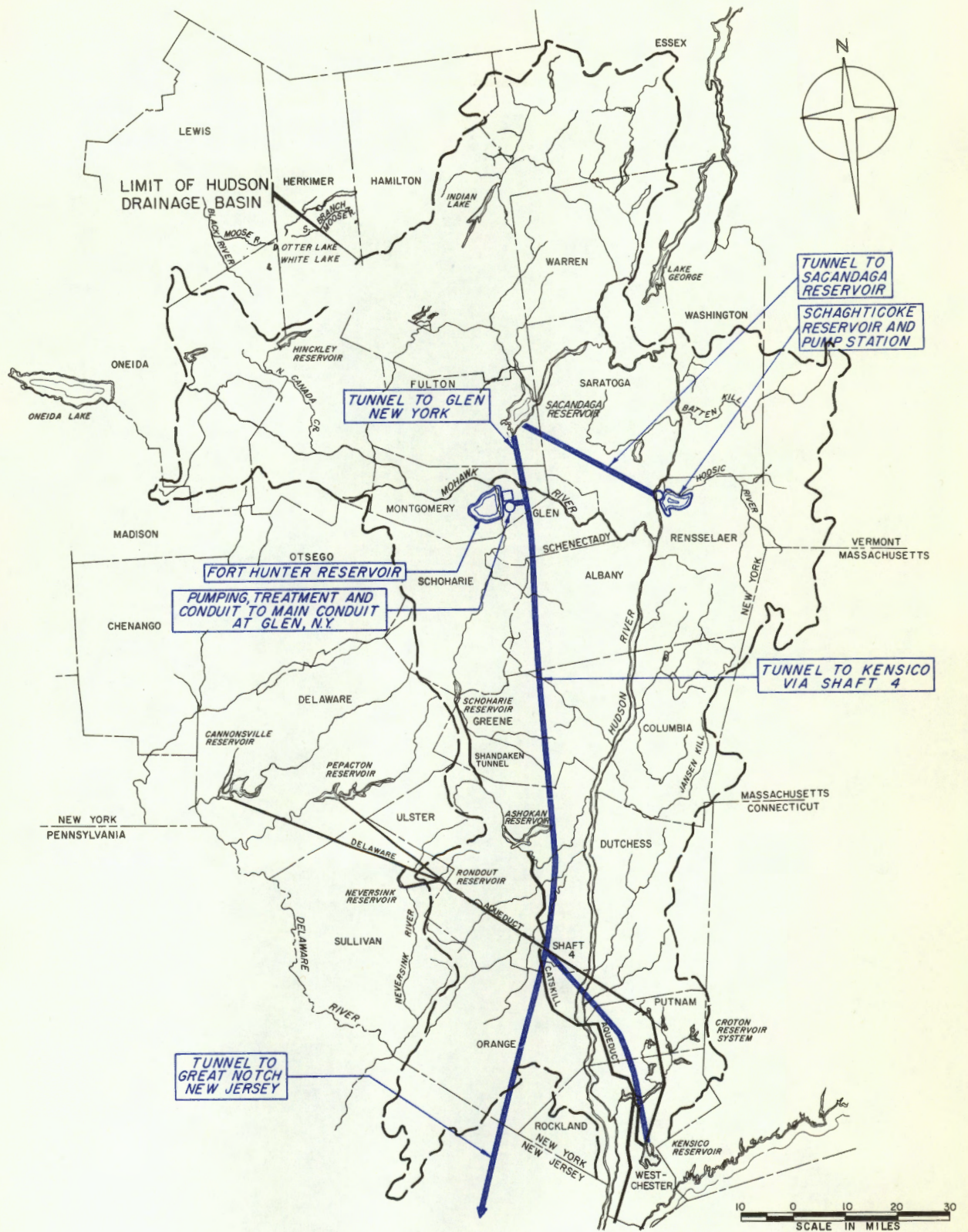


Figure 5 UPPER HUDSON RIVER
BASIN-PROJECT UH-2



UNITED STATES GEOLOGICAL SURVEY
WASHINGTON, D. C.

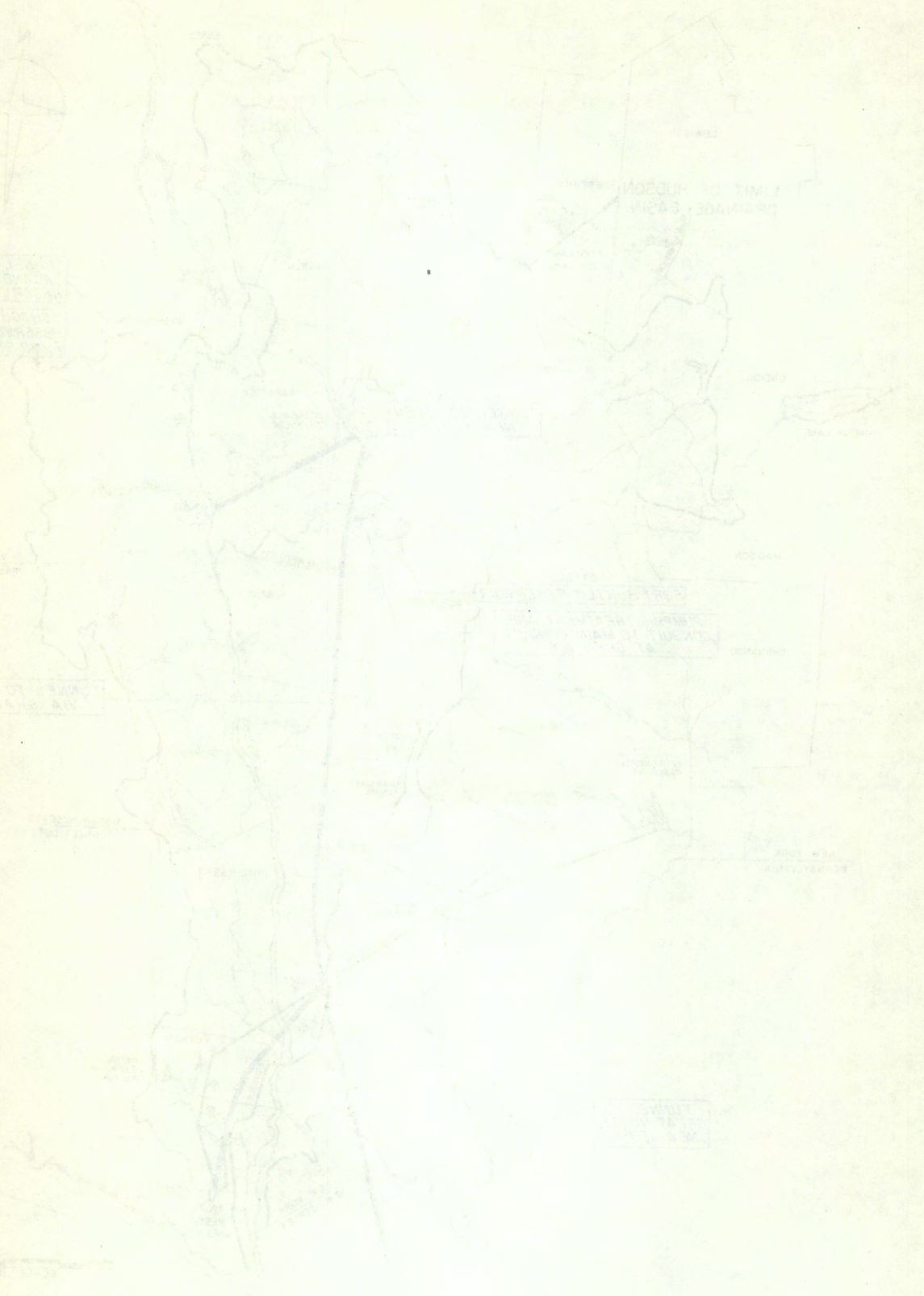
WATER TO KANSAS
No. 1111

LIMIT OF HUDSON
DRAINAGE BASIN

WATER TO KANSAS
No. 1111

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This division of flow is used to demonstrate that this project could also provide substantial portions of Northern New Jersey's future needs and those of Orange and Rockland Counties, as well as those of the New York City system. The basic project cost is contained in Appendix A.

C-3. Upper Hudson River Basin - Project UH-3

The objective of the analysis of Project UH-3 was to develop a scheme for providing upper Hudson River basin yields to the New York Study Area in excess of the 900 MGD developed in Projects UH-1 and UH-2 by investigating supplemental supplies from the Moose River, Black River, and West Canada Creek, as shown on Figure 6.

A small diversion reservoir would be constructed on the Moose River, near McKeever, together with a series of concrete-lined canals interconnecting the reservoir with Otter Lake, White Lake and Woodhull Creek. This diversion would permit transfer of 100 MGD from the Moose River watershed into the proposed reservoir on the Black River at Forestport. The 100 MGD would combine with an additional 200 MGD developed by constructing a 123' high dam at Forestport, and the total 300 MGD would be pumped from the new Forestport Reservoir, via a 16.7-mile long tunnel, to Hinckley Reservoir. This project would result in an interbasin transfer of water from the Lake Ontario basin into the Hudson River basin.

The yield from the McKeever Diversion and the Forestport Reservoir is less than the yields computed in the Joint Venture Report and those developed by the State of New York, since the facility is drawn upon continuously for supply directly to New York, rather than intermittently to make up for low flow in the Hudson River.

Hinckley Reservoir would be expanded by enlarging the dam height to 140', thereby impounding water supplies for an additional 300 MGD from West Canada Creek.

A 300 MGD yield would be developed by constructing a 123'-dam with a 176 billion gallon capacity at Forestport on the Black River with diversion facilities from the Moose River at McKeever. The Forestport site would yield 200 MGD with an additional 100 MGD resulting from the high-flow skimming of the Moose River to storage in the Forestport reservoir. The diversion facilities would include a small diversion reservoir on the Moose River near McKeever. The water from the McKeever Diversion would flow by gravity to Otter Lake, then further from Otter Lake to White Lake and into the Forestport site. Flow would be by gravity through a newly constructed series of canals.

The additional 300 MGD from Hinckley Reservoir expansion plus 300 MGD from the McKeever Diversion-Forestport Reservoir, for a total of 600 MGD, would be released through a 20' diameter, 45.7-mile long tunnel to existing Sacandaga Reservoir.

The features described in Upper Hudson River Basin Project UH-1 would also be developed. These included development of Schaghticoke Reservoir for pumping of 400 MGD into the Sacandaga Reservoir, use of an additional 200 MGD from the Sacandaga River basin, and development of the Fort Hunter Reservoir to yield 300 MGD.

The total 1200 MGD from Schaghticoke, Sacandaga and Hinckley Reservoirs would be released to Glen, New York, via a 16.4-mile long, 23'Ø tunnel, and join the 300 MGD from Fort Hunter Reservoir, with a total yield of 1500 MGD flowing from Glen to Shaft 4 of the New York City supply system in a 89.6 mile long, 24'Ø tunnel.

At Shaft 4, the flow would divide, with portions flowing to Kensico Reservoir and to Great Notch for distribution in the New York City and New Jersey water supply system.

For purposes of preparing cost estimates, it was assumed that 650 MGD, meeting a large portion of the demands of northern New Jersey through the year 2020, would be diverted to Great Notch, with the remaining 850 MGD flowing to Kensico Reservoir, meeting the needs of New York through the year 2020. The division of flow is subject to more detailed analysis, however, taking all other regional factors into account.

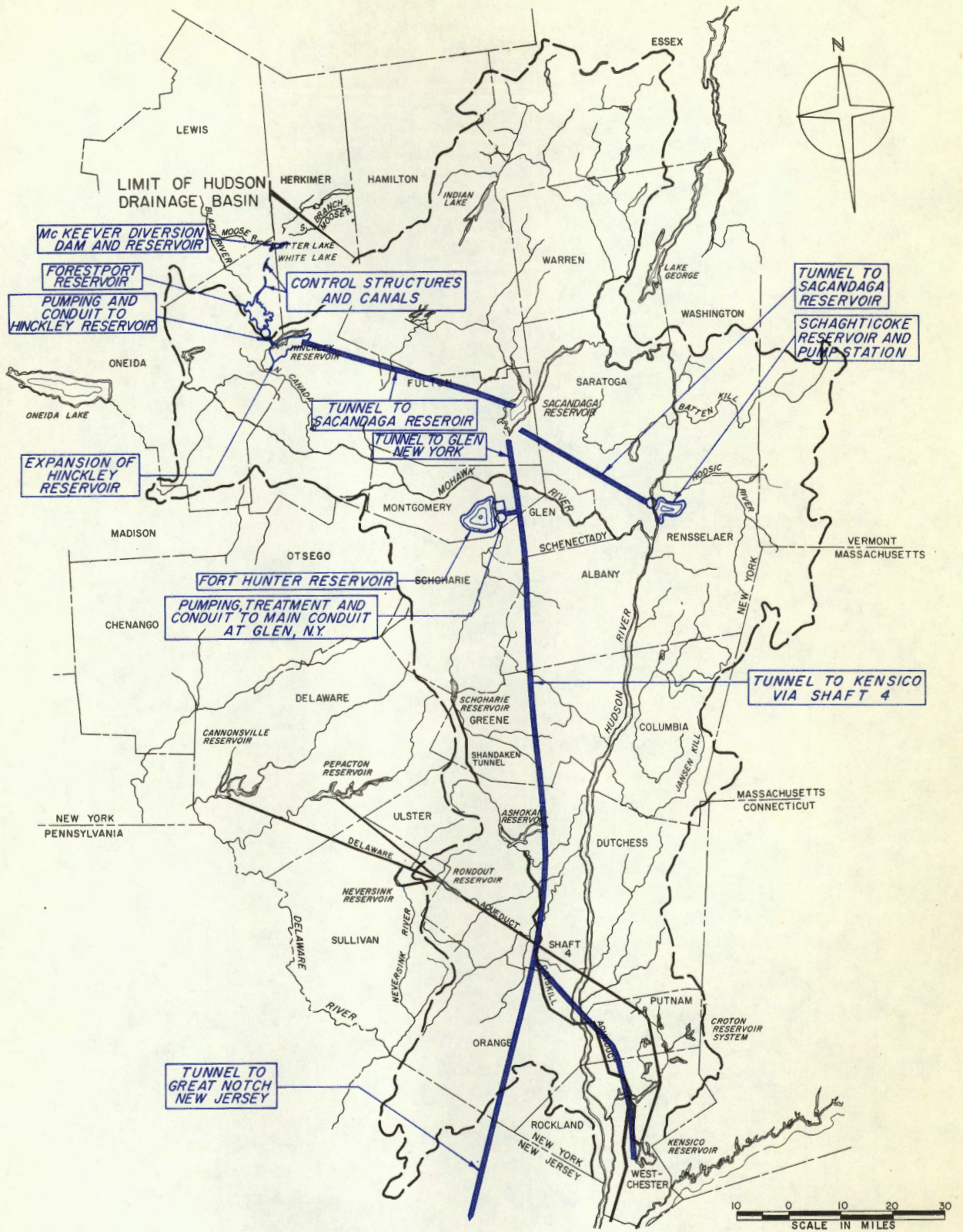


Figure 6 UPPER HUDSON RIVER
BASIN-PROJECT UH-3



STATE OF NEW YORK
DEPARTMENT OF ENVIRONMENTAL CONSERVATION
BUREAU OF WATER

STATE OF NEW YORK
DEPARTMENT OF ENVIRONMENTAL CONSERVATION
BUREAU OF WATER

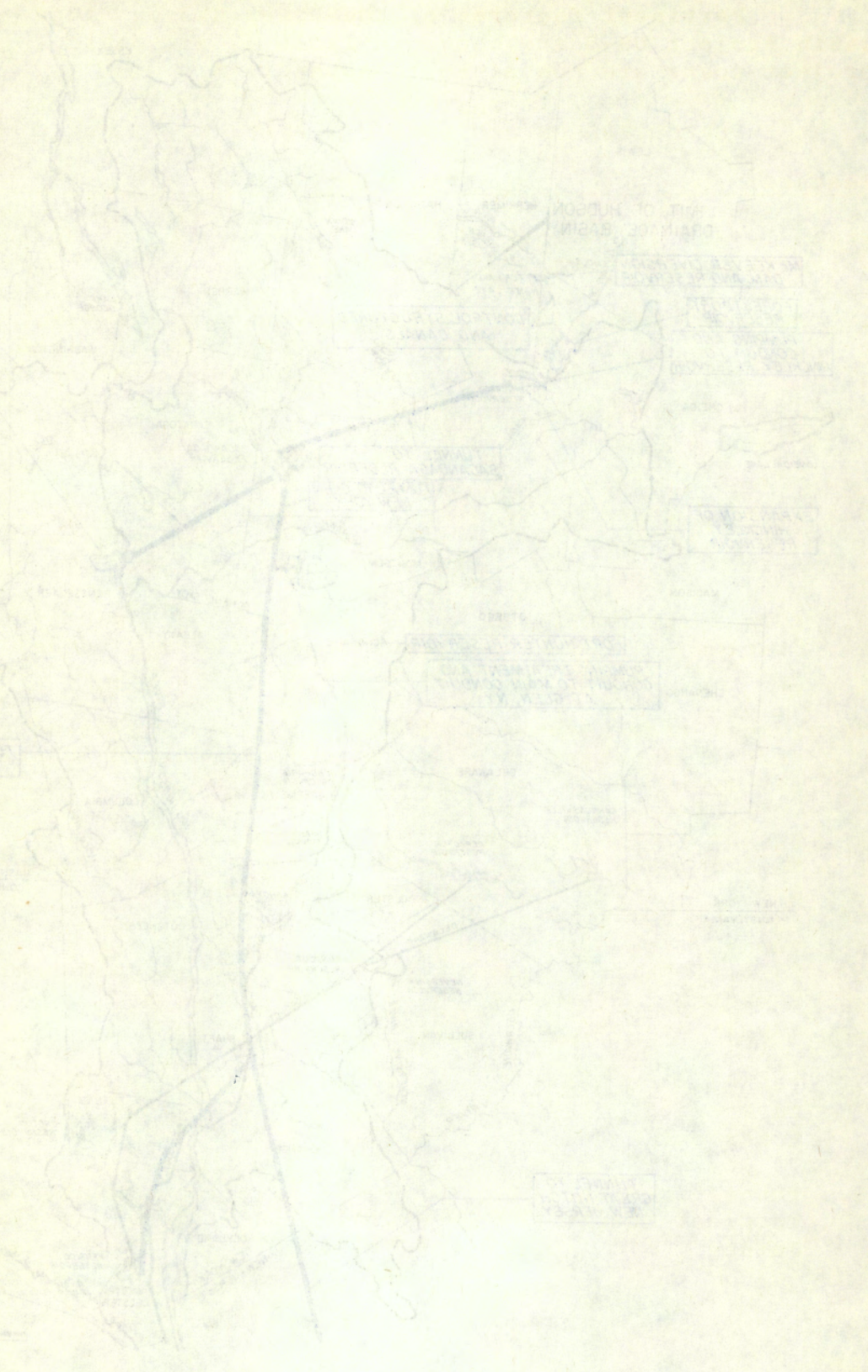


Figure 5. UPPER HUDSON RIVER
BAC - PROJECT UH 3

Pertinent features of the Upper Hudson River Basin Project UH-3 are shown in Table 6, and basic project costs are contained in Appendix A.

Table 6
UPPER HUDSON PROJECT UH-3 FEATURES

Feature	Description
Items 1, 2a, 2b, 4 and 5 from features for Upper Hudson River Basin Project UH-1 additionally:	
1. McKeever Diversion	Small diversion reservoir, 8.5 miles of concrete-lined channel linking the McKeever Reservoir with Otter Lake, White Lake, and Woodhull Creek to Forestport
2. Forestport Reservoir	123'-high dam on the Black River as described in the Joint Venture Report
3. Forestport Pumping Station	13,800-HP pumping capacity to move 300 MGD through tunnel to Hinckley Reservoir
4. Tunnel from Forestport to Hinckley Reservoir	13'Ø, 16.7-mile long reinforced concrete-lined tunnel on slope of S=0.5%
5. Tunnel from Sacandaga to Glen, New York	23'Ø, 16.4-mile long reinforced concrete-lined tunnel on slope of S=0.44%
6. Tunnel from Glen, New York, to Shaft 4, New York City Water Supply System	24'Ø, 89.6-mile long reinforced concrete-lined tunnel on slope of S=0.47%
7. Tunnel from Shaft 4 to Kensico Reservoir	18'Ø, 46.1-mile long reinforced concrete-lined tunnel on slope of S=0.5%
8. Tunnel from Shaft 4 to Great Notch, New Jersey	12'Ø, 54-mile long reinforced concrete-lined tunnel on slope of S=1.1%

C-4 Projects UH-4A, UH-4B

4A. Upper Hudson River Basin Project UH-4A

Project UH-4A is similar to project UH-3 described previously, except that West Canada Creek is used to transport water from Hinckley Reservoir to a location closer to the new aqueduct from Sacandaga Reservoir to New York City, as shown on Figure 7. Diversion works at the McKeever Reservoir site described previously are used to transmit 100 MGD to the proposed Forestport Reservoir. The 100 MGD from McKeever, plus 200 MGD developed from the Black River in the Forestport Reservoir, are pumped to Hinckley Reservoir, where an additional 300 MGD are developed by reservoir expansion all as described under Upper Hudson River Basin Project UH-3.

The 600 MGD available from Hinckley Reservoir is released to West Canada Creek which joins the Mohawk River, carrying the water down to Fonda, New York. The 600 MGD is diverted at Fonda, New York (el. 280), treated, and pumped to Glen, New York, via a 4.5-mile long, 15' \emptyset reinforced concrete-lined tunnel.

At Glen, the 600 MGD joins the 600 MGD from Schaghticoke-Sacandaga, and the 300 MGD from Fort Hunter Reservoir, as described in Upper Hudson River Basin Project UH-1, and proceeds via tunnel to Shaft 4. At Shaft 4, the flow divides to Great Notch, New Jersey, and Kensico Reservoir in a manner identical to that described in Upper Hudson River Basin Project UH-3.

A listing of pertinent features is contained in Table 7, and basic project costs are contained in Appendix A.

Table 7
UPPER HUDSON PROJECT UH-4A FEATURES

<u>Feature</u>	<u>Description</u>
Items 1, 2a, 2b, 3, 4, 5, and 6 from Upper Hudson River Basin Project UH-1	
Items 1, 2, 3, 4, 6, 7, and 8 from Upper Hudson River Basin Project UH-3	
1. Diversion Treatment and Pumping At Fonda, New York	Diversion and treatment for 600 MGD from the Mohawk River at elevation 280', and pumping capacity of 85,300 HP
2. Tunnel from Fonda, New York, to Glen, New York	15' \emptyset , 4.5 mile long reinforced concrete-lined tunnel on a slope of $S=0.93\%$

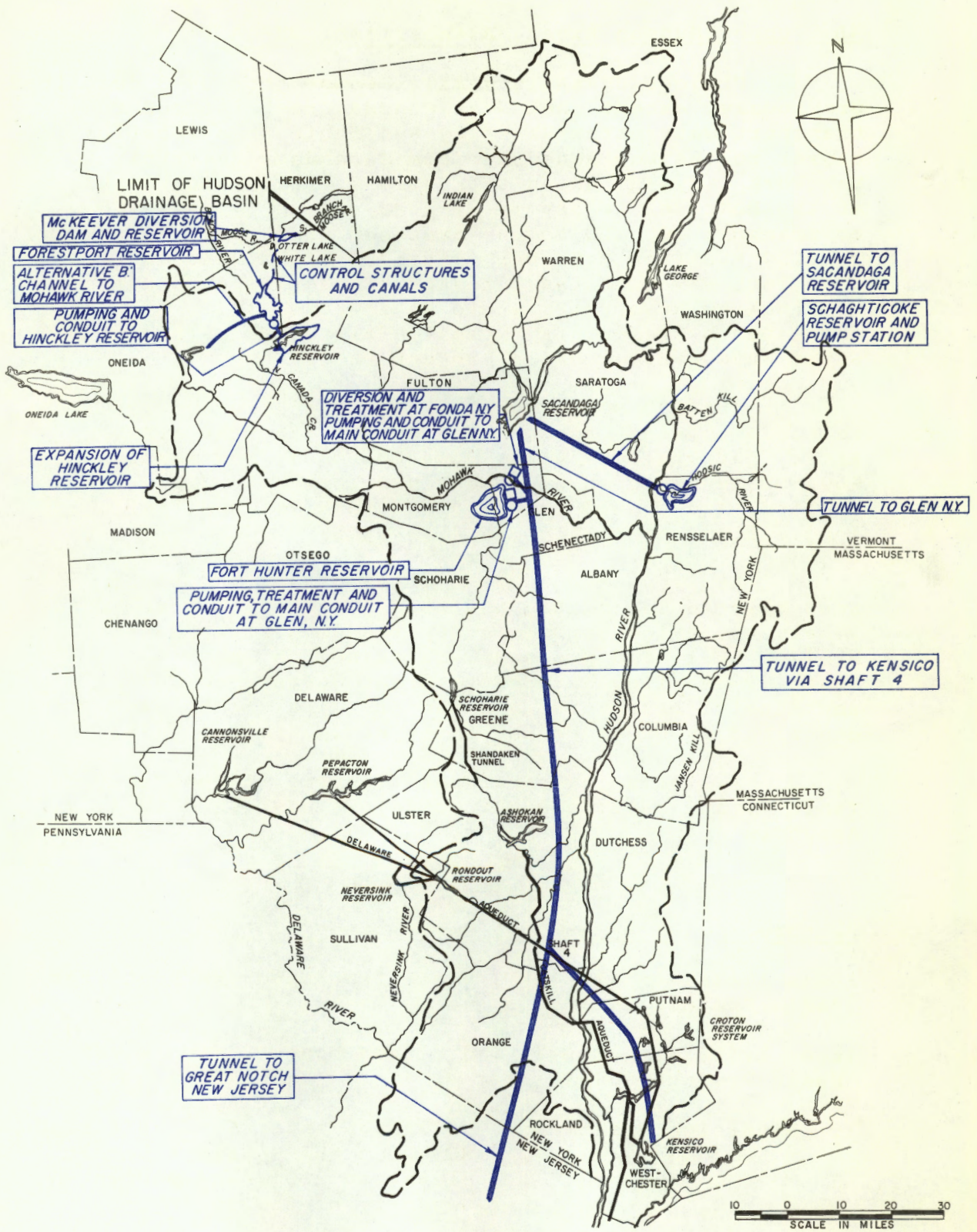


Figure 7 UPPER HUDSON RIVER BASIN-PROJECTS UH- 4A, 4B

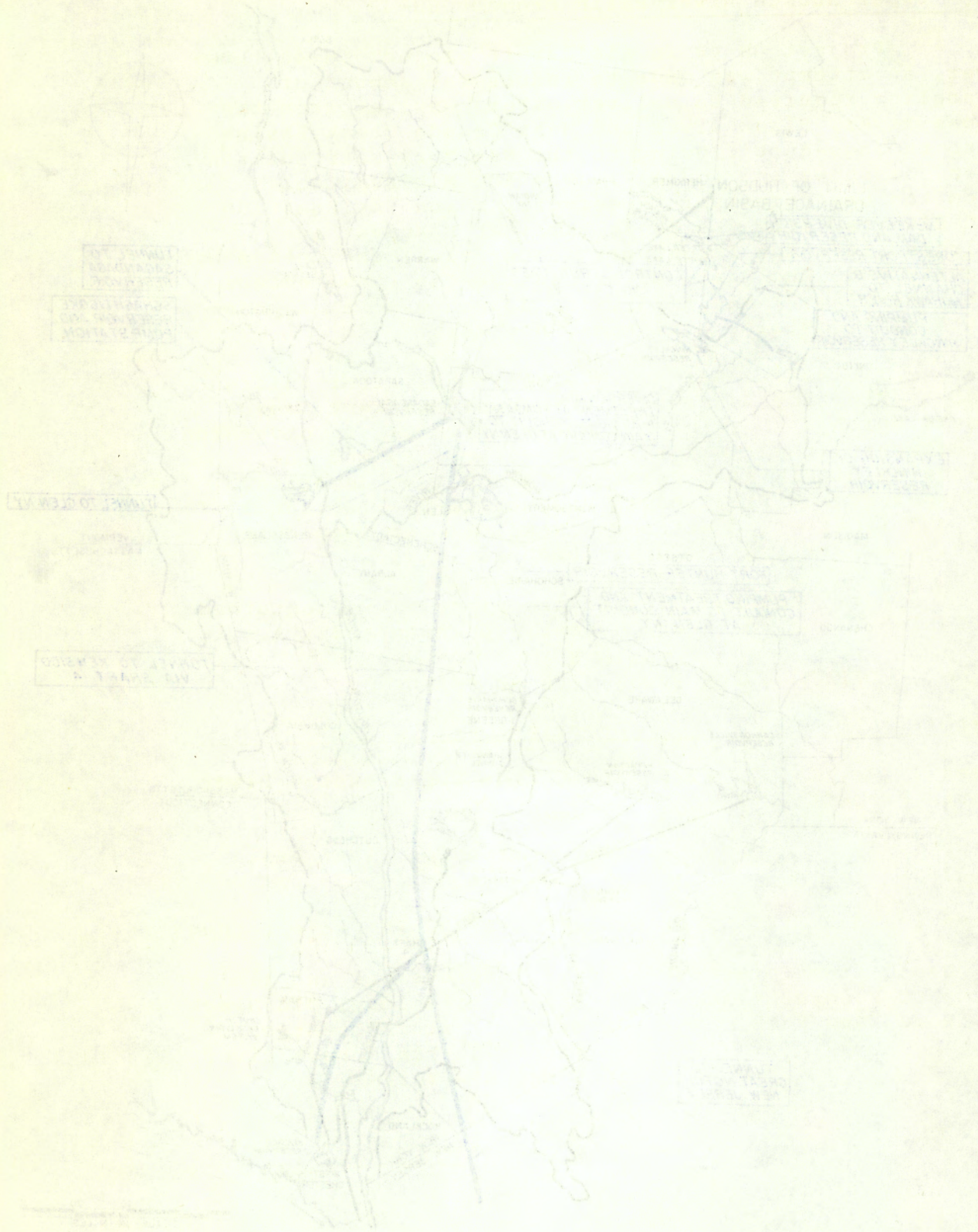


Figure 1. Hudson River Basin
Basin Hydrology

4B. Upper Hudson River Basin Project UH-4B

Project UH-4B is similar to project UH-4A; however, an attempt was made to reduce the amount of tunneling required to deliver water supplies from the Moose River, Black River and West Canada Creek Basins into the aqueduct flowing to the New York Metropolitan Area, as shown in Figure 7. The 300 MGD available from the new Forestport Reservoir, which includes 100 MGD diverted from the Moose River at McKeever are released into the Forestport feeder canal and thence by gravity into the Black River Canal. The canal enters the Mohawk River Basin 13 miles downstream, at a point south of Boonville, near Rome, New York.

The additional 300 MGD available after enlargement of Hinckley Reservoir is released to West Canada Creek, which also joins the Mohawk River. The diversion at McKeever, the new Forestport Reservoir, and the expansion of Hinckley Reservoir are all as described in Upper Hudson River Basin Project UH-3. The total of 600 MGD is diverted at Fonda, New York, and pumped to Glen, New York, all as described previously.

Pertinent features of the project are contained in Table 8, and costs are summarized in Appendix A.

Table 8

UPPER HUDSON PROJECT UH-4B FEATURES

<u>Feature</u>	<u>Description</u>
Items 1, 2a, 2b, 3, 4, 5, and 6 from Upper Hudson River Basin Project UH-1	
Items 1, 2, 6, 7, and 8 from Upper Hudson River Basin Project UH-3	
Items 1 and 2 from Upper Hudson River Basin Project UH-4A	
1. Canal from Forestport Reservoir to Rome, New York	Partial improvement and lining of the 13-mile long, Old Black River Canal from Forestport Reservoir to the Mohawk River at Rome, New York

C-5. Upper Hudson River Basin Project UH-5

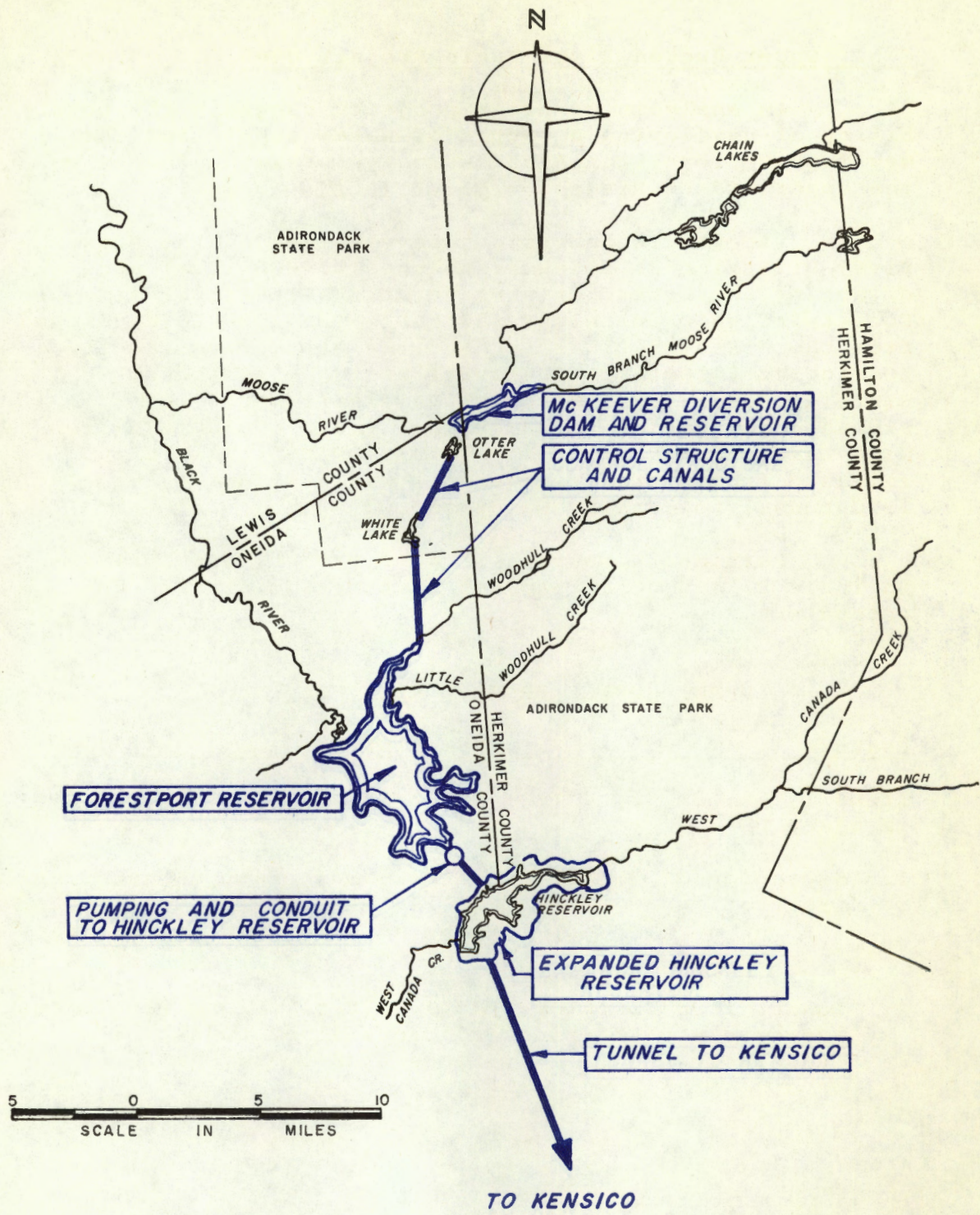
An analysis of prior projects suggests the possibility of developing a source of water supply for the New York Metropolitan Area exclusive of impoundments on the upper Hudson River, as shown in Figure 8.

The project envisions development of the Moose River Diversion at McKeever to the 100-MGD level and diverting the water for storage at the reservoir site at Forestport which develops 200 MGD. The 300 MGD developed from the McKeever Diversion and the Black River in the considered Forestport Reservoir would be pumped to Hinckley Reservoir. Hinckley Reservoir would be expanded to develop an additional yield of 300 MGD from West Canada Creek, with the total 600 MGD treated and released from Hinckley Reservoir via a 172-mile long 28'Ø tunnel to Kensico Reservoir.

Pertinent features of this project are contained in Table 9, and basic project costs are contained in Appendix A.

Table 9
UPPER HUDSON PROJECT UH-5 FEATURES

<u>Feature</u>	<u>Description</u>
Items 1, 2a, 2b, 3, 4 from Upper Hudson River Basin Project UH-3	
1. Expansion of Hinckley Reservoir	Raise dam on West Canada Creek to 140', enlarging the impoundment as described in the Joint Venture Report
2. Tunnel from Hinckley Reservoir to Kensico Reservoir	28'Ø, 172-mile long reinforced concrete lined tunnel on a slope of S=0.88%



**Figure 8 UPPER HUDSON RIVER
BASIN - PROJECT UH-5**

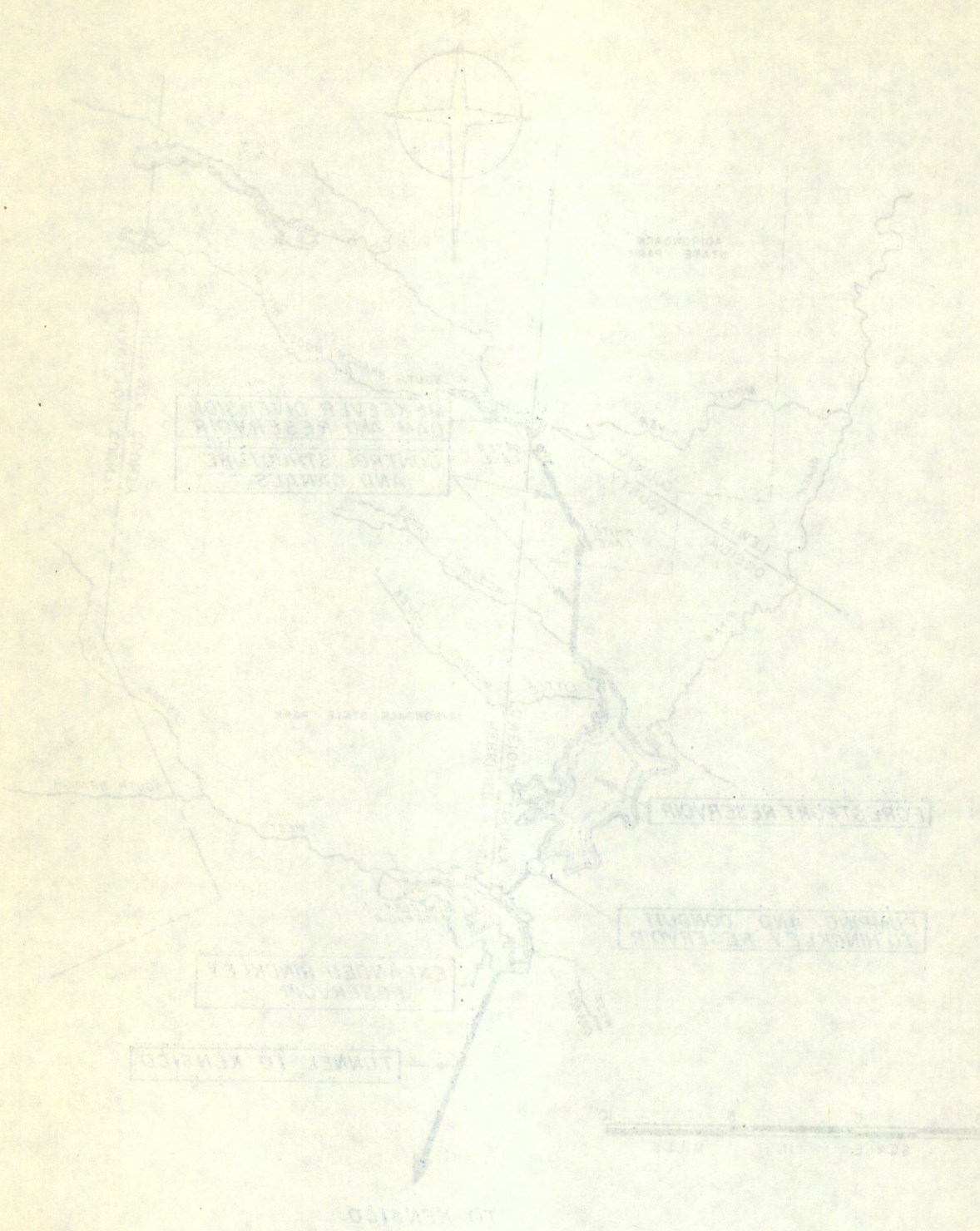


Figure 8 UPPER HUDSON RIVER
BASIN - PROJECT UH-8

II-D. LONG ISLAND GROUNDWATER EXCHANGE PROJECT - LIX

This analysis deals with the engineering feasibility of supplying Long Island groundwater to New York City during the dry months of a drought year while normally supplying Long Island with surplus water from the New York City system, thereby allowing minimal pumping from Long Island groundwater supply during normal years. This would permit natural recharging of the Long Island aquifer while New York City water is consumed on the Island. The system layout is shown on Figure 9. Prior studies show that withdrawal of Long Island groundwater up to 150 MGD is feasible, and, if implemented, would meet the demands of the New York City metropolitan area during the driest months of the drought of record. During wetter months, pumping of groundwater resources from Long Island would be reduced by the rate of excess water delivered from the New York City system.

In order to assess the total availability of Long Island groundwater, a detailed analysis, including field testing at test wells, would be required. Within the framework of this analysis, it was assumed that the results of other studies showing demand that could be met by resources in Long Island were valid.

D-1. Availability of Long Island Groundwater

Several studies have been made regarding the availability of groundwater from the Long Island aquifers. The Temporary State Commission on Water Supply Needs of Southeastern New York reported its findings on the basis of the Comprehensive Public Water Supply Study for Suffolk County (CPWS-24) and the Comprehensive Public Water Supply Study for Nassau County (CPWS-60). These reports, used by the Temporary State Commission, allowed maximum permissive yields for Nassau County aquifers of 150 MGD, and maximum permissive yields for the Suffolk County aquifers of 466 MGD. These data were used as the basis of this report, although in other studies it was assumed that additional withdrawals from the groundwater aquifer are feasible.

Further, it has been noted in CPWS-24 and CPWS-60 that "the yields are possible, provided some deleterious environmental affects are acceptable" and "in Suffolk County the use of 466 MGD permissive yield figure does not mean that withdrawals will necessarily ever equal this yield or that such withdrawals are publicly or environmentally acceptable". On the basis of these statements, it was concluded that for purposes of this report a maximum permissive yield of 150 MGD in Nassau County and the 466 MGD in Suffolk County was the most sound assumption available.

D-2. Water Demand on Long Island

Against the availability of groundwater resources the water demands of Long Island through the year 2020 are noted in Table 10. Table 10 shows a net surplus of water of 229 MGD available in 1980 and a net surplus available of 100 MGD in the year 2000. In 2020, Long Island will require an additional 57 MGD just to meet its own requirements. Thus, the drought requirements for New York City could be supplemented with Long Island groundwater surplus during the drought period through the year 2000. Although Table 10 indicates that only 100 MGD is available in 2000, it is estimated that withdrawals up to 150 MGD for short periods of time are possible, provided that Long Island water is supplemented and the wells are either not pumped or minimally pumped in the following time period.

Prior studies indicate that the New York City system has a surplus of 19.24 billion gallons (BG) of water during the six wet months of the average year (December to May), thus this water could be supplied at a varying rate of up to 150 MGD to supplement the needs of Long Island thereby reducing the total annual pumpage of the aquifers. This will assure storage in the aquifer to supply water to the New York City system during an acute drought year. In 2020, Long Island itself will need 57 MGD throughout the entire year assuming a drought year. This water would have to come from the New York City system or some other sources.

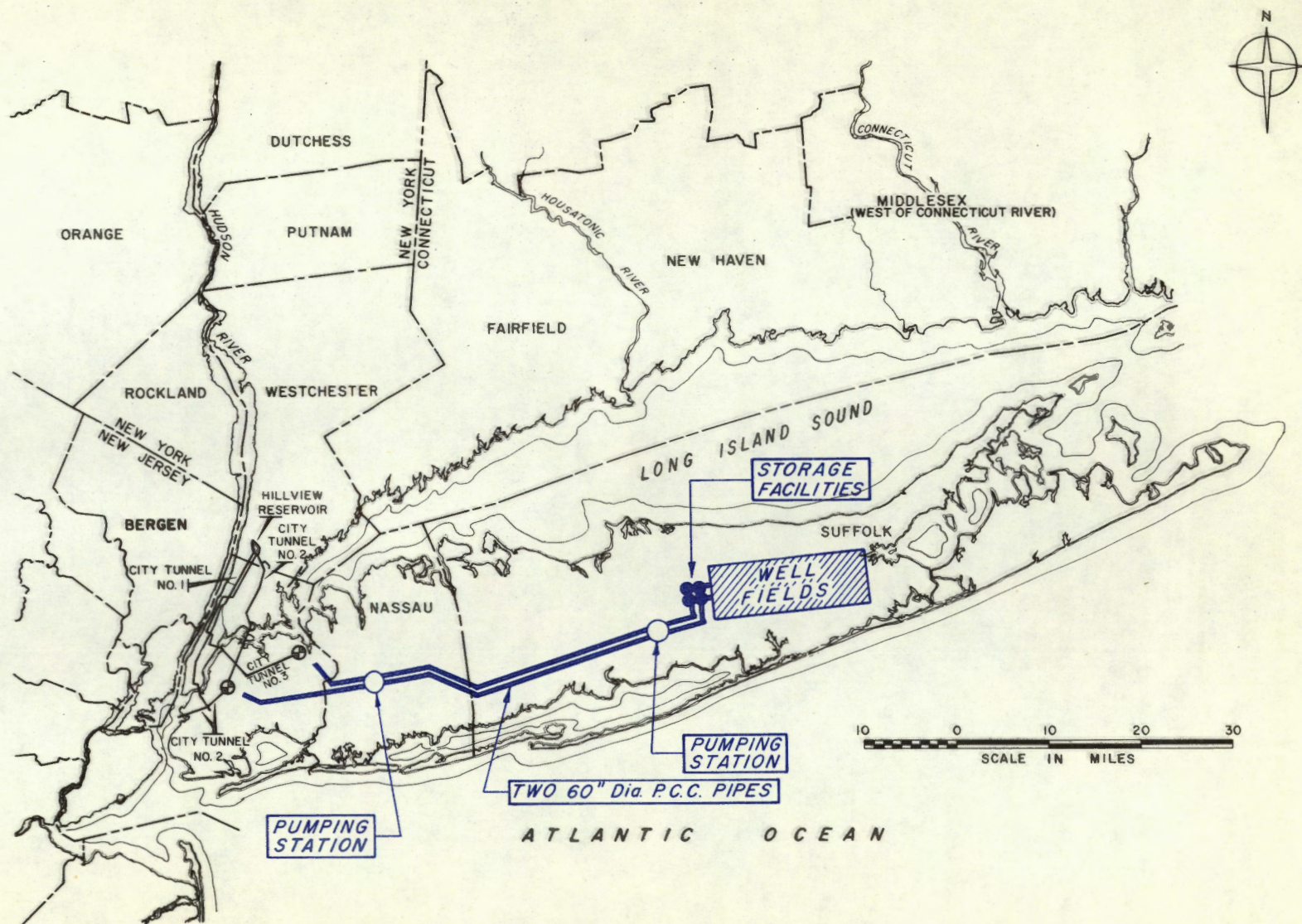


Figure 9 LONG ISLAND GROUNDWATER EXCHANGE PROJECT L. I. X.

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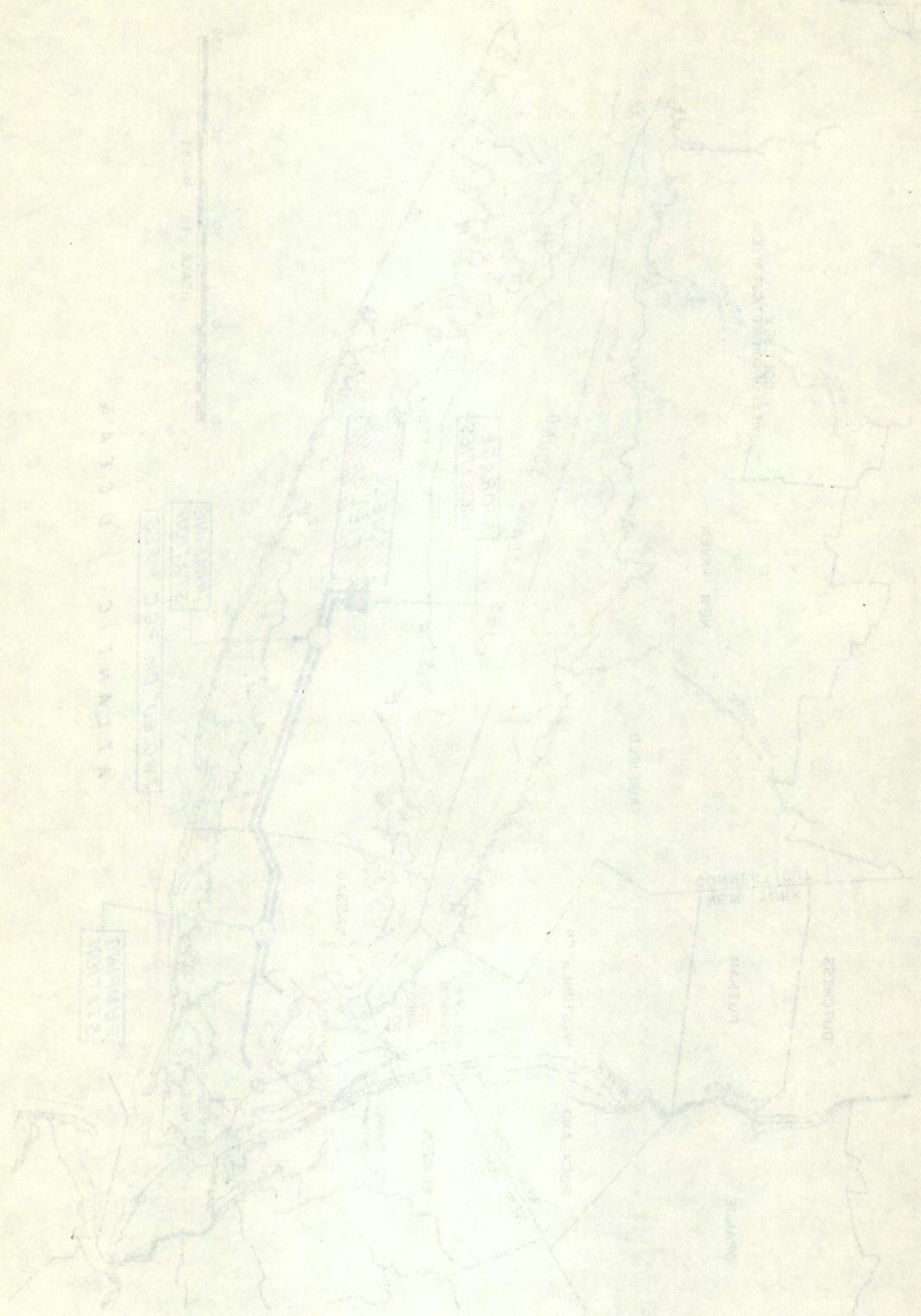


Table 10

LONG ISLAND WATER DEMANDS AND YIELDS

County	Safe Yield MGD (2)	Present		1980		2000		2020	
		Demand	Surplus or Deficit	Demand	Surplus or Deficit	Demand	Surplus or Deficit	Demand	Surplus or Deficit
Nassau (1)	150	*112	-	*161	-	*208	-	*256	-
Suffolk (1)	466	122	-	226	-	308	-	417	-
Total (1)	616	234	+382	387	+229	516	+100	673	- 57
Total (2)	-	200	+416	250	+366	350	+266	780	-164

* 40 MGD recovered from recharge is not included

(1) As stated in the Joint Venture Report

(2) As stated in CPWS-24 and CPWS-60

Projections of groundwater availability are based on the stated aim of achieving full sewerage, with remote disposal of waste, on Long Island. If methods of recharging wastewater into the ground water supplies are found, the projections of yield will require revisions. Further, an area-wide storm water management program to obtain the maximum amount of rainfall for use in the system would modify the yield projections.

D-3. New York City-Long Island Water Exchange

Alternatives for using Long Island groundwater resources considered previously are (1) supplying surplus Long Island water to New York City throughout the year and (2) using Long Island groundwater resources to meet the needs of Long Island alone. Although the costs of these alternatives are comparable to an exchange, the exchange provides the following other benefits:

- a. The New York City system could rely on 150 MGD from Long Island during an acute drought through the year 2000, since surplus are available through 2000 and since underground water supplies are less sensitive to droughts than surface supplies.
- b. During the six wet months of the average year, surplus water from the New York City system at a rate of up to 150 MGD would be used to supplement Long Island needs which would mean less pumping than normal of the Long Island aquifers and, ultimately, a reduction in adverse environmental effects caused by overwithdrawal. The effect of constant water withdrawal at a rate equal to maximum permissive yield would be to lower the groundwater table, reducing stream flow and lowering water levels in lakes and ponds. In view of the growing pollution of the aquifers which has already limited groundwater use in parts of Queens and Nassau Counties, it would be worthwhile to give serious consideration to supplementing the Long Island water needs from the surpluses of the New York City system.

- c. The two-way facilities permit development of a balanced, comprehensive water resources management program. During normal or wet years, Long Island could receive all or most of its water from the New York City system until the groundwater table stabilized at a predetermined level. Judgements on withdrawals from the system would then be made on the basis of management decisions of maintaining groundwater levels as full as possible, without allowing intrusions of excess water into areas where damage could be caused.
- d. The flexibility in the system would permit time to deal with spills or other local accidental polluting of the aquifer, since an alternative source of water would be available.
- e. The project does not involve dams, tunnels, or other relatively long lead time construction operations. The work, therefore, could be initiated relatively quickly, and be completed and operational in the near future.
- f. As noted previously, Long Island will have a net deficit of 57 MGD of water in the year 2020, and the most reasonable method of delivering this water is through the New York City water system. Thus from the year 2020 onward the transmission mains would become a one-way source of water from New York City to Long Island.

Major components of the Long Island groundwater exchange system would be as follows:

- a. Well Fields and Long Island Storage - for an average yearly yield of 150 MGD, it was estimated that 150 wells properly spaced east of Lake Ronkonkoma, Long Island, would be required. The wells would be in an area of roughly 150 square miles and spaced as required. Each well would cover an area of 1 square mile, and it is estimated that water of good quality requiring no treatment other than chlorination could be withdrawn.

Previous studies (CPWS-27) have shown that the three principal aquifers; namely, the Jameco (Pleistocene) Magothy (upper Cretaceous), and Lloyd (upper Cretaceous) can yield 1,300 gallons per minute (GPM),

2200 GPM, and 200 GPM, respectively, to individual wells. Therefore, it appears safe to assume a yield for any particular well in the system at 700 GPM, which is the equivalent of 1.0 MGD.

The wells would include a collection system (laterals and headers), individual pumps, chlorination facilities, and ground storage tanks with a total capacity of 30 million gallons.

- b. Transmission Facilities - From the storage tanks, two 60"Ø prestressed cylindrical concrete pipes could transmit the water from the well fields along the existing Long Island Railroad right-of-way. At its western terminus, one of the 60"Ø lines would be connected to City Tunnel No. 2 at Shaft 16A, and the other would be connected to City Tunnel No. 3 which is presently under construction and projected to be completed after 1980.

There would be two transmission pumping stations, with a total installed capacity of 40,400 HP. The pumping stations would have necessary piping and fitting such that the pumps could be used in either direction. During wet periods, the pumps would pump water from the New York City system into the ground storage tanks on Long Island for distribution, thus meeting the needs of Nassau and Suffolk County, and would draw water from the ground storage tanks to supply New York City during the six dry months of a drought year.

Table 11, following is a listing of major system components.

Table 11
LONG ISLAND EXCHANGE PROJECT LIX FEATURES

<u>Feature</u>	<u>Description</u>
1. Well Field	150 wells over an area of approximately 150 sq. miles with approximately one sq. mile allocated per well and individual pumps on the wells to withdraw approximately 750 GPM
2. Ground Storage Tanks	Four 7.5-million gallon ground level storage tanks for total storage of 30 mil. gals.

Table 11 (Continued)

Feature	Description
3. Transmission Mains	60"Ø reinforced concrete cylindrical pipes, two required- one 50 miles in length, the other 48 miles in length.
4. Pumping Stations	Two each, with a total distributed between them of 40,400 HP and a total pumping capacity of 75 MGD each
5. Terminal Points	Terminal point at New York City Tunnel No. 2, Shaft 16A, for one of the 60"Ø pipes. Terminal point somewhere on New York City Tunnel No. 3 for the other pipe.

D-4. Long Island Wastewater Recycling

The present wastewater disposal practice in Suffolk County is largely through the use of individual cesspools or septic tanks and leaching fields. As of 1970 only 7% of the population was served by sanitary sewers. In order to reduce the pollution of the Long Island groundwater aquifers, Suffolk County has been studying a proposal that would provide 100% sewerage throughout the County by the year 2020. The reports CPWS-60 and CPWS-24 state that the total consumptive use of water in Nassau and Suffolk will increase by 350 MGD by the year 2020 if the County's sewerage plan is carried out. This 350 MGD is the assumed amount of water diverted by the sewers out of the affected water budget and released to Long Island Sound or other waterways.

However, after proper and suitable treatment of the wastewater, it is possible that fresh water aquifers could be recharged at suitable sites using the treated effluent through recharge basins or injection wells. It could be possible to recover a substantial portion of the effluent which would supplement the needs not only of Long Island but of New York City during a drought year from 2020 onward. The U.S. Environmental Protection Agency is currently supporting research efforts to safeguard Long Island's dwindling water supply by recharging

treated wastewater back into the ground. The EPA is sponsoring a Long Island study of groundwater recharge technology which includes future construction of a 5 MGD demonstration plant in Wantagh, Long Island. It is anticipated that better recharge techniques for wastewater effluents will be available by the year 2000 and if there are favorable results from the research, Long Island groundwater may be available to supplement New York City supplies during a drought year through the year 2020 and the Long Island groundwater project would continue to function as an exchange.

III. GUIDELINES FOR A NEW YORK CITY METERING DEMONSTRATION PROJECT

The question of whether New York City should meter water to its residents is an old one. The debate probably started around the turn of the century, when water meters became available in quantity. New York City, and Chicago, Illinois, the two major cities which do not install water meters on service lines, were supplying water before water meters were commercially available, and their installation would have represented an appreciable capital investment at any point in time.

Arguments against universal metering at the customers' service tap include:

- a. that water metering does not materially change water consumption
- b. the relatively large initial capital investment required
- c. the recurring cost of calibration and maintenance
- d. the cost of meter reading and billing.

Whereas proponents of universal metering contend that:

- a. users can be billed for the amount of water consumed, resulting in more equitable charges
- b. treating water as a commodity results in less waste
- c. income from water sales is separate from tax revenues, hence the water supplying agency can be treated as a semi-autonomous utility
- d. the quantity of unsold water is easily recognized and can be used to measure the quantity of leakage throughout the water network.

From the viewpoint of water conservation, the most important aspect of universal metering is the information defining unsold water, which permits the extrapolation of estimates of water losses. In a system having universal metering, all water delivered to customers is registered on the meters. This quantity, subtracted from the volume of water sent to the water network, yields the volume of unsold water. Unsold water includes water taken from fire hydrants for fire fighting, construction, and street flushing. After an allowance is made for unrecorded water connections and metering inaccuracies, the amount of leakage in a water system can be estimated.

Some relatively new and well maintained water utilities can boast of unsold water ratios below 10 percent of production. Some large and older systems have unsold water ratios approaching 25 percent. It would appear that a continuing maintenance program coupled with a method of monitoring the volume of lost water can result in savings of nearly 10 percent of water production. In New York City, 10 percent represents approximately 120 MGD.

A number of reports and estimates of water savings through the use of water meters have been made for the New York water system. No conclusions have been agreed to as a result of these reports since basic assumptions have been questioned, impugning the validity of each report. In an effort to find a way to resolve some of the conflicting arguments, guidelines for development of a metering demonstration project have been defined so that the effect of metering can be measured on a small scale.

The various reports discussing universal metering of service connections generally indicate that this change in policy will reduce the City's water needs by 100 MGD to 150 MGD. The Comprehensive Public Water Supply Study for the City of New York, August 1967 (CPWS-27) includes an estimated 145 MGD in the 1975 water requirements, due to universal metering. The New York City Department of Water Supply report of October 7, 1964 indicates demand reductions of approximately 125 MGD due to metering of water, and this data was assumed to be valid for use as a metering project in the Regional Programs. In a later segment of this section, a comparable estimate of water savings due to universal metering is shown. This estimate was made independently of previous published reports.

The guidelines in this section are expected to define the extent of the demonstration project and the methods to be used to evaluate the results of the program. In order for the program to be definitive, a sufficiently large test volume must be analyzed so that the test will be statistically significant. The test must be performed with appropriate control areas, so that results can be compared directly and evaluated. The metering demonstration project should define residential water use and the effect of a metered billing base on residential water use patterns. An effort should also be made to learn whether a metered billing basis for water will affect building plans for new construction.

In the program, whenever feasible, an effort should be made to compare the water supplied to an area with the quantity of water actually delivered to each water service connection. This may provide insight into the amount of controllable waste, even though the program is not structured to define the unsold water ratio nor the amount of leakage in the City's water mains.

III-A. SELECTION OF SURVEY SITES

A-1. Type of Buildings

The demonstration project is intended to sample the predominant types of residential housing in the New York City area. Meters would be installed on the incoming water service to measure the total water consumption within a particular building. This type of installation is the type of metering that is considered practical for the complete metering of a water system. The amount of water use within an individual dwelling unit (apartment) should not be metered since this type of installation is not normally considered practical for a full scale operation.

The types of residential construction to be included in the survey are:

- a. luxury apartment buildings
- b. medium income apartment buildings (privately owned)

- c. medium/low income housing (publicly owned)
- d. public housing projects (low income)
- e. townhouse developments
- f. two-family residences
- g. single-family residences

The definition of the income status for housing development residents is somewhat arbitrary, and for consistency, the definitions used by the Federal Housing Administration should be used.

A-2. Age of Buildings

A minimum scope demonstration project should include only new buildings, which are free of leaks and other conditions that would render the results difficult to interpret, and where proper installation of meters is more easily accomplished. Further, owners of new buildings would probably be more inclined to cooperate than owners of established buildings. It is expected that there will be less resistance to paying for water on a metered basis in a new building than where the owner has become accustomed to a flat rate charge. Since the objective of the program is to measure the effect of metering after initial reactions have dissipated, sampling new housing is considered justified. Care must be taken to assure that the gathering of statistical data begins only after building occupancy has been completed and has achieved a stable condition.

Meter installations in older buildings will reflect the state of maintenance of the plumbing in the amount of water consumption data, and selection of a convenient location for subsequent meter reading may be quite difficult, affecting the projections of annual cost of metering. It is believed that the program would provide the most meaningful results from the direct comparison of water use in buildings of the same type and in a similar environment.

A-3. Statistical Base

In order to provide a meaningful measure of water use, each sample must contain enough buildings for comparison and enough population to eliminate bias caused by a few individuals. The guidelines given in Table 12 below are for a basic survey incorporating new construction. Each sample should involve a population of at least 1,000

Table 12
SAMPLE SIZE

<u>Type of Development</u>	<u>Minimum Number of Buildings</u>
luxury apartment	4
medium income apartment	8
medium/low income housing	8
public housing	8
townhouse	200
two-family	125
single-family	250

III-B. STRUCTURING THE DEMONSTRATION PROJECT

Regardless of whether the project involves only the basic installation in new buildings, or a parallel sampling in existing buildings, the same project procedures are required. Housing developments of each category should be identified. These should be situated in neighborhoods that are typical of the city as a whole. If possible, apartment buildings of a particular category should be located in a single complex. Since large complexes of new single and two-family residences may not be available for the demonstration project at the time of the study, samples for each category can be divided between several residential developments in order to obtain an appropriate data base.

B-1. Metering

A water meter should be installed on the incoming house service line of each building included in the demonstration project. These meters will record the total quantity of water used within the building. Approximately half of the buildings in each category should be billed for water at the prevailing New York City rates for metered consumption. The remainder of the structures should be billed on the standard flat-rate basis, but the meters should be read on the same schedule as those being used for billing. Meters should be read for billing on a quarterly basis consistent with practice elsewhere, but supplementary meter readings on a monthly basis are recommended to obtain additional data.

If a development is served by a single water main, the opportunity for measuring area-wide consumption should be utilized. A propeller meter on the feeder main can be used to determine the water demands of the complex, including the water used for fire fighting, street flushing and recreational use. The same results can be obtained if the complex is fed from a single water main passing through the area. Two propeller meters would be required one at either end of the water main. Each meter should be equipped with dual (forward and reverse) totalizers and dual straightening vanes.

If the development is served by a single sewer, additional data can be conveniently collected. A sewage flow meter will provide an indication of in-house water consumption. A Parshall flume or wier can be installed in a manhole through which the area's flow passes. A recording-totalizing meter installed in the manhole will yield a record of the total volume of sewage flow, and the amount of water consumed by the residents can be estimated from this data after allowances for infiltration. A schematic diagram of such an installation is contained in the following sketch.

Access to water meters will be an important consideration, especially with the frequent meter readings that will be required for the demonstration project. Normally, a water utility expects to incur a proportion of lockouts in its meter reading schedule. In the demonstration project, however, lockouts and estimated readings will compromise the quality of the raw data and should be minimized. Water meters and their registers must be accessible to the meter reader during all reasonable hours.

For apartment buildings with a full-time maintenance staff, access to service areas should present little problem. The meters should be located in the basement of apartment buildings in a freely accessible place. Meter settings should be selected for maximum ease of reading.

Individual residences, including two-family structures, present more difficult access problems. Susceptibility to vandalism mitigates against the installation of exposed remote meter registers outside the building. Installing the meters in meter boxes outside the property line will permit ready access and provide protection against vandalism. This type of installation is in common use in suburban areas adjacent to New York City.

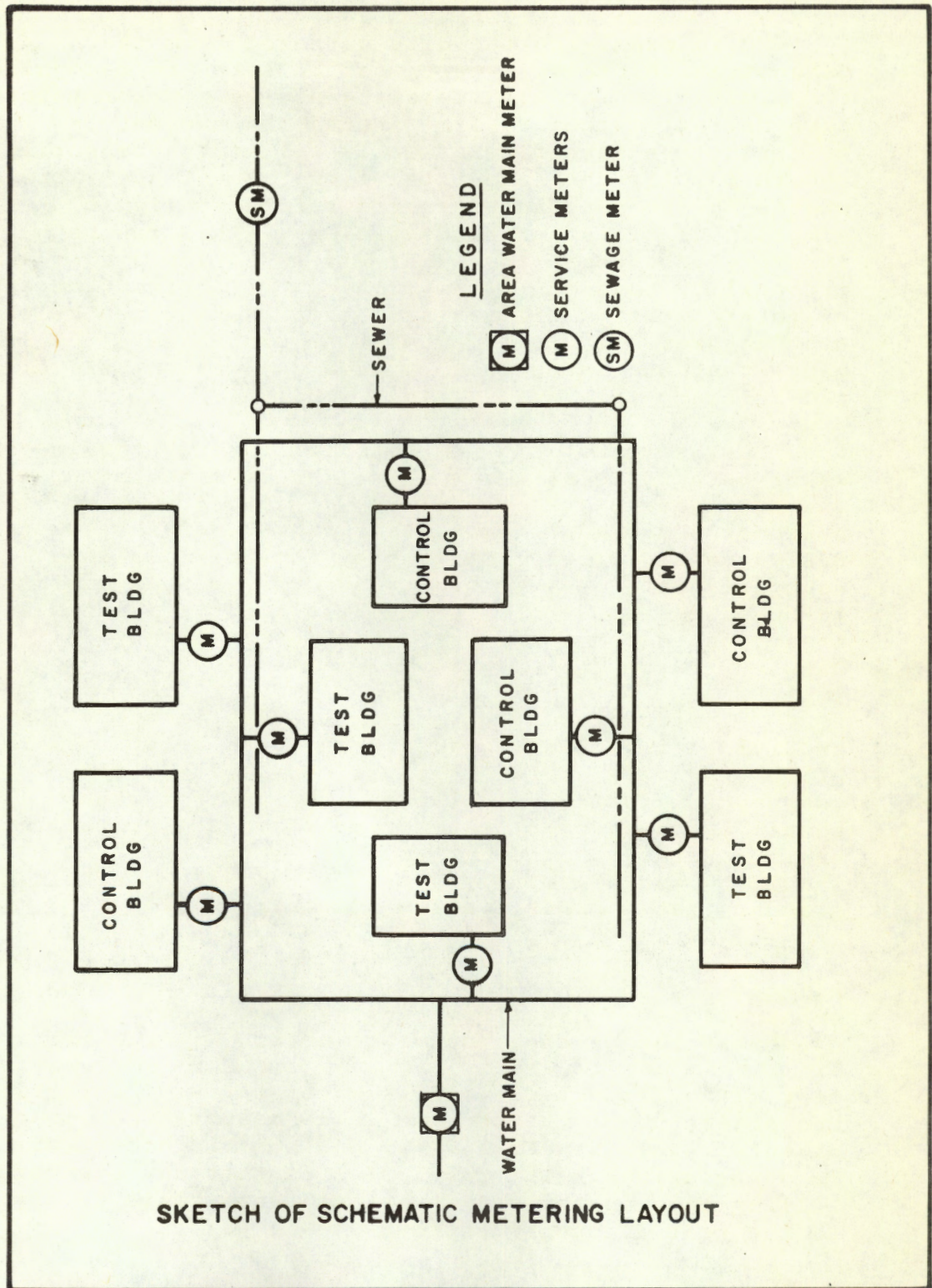
B-2. Data Evaluation

In examining the data gathered from the demonstration project, care must be taken to recognize the limitations of each metering device. Water meters have definite accuracy limitations and two meters measuring the same flow of water will not necessarily record exactly the same total flow. Meter accuracies stated by the manufacturers refer to a statistic sampling of two standard deviations. This can be interpreted to mean that there is less than a five percent probability that the meter accuracy at a given percentage of meter capacity will be less than that stated by the manufacturer. There is a definite probability (67 percent) that the meter will be accurate within half of the accuracy tolerance claimed.

The volume of water metered through the incoming water main represents the water supplied to the area. The aggregate of the service meter readings is the customer's demand. The difference between the two is called unsold water. Customers' demand represents lawn irrigation and general water use as well as the in-house use of water. Sewage flow, after infiltration is accounted for, is a good measure of in-house water use.

As described above each housing category should be divided into two segments. The test group should be billed for water service on the basis of metered consumption for each building. The control group should be charged for water service on a flat rate basis. Meters should be read each month but billings should be made quarterly. Billing should be set at the standard rates pro-rated for quarterly billing.

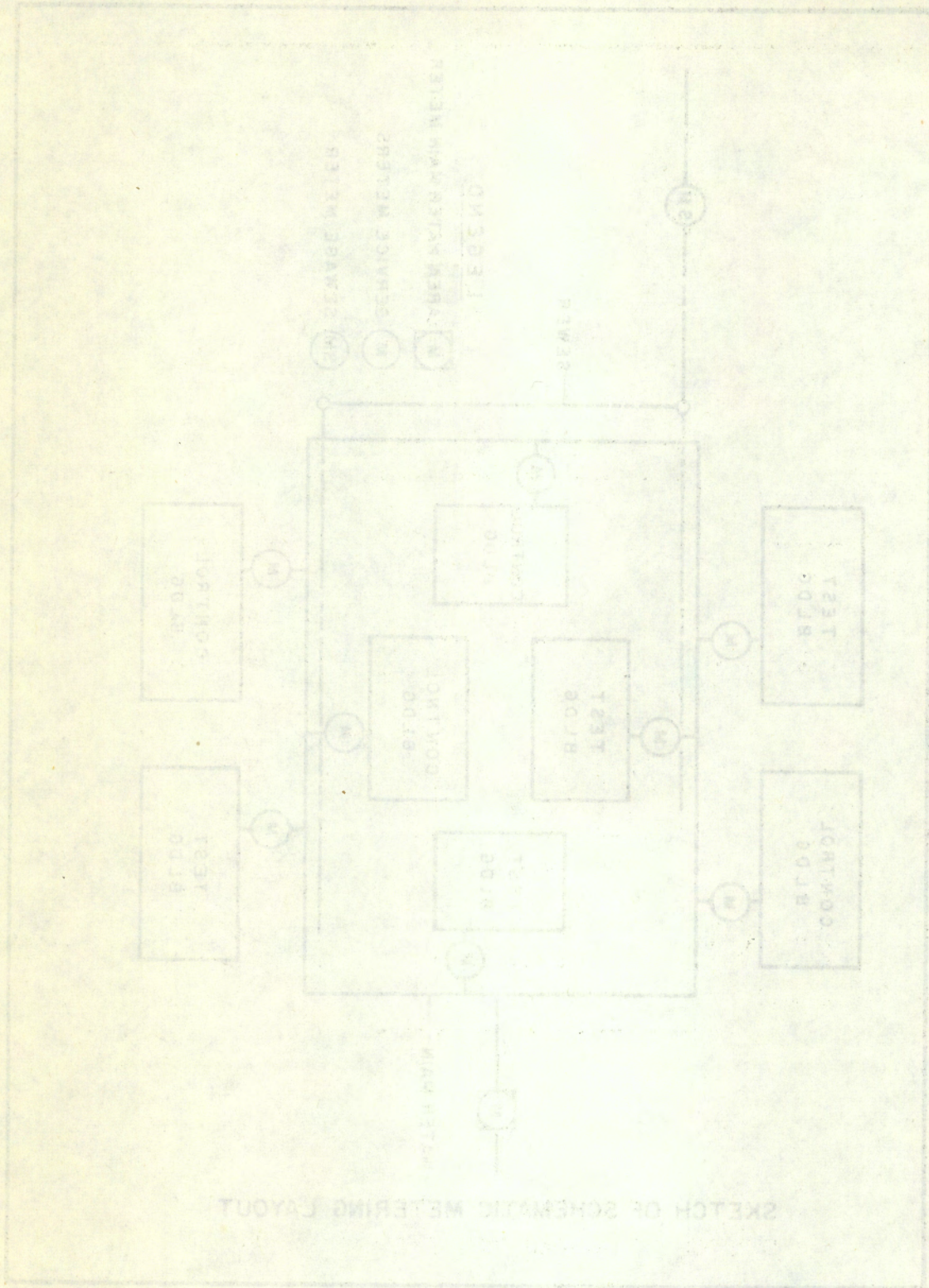
Consideration has been given to evaluating the effect of higher and lower water rates. The legal implications of discriminating against individual customers render this course of action impractical. Any rebate scheme would cloud the validity of any test of the effect of various water rates. Further, the objective of the program is to measure the impact of metering in New York City, and not the effect of rate variations. The conclusion is that the standard billing rate is the only practical water rate to apply to the test and control groups.



SKETCH OF SCHEMATIC METERING LAYOUT

PARSONS, BRINCKERHOFF, QUADE & DOUGLAS, INC.

SKETCH OF SCHEMATIC METERING LAYOUT



WATSON, BRICKERHOFF, CHASE & COMPANY, INC.

Row housing, or townhouses, have residential parameters similar to that of luxury or medium income apartment dwelling units. Row houses have very little lawn area requiring irrigation. The amount of living space and the habits of the residents are analogous to that which might be found in apartments. The per-capita water consumption found in townhouses can probably be applied with confidence to individual consumption in apartment dwelling units. In order to obtain this data, row housing should be metered at each house; metering each block of houses will not yield this important data.

The following forms are guides for the recording and evaluation of the test data. The forms used during the demonstration project should be similar. Additional data that will assist in the evaluation of test results can be incorporated when the program is developed to the point of implementation.

METER CONSUMPTION RECORD

Building Data Date _____

Owner _____

Address _____

Borough _____ Building I.D. No. _____

Type of Building _____

Number of Apartments _____

Est. Number of Residents _____

Water Use Data

Meter Number _____

Latest meter reading: _____ Gallons Date _____

Previous meter reading: _____ Gallons Date _____

Water Used _____ Gallons Days Elapsed _____

Daily Consumption for period _____ gallons per day

Per-capita daily consumption _____ gallons per day

Billing Data

Date of last bill _____ billing basis _____

Amount billed \$ _____

Quantity billed _____ gallons

Meter Data

Meter Number _____ Type of Meter _____

Manufacturer _____ Model _____

Date last tested _____

Register reading after test _____

MONTHLY COMPOSITE CONSUMPTION RECORD

Month of _____ 197__

Type of Housing _____

Water Use:

Control Group _____ gallons/day

Test Group _____ gallons/day

Difference _____ gallons/day

Water Use Per Dwelling Unit:

Control Group _____ gallons/day

Test Group _____ gallons/day

Difference _____ gallons/day

Per Capita Water Usage:

Control Group _____ gallons/day

Test Group _____ gallons/day

Difference _____ gallons/day

Utilization:

Gallons supplied _____

Gallons metered _____ % of water supplied

Unsold water _____ gallons _____ % of water supplied

Sewage contribution

from residents _____ gallons _____ % of water supplied

III-C. DEMONSTRATION PROJECT DURATION AND COST

C-1. Duration

In order to obtain significant data, the minimum data base period must be long enough to test the change in consumption patterns over a full calendar year. Several years would yield more reliable data than a single year since the longer period would tend to eliminate the effect of a particularly cold or wet year. The longer period would also reduce the effect of temporary psychological effects on water consumers at the start of the demonstration project. The longer test period would also assure that sufficient data would be collected to cover more than one full calendar year.

The minimum length of time to provide a full calendar year of reliable data for the demonstration project is estimated to be two calendar years of observations in each development being metered. This period would assure that at least one full year of valid data can be obtained. A three-year demonstration period could be expected to yield a minimum of two-years of valid data, and this extended period of study is recommended.

C-2. Cost

The cost of the demonstration project can be divided into three segments:

- a. Initial cost of installations
- b. Annual operation cost
- c. End of project costs

For estimating purposes, the basic program of installation only on new buildings has been assumed. The basic program includes approximately 752 metered services on newly constructed residential buildings. The expanded project would include a parallel sampling of older buildings. A slightly smaller sampling cost, but higher meter installation costs for existing buildings would result in the cost of an expanded program being twice that of the basic program.

The initial cost of installing service meters, main-line water meters, and sewage meters is shown on Table 13. The cost of the expanded program would be approximately \$520,000 or twice the cost of installing meters for the basic program.

The annual operating cost for the programs, including salary, fringe benefits, and direct costs, but not including office space and overhead is estimated as follows:

<u>Activity</u>	<u>Operating Cost</u>	
	<u>Basic Program</u>	<u>Expanded Program</u>
Meter reading and Maintenance	\$18,000	\$36,000
Billing and data analysis	18,000	36,000
Meter repairs and calibration	<u>4,000</u>	<u>8,000</u>
Total	\$40,000	\$80,000

End-of-project costs include the removal of service meters except where the landlord asks that they be left in place. Payment for the meter could be requested from the landlord at that time. Once the meters are removed, they have scrap value and could be sold to a plumbing supply company or to another water supply agency. Main line water meters can be removed at the cost of approximately \$1000 each. The estimated cost of removing a sewage meter is \$500. These meters will also have considerable salvage value.

The net cost of terminating the project is difficult to estimate because of the uncertainty surrounding the salvage value of the meters. An allowance of \$20,000 has been made for the basic program; the allowance for the expanded program is double that.

An allowance of \$5,000 has been made for printing costs required to publish the findings of the demonstration project.

The total cost for a three-year demonstration project can be expected to be:

	<u>Basic Program</u>	<u>Expanded Program</u>
Initial cost	\$260,000	\$520,000
Operating cost	120,000	240,000
Termination cost	<u>25,000</u>	<u>45,000</u>
	\$405,000	\$805,000
Contingencies 15%	<u>60,000</u>	<u>120,000</u>
Total	\$465,000	\$925,000

Table 13

DEMONSTRATION PROJECT INSTALLATION COST ESTIMATES

(Includes an allowance of 25 percent
in number of connections)

BASIC PROGRAM

TYPE OF HOUSING	NO. OF SERVICE METERS	INSTALLED		NO. OF MAIN LINE WATER METERS	UNIT COST		NO. OF SEWAGE METERS	UNIT COST	
		COST OF METER	AMOUNT		INSTALLED	AMOUNT		INSTALLED	AMOUNT
Luxury Apartment	5	\$1,100	\$ 5,500	1	\$ 3,000	\$ 3,000	1	\$ 2,000	\$ 2,000
Medium Income Apartment	10	1,100	11,000	2	3,000	6,000	1	2,000	2,000
Medium/Low Income Housing	10	1,100	11,000	2	3,000	6,000	1	2,000	2,000
Public Housing	10	1,100	11,000	2	3,000	6,000	1	2,000	2,000
Town House	250	190	47,500	4	3,000	12,000	1	2,000	4,000
Two-Family	155	260	40,300	2	3,000	6,000	1	2,000	2,000
Single-Family	<u>312</u>	205	<u>64,000</u>	4	3,000	<u>12,000</u>	2	2,000	<u>4,000</u>
	752		\$190,300			\$51,000			\$18,000
TOTAL PROJECT COST			\$259,300						
			say	\$260,000					

III-D. METER SPECIFICATIONS

Water meters used for the demonstration should be standard commercial meters calibrated and certified for accuracy. The type of meter to be used and its method of installation should be determined at the start of the program based on the use and expected range of flows. Meter settings should be designed for ease of reading and for rapid installation and dismounting of the metering element.

All meters used in the demonstration conform to AWWA standards except that accuracy of registration should conform to the limits stated in the "Metering Accuracy" section of this chapter, which are somewhat more stringent than the AWWA standards. Each meter used in the program should be new, be the product of a recognized manufacturer, and be furnished with an affidavit from the manufacturer that the meter complies with the applicable AWWA standards. The affidavit shall also state that each individual meter has been tested for accuracy, and should include the findings of the volumetric meter test. Test procedures should conform to AWWA Standard C705-60.

D-1. Displacement Meters

Displacement meters should be used for services from 5/8-inch to 3-inch size, should conform to the requirements of AWWA Standard C700-71, and should be of frost-proof construction. The meter register should be driven through a magnetic coupling. The main case should be copper alloy. Registers should be of the type designated as AWWA straight reading register.

D-2. Turbine Meters

Turbine meters should be used only on services larger than two-inches where the expected range of flows is narrow and no flows below 150 percent of the minimum rated flow rate are expected. Meters should be equipped with magnetic drive couplings. Meter registers should be AWWA straight reading type. Turbine meters should conform to AWWA Standard C701-70.

D-3. Compound Meters

Compound meters should be used on services two inches and larger unless it can be determined that a turbine meter or displacement meter will accurately measure the quantities of water being taken. Compound meters should conform to the requirements of AWWA Standard C702-70. The register of each meter should be driven through magnetic couplings. The register for each meter should be a coordinator register of the AWWA straight reading type.

D-4. Propeller Meters

Metering of water mains must be accomplished using full-bodied tube-type propeller meters. The meters should conform to the requirements of AWWA Standard C704-70. Meter drives should be of the magnetic coupling type and each meter should be furnished with stainless steel straightening vanes in the line on each side of the meter. Each meter should be equipped with two straight reading registers, one for forward flow and one for reverse flow.

D-5. Meter Settings

Each meter should be installed so that the register face is in a horizontal plane and positioned for ease of reading. A shut-off valve upstream of the meter should be provided on each installation; a downstream valve should be provided on each meter except those on a service to one-family residences. A mechanical coupling or meter-yoke device should be provided for ease in installing and dismounting each meter.

Each meter serving a one or two-family residence should be mounted in a meter box located in an area easily accessible for reading. Whenever possible, the meter box should be located under a sidewalk or curb strip. The meter should be mounted on a meter-yoke or meter setter. Alternatively, meters may be set in the basements of the buildings. In this case, remote reading registers located outside the building should be installed as required. The extent of possible vandalism of remote registers must be carefully evaluated beforehand.

D-6. Metering Accuracy

The accuracy of the flow measuring equipment used for the pilot program is necessarily an important consideration. Any metering equipment utilized should be as accurate as practical and the accuracies should be recognized and documented. This means that the most accurate equipment commercially available should be employed. The equipment should be tested before it is installed and re-calibrated at set intervals as the program progresses.

Service meters should be of positive-displacement type where the required meter size is two inches or smaller. Compound meters will be needed for larger customer services. Meter accuracies should be within the tolerances stated for new meters in AWWA manual M6. Each meter should be displacement tested and its accuracy certified before it is installed. Meters should be retested on an annual basis and at the end of the program; retesting should also be performed when a predetermined quantity of water has been metered. Meter accuracy requirements and the quantity limits between tests are listed in Table 14.

Table 14

METER ACCURACY REQUIREMENTS

SIZE (INCHES)	MAXIMUM RATE				INTERMEDIATE RATE				MINIMUM RATE				TEST INTERVAL (WHICHEVER COMES FIRST) THOUSAND MONTH GALS.	
	FLOW (GPM)	TEST QUANT. (GALS.)	ACCURACY RANGE PRESENT		FLOW (GPM)	TEST QUANT. (GALS.)	ACCURACY RANGE PRESENT		FLOW (GPM)	TEST QUANT. (GALS.)	ACCURACY RANGE PRESENT			
			LOW	HIGH			LOW	HIGH			LOW	HIGH		
P.D. Meters														
5/8	15	100	98.5	101.5	2	10	98.5	101.5	0.25	10	95.0	101.5	500	12
5/8 x 3/4	15	100	98.5	101.5	2	10	98.5	101.5	0.25	10	95.0	101.5	500	12
3/4	25	1000	98.5	101.5	3	10	98.5	101.5	0.50	10	95.0	101.5	750	12
1	40	1000	98.5	101.5	4	100	98.5	101.5	0.75	10	95.0	101.5	1,000	12
1 1/2	80	1000	98.5	101.5	8	100	98.5	101.5	1.50	100	95.0	101.5	2,000	8
2	120	1000	98.5	101.5	15	100	98.5	101.5	2.0	100	95.0	101.5	3,000	8
3	250	1000	98.5	101.5	20	1000	98.5	101.5	4.0	100	95.0	101.5	6,000	6
4	350	10000	98.5	101.5	40	1000	98.5	101.5	7.0	1000	95.0	101.5	10,000	6
5	700	10000	98.5	101.5	60	1000	98.5	101.5	12.0	1000	95.0	101.5	20,000	6
Current Meters														
4	400	10000	98.0	102.0	200	10000	99.0	101.0	60	10000	98.0	102.0	50,000	6
6	900	10000	98.0	102.0	400	10000	99.0	101.0	100	10000	98.0	102.0	100,000	6
8	1200	50000	98.0	102.0	600	10000	99.0	101.0	120	10000	98.0	102.0	150,000	6
10	1600	50000	98.0	102.0	800	10000	99.0	101.0	160	10000	98.0	102.0	200,000	6
12	2200	100000	98.0	102.0	1100	50000	99.0	101.0	220	10000	98.0	102.0	250,000	6
16	3800	10000	98.0	102.0	1900	50000	99.0	101.0	350	10000	98.0	102.0	400,000	6
Compound Meters														
1 1/2	80	1000	98.0	102.0	15	1000	98.0	102.0	0.25	10	95.0	101.5	20,000	8
2	120	1000	98.0	102.0	20	1000	98.0	102.0	0.25	10	95.0	101.5	30,000	8
3	250	1000	98.0	102.0	30	10000	98.0	102.0	0.50	10	95.0	101.5	50,000	8
4	350	10000	98.0	102.0	50	10000	98.0	102.0	0.75	10	95.0	101.5	50,000	6
6	700	10000	98.0	102.0	100	10000	98.0	102.0	1.50	100	95.0	101.5	100,000	6
8	1200	10000	98.0	102.0	200	10000	98.0	102.0	2.0	100	95.0	101.5	150,000	8

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III-E. WATER CONSERVATIVE PLUMBING FIXTURES

Experience indicates that the average in-house use of New York City residents can be expected to be between 50 and 70 gallons per person per day. This is defined as the water used in a dwelling unit for toilet flushing, washing, bathing, kitchen use, household cleaning, drinking and the like.

Toilet flushing is estimated to represent 40 to 45 percent, or 26 gallons per capita per day (gcd), of the in-house demand. The average toilet tank capacity for fixtures manufactured in the United States is five to six gallons, however, this is not a universal standard. In Australia, for instance, the average flush tank holds three gallons, and many types of toilet fixtures in use in New York will flush properly using only three gallons. Although domestic plumbing fixture manufacturers do not now make small size flush tanks, a flush tank displacer is available which displaces two gallons in such a manner that most toilets will continue to operate properly. The unit sells for approximately \$1.00 and can be quickly inserted into the flush tank at a total installed cost of \$2.00. If these units were installed in New York City, the amount of water required for flushing would be reduced by nearly ten gcd, or a total for the City of 80 MGD.

Washing and bathing represents 30 to 35 percent of in-house use. This can be taken as 20 gcd. Half of this could be assumed to be used at the lavatory. Single lever faucets, according to some sources, can save nearly 20 percent. This saving would be about 16 MGD city-wide. If the assumptions are valid, comparable savings in water demands would accrue to the installation of single-lever faucets in kitchen sinks. The cost of single-lever faucets is approximately the same as that of separate fixtures in more common use.

If it is assumed that showers require about five gcd, about equal to the amount of water used for bathtubs, a small amount of water can be saved by installing flow restrictors. A restrictor would cost approximately \$4.00 installed, and could be expected to reduce water requirements by 30 percent. This amount is 1.5 gcd or a total of 12 MGD.

More exotic and complicated water conservative fixtures have been suggested and may be tested under operating conditions for the New York City market. Among these are vacuum toilet systems requiring approximately one quart of flushing water, special faucets using less than one GPM when wide open, and pressure-reducing valves for each dwelling unit. In addition to the initial cost of these systems, the dependability and maintenance must be evaluated as well as their acceptability by the general public.

An interview with the Design and Construction Department, New York State Urban Development Corporation, revealed that this agency has considered the use of many types of water conservative plumbing fixtures. The agency is planning to install these devices in a metered area in upstate New York and is considering installing low-water-use fixtures, even where flat-rate water service is available. These fixtures permit appreciable savings in construction cost, because smaller piping and a smaller hot water heating unit can be installed. The reduced consumption of hot water results in lower operating costs over the life of a housing unit.

Certain studies by others indicate that water metering, per se, does not change the basic pattern of household water use in apartments. Water metering, it is indicated, does have some effect on the excessive use of water for lawn sprinkling, car washing, etc., and will encourage better maintenance of plumbing.

If this assumption is correct, then the advantage of universal metering would be in influencing building owners and developers of new housing to install the more conventional types of water conservative fixtures. It appears from the above that appreciable reduction in water use could result from this step as follows:

<u>Fixtures</u>	<u>MGD</u>
Toilets	80
Single-lever faucets	32
Shower restrictors	<u>12</u>
Total	124

It must be recognized that these savings would only be realized after the plumbing fixtures were in general use. It is estimated that a period of 40 to 50 years must elapse before substantially all of the dwelling units in New York City have the new types of fixtures, since they would be introduced as new housing is constructed and as plumbing in older houses is modernized.

A concerted effort should be made to estimate the effect of water metering on pre-construction planning. Builders, developers and realty companies should be polled. A questionnaire could be used to analyze the attitudes toward water conservation of agencies and individuals responsible for planning of new housing developments.

IV. ILLUSTRATIVE REGIONAL PROGRAMS

The excess demands for water in the New York Metropolitan Region are summarized in Table 1 of this report. These demands represent water supply deficiencies in the study area, beyond the present short-term deficiencies, to be made up by presently planned or under construction water supply programs.

Meeting these demands by the development of regional water supply programs is described in this chapter by eight illustrative programs, each of which consists of selected features described elsewhere in this report and in the Joint Venture Report. The purpose of developing the eight illustrative regional programs was to test the impact of constructing a groundwater exchange with Long Island and implementing universal metering in New York City on two promising Hudson River sources. The two water sources from the Hudson River that are considered in the programs are a diversion at Hyde Park with conduit to Kensico Reservoir and a diversion at West Park with conduits to Shaft 4, Great Notch, and Kensico Reservoir. For purposes of obtaining comparability between programs, as many common features as possible are incorporated in order to facilitate ready cost comparisons.

The eight illustrative programs are described in detail in succeeding sections, with the projects and their yields shown in tabular form on the schematic drawings for each project. Project yields are based on droughts of record. The cost for local distribution systems is not included, since greater detail is required and further study beyond the scope of this work would be necessary to make any reasonable determination regarding local distribution costs.

The planning horizon is the year 2020, with the years 1980, 2000 and 2020 selected as representing intervals in which to examine program development, and in particular, cumulative program expenditures.

The cumulative program costs are tabulated after each program, showing the capital expenditures at each of the three time periods, and the average cost per million gallons of water at that date. The cumulative present worth of the programs, discounted at percentages of 4-5/8, 5, and 10, is tabulated in Appendix B, both for the cumulative present worth of capital costs, and the cumulative present worth of capital cost plus 50 years of operating and maintenance costs. The cost of waste water management programs that may be implemented to preserve or enhance many of the region's existing developed water sources is not included in the Regional Program analysis, since in most cases these costs would be common to all programs.

Projects used in developing the regional programs include the Long Island Groundwater Exchange Project LIX, and New York City Metering Project M-1, described in detail in previous sections of this report, plus the following projects described in detail in the Joint Venture Report.

1. Housatonic Project HO-1, which draws water from Lake Housatonic above the Shelton Tidal Dam in Connecticut. The project depends upon diversions at Shelton, except when releases from upstream power reservoirs are insufficient and power companies would have to be reimbursed for additional releases. The project is developed to yield 40 MGD.

2. Housatonic Project HO-2, with the development of Robbins No. 2 pumped storage reservoir near Falls Village, Connecticut. Use of Robbins permits development to 60 MGD in the year 2000 and 200 MGD in the year 2020. In early years of development, storage in the existing power reservoirs, Candlewood Lake and Lake Lillinonah, could be used until demands warranted development of the Robbins site.

3. Raritan Project R-1, which would increase the yield of the Raritan River by 70 MGD by full utilization of Spruce Run and Round Valley reservoirs and the Hamden pumping station and force main to Round Valley. Water treatment and transmission facilities would be required to make use of the additional supply, available to northern New Jersey as described in the Joint Venture Report.

4. Raritan Project R-3, developed to 300 MGD in the year 2000. The water would be released from Tocks Island Reservoir on the Delaware River for diversion at Frenchtown, New Jersey and delivery via a conduit to the Raritan River channel at Hamden.

5. Passaic Project P-6, which would utilize Hudson River water diverted at West Park, New York and pumped to the upper Ramapo River channel for further diversion at Pompton Lakes into Wanaque Reservoir in northern New Jersey. The project is first developed for yields of only 30 to 50 MGD, and as such is initially uneconomical. Further study, beyond the scope of this work, is required to investigate an initial staging scheme which would reduce the large first investment for this project. This project could also supply the needs of Orange and Rockland Counties in New York State.

6. Hudson Project HU-1, which is a diversion from the Hudson River at Hyde Park, with treatment plant, pumping facilities and tunnel to Kensico Reservoir. The project is developed for yields ranging from 300 MGD up to 840 MGD, with Forestport, Hinckley Enlargement, and Schaghticoke Reservoirs selected for development as the demand requires.

7. Hudson Project HU-6, which diverts Hudson River water at West Park with treatment, pumping facilities and tunnel to Shaft 4 at the intersection of the Delaware and Catskill Aqueducts of the New York City water supply system. This project initially is a high-flow skimming project which can economically provide about 500 MGD by making full and early use of existing capacity in the New Jersey and New York City storage and aqueduct systems, and of flows in the Hudson River. The project is developed for yields ranging from 50 MGD to 1,290 MGD, with selection of the construction of upstream Forestport, Hinckley Enlargement, and Schaghticoke Reservoirs based on demand levels in later stages of development. An economical feature of this project is the ability to use excess capacity in the Delaware and Catskill systems before construction of a major new aqueduct to Kensico Reservoir is required for delivery of water to the New York City system. Small demands during early time periods in New Jersey, on the order of 30 MGD to 50 MGD, are met by initial construction of a pipeline from Shaft 4 to DeForest Reservoir, with construction of a major aqueduct to Great Notch deferred until it is required.

IV-A. REGIONAL PROGRAM 1

The main features of Regional Program 1 are shown schematically on Figure 10. The program is intended to present a regional water supply scheme based on a high-flow skimming diversion of Hudson River water at West Park to serve the needs of New York and New Jersey, together with development of the Housatonic River, Raritan mainstem and Tocks Island, an exchange of water with Long Island and universal metering of New York City. A summary of the features is presented in the following subsections.

A-1. New Jersey

Initially, the Raritan River mainstem would be developed together with the first stages of development of Hudson River high-flow diversion at West Park. The Hudson River water would enter the New Jersey system via a pipeline from Shaft 4 on the New York City system to the DeForest Reservoir in northern New Jersey. Later the Tocks Island Reservoir would deliver water to New Jersey and the Hudson River diversion would ultimately be expanded to deliver water from the Hudson River to Great Notch.

The program has the advantage for New Jersey of including the easily implementable and relatively inexpensive development of additional yield from the Raritan River mainstem as an early action project. By the year 2000, when demands increase, the Tocks Island Reservoir utilizing Delaware River water diversions into the Raritan River basin has been selected as the project considered to meet most of the demands.

The year 2000 is a reasonable time horizon for the Tocks Island project, considering both the construction period and the remaining political and environmental issues to be solved. Both the development of the Raritan River mainstem and the construction of Tocks Island Reservoir are common features to all of the regional programs.

PROGRAM YIELD IN MGD

WATER SUPPLY PROJECT		1980	2000	2020
1	RARITAN MAINSTEM R-1	70	70	70
2	DELAWARE-TOCKS ISLAND R-3	—	300	300
3	LONG ISLAND EXCHANGE LIX	150	150	—
4	HUDSON-WEST PARK HU-6	50	330	1165
5	NEW YORK CITY METERING M-1	—	—	125
6	HOUSATONIC-TRAP FALLS HO-1	40	40	40
	HOUSATONIC-ROBBINS HO-2	—	60	200
TOTAL		310	950	1900

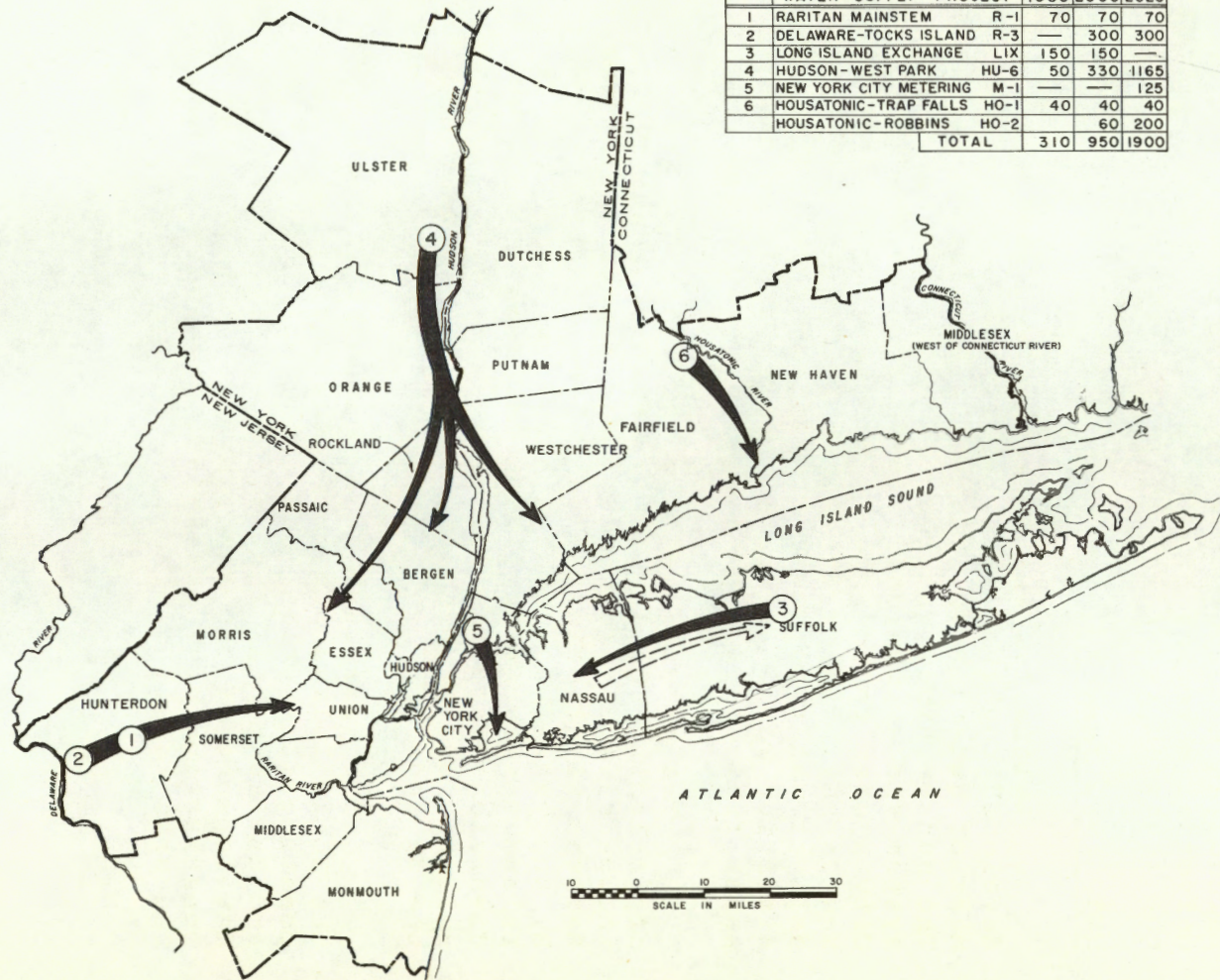


Figure 10 REGIONAL PROGRAM I

The excess demands of 50 MGD and 30 MGD in the years 1980 and 2000, respectively, are filled by the use of Hudson River water. Diversion works at West Park with a conduit to Shaft 4 of the New York City system, required by the year 2000 for New York, are implemented early, and a pipeline from Shaft 4 to DeForest Reservoir is constructed to deliver the water to New Jersey.

By the year 2020, excess demands in the State of New Jersey will increase to 820 MGD, of which 370 MGD will continue to be delivered from the Raritan River mainstem development. The remaining 450 MGD will come from the Hudson River diversion at West Park with a tunnel to Shaft 4 of the New York City system, thence by tunnel from Shaft 4 to Great Notch for distribution in northern New Jersey.

A.2. New York

Initially, New York would receive water from Suffolk County groundwater during an acute drought period while supplying excess water to Long Island during periods of normal rainfall. As the demand increases, New York would continue to exchange water with Long Island, while excess capacity in the existing Delaware and Catskill Aqueducts would be utilized to deliver Hudson River water diverted at West Park into the New York City system through Shaft 4 at the intersection of the two aqueducts. Ultimately, a new aqueduct would be developed from Shaft 4 to Kensico Reservoir delivering larger Hudson River supplies; however, the required supplies would be reduced by the amount saved due to universal metering in New York City which would be accomplished over an extended period of time.

The early implementation of the Long Island groundwater exchange provides all of the benefits to both parties described in previous sections, and also delays requirements for the use of Hudson River water until the year 2000, even though some of the facilities must be built to meet New Jersey requirements.

In the year 2000, the excess demands will be met by implementation of the Hudson River high flow diversion project at West Park with an aqueduct to Shaft 4 of the New York City system. By diverting water to Shaft 4, excess capacity in the existing Catskill and Delaware systems is taken advantage of, and construction of a new aqueduct from the Hudson River diversion to Kensico Reservoir is delayed as long as possible. High-flow skimming from the Hudson River also delays construction of new impoundments in upstate New York.

By the year 2020, a new aqueduct from Shaft 4 and Kensico Reservoir is required, as well as Hudson River regulation, by upstream impoundments. However, the extent of the required facilities will be somewhat reduced by the effect of reduced water consumption in New York City due to the projected effects of metering. By the year 2020, there will no longer be a surplus of groundwater available from Long Island, and the facilities constructed as a two-way exchange in 1980 will then function as a conduit to Long Island to supply demands in excess of those to be met by the Long Island aquifers.

A-3. Connecticut

Early needs for water would be provided for by run-of-the-river diversions from the lower Housatonic River above the Shelton Tidal Dam. The scheme would require no additional impoundment development. Further development of the upper Housatonic River would make use of storage in existing power reservoirs for the major portion of the yield. In later stages of the study period, it would be necessary to develop some upstream storage to meet demands through the year 2020.

The development of the Housatonic River diversions is advantageous to Connecticut in that the projects are readily implementable and relatively inexpensive. The maximum use of existing storage in the power reservoirs for water supply purposes, would put off the construction of upstream storage until the later stage of development.

The development of Projects HO-1 and HO-2, described briefly in the first section of this chapter and in detail in the Joint Venture Report, are common to all of the Regional Programs.

The cumulative program costs and average unit costs are described in detail in Appendix B and summarized as follows:

	<u>1980</u>	<u>2000</u>	<u>2020</u>
Total yield (MGD)	310	950	1,900
Cumulative program cost, (million \$)	483	893	1,704
Average unit water cost (\$/MG)	290	212	189

The distribution of yields and designation of projects comprising this program are as follows:

Project Designation	Yield (MGD)		
	<u>1980</u>	<u>2000</u>	<u>2020</u>
<u>New Jersey</u>			
R-1	70	70	70
R-3	-	300	300
HU-6	<u>50</u>	<u>30</u>	<u>450</u>
Total	120	400	820
<u>New York</u>			
LIX	150	150	-
HU-6	-	300	715
M-1	-	-	<u>125</u>
Total	150	450	840
<u>Connecticut</u>			
HO-1	40	40	40
HO-2	-	<u>60</u>	<u>200</u>
Total	40	100	240
<u>Major Project Development</u>			
HU-6	50	330	1165

IV-B. REGIONAL PROGRAM 2

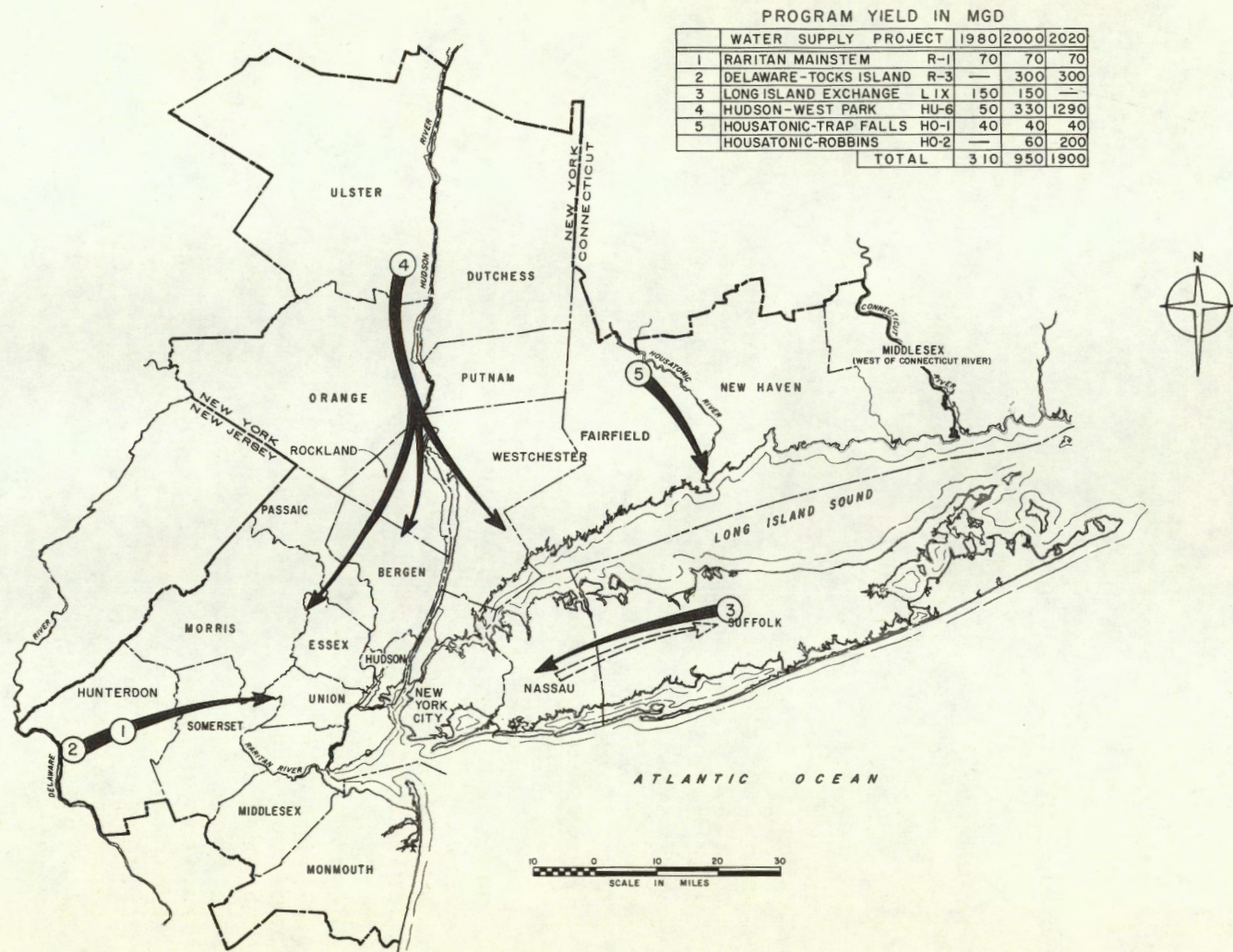
The features of Regional Program 2 are represented schematically on Figure 11. The primary purpose of developing the program was to contrast the difference between this program and Program 1 in that universal metering of New York City is assumed not to occur. The basic features of the program are summarized in the following sections.

B-1. New Jersey

Initially, the Raritan River mainstem would be developed together with the first stages of development of Hudson River high-flow diversion at West Park. The Hudson River water would enter the New Jersey system via a pipeline from Shaft 4 of the New York City system to DeForest Reservoir in northern New Jersey. Later the Tocks Island Reservoir would deliver water to New Jersey and the Hudson River diversion would ultimately be expanded to deliver water from the Hudson River to Great Notch. The features of the program which supply New Jersey water needs are identical to those described in Regional Program 1.

B-2. New York

Initially, groundwater from Suffolk and Nassau County would be used to supply New York during any period of acute drought, should it occur, with excess water from New York delivered to Long Island during normal rainfall years. Second, the Hudson River high-flow diversion at West Park would be developed with an aqueduct to Shaft 4 and would then utilize spare capacity in the existing Catskill and Delaware aqueducts to deliver water to Kensico Reservoir. The precise amount of additional capacity in these aqueducts is not presently known and is the subject of another study. The assumption was made that capacity for demands through the year 2000 was available. In order to meet demands beyond that time, construction of a new aqueduct from Shaft 4 of the New York City system to Kensico Reservoir will be required.



PROGRAM YIELD IN MGD

WATER SUPPLY PROJECT		1980	2000	2020
1	RARITAN MAINSTEM R-1	70	70	70
2	DELAWARE-TOCKS ISLAND R-3	—	300	300
3	LONG ISLAND EXCHANGE LIX	150	150	—
4	HUDSON-WEST PARK HU-6	50	330	1290
5	HOUSATONIC-TRAP FALLS HO-1	40	40	40
	HOUSATONIC-ROBBINS HO-2	—	60	200
TOTAL		310	950	1900

Figure 11 REGIONAL PROGRAM 2

By the year 2020, the diversion at West Park would be developed to meet the full needs of New York, since the Long Island groundwater sources would no longer have surplus capacity available.

The program has the advantage of postponing the use of Hudson River water for New York until the year 2000, and then utilizing spare capacity in the New York City system for transmission of the Hudson diversions until the 2020 time frame, when Hudson River regulation by the use of upstream impoundments would be required.

B-3. Connecticut

Early needs for water would be provided by run-of-the-river diversions from the Lower Housatonic River above the Shelton Tidal Dam. The scheme would require no additional impoundment development.

Later development of the upper Housatonic River would make use of storage in existing power reservoirs for the major portion of the yield. In late stages of the study period, it would be necessary to develop upstream storage to meet demands through the year 2020. The features of the program developed to meet the needs of western Connecticut are identical for all programs and are described in detail in Regional Program 1.

The cumulative program costs and average unit water costs are described in detail in Appendix B and summarized as follows:

	<u>1980</u>	<u>2000</u>	<u>2020</u>
Total yield (MGD)	310	950	1,900
Cumulative program cost (million \$)	483	893	1,703
Average unit water cost (\$/MG)	290	212	187

The distribution of yields and the designation of projects comprising Regional Program 2 are as follows:

Project Designation	Yield (MGD)		
	<u>1980</u>	<u>2000</u>	<u>2020</u>
<u>New Jersey</u>			
R-1	70	70	70
R-3	-	300	300
HU-6	50	30	450
Total	120	400	820
<u>New York</u>			
LIX	150	150	-
HU-6	-	300	840
Total	150	450	840
<u>Connecticut</u>			
HO-1	40	40	40
HO-2	-	60	200
Total	40	100	240
<u>Major Project Development</u>			
HU-6	50	330	1290

IV-C. REGIONAL PROGRAM 3

The basic elements of Regional Program 3 are shown on Figure 12. The program is similar to Program 1 in characteristics; however, it is assumed that the Long Island groundwater exchange will not be a viable project but that universal metering of New York City will eventually take place. A summary of the major elements of this project are presented in the following sections.

C-1. New Jersey

Initially, the Raritan River mainstem would be developed together with the first stages of development of Hudson River high-flow diversion at West Park. The Hudson River water would enter the New Jersey system via a pipeline from Shaft 4 of the New York City system to DeForest Reservoir in northern New Jersey. Later, the Tocks Island Reservoir would deliver water to New Jersey and the Hudson River diversion would ultimately be expanded to deliver water from the Hudson River to Great Notch. The features of the program which supply New Jersey water needs are identical to those described in Regional Program 1.

C-2. New York

Initially, the Hudson River diversion at West Park would have to be developed to a larger extent than in the previous programs. However, the spare capacity to deliver the water to New York City is utilized in the Catskill and Delaware aqueducts. In the year 2000, the Hudson River diversion at West Park is developed to a greater extent and the spare capacity in the Catskill and Delaware aqueducts was assumed to be completely utilized during this time period. Another study currently underway is investigating this assumption. In the year 2020, the Hudson River diversion at West Park would be developed to meet the full needs of New York, including construction of a new aqueduct from Shaft 4 to construction of Kensico Reservoir and the provision of Hudson River regulation. The needs would be less than those projected for Regional Program 2 due to the assumed savings to be gained by universal metering in New York City.

Without the early implementation of the Long Island groundwater exchange, the initial cost of the program is considerably less than the cost of Regional Programs 1 and 2; however, the benefits of the Long Island exchange are also lacking. The advantage of using spare capacity in the Catskill and Delaware system occurs early, while construction of upstream impoundments for Hudson River regulation can be delayed until the year 2020.

Facilities for meeting excess demands on Long Island beyond the year 2000 must also be constructed in the form of an aqueduct from Kensico Reservoir or a pro-rata share of a New York City aqueduct as described in Appendix K of the Joint Venture Report.

C-3. Connecticut

Early needs for water would be provided from run-of-the-river diversions from the lower Housatonic River above the Shelton Tidal Dam. The scheme would require no additional impoundment development.

Later development of the upper Housatonic River would make use of storage in existing power reservoirs for the major portion of the yield. In late stages of the study period, it would be necessary to develop upstream storage to meet demands through the year 2020. The features of the program developed to meet the needs of western Connecticut are identical for all programs and are described in detail in Regional Program 1.

The cumulative program costs and average unit water costs are described in detail in Appendix B and are summarized as follows:

	<u>1980</u>	<u>2000</u>	<u>2020</u>
Total yield (MGD)	310	950	1,900
Cumulative program cost (million \$)	304	796	1,852
Average unit water cost (\$/MG)	206	190	200



Figure 12 REGIONAL PROGRAM 3

The distribution of yields and the designation of projects comprising Regional Program 3 are as follows:

Project Designation	Yield (MGD)		
	1980	2000	2020
<u>New Jersey</u>			
R-1	70	70	70
R-3	-	300	300
HU-6	50	30	450
Total	120	400	820
<u>New York</u>			
HU-6	150	450	715
M-1	-	-	125
Total	150	450	840
<u>Connecticut</u>			
HO-1	40	40	40
HO-2	-	60	200
Total	40	100	240
<u>Major Project Development</u>			
HU-6	200	480	1165

IV-D. REGIONAL PROGRAM 4

The basic features of Regional Program 4 are shown on Figure 13. The purpose of this program was to display the effect of eliminating the Long Island groundwater exchange project and allowing New York City to continue into the future without metering. The elements required for development of this program are summarized in the following sections.

D-1. New Jersey

Initially, the Raritan River mainstem would be developed together with the first stages of development of Hudson River high-flow diversion at West Park. The Hudson River water would enter the New Jersey system via a pipeline from Shaft 4 of the New York City system at the intersection of the Delaware and Catskill Aqueduct to DeForest Reservoir in northern New Jersey. Later, the Tocks Island Reservoir would deliver water to New Jersey and the Hudson River diversion would ultimately be expanded to deliver water from the Hudson River to Great Notch. The features of the program which supply the water needs of New Jersey are identical to those described in Regional Program 1.

D-2. New York

Initially, the Hudson River diversion at West Park would be developed to supply the full needs of New York City in 1980. This source would continue to be expanded and would become the primary source for New York City through the year 2020. It is assumed that the Delaware and Catskill Aqueducts have excess capacity equal to the amount required through the year 2000; however, this assumption is to be verified in another study. The initial economics are as described in Regional Program 3, due to the fact that the Long Island groundwater exchange, with early initial construction, is not implemented. Without the assumed reduction of demand due to metering in New York City, the Hudson River diversion at West Park must be developed to meet the full excess demands of New York through the year 2020.

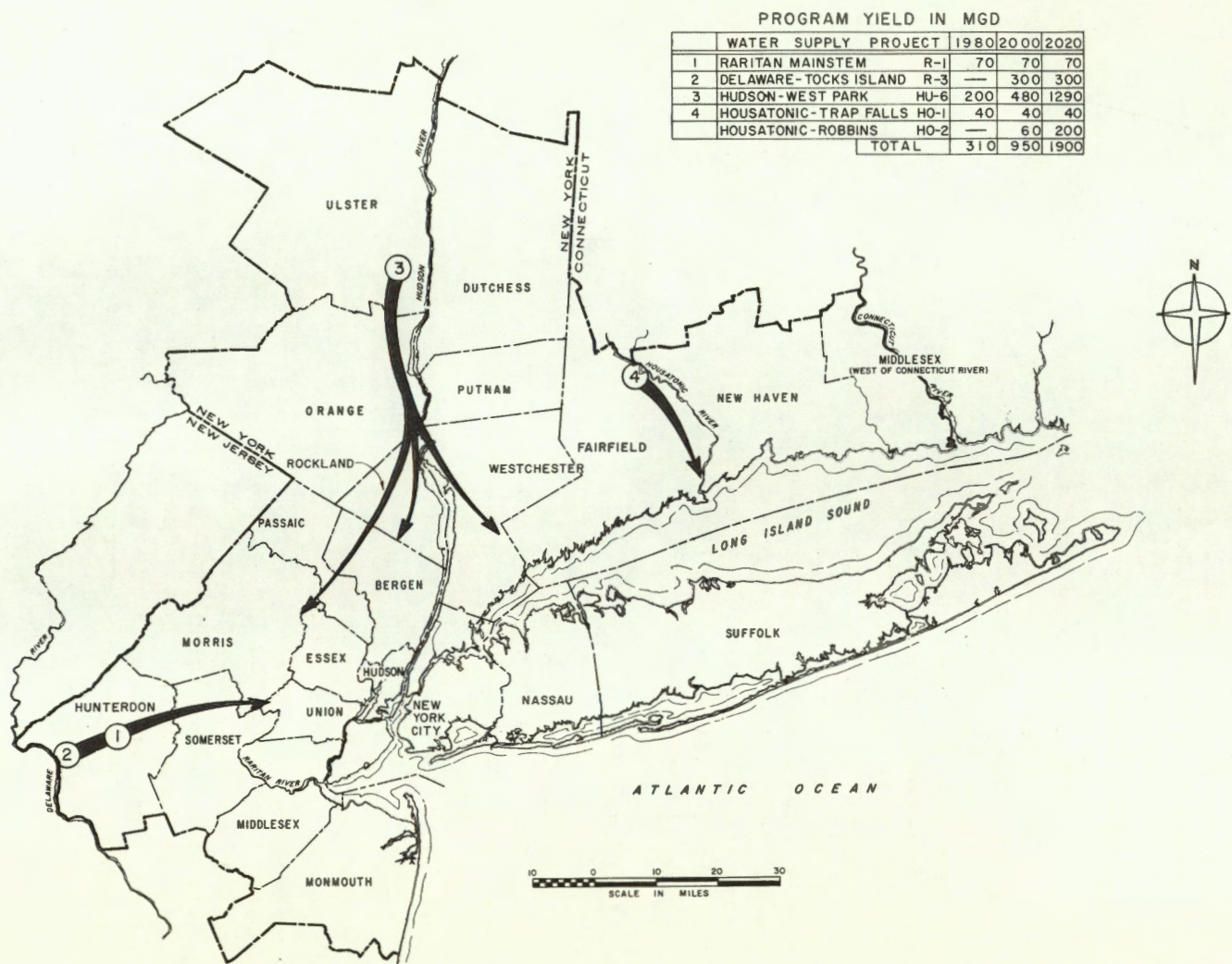
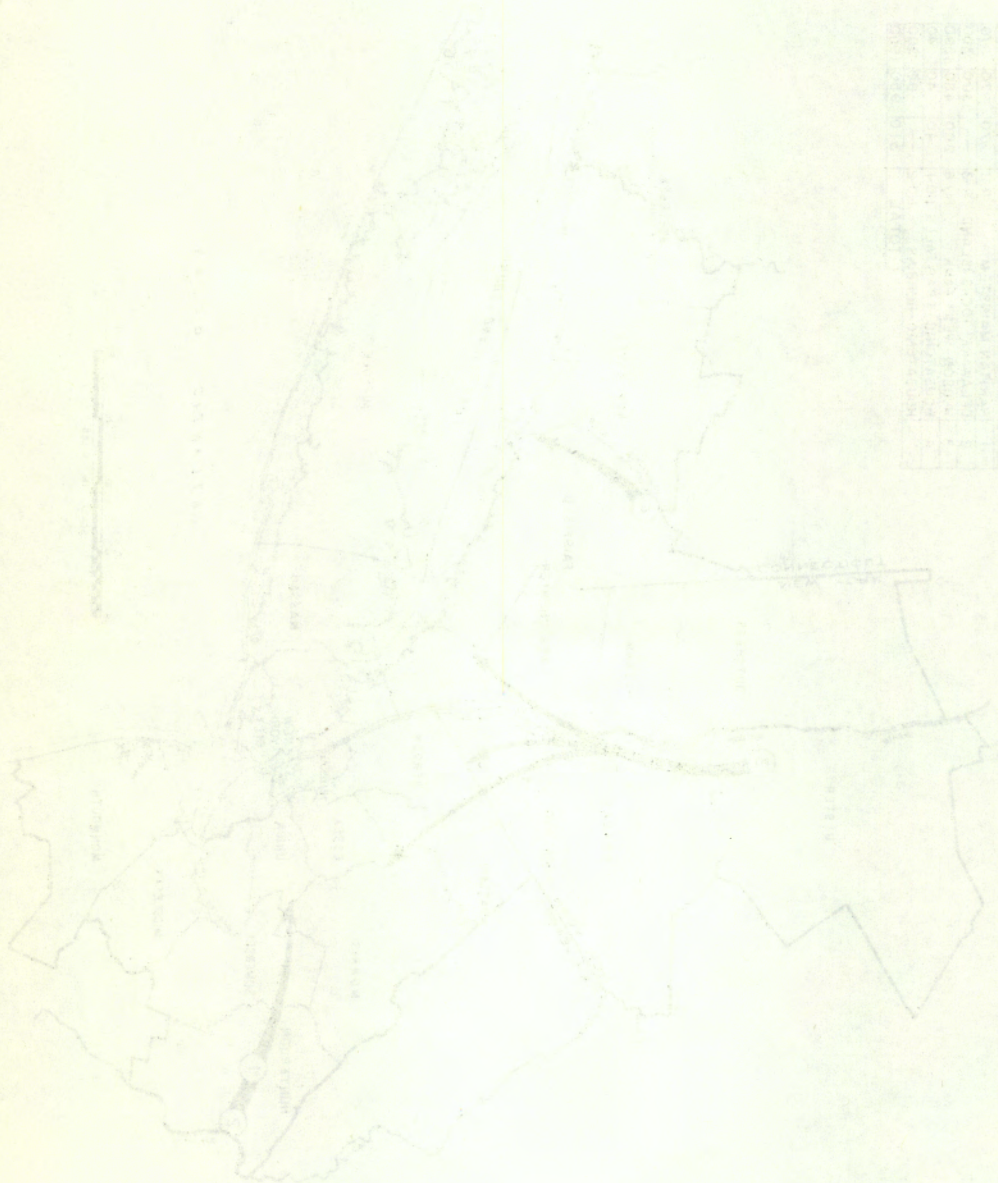


Figure 13 REGIONAL PROGRAM 4

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NO.	DESCRIPTION	AREA (SQ. FT.)	PERCENT
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SECTION 16 T12N R10E

D-3. Connecticut

Early needs for water would be met by run-of-the-river diversions from the lower Housatonic River above the Shelton Tidal Dam, and would require no additional impoundment development.

Later development of the upper Housatonic River would make use of storage in existing power reservoirs for the major portion of the yield. In late stages of the study period, it would be necessary to develop upstream storage to meet demands through the year 2020. The features of the program developed to meet the needs of Western Connecticut are identical for all programs and are described in detail in Regional Program 1.

The cumulative program costs and average unit water costs are described in detail in Appendix B and are summarized as follows:

	<u>1980</u>	<u>2000</u>	<u>2020</u>
Total yield (MGD)	310	950	1,900
Cumulative program cost (million \$)	304	796	1,866
Average unit water cost (\$/MG)	206	190	199

The distribution of yields and the designation of the projects comprising Regional Program 4 are as follows:

Project Designation	Yield (MGD)		
	<u>1980</u>	<u>2000</u>	<u>2020</u>
<u>New Jersey</u>			
R-1	70	70	70
R-3	-	300	300
HU-6	<u>50</u>	<u>30</u>	<u>450</u>
Total	120	400	820
<u>New York</u>			
HU-6	<u>150</u>	<u>450</u>	<u>840</u>
Total	150	450	840
<u>Connecticut</u>			
HO-1	40	40	40
HO-2	-	<u>60</u>	<u>200</u>
Total	<u>40</u>	100	240
<u>Major Project Development</u>			
HU-6	200	480	1290

IV-E. REGIONAL PROGRAM 5

The main features of Regional Program 5 are shown on Figure 14. The intent of this program is to present a concept for developing an exchange of water with Long Island, universal metering of New York City, and the development of the Hudson River as a water supply source for New York utilizing a diversion at Hyde Park, New York. The features of this program are summarized in the following sections.

E-1. New Jersey

Initially, the Raritan mainstem would be developed to supply most of New Jersey's needs together with a diversion from the Hudson River at West Park into the upper Ramapo River. This additional water would flow through the Ramapo River for diversion at Pompton Lakes into Wanaque Reservoir and then be distributed into New Jersey via Great Notch. The limited development at West Park into the upper Ramapo would continue through the year 2000, while the Tocks Island Reservoir was developed to its full capacity. Ultimately, the Hudson River diversion at West Park would be developed to meet the balance of the needs of New Jersey via the upper Ramapo River, Wanaque Reservoir, and a new aqueduct to Great Notch.

The advantages of developing the Raritan River mainstem in the year 1980 and the Tocks Island Reservoir for diversion of Delaware River water into the Raritan Basin are discussed in Regional Program 1 and the projects are described in detail in the Joint Venture Report.

The development of the Hudson-Ramapo diversion to serve the initial needs of New Jersey is expensive in the early stages compared to the development of the same diversion in Regional Program 1. This is due to the fact that the facilities require a high initial investment even though full usage of the capacity of the facilities does not occur until a much later stage in the program.

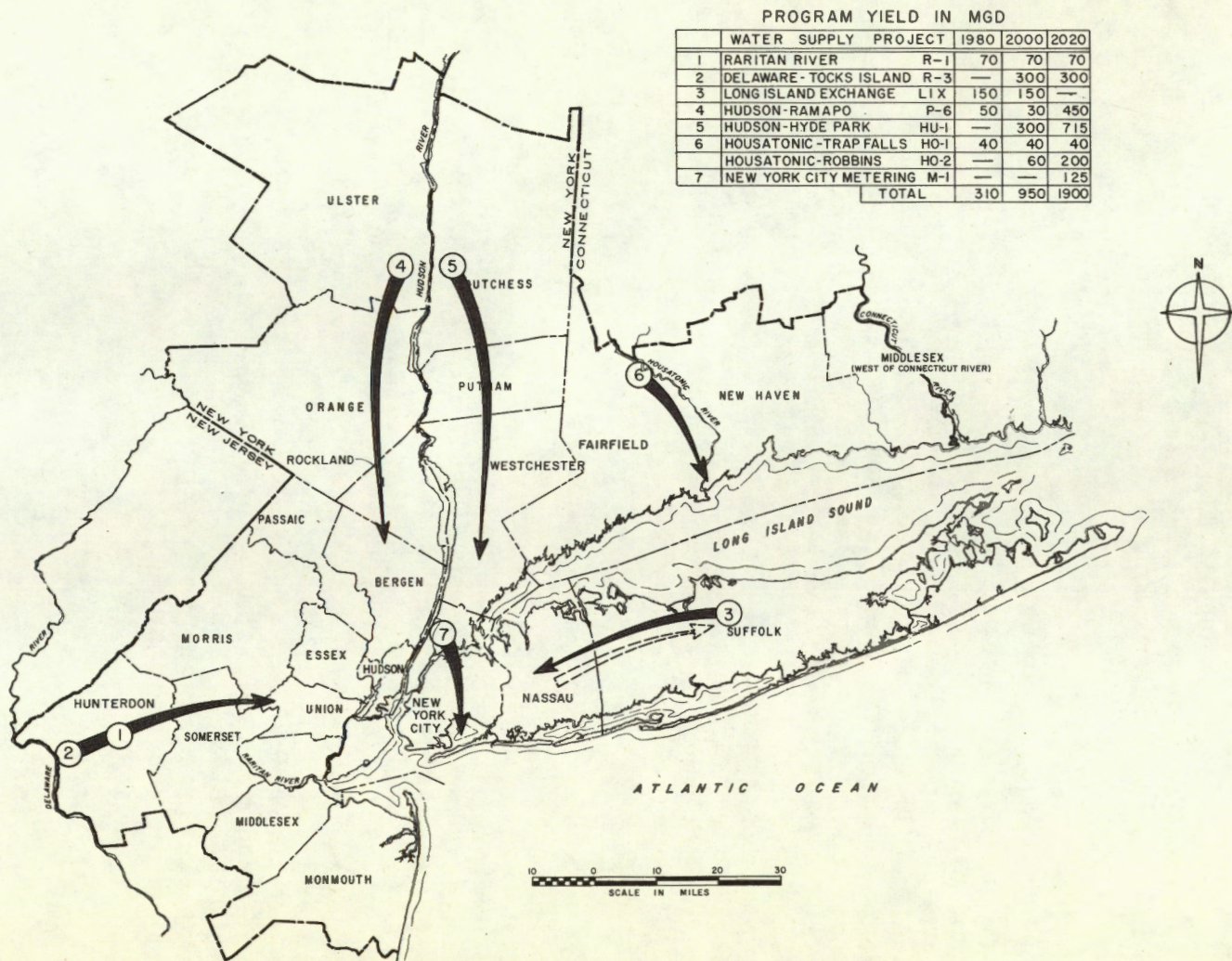
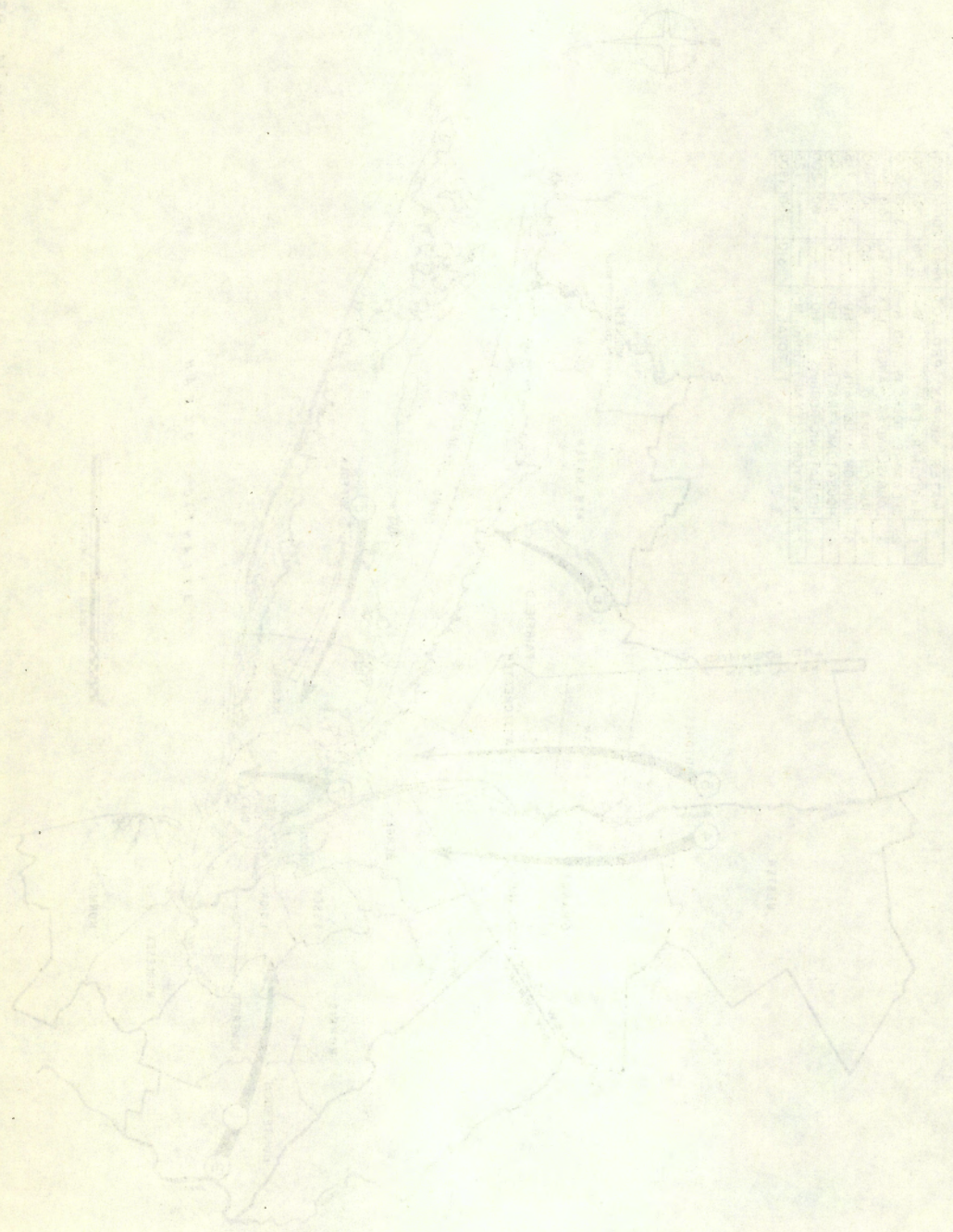


Figure 14 REGIONAL PROGRAM 5

PLATE II. MESSIAH'S WOODS



Additionally, all of the features of the project serve New Jersey alone; a separate project is developed for New York. By the year 2020, the cost of implementing the program is similar to that of other programs. However, although not indicated in these programs, the project could be used to supply Orange and Rockland Counties in the later time frames.

It is possible that development of off-stream storage near the upper Ramapo River, as described previously under Project PA-6 in this report, could delay the implementation of upper Hudson River storage beyond the year 2000. However, more precise data on Hudson River drought flows, and a further, more comprehensive study of the combined operation of the off-stream Ramapo storage, West Park diversion and Hyde Park diversion is required before the statement would be justified.

E-2. New York

Initially, the groundwater exchange with Nassau and Suffolk Counties would be developed to meet the immediate needs of New York City by pumping from groundwater during an acute period of drought while delivering excess New York City water to Long Island during periods of normal rainfall. Next, the Hudson River diversion at Hyde Park would be developed to deliver water via a new aqueduct to Kensico Reservoir. Ultimately, the Long Island supplies would be required entirely to meet Long Island's needs, and the Hudson River diversion at Hyde Park would meet all of New York City's needs in 2020. These needs, however, are reduced by savings that are available through universal metering in New York City.

Implementation of the Long Island exchange in the year 1980 reduces the initial investment for the program considerably, since construction of a diversion at Hyde Park, described in detail in the Joint Venture Report under Project HU-1, is deferred until the year 2000. Unlike Regional Program 1 through 4, where spare capacity in the existing

aqueduct system is utilized through the year 2000, the construction of a Hudson River diversion at Hyde Park requires the immediate and costly installation of a new aqueduct to Kensico Reservoir.

It is possible that some reduction in the cost of the Hyde Park diversion could be achieved by constructing the new aqueduct to the West Branch of the Croton Reservoir system instead of to Kensico Reservoir. The cost of pumping would increase, however, since the Croton Reservoir system is at a higher elevation than Kensico Reservoir, and the operational requirements of the Croton system and its aqueducts to Kensico Reservoir require further study beyond the scope of this report before a determination as to whether or not there would be any savings.

By the year 2020, New York would meet all of its excess demands using the Hudson River diversion at Hyde Park, less the projected savings due to metering of New York City.

E-3. Connecticut

Early water needs in Connecticut would be met by run-of-the-river diversions from the lower Housatonic River above the Shelton Tidal Dam. The scheme would require no additional impoundment construction.

Later development of the upper Housatonic River would make use of existing power reservoirs for the major portion of the yield. In late stages of the study period, it would be necessary to develop some upstream storage to meet demands through the year 2020. The features of the program developed to meet the needs of western Connecticut are identical for all programs and are described in detail in Regional Program 1.

The cumulative program costs and average unit water costs are described in detail in Appendix B and are summarized as follows:

	<u>1980</u>	<u>2000</u>	<u>2020</u>
Total yield (MGD)	310	950	1,900
Cumulative program cost (million \$)	623	1,546	1,740
Average unit water cost (\$/MG)	352	297	193

The distribution of yields and designation of projects comprising Regional Program 5 are as follows:

Project Designation	Yield (MGD)		
	<u>1980</u>	<u>2000</u>	<u>2020</u>
<u>New Jersey</u>			
R-1	70	70	70
R-3	-	300	300
P-6	<u>50</u>	<u>30</u>	<u>450</u>
Total	120	400	820
<u>New York</u>			
LIX	150	150	-
M-1	-	-	125
HU-1	-	300	715
Total	150	450	840
<u>Connecticut</u>			
HO-1	40	40	40
HO-2	-	60	200
Total	40	100	240

IV-F. REGIONAL PROGRAM 6

The elements of Regional Program 6 are shown on Figure 15. The program involves a study of supplying New York City and New Jersey with Hudson River water on the assumption that the Long Island groundwater exchange will be implemented but that metering of New York City water will not become a reality. The major features of this program are summarized in the following sections.

F-1. New Jersey

Initially, the Raritan mainstem would be developed to supply most of New Jersey's needs together with a diversion from the Hudson River at West Park into the upper Ramapo River. This additional water would flow through the Ramapo River for diversion at Pompton Lakes into Wanaque Reservoir and then be distributed into New Jersey via Great Notch. The limited development at West Park into the upper Ramapo would continue through the year 2000 while the Tocks Island Reservoir is developed to its full capacity during that time period. Ultimately, the Hudson River-Ramapo diversion at West Park would be developed to meet the balance of the needs of New Jersey via the upper Ramapo River, Wanaque Reservoir, and a new aqueduct to Great Notch.

The features of the portion of Regional Program 6 serving the needs of New Jersey are identical to those in Regional Program 5.

F-2. New York

Initially, an exchange of water with Long Island using groundwater in Nassau and Suffolk Counties would be developed to supply New York City during an acute period of drought. Subsequently, New York City would supply Long Island with excess water during normal years as described in previous sections. Next, the Hudson River diversion at Hyde Park would be developed with a new aqueduct to Kensico Reservoir in order to meet New York City needs in 2000. In the year 2020, the Long Island groundwater supplies

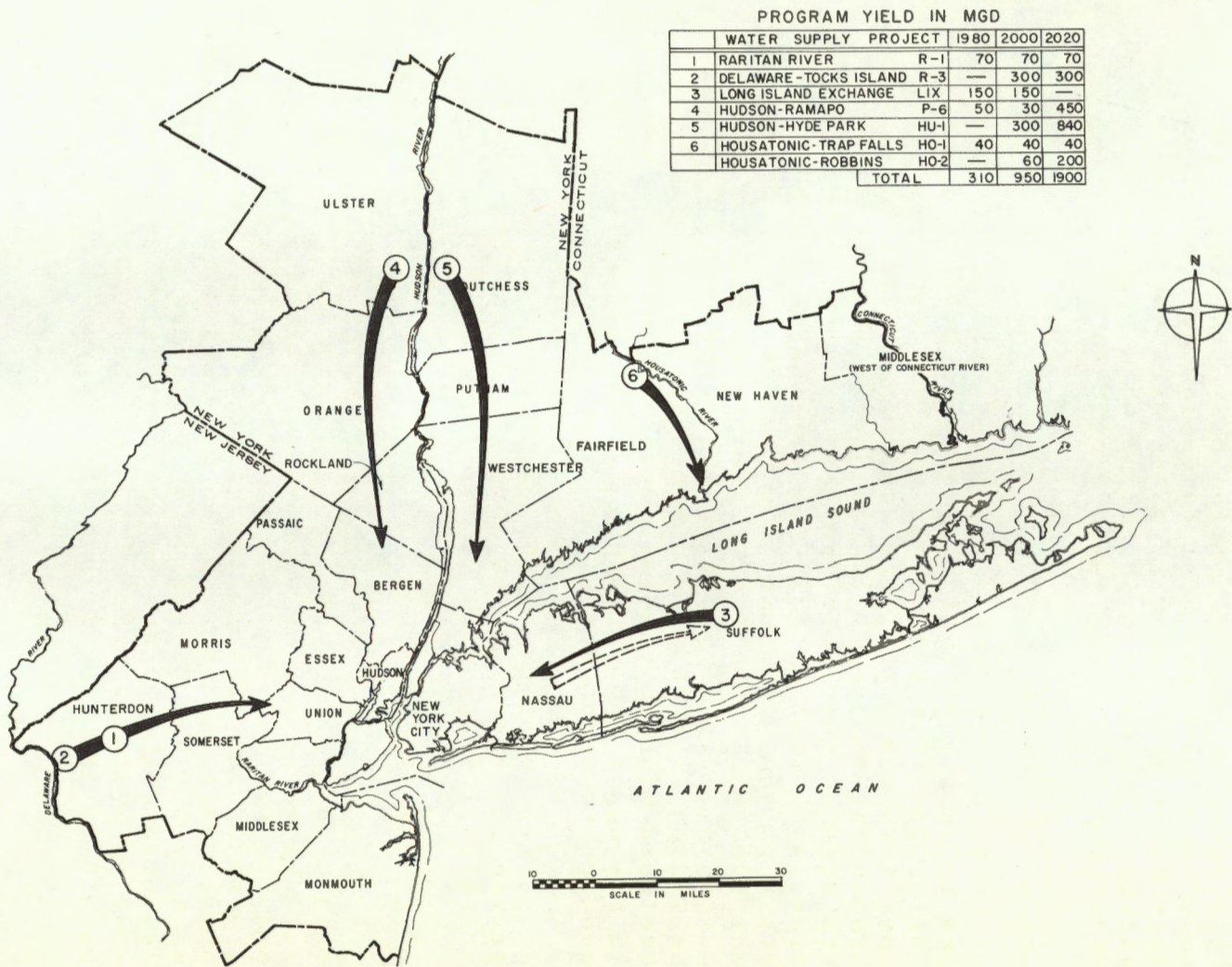
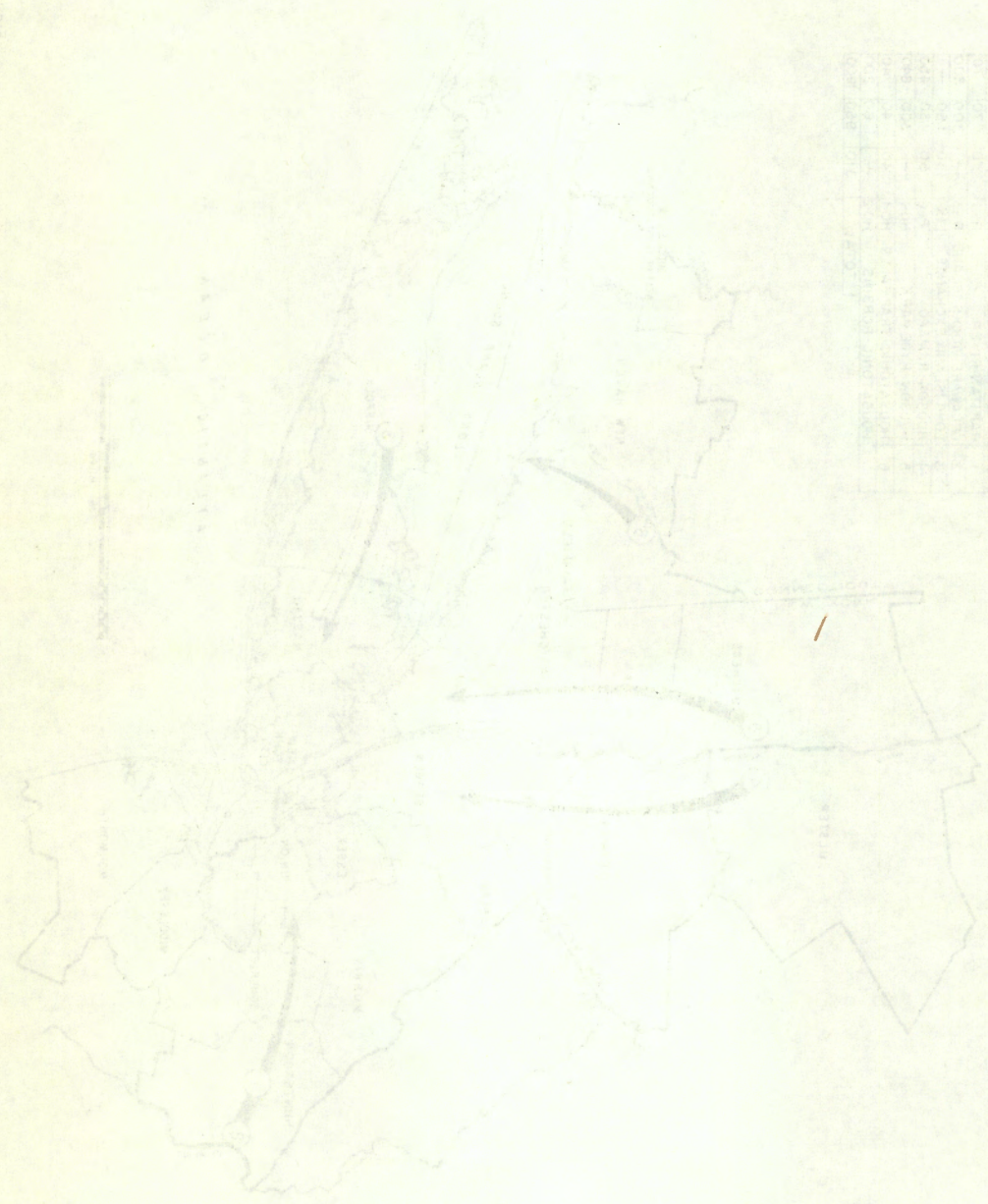


Figure 15 REGIONAL PROGRAM 6



№	НАИМЕНОВАНИЕ РАЙОНА	ПЛОЩАДЬ (кв. км)	НАСЕЛЕНИЕ (тыс. чел.)	ПЛОТНОСТЬ НАСЕЛЕНИЯ (чел./кв. км)
1	АКШУКАТ	120	150	1,25
2	АКШУКАТ	120	150	1,25
3	АКШУКАТ	120	150	1,25
4	АКШУКАТ	120	150	1,25
5	АКШУКАТ	120	150	1,25
6	АКШУКАТ	120	150	1,25
7	АКШУКАТ	120	150	1,25
8	АКШУКАТ	120	150	1,25
9	АКШУКАТ	120	150	1,25
10	АКШУКАТ	120	150	1,25
11	АКШУКАТ	120	150	1,25
12	АКШУКАТ	120	150	1,25
13	АКШУКАТ	120	150	1,25
14	АКШУКАТ	120	150	1,25
15	АКШУКАТ	120	150	1,25
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21	АКШУКАТ	120	150	1,25
22	АКШУКАТ	120	150	1,25
23	АКШУКАТ	120	150	1,25
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25	АКШУКАТ	120	150	1,25
26	АКШУКАТ	120	150	1,25
27	АКШУКАТ	120	150	1,25
28	АКШУКАТ	120	150	1,25
29	АКШУКАТ	120	150	1,25
30	АКШУКАТ	120	150	1,25
31	АКШУКАТ	120	150	1,25
32	АКШУКАТ	120	150	1,25
33	АКШУКАТ	120	150	1,25
34	АКШУКАТ	120	150	1,25
35	АКШУКАТ	120	150	1,25
36	АКШУКАТ	120	150	1,25
37	АКШУКАТ	120	150	1,25
38	АКШУКАТ	120	150	1,25
39	АКШУКАТ	120	150	1,25
40	АКШУКАТ	120	150	1,25
41	АКШУКАТ	120	150	1,25
42	АКШУКАТ	120	150	1,25
43	АКШУКАТ	120	150	1,25
44	АКШУКАТ	120	150	1,25
45	АКШУКАТ	120	150	1,25
46	АКШУКАТ	120	150	1,25
47	АКШУКАТ	120	150	1,25
48	АКШУКАТ	120	150	1,25
49	АКШУКАТ	120	150	1,25
50	АКШУКАТ	120	150	1,25

1:100,000

would be entirely dedicated to meeting the needs of Long Island, and the diversion at Hyde Park would be expanded to supply the entire needs of New York City and surrounding counties.

The operation and description of the New York portion of the system is similar to Regional Program 5, except that the demands are not reduced by savings due to metering of New York City. The total cost of the program in the year 2020 is less than the cost of Regional Program 5, which includes metering, because of the relatively small additional investment required to achieve greater capacity in the Hudson River diversion project at Hyde Park.

F-3. Connecticut

Early water needs would be met by run of the river diversions from the lower Housatonic River above Shelton Tidal Dam. The scheme would require no additional impoundment construction.

Later development of the upper Housatonic River would make use of existing power reservoirs for a major portion of the yield. In late stages of the study period, it would be necessary to meet demands through the year 2020 by construction of upstream impoundments. The features of the program developed to meet demands in Western Connecticut are identical for all programs and are described in detail in Regional Program 1.

The cumulative program costs and average unit water costs are described in detail in Appendix B and are summarized as follows:

	<u>1980</u>	<u>2000</u>	<u>2020</u>
Total yield (MGD)	310	950	1,900
Cumulative program cost (million \$)	623	1,546	1,716
Average unit water cost (\$/MG)	352	297	183

The distribution of yields and designation of projects comprising Regional Program 6 are as follows:

Project Designation	Yield (MGD)		
	1980	2000	2020
<u>New Jersey</u>			
R-1	70	70	70
R-3	-	300	300
P-6	50	30	450
Total	120	400	820
<u>New York</u>			
LIX	150	150	-
HU-1	-	300	840
Total	150	450	840
<u>Connecticut</u>			
HO-1	40	40	40
HO-2	-	60	200
Total	40	100	240

IV-G. REGIONAL PROGRAM 7

The features of Regional Program 7 are shown schematically on Figure 16. The purpose of this program was to present a comparison of water supply development to the New York study area assuming that the exchange of water with Long Island would not be implemented but that New York City would adopt a policy of requiring metering of new residential connections. A summary of the major features of the program development follows.

G-1. New Jersey

Initially, the Raritan mainstem would be developed to supply most of northern New Jersey's needs together with a limited diversion from the Hudson River at West Park into the upper Ramapo River. This additional water would flow through the Ramapo River for diversion at Pompton Lakes into Wanaque Reservoir and then be distributed into New Jersey via Great Notch. The limited development at West Park into the upper Ramapo would continue through the year 2000, while the Tocks Island-Delaware River source is developed to its full capacity during that time period. Ultimately, the Hudson River-Ramapo diversion at West Park would be developed to meet the balance of the needs of New Jersey via the upper Ramapo River, Wanaque Reservoir, and a new aqueduct to Great Notch.

The features and operation of this portion of Regional Program 7 are identical to those described in Regional Program 5.

G-2. New York

In order to meet the demands of New York, immediate development of a Hudson River diversion at Hyde Park is required, and this development would continue progressively in order to meet the demands through the year 2020, less the savings in water consumption achieved due to metering of New York City.

Since the Long Island groundwater exchange would not be implemented, Regional Program 7 is more expensive initially than Programs 5 and 6 due to the fact that the diversion at Hyde Park and tunnel to Kensico Reservoir represent a large first cost.

The operation and features of the Hyde Park diversion are as described in Regional Program 5, modified by the requirement for early implementation.

Since conduits will not be available to meet excess demands on Long Island, it will be necessary to construct facilities for the purpose of supplying New York City water to Long Island in the year 2020. The cost of the facilities will include either a new tunnel from Kensico Reservoir or a pro-rata share of the cost of a New York City aqueduct, all as described in detail in Appendix K of the Joint Venture Report.

G-3. Connecticut

Demands in early stages would be met by diversions from the lower Housatonic River above Shelton Tidal Dam. The project would not require any additional construction of upstream impoundments at first.

Later development of the upper Housatonic River would make use of existing power reservoirs for a major portion of the yield. In late stages of the study period, construction of additional impoundments would be necessary to meet demands through the year 2020. The features of the program developed to meet demands in Western Connecticut are identical for all programs and are described in detail under Regional Program 1.

The cumulative program costs and unit water costs are presented in detail in Appendix B, and are summarized as follows:

PROGRAM YIELD IN MGD

	WATER SUPPLY PROJECT	1980	2000	2020
1	RARITAN RIVER R-1	70	70	70
2	DELAWARE-TOCKS ISLAND R-3	—	300	300
3	HUDSON-RAMAPO P-6	50	30	450
4	HUDSON-HYDE PARK HU-1	150	450	715
5	HOUSATONIC-TRAP FALLS HO-1	40	40	40
	HOUSATONIC-ROBBINS HO-2	—	60	200
6	NEW YORK CITY METERING M-1	—	—	125
TOTAL		310	950	1900

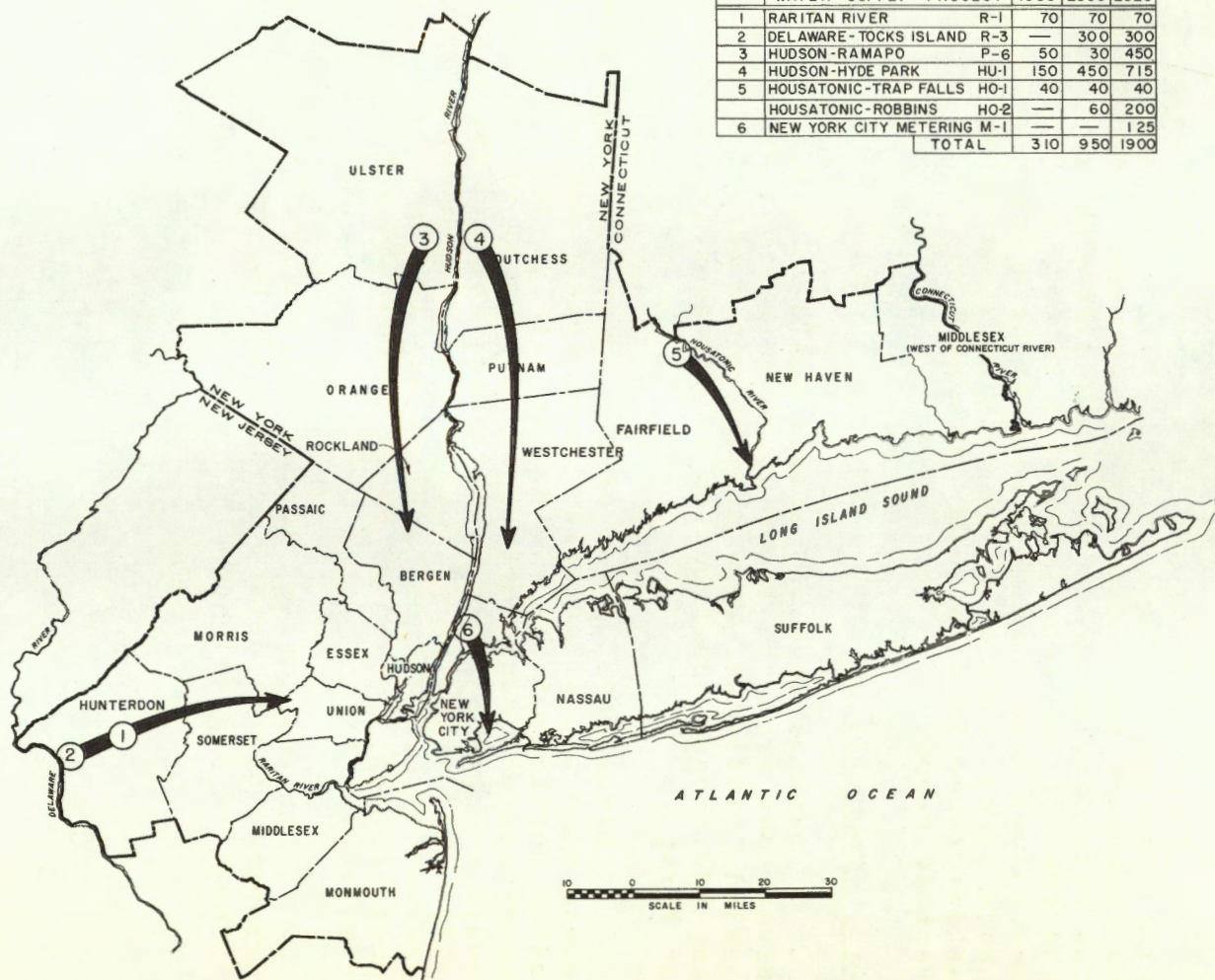


Figure 16 REGIONAL PROGRAM 7

	<u>1980</u>	<u>2000</u>	<u>2020</u>
Total yield (MGD)	310	950	1,900
Cumulative program cost (million \$)	913	1,439	1,868
Average unit water cost (\$/MG)	494	280	202

The distribution of yields and designation of projects comprising Regional Program 7 are as follows:

Project Designation	Yield (MGD)		
	<u>1980</u>	<u>2000</u>	<u>2020</u>
<u>New Jersey</u>			
R-1	70	70	70
R-3	-	300	300
P-6	50	30	450
Total	<u>120</u>	<u>400</u>	<u>820</u>
<u>New York</u>			
M-1	-	-	125
HU-1	150	450	715
Total	<u>150</u>	<u>450</u>	<u>840</u>
<u>Connecticut</u>			
HO-1	40	40	40
HO-2	-	60	200
Total	<u>40</u>	<u>100</u>	<u>240</u>

IV-H. REGIONAL PROGRAM 8

The major features of Regional Program 8 are shown schematically on Figure 17. This program was developed to provide a comparable program to those developed in preceding sections for an assumed Hudson River diversion at Hyde Park, except that it is assumed that the Long Island groundwater project will not become viable and that New York City will continue to permit installation of residential service taps without metering.

H-1. New Jersey

Initially, the Raritan mainstem would be developed to supply most of northern New Jersey's needs together with a diversion from the Hudson River at West Park into the Upper Ramapo River. This additional water would flow through the Ramapo River for diversion at Pompton Lakes into Wanaque Reservoir and then be distributed into northern New Jersey via Great Notch. The limited development at West Park into the upper Ramapo would continue through the year 2000, while the Tocks Island Reservoir is developed to its full capacity. Ultimately, the Hudson River diversion at West Park would be developed to meet the balance of the needs of northern New Jersey via the upper Ramapo River, Wanaque Reservoir, and a new aqueduct to Great Notch.

The features of this portion of the program are identical to those described in Regional Program 5.

H-2. New York

The needs of New York City would be served entirely by the Hudson River diversion at Hyde Park with an aqueduct to Kensico Reservoir. This project would continue to be expanded through the year 2020 to meet all of the excess demands in New York.

The features of this portion of the program are similar to those described in Regional Program 5, with early implementation of Project HU-1 required and no savings because of New York City metering.

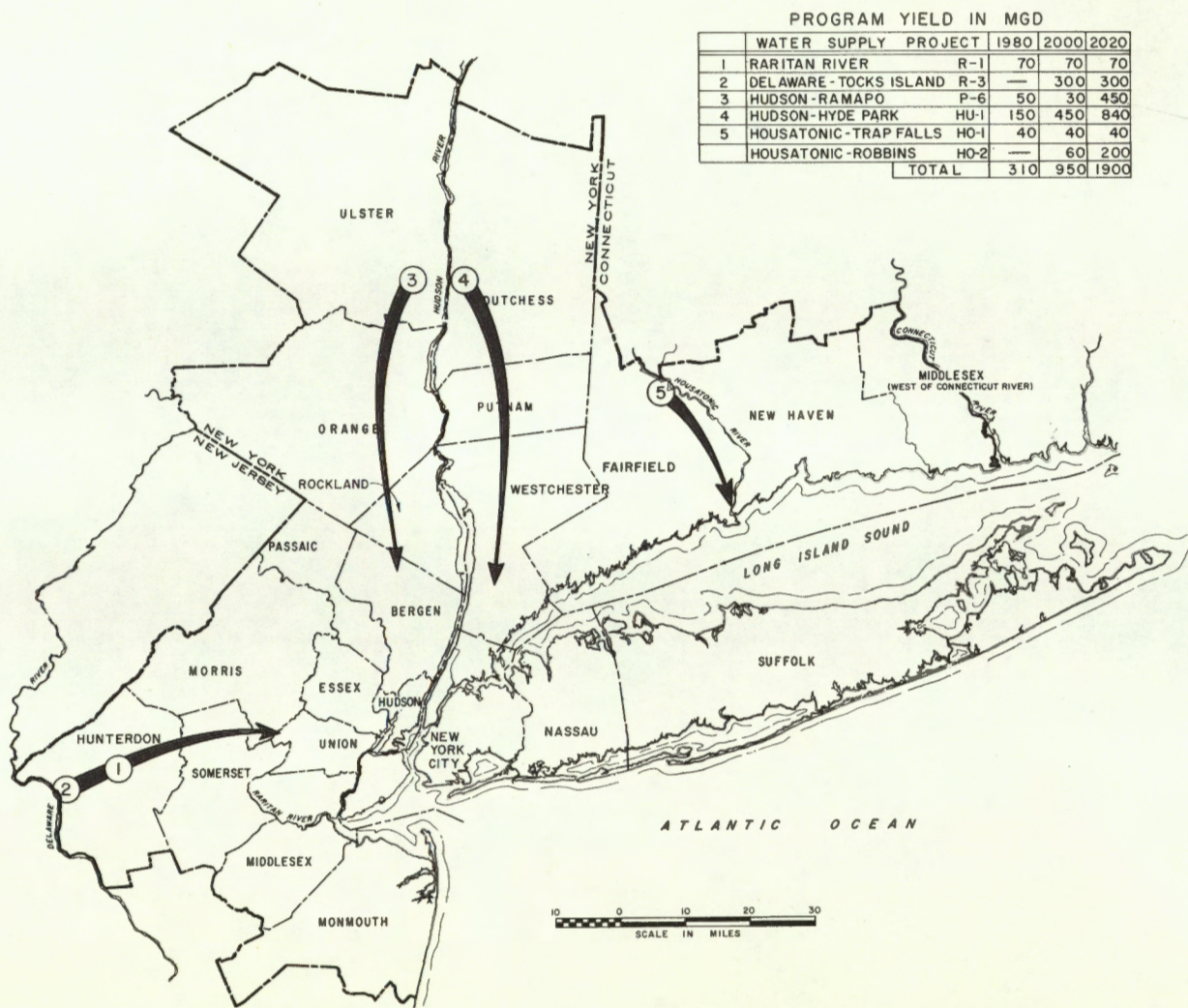
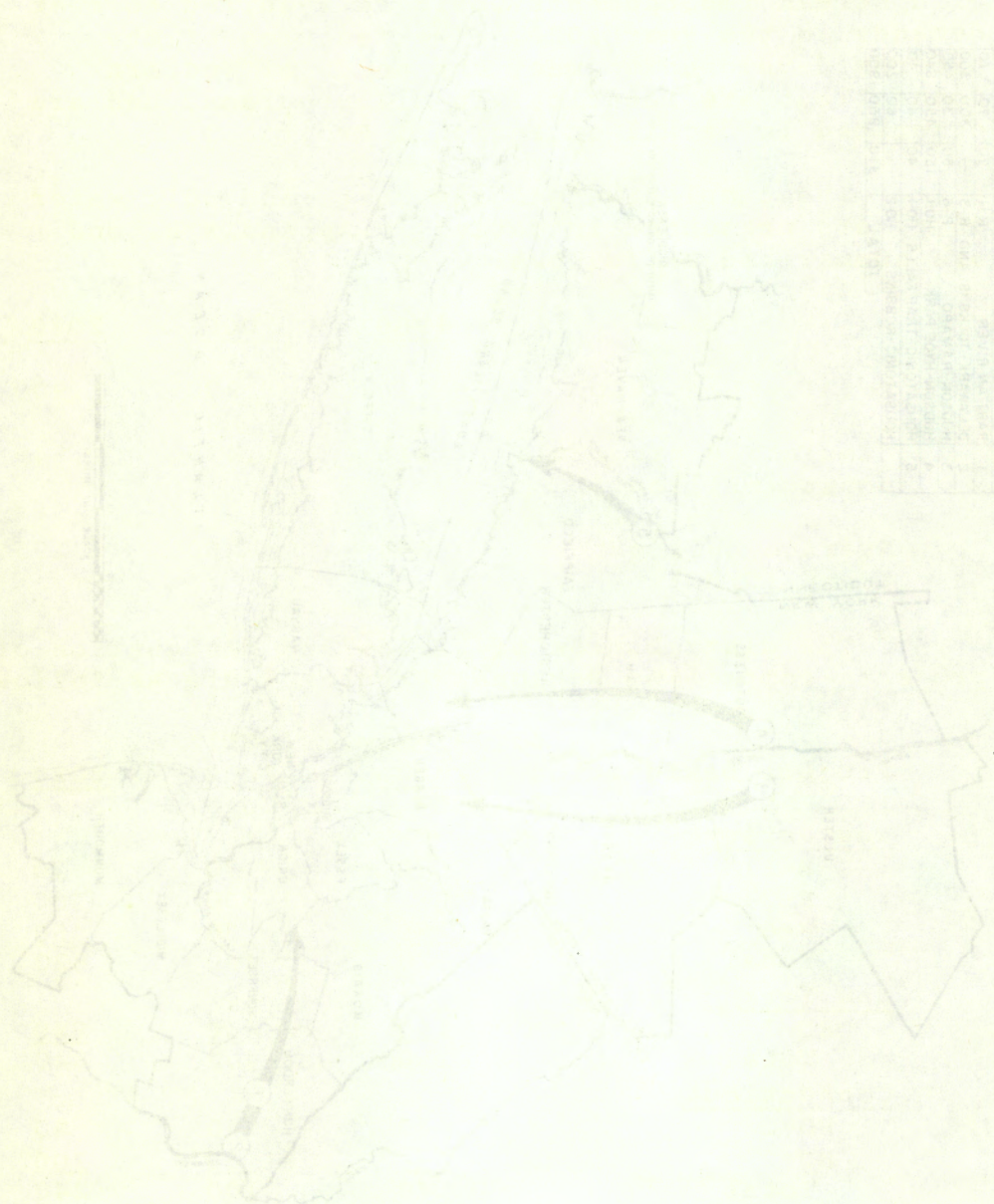


Figure 17 REGIONAL PROGRAM 8



Room	Area	Volume	Height
Room 1	1000	1000	10
Room 2	1000	1000	10
Room 3	1000	1000	10
Room 4	1000	1000	10
Room 5	1000	1000	10
Room 6	1000	1000	10
Room 7	1000	1000	10
Room 8	1000	1000	10
Room 9	1000	1000	10
Room 10	1000	1000	10

Scale: 1:1000

H-3. Connecticut

Early water needs would be met from run of the river diversions on the lower Housatonic River above Shelton Tidal Dam, without development of additional impoundments. Later development of the upper Housatonic River would make use of existing power reservoirs for a major portion of the yield. In late stages of the study period, construction of upstream impoundments would be required to meet demands in the year 2020. The features of the program developed to meet the needs of Western Connecticut are identical in all programs, and are described in detail in Regional Program 1.

The cumulative program costs and unit water costs are presented in detail in Appendix B, and are summarized as follows:

	<u>1980</u>	<u>2000</u>	<u>2020</u>
Total yield (MGD)	310	950	1,900
Cumulative program cost (million \$)	913	1,439	1,849
Average unit water cost (\$/MG)	494	280	195

The distribution of yields and designation of projects comprising Regional Program 8 are as follows:

Project Designation	Yield (MGD)		
	<u>1980</u>	<u>2000</u>	<u>2020</u>
<u>New Jersey</u>			
R-1	70	70	70
R-3	-	300	300
P-6	<u>50</u>	<u>30</u>	<u>450</u>
Total	120	400	820
<u>New York</u>			
HU-1	<u>150</u>	<u>450</u>	<u>840</u>
Total	150	450	840
<u>Connecticut</u>			
HO-1	40	40	40
HO-2	<u>-</u>	<u>60</u>	<u>200</u>
Total	40	100	240

Early water needs would be satisfied by the river diversions on the lower Housatonic River above Shelton Dam, without development of additional impoundments. Later development of the upper Housatonic River would make use of existing power reservoirs for a water portion of the yield in later years of the study period. Construction of upstream impoundments would be required to meet demands in the year 2020. The features of the program developed to meet the needs of Western Connecticut are identical in all programs, and are described in detail in Regional Program 1.

The cumulative program costs and unit water costs are presented in detail in Appendix B, and are summarized as follows:

Year	1980	2000	2020
Total yield (MGD)	310	330	1,000
Cumulative program cost (million \$)	913	1,439	1,849
Average unit water cost (\$/MG)	291	390	185

The distribution of yields and destination of projects comprising Regional Program 2 are as follows:

Project Destination	Yield (MGD)		
	1980	2000	2020
<u>New Jersey</u>			
N-1	0	70	70
R-2	0	300	300
Y-7	0	30	300
Total	0	400	670
<u>New York</u>			
BU-1	100	450	840
Total	100	450	840
<u>Connecticut</u>			
HO-1	40	40	40
HO-2	0	100	200
Total	40	100	240

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APPENDICES

APPENDICES

APPENDIX A

APPENDIX A

POTENTIAL RESERVOIR SITES

Reservoir Site	Stream	Drainage Area (square miles)	Total Storage (billion gallons)	Spillway Crest Elevation (feet above MSL)	Maximum Depth (feet)	Estimated Capital Cost*	
						Million Dollars	Dollars Per Million Gallons of Storage
Forestport	Black River	237	171	1,250	123	65.1	477
Fort Hunter	Schoharie Creek	612	90	485	185	107.0	1,190
Hinckley Expansion	West Canada Creek	374	118**	1,274	51***	60.4	520
Schaghticoke	Hoosic River	645	82	230	140	56.6	691
Little Dam	Ramapo River	4.7	11.7	780	100	16.9	1,440
Long Swamp	Ramapo River	1.6	8.3	620	120	61.7	7,440
Pine Meadow	Ramapo River	5	8.1	1,060	140	35.6	4,390

* Including engineering and contingencies, legal and administrative.

** Total capacity added by expansion.

*** Depth above previous level.

SUMMARY OF COST AND YIELD DATA
FOR PROJECTS DEVELOPED IN CHAPTER II
 (Engineering News Record Index = 1,400)

Project	Yield		Capital Cost (thousand \$)	Capital Cost/MGD (thousand \$)	Annual Cost (thousand \$)	Unit Water Cost (\$)
	MGD	MG				
PA-6	250	91,250	611,907	2,448	40,985	449
HUA-6	530	193,450	887,977	1,680	70,275	367
UH-1	900	328,500	2,535,614	2,817	146,162	445
UH-2	900	328,500	2,746,760	3,052	157,099	478
UH-3	1,500	547,500	4,120,309	2,747	230,393	421
UH-4A	1,500	547,500	3,612,873	2,409	213,747	390
UH-4B	1,500	547,500	3,498,554	2,332	207,133	378
UH-5	600	219,000	4,427,165	7,379	236,931	1,082
LIX	150	54,800	215,750	3,937	15,450	282

Note: Unit water cost = Annual cost/MG.

HUDSON RIVER DIVERSION TO THE UPPER RAMAPO RIVER

<u>Item</u>	<u>Estimated Cost</u>
<u>Project PA-6 Capital Cost</u>	
A. Construction Costs:	
1. West Park Diversion	\$ 5,300,000
2. Tunnel (West Park El Y50)	181,431,000
Plus 15% shafts and chambers	27,215,000
3. Pine Meadow Embankment (including clearing, grubbing and land)	25,282,000
4. Little Dams Embankment	11,396,000
5. Long Swamp Embankment	44,832,000
6. West Park Pump Station	21,612,000
7. Pipeline (El. 450, Pine Meadow)	2,178,000
8. Pipeline (El 450, Little Dams)	2,450,000
9. Pipeline (El. 450, Long Swamp)	1,188,000
10. Pump (El. 450, Pine Meadow)	2,128,000
11. Pump (El. 450, Little Dams)	1,579,000
12. Pump (El. 450, Long Swamp)	641,000
13. Pompton Lakes Diversion	5,300,000
14. Pompton Lakes Pump Station	3,863,000
15. Tunnel (Pompton Lakes and Wanaque)	16,854,000
Plus 15% shafts and chambers	2,528,000
16. Tunnel (Wanaque and Great Notch)	52,166,000
Plus 15% shafts and chambers	7,825,000
17. Treatment Plant (Wanaque)	28,125,000
B. Total Construction	\$443,893,000
C. Engineering and Contingencies @ 25% of Total Construction	110,973,000
D. Land Cost @ \$1.00/LF + 100%	1,413,000
E. Legal and Administrative @ 10% of B, C and D	55,628,000
F. <u>Total Capital Cost</u>	<u>\$611,907,000</u>
<u>Project PA-6 Annual Cost</u>	
1. Interest and Amortization @ 4-5/8%—50 years (CRF = 0.05169)	\$31,630,000
2. Taxes @ 2%	2,817,000
3. Personnel—Treatment Plant/Pump Stations	420,000
4. Chemicals, Supplies and Materials—Treatment Plant(s)	1,790,000
5. Power:	
5A. Demand	1,217,000
5B. Energy	3,111,000
<u>Total Annual Cost</u>	<u>\$40,985,000</u>

HUDSON RIVER DIVERSION TO THE UPPER RAMAPO RIVER

TWO-WAY EXCHANGE WITH ASHOKAN RESERVOIR

<u>Item</u>	<u>Estimated Cost</u>
<u>Project HUA-1 Capital Cost</u>	
A. Construction Costs:	
1. West Park Diversion	\$ 10,600,000
2. Tunnel (West Park and Ashokan)	104,966,000
3. Plus 15% shafts and chambers	15,745,000
Tunnel (Hyde Park and Kensico)	347,800,000
3. Pump Station—Ashokan	39,827,000
Pump Station—Hyde Park	11,300,000
4. Treatment Plant (Ashokan)	62,280,000
Treatment Plant (Hyde Park)	53,900,000
B. Total Construction	\$646,561,000
C. Engineering and Contingencies @ 25% of Total Construction	161,390,000
D. Land Cost	300,000
E. Legal and Administrative at 10% of B, C and D	80,725,000
<u>F. Total Capital Cost</u>	<u>\$887,977,000</u>
<u>Project HUA-1 Annual Costs</u>	
1. Interest and Amortization @ 4-5/8%—50 years (CRF = 0.05169)	\$45,900,000
2. Taxes @ 2%	3,352,000
3. Personnel—Treatment Plant/Pump Stations	1,496,000
4. Chemicals, Supplies and Materials—Treatment Plant(s)	7,960,000
5. Power	11,567,000
<u>Total Annual Cost</u>	<u>\$70,275,000</u>

UPPER HUDSON RIVER ANALYSIS

<u>Item</u>	<u>Estimated Cost</u>
<u>Project UH-1 Capital Cost</u>	
A. Construction Costs	
1. Pump Station (Schaghticoke)	\$ 32,801,000
2. Treatment Plant (Schaghticoke)	43,000,000
3. Tunnel (Schaghticoke and Sacandaga)	124,397,000
4. Plus 15% shafts and chambers	18,705,000
4. Tunnel (Sacandaga and Glen)	93,519,000
Plus 15% shafts and chambers	14,028,000
5. Ft. Hunter Embankment	67,592,000
6. Treatment Plant (Ft. Hunter)	33,120,000
7. Pump Station (Ft. Hunter)	12,954,000
8. Tunnel (Ft. Hunter and Glen)	15,650,000
Plus 15% shafts and chambers	2,348,000
9. Tunnel (Glen and Kensico)	1,167,888,000
Plus 15% shafts and chambers	175,183,000
B. Total Construction (without Schaghticoke Embankment)	\$1,801,185,000
C. Engineering and Contingencies @ 25% of Total Construction	448,515,000
D. Land Costs	33,949,000
E. Legal and Administrative @ 10% of B, C and D	225,365,000
Plus Capital Cost of Schaghticoke Embankment	56,600,000
<u>F. Total Capital Cost</u>	<u>\$2,535,614,000</u>
<u>Project UH-1 Annual Costs</u>	
1. Interest and Amortization @ 4-5/8%— 50 years	\$131,066,000
2. Taxes @ 2%	4,598,000
3. Personnel—Treatment Plant/Pump Stations	622,000
4. Chemicals, Supplies and Materials—Treatment Plant(s)	4,995,000
5. Power:	
5A. Demand	1,488,000
5B. Energy	3,393,000
<u>Total Annual Cost</u>	<u>\$146,162,000</u>

UPPER HUDSON RIVER ANALYSIS

<u>Item</u>	<u>Estimated Cost</u>
<u>Project UH-2 Capital Cost</u>	
A. Construction Costs	
1. Pump Station (Schaghticoke)	\$ 32,801,000
2. Treatment Plant (Schaghticoke)	43,000,000
3. Tunnel (Schaghticoke and Sacandaga)	124,397,000
Plus 15% shafts and chambers	18,705,000
4. Tunnel (Sacandaga and Glen)	93,519,000
Plus 15% shafts and chambers	14,028,000
5. Ft. Hunter Embankment	67,592,000
6. Pump Station (Ft. Hunter)	33,120,000
7. Treatment Plant (Ft. Hunter)	12,954,000
8. Tunnel (Ft. Hunter and Glen)	15,650,000
Plus 15% shafts and chambers	2,348,000
9. Tunnel (Glen and Shaft No. 4)	771,133,000
Plus 15% shafts and chambers	115,670,000
10. Tunnel (Shaft No. 4 and Great Notch)	216,691,000
Plus 15% shafts and chambers	32,504,000
11. Tunnel (Shaft No. 4 and Kensico)	311,562,000
Plus 15% shafts and chambers	46,437,000
B. Total Construction (without Schaghticoke Embankment)	\$1,952,408,000
C. Engineering and Contingencies at 25% of Total Construction	448,102,000
D. Land Costs	5,090,000
E. Legal and Administrative @ 10% of B, C and D	244,560,000
Plus Capital Cost of Schaghticoke Embankment	56,600,000
<u>F. Total Capital Cost</u>	<u>\$2,746,760,000</u>
<u>Project UH-2 Annual Costs</u>	
1. Interest and Amortization @ 4-5/8%—50 years	\$141,980,000
2. Taxes @ 2%	4,621,000
3. Personnel—Treatment Plant/Pump Stations	622,000
4. Chemicals, Supplies and Materials—Treatment Plant(s)	4,995,000
5. Power:	
5A. Demand	1,488,000
5B. Energy	3,393,000
Total Annual Costs	<u>\$157,099,000</u>

UPPER HUDSON RIVER ANALYSIS

<u>Item</u>	<u>Estimated Cost</u>
Project UH-3 Capital Cost	
A. Construction Costs:	
1. Pump Station (Schaghticoke)	\$ 32,801,000
2. Treatment Plant (Schaghticoke)	43,000,000
3. Tunnel (Schaghticoke—Sacandaga)	124,397,000
Plus 15% shafts and chambers	18,705,000
4. Tunnel (Sacandaga—Glen)	161,061,000
Plus 15% shafts and chambers	24,159,000
5. McKeever Diversion	6,243,000
5a. Channel Improvement (McKeever—Forestport)	4,500,000
6. Forestport Embankment	42,588,000
7. Pump Station (Forestport)	4,595,000
8. Tunnel (Forestport—Hinckley)	73,186,000
Plus 15% shafts and chambers	10,978,000
9. Hinckley (Enlarged) Embankment	35,560,000
10. Tunnel (Hinckley—Sacandaga)	364,357,000
Plus 15% shafts and chambers	54,654,000
11. Ft. Hunter Embankment	67,592,000
12. Treatment Plant (Ft. Hunter)	33,120,000
13. Pump Station (Ft. Hunter)	12,954,000
14. Tunnel (Ft. Hunter—Glen)	15,650,000
Plus 15% shafts and chambers	2,348,000
15. Tunnel (Glen—Shaft No. 4)	927,252,000
Plus 15% shafts and chambers	139,088,000
16. Tunnel (Shaft No. 4—Great Notch)	256,608,000
Plus 15% shafts and chambers	38,491,000
17. Tunnel (Shaft No. 4—Kensico)	396,755,000
Plus 15% shafts and chambers	59,513,000
B. Total Construction Cost (without Schaghticoke)	\$2,950,155,000
C. Engineering and Contingencies at 25% of Total Construction	737,539,000
D. Land Costs	6,587,000
E. Legal and Administrative at 10% of B, C and D	309,428,000
Plus Capital Cost of Schaghticoke Embankment	56,600,000
F. Total Capital Cost	<u>\$4,120,309,000</u>
 Project UH-3 Annual Costs	
1. Interest and Amortization @ 4-5/8%—50 years	\$212,979,000
2. Taxes @ 2%	6,306,000
3. Personnel—Treatment Plant/Pump Stations	742,000
4. Chemicals, Supplies and Materials—Treatment Plant(s)	4,995,000
5. Power:	
5A. Demand	1,637,000
5B. Energy	3,734,000
Total Annual Cost	<u>\$230,393,000</u>

UPPER HUDSON RIVER ANALYSIS

<u>Item</u>	<u>Estimated Cost</u>
Project UH-4A Capital Cost	
A. Construction Costs:	
1. Pump Station (Schaghticoke)	\$ 32,801,000
2. Treatment Plant (Schaghticoke)	43,000,000
3. Tunnel (Schaghticoke—Sacandaga)	124,397,000
Plus 15% shafts and chambers	18,705,000
4. Tunnel (Sacandaga—Glen)	93,519,000
Plus 15% shafts and chambers	14,028,000
5. McKeever Diversion	6,243,000
6. Channel Improvement (McKeever—Forestport)	4,500,000
7. Forestport Embankment	42,588,000
8. Pump Station (Forestport)	4,595,000
9. Tunnel (Forestport—Hinckley)	73,186,000
Plus 15% shafts and chambers	10,978,000
10. Hinckley (Enlarged) Embankment	35,560,000
11. Fonda Diversion	10,600,000
12. Treatment Plant (Fonda)	62,280,000
13. Pump Station (Fonda)	28,405,000
14. Tunnel (Fonda—Glen)	23,522,000
Plus 15% shafts and chambers	3,528,000
15. Ft. Hunter Embankment	67,592,000
16. Treatment Plant (Ft. Hunter)	33,120,000
17. Pump Station (Ft. Hunter)	12,954,000
18. Tunnel (Ft. Hunter—Glen)	15,650,000
Plus 15% shafts and chambers	2,348,000
19. Tunnel (Glen—Shaft No. 4)	927,252,000
Plus 15% shafts and chambers	139,088,000
20. Tunnel (Shaft No. 4—Great Notch)	256,608,000
Plus 15% shafts and chambers	38,491,000
21. Tunnel (Shaft No. 4—Kensico)	396,755,000
Plus 15% shafts and chambers	59,513,000
B. Total Construction Cost (without Schaghticoke)	\$2,581,806,000
C. Engineering and Contingencies @ 25% of Total Construction	645,452,000
D. Land Costs	5,717,000
E. Legal and Administrative @ 10% of B, C and D	323,298,000
Plus Capital Cost of Schaghticoke Embankment	56,600,000
F. Total Capital Cost	<u><u>\$3,612,873,000</u></u>
Project UH-4A Annual Cost	
1. Interest and Amortization @ 4-5/8%—50 years	\$186,749,000
2. Taxes @ 2%	8,102,000
3. Personnel—Treatment Plant/Pump Stations	1,238,000
4. Chemicals, Supplies and Materials—Treatment Plant(s)	9,256,000
5. Power:	
5A. Demand	2,561,000
5B. Energy	5,841,000
Total Annual Cost	<u><u>\$213,747,000</u></u>

UPPER HUDSON RIVER ANALYSIS

<u>Item</u>	<u>Estimated Cost</u>
<u>Project UH-4B Capital Cost</u>	
A. Construction Costs:	
1. Pump Station (Schaghticoke)	\$ 32,801,000
2. Treatment Plant (Schaghticoke)	43,000,000
3. Tunnel (Schaghticoke—Sacandaga)	124,397,000
Plus 15% shafts and chambers	18,705,000
4. Tunnel (Sacandaga—Glen)	93,519,000
Plus 15% shafts and chambers	14,028,000
5. McKeever Diversion	6,243,000
6. Channel Improvement (McKeever—Forestport)	4,500,000
7. Forestport Embankment	42,588,000
8. Channel Improvement (Forestport—Rome)	5,718,000
9. Hinckley (Enlarged) Embankment	35,560,000
10. Fonda Diversion	10,600,000
11. Treatment Plant (Fonda)	62,280,000
12. Pump Station (Fonda)	28,405,000
13. Tunnel (Fonda—Glen)	23,522,000
Plus 15% shafts and chambers	3,528,000
14. Ft. Hunter Embankment	67,592,000
15. Treatment Plant (Ft. Hunter)	33,120,000
16. Pump Station (Ft. Hunter)	12,954,000
17. Tunnel (Ft. Hunter—Glen)	15,650,000
Plus 15% shafts and chambers	2,348,000
18. Tunnel (Glen—Shaft No. 4)	927,252,000
Plus 15% shafts and chambers	139,088,000
19. Tunnel (Shaft No. 4—Great Notch)	256,608,000
Plus 15% shafts and chambers	38,491,000
20. Tunnel (Shaft No. 4—Kensico)	396,755,000
Plus 15% shafts and chambers	59,513,000
B. Total Construction Cost (without Schaghticoke)	\$2,498,765,000
C. Engineering and Contingencies @ 25% of Total Construction	624,691,000
D. Land Costs	5,593,000
E. Legal and Administrative @ 10% of B, C and D	312,905,000
Plus Capital Cost of Schaghticoke	56,600,000
F. <u>Total Capital Cost</u>	<u>\$3,418,554,000</u>
 <u>Project UH-4B Annual Cost</u>	
1. Interest and Amortization @ 4-5/8%—50 years	\$180,840,000
2. Taxes @ 2%	8,008,000
3. Personnel—Treatment Plant/Pump Stations	1,118,000
4. Chemicals, Supplies and Materials—Treatment Plant(s)	9,256,000
5. Power:	
5A. Demand	2,411,000
5B. Energy	5,500,000
<u>Total Annual Cost</u>	<u>\$207,133,000</u>

UPPER HUDSON RIVER ANALYSIS

<u>Item</u>	<u>Estimated Cost</u>
<u>Project UH-5 Capital Cost</u>	
A. Construction Costs:	
1. McKeever Diversion	\$ 6,243,000
2. Channel Improvement	4,500,000
3. Forestport Embankment	42,588,000
4. Pump Station (Forestport)	4,595,000
5. Tunnel (Forestport—Hinckley)	73,186,000
Plus 15% shafts and chambers	10,978,000
6. Hinckley (Expanded) Embankment	35,560,000
7. Treatment Plant (Hinckley)	62,280,000
8. Tunnel (Hinckley—Kensico)	2,588,256,000
Plus 15% shafts and chambers	<u>388,238,000</u>
B. Total Construction Cost	\$3,216,424,000
C. Engineering and Contingencies @ 25% of Total Construction	804,106,000
D. Land Costs	4,165,000
E. Legal and Administrative @ 10% of B,C, and D	<u>402,470,000</u>
F. <u>Total Capital Cost</u>	<u>\$4,427,165,000</u>
 <u>Project UH-5 Annual Cost</u>	
1. Interest and Amortization @ 4-5/8%—50 years	\$228,840,000
2. Taxes @ 2%	2,984,000
3. Personnel—Treatment Plant/Pump Stations	356,000
4. Chemicals, Supplies and Masterials—Treatment Plant(s)	4,261,000
5. Power:	
5A. Demand	149,000
5B. Energy	<u>341,000</u>
<u>Total Annual Cost</u>	<u>\$236,931,000</u>

LONG ISLAND GROUNDWATER EXCHANGE

<u>Items</u>	<u>Estimated Cost</u>
<u>Project LIX Capital Costs</u>	
A. <u>Construction Cost</u>	
1. Well System, including wells, collection system (laterals and headers), storage tanks for total capacity of 30 million gallons and chlorinators	\$ 82,670,000
2. Transmission Pumping Stations (Long Island to New York City)	12,850,000
3. Additional Installation, Piping and Special Fittings, for pumps to work in reverse direction (from New York City to Long Island)	1,930,000
4. Transmission Pipeline	<u>56,900,000</u>
B. Total Construction Cost	\$154,350,000
C. Engineering and Contingencies @ 25% of Total Construction	38,590,000
D. Land Costs	3,200,000
E. Legal and Administrative @ 10% of B, C and D	<u>19,610,000</u>
F. <u>Total Capital Cost</u>	<u><u>\$215,750,000</u></u>
 <u>Project LIX Annual Costs</u>	
1. Interest and Amortization @ 4-5/8%—50 years	\$11,140,000
2. Taxes @ 2%	160,000
3. Personnel—Treatment Plant/Pumping Stations	310,000
4. Power	3,670,000
5. Chemicals, Supplies and Materials—Treatment Plant(s)	<u>170,000</u>
<u>Total Annual Cost</u>	<u><u>\$15,450,000</u></u>

Notes: (1) Average yield: 150 MGD throughout the year.
 (2) Transmission main sized for 180 MGD.

PROJECT ELEMENTS

Project	New Impoundments			Pumping Stations		Water Transmission			Water Treatment Plant Capacity (MGD)
	Reservoir	Storage (BG)	Type	MGD	Horsepower	Length (miles)	Diameter (feet)	Type	
PA-6	Pine Meadow	8.1	Pumped storage	30	6,080	41.4	13	Tunnel	250
	Little Dams	11.7	Pumped storage	40	4,510	4.2	12	Tunnel	
	Long Swamp	8.3	Pumped storage	30	1,780	5.1	5½	Pumped storage	
		28.1		350	64,900	3.2	6	Pumped storage	
HUA-6				600	119,600	14.2	19	Tunnel	600
				400	73,000	2.5	11	Tunnel	400
						50.0	16	Tunnel	
UH-1	Schaghticoke	82	Gravity	400	98,500	34.9	12	Tunnel	400
	Ft. Hunter	90	Gravity	300	38,900	16.4	16	Tunnel	300
		172				135.7	21	Tunnel	700
UH-2	Schaghticoke	82	Gravity	400	98,500	88.9	12	Tunnel	400
	Ft. Hunter	90	Gravity	300	38,900	16.4	16	Tunnel	300
		172				89.6	21	Tunnel	700
						46.1	18	Tunnel	
UH-3	Schaghticoke	82	Gravity	400	98,500	34.9	12	Tunnel	400
	Ft. Hunter	90	Gravity	300	38,900	16.7	13	Tunnel	300
	McKeever	—	—	300	13,800	54.0	14	Tunnel	700
	Forestport	171	Gravity			45.7	20	Tunnel	
	Hinckley	118*	Pumped storage			46.1	21	Tunnel	
						16.1	23	Tunnel	
						89.6	24	Tunnel	
UH-4A	Schaghticoke	82	Gravity	400	98,500	34.9	12	Tunnel	400
	Ft. Hunter	90	Gravity	300	38,900	16.7	13	Tunnel	300
	McKeever	—	—	300	13,800	54.0	14	Tunnel	600
	Forestport	171	Gravity	600	85,300	4.5	15	Tunnel	1,300
	Hinckley	118*	Pumped storage			16.4	16	Tunnel	
						46.1	21	Tunnel	
						89.6	24	Tunnel	
UH-4B	Schaghticoke	82	Gravity	400	98,500	34.9	12	Tunnel	400
	Ft. Hunter	90	Gravity	300	38,900	54.0	13	Tunnel	300
	McKeever	—	—	600	85,300	4.5	15	Tunnel	600
	Hinckley	118*	Pumped storage			16.4	16	Tunnel	1,300
	Forestport	171	Gravity			46.1	21	Tunnel	
						89.6	24	Tunnel	
UH-5	McKeever	—	—	300	13,800	16.7	13	Tunnel	600
	Forestport	171	Gravity			172.0	28	Tunnel	
	Hinckley	118*	Pumped storage						
LIX	Ground storage tanks	30 MG	Pumped storage	150	40,400	50-I 48-II	5	Pumped storage	150 Chlorination only

* Added capacity due to expansion.

APPENDIX B

APPENDIX B

REGIONAL PROGRAM COST COMPARISONS
 (Engineering News Record Index = 1,400)

Program	Year		
	1980	2000	2020
	Cumulative Yield, MGD		
	310	950	1,900
Cumulative Program Cost (Million \$)			
Program No. 1	483	893	1,704
Program No. 2	483	893	1,703
Program No. 3	304	796	1,852
Program No. 4	304	796	1,866
Program No. 5	623	1,546	1,740
Program No. 6	623	1,546	1,716
Program No. 7	913	1,439	1,868
Program No. 8	913	1,439	1,849
Average	581	1,169	1,787
Average Unit Water Costs (\$/million gallons)			
Program No. 1	290	212	189
Program No. 2	290	212	187
Program No. 3	206	190	200
Program No. 4	206	190	199
Program No. 5	352	297	193
Program No. 6	352	297	183
Program No. 7	494	280	202
Program No. 8	494	280	195
Average	336	245	194

**PRESENT WORTH COMPARISON OF REGIONAL PROGRAM COSTS
(1970 BASE), EXCLUDING OPERATING AND MAINTENANCE COSTS**

(Engineering News Record Index = 1,400)

Program	Year		
	1980	2000	2020
	Cumulative Yield, MGD		
	310	950	1,900
Cumulative Present Worth of Program (Costs in million \$)			
(1) Discounted at a rate of 4-5/8% interest:			
Program No. 1	307.3	418.7	532.2
Program No. 2	307.3	418.7	532.1
Program No. 3	193.1	325.7	449.6
Program No. 4	193.1	325.7	451.1
Program No. 5	395.9	639.9	689.2
Program No. 6	395.9	639.9	686.7
Program No. 7	580.5	722.1	780.7
Program No. 8	580.5	722.1	778.8
Average	369.2	526.6	612.6
(2) Discounted at a rate of 5% interest:			
Program No. 1	296.6	396.3	491.3
Program No. 2	296.6	396.3	491.2
Program No. 3	186.4	305.1	408.7
Program No. 4	186.4	305.1	410.0
Program No. 5	382.2	600.7	642.0
Program No. 6	382.2	600.7	639.9
Program No. 7	560.4	687.2	736.2
Program No. 8	560.4	687.2	734.6
Average	356.4	497.3	569.2
(3) Discounted at a rate of 10% interest:			
Program No. 1	186.5	211.1	220.9
Program No. 2	186.5	211.1	220.9
Program No. 3	117.2	146.5	157.2
Program No. 4	117.2	146.5	157.4
Program No. 5	240.3	294.2	298.5
Program No. 6	240.3	294.2	298.3
Program No. 7	352.3	383.6	388.7
Program No. 8	352.3	383.6	388.5
Average	224.4	258.9	266.3

**PRESENT WORTH COMPARISON OF REGIONAL PROGRAM COSTS
(1970 BASE), INCLUDING OPERATING AND MAINTENANCE COSTS**

(Engineering News Record Index = 1,400)

Program	Year		
	1980	2000	2020
	Cumulative Yield, MGD		
	310	950	1,900
Cumulative Present Worth of Program (Cost in million \$)			
(1) Discounted at a rate of 4-5/8% interest:			
Program No. 1	418.9	654.1	839.1
Program No. 2	418.9	654.1	836.1
Program No. 3	300.8	575.8	784.3
Program No. 4	300.8	575.8	782.9
Program No. 5	506.1	850.7	973.6
Program No. 6	506.1	850.7	959.6
Program No. 7	690.4	963.4	1,108.4
Program No. 8	690.4	963.4	1,099.0
Average	479.1	761.0	922.9
(2) Discounted at a rate of 5% interest:			
Program No. 1	398.2	602.4	753.8
Program No. 2	398.2	602.4	751.4
Program No. 3	284.4	523.3	693.6
Program No. 4	284.4	523.3	692.6
Program No. 5	482.5	785.9	885.2
Program No. 6	482.5	785.9	874.1
Program No. 7	660.4	898.1	1,015.2
Program No. 8	660.4	898.1	1,007.7
Average	456.4	702.4	834.2
(3) Discounted at a rate of 10% interest:			
Program No. 1	221.2	259.8	272.8
Program No. 2	221.2	259.8	272.6
Program No. 3	150.6	196.0	210.4
Program No. 4	150.6	196.0	210.5
Program No. 5	274.6	339.9	347.5
Program No. 6	274.6	339.9	346.7
Program No. 7	386.4	432.6	441.5
Program No. 8	386.4	432.6	441.1
Average	258.2	307.1	317.9

REGIONAL PROGRAM 1 – PROJECT YIELDS AND COST

Project (1)	Terminal Point (2)	1980				2000				2020			
		Yield (MGD) (3)	Project Cost (million \$)		Unit Water Cost (\$/million gal) (6)	Yield (MGD) (7)	Project Cost (million \$)		Unit Water Cost (\$/million gal) (10)	Yield (MGD) (11)	Project Cost (million \$)		Unit Water Cost (\$/million gal) (14)
			Total (4)	Per MGD (5)			Total (8)	Per MGD (9)			Total (12)	Per MGD (13)	
HO-1: Lower Housatonic River	Norwalk and New Haven	40	24.0	0.60	150	40	24.0	0.60	150	40	24.0	0.60	150
HO-2: Upper Housatonic River	Shelton	—	—	—	—	60	67.5	1.13	242	200	79.1	0.40	99
R-1: Raritan River	Bound Brook	70	20.1	0.29	141	70	20.1	0.29	141	70	20.1	0.29	141
R-3: Tocks Island Direct	Bound Brook	—	—	—	—	300	208.1	0.70	175	300	208.1	0.70	175
Modified Hudson River—HU-6: West Park Diversion	Kensico Reservoir and Great Notch	50	201.2	4.02	1,100	330	292.4	0.89	217	1,165	1,064.0	1.63	199
Forestport Reservoir	—	—	—	—	—	—	—	—	—	—	65.1		
Hinckley Enlargement	—	—	—	—	—	—	—	—	—	—	60.4		
LIX: Long Island Exchange	—	150	215.8	1.44	255	150	215.8	1.44	255	—	—	—	—
M1: Metering	—	—	—	—	—	—	—	—	—	125	100.0	0.80	223
Subtotal		310	461.1	1.49	280	950	827.9	0.87	202	1,900	1,620.8	0.85	183
Allowance for Related Transmission to Principal Centers of Consumption		—	22.0	0.71	10	—	65.0	0.07	10	—	83.0	0.05	6
Total		310	483.1	2.20	290	950	892.9	0.94	212	1,900	1,703.8	0.90	189

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REGIONAL PROGRAM 2 – PROJECT YIELDS AND COST

Project (1)	Terminal Point (2)	1980				2000				2020			
		Yield (MGD) (3)	Project Cost (million \$) (4) (5)		Unit Water Cost (\$/million gal) (6)	Yield (MGD) (7)	Project Cost (million \$) (8) (9)		Unit Water Cost (\$/million gal) (10)	Yield (MGD) (11)	Project Cost (million \$) (12) (13)		Unit Water Cost (\$/million gal) (14)
			Total	Per MGD			Total	Per MGD			Total	Per MGD	
HO-1: Lower Housatonic River	Norwalk and New Haven	40	24.0	0.60	150	40	24.0	0.60	150	40	24.0	0.60	150
HO-2: Upper Housatonic River	Shelton	—	—	—	—	60	67.5	1.13	242	200	79.1	0.40	99
R-1: Raritan River	Bound Brook	70	20.1	0.29	141	70	20.1	0.29	141	70	20.1	0.29	141
R-3: Tocks Island Direct	Bound Brook	—	—	—	—	300	208.1	0.70	175	300	208.1	0.70	175
Modified Hudson River—HU-6: West Park Diversion	Kensico Reservoir and Great Notch	50	201.2	4.02	1,100	330	292.4	0.89	217	1,290	1,106.2	1.00	198
Forestport Reservoir	—	—	—	—	—	—	—	—	—	—	65.1		
Hinckley Enlargement	—	—	—	—	—	—	—	—	—	—	60.4		
Schaghticoke Reservoir	—	—	—	—	—	—	—	—	—	—	56.6		
LIX: Long Island Exchange	—	150	215.8	1.44	255	150	215.8	1.44	255	—	—	—	—
Subtotal		310	461.1	1.49	280	950	827.9	0.87	202	1,900	1,619.6	0.86	181
Allowance for Related Transmission to Principal Centers of Consumption		—	22.0	0.71	10	—	65.0	0.07	10	—	83.0	0.05	6
Total		310	483.1	2.20	290	950	892.9	0.94	212	1,900	1,702.6	0.91	187

B-5

REGIONAL PROGRAM 3 – PROJECT YIELDS AND COST

REGIONAL PROGRAM 3 – PROJECT YIELDS AND COST

Project (1)	Terminal Point (2)	1980				2000				2020			
		Yield (MGD) (3)	Project Cost (million \$)		Unit Water Cost (\$/million gal) (6)	Yield (MGD) (7)	Project Cost (million \$)		Unit Water Cost (\$/million gal) (10)	Yield (MGD) (11)	Project Cost (million \$)		Unit Water Cost (\$/million gal) (14)
			Total (4)	Per MGD (5)			Total (8)	Per MGD (9)			Total (12)	Per MGD (13)	
HO-1: Lower Housatonic River	Norwalk and New Haven	40	24.0	0.60	150	40	24.0	0.60	150	40	24.0	0.60	150
HO-2: Upper Housatonic River	Shelton	—	—	—	—	60	67.5	1.13	242	200	79.1	0.40	99
R-1: Raritan River	Bound Brook	70	20.1	0.29	141	70	20.1	0.29	141	70	20.1	0.29	141
R-3: Tocks Island Direct	Bound Brook	—	—	—	—	300	208.1	0.70	175	300	208.1	0.70	175
Modified Hudson River—HU-6: West Park Diversion	Kensico Reservoir and Great Notch	200	237.5	1.19	225	480	340.9	0.71	156	1,165	1,082.0	1.04	200
Forestport Reservoir	—	—	—	—	—	—	—	—	—	65.1			
Hinckley Enlargement	—	—	—	—	—	—	—	—	—	60.4			
M-1: Metering	—	—	—	—	—	—	—	—	—	125	100.0	0.80	223
Subtotal		310	281.6	0.91	196	950	660.6	0.70	170	1,900	1,638.7	0.87	184
Allowance for Related Transmission to Principal Centers of Consumption		—	22.0	0.71	10	—	135.0	0.14	20	—	213.0	0.11	16
Total		310	303.6	1.62	206	950	795.6	0.84	190	1,900	1,851.7	0.98	200

B-6

REGIONAL PROGRAM 3 - PROJECT YIELDS AND COST

REGIONAL PROGRAM 4 – PROJECT YIELDS AND COST

Project (1)	Terminal Point (2)	1980				2000				2020			
		Yield (MGD) (3)	Project Cost (million \$) (4) (5)		Unit Water Cost (\$/million gal) (6)	Yield (MGD) (7)	Project Cost (million \$) (8) (9)		Unit Water Cost (\$/million gal) (10)	Yield (MGD) (11)	Project Cost (million \$) (12) (13)		Unit Water Cost (\$/million gal) (14)
			Total	Per MGD			Total	Per MGD			Total	Per MGD	
HO-1: Lower Housatonic River	Norwalk and New Haven	40	24.0	0.60	150	40	24.0	0.60	150	40	24.0	0.60	150
HO-2: Upper Housatonic River	Shelton	—	—	—	—	60	67.5	1.13	242	200	79.1	0.40	99
R-1: Raritan River	Bound Brook	70	20.1	0.29	141	70	20.1	0.29	141	70	20.1	0.29	141
R-3: Tocks Island Direct	Bound Brook	—	—	—	—	300	208.1	0.70	175	300	208.1	0.70	175
Modified Hudson River—HU-6: West Park Diversion	Kensico Reservoir and Great Notch	200	237.5	1.19	225	480	340.9	0.71	156	1,290	1,139.7	0.87	183
Forestport Reservoir	—	—	—	—	—	—	—	—	—	—	65.1	1.03	210
Hinckley Enlargement	—	—	—	—	—	—	—	—	—	—	60.4		
Schaghticoke Reservoir	—	—	—	—	—	—	—	—	—	—	56.6		
Subtotal		310	281.6	0.91	196	950	660.6	0.70	170	1,900	1,653.1	0.87	183
Allowance for Related Transmission to Principal Centers of Consumption		—	22.0	0.71	10	—	135.0	0.14	20	—	213.0	0.11	16
Total		310	303.6	1.62	206	950	795.6	0.84	190	1,900	1,866.1	0.98	199

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REGIONAL PROGRAM 2 – PROJECT YIELDS AND COST

REGIONAL PROGRAM 5 – PROJECT YIELDS AND COST

Project (1)	Terminal Point (2)	1980				2000				2020			
		Yield (MGD) (3)	Project Cost (million \$) (4) (5)		Unit Water Cost (\$/million gal) (6)	Yield (MGD) (7)	Project Cost (million \$) (8) (9)		Unit Water Cost (\$/million gal) (10)	Yield (MGD) (11)	Project Cost (million \$) (12) (13)		Unit Water Cost (\$/million gal) (14)
			Total	Per MGD			Total	Per MGD			Total	Per MGD	
HO-1: Lower Housatonic River	Norwalk and New Haven	40	24.0	0.60	150	40	24.0	0.60	150	40	24.0	0.60	150
HO-2: Upper Housatonic River	Shelton	—	—	—	—	60	67.5	1.13	242	200	79.1	0.40	99
R-1: Raritan River	Bound Brook	70	20.1	0.29	141	70	20.1	0.29	141	70	20.1	0.29	141
R-3: Tocks Island Direct	Bound Brook	—	—	—	—	300	208.1	0.70	175	300	208.1	0.70	175
P-6: Hudson—Ramapo River	Wanaque Reservoir, Great Notch	50	340.6	6.81	1,040	30	345.0	2.87	468	450	451.0	1.05	206
HU-1: Hudson—Hyde Park Diversion	Kensico Reservoir	—	—	—	—	300	535.7			715	649.0		
Forestport Reservoir	—	—	—	—	—	—	65.1			—	65.1		
Hinckley Enlargement	—	—	—	—	—	—	—			—	60.4		
LIX: Long Island Exchange	—	150	215.8	1.44	255	150	215.8	1.44	255	—	—	—	—
M-1: Metering	—	—	—	—	—	—	—	—	—	125	100.0	0.80	223
Subtotal		310	600.5	1.94	342	950	1,481.3	1.56	287	1,900	1,656.8	0.87	187
Allowance for Related Transmission to Principal Centers of Consumption		—	22.0	0.71	10	—	65.0	0.70	10	—	83.0	0.05	6
Total		310	622.5	2.65	352	950	1,546.3	1.63	297	1,900	1,739.8	0.92	193

B-8

REGIONAL PROGRAM 6 – PROJECT YIELDS AND COST

Project (1)	Terminal Point (2)	1980				2000				2020			
		Yield (MGD) (3)	Project Cost (million \$)		Unit Water Cost (\$/million gal) (6)	Yield (MGD) (7)	Project Cost (million \$)		Unit Water Cost (\$/million gal) (10)	Yield (MGD) (11)	Project Cost (million \$)		Unit Water Cost (\$/million gal) (14)
			Total (4)	Per MGD (5)			Total (8)	Per MGD (9)			Total (12)	Per MGD (13)	
HO-1: Lower Housatonic River	Norwalk and New Haven	40	24.0	0.60	150	40	24.0	0.60	150	40	24.0	0.60	150
HO-2: Upper Housatonic River	Shelton	—	—	—	—	60	67.5	1.13	242	200	79.1	0.40	99
R-1: Raritan River	Bound Brook	70	20.1	0.29	141	70	20.1	0.29	141	70	20.1	0.29	141
R-3: Tocks Island Direct	Bound Brook	—	—	—	—	300	208.1	0.70	175	300	208.1	0.70	175
P-6: Hudson—Ramapo River	Wanaque Reservoir, Great Notch	50	340.6	6.81	1,040	30	345.0	2.87	468	450	451.0	1.01	192
HU-1: Hudson—Hyde Park Diversion	Kensico Reservoir	—	—	—	—	300	535.7			840	668.1		
Forestport Reservoir	—	—	—	—	—	—	65.1			—	65.1		
Hinckley Enlargement	—	—	—	—	—	—	—			—	60.4		
Schaghticoke Reservoir	—	—	—	—	—	—	—	—	—	56.6	—	—	—
LIX: Long Island Exchange	—	150	215.8	1.44	255	150	215.8	1.44	255	—	—	—	—
Subtotal		310	600.5	1.94	342	950	1,481.3	1.56	287	1,900	1,632.5	0.86	177
Allowance for Related Transmission Principal Centers of Consumption		—	22.0	0.71	10	—	65.0	0.87	10	—	83.0	0.05	6
Total		310	622.5	2.65	352	950	1,546.3	1.63	297	1,900	1,715.5	0.91	183

B-9

REGIONAL PROGRAM 7 – PROJECT YIELDS AND COST

Project (1)	Terminal Point (2)	1980				2000				2020			
		Yield (MGD) (3)	Project Cost (million \$)		Unit Water Cost (\$/million gal) (6)	Yield (MGD) (7)	Project Cost (million \$)		Unit Water Cost (\$/million gal) (10)	Yield (MGD) (11)	Project Cost (million \$)		Unit Water Cost (\$/million gal) (14)
			Total (4)	Per MGD (5)			Total (8)	Per MGD (9)			Total (12)	Per MGD (13)	
HO-1: Lower Housatonic River	Norwalk and New Haven	40	24.0	0.60	150	40	24.0	0.60	150	40	24.0	0.60	150
HO-2: Upper Housatonic River	Shelton	—	—	—	—	60	67.5	1.13	242	200	79.1	0.40	99
R-1: Raritan River	Bound Brook	70	20.1	0.29	141	70	20.1	0.29	141	70	20.1	0.29	141
R-3: Tocks Island Direct	Bound Brook	—	—	—	—	300	208.1	0.70	175	300	208.1	0.70	175
P-6: Hudson—Ramapo River	Wanaque Reservoir, Great Notch	50	340.6	4.23	1,150	30	345.0	2.06	324	450	451.0	1.05	204
HU-1: Hudson—Hyde Park Diversion	Wanaque Reservoir, Kensico Reservoir	150	506.0			450	514.8			715	647.4		
Forestport Reservoir	—	—	—			—	65.1			—	65.1		
Hinckley Enlargement	—	—	—	—	—	—	—	—	—	60.4	—	—	
M-1: Metering	—	—	—	—	—	—	—	—	—	125	100.0	0.80	223
Subtotal		310	890.7	2.88	484	950	1,304.6	1.37	260	1,900	1,655.2	0.87	186
Allowance for Related Transmission to Principal Centers of Consumption		—	22.0	0.71	10	—	135.0	0.14	20	—	213.0	0.11	16
Total		310	912.7	3.59	494	950	1,439.6	1.51	280	1,900	1,868.2	0.98	202

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REGIONAL PROGRAM 7 – PROJECT YIELDS AND COST

REGIONAL PROGRAM 8 – PROJECT YIELDS AND COST

Project (1)	Terminal Point (2)	1980				2000				2020			
		Yield (MGD) (3)	Project Cost (million \$)		Unit Water Cost (\$/million gal) (6)	Yield (MGD) (7)	Project Cost (million \$)		Unit Water Cost (\$/million gal) (10)	Yield (MGD) (11)	Project Cost (million \$)		Unit Water Cost (\$/million gal) (14)
			Total (4)	Per MGD (5)			Total (8)	Per MGD (9)			Total (12)	Per MGD (13)	
HO-1: Lower Housatonic River	Norwalk and New Haven	40	24.0	0.60	150	40	24.0	0.60	150	40	24.0	0.60	150
HO-2: Upper Housatonic River	Shelton	—	—	—	—	60	67.5	1.13	242	200	79.1	0.40	99
R-1: Raritan River	Bound Brook	70	20.1	0.29	141	70	20.1	0.29	141	70	20.1	0.29	141
R-3: Tocks Island Direct	Bound Brook	—	—	—	—	300	208.1	0.70	175	300	208.1	0.70	175
P-6: Hudson-Ramapo River	Wanaque Reservoir, Great Notch	50	340.6	4.23	1,150	30	345.0	2.19	314	450	451.0	1.02	196
HU-1: Hudson-Hyde Park Diversion	Kensico Reservoir	150	506.0			450	574.8			840	672.0		
Forestport Reservoir	—	—	—	—	—	—	65.1	—	—	—	65.1	—	—
Hinckley Enlargement	—	—	—	—	—	—	—	—	—	—	60.4	—	—
Schaghticoke Reservoir	—	—	—	—	—	—	—	—	—	—	56.6	—	—
Subtotal		310	890.7	2.88	484	950	1,304.6	1.37	260	1,900	1,636.4	0.86	179
Allowance for Related Transmission to Principal Centers of Consumption		—	22.0	0.71	10	—	135.0	0.14	20	—	213.0	0.11	16
Total		310	912.7	3.59	494	950	1,439.6	1.51	280	1,900	1,849.4	0.97	195

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