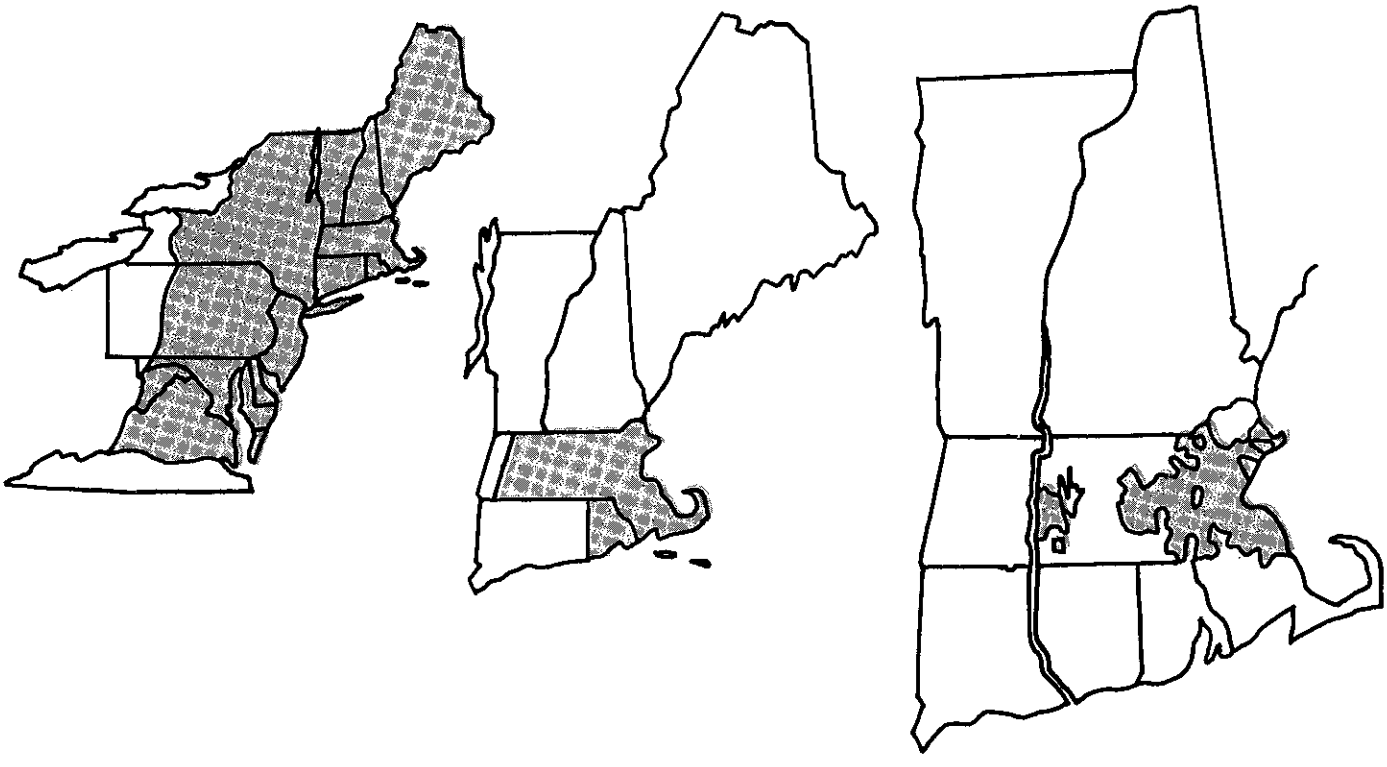
NORTHEASTERN UNITED STATES WATER SUPPLY STUDY

NORTHFIELD MOUNTAIN WATER SUPPLY PROJECT

VOLUME I, MAIN REPORT



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STATEMENT OF FINDINGS

NORTHFIELD MOUNTAIN WATER SUPPLY PROJECT

1. I have reviewed and evaluated, in the best over-all public interest, the documents concerning the Northfield Mountain Water Supply Project, as well as the stated views of other interested agencies and the concerned public, relative to the various practical alternatives available to meet the short range water supply needs of eastern Massachusetts, recognizing the regional objectives set forth in P. L. 89-298, Title I - Northeastern United States Water Supply Study.

2. The possible consequences of these alternatives have been studied according to engineering feasibility, environmental, social well-being and economic effects, including regional and national development goals.

3. In evaluation, the following points were considered pertinent:

A. Environmental Considerations - From an environmental standpoint, I have selected the optimum plan which will afford more enhancement than adverse effects. The recommended project will have beneficial effects on water supply, water quality and aesthetics. From the outset, this study made a determined effort to evaluate the impact which the project might have on environmental quality. An analysis was made regarding possible impacts on the Connecticut River estuary, the Connecticut River, and the receiving water storage reservoir. In general, impact caused by the diversion on the estuary and Connecticut River itself is expected to be minimal. The primary reason for this lack of environmental impact is the timing of diversions during high flow periods and the relatively small amount of water, when compared to river flow, which would be diverted.

In evaluating environmental impact on Quabbin and Wachusett Reservoirs, field and laboratory data included about 100 parameters, including chemical, physical, biological and pesticides data. In addition, radiological data, hydrodynamic studies, fisheries information and pollution abatement plans were considered and evaluated.

Within the receiving water body at Quabbin, the diverted flow may have impacts, but these possible impacts depend to a large degree on what engineering steps are taken prior to the actual diversion. For

example, the present waste loads in the river may provide opportunities for algae growth or oxygen depletion. But when current pollution abatement schedules are followed as required by the Water Quality Act of 1972, present loadings in the river will be reduced; and as a consequence, the probability of possible damage to Quabbin also minimized.

If no additional water is made available to the reservoir, then increased demands will deplete available storage. Declining storage volumes in turn will cause an overall loss in water quality. In addition to this, possible reservoir water quality deterioration caused by reduced storage levels and supply shortages in the receiver area could also cause a loss in environmental quality for those communities served by the system.

Finally, if the project was implemented, the additional water supplied would cause a corresponding increase in waste water discharge. However, the Water Quality Act of 1972 calls for full treatment of waste discharges by the early 1980's, thus, minimal impact can be expected.

B. Social Well-Being Considerations - I find that the overriding social well-being consideration in the study area is the reduction of the water supply shortage hazard which could cause damages and curtail normal development in communities to be serviced. The recommended project will provide a high degree of reliability for meeting future supply needs. Since the project under consideration involved transfer of a resource through inter-basin diversion, impacts were investigated for both source and receiver areas.

In general, tangible impacts felt by source areas will be related principally to limited land taking and subsequent construction activity of short term duration. Apart from the few physical structures proposed, the natural character of the area will remain unchanged. The bulk of surface work will come in remote wooded areas with a minimum of disruption to local traffic patterns. Evidence of the tunneling to Quabbin will be seen primarily as access shafts in three or four locations.

Apart from relatively small economic impacts, social impacts relating to supplier area residents' perception of equity are particularly significant and every effort was made to include these feelings in the plan formulation.

On the other hand, development of the recommended project would insure protection from water shortages and associated social and economic losses in the receiver communities. If the project was not implemented, social costs as well as economic costs could be expected.

C. Engineering Considerations - From an engineering standpoint, I have selected the project that would provide a high degree of protection and dependability against water supply shortages. Because the Connecticut River upstream from the intake is presently subjected to waste discharges, I find that implementation of the existing Federal - State abatement program should proceed as scheduled without delay.

The present "state-of-the-art" concerning potential benefits and possible shortcomings of water demand conservation measures was also investigated closely. I believe such measures have not advanced to the point where they can be relied upon as an alternative to the proposed structural measures. I do feel, however, that the potential of certain conservation techniques warrants further study as a management tool in assuring wise use of available resources. Concurrent investigations on water demand, its make-up and opportunities for conservation measures, therefore, are recommended as a parallel effort to the project. Other considered project alternatives did not meet the criteria and requirements for economic, social and environmental reasons.

D. Economic Considerations - From an economic standpoint, I have selected the economically optimum plan by providing a high degree of protection from water supply shortages and enhancement of social well-being and economic growth. The recommended project will have a net effect of increasing employment, tax revenues and property values and will preserve and stimulate further growth in the protected area.

4. I find that the proposed actions, as developed in the Recommendations, are based on thorough analysis and evaluation of various practicable alternative courses of action for achieving the stated objectives; that wherever adverse effects are found to be involved, they cannot be avoided by following reasonable alternative courses of action which would achieve the Congressionally specified purpose; that where the proposed action has an adverse effect, this effect is either ameliorated or substantially outweighed by other considerations

of national policy; that the recommended action is consonant with national policy, statutes and administrative directives; and that on balance the total public interest should best be served by implementation of the recommendations.

JOHN H. MASON
Colonel, Corps of Engineers
Division Engineer

NORTHFIELD MOUNTAIN WATER SUPPLY PROJECT

Volume	Contents
I	Main Report
II	Appendix A - Economic Development
	Appendix B - Future Population and Water Demand Studies
	Appendix C - Tunnel Geology and Cost Estimates
	Appendix D - Water Quality Studies of Connecticut and Millers Rivers and Quabbin and Washusett Reservoirs
III	Appendix E - Possible Effects of Various Diversions from the Connecticut River (or its estuary)
	Appendix F - Identification and Assessment of Social and Economic Impacts - Connecticut and Millers River Basin Diversions
	Appendix G - Environmental Protection Agency Report on Water Quality Studies
	Appendix H - Open Planning Program
	Appendix I - Effect of Diversion Control Flow on Project Yields and Cost of Water Delivered
	Appendix J - Letters of Comment

ACKNOWLEDGEMENT

This report was prepared by the Planning Branch of the New England Division, Corps of Engineers, Waltham, Massachusetts. The study itself was conducted under the general direction of Mr. John Wm. Leslie, Chief, Engineering Division, New England, and Mr. Harry Schwarz, Chief, Special Studies Branch, North Atlantic Division, New York. Mr. Joseph L. Ignazio, Chief, Planning Branch, was responsible for the technical direction of the investigation with staff assistance during the course of the study from Messrs. Lawrence J. Bergen, Paul E. Pronovost, John T. Smith, and Alan D. Randall.

The New England Division wishes to express its appreciation to those agencies who have participated in this challenging undertaking and have made available the services of many of their people. Special thanks are given to the Massachusetts Water Resources Commission; the Metropolitan District Commission; the New Hampshire Division of Economic Development and the Water Supply and Pollution Control Commission; and the Rhode Island Water Resources Board. Other Federal Agencies who have given generously of their time include the U. S. Geological Survey; U. S. Public Health Service; and the U. S. Fish and Wildlife Service and the Environmental Protection Agency.

The cooperation of interested citizens and water resources groups is also gratefully acknowledged. Special mention is given to the Citizens Participation Group and the Millers River Watershed Council, whose participation in the study provided valuable input to the report's recommendations.

INTRODUCTION TO REPORT

1. Introduction

A. Background

The long-term normal rainfall in southeastern New England is about 42 inches per year. This "normal" condition is actually the average of many high and low rainfall years. When rainfall is below average for a period of time, the area experiences a drought. The recent drought of the sixties in southeastern New England caused many water supply systems to re-evaluate the dependable yield which their facilities could produce. In many cases, the new dependable yield was significantly less than previously estimated. In turn, water demands on these same systems have been increasing; therefore, additional supplies are necessary.

The drought began in 1961 and continued for seven years, with the severest deficiency occurring in 1965. During this period, an extreme drought condition existed in the northern half of New Jersey, northeast Pennsylvania, southeastern New York, all of Vermont and New Hampshire, parts of southern Maine, and the western half of Massachusetts. Within the region, the heavily industrialized and urbanized area extending from Boston to Washington was most severely affected.

The severity of the situation was caused by a combination of two factors -- a severe hydrologic adversity and the centering of the drought on the most densely populated region of the United States. In addition, many water supplies had been developed on the smaller upland prestine streams rather than on larger rivers with lower quality, but having a more dependable flow. Thus, the many cities and towns which relied upon upland sources were particularly hard hit by the drought.

At the height of the drought, major metropolitan regions surrounding Philadelphia and New York City faced mandatory restrictions in water use. Within Massachusetts, 85 cities and towns, including the two million customers of the Metropolitan District Commission, were asked to institute voluntary water rationing programs. Normal water use practices, such as lawn sprinkling and car washing, were sharply curtailed. In 23 Massachusetts' communities, emergency sources of water, sanctioned by the Public Health Department for temporary use only, were necessary to meet water needs.

In addition to affecting the water supply of almost 14 million people, the drought also had a severe impact on the environment. Low stream flow intensified pollution problems, affecting water quality and fish and wildlife. Algae blooms caused problems of taste and odor in water supplies and interfered with recreational use of lakes and reservoirs.

The prolonged sixties' drought thus caused extensive hardships on man and his environment. Fortunately, the years immediately prior to the advent of the drought were abnormally "wet" years. These "wet" years allowed many of the region's supply reservoirs to enter the drought period in a filled condition, precluding even more severe water use restrictions. There is no assurance, however, that the next drought, whenever it may occur, will be preceded by reservoir and aquifer filling "wet" years.

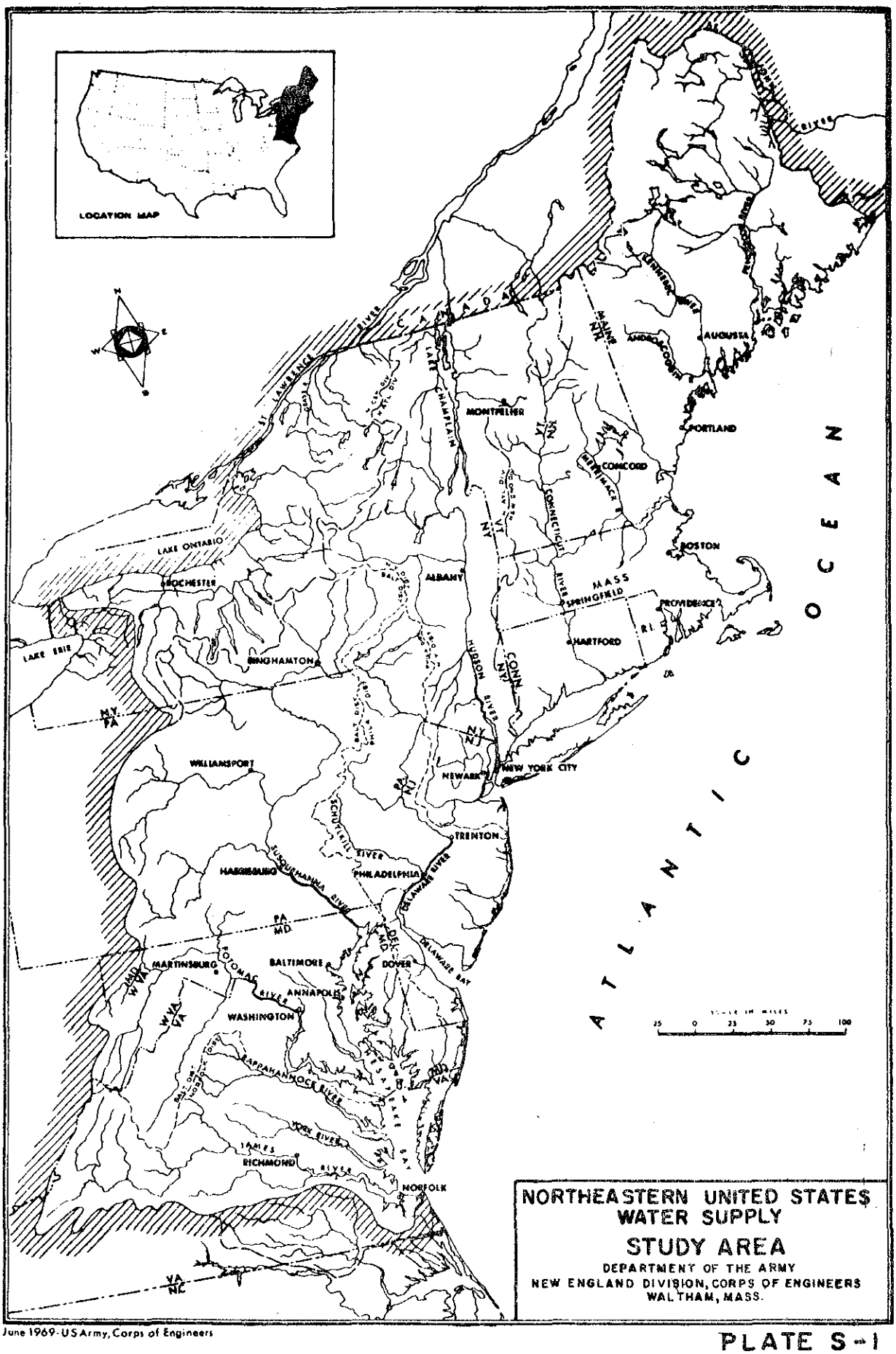
B. Authorization

The 89th Congress recognized that the assurance of adequate supplies of water for the great metropolitan centers had become a problem of such magnitude that the welfare and prosperity of the United States required the Federal Government to assist in its resolution. Consequently, the Congress enacted the Northeastern United States Water Supply (NEWS) Study on 27 October 1965, under Title I of Public Law 89-298.

The NEWS Study Act authorized the Secretary of the Army, acting through the Chief of Engineers, to prepare plans to meet the long range water supply needs of the Northeast, in cooperation with Federal, State and local agencies. The Chief of Engineers, in turn, assigned responsibility for the NEWS Study to the Division Engineer, North Atlantic.

C. Study Area

The NEWS Study Area includes those river basins within the United States which drain into Chesapeake Bay, into the Atlantic Ocean north of Chesapeake Bay, into the St. Lawrence River, and into Lake Ontario. The study area, therefore, includes all of Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New Jersey, Delaware, and the District of Columbia, and parts of New York, Pennsylvania, Maryland, Virginia and West Virginia. A plan of the area is shown on Plate No. S-1.



June 1969-US Army, Corps of Engineers

PLATE S-1

present population is concentrated in the five metropolitan areas of Boston, New York, Philadelphia, Baltimore and Washington; and the region includes twenty of the nation's one hundred largest cities.

Although the area has an average annual precipitation rate of about 40 inches, as compared to the national average of 30 inches, precipitation deficiencies in some parts of the area were up to 50 inches during the October '61 to December '65 period. The area's vulnerability to water shortage is revealed by the fact that some 14 million people, about 28 percent of the population, were restricted to some degree in their use of water during this drought. Although public awareness of the problems of water supply was increased by the drought experience, drought is not the only reason for concern. Available supplies of water of good quality will soon be inadequate, even under normal conditions, to meet the needs of the anticipated population and industrial growth.

D. Objective

The objective of the overall NEWS Study is the preparation of a coordinated general plan for essential water supply development in the Northeast which will recommend to the Congress an active program for Federal, State, local and private organizations. It thus provides a public forum where all vitally concerned with the water supply problems of the area can be heard in developing a plan to resolve one of the many domestic problems now facing the United States.

E. Methods

In achieving its objective, the NEWS Study will present a regional assessment of present and future water supply needs and will present alternatives for their solution. The study effort is being fully coordinated through the various Federal, State, local and private agencies and organizations. Such coordination assures that plans are consistent with, and integral to, other concurrent water resource planned development being formulated. During the study, interim reports will be prepared to deal with critical problems which may be encountered. These reports will contain specific recommendations to the Congress for authorization of major reservoirs, conveyance facilities, or treatment facilities, as may be appropriate. The Northfield Mountain Water Supply Project, described later, is the result of such interim reports.

F. The Urgent Need Areas

The NEWS Study established the premise that areas which will probably exceed the present capabilities of the water supply systems by 1980 are to be considered in the "urgent" category. Under NEWS procedures, projects and regional programs for these "urgent" areas are being developed and made the subject of interim reports which will be submitted to the Congress for authorization. To identify these urgent areas, an initial appraisal, through reconnaissance studies, was made of the present system's capability to satisfy the projected 1980 demands. This appraisal included an evaluation of present system yields, present and projected domestic and industrial consumption, population expansion and economic growth. The appraisal disclosed four critically urgent areas as follows:

1) Eastern Massachusetts and Rhode Island

2) Western Connecticut - Metropolitan New York City and Northern New Jersey

3) South Central Pennsylvania

4) Metropolitan Washington, D. C.

Once these critical areas had been identified, feasibility detail studies were initiated to investigate alternative engineering solutions. The Western Connecticut area, although in the New England Division, because of its geographic proximity to the Metropolitan New York area, was studied in conjunction with that region. The second "urgent" need area within New England, Eastern Massachusetts and Rhode Island (Southeastern New England), was studied by members of the New England Division and is described in the following section. A plan of the Southeastern New England Region is given on Plate No. S-2.

Although, as described earlier, the NEWS Study area includes eastern seaboard states from Maine to Virginia, the subject of this interim report of survey is a project designed to meet a large portion of the critical supply needs within Southeastern New England. The following sections, therefore, focus on those NEWS Studies conducted to date within New England which led to the selection of the Northfield Mountain project as a candidate for Congressional authorization. Similar reports in the other regions of the NEWS Study area are under way, and will be reported upon by the North Atlantic Division, Corps of Engineers.

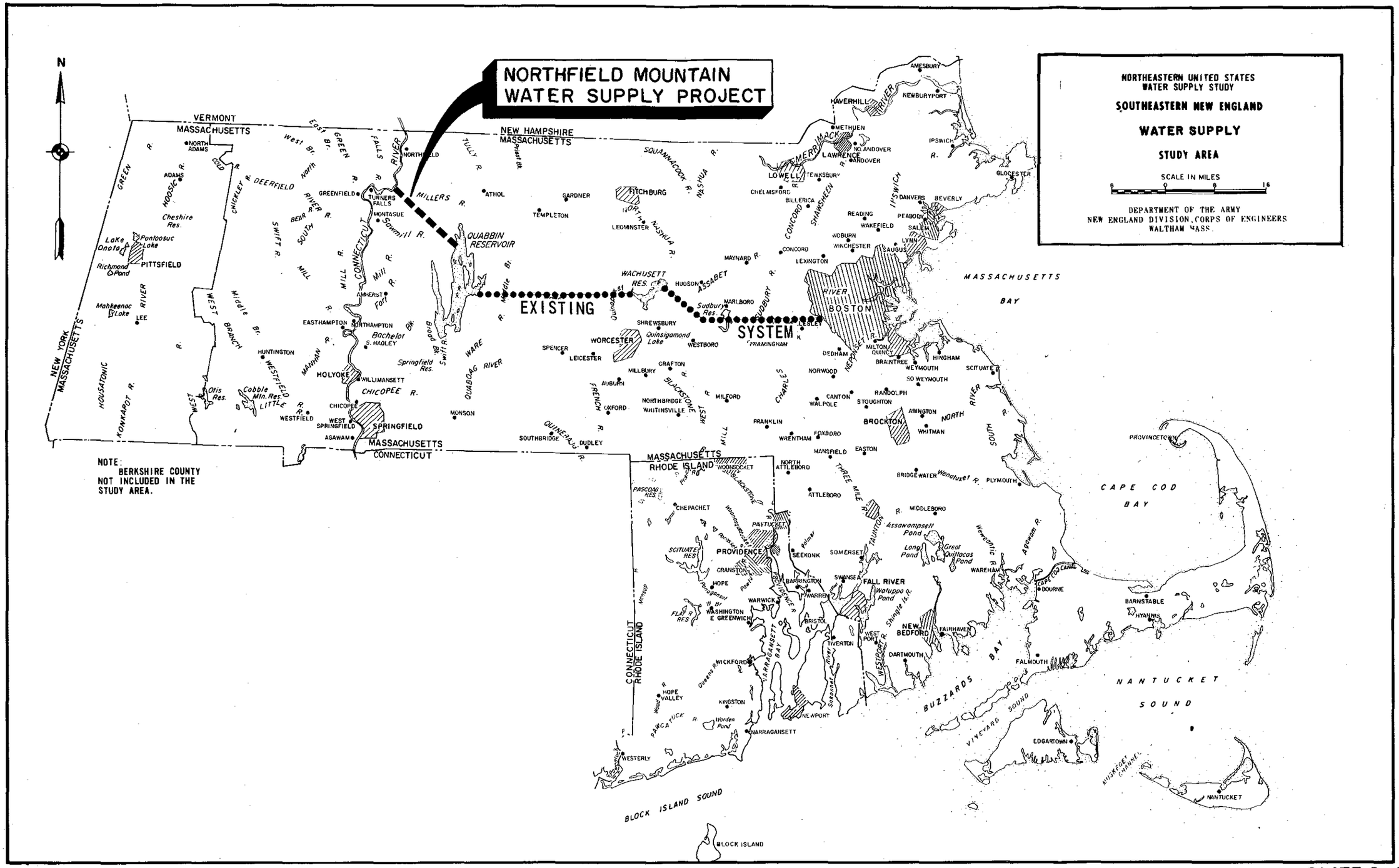

NORTHFIELD MOUNTAIN
WATER SUPPLY PROJECT
NORTHEASTERN UNITED STATES
WATER SUPPLY STUDY
SOUTHEASTERN NEW ENGLAND
WATER SUPPLY
STUDY AREA
SCALE IN MILES
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM MASS.
N
EXISTING
SYSTEM
VERMONT
MASSACHUSETTS
NEW HAMPSHIRE
MASSACHUSETTS
NEW YORK
MASSACHUSETTS
MASSACHUSETTS
CONNECTICUT
MASSACHUSETTS
RHODE ISLAND
CONNECTICUT
RHODE ISLAND
QUABBIN RESERVOIR
WACHUSETT RES.
Sudbury Res.
Quinsigamond Lake
Bachelor
Springfield Res.
Cobble Mtn. Res.
Otis Res.
Cheshire Res.
Lake Onota
Pontoosuc Lake
Richmond Pond
Mahkeenac Lake
Scituate Res.
Pascoag Res.
Flat R. Res.
Assawampsett Pond
Long Pond
Great Quittacas Pond
Watuppo Pond
Shingle Is. R.
Worden Pond
Hope Valley
Cape Cod Canal
MASSACHUSETTS BAY
CAPE COD BAY
BUZZARDS BAY
NANTUCKET SOUND
VINEYARD SOUND
BLOCK ISLAND SOUND
NORTHFIELD
TURNERS FALLS
GREENFIELD
MONTAGUE
ATHOL
GARDNER
TEMPLETON
FITCHBURG
LEOMINSTER
LOWELL
LAWRENCE
HAVERHILL
NEWBURYPORT
AMESBURY
METHUEN
NO. ANDOVER
ANDOVER
TEWKSBURY
CHELMSFORD
BILLERICA
READING
WAKEFIELD
WOBURN
WINCHESTER
SALEM
LYNN
SAUGUS
DANVERS
BEVERLY
PEABODY
IPSWICH
GLOUCESTER
CONCORD
LEXINGTON
MAYNARD
HUDSON
MARLBORO
SHREWSBURY
WESTBORO
FRAMINGHAM
LESLIE K.
BOSTON
DEDHAM
MILTON
QUINCY
BRAINTREE
WEYMOUTH
HINGHAM
SCITUATE
SO. WEYMOUTH
NORWOOD
CANTON
STOUGHTON
RANDOLPH
WALPOLE
BROCKTON
ABINGTON
WHITMAN
FOXBORO
MANSFIELD
EASTON
BRIDGEWATER
PLYMOUTH
PROVINCETOWN
WORCESTER
SPENCER
LEICESTER
GRAFTON
MILLBURY
AUBURN
OXFORD
NORTHBRIDGE
WHITINSVILLE
MILFORD
FRANKLIN
WRENTHAM
SOUTHBRIDGE
DUDLEY
MONSON
HOLYOKE
WILLIMANSETT
CHICOPEE
WEST SPRINGFIELD
SPRINGFIELD
AGAWAM
WESTFIELD
HUNTINGTON
EASTHAMPTON
NORTHAMPTON
S. HADLEY
AMHERST
ADAMS
NORTH ADAMS
PITTSFIELD
LEE
WOONSOCKET
NORTH ATTLEBORO
ATTLEBORO
MIDDLEBORO
PAWTUCKET
PROVIDENCE
CHEPACHET
SEEKONK
SOMERSET
SWANSEA
FALL RIVER
BARRINGTON
WARREN
CRANSTON
HOPE
WARWICK
WASHINGTON
E. GREENWICH
BRISTOL
TIVERTON
WEST PORT
NEW BEDFORD
FAIRHAVEN
DARTMOUTH
WAREHAM
BOURNE
FALMOUTH
BARNSTABLE
HYANNIS
EDGARTOWN
NANTUCKET
WICKFORD
KINGSTON
NARRAGANSETT
NEWPORT
WESTERLY
BLOCK ISLAND
NOTE:
BERKSHIRE COUNTY
NOT INCLUDED IN THE
STUDY AREA.

PLATE S1-2

2. Southeastern New England

A. Reconnaissance Studies

The New England Division, at the request of the North Atlantic Division, began work on the NEWS Study within the New England area in 1967. First, major metropolitan areas, such as Boston, Worcester, Springfield, New Bedford, Fall River, Providence, Bridgeport, New Haven and the tri-city region of New Hampshire (Nashua - Manchester - Concord) were investigated to determine if their present systems could meet the expected water demand in 1980. This appraisal disclosed two "urgent need" areas within New England. The first, Western Connecticut, because of its geographic proximity to the Metropolitan New York area, was studied in conjunction with that region. The Eastern Massachusetts and Rhode Island area was also classified as an "urgent need" area, and the staff of the New England Division initiated a twelve-month engineering feasibility study in December 1968.

B. Feasibility Study

Following completion of reconnaissance studies on the water supply situation within Southeastern New England, a feasibility study on possible engineering solutions was undertaken. The objective of this investigation was to formulate feasible engineering alternatives for a regional water supply for the study area. In achieving this objective, the evaluation of alternatives was prepared without regard to the institutional restraints -- legal, economic or organizational -- so that all physically feasible projects could be evaluated.

The feasibility study area falls within the boundaries of the so-called "megalopolis" which extends from Boston, Massachusetts to Washington, D. C. Following the general trend of population growth within the megalopolis, the population within the Southeastern New England region is expected to increase at a steady rate from a 1970 total of 6.5 to 7.8 million in 2000 and to 9.7 million by 2020, or an increase of 49 percent. The largest increases, however, are most likely to occur around the urban centers of Boston and Providence.

Water use from public water supply systems in the region has increased dramatically since the turn of the century. Increases in population and productivity, movement to urban regions, and rises in per capita usage are important factors in this increase in demand from public water supply utilities. Forecasts of future demands were made utilizing past trends of water use, modified to reflect expected

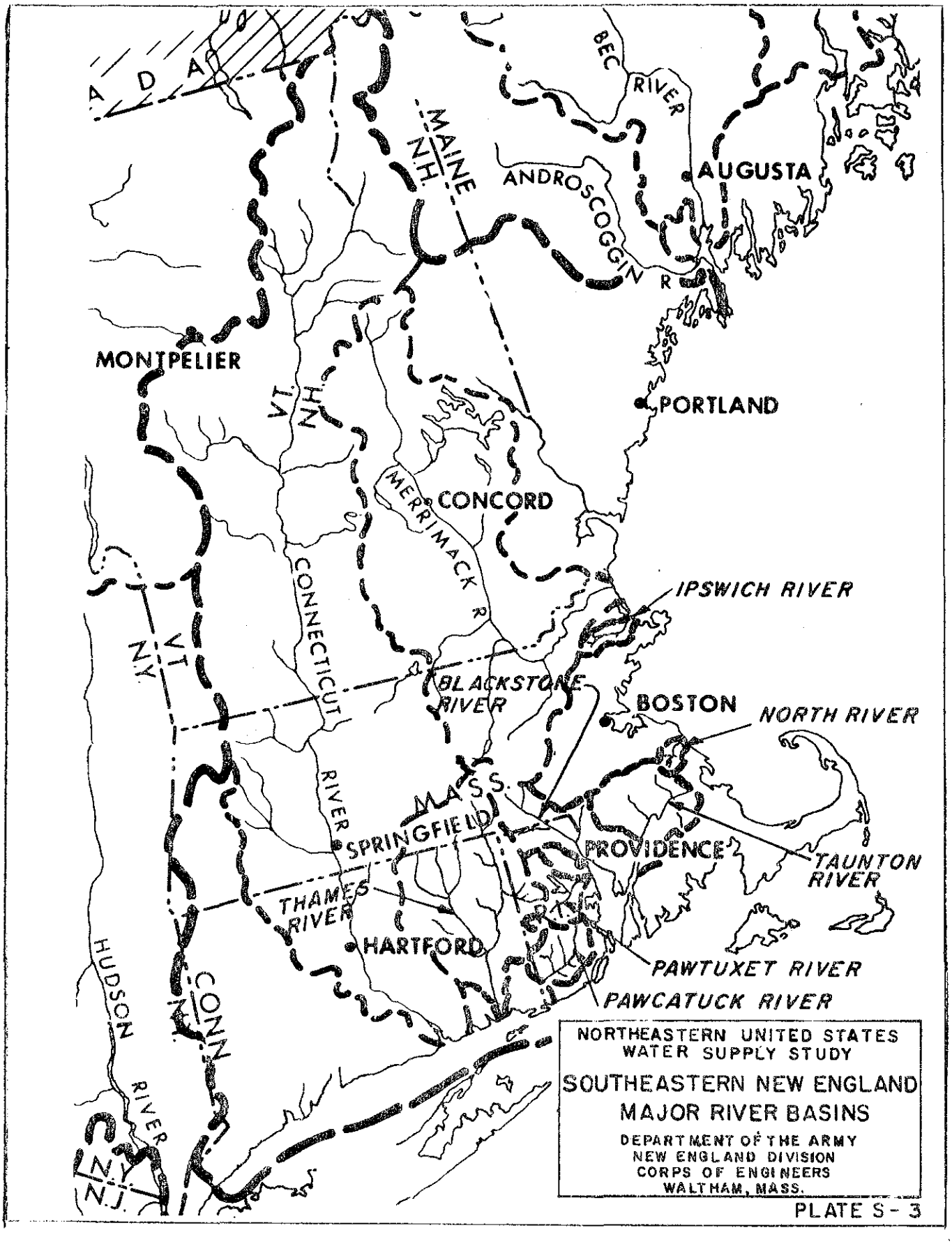
increases in industrial reuse and possible decreases in the proportion of domestic use. Average water demands in the study area could rise from a 1970 total of 850 million gallons per day to about 1300 million gallons per day in 1990 and almost 2100 million gallons per day by the year 2020.

At present, there are a total of 369 public water supply systems within the region. The aggregate developed yield or water available for consumers from these systems totals about 1,000 million gallons per day. The largest regional system within the area is the Metropolitan District Commission system, which services either wholly or partially the water supply needs of 41 municipalities with a population of about 2,000,000. The average daily consumption of these communities in 1971 was 322 million gallons per day, while the safe yield of the system is estimated to be 300 million gallons per day. If this system and others in the region are to provide the anticipated demand without major modifications of consumer water use habits, then large quantities of new supplies are needed.

Nine major river basins were investigated to determine their potential in meeting the previously described water supply needs. Included were the Connecticut, Merrimack, Ipswich, North, Taunton, Pawtuxet, Blackstone, Pawcatuck, and Thames River Basins. A plan showing the location of the basins is given on Plate No. S-3. Also, ground water resources were assessed for regional use and for local potential development. Other techniques such as desalination, waste water reuse, and weather modification were evaluated for their role in augmenting regional water supply systems.

From a regional view, available water resources were identified in sufficient quantities to meet forecast water demands even beyond the year 2020. Potential supply problems within the region thus are not occasioned by a scarcity of resources, but rather by the lack of facilities which develop the resource. Water supply problems within the region arise from shortage of developed facilities, shortage of suitable sites for new facilities, and competing alternative uses for land and water resources.

Twenty-eight regional projects, shown on Tables S-1 and S-2, were described in the feasibility report as possible engineering solutions.



NORTHEASTERN UNITED STATES
WATER SUPPLY STUDY

SOUTHEASTERN NEW ENGLAND
MAJOR RIVER BASINS

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

PLATE S-3

TABLE S-1

POTENTIAL PROJECTS REPORTED UPON IN FEASIBILITY REPORT TO MEET 1990 SUPPLY NEEDS

Basin	Project Name	Yield (mgd)	Method of Development	Construction[1] Cost (1×10^6 $)	Annual Cost[1] ($1 mg)
Connecticut River	Tully	55	High Flow Withdrawal	25.3	93
	Northfield Mountain	125	High Flow Withdrawal	37.9	91
	Hadley	125	High Flow Withdrawal	60.5	141
	W. Deerfield	125	High Flow Withdrawal	74.6	154
Merrimack River	Merrimack - No. Middlesex	35	High Flow Withdrawal	18.1	131
	Merrimack - No. Middlesex - Essex	50	High Flow Withdrawal	36.4	165
	Merrimack - E. Massachusetts	230	High Flow Withdrawal	146.5	141
Ipswich River	Ipswich River Reservoirs	15	High Flow Withdrawals & Storage	15.8	224
North River	North River Reservoir	25	Storage	18.1	151
Taunton River	Lakeville Ponds	25	High Flow Withdrawal	45.7	288
	Copicut Reservoir	25	High Flow Withdrawal & Storage	64.0	403
Pawtuxet River	Big River Reservoir	29	Storage	45.9	322
Massachusetts Ground Water	Plymouth County Ground Water - No. Plymouth	12	Withdrawal from Ground Water Aquifer	20.2	423
	Plymouth County Ground Water - Bristol County	28	Withdrawal from Ground Water Aquifer	48.9	378

[1] 1969 Feasibility Study Costs Updated to 1972 Price Level.

TABLE S-2

POTENTIAL PROJECTS REPORTED UPON IN FEASIBILITY REPORT TO MEET 2020 SUPPLY NEEDS

Basin	Project Name	Yield (mgd)	Method of Development	Construction[1] Cost (1×10^6 $)	Annual Cost[1] ($1 mg)
Connecticut River	Hadley - A	500	High Flow Withdrawal	595 (495)[2]	253 (219)[2]
	Hadley - B	550	High Flow Withdrawal	615 (523)[2]	237 (213)[2]
	Knightville Reservoir	20	Storage	35.4	218
	South Hadley	40	Direct Withdrawal	19.7	141
Merrimack River	Lowell - A	500	Direct Withdrawal	452 (398)[2]	191 (176)[2]
	Lowell - B	550	Direct Withdrawal	468 (427)[2]	178 (168)[2]
Combined Connecticut & Merrimack Rivers	Lowell - So. Hadley - A	500	Direct & High Flow Withdrawal	465 (421)[2]	200 (186)[2]
	Lowell - So. Hadley - B	550	Direct & High Flow Withdrawal	489 (445)[2]	194 (183)[2]
Taunton River	Taunton River Estuary Dam	97	Storage and Direct Withdrawal	80.2	183
Pawtuxet River	Flat River Reservoir	13	High Flow Withdrawal	9.7	203
Thames River	Moosup River Reservoir	20	Storage and High Flow Withdrawal	23.1	290
Pawcatuck River	Wood River Reservoir	30	Storage and High Flow Withdrawal	30.0	247
Blackstone River	Nipmuc and Tarkiln Reservoir	14	Storage and High Flow Withdrawal	23.0	302
Pawcatuck Ground Water	So. Central Rhode Island	11	Withdrawal from Ground Water Aquifer	9.4	236

[1] 1969 Feasibility Study Costs Updated to 1972 Price Level.

[2] Based on Earlier (1990) Merrimack River Development.

C. Events Leading to Project Selection

The feasibility report on possible engineering alternatives for meeting future water supply needs within southeastern New England was completed in November 1969. Draft copies of the report were then distributed for comments by other agencies with responsibility in water resource planning and implementation.

Other Federal Agencies receiving review drafts included the Departments of: Interior; Agriculture; Health, Education and Welfare; Housing and Urban Development; and Commerce.

Draft copies were also sent to the six New England State Coordinators whose offices had been designated by the respective State Governors as state clearing houses for the NEWS Study. These state coordinators in turn distributed the reports to State Agencies which could provide input as review comments.

Established Regional Planning Agencies in the New England States received review copies and were asked to forward their comments through the State Coordinators.

Following the receipt of comments from the various agencies, a meeting was scheduled by the North Atlantic Division in Boston, Massachusetts, for 7 May 1970. The objectives of this meeting were as follows:

(1) To present and discuss the various alternative water supply projects reported upon in the feasibility study. Included in this element was a description of an alternative technique for diverting excess flows from the Merrimack River without upstream augmentation reservoirs and the need for implementing a pollution abatement program to insure adequate water quality.

(2) To discuss the need for and scope of an environmental impact study of the various engineering alternatives.

(3) To select one or more of the engineering alternatives for which more detailed studies in engineering, economic evaluation, environmental and social impact might be undertaken as NEWS Studies.

In a broader sense, the objective was to assure adequate supplies of water for the region in the most beneficial manner possible; i.e., with the optimum overall economic, environmental, and social impact

on the region and the country as a whole. Flexibility, reliability and timeliness are some of the selection criteria used to maximize these components. Political and institutional tendencies and existing laws or statutes act, with varying degrees of rigidity, as constraints in project selection.

Attendees at the meeting varied from Federal and State Agencies to private organizations such as the Audubon Society. A complete list of organizations in attendance is as follows:

Massachusetts

- Metropolitan District Commission
- Division of Water Resources
- Division of Fish and Game
- Division of Marine Fisheries
- Water Resources Commission
- Department of Public Health

Connecticut

- Water Resources Commission

Rhode Island

- Water Resources Board

New Hampshire

- Water Supply and Pollution Control Commission
- Water Resources Board

New England River Basins Commission

United States Department of the Interior

United States Public Health Service

Office, Secretary of the Army

United States Army, Corps of Engineers

- Office, Chief of Engineers
- North Atlantic Division
- New England Division

New England Natural Resources Center

Massachusetts Audubon Society

City of Boston

Anderson Nichols and Company

Union of Concerned Scientists

At the outset of the meeting, a Corps of Engineers representative stated that the NEWS Study was prepared to undertake detailed investigations on potential water supply projects in southeastern New England. These projects, if authorized and constructed, would then aid in meeting the short range "urgent" water supply needs of the region.

The Corps of Engineers spokesman noted, however, that available funding and manpower did not allow for detailed analysis of each alternative project. Therefore, the various agencies and organizations present were requested to state their views on those projects for which immediate detailed studies might be undertaken. By this manner, it was felt that the Corps of Engineers could then proceed with those projects which would efficiently utilize available funds to study projects with maximum relief to the region.

Discussion at the meeting ranged from engineering and environmental considerations of the various possible alternatives to concern with socio-economic impacts. At the end of the meeting, consensus on a number of detailed studies, which should be initiated immediately, was reached. These projects selected from the many potential alternatives described in the feasibility report are as follows:

(1) The Corps of Engineers should proceed with detailed studies on the development of Tully Reservoir.

(2) The Corps of Engineers should consider the Northfield Mountain Water Supply Project as a very viable element in any regional water supply plan for southeastern New England. Accordingly, the Corps should initiate detailed studies on this project and these studies should be designed to complement those already under way or planned by the Metropolitan District Commission.

(3) The Corps of Engineers should conduct studies on the possibility of using the Merrimack as a regional source of water supply and concomitant studies on requirements for improving its quality.

(4) The Corps should conduct a broad environmental impact study of all alternatives proposed for southeastern New England.

(5) The Corps should conduct a detailed study specifically directed at determining the effects of upstream diversion on the estuaries of both the Merrimack and Connecticut Rivers.

(6) The Corps should explore the possibilities of advanced site acquisition, beginning in the State of Rhode Island.

Utilizing the selected work items as a basis, the NEWS work program for southeastern New England was constructed. One of the projects selected at the May 1970 meeting, namely, the Northfield Mountain Water Supply Project, is the subject of this report.

D. Other Areas Requiring Early Attention

The projects selected for detailed studies, as described in the previous section, would provide a large input towards supplying short range water needs in southeastern New England. Even if the projects undergoing detailed investigations, such as the Northfield Mountain Water Supply Project, were constructed, other areas within the region will require early augmentation of available supplies.

As illustrated in the graph displayed on Plate No. S-4, implementation of the Northfield Mountain Project and its companion report, Millers River, projects would provide 148 million gallons per day of additional supply.

Total forecast short range additional (1990) water needs, however, within southeastern New England are estimated to be about 316 million gallons per day, while additional long range (2020) needs may total about 1,084 million gallons per day. Thus, although the Northfield Mountain and its completion report (i.e. Millers River) will contribute significantly toward meeting both short and long range needs, other projects will be necessary.

As a means of meeting a portion of these other need areas, the NEWS Study is presently preparing an Interim Report of Survey on the potential development of the Merrimack River as a supply source. The possibility of such development was an element agreed upon at the May 1970 meeting as requiring detailed analysis.

Since present water quality in the Merrimack River is poor, an investigation[1] of alternatives for managing wastewater in the basin was the

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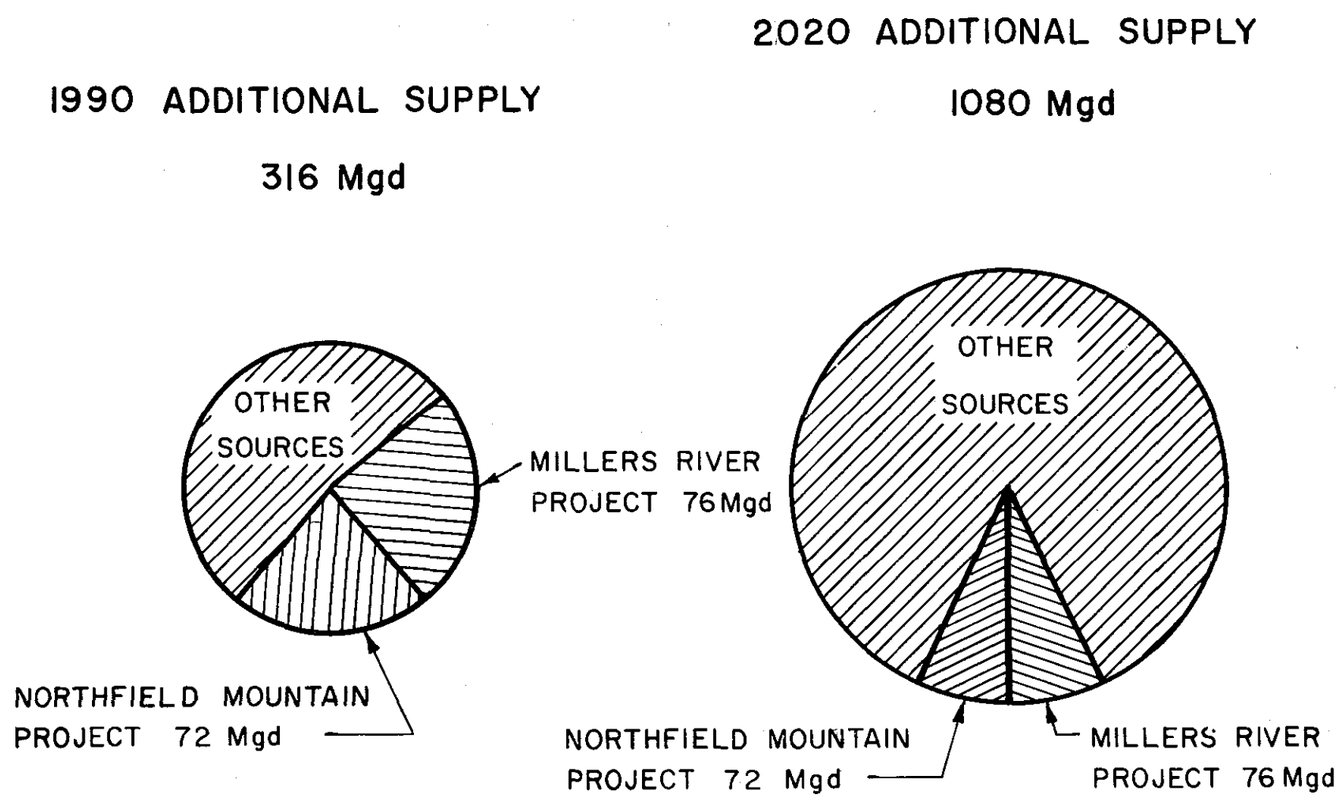
[1] The Merrimack: Designs for a Clean River: Alternatives for Managing Wastewater in the Merrimack River Basin, September 1971, prepared by Northeastern United States Water Supply Study.



NORTHEASTERN UNITED STATES
WATER SUPPLY STUDY

ADDITIONAL WATER SUPPLY NEEDS
SOUTHEASTERN NEW ENGLAND AREA

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

PLATE S-4

first study undertaken by the NEWS Study. A follow-up Interim Report of Survey on possible wastewater treatment plants in the Massachusetts portion of the basin is now being conducted.

The completion of the water supply and wastewater studies presently under way will identify the potential which the Merrimack River Basin has in meeting water supply needs not met by the Northfield Mountain and Millers River Basin Water Supply Projects.

Other areas slated for detailed investigation include the Providence, Rhode Island Metropolitan Region; the Ipswich River Basin; northern Plymouth County and southeastern Massachusetts. Completion of all these detailed studies and implementation of recommended projects would insure adequate supply for the entire southeastern New England region.

3. Summary of Selected Project -- Northfield Mountain Water Supply Project

A. Water Supply Setting

As recognized in the NEWS Legislation, natural departures from normal precipitation and runoff conditions can have regional impacts on the social well-being of a large segment of the nation's population.

The sixties' drought, which began in 1961 when precipitation and water levels fell below normal, ultimately directly affected the water use patterns of more than 20 million people. In 1965 alone, drought related water shortages and associated problems were severe enough to warrant emergency actions by local, state and Federal agencies. Within Massachusetts, 85 cities and towns imposed restrictions on water use.

Historically, within the study area, public water supply has been furnished through municipal level utilities. In 1965, there was a total of 369 public water systems servicing water needs of the region. Population served by these suppliers varies from less than one hundred to more than two million for the largest system, the Metropolitan District Commission (Boston).

During and following the drought, a number of communities conducted engineering studies to determine methods for augmenting their existing supplies. In some cases, new supplies have been developed by municipalities which would allow them to meet supply needs.

As a supplement to the actions taken by the local and regional supply agencies, regional planning agencies have been active in evaluating the various systems' capability to meet future supply requirements. Investigations conducted by the local water utilities, the regional planning agencies and the NEWS Study all indicate that additional supplies are necessary if the short range needs are to be met.

In this Interim Report of Survey, three[1] major groups of communities which could be serviced by the addition of the Northfield Mountain Water Supply Project have been identified. These are:

(1) Forty-one communities which are presently serviced by the Metropolitan District Commission (Boston), the largest regional system in the study area.

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[1] Background data contained in Appendix B - Future Population and Water Demand Studies.

(2) Twenty-four communities which the various local and regional planning agency studies identified as having no reported future source of supply except connection to the MDC system.

(3) Sixty-six communities which have reported local resource potential to meet short range (1990) needs. As an alternative to further local resource development, these communities could also attempt to join the existing regional system.

The municipalities included in the first two categories above are considered for purposes of this report to be the probable 1990 service area which would utilize the supply made available by the Northfield Mountain Project. Existing and proposed dependable yield of these cities and towns is estimated to be about 383 million gallons per day. Total 1990 water supply requirements on the other hand are estimated to be about 524 mgd, thus forecast water deficits could total about 141 mgd.

The Northfield Mountain Water Supply Project would add an estimated 76 mgd to the available supplies. Implementation of the Northfield Mountain Project, therefore, would provide about half of the estimated 1990 supply deficit of the serviced communities. In order to meet the total deficit, another source of supply must be developed. The Millers River Basin in north-central Massachusetts is a candidate for development for this needed supply and is the subject of a separate report.

The sixty-six communities listed in category (3) as possessing sufficient local resource potential to meet 1990 needs were considered for purposes of this report as a "possible" service area. The focus of present planning by these municipalities, however, appears directed toward development of these local resources rather than connection to the existing regional system. Therefore, it is not considered likely that these communities will join the system in the short range.

In summary, certain groups of communities (particularly those outside Metropolitan Boston) can satisfy their present and projected 1990 needs without relying directly on the MDC. However, they cannot do so unless the MDC supplies certain key communities. It, therefore, becomes apparent that any concept of regional supply for the eastern Massachusetts - Rhode Island Study Area depends on firming up the existing regional system i.e., the MDC. This is the specific problem addressed by the present survey report.

Also by 1990, many eastern Massachusetts communities not served by the MDC will collectively require water in addition to that available in their immediate watersheds. The development of institutions and physical systems to cope with this regional problem is critical. By 2020, the MDC will also require additional water from a large regional source. These two problems are the subjects of on-going studies.

B. Description of the Project

Authorization for construction of the diversion facilities from Northfield Mountain to Quabbin Reservoir has been granted to the Metropolitan District Commission by the Massachusetts State Legislature. Recognizing this fact, the representatives of the Federal, State and local agencies and interests at the May 1970 meeting recommended that the Corps of Engineers investigate the project as a very viable element in any regional water supply plan for Southeastern New England. It was further recommended that the NEWS studies be designed to complement those under way or planned by the Metropolitan District Commission.

The Northfield Mountain Diversion project would use a high flow skimming technique; that is, flow would be diverted during high flow periods, principally during spring run-off periods. Water would be diverted from the Connecticut River through the Northfield Mountain pumped storage hydroelectric facility located in Northfield and Erving, Massachusetts. As a means of control, diversions would not occur if flow in the Connecticut River at Montague City U.S. Geological Survey gaging station is less than 17,000[1] cubic feet per second or about 11,000 million gallons per day.

The pumped storage project for electricity generation consists of a high level storage reservoir on Northfield Mountain, underground pump-turbine facilities and low level storage in the Turners Falls pool. The high level reservoir consists of a system of dams and spillways to provide 17,000 acre-feet of storage, about 800 feet above the Turners Falls pool on the Connecticut River.

In order to provide the water supply diversion volume, the electric utility would pump an additional 375 million gallons each day that control flows in the Connecticut River would allow. The additional yield which could be made available by this plan would be 84 million gallons

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[1] This control flow is specified in the current Massachusetts State Legislation regarding the Northfield Mountain Project.

per day on a long term average annual basis. Because of operational considerations, however, the yield estimated to be made available to Quabbin Reservoir is about 72 million gallons per day.

In order to incorporate the water supply diversion into the Northfield Mountain Project, three modifications to the pumped storage facilities are necessary. These are:

(1) Raising the upper reservoir located on Northfield Mountain about 4 feet to provide about 50,000,000 cubic feet of additional storage capacity.

(2) Provision of headworks at the upper reservoir for the diversion aqueduct to Quabbin Reservoir.

(3) About 9.8 miles of connecting aqueduct and outlet facilities at Quabbin Reservoir.

The first two items necessary for water supply diversion have been essentially completely constructed at the upper reservoir on Northfield Mountain by the electric utility construction forces.

The third item necessary for water supply diversion is presently in preliminary design stages by engineers at the MDC. At present, plans indicate water would be diverted from the upper reservoir through an eight-foot diameter steel pipe constructed in the east dike of the Northfield Mountain upper reservoir. Water would be withdrawn at an average rate of 375 million gallons per day and delivered to an intake shaft of the Northfield - Quabbin tunnel aqueduct.

The intake down shaft would be a scroll type configuration with a diameter of 16 to 18 feet. The aqueduct itself would be a 10-foot finished diameter tunnel with a reinforced concrete liner.

Cost estimates for the water supply facilities including the raising of the upper reservoir at Northfield Mountain, intake works, connecting tunnel aqueduct to Quabbin Reservoir and outlet works would total about 40 million dollars.

1) Water Treatment Required

The quality of the Connecticut River varies depending upon upstream municipal and industrial waste discharges, river flow, velocity, time

of year and other considerations. The river's water quality in the vicinity of the Northfield intake has been tested by a number of Federal and State agencies. In addition, testing of the water quality, reported upon in Appendix D, was conducted as part of this study.

Upon analysis of available data, it was concluded that no water treatment is necessary prior to the diversion of Connecticut River water to Quabbin Reservoir. This conclusion is based on the assumption that proper water quality monitoring of Connecticut River water would be performed in the interim years during construction as well as during actual diversion periods and that planned pollution abatement plants will be constructed and in operation.

To safeguard Quabbin itself, the option of including a dual outlet system has been considered. To provide for this future flexibility, if needed, the Northfield-Quabbin aqueduct would include a tunnel stub heading toward the West Branch of the reservoir. If needed in the future, because of water quality considerations, the remaining portion of this tunnel could be constructed.

2) Waste Treatment Required

Water quality investigations indicate that the Connecticut River can be used as a supply source after reservoir storage detention and adequate measures for disinfection. If pollution loads upstream from the Northfield intake continue unchecked, however, there is no assurance that the quality will remain satisfactory.

The Environmental Protection Agency, in cooperation with the New Hampshire Water Supply and Pollution Control Agency and the Vermont Division of Water Supply and Pollution Control, has established an implementation schedule for abatement of pollution discharges upstream from the diversion intake at Northfield. This implementation schedule [1] calls for secondary waste treatment facilities to be constructed and in operation by 1976. Adherence to this established schedule is vital to the quality of the Connecticut River water which is to be diverted for water supply purposes. If the schedule is not adhered to, the potential for increased pollution loads hindering the use of the river as a water supply source is a strong possibility.

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[1] In addition, the Water Quality Act of 1972 calls for zero pollution discharge by 1985.

C. Project Impact Analysis

The evaluation of the project's impacts was accomplished using the three account system developed by the Water Resources Council. Under the Council's proposed guidelines, the overall purpose of the project is measured with regard to enhancing National Economic Development. Environmental Quality and Regional Development.

In order to assess the project's impacts, studies on engineering, socio-economic[2] and environmental[3] considerations were examined. The objectives were to determine and evaluate the potential beneficial contributions as well as neutral or adverse effects which the projects may have. Since the project under consideration involved transfer of a resource through inter-basin diversion, impacts were investigated for both source and receiver areas.

Impacts are quantified and translated into dollar values where possible. In those cases where impacts are not quantifiable, the effects of the project are discussed such that the reader will be aware of all the ramifications of implementing the project.

In general, tangible impacts felt by source areas will be related principally to limited land taking and subsequent construction activity.

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[2] Background data contained in Appendix F.

[3] Background data contained in Appendices D and E.

Apart from the few physical structures proposed, the natural character of the area will remain unchanged. The bulk of surface work will come in remote wooded areas with a minimum of disruption to local traffic patterns. Evidence of the tunneling to Quabbin from Northfield will be seen primarily as access shafts in three or four locations and spoil disposal sites which have not yet finally identified.

From an economic standpoint, changes relate chiefly to the job openings stimulated by construction. Two qualifying points must be made, though, to establish a proper perspective on a labor influx. First, the project will require about 500 men, a comparatively small number with respect to the much larger work forces assembled at the Vermont Yankee Nuclear power generating plant and the Northfield Mountain pumped storage project now under construction. Experience indicates that even if this number were to be larger than the Vernon case, it is unlikely that the supplier area would suffer any adverse effects, e.g., school over-crowding, housing shortages, transportation snarls, etc. As a second mute on impacts, it may be that workers at the Vernon nuclear and Northfield hydroelectric project will move on to the water supply project.

Apart from relatively small economic impacts, social impacts relating to supplier area residents' perceptions of equity are particularly significant. The source area feels a kind of moral outrage at being "forced to give up our water." The statements of their spokesmen sound a sense of frustration with the present system of water allocation decision-making. The personification of this attitude was observed at all of the NEWS Public Meetings held within the Connecticut River Basin. At these Public Meetings, both this report's project and a companion project in the Millers River Basin (the subject of a separate report) came under fire by local opposition. However, of the two projects, the Millers River Basin plan drew the heaviest antagonism.

On the other hand, development of the Northfield Mountain water supply project would insure protection from water shortages and associated social and economic losses. Estimates of economic losses prevented by project implementation when compared to project costs indicate the project to be economically efficient. With respect to the Regional Development objective, the project would provide a benefit/cost ratio of 1.2 under average runoff conditions; and under a hypothetical drought situation, this ratio was estimated to be 1.9. In the National Economic Development account, concrete losses prevented by implementation compared to project costs yields a benefit/cost ratio of 1.1 under normal and 1.7 under drought runoff conditions.

If the project were not implemented, social costs as well as economic costs could be expected in the receiver communities. Social impacts in the receiver area are principally "shadow costs" of concrete losses generated by water shortage. As municipal efforts turn to finding new sources, building bans to hold the line on new demand are a likely eventuality. Second-order effects of expenditures on water searching manifest themselves as slowed school building programs, poorer municipal services (especially fire protection) and a general malaise in the development plans of the subject town. In many ways, these effects are reflected in attitudes about the desirability of the town as a place to live and work. The net result is stagnating growth, hostility toward the communities which snare the industries unable to locate in a water-deprived town, and a growing dependence on MDC admission as the ultimate solution to water shortage.

From the outset, this study made a determined effort to evaluate the impact which the Northfield Mountain water supply diversion might have on Environmental Quality. An analysis was made regarding impact on the Connecticut River Estuary, on the Connecticut River downstream from the point of diversion, and on the environment of the receiving water storage reservoir.

In general, as described in the main report and fully in Appendices D and E, impact caused by the diversion on the estuary and Connecticut River itself is expected to be minimal. The primary reason for this lack of environmental impact is the relatively small amount of water when compared to river flow which would be diverted.

In evaluating environmental impact on Quabbin and Wachusett Reservoirs, field and laboratory data included about 100 parameters, including chemical, physical, biological and pesticides data. In addition, radiological data, hydrodynamic studies, fisheries information and pollution abatement plans were considered and evaluated.

Central to the evaluation was a qualitative model of reservoir dynamics. If water of lower quality such as that in the Connecticut River is introduced to a high quality supply like Quabbin Reservoir, there will most likely be a loss in the reservoir system. A number of parameters including turbidity, chemical oxygen demand, dissolved oxygen and nutrients such as nitrogen and phosphorous received close attention.

Within the receiving water body at Quabbin, the diverted flow may have impacts, but these possible impacts depend to a large degree on what engineering steps are taken prior to the actual diversion. For example, the present waste loads in the river may provide opportunities for

algae growth or oxygen depletion. However, if current pollution abatement schedules are followed and the goals of the Water Quality Act of 1972 attained, then present loadings in the river will be reduced; and as a consequence, the probability of possible damage to Quabbin also minimized.

On the other hand, if no additional water is made available to the reservoir, then increased demands may deplete available storage. Declining storage volumes, in turn, will cause an overall loss in water quality. In addition to this possible reservoir water quality deterioration caused by reduced storage levels, supply shortages in the receiver area could also cause a loss in environmental quality for those communities served by the system.

Although exact quantifications of all potential impacts could not be defined, basically because of the present state of the art of ecological investigations, the relative probability of impacts occurring was defined. A summary of these impacts are included in the main report, and a full description of the studies is given in Appendix D - Water Quality Studies of Connecticut and Millers Rivers and Quabbin and Wachusett Reservoirs.

Followup studies of those parameters which require further detail are presently under way with sponsorship from the Metropolitan District Commission.

Finally, if the project was implemented, the additional water supplied would be returned as waste water. If this effluent was not treated adequately, it could cause a degradation of water quality in the receiver area. However, the Water Quality Act of 1972 calls for full treatment of waste discharges by the early 1980's.

D. Other Alternatives

In this report, a wide range of alternatives to the Northfield Mountain Project was investigated. Included in these alternative were other possible diversions, use of new technology as a means of augmenting existing supplies, non-structural approaches such as reduction of demand and the evaluation of the no-action alternative. A description of these alternatives and their potential as solutions to the existing problem are summarized in the following paragraphs.

1) No Action

In the evaluation of this alternative, it was assumed that any failure to implement additional supplies for the study area would cause socio-economic impacts on serviced communities. To verify this assumption, a quantification of these impacts was necessary.

Estimates of impacts caused by a no-action policy can be expressed in two different ways. First concrete losses without the diversion total $84 million to 1990 and $528 million to 2020 if average runoff conditions prevailed. Under drought conditions, concrete losses without diversion total $201 million to 1990 and $623 million to 2020. Categories included in these totals encompass industrial, city emergency, city, revenue: commerce, sprinkling, business investment and domestic investment losses.

Social impacts in communities serviced by the supply system under a no-action alternative would be principally "shadow costs" of the concrete losses. As municipal efforts turn to finding other sources of supply, building bans to hold the line on new demands are a likely eventuality. Second-order effects of expenditures on water searching manifest themselves as slowed school building programs, poorer municipal services (such as fire protection) and a general malaise in the region's development plans. In many ways, these effects are reflected in attitudes about the desirability of the community as a place to live and work. The net result could be stagnated growth, hostility toward other communities able to lure industries unable to locate in the water short municipalities.

In addition to socio-economic impacts, a second major impact could occur with the no-action alternative. This second impact regards the probable deterioration in water quality within Quabbin Reservoir which could be caused by lowered reservoir volumes.

Based on the evaluation of the socio-economic and environmental impacts, the no-action alternative has many disadvantages. Use of this alternative, therefore, does not offer a realistic solution to the short range needs of the study area.

2) Weather Modification

The primary source of the water used for public and private water supply in Massachusetts, as in most humid areas, is precipitation falling directly on the areas concerned. It follows then that if precipitation

can be increased in a regulated manner, the water supply can also be increased. To this end, several major agencies such as the National Oceanic and Atmospheric Administration (NOAA), the United States Bureau of Reclamation, the American Meteorological Society, and the National Science Foundation are investigating ways of productively modifying natural precipitation patterns. The primary focus of research is in the area of cloud seeding.

Research has continued to improve the state of the art of weather modification by cloud seeding and other means. At best, however, weather modification is still an inexact science. Studies are unable to predict optimum cloud conditions and seeding results with any degree of accuracy. It is the conclusion of this section, therefore, that at this time weather modification operations to augment water supplies in Massachusetts does not appear to be a viable solution to the immediate water supply problem.

3) Desalinization

Desalinization, the process in which brackish and salt water is converted to fresh, is currently being used in some parts of the world as a viable, economically feasible source of fresh water. This process thus was considered for its potential as a future alternative solution to the water supply needs of eastern Massachusetts.

The conversion of saline to fresh water is accomplished through four major processes: distillation-evaporation, membrane separation, crystallization, and chemical differentiation.

Desalinization by numerous processes is already feasible in parts of the world when the natural water supply is either scarce or of poor quality. In these areas, the relatively high costs of water produced by desalinization are justified. Research completed by the Office of Saline Water has indicated that when larger capacity plants are designed and in production, the costs could ultimately be reduced to approximately 50¢ per thousand gallons in the size range of the Northfield Mountain Project, although a recently proposed California plant would produce water at 73¢ per thousand gallons. Even at this reduced cost, however, desalinization is not competitive with present costs of developing natural surface and sub-surface water supplies. For example, costs of water from this report's recommended project is about 15¢ per thousand gallons.

Aside from the economic costs involved with desalinization, the Office of Saline Water is also investigating the potential hazards to the

environment. In considering placement for any type of desalting plant, environmental factors are as important as any other factor. Pure water is not the only product. A plant will produce extremely concentrated brine as an effluent, plus any waste products from the power source such as soot, heat, smoke, toxic gasses, etc. So far as brine is concerned, this brine from distillation plants is of high temperature, higher chloride content and may contain concentrations of copper which may prove injurious to the environment. Two methods of brine disposal have been studied: (1) evaporation to dryness; and (2) deep-well injection. Evaporation is expensive, though this is highly dependent on land costs presently quite costly in urban areas such as this report's study area. Injection method costs are estimated at 25 to 70 cents per 1,000 gallons of brine. Such costs must be added to plant production and distribution costs to arrive at a true cost of water from this technology. At present, the Office of Saline Water is investigating other methods of brine disposal.

On the basis of the economic costs and environmental problems associated with this technology, this report concludes that desalinization not be considered at this time as a viable alternative source of water in eastern Massachusetts for the short range water supply problems. When and if the technology and efficiency of this process is refined so that it is economically and environmentally competitive with other methods of supplying water, its feasibility can be re-evaluated.

4) Importation

During the crisis years of the sixties' drought, many newspaper and periodical articles pondered the possibility of diverting water from extra-regional sources as a solution. One of the major basins often mentioned as a water supply source for the Northeast was the St. Lawrence. As an alternative to developing local resources to meet future water needs, an investigation was made regarding the feasibility of diverting St. Lawrence flow to meet future needs.

Engineering studies were conducted to assess various methods and quantities of development from the basin. Cost estimates were prepared for projects which would service all of the Northeast through the year 2020. Construction costs for such facilities were estimated to be as high as 8.5 billion dollars excluding any necessary water treatment costs. Water delivered from such an undertaking would cost substantially more than similar volumes made available from local resource potential.

In addition to the high cost of water, this alternative also has several other major disadvantages. First, the nature of the project would not allow stage development. Thus, large expenditures of funds would be required for distant long range needs. Second, since the basin is international, negotiations with Canada would have to be held and a treaty consummated prior to diversion. Assuming that Canada would be favorable to such negotiations, at best, any treaty would be in the distant future.

Based on the results of investigations conducted as part of this report, the importing of water to meet short range water supply needs does not present a viable alternative for the Southeastern New England Region.

5) Waste Water Reuse As A Municipal Supply

Waste water reuse, especially in industrial process application, has been economically successful in many sections of the country.

Other uses to which treated waste water has been applied include irrigation of both crop land and lawns, as a fresh water barrier against salt water intrusion, and in some cases as a source of supply for formation of recreation lakes and ponds.

Direct reuse of waste water effluent as a public water supply, however, has not been utilized to a large degree. Advanced waste treatment research and development programs at the Federal level are continuing, and pilot plant studies such as the noted Lake Tahoe project are apparently meeting with some success in producing a high quality effluent.

The current Drinking Water Standards do not apply to direct reuse of reclaimed water for drinking. Health officials feel many questions remain unanswered which must be fully investigated if renovated waste water is to be considered for drinking water purposes. Research is considered vital before development of intimate personal-contact uses of renovated waste waters.

The future of direct waste water reuse particularly in industrial applications seems promising. Future water demand forecasts for industrial usage used in this report, in fact, anticipate greater recycling of water in the industrial sector.

Use of renovated waste water as a regular domestic supply, however, requires full results of proposed research. Until such research is

completed, waste water reuse as a municipal water supply is not a viable alternative to meet short range supply needs.

6) Ground Water Resources

A study[1] of the ground water resources of Massachusetts was prepared for the Corps of Engineers by the United States Geological Survey. The study was based upon analysis and interpretation of available data and did not include any new exploratory work. The objectives of the study included an estimate of the area extent and sustained yield of principal aquifer reservoirs which might be used for supplementing municipal and industrial water supplies.

The survey of ground water resources indicated that the aquifers in Plymouth County and parts of Cape Cod have the capacity to sustain long term, large magnitude withdrawals. The water demand on Cape Cod is increasing at a fast rate; therefore, this area is not considered in this report. The Plymouth County area studied comprises 300 square miles and its estimated safe yield is 300 mgd. This estimated rate exceeds the required quantity established as a goal of this study. Thus, it was concluded that the Plymouth County area could offer a viable alternative source of water supply for eastern Massachusetts.

Cost estimates for the necessary resource development were then prepared. Major development items included in these estimates were land acquisition, cost of ground water well development, water treatment facilities, pumping installations and connecting aqueduct system to the metropolitan service area. The estimated construction cost for the ground water development per million gallons per day (mgd) capacity is about 1.2 million dollars. Costs for the Northfield Mountain project, on the other hand, are estimated to be about $600,000 per mgd capacity. Annual costs of ground water development which includes interest and amortization; maintenance, repair and operating cost; and major replacement costs are estimated to require charges of about 30¢ per 1000 gallons produced. Annual costs for the Northfield Project would require about 15¢ per 1000 gallons produced.

In addition to the economic costs associated with development of the ground water alternative, there are also potentially significant environmental and socio-economic impacts. For example, land taking activities associated with sanitary protection of the various wells may be substantial. Preliminary estimates of necessary land acquisition for

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[1] This investigation was conducted as part of the feasibility study of potential engineering alternatives in the study area.

the wellfield development indicate 1,000 to 1,500 acres of land would be necessary. This compares quite unfavorably with the 40 acres estimated to be required for the Northfield Mountain water supply project.

Connecting pipelines between wells in the wellfield and transmission facilities to point of use would require a large amount of surface construction. Such extensive surface construction would have an impact on the environment in the vicinity of the wellfield and transmission facilities. Since portions of the aqueduct systems would pass through heavily urbanized areas, disruption would be expected to be extensive.

Since all water developed from the wellfield would have to be pumped to the consumer, this alternative would utilize large amounts of electricity. Thus, depending on the method used to provide this power, impacts on the environment can be expected.

The Northfield Project would utilize off-peak power; therefore, no additional potential environmental damage would accrue because of power requirements.

On the basis, then, of cost comparisons and potential socio-economic impacts, use of ground water does not appear to offer an attractive alternative to the proposed project.

7) Dual Water Supply Systems

An alternative which has been receiving attention of late has been the use of dual water supply systems. In these systems, a hierarchy of water supply would be established whereby higher quality supplies could be used to furnish a potable source for drinking, cooking, dishwashing, cleaning, bathing and laundering. All other uses could be furnished by a second supply of lesser quality.

Two general methods have been suggested for such a dual system. The first is the possibility of recycling at the point of usage. Under this scheme, drinking, washing and bathing water would undergo treatment and then be further utilized as toilet flush water and outdoor uses. It is estimated that such a system could reduce domestic water use by as much as 50%.

Various systems for in-house reuse or for outdoor usage have been proposed, and some are being marketed on a small scale.

Advantages to this system beyond potable water consumption reduction are the reduction in sewage water volume, sewer pipe and pumping requirements. Capital cost outlay for such a system based on limited

cost data would be over twice as expensive as water delivered from this report's recommended project. Other disadvantages to this alternative lie with its limited application and accompanying operational experience, potential problems of odor and other aesthetic considerations. Health officials in general have not expressed their acceptance or rejection of such systems. However, their general apprehension on introducing less than potable water into the home environment could also reasonably be expected with regard to any system of this nature.

The second method which has been suggested for delivering higher and lower quality water for various uses would require a second distribution system. This second distribution system would carry river water or even sea water to supplement the high quality primary supply source.

To estimate costs for such a system, a report on the New York City area, prepared as part of the NEWS Study, was utilized. Based on the results of that investigation, preliminary capital cost estimates for such a dual system would be about 6.5 million dollars per mgd saved. The Northfield Mountain Project recommended in this report is estimated to cost about $600,000 per mgd. Therefore, use of a dual supply distribution system as an alternative would be an extremely expensive alternative.

In summary, then, use of dual water supply systems to meet immediate short range supply needs does not offer an alternative to the recommended project in this report. Of the two methods, the system which would recycle water at the point of usage holds the more promise for future application.

8) Other Diversion Sites

In addition to the Northfield Mountain Diversion proposal described in this report, a number of other diversion possibilities were also evaluated. These other possible sources included diversions from: the mainstem Connecticut River at other than the Northfield Mountain location; other major tributaries of the Connecticut River, namely, the Deerfield and Millers Rivers; the mainstem of the Merrimack River and the Sudbury River, a tributary of the Merrimack, formerly extensively used by the MDC.

The possibility of diversions from the Millers River, a tributary of the Connecticut River, offers a viable companion source which when combined with the yield of the Northfield would allow serviced

communities to meet short range needs. Development of this Millers River Basin potential is the subject of another Interim Report of Survey.

Other alternative development of the Connecticut River Basin to meet short range needs such as the Deerfield River or another location on the Connecticut River itself could provide an equivalent yield to that of Northfield Mountain. Development of either of these proposals, however, would be more expensive than the Northfield Mountain Project (or the Millers River Basin Project). Aside from economic costs, neither alternative presents any clear cut advantage from an environmental or socio-economic viewpoint.

As an alternative to further diversions from the Connecticut River Basin, the potential of developing the mainstem Merrimack River was also investigated. At present, the physical, chemical and bacteriological quality of the river is poor. For years, the river has been subjected to major discharges of municipal wastes.

An investigation is feasibility detail[1] was conducted to assess methods of improving water quality within the river. At present, an Interim Report of Survey by the NEWS Study is evaluating alternative waste treatment techniques which would improve the river's quality. As a companion study to the waste water element, investigations in survey detail on the river's potential for water supply development are also being conducted.

Based on studies to date, use of the river to meet longer term supply needs holds promise. Use of the river to meet immediate needs within the study area, however, does not appear to offer an attractive alternative to this report's recommended project from either an economic or public health standpoint.

One of the earlier historical supply sources of the MDC was development on a portion of the Sudbury River Basin, a tributary of the Merrimack River. In 1947, in response to the availability of supply from Quabbin Reservoir and the higher quality water from this source, the Massachusetts Legislature transferred control of a number of supply reservoirs to the Department of Conservation.

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[1] The Merrimack: Designs for a Clean River: Alternatives for Managing Wastewater in the Merrimack River Basin, September 1971, prepared for the Northeastern United States Water Supply Study.

With its existing available supplies, the MDC is presently re-evaluating the potential which the full Sudbury system may have. The Sudbury Basin waters, however, have a number of reported water quality problems, thus water treatment facilities would be necessary to develop this source. Based on preliminary cost figures, this redevelopment could cost about twice that of this report's recommended project.

In summary, then, the redevelopment of the Sudbury River Basin could add an attractive increment to the region's available supplies. The redevelopment plan needs further study for a full assessment of its potential; and if implemented, it would be fully compatible with this report's recommended project.

9) Water Demand Control

The NEWS Study, cognizant of the narrow margin separating available yield and consumer demand, conducted studies on methods available to alleviate this critical water supply situation. Two general approaches to the problem were investigated: the first considered various methods of increasing the supply available to the system; the second approach summarized in this section was investigation of methods whereby demand could be curtailed.

There are basically five methods which have been suggested as effective in controlling demands on water supplies. These are:

(1) Changing from flat-rate to metered supply
(2) Increasing the price of metered supply
(3) Imposing of restrictions on water use
(4) Utilization of water-saving devices
(5) Public Water Conservation Education Programs

Each of these methods, outlined above, are described in the following sections as they might apply to the demand forecasts prepared for this report.

(1) Metering

The installation of meters which measure the amount of water used by a consumer have been shown to be effective in varying degrees in reducing demand for water supply. With metering, the customer is now

charged for the quantity of water used, instead of being charged a flat rate for a period of time regardless of quantity used. Most of the studies conducted regarding the effects of metering indicate domestic in-house use is relatively in-elastic, but lawn sprinkling use and some industrial applications apparently are affected.

Use of metering then appears to present a good opportunity for conservation of a resource. In the Boston area, however, application of this technique to reduce demand is quite limited. Most municipalities in eastern Massachusetts already meter extensively. For example, the customers of communities served by the MDC are presently 96 percent metered. Complete metering, therefore, would affect only 4 percent of service connections in this system and not, therefore, affect to any significance, water supply demands forecast in this study.

(2) Pricing Effects on a Metered Supply

A number of articles have appeared in recent years in water supply and water resource professional journals regarding the impact of price increases on water demand. All of these articles attempt to quantify the constraining influence which pricing may have upon demands. In these articles, a number of various pricing techniques have been suggested for administration of price hikes. These include general increases in price levels, seasonal pricing and increasing block rates for varying usage of water. Aside from the administrative technique employed, however, the objective of the articles is to define impact of price increases on demand. Generally, the authors, however, are forced to base conclusions on a generally incomplete and sporadic empirical data base.

On the basis of equations submitted by some of these authors, price adjustments would appear to offer an alternative to development of supplemental water supplies. Theoretically, a price increase of 50¢ per 1,000 gallons could be expected to reduce domestic in-house demands by about 34 mgd and a corresponding decrease in lawn sprinkling demand by about 5 mgd. Industrial water use demands are indicated to react by decreasing almost 14 mgd. The total theoretical decrease on the system then with such a price increase would be about 53 mgd.

On the basis of the theoretical equations then pricing would appear to be a valuable tool for conservation of the water resource. A number of questions, however, arise concerning the direct application of these forecast decreased demands to the water supply situation at hand.

First, the empirical data used in the derivation of the domestic use equations, although the most extensive to date, is far from all inclusive. Data used was derived from 21 areas nationwide, which contained about 5000 dwelling units. None of the test areas were located within southeastern New England, although data available from the Middle Atlantic States was used.

In the analysis of industrial water demand reaction, data utilized was quite limited, and other research in this area is almost non-existent. Development of any hard policy conclusions based on such sketchy information is, therefore, uncertain at best.

Second, the derivation of the empirical equations for domestic use was based on a "static" view of cost versus use. That is, the data employed was not an observation of a group of communities' actual reaction to pricing changes. Rather, the equations were developed by using a number of communities, which for a given point in time, had different water use with their individual rate structures. For example, Community A in 1970 used 100 gpcd at a cost of 20¢ per thousand gallons; Community B in the same year recorded an average use of 50 gpcd at a cost of 40¢ per thousand gallons. Based on the approach used by Howe and Linaweaver, the expected decrease in use from Community A with a price increase to 40¢/1000 gallons would be 50 gpcd. Whether the use of such a "static" scenerio to predict dynamic conditions is valid is unknown.

That the equations may not indeed reflect the dynamic situation which would occur with a price increase is particularly suspect with actual operating experience in the Boston Region. For example, in the Boston Region, the MDC increased wholesale prices for its water from $40 to $80 per million gallons in 1954, and $80 to the current $120 per million gallons in 1962. Neither of these price increases was accompanied by a decrease in per capita demand on the system; in fact, demand increased on the system.

To further evaluate the dynamic impact of pricing in an actual operating experience, a survey was made of a privately owned water company which recently applied a 24¢ per 1000 gallons to its water rates. This rate increase raised the cost of water to the consumer from $1.00 to $1.24 per 1000 gallons. The two communities serviced by the company are principally residential, thus the rate increase based on the empirical equation should be expected to result in a demand decrease, or in any event, a decrease in the rate of increase. The company reports, however, that instead of experiencing a decrease in per capita usage,

it experienced a 5 gpcd increase, an increase in excess of that reported in years prior to the price increase.

Based on the actual operating experience of these utilities within Metropolitan Boston, it appears any arbitrary adoption of the empirical equation as a forecast tool with respect to water demand carries a large degree of uncertainty.

Third, all of the studies upon which the pricing-demand relationship was developed have been basically economic studies. No attempts have been made to evaluate or quantify cost to the consumers from either environmental quality or social considerations. Both the social and environmental costs of reducing water demand may outweigh the gains derived from institution of such a policy. Whether, in fact, the costs would outweigh the benefits is unfortunately unknown.

In summary, use of increased water supply prices as a method to conserve a resource may have merit. Yet to be determined, however, are data to support the theoretical impact such increases would have upon the demand within New England. Also unknown with this approach are the social and environmental costs which would be borne by the consumer. It appears then that much work remains to be done on this approach such that it can be evaluated as a viable alternative to increased supply.

(3) Imposing of Restrictions on Water Use

Historically, water utilities have used water use restrictions as a "safety factor" against depletion of supply during a drought. In general, however, most water utilities attempt to avoid restrictions whenever practical. Public reaction to such restrictions, however, is almost always unfavorable, and many examples of such public disapproval can be found in newspaper clippings during the recent sixties' drought.

Imposition of restrictions on water use could not fail to interrupt the existing and planned life styles of communities serviced by a water supply system. As described in the appendix on socio-economic impacts, restrictions on water use, depending on its degree, would have far reaching social and economic costs. On the basis of costs which would be incurred with a restriction policy, it does not appear to offer a viable alternative.

(4) Utilization of Water Saving Devices In-House

Much of the recent increase in municipal water supply by individual consumers has been attributed to the adoption of multiple toilet facilities; water using devices such as automatic clothes and dish washers; and shower installations. Variation in water use between brand names differs markedly. For example, automatic home washers for an 8 pound load require from 32 to 59 gallons per load, while toilets vary from 3.2 to 8 gallons per usage. Information on the impact of domestic water saving appliances on in-house use is limited and variable in quality.

An article[1] presented last year in the American Water Works Association demonstrated possible water savings which could be brought about by adoption of presently available appliances for toilet, clothes washing and shower use. Based on their findings, the authors conclude that there doesn't appear to be current financial incentives for adoption of water saving appliances. They do note, however, that conversely economic costs to consumers from utilizing water saving appliances do not seem great. Presumably, their conclusion refers to replacement costs when currently used appliances wear out. The authors suggest that complete replacement of appliances with water saving models might reduce domestic water use by 32 percent.

A second study[2] of water conservation measures for the Office of Water Resources, U. S. Department of the Interior, also contains some information on water saving devices. In this study, it was noted that increasing use of water by automatic dish and clothes washers over the years has been occasioned by a rise in required performance standards. Thus, customer desires are reflected in the increased water use.

A third study[3] recently completed for the Washington Suburban Sanitary Commission provides a brief review on the effectiveness of water saving measures and the relationship of their use to rate-making policy

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[1] Howe, Charles W. and Vaugham, William J. "In House Water Savings," Journal of the American Water Works Association, Vol. 64, No. 2, (February 1972).

[2] Hittman Associates, Inc., "Main C. Computerized Methodology for Evaluation of Municipal Water Conservation Research Programs," No. HIT-409, Columbia, Maryland, August 1969.

[3] Boland, John J., Hanke, Steve H., and Church, Richard L. An Assessment of Rate-Making Policy Alternatives for the Washington Suburban Sanitary Commission, Prepared for the Washington Suburban Sanitary Commission, September 1972.

formulation. In this report, the authors state "A major deficiency in the data reported by all investigators to date is that it refers to isolated uses of specific appliances and fixtures, but does not reflect actual use conditions."

In reference to the suggestion that 32 percent of the domestic water use could be saved by adoption of water saving devices, the authors state "Such a result implies, of course, no reduction in the actual or perceived efficiency of operation of any of the appliances or futures. In the latter instance, the net reduction in water use is more difficult to predict; however, it should be somewhat less than 32 percent."

Statements made at a number of progress meetings suggested that use of incentives such as subsidies or tax concessions and revision of plumbing codes to require water saving devices would result in substantial water savings. In general, however, the same questions which burden analysis of price as a demand moderation measure also apply to use of water saving devices. Regardless of managerial technique used to implement use of such devices (i.e., subsidy, tax concessions, etc.) the question still remains as to the effectiveness and impacts on water use which may occur. Research conducted to date has been limited. In addition, socio-economic impacts which might occur with a general requirement that older appliances be replaced with the water saving models has not been addressed at all. Environmental impacts generated as a spinoff of producing the new replacement models may also be significant and must be included in any analysis.

In summary, adoption of water saving devices as a method of conserving water supply may have merit in the long run. At present, however, supporting data to measure the impacts of either requiring new housing units or replacement by older housing with water saving appliances is not available. Without this data, evaluation of potential savings as an alternative course of action to the recommended project cannot be documented.

(5) Public Water Conservation Education Programs

Historically, the water supply industry has not advocated wide-scale public water conservation, except in communities where supply or distribution systems were inadequate to meet demand. Recently, however, increased awareness of the need to protect and enhance the environment has required a review of this earlier policy.

At present, two major metropolitan supply systems[1] have adopted a water conservation policy during a time of water surplus. In the past year, both utilities have promoted expanded voluntary customer water conservation through a public education program.

Bill inserts and information handbooks on water-saving measures have been distributed widely. In addition, speeches to individuals, schools and clubs have been employed to inform the public of why the water resource should be used properly and what they can do to help conserve water. Results of the education programs are now being evaluated for their effectiveness.

The Washington utility which has the longest experience record reports results have been encouraging to date; however, major reductions in per capita usage have not been observed.

In addition to voluntary conservation measures, the two utilities are also considering the use of regulatory powers to conserve water. Regulatory measures under consideration include, for example, price increases, utilization of water-saving household appliances and restriction of lawn sizes. All such measures, however, are being carefully evaluated by the utilities because of the many questions, described in earlier sections, which surround use of such devices.

In summary, adoption of public water conservation programs as a management tool has received attention of late. Results on water use modification of the voluntary conservation programs now under way are limited. However, based on the Washington area experience, no major decrease in per capita usage has been observed.

10) Re-Examination of the Swift and Ware Rivers Downstream Release Schedules

At the time diversions were contemplated from the Connecticut River Basin, via the Swift and Ware Rivers, Massachusetts applied to the Secretary of War for authority to make the proposed diversions. After hearing arguments pro and con from Massachusetts and Connecticut, the Secretary permitted diversion of the flood waters of the Ware in excess of 85 million gallons per day between 15 October and 15 June and prohibited the taking of any water except during that period.

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[1] Washington Suburban Sanitary Commission and East Bay Municipal Utility District. Note: both utilities service populations of about 1.1 million each.

With regard to the Swift River, the Secretary permitted diversion of all waters of the Swift except enough to maintain a flow therein of 20 million gallons per day (mgd) or 31 cubic feet per second (cfs). The Secretary did require that during the period from 1 June to 30 November, there shall be released from the impounding dam 71 mgd (110 cfs) whenever the flow of the Connecticut River at Sunderland, Massachusetts is 4650 cfs and 45 mgd (70 cfs); when the flow is more than 4,650 and less than 4,900 cfs.

These findings of the Secretary of War regarding operational schedules for the diversions were later made a part of the Supreme Court Decision, dated March 1931, in the suit between Connecticut and Massachusetts. Since the date of that decision, diversions from the Swift and Ware Rivers have been accomplished under the Secretary of War findings.

During the progress of the NEWS Study, an interested citizens' group suggested the setting aside of the Swift River diversion limitations with the objective of retaining presently scheduled releases within Quabbin Reservoir. The citizen group further suggested any diminution of flow in the Connecticut River could be made up by releases from existing Corps of Engineers' flood control reservoirs. In keeping with this suggestion, an examination was made of the potential which such rescheduling might have on the short-range supply problems.

The drainage area of the Swift River controlled by the Quabbin Reservoir totals 186 square miles. The long-term average annual runoff from the watershed is 187 mgd (289 cfs) of which 32 mgd (50 cfs) has been released downstream in compliance with the existing downstream release schedule.

Thus, the maximum addition to the existing water supply system which could be achieved through re-scheduling would be 32 mgd (50 cfs). To provide this increment, however, all downstream releases with the subsequent "drying up" of the river reach downstream are, of course, impracticable. The question then raised is what level is practicable. A recent study[1] completed for the entire Connecticut River Basin recommends an instantaneous discharge rate, from power reservoirs on the Connecticut River of 0.20 cubic feet per second per square mile of upstream watershed. An application of this criteria to Quabbin

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[1] Comprehensive Water and Related Land Resources Investigation, Connecticut River Basin, Connecticut River Basin Coordinating Committee, June 1970.

Reservoir, for example, would result in a downstream release requirement of 24 mgd (37 cfs). Adoption, then, of such a modified operational schedule could result in an additional 8 mgd being made available. This increment of yield, however, would not begin to meet the short-range needs of this report's study area which are estimated to total an additional 141 mgd. In short, then, a re-examination of downstream release schedules with the objective of conserving such releases for water supply has merit. However, based on the requirement of maintaining a viable river environment downstream from Quabbin, the opportunity for reducing downstream releases does not offer an alternative to the project reported upon in this study.

The spring runoff which occurred in 1972 was of longer duration and of greater magnitude than is usually experienced. As a result, diversions from the Ware River, in compliance with the operation schedule, described earlier, were forced to cease even though flows in excess of 85 mgd were still occurring. This event triggered a suggestion to the NEWS Study that if the 15 June to 15 October no diversion constraint were lifted, large additional supplies of water could be made available to Quabbin.

A computer test was made to determine the impact of the 15 June to 15 October constraint. The results of the computer simulation indicated that only an additional 2.6 mgd might be made available if the 4 month no diversion period currently in effect was terminated.

In the Ware River, as in the case of the Swift River, a re-examination of downstream release schedules may have merit. However, terminating the 15 June to 15 October diversion period constraint does not offer an alternative to this report's recommended project.

E. Coordination

Since the initiation of this work, a determined effort has been made to inform the public of the work's progress. Nine progress meetings were held in the Boston Metropolitan area, generally at Waltham, Massachusetts; the first held on 7 May 1970, with the latest held on 7 June 1972. Attendance at these meetings generally averaged about 50 people, with attendees representing Federal and State Agencies, conservation commissions, the Audubon Society, sportsmen groups, and interested citizens.

In addition to the progress meetings, four informal information meetings have been held within the Millers River Basin. These meetings were held in Athol, Massachusetts on 21 October 1971 and 4 January 1972; in Winchendon, Massachusetts on 2 March 1972; and in Athol, Massachusetts on 8 May 1972.

During December 1971 and January 1972, a series of four formulation stage public meetings were held in Needham, Woburn, Orange and Longmeadow, Massachusetts. These meetings were designed to broaden public participation in the open planning process by describing the on-going studies and receiving audience input.

In July 1972, two late stage public meetings were held at Waltham and Orange, Massachusetts, and the various plans for augmenting water supply systems were discussed and described.

A full description of the coordination held during the study is included in the main report and Appendix H.

4. Conclusions

As recognized in the NEWS Legislation, natural departures from normal precipitation and runoff conditions can have regional impacts on the social well-being of a large segment of the nation's population. The sixties' drought which began in 1961 ultimately through its duration directly affected the water use patterns of more than 20 million people. In 1965 alone, drought-related water shortages and associated problems were severe enough to warrant emergency actions by local, State and Federal agencies. Within Massachusetts, for example, more than 50 cities and towns imposed restrictions on water use.

During and following the drought, a number of communities and regional planning agencies conducted engineering studies to determine methods for augmenting existing supplies. In many cases, new supplies have been developed by communities which would allow them to meet future needs. Investigations conducted by the NEWS Study in Southeastern New England indicate that even with the actions undertaken by local authorities, additional supplies must be made available if future needs are to be met.

In 1969, a feasibility report on possible engineering alternatives to meet the region's needs was prepared by the NEWS Study. A total of 28 projects were identified as possible candidates for implementation to provide an adequate water supply system within the region. The Northfield Mountain project examined in this report was one of the engineering alternatives included in the feasibility study. Upon implementation, output from the project would provide additional supply, as shown on Plate No. S-4, to meet a large segment of the region's future needs.

This report has investigated and assessed all aspects of the water supply situation within the study area. The Metropolitan District Commission (MDC), Boston, is the largest regional system in New England, supplying about two million people in 1970. The MDC relies upon surface water as its supply source, and the present estimated safe yield of these sources is 300 million gallons per day (mgd). In 1971, the average daily delivery of water from this system was about

322 mgd. Available safe yield of the largest regional system in New England has been outstripped by rising supply demands.

The land area encompassed by this study falls within the boundaries of the so-called "megalopolis" which extends from Boston, Massachusetts to Washington, D. C. Latest population estimates for the Massachusetts study area forecast increases from 6.5 million in 1970 to 7.8 million by 1990, and 9.7 million by the year 2020.

Estimates of future water requirements within the region and on the existing regional system demonstrate the need for additional supply. Development of a single regional system to meet 1990 needs of all communities within the study area was not found to be an attractive approach, either from an economic or resource utilization viewpoint.

Based on a review of the area's 1990 water supply needs, it is concluded that the MDC system, as it exists at present, will require additional supply. In addition, studies reveal about 23 communities which may require admission to the system to satisfy their short range (1990) needs.

The estimated total demand for 1990 for presently serviced and other needy communities on the existing regional (MDC) supply sources is calculated to be about 441 mgd. Future demand forecasts were derived using both population and industrial output projections. In general, although some modification of consumer and industrial water usage patterns are included in these estimates, no major modifications or shifts in usage patterns are included.

In order to meet the 141 mgd additional demand, a large number of alternatives were investigated to determine their environmental and socio-economic impacts. Alternatives to the Northfield Mountain project included no action, desalination, groundwater development, waste water reuse, other diversion sites, re-regulation of existing supply sources, local resource development and controlling the water supply demand. Based on the investigations conducted, it is concluded that the Northfield Mountain supply project offers an attractive opportunity for providing early relief to the short range needs.

In the evaluation of the Northfield Project, particular attention was given to the impacts on downstream water users which implementation might cause. All of the investigations indicated minimal downstream effects could be expected with operation of the project.

On the other hand, implementation of the project would provide protection against water shortages and associated socio-economic losses. Estimates of economic losses prevented when compared to project costs demonstrate the economic efficiency of the project. With respect to the Regional Development objective, the project would provide a benefit/cost ratio of 1.2 under average runoff conditions; and under a hypothetical drought situation, the ratio was estimated to be 1.9 In the National Economic Development account, the benefit/cost is estimated to be 1.1 under normal and 1.7 under drought runoff conditions.

In assessing the Environmental Quality Impact, the Connecticut River Estuary, the river itself and the receiving water body at Quabbin Reservoir were examined to determine what changes would accompany the project's implementation. In general, minimal changes can be expected in the river and estuary downstream of the diversion intake. These minimal impacts forecast are due to the relatively small diversion volumes compared with river flow. Within Quabbin Reservoir, the diverted flow may have impacts depending to a large degree on the pollution abatement steps taken. For example, the present waste loads may provide opportunities for localized algae growth or oxygen depletion. The Metropolitan District Commission is currently investigating certain chemical and physical parameters to better define the probable impacts on the reservoir.

Based on all investigations conducted, it is concluded that resources are available within the region which can be developed from both economical and environmental viewpoints. Development of these resources through the Northfield Mountain Project and a companion project (subject of another report) offers a means of meeting supply needs through 1990. The availability of the resource and the opportunity for their development provides an optimistic outlook for the region at least in the short run.

In addition to the conclusion that the Northfield Mountain Project should be implemented, it is also felt that concurrent investigations on water demand and its makeup should be conducted.

For example, detailed breakdown of water use or demand by consumers is not readily available. Although use, on a per capita basis, is readily available, data on how and by whom the water is used is not well documented. Increased per capita demands are, of course, a reflection of the nation's rising standard of living, but the breakdown of this demand into various use categories is poorly understood. A clearer understanding of the breakdown would permit the most efficient long range use of water supply resources.

Household items, which are undoubtedly contributing to increased water usage, include clothes and dish washing machines; multiple toilet facilities, and installation of shower facilities. Among these appliances, a wide range of water requirements per usage is needed. A search of available literature indicates these wide variances in water requirements may not be occasioned by economic or environmental efficiency objectives, but rather the result of independent design criteria. It appears then a rationalization of criteria used in design of water using appliances may offer opportunities for reduction of longer range water needs upon the public supply systems. The true measure of this opportunity would require extensive investigation, including the various appliances' efficient water needs; the impact which re-design would have on consumers; identification of incentives necessary to achieve full use of such devices, such as use of plumbing regulations, subsidies, and the effect which such potential in-house savings may have on future, particularly long range, water demands.

A second area worthy of investigation regards the impact which restructuring of pricing policy as a conservation measure for long range needs may have. Studies conducted to date indicate increases in cost of water supplied to the consumer may decrease use of water by the individual. Data developed to date on this pricing/use reaction has been limited. Thus, any theoretical anticipated decrease in water use caused by a price hike must be viewed as speculative.

In addition, none of the work has addressed the question of whether such price increases would in fact be beneficial or detrimental to the socio-economic objectives of the public water supply consumer. For example, if water rates were raised substantially in excess of the economic costs of delivering the water, the rate increase would, in effect, be a tax placed upon the consumer; consequently, questions of equity then arise. In short, the use of pricing as a conservation tool is an unproven venture, given the present "state of the art" concerning its potential benefits and possible shortcomings. Studies should be conducted, therefore, which address these questions and provide answers as to the impacts of such measures.

During the course of the study, at a number of informal progress and formal public meetings, it became evident that public interest in water supply planning was far from consistent. Meetings held within the Connecticut River Basin or the supplier area always were will attended with high audience participation. On the other hand, at three public meetings held in the Eastern Massachusetts region, the area which could be supplied water from this report's recommended project, less than 50 people attended each of the meetings. It appears that the public

in Eastern Massachusetts takes its present good quality and available water as unlimited. This attitude can be attributed, in part at least, to the continuing availability of supply made available by the efforts of the local and regional water supply agencies. The question arises, however, whether such casual public concern over their water resources is a healthy state of mind. Many conservation groups at the NEWS meetings characterized this lack of public concern as leading to misuse of the resources through waste. There is no evidence to substantiate this charge in the study region. However, an education program to inform the public about their supply system, its limits and future, is in consonance with good management practice. The development of such an educational program, therefore, not only within the study area of this report, but nation-wide, should be considered as part of any water supply plan.

Throughout the conduct of this study, a number of groups, primarily conservation oriented, have advocated the re-cycling of waste water for water supply uses. In some cases, such as in certain industrial processes, effluent from waste treatment facilities can be utilized. The use of such waste water effluent, regardless of the degree of waste water treatment, as a source of supply for municipal systems is not sanctioned at this time. Echoing the position of the Division of Water Supply, Environmental Protection Agency, State and local health officials and professional water supply engineers, any application of reused water as a municipal supply would require a considerable amount of research on associated potential health hazards. Since, in many regions, less than desirable sources may be needed in the future, it is imperative such research be accelerated.

The Northfield Mountain Water Supply Project would be an important supply increment in the regional plan for the metropolitan Boston area and is compatible with the short and long range water resource development objectives of the region. Included in the regional plan for the Boston area would be one of the Millers River Basin alternatives described in a companion report. Also, there is the possibility of utilizing the South Sudbury River and/or the Merrimack River for future demands. Studies should be conducted to determine whether certain measures designed to conserve and moderate water demand should be implemented to reduce the size of needed long range water supply developments. For the region as a whole, water resources are available which can be developed efficiently from both an environmental and economic viewpoint to meet the water demands. Sources include the Merrimack, Taunton, North and Connecticut River Basins, together with local groundwater sources. The future water supply view of the area, therefore, can be described as optimistic. However, a continuing planning program, dynamic in nature, must be pursued to insure adequate, safe, dependable water supplies are available when necessary.

NORTHFIELD MOUNTAIN WATER SUPPLY PROJECT

TABLE OF CONTENTS

Paragraph		Page
	SECTION I - GENERAL	
1.	Purpose	1
2.	Authority	1
3.	Scope of Studies	2
	SECTION II - PRIOR REPORTS	
4.	Published Reports	4
	A. General	4
	B. Federal	4
	C. State	7
	1) Massachusetts	7
	2) Connecticut	9
	D. Regional Planning Agencies	9
	SECTION III - COORDINATION	
5.	Project Coordination	11
	A. Public Meetings	11
	B. Progress Meetings	12
	C. Information Meetings	12
	D. Citizens Participation Board	12

Paragraph		Page

SECTION IV - PHYSIOGRAPHY
CONNECTICUT RIVER BASIN

6.	Location	13
7.	Natural Resources	13
	A. Surface - Land Forms Elevation	13
	B. Geology - Soil - Mineral Resources	14
	C. Biological Productivity	15
	D. Land Use	16
8.	Climate	16
	A. General	16
	B. Precipitation	17
	C. Temperature	17
	D. Storms	17
9.	Water	18
	A. General	18
	B. Flow and Fall	18
	C. Reservoirs - Lakes - Ponds	18
	D. Estuary	19
	E. Wetlands	19
	F. Groundwater	19

Paragraph | Page

SECTION V - ECONOMIC DEVELOPMENT

10. General 20

11. Measures of Economic Activity 20

12. Past Trends in Economic Growth 21

13. Projected Economic Growth 23

SECTION VI - THE WATER SUPPLY SETTING

14. General 26

A. Sixties Drought 26

B. Water Supply Agency Action 26

15. Existing Regional System - Metropolitan District Commission (Boston) 27

16. Local Resource Potential 31

A. General 31

B. Subdistrict Water Systems 32

17. Expected Expansion of the System Service Area 37

18. Capability of System to Meet Future Needs 45

A. Source 45

B. Transmission Facilities 45

SECTION VII - DESCRIPTION OF THE PROJECT

19. General 48

20. Facilities Required and Project Operation 50

A. Hydroelectric Facilities and Operation 50

B. Water Supply Facilities and Operation 51

Paragraph		Page
21.	Water Treatment Required	53
22.	Waste Treatment Required	57
23.	Multi-Purpose Applications	59
24.	Monitoring Program	60
	SECTION VIII - ESTIMATES OF FIRST COSTS AND ANNUAL CHARGES	
25.	First Costs	62
	A. Available Geologic Data	62
	B. Proposed Tunnel Alignment	63
	C. Tunnel Cost Estimate	65
26.	Annual Charges	67
	SECTION IX - PROJECT IMPACT ANALYSIS	
27.	General	69
	A. Background	69
	B. Parameters used in Benefit/Cost Analysis	71
	C. Elements Included in Analysis	72
28.	Evaluation	83
	A. Regional Development	83
	B. National Efficiency	116
	C. Environmental Quality	117

Paragraph		Page

SECTION X - OTHER ALTERNATIVES

29.	General	136
30.	No Action	136
31.	Weather Modification	139
	A. Cloud Seeding	139
	B. Conclusions	141
32.	Desalination	142
	A. Distillation - Evaporation	142
	B. Membrane Separation	142
	C. Crystallization	143
	D. Chemical	143
	E. Present Application	143
	F. Costs of Desalination	144
	G. Conclusion	144
33.	Importation	146
34.	Waste Water Reuse as a Municipal Supply	147
35.	Ground Water Resources	149
	A. Occurrence of Ground Water	150
	B. Hydrologic Parameters	150
	C. Conclusion	151
36.	Dual Water Supply Systems	152

Paragraph		Page
37.	Other Diversion Sites	154
	A. Other Connecticut River Basin Alternatives	154
	B. Merrimack River Basin Alternatives	155
	C. Conclusion	157
38.	Water Demand Control	157
	A. Components of Demand	157
	B. Methods of Controlling Demand	159
39.	Re-examination of the Swift and Ware Rivers' Downstream Release Schedule	170

SECTION XI - CONCLUSIONS AND RECOMMENDATIONS

40.	Conclusions	173
41.	Recommendations	182

LIST OF TABLES

		Page
Table 1	Metropolitan District Commission System	30
Table 2	Communities Presently Being Serviced by the MDC	40
Table 3	Communities with No Other Reported Option	41
Table 4	Communities with Other Options Including the MDC System	42
Table 5	Water Quality Data, Connecticut River at Northfield, Massachusetts	54
Table 6	Waste Loads to Connecticut River Basin Streams	58
Table 7	Northfield Mountain to Quabbin Reservoir Aqueduct Costs	66
Table 8	Summary of First Costs and Annual Charges	68
Table 9	Socio-Economic Impact Measurement	77
Table 10	Supplier Communities	84
Table 11	Receiver Communities	85
Table 12	Impacts on Suppliers	93
Table 13	Losses Prevented by Implementation of Northfield Mountain Project	104
Table 14	Regional Development Objective, Benefit/Cost Ratio, Northfield Mountain Diversion Project	105
Table 15	Impacts on Receivers	108
Table 16	National Economic Development Objective, Benefit/Cost Ratio, Northfield Mountain Diversion Project	117

		Page
Table 17	Summary of Probable Impacts of the Proposed Diversion on Quabbin Reservoir	132
Table 18	Domestic Water Use	158
Table 19	Effect of Hypothetical Water Supply Rate Increases on MDC Demand, Theoretical Decrease	164

LIST OF PLATES

Section 1

		Following Page
Plate No. 1	Southeastern New England Study Area	1
Plate No. 2	Northeastern United States Water Supply Study Area	1
Plate No. 3	Connecticut River Basin	13
Plate No. 4	Franklin County and Boston Metropolitan Region	20
Plate No. 5	Metropolitan District Commission	27
Plate No. 6	MAPC Subdistrict Areas	32
Plate No. 7	Quabbin-Wachusett Water Supply System, Existing and Future Service Area	37
Plate No. 8	Estimated Demand on Quabbin-Wachusett System	39
Plate No. 9	Northfield Mountain Pumped Storage Project	50
Plate No. 10	Section Through Power House and Water Conduits, Northfield Mountain Pumped Storage Project	50
Plate No. 11	Northfield Mountain Water Supply Project	52
Plate No. 12	Average Monthly Runoff, Connecticut River at Turners Falls and Proposed Diversion Effects	122

NORTHFIELD MOUNTAIN WATER SUPPLY PROJECT

SECTION I

GENERAL

1. Purpose

The severe five-year sixties' drought which plagued the Northeastern United States revealed a soon to be critical water shortage within eastern Massachusetts. More important detailed examination accomplished in this study indicates that many water supplies available to this area are inadequate to meet today's needs and the area's expanding population and industrial growth. This report presents a plan for diverting excess high flows from the Connecticut River Basin, to meet a portion of the future water supply needs within eastern Massachusetts. The study area is shown on Plate No. 1.

2. Authority

The Northeastern United States Water Supply Study (NEWS) was authorized by Congress under Title I of Public Law 89-298, enacted on 27 October 1965. Congress thereby recognized that assuring adequate water supplied for our great metropolitan centers had become a problem requiring the assistance of the Federal Government in its resolution.

Under direction of the Congress, the Secretary of the Army, acting through the Chief of Engineers, was 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. In meeting these needs, this plan may provide for the construction, operation and maintenance by the United States of a system of major reservoirs, major conveyance facilities and major purification facilities within the study area. The Chief of Engineers in turn assigned responsibility for the NEWS Study to the Division Engineer, North Atlantic. This report is submitted in partial fulfillment of the above authorization and will be incorporated as part of the overall NEWS effort. A plan of the entire NEWS study area is shown on Plate No. 2.

3. Scope of Studies

Studies conducted as part of this report included the following tasks:

a) Detailed projections of population, water demand, and potential service areas, principally within Eastern Massachusetts as well as within the Connecticut River Basin, were completed in this study.

b) Geologic investigations with existing sub-surface data of proposed tunnel and conduit routes and reservoir sites were accomplished.

c) Requirements for waste and water treatment studies were investigated.

d) Ecological and environmental studies were completed which consider the effects, both immediate and future, of the various proposals on the environment and ecology of both the Connecticut River, its estuary, and the receiving storage impoundment at Quabbin Reservoir.

e) Hydrologic and hydraulic analyses.

f) Economic studies and evaluations.

g) Estimates of quantities and costs of major items of construction.

h) Alternatives to the proposed project, ranging from the development of small local water supply sources to an assessment of desalination, waste water reuse and weather modifications.

i) Inclusion of multi-purpose applications within the proposed water supply project.

j) An investigation of the broad socio-economic impact of the proposed project.

Since the initiation of these studies, a determined effort has been made to inform the public of the work's progress. Beginning in May 1970, a total of six formal public meetings, nine progress and four informal informational meetings were held. At all of these meetings, progress on various elements of the NEWS Study was described.

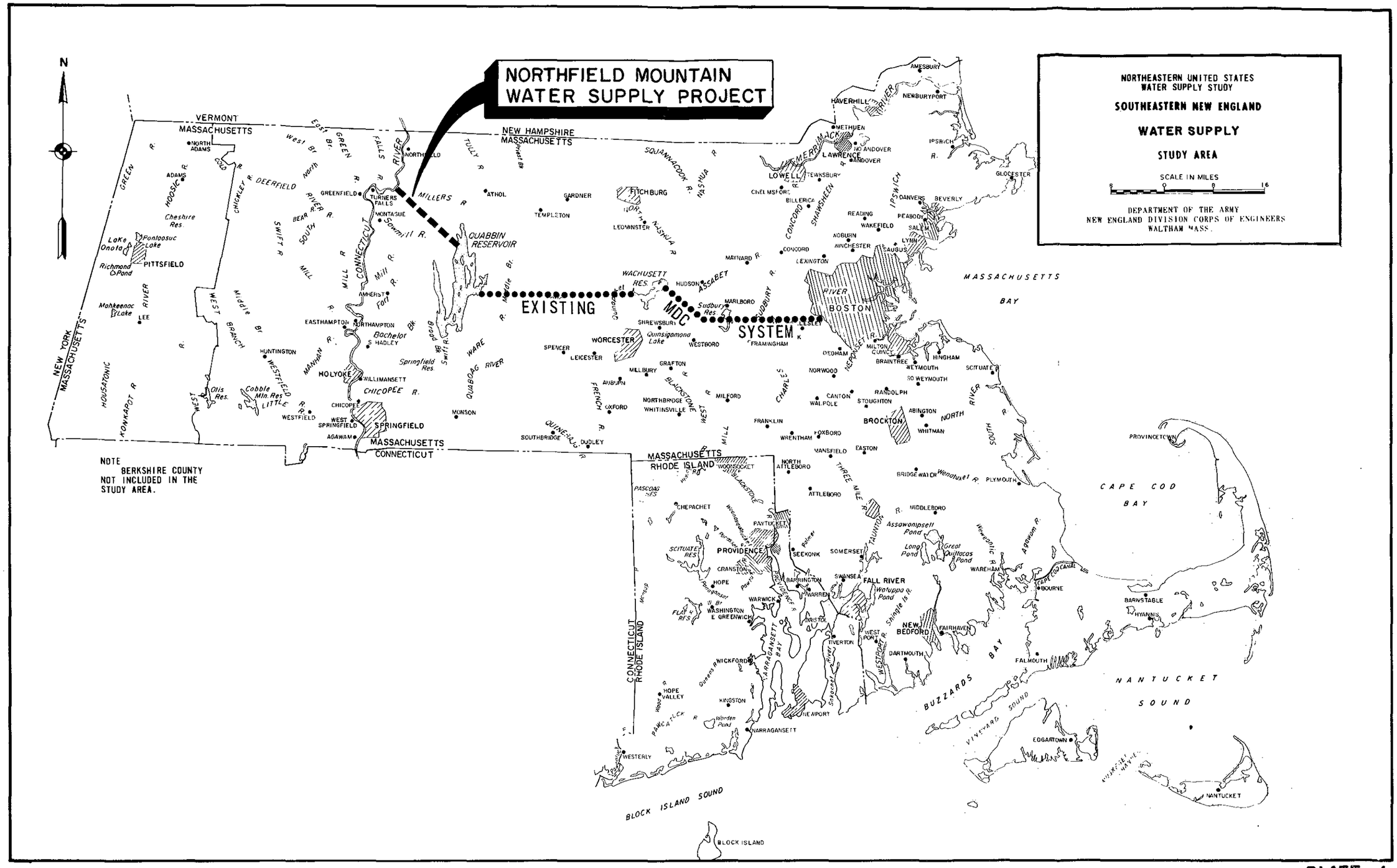
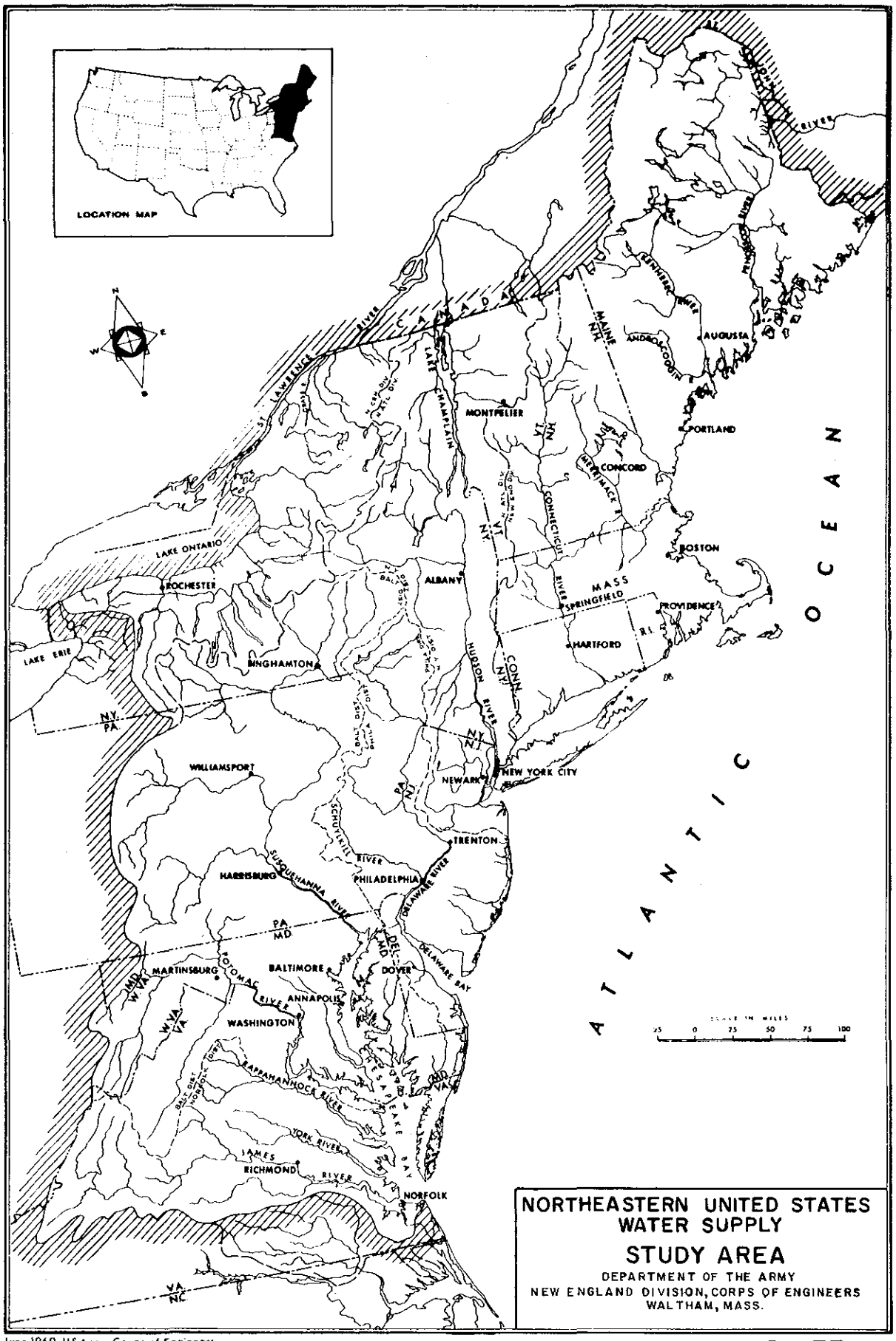

NORTHFIELD MOUNTAIN
WATER SUPPLY PROJECT
NORTHEASTERN UNITED STATES
WATER SUPPLY STUDY
SOUTHEASTERN NEW ENGLAND
WATER SUPPLY
STUDY AREA
SCALE IN MILES
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION CORPS OF ENGINEERS
WALTHAM MASS.
N
EXISTING
MDC
SYSTEM
VERMONT
MASSACHUSETTS
NEW HAMPSHIRE
MASSACHUSETTS
NEW YORK
MASSACHUSETTS
MASSACHUSETTS
CONNECTICUT
MASSACHUSETTS
RHODE ISLAND
CONNECTICUT
RHODE ISLAND
QUABBIN RESERVOIR
MASSACHUSETTS BAY
CAPE COD BAY
NANTUCKET SOUND
BUZZARDS BAY
BLOCK ISLAND SOUND
BOSTON
WORCESTER
SPRINGFIELD
PITTSFIELD
PROVIDENCE
FALL RIVER
NEW BEDFORD
BROCKTON
LOWELL
LAWRENCE
HAVERHILL
FITCHBURG
HOLYOKE
NORTHAMPTON
GREENFIELD
TURNERS FALLS
NORTHFIELD
ATHOL
GARDNER
TEMPLETON
LEOMINSTER
HUDSON
MARLBORO
SHREWSBURY
WESTBORO
FRAMINGHAM
LESLEY
SPENCER
LEICESTER
MILLBURY
GRAFTON
AUBURN
OXFORD
NORTHBRIDGE
WHITINSVILLE
MILFORD
FRANKLIN
WRENTHAM
FOXBORO
MANSFIELD
EASTON
NORTH ATTLEBORO
ATTLEBORO
MIDDLEBORO
PLYMOUTH
WAREHAM
BOURNE
FALMOUTH
BARNSTABLE
HYANNIS
PROVINCETOWN
EDGARTOWN
NANTUCKET
WESTERLY
NARRAGANSETT
NEWPORT
TIVERTON
WEST PORT
DARTMOUTH
FAIRHAVEN
SWANSEA
WARREN
BARRINGTON
WARWICK
WASHINGTON
E GREENWICH
HOPE
CRANSTON
PAWTUCKET
SEEKONK
SOMERSET
CHEPACHET
WICKFORD
KINGSTON
HOPE VALLEY
NORTH ADAMS
ADAMS
LEE
HUNTINGTON
WESTFIELD
WEST SPRINGFIELD
AGAWAM
CHICOPEE
WILLIMANSETT
EASTHAMPTON
S HADLEY
AMHERST
MONSON
SOUTHBRIDGE
DUDLEY
NORWOOD
CANTON
WALPOLE
STOUGHTON
RANDOLPH
ABINGTON
WHITMAN
BRAINTREE
WEYMOUTH
HINGHAM
SCITUATE
SO WEYMOUTH
DEDHAM
MILTON
NORTH ANDOVER
ANDOVER
METHUEN
NEWBURYPORT
AMESBURY
IPSWICH
GLOCESTER
BEVERLY
DANVERS
PEABODY
SALEM
LYNN
SAUGUS
WINCHESTER
NOBURN
READING
WAKEFIELD
CONCORD
LEXINGTON
BILLERICA
CHELMSFORD
TEWKSBURY
NOTE
BERKSHIRE COUNTY
NOT INCLUDED IN THE
STUDY AREA.

PLATE I



June 1969 - US Army, Corps of Engineers

PLATE 2

Questions, answers and opinions were interchanged between the study team and audience. Input gained at these meetings served to guide the direction of the tasks and the final recommendations.

At the November 1971 progress meeting, a number of citizens stated a desire for formation of a "Citizens Participation Board." The purpose of this group was to act as an ombudsman for citizens in the watershed from which diversion of water was contemplated. Initiated in December 1971, this board has worked with members of the study team to insure that views and concerns of the watershed citizens were known throughout the conduct of this study.

SECTION II

PRIOR REPORTS

4. Published Reports

A. General

A large number of reports have been prepared on the various rivers within the Connecticut River Basin. These reports, prepared by Federal, State and Regional Agencies, cover many areas of resource interest, both in the public and private sectors. In the Corps of Engineers on-going flood control program, for example, there have been completed, beginning in calendar year 1926 and continuing through 1968, a total of 25 reports in response to separate Congressional directives. In the area of navigation, from 1911 through 1969, the Corps had submitted 18 separate reports, while six summary reports on flood plan information have been submitted as guides to local municipalities. In addition, two multi-purpose flood control reservoirs recently constructed have included water supply storage under the provisions of the Water Supply Act of 1958. Few of these prior Federal reports, however, address themselves to water supply planning, thus a complete listing was not considered necessary for this report. A few of the more pertinent Federal reports are included in the following section.

State and Regional Planning Agencies, however, have been active in preparing plans for future water supply needs. Wherever applicable, these reports have been reviewed and considered in the preparation of this study. A listing, including these agencies and some of their reports, is given in paragraphs 4 C. and 4 D.

B. Federal

The land and water resources and flood control needs have been considered in the following published reports:

1) "308" Report, dated 11 February 1936, was submitted to Congress with recommendations which included the construction of ten flood control reservoirs on the tributaries of the Connecticut River in the states of Vermont and New Hampshire.

2) "House Document 455, Seventy-fifth Congress, 2nd Session" was published in 1937. This report proposed a revised comprehensive plan for flood control of the Connecticut River and its

tributaries consisting of 20 reservoirs and dikes at seven locations. The report recommended that the authorization for additional reservoirs be deferred and that the authorized project be modified to provide for the protection by dikes and related works of cities.

3) "The Resources of New England - New York Region," as authorized in Section 205 of the Flood Control Act of 1950 (P. L. 516-81st Congress, Second Session) together with a Presidential Directive of 9 October 1950, establishing a six-member Federal interagency committee. This report recommended that the river basin and regional plans set forth in the report serve as a guide for the development, conservation, and utilization of land, water, and related resources of the New England - New York Region. The report is commonly referred to as NENYIAC. Part I and Chapter I of Part 2 are printed as SD 14, 85th Congress, 1st Session.

4) "Comprehensive Water and Related Land Resources Investigation, Connecticut River Basin," was published in June 1970. This report was authorized in resolution of the Committee on Public Works of the United States Senate, adopted 11 May 1962. The purpose of the report is to present a comprehensive plan of development that will serve as a flexible guide for the optimum utilization of the water and related land resources of the basin. Specific objectives of the studies made for this report were: to isolate the basin's problems and potentials related to its water and land resources; to develop possible solutions to these problems and formulate from them projects and programs to satisfy the immediate (1980) and to identify potential measures for long-range (2020) needs.

The study was directed and reviewed by the Connecticut River Basin Coordinating Committee composed of representatives of the Departments of Agriculture; Army; Commerce; Health, Education and Welfare; and the Interior; the Federal Power Commission; and the States of New Hampshire; Vermont; Massachusetts; Connecticut; and the New England River Basins Commission.

In formulating a plan to meet the needs and desires of the people in the Connecticut River Basin, the Coordinating Committee strove to insure that all elements be compatible and that programs and projects be flexible and adaptable to unforeseen demands and changing patterns of needs. Alternatives were given due and responsible consideration.

The Committee developed a plan to accomodate two time frames; namely, an "early action" plan covering the next ten years; and a long-range framework type plan embracing requirements and

opportunities to the year 2020. The 1980 Basin Plan, as recommended by the Coordinating Committee, is estimated to cost $1,800,000,000 (based on 1969 price levels). The proposals are presented in ten broad element categories as follows: Water Quality, Power, Outdoor Recreation, Preservation of Sites, Anadromous Fisheries Restoration, Resident Fish and Wildlife, Water Supply, Navigation, Upstream Water and Related Land Resource Potential, and Flood Control and Large Multiple-Purpose Reservoirs.

The water supply element of the 1980 Basin Plan is presented in five parts, four of which concern water supply requirements for the four basin States and part number five in regard to out of basin diversion of water supply.

Water supply needs are presented for each of the basin States in detail. The study finds that the natural abundance of available surface and groundwater supplies, if properly developed, can meet all projected municipal and industrial needs of the basin. Out of basin needs for the 1980 time period are recognized as being met by flood-skimming operations such as that proposed in conjunction with the Northfield Mountain pump storage power project. Similar flood-skimming operations potential was identified at the existing Corps of Engineers' Tully Reservoir located in the Millers River watershed.

Thus the need for, and potential of, servicing out of basin water supply demands from the Connecticut Basin was identified in the comprehensive study. The Northfield Mountain Water Supply Project, described in this report, therefore, is compatible[1] with the comprehensive Basin Plan.

5) "North Atlantic Regional Water Resources Study" was published in June 1972. This report was authorized in Section 208, Public Law 89-298, 27 October 1965. The purpose of the report was to present a comprehensive framework plan for the management of water, related land and other environmental resources in the North Atlantic Region of the nation, a region which closely approximates the NEWS study area.

The study was directed and reviewed by the North Atlantic Region Water Resources Study Coordinating Committee. This Coordinating Committee was comprised of representatives of the Departments of Agriculture; Army; Commerce; Housing and Urban Development; Interior; Transportation; Environmental Protection Agency; and the Federal Power Commission. The States of Vermont, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania,

(1) See New England River Basins Commission letter of 15 June 1973 in Appendix N.

Delaware, Maryland, West Virginia, and Virginia also served on the Committee as well as representatives of the District of Columbia, Delaware River Basin Commission and the New England River Basins Commission.

The Coordinating Committee used a multiple objective planning process to consider alternative objectives, needs, devices, benefits and costs to develop a 50-year management program for the Region's water and related land resources. Answers to all questions are not provided in this report. As a framework document only, guideposts are presented that will lead its users to more direct routes in finding answers related to water resources management and will lead users away from or warn them of potential pitfalls.

6) "Organizational, Legal and Public Finance Aspects of Water Supply for Southeastern New England the Metropolitan Area of New York City - Northern New Jersey - Western Connecticut," July 1972. This report was prepared as part of the overall Northeastern United States Water Supply Study (NEWS). The purpose of this report was to analyze organizational, legal, and economic problems of water supply within the study area. Alternative solutions to the problems are described and discussed.

The results of engineering studies supplemented by the results of this institutional feasibility study constitute the tools with which the Corps of Engineers and other agencies and organizations concerned may reach a decision on which of the various alternatives more detailed study effort should be concentrated.

7) In addition to the published reports described in the previous paragraphs, a report entitled "Feasibility Report on Alternative Regional Water Supply Plans for Southeastern New England" was recently prepared by the New England Division Division for the North Atlantic Division as part of the Northeastern United States Water Supply Study (NEWS). This report, as described in the summary, assesses the capability of the public water supply systems within eastern Massachusetts and Rhode Island to meet future needs. Plans and alternatives are proposed which when added to the present systems, would assure future adequate water supply for the study area.

C. State

1) Massachusetts

Massachusetts State Agencies with responsibility in water supply planning, construction and certification are the Department of Natural

Resources, the Metropolitan District Commission, and the Department of Public Health.

Studies regarding the present water supply situation in the Boston Metropolitan Region have provided a significant input to the preparation of this report. Some of the regional reports include:

a) Massachusetts Senate Document No. 1216, Report of the Metropolitan District Commission to Make an Investigation and Study Relative to Increasing the Sources of Water to the Metropolitan Water District and Increasing Membership of Said District, December 1971.

b) Hill and Lind, Inc., Report on Ipswich River District Water Supply, Prepared for the Massachusetts Water Resources Commission, Division of Water Resources, September 1971.

c) Massachusetts Senate Document No. 1008, Report of the Metropolitan District Commission Relative to the Diversion of Excess Water From Millers River and Other Sources Into Quabbin Reservoir, March 1971.

d) Massachusetts House Document No. 5543, Report of the Special Commission Relative to Providing Funds for Extension and Development of Water Supply Sources and Diversion of Water from Connecticut River to Quabbin Reservoir, May 1970.

e) Massachusetts Senate Document No. 1230, Report of the Metropolitan District Commission Relative to the Diversion of Excess Water From Millers and Other Sources Into Quabbin Reservoir As Required by Chapter 46, 1967, March 1969.

f) Massachusetts Senate Document No. 1095, Report of the Metropolitan District Commission Relative to the Diversion of Excess Water from Millers River and Other Sources into Quabbin Reservoir, December 1966.

g) Massachusetts Senate Document No. 808, Special Report of the Metropolitan District Commission Relative to Diversion of Excess Water from Millers River into Quabbin Reservoir, January 1966.

h) Massachusetts House Document No. 4100, The Public Water Supply Resources of the Ipswich River, Prepared for the Massachusetts Water Resources Commission, Division of Water Resources, January 1965.

2) Connecticut

In the State of Connecticut, responsibility for the adequacy and safety of public drinking water supplies lies with the Connecticut Department of Public Health. In addition to this agency's work, a large amount of regional water supply planning has been conducted by regional planning agencies and the private investor-owned water supply companies. In 1967, an Interagency Water Resources Planning Board was formed to coordinate and report the State's water resources. The agencies which make up the Board are the Office of Statewide Planning, Department of Environmental Protection and the Department of Public Health. Reports prepared by Connecticut State Agencies and reviewed as part of this study include:

a) Statewide Long Range Plan for the Management of the Water Resources of Connecticut, Phase I, Prepared by the Interagency Water Resources Planning Board, 1971.

b) Dewey and Kropper, Engineers, Inc., Effect of Proposed Northfield Mountain Diversion Project on State of Connecticut's Interests, Prepared for Connecticut Water Resources Commission, May 1966.

D. Regional Planning Agencies

Seven regional planning agencies in Massachusetts and Connecticut are located in the vicinity of and downstream from this study's project area. Those within Massachusetts are the Franklin County, Department of Planning and the Lower Pioneer Valley Regional Planning Commission. Within Connecticut, five agencies have been active. They are the Capitol Region, Midstate, Central Connecticut, Connecticut River Estuary and Southeastern Connecticut Regional Planning Agencies. A number of reports regarding future water supplies of the agencies' respective regions have been prepared and include:

1) Unpublished Report on Water Supply Needs in Franklin County, Massachusetts, 1971.

2) Metcalf and Eddy, Engineers, Inc., Water Supply Facilities, Prepared for the Lower Pioneer Valley Regional Planning Commission, March 1970.

3) James S. Minges and Associates, Alternative Plans for Regional Utilities Study, Prepared for the Capitol Region Planning Agency, June 1968.

4) Maguire, Charles A. and Associates, Regional Water Supply and Distribution in the Central Connecticut Planning Region, Prepared for the Central Connecticut Regional Planning Agency, March 1969.

5) Water Supply Plan for the Southeastern Connecticut Region, Volume 2, Recommended Plan, Prepared by the Southeastern Connecticut Water Authority and the Southeastern Connecticut Regional Planning Agency, February 1970.

In addition to reports prepared by planning groups in the Connecticut River Basin, water supply studies prepared by regional groups in eastern and central Massachusetts were also reviewed. These included:

6) Camp, Dresser and McKee Engineers, Inc., Alternative Regional Water Supply Systems For the Boston Metropolitan Area, Prepared for Metropolitan Area Planning Council, February 1971.

7) Metcalf and Eddy Engineers, Inc., Water Supply and Sewage Planning in Central Merrimack Valley Region, Prepared for Central Merrimack Valley Regional Planning Commission, September 1970.

8) Northern Middlesex Area Commission, Regional Utilities, Volume 2, Alternative Plans for Sewer and Water Facilities, July 1969.

9) Metcalf and Eddy Engineers, Inc., Report to Old Colony Planning Council, Brockton, Massachusetts, on Phase Three of Water and Sewerage Study, March 1971.

10) Tippetts - Abbett - McCarthy - Stratton, Regional Study for Water Supply, Sewerage Disposal and Drainage, Southeastern Massachusetts, Phase II, Prepared for Southeastern Massachusetts Regional Planning Commission, April 1969.

11) Maguire, Charles A. and Associates, Regional Water System Study, Prepared for the Connecticut River Estuary Regional Planning Agency, April 1972.

SECTION III

COORDINATION

5. Project Coordination

The study effort provided for direct participation and coordination by Federal, State and local agencies as well as interested conservation and citizen groups. To achieve full participation by all interested, a series of formal public meetings, progress meetings and informal informational meetings was employed.

All of these meetings and extensive letter communications furnished the principal means of contact with the public. Appendix H describes these meetings in detail including summaries of the statements made.

A. Public Meetings

A total of 13 formal public meetings were held within New England during the studies. Seven meetings were held at the outset of the NEWS investigations in May and June 1967. These meetings were held in all six New England States at Springfield and Waltham, Massachusetts; Portland, Maine; Concord, New Hampshire; Montpelier, Vermont; Bloomfield, Connecticut; and Providence, Rhode Island. At these meetings the background leading to the Northeastern United States Water Supply Study and the studies' objectives described. Citizen input was solicited and questions on the study were answered.

During December 1971 and January 1972, a series of four formulation stage public meetings were held in Needham, Woburn, Orange, and Longmeadow, Massachusetts. These meetings were designed to broaden public participation in the open planning process by describing on-going studies and receiving audience input. Some people spoke in favor of the plans presented. Others thought that we should concentrate on reducing demand instead of diverting more water to Eastern Massachusetts.

In July 1972 two late stage public meetings were held in Waltham and Orange, Massachusetts. At these meetings, the results of the NEWS investigations were described. Advantages and shortcomings of the

alternative proposals for meeting short-range water supply needs were outlined and discussed. Audience input at these meetings ranged from approval of the projects described as most advantageous to requests for modification of various elements and in some cases opposition to any of the diversions proposed.

A court stenographer was employed to provide permanent records of all three series of meetings. An abstract of the results of these meetings is given in Appendix H.

B. Progress Meetings

Since the initiation of these studies, a determined effort has been made to inform the public of the work's progress. Nine progress meetings were held in the Boston Metropolitan area, generally at Waltham, Massachusetts, the first held on 7 May 1970, with the latest held on 7 June 1972. Attendance at these meetings generally averaged about 50 people, with attendees representing Federal and State Agencies, conservation commissions, the Audubon Society, sportsmen groups, and interested citizens. Progress on various elements of the NEWS study was described by the study team. In an informal atmosphere, questions, answers and opinions were interchanged between the study team and audience. Input gained at these meetings served to guide the direction of the study and the final recommendations.

C. Information Meetings

In addition to the progress meetings, four informal information meetings were held within the Millers River Basin. These meetings were held in Athol, Massachusetts on 21 October 1971 and 4 January 1972, and in Winchendon, Massachusetts on 2 March 1972, and in Athol, Massachusetts on 8 May 1972. These meetings were held at the request of local government or citizens' groups and offered a further opportunity for public understanding of the study and public participation in its conduct.

D. Citizens' Participation Board

At the November progress meeting, a number of citizens stated a desire for formation of a "Citizens' Participation Board." The purpose of this Board was to act as an ombudsman for citizens in the watershed from which diversion of water was contemplated. Initiated in December 1971, this Board has worked with members of the study team to insure that views of the watershed citizens were known throughout the conduct of the study.

SECTION IV

PHYSIOGRAPHY - CONNECTICUT RIVER BASIN

6. Location

The Connecticut River Basin, shown on Plate No. 3, encompasses an area of about 11,250 square miles, of which 114 square miles are located in the Province of Quebec, Canada. The mainstem of the river traverses a length of more than 400 miles from the Canadian border to the tidal waters of Long Island Sound. The basin has a maximum width of 60 miles and includes land in 4 States. Land area in these States is distributed as follows: in New Hampshire, 3,047 square miles or about 28%; in the State of Vermont, approximately 3,928 square miles or about 35% of the drainage area; in the State of Massachusetts, about 2,726 square miles or approximately 24% of the basin area; and in the State of Connecticut, 1,436 square miles or about 13% of the study area.

The estuary is bounded by the mouth of the river at Saybrook. Here the river ends as it enters Long Island Sound. Throughout its entire length, the Connecticut River displays a rather unique profile, augmented along the way by many tributary streams. More than 200 dams, each controlling more than 50 square miles of drainage area, are harbored within the basin. Most of these dams are used for production of electric energy or for other manufacturing purposes. Several are used as municipal water supply reservoirs. Included are 16 flood control reservoirs constructed by the Corps, representing approximately 60% of a yet to be completed comprehensive flood control system. Many native lakes and ponds are available. For example, within New Hampshire alone, there are 199 of these ponds of over 10 acres, the largest of which is Lake Sunapee with 4,085 acres, followed by the First Connecticut Lake with 2,087 acres.

7. Natural Resources

A. Surface - Land Forms Elevation

The Connecticut River Basin is located within the Appalachian highlands of North America, which extends from Newfoundland to Alabama. The basin is entirely within the New England physiographic province which is further divided into sections, several of which have portions within the Connecticut River Basin.

Within the northeastern mountain delineation, one finds elevations varying from 1,000 to 4,000 feet above mean sea level with a few peaks up to 5,000 feet or more. Mount Washington, in the White Mountain range, has an elevation of 6,288 feet. In the New England upland section, elevations range from sea level in southern Connecticut to about 1,000 feet in the middle portion. Some hills rise to 2,000 feet, and there are a few peaks which rise above 3,000 feet. The Connecticut Valley lowland, which makes up the Connecticut and Massachusetts portion of the basin, has elevations which range from sea level between Hartford and Middletown to ridge crest 500 to more than 1,000 feet above sea level.

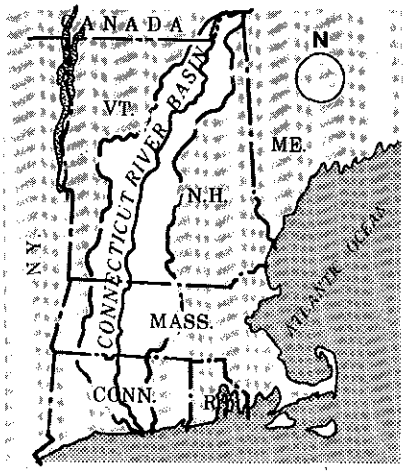
B. Geology - Soil - Mineral Resources

The northeastern mountains and the New England upland sections are underlain by crystalline bedrock which varies widely with regard to structure and rock type. These two land resources are underlain by metamorphic and igneous bedrock as well. The dominant rocks are gneiss, schist, phyllite, slate, and quartzite.

Known occurrences of minerals are numerous. Most of these minerals are located in areas that are not conducive for exploitation, at least under present economic technical conditions. However, there are important exceptions to this; namely, beryl, mica, gems, abrasive, feldspar, copper and dimension stone. Economically far more important are the triassic trap rock which forms an important source of crushed rock. It is used in a number of different projects and as an aggregate for concrete. Also of importance are the blue clays which are used for the manufacture of bricks and drain tile. Sand and gravel deposits are plentiful in the valley, particularly below Turners Falls and south to Middletown, Connecticut.

Soil condition and physiography of the area have a marked influence on its use. The most intensive agriculture in the basin is in the Connecticut Valley lowland. The silty and fine sandy soils on the high, level flood plains and terraces along the Connecticut River are largely devoted to the production of potatoes, nursery stock, and vegetables. The more sandy and gravelly soils on the till from triassic shales and sandstones are widely used for production of tobacco, potatoes, vegetable crops, and forage for dairy herds.

The New England upland is less suited to intensive agriculture than the Connecticut Valley lowland. Much of the present agriculture in this area is based on the bottom and terraced lands of the Connecticut River and its major tributaries included.



CANADA

VT.

N

N.H.

MAINE

VT.

N.H.

Upper Ammonoosuc R.

Moose R.

Passumpsic R.

St. Johnsbury

Ammonoosuc R.

Woodsville

CONNECTICUT RIVER

Ompompanoosuc R.

White R.

Ottauquechee R.

Mascoma R.

Hartland

Black R.

Sugar R.

Springfield

West R.

Brattleboro

Ashuelot R.

VT.

MASS.

N.H.

MASS.

Deerfield R.

Greenfield

Millers R.

Athol

Ware R.

Quaboag R.

Westfield R.

Chicopee R.

MASS.

CONN.

Farmington R.

New Britain

New Haven

New London

LONG ISLAND SOUND

NORTHEASTERN UNITED STATES WATER SUPPLY STUDY

CONNECTICUT RIVER BASIN

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

SCALE IN MILES

8 0 8 16 24

PLATE 3

C. Biological Productivity

The Connecticut River Basin extends from just inside the southern border of Canada southerly to Long Island Sound. During its trip to the ocean, water in the basin will pass through one or more life zones. The life zones, more fully described below, are those areas which contain a specialized system of plant and animals which have evolved through the years by means of climate and elevation. Being entities, there is little crossover between these zones except where they meet.

1) Sub-Arctic Zone - This type of environment is less than 1/10 of 1% of the total area of the basin. It is characteristically a treeless area of heath and bogs. Ground ferns, hardy members of the buttercup family, stunted willows and lichens like reindeer moss are the plants commonly associated with this type of area. The animals normally associated with this life zone are absent with the exception of insects notably a single species of butterfly found on Mt. Washington.

2) Boreal Forest - At lower elevations we find the taiga or boreal forest, characterized by spruce - fir associations. Snowy owls, Canadian lynx, and moose are the most striking animals associated with this life zone. Less remarkable but most often encountered are the varying hares, red squirrels, and Canada jays. Brook trout, a type of char, are found in the streams.

3) Temperate Hardwood Forest - The major portion of the basin is characteristically the hemlock - deciduous hardwood forests found in the central and lower portion of the basin. Maple, beech, hemlock, and pines are the dominant tree types in the area. In the woods of the lowest portion of this zone, oaks and hickory are frequently encountered. White tailed deer, black bear, gray fox and gray squirrel and cotton tail rabbits are characteristic animals of these forests.

4) Estuarine Zone - The lower Connecticut River Basin is influenced by the proximity to the marine environment, with tidal waters extending upstream to the vicinity of Hartford, Connecticut, a river distance of approximately 60 statute miles. Associated with this marine affected climate is a community of flora and fauna adapted ecologically.

As influenced by the tide, the streamside meadows and woodlands give way to tidal salt marshes. The grasses and shrubs found here

are identical to those found north and south along the coastal estuarines. The marsh animals are characterized by their ability to resist continual changes in salinity and periodic fluctuation in water level. Insects are largely replaced by the crustaceans such as crabs and shrimp, the freshwater clam gives way to the mussels, clams and other shellfish normally associated with estuaries. Freshwater fish species are replaced by species of the coastal waters such as silversides, varigated minnows, tomcods, and flounders.

D. Land Use

There are approximately 169,400 acres of water and 6,957,600 acres of land in the United States portion of the Connecticut River Basin study area. The distribution is as follows: 79 percent in forests; 9 percent in crop lands; 4 percent in pastures; 4 percent in urban and built-up areas; 4 percent carried in the "other" category. To the year 2020 this land use is projected to grow in the direction of urban and as follows: 79 percent will remain in forests; 10 percent will become urban and built-up; only 2 percent remaining in crop lands; 1 percent in pastures; and 8 percent in the "other" category.

Presently, over 85 percent of the land is privately owned by individuals or corporations, but the remainder is publicly owned. Farmers own about 1.7 million acres. Other private owners own about 4.5 million acres including that land in urban and built-up areas. Public ownership principally forested land consists of about 306,600 acres of Federal land in the Green Mountain and White Mountain National Forests and 410,000 acres of State, County and municipal lands. Some 17,000 acres of Federal land is also found in Corps of Engineers reservoir projects.

8. Climate

A. General

In addition to normal variation with latitude, the climate of the basin varies to a marked extent with differences in elevation. The Connecticut River Basin lies in the realm of prevailing westerlies, and as such, comes under the influence of cyclonic storms which traverse from the west and southwest. The southern part of the basin is also influenced by warm, moisture laden anti-cyclonic storms. In the winter months, highs from Canada bring arctic air into the basin. Precipitation is moderate and well distributed on an average annual

basis. However, monthly rainfall records show great variety from year to year. Individual storms rarely affect the basin in its entirety owing to the elongated character of the watershed. Generally, west to southwest airflow brings the hot dry weather which is responsible for occasional summer drought.

B. Precipitation

Mean annual precipitation over the entire basin averages 43 inches of water and ranges from 36 inches to 74 inches. Run-off, that portion of precipitation left after evaporation and transpiration, as well as deep underground flow to the sea, averaged about one-half or approximately 23 inches.

C. Temperature

The mean annual temperature for the basin is about 45°. It varies from 38° at First Connecticut Lake to 49° at Westbrook, Connecticut, near the mouth of the river. Average monthly temperatures vary widely throughout the year from between 63° and 74° in July and August to between 11° and 30° in January and February. Average daily temperatures range from occasional highs in the 100's to infrequent lows in the minus 40's in the northern portion and in the minus 20's in the southern portion. Frost-free periods range from 180 days in southern Connecticut to about 100 days at northern points.

D. Storms

There are three general types of storms that cause precipitation over the basin; namely, continental, coastal, and frontal storms. Continental storms originate over the western or central portion of the United States. They generally move easterly or northeasterly in direction and may be rapidly moving intense cyclones or the stationary frontal type. They are not limited to any season or month, but follow one another at more or less regular intervals with varying intensities throughout the year. Tropical hurricanes, the most severe of the coastal storms originate in the South Atlantic or Western Carribean Sea. They usually move in a westerly direction, recurving to a more northerly path near the mainland and then northeast approaching New England. Although the general path is to the south and east of New England, they may be drawn over this area by continental cyclonic disturbances, or deflected by a large slow anti-cyclone center, sometimes referred to as a blocking high and generally located to the east of New England. Hurricanes have occurred during the late summer or fall

months with a higher incidence in August and September. Extra-tropical coastal storms generally originate near the Middle Atlantic States. They travel northward along the coastline and frequently occur during the autumn, winter and spring months.

9. Water

A. General

The Connecticut River mainstem follows a general southerly course along the approximate center line of its watershed for about 404 miles to its mouth on Long Island Sound at Saybrook, Connecticut. The lower 60-mile reach of the river is tidal having a mean tidal range during low river stages of 3.4 feet at the mouth and about 1.2 feet at Hartford, some 52 miles upstream of the mouth.

B. Flow and Fall

The Connecticut River mainstem in its total length has a total fall of about 2,650 feet. In the initial 30 miles from its origin at the Canadian border, the river accomplishes half of this total fall. From this point, approximately at the First Connecticut Lake, and proceeding to tide-water at Hartford, Connecticut, a distance of about 360 miles, the river accomplishes a fall of about 1,640 feet. In the lower reaches of the river, the average annual flow is approximately 16,000 cubic feet per second, or equivalent to 23 inches of run-off. A review of hydrologic records in the valley indicates that during low flow periods, flows on some of the tributaries dropped to less than .1 csm, and on an average, approximately .15 csm. This is contrasted to the average annual figure of 1.6 csm, that represents nearly 1 million gallons a day per square mile of drainage area. It can be seen, therefore, that summer low flows contrast markedly with average flows and represent about 1/10 of the yearly average flow.

C. Reservoirs - Lakes - Ponds

The Connecticut River is blessed with numerous bodies of water, some natural and others man-made. For example, there are 172 bodies of water that range in size from 100 to 499 acres. Of this amount, 29 are used for water supply purposes and 143 are used for non-water supply purposes.

D. Estuary

The shell fisheries of the Connecticut River estuary are not extensive nor do they support any significantly important commercial enterprise. Oyster operators do a small amount of commercial oystering on beds near the mouth of the river, however, the harvesting of soft-shell clams and hard clams has not been important in recent years. The major value of the estuary from an ecological viewpoint is that within the estuary the basic formation of the food chain and life cycle of estuarine dependent species occurs.

The lower river thrives as a recreational boating center. Power boats, sail boats, water skiers, skim over its waters, while its shores provide safe harbor for small and large craft. Marina development is steadily creeping up the river, and in most cases is taking place on tidal wetlands, a vital resource to the fisheries.

E. Wetlands

The Connecticut Valley is a migratory route for considerable numbers of waterfowl. Many of these birds pass through without tarrying. Principal waterfowl habitat in the upper basin is the main stem of the river; the Ox Bow Ponds, primarily in New Hampshire between Stratford and Lancaster; the numerous natural lakes, ponds, and bogs; and innumerable beaver flowages.

There are a number of excellent marshes near the mouth of the river in the Connecticut mainstem with heavy waterfowl usage. Great Island, Ragged Rock Creek, Lord's Cove, Selden Neck, North Cove, Essex, Cromwell Meadows, and South Windsor marshes are waterfowl habitat areas receiving heaviest use.

F. Groundwater

A reconnaissance of the groundwater resource of the Connecticut River Basin has been performed by the U. S. Geological Survey of the Department of the Interior. The report summarized that groundwater is available in large quantities in some of the larger valleys from sands and gravels of glacial-fluvial and alluvial origin. Groundwater recharge is about equal to 1 million gallons per square mile in unconsolidated sandy sediment. Where earth material is underlain in large part by consolidated rock, this drops to 1/3 MGD per square mile. The total quantity of groundwater available from the basin is perhaps more than 1 billion gallons per day. The more generous amounts are located in the upper watershed where demands are lightest.

SECTION V

ECONOMIC DEVELOPMENT

10. General

This section is drawn from data contained in Appendix A and describes the past and projected changes in the economic growth of the source area within the Connecticut River Basin and the service area, the Boston Metropolitan Region. For purposes of this analysis, the source area is considered to be Franklin County, Massachusetts. This choice was made since the Northfield Mountain Project lies within its boundaries and any impacts caused by the project would be expected to be largest here.

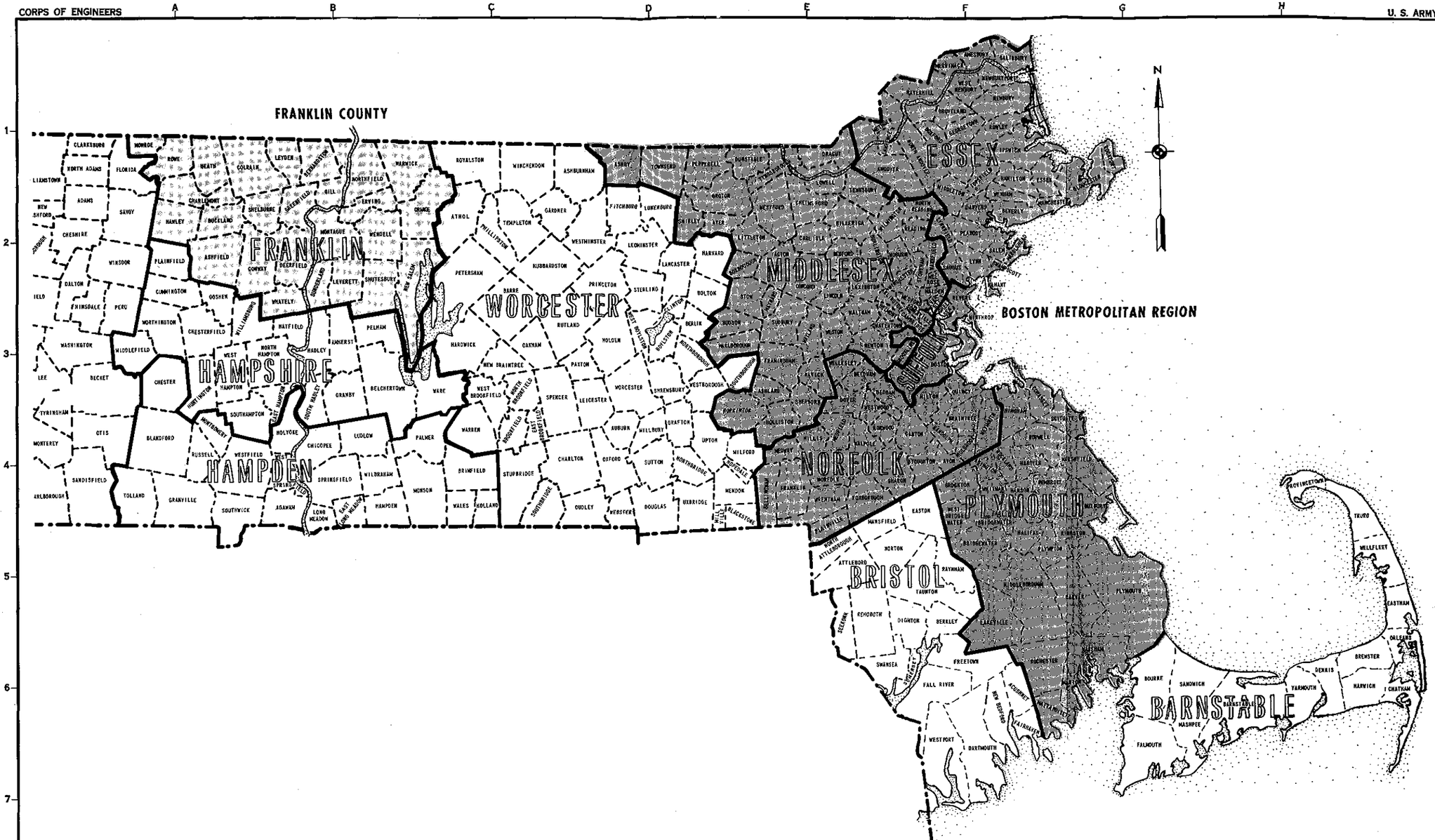
A discussion of the historical forces which have been influential in shaping both regions' present day economic characteristics is given. This discussion then sets the stage for the analysis of future economic growth for both the Franklin County and Boston Economic Areas.

11. Measures of Economic Activity

Economic changes can be measured by a set of interrelated variables; namely, population, labor force employment, personal income and net output. These indicators express in economic terms the need for water resource development in an area. Especially important are the numbers of people projected to live in an area and any expected changes in industrial activity.

National projections of the overall economy for both regions were made in terms of benchmark aggregates such as gross national product, population, personal income and employment. From these summary measures were derived national totals of the economic series to be projected for local areas. Implicit in this procedure is the fact that national forces clearly dominate economic development throughout the nation. Because of the lack of gross area product data which could be compared to gross national product data, other indications of economic activity at the regional level are utilized. Employment data available in detail at the regional level are used to indicate changes in industrial activity and total personal income provides an overall measure of regional economic growth.

CORPS OF ENGINEERS U. S. ARMY



NORTHEASTERN UNITED STATES
WATER SUPPLY STUDY

ECONOMIC AREAS

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

PLATE 4

12. Past Trends in Economic Growth

Franklin County is divided almost in half by the Connecticut River. West of the Connecticut, the rugged terrain and well defined valleys, especially in the northwestern portion along the famed Mohawk Trail, provide some of the most beautiful scenery and panoramic views in Massachusetts. East of the river, the elevations are more moderate and the terrain mostly covered with rolling hills. Here, the Millers River, a tributary of the Connecticut, also provides tourists with additional recreation opportunities. Five ski areas and facilities for boating, camping, hunting, picnicking, and swimming in various combinations at several state forests and parks make the County a desirable year-round vacation area. A large section of Quabbin Reservoir, which supplies many of the municipalities of Metropolitan Boston, is located in the southeast corner of the County.

Beginning with the earliest settlements in the late 1600's, agriculture was the major industry with areas too steep for plowing used for sheep grazing. The plains yielded crops of wheat, tobacco, and corn without too much difficulty, and by the late 1800's, the County had grown to be the largest potato producing area in Massachusetts.

The abundance of water was a prime factor in the early development of hydro-electric power in the region. Later, the same abundance of water was a prime factor for the siting of a nuclear power plant of the Yankee Atomic Electric Company in the town of Rowe.

At present, Franklin County is a predominantly rural area with several industrialized areas concentrated in the central and eastern sectors. In many ways, the County has more in common with southern Vermont than with the remainder of Massachusetts. It is a slow growth region with low population density, has no large metropolitan area, and its labor force, a product of the economic structure, is composed of mainly blue collar workers and few white collar workers.

The only higher educational facility located in the County is Greenfield Community College. Deerfield Academy, one of the oldest boarding schools in the country, Englebrook, a preparatory school for boys, and Bement, coeducational, constitute the major industry for the town of Deerfield. Located in surrounding towns, however, are several major schools of higher learning including the University of Massachusetts, Amherst College, and Hampshire College in Amherst, Smith and Northampton Commercial College in Northampton, Mount Holyoke College in South Hadley, Williams College in Williamstown, the State College at North Adams, and Mount Wachusett Community College in Gardner.

Among the County's primarily basic or export industries, manufacturing and agriculture stand out as being the most significant. Manufacturing now, as it has throughout the early 1900's, contributes the most to the economy of the region as measured by the number of persons employed, the next most important sector being services.

In 1963, the seven largest manufacturing groups, in order of importance as employers, were non-electrical machinery, paper and allied products, fabricated metal products, textile mill products, food and kindred products, lumber and wood products, and printing and publishing. The manufacture of non-electrical machinery and fabricated metal products alone accounts for about one-half of total manufacturing employment.

In 1970, the major water using manufacturing industries in the County; namely, food and kindred products, textile mill products, paper and allied products, employed 2,256 persons. This represented approximately 30 percent of manufacturing employment and 10 percent of total employment in the County for that year. Total employment in these industries has remained relatively stable between 1956 and 1970. Hidden within these totals, however, are substantial declines in textiles and increases in food and kindred products.

The only remaining natural resource industries are food processing and lumber products manufacture which together provided 8.6 percent of manufacturing employment in 1963. The paper industry originally located in the County because of locational factors such as closeness to markets, low cost labor and low transport costs. These advantages no longer exist today. The remaining manufacturing industries, not dependent on natural resources, are producing products which can be described as high-valued and lightweight.

As for agriculture, once Franklin County's most thriving industry, it is today the most rapidly declining sector in terms of employment. The primary cause, as elsewhere in the Connecticut River Valley, is the rising value of farm land in alternative uses resulting from expanding urbanization with its high taxes and wage levels.

On the other hand, the service area, the Boston Metropolitan Area, was one of the earliest settled areas of the United States and has for many years experienced a high level of urbanization. Only in recent years, however, have the outer most towns of the area begun to feel the urban pressures. Like the Franklin County Economic Area, farming was the principal occupation of early settlers and the abundance of water power was a vital factor in the industrialization of the area.

However, the Boston Area also has good marine resources and soon became one of the most important commercial and trade centers on the east coast.

Today, the Boston Metropolitan Area is geographically and economically the center of the largest employment and population cluster in New England. This cluster is the northern terminus of "megalopolis," the Atlantic coastal strip between Washington and Boston, in which live approximately one-fifth of the United States' population. Boston, the central city, is the Massachusetts State Capital, the most populous city in New England, and the center of the eighth largest SMSA in the country. While only secondarily a manufacturing center, the city's primary function in the area is as a trade and finance center. In the economic area as a whole, however, manufacturing has the largest share of total employment, followed by the service industries. Specialization occurs in miscellaneous manufacturing, electrical machinery, textiles, professional services, trade and construction. In recent years, the Boston area has experienced a remarkable growth in technologically-oriented industries which have located here in response to, or as spinoffs of, the concentration of advanced education and research facilities.

13. Projected Economic Growth

Projections are based on extensions of past relationships believed to have future relevance for the measures being projected. Underlying these extensions of past relationships are assumptions that make the projections conditional forecasts. For instance, it is assumed that the Federal government will implement policies needed to maintain relatively full employment and avoid prolonged levels of inflation and that the economy will be free of the distorting effects of a major military conflict during the 50-year projections interval. It is assumed that water will play the same role in stimulating or depressing economic growth in the future as it has in the past.

In general, the examined historical data and projections derived indicate that both the Franklin County and Boston Metropolitan Area economies will continue to expand and prosper in the period 1970 - 2020. The projected rates of expansion for the two regions, however, differ markedly. In the process of expansion, both areas will continue to export valuable services and/or manufactured goods beyond their boundaries. Changes within and around the area's various economic sectors are, of course, inevitable and will play a dominant role in determining

the region's growth paths. Population, urbanization, employment, personal income and the nature and co-position of the industrial and business mix of the economies will all be of special relevance to the diverse water resource problems and needs of the two areas.

Population in the Franklin County Economic Area is expected to increase from 58,853 in 1970 by a factor of 1.4, to 80,000 people by the year 2020, although a decline is anticipated in relation to the total population of New England from about 0.5 percent to about 0.4 percent of the six-state figure. At the same time, population in the Boston Metropolitan Area is expected to increase from 3,652,000 in 1970 by a factor of 1.7 to 6,126,000 by the year 2020. Here again, a decline is anticipated in relation to the total population of New England from 31.3 percent to 30.9 percent of the six-state figure.

Total personal income in the Franklin County Economic Area is expected to rise by a factor of 4.9 by the end of the projection period. Since the area's population will be 1.35 times greater, per capita personal income will rise about 3.6 times present levels. At the same time, total personal income in the Boston Metropolitan Area is projected to increase by a factor of 6.3. Thus, per capita personal income in the Boston Area will increase close to 3.7 over the projection period.

The manufacturing sectors in both the Franklin County Economic Area and the Boston Metropolitan Area are projected to decline relative to the non-manufacturing sectors in importance as sources of employment. Employment in Franklin County's manufacturing industries is expected to drop from 33 percent of total employment in 1970 to roughly 25 percent by the year 2020. In the Boston Area, manufacturing employment as a percentage of total employment is projected to decline from 29 percent to 20 percent over the projection interval. By the year 2020, there will be more employees in non-manufacturing jobs than in manufacturing positions in both areas. Employment in the services is expected to increase 93 percent by the year 2020 in Franklin County and 153 percent in the Boston Metropolitan Area. Expanding population and rising personal income indicate further advances for urban services such as finance, insurance, real estate and medicine and health in the Boston Metropolitan Area. Thus, the projections of manufacturing and non-manufacturing employment show the structural shifts which both economies are expected to experience.

The major water using industries in both the source and service area include food and kindred products, textile mill products, chemical and allied products, petroleum refining and primary metals industries. In

the Boston Area, employment in food, textiles, and petroleum are projected to decrease greatly while employment in the chemical and paper industries is expected to more than double by 2020. Projections specific to Franklin County's water using industry are not available. However, available past employment data as shown in Table A-9 indicate that total future employment in these industries can be expected to remain stable during the projection interval.

In 1970, Franklin County had a total of about 2,300 people employed in the water using industries, while the Boston Area had a total of about 171,000 employed. Thus, the Boston Region industries employed about seventy-five times as many people as in Franklin County. In both areas, the economic production per employee is projected to dramatically increase. Therefore, the economic production in dollars for the water using industries in both areas is actually increasing. In absolute terms, however, the production of the Boston Region far exceeds Franklin County.

SECTION VI

THE WATER SUPPLY SETTING

13. General

A. Sixties Drought

As recognized in the NEWS Legislation, natural departures from normal precipitation and runoff conditions can have regional impacts on the social well-being of a large segment of the nation's population.

The long-term normal rainfall in southeastern New England is about 42 inches per year. This "normal" condition is actually the average of many high and low rainfall years. When rainfall is below average for a period of time, the area experiences a drought. The recent drought of the sixties in southeastern New England, for its duration, was the greatest ever experienced in the region based on over 200 years of rainfall record.

Because of the severity of this drought, many water supply systems were required to re-evaluate the dependable yield which their facilities could be relied on to produce. For example, the Metropolitan District Commission which, based on previous drought conditions, had estimated available sources at 330 million gallons per day (mgd) revised their dependable yield figure downward to 300 mgd.

The sixties' drought which began in 1961 when precipitation and water levels fell below normal, ultimately through its duration, directly affected the water use patterns of more than 20 million people. In 1965 alone, drought related water shortages and associated problems were severe enough to warrant emergency actions by local, state and Federal agencies. Within Massachusetts, more than 50 cities and towns imposed restrictions on water use.

B. Water Supply Agency Action

During and following the drought, a number of communities and regional planning agencies conducted engineering studies to determine methods for augmenting their existing supplies. In many cases, new supplies have been developed by the communities which would allow them to meet future supply needs. Investigations conducted by NEWS in the southeastern New England region, however, indicate that even

with the actions undertaken by local authorities, additional supplies must be made available.

It is anticipated that as water requirements increase and local water resources are fully developed, particularly in urban areas, many municipal systems will likely join some of the major systems, such as the Metropolitan District Commission (MDC) and increase the regional character of these systems. A description of the MDC system is given in the following paragraphs.

14. Existing Regional System - Metropolitan District Commission - (Boston)

The Metropolitan District Commission (Boston) is the largest regional system within New England. At present, this system supplies either wholly or partially the water supply needs of 42 communities within the Commonwealth of Massachusetts. Consumers of the serviced population number about two million or fully 37 percent of the Commonwealth's 1970 population.

Existing dependable yield of the system is estimated to be 300 mgd. Average daily water consumption furnished by the system in 1971 was 322 million gallons per day (thus the system is outstripping available supply) of which 273 mgd was delivered to municipalities which rely exclusively upon the MDC as their only supply source. A plan of the communities is shown on Plate No. 5.

The MDC relies upon surface water as its supply source. Three major reservoirs: Quabbin, Wachusett and Sudbury impound flow from tributaries of both the Connecticut and Merrimack River Basins. A plan showing the location of these reservoirs and interconnecting aqueducts is shown on Plate No. 6.

The Quabbin Reservoir, located in the center of Worcester County, is the backbone of the MDC system. It impounds the runoff from 186 square miles of the Swift River Watershed and flow diverted from 98 square miles of the Ware River Watershed, both tributaries of the Connecticut River. It has a capacity of 412 billion gallons at full reservoir elevation and is approximately 18 miles long.

The water from Quabbin Reservoir flows through the Quabbin Aqueduct for a distance of 24.6 miles to the upper end of Wachusett Reservoir in West Boylston. This aqueduct, which is "horseshoe" shaped, is excavated through solid rock and line with concrete. Provisions have been made at the Ware River Intake Works at Coldbrook to divert the

flood flows from approximately 98 square miles of the Ware River Watershed into the aqueduct for storage in either the Quabbin Reservoir or the Wachusett Reservoir. Under ordinary circumstances, the water is diverted directly to the Quabbin Reservoir for storage and then is drawn back into the Wachusett Reservoir as occasion requires.

The Wachusett Reservoir on the Nashua River, a tributary of the Merrimack River, above Clinton, was the principal reservoir of the MDC system prior to the construction of Quabbin Reservoir. It has a watershed of 107.7 square miles and a capacity of 65 billion gallons. It is approximately 8.4 miles long with a surface area of 6.5 square miles.

The water has two means of conveyance from Wachusett Reservoir -- the Wachusett Aqueduct and the recently completed Wachusett - Marlborough tunnel. The Wachusett Aqueduct consists of a rock tunnel section 2 miles in length, a brick and masonry conduit, "horseshoe" shaped, 7 miles in length and an open channel section of 20 feet wide at the bottom and 3 miles in length. The open channel section terminates in the Sudbury Reservoir in Southborough.

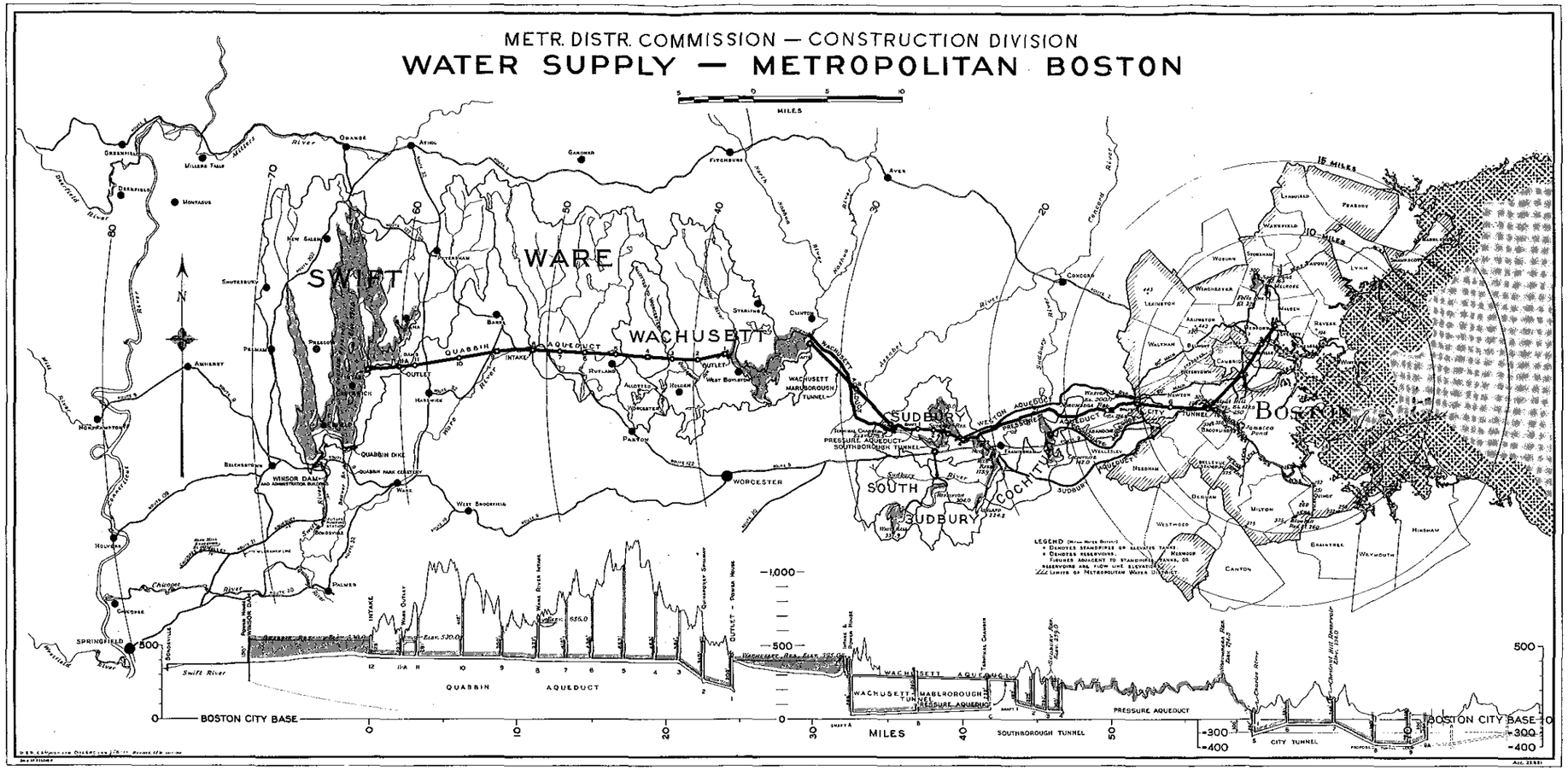
The major portion of the water supplied by the Wachusett Aqueduct is diverted at a diversion dam on the open channel section of the aqueduct in Marlborough into the Hultman Aqueduct. The remaining water flows into the Sudbury Reservoir.

The Sudbury Reservoir is situated on the north branch of the Sudbury River and impounds the runoff of approximately 22 square miles of watershed; has a storage capacity of approximately 7 billion gallons.

During summer months, large quantities of water flow from this reservoir through the Sudbury Aqueduct to the Chestnut Hill Reservoir in Brighton. From there, it is pumped into the distribution system.

The new Wachusett-Marlborough Aqueduct is a deep rock concrete lined tunnel, 8.0 miles long. It extends from the Wachusett Reservoir to the Hultman Aqueduct intake structure. The major portion of the water supply requirements of the Metropolitan Water District is delivered through this aqueduct to the Hultman Aqueduct and thence to the Norumbega and Weston distribution reservoirs.

The Hultman Aqueduct begins at the previously mentioned diversion dam located on the open channel section of the Wachusett Aqueduct. It extends from this point 22.7 miles in an easterly direction to the Chestnut Hill Reservoir and pumping stations. This aqueduct consists of cut and cover concrete conduit and a section of hardrock tunnel. At the



NORTHEASTERN UNITED STATES
WATER SUPPLY STUDY

METROPOLITAN DISTRICT COMMISSION
EXISTING WATER SUPPLY SYSTEM

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

Sudbury Dam, it is interconnected to the Weston Aqueduct which is a cut and cover conduit extending to the low pressure service Weston Reservoir.

From an intake shaft at Norumbega, the City tunnel runs a distance of approximately 5 miles to a point in the vicinity of the Chestnut Hill Reservoir in Boston, where it is connected directly to several large distribution mains which convey the water to several of the communities serviced by the Low Service, Southern High and Southern Extra High distribution systems. The City tunnel, reduced from 12 feet to 10 feet in diameter, extends from Chestnut Hill Reservoir, a distance of approximately 7 miles, to a point in Malden, where it is connected directly into large distribution mains which convey the water to other communities serviced by the Low Service and Northern High Service distribution systems. Presently, construction of an additional deep rock tunnel, extending from Chestnut Hill Reservoir in Boston to a point in the vicinity of the Boston-Milton town line at Dorchester Lower Mills, is under way. The completed construction of this tunnel will enable the Commission to improve pressures in its Southern High Service distribution system.

The Chicopee Valley Aqueduct, consisting of 36 and 48 inch pipe, conveys water from the Quabbin Reservoir to the town of Wilbraham, South Hadley Fire District No. 1, and the city of Chicopee, extends from the outlet works of Winsor Dam to the Keating Hill Standpipe of the city of Chicopee.

Water supplied to consumers in the Metropolitan Water District is treated with small amounts of chlorine and ammonia as it enters the distribution system. Occasionally it is necessary to treat some of the storage and distribution reservoirs with small amounts of copper sulphate in order to combat algae growths which materialize from time to time. The Water Division of the Metropolitan District Commission maintains three laboratories, one at the Quabbin Reservoir, another in Framingham, and a third in Boston.

Pertinent data on the three major source reservoirs is shown in the following table:

TABLE 8

METROPOLITAN DISTRICT COMMISSION
SYSTEM SOURCES

	Location	Drainage Area Sq. Mi.	Storage Capacity (mg)
Sudbury:	Southborough Marlborough	22.0	7,000
Wachusett:	West Boylston Sterling Clinton Boylston	107.7	65,000
Quabbin:	New Salem Petersham Hardwick Ware Belchertown	284.8 [1]	412,000
	TOTAL	414.5	484,000

[1] Includes 96.8 square miles of Ware River Watershed

15. Local Resource Potential

A. General

In estimating needs which might be required of the existing regional supply system (MDC), the role which locally available resources might play was investigated. The majority of new communities reported in this study as requiring connection to the regional system to meet future needs was the result of engineering studies[1] conducted by the Metropolitan Area Planning Council (MAPC). The MAPC comprises 98 municipalities in the Boston Metropolitan Region which include the majority of presently serviced MDC communities and the MDC's future short-range customers. In the following paragraphs, a brief summary of the MAPC engineering studies pertaining to local resource potential development is given.

"The purpose of this study is to identify and evaluate alternative water supply systems which may be developed to satisfy the water supply demands of the communities in the Council District through the year 1990. These systems would supplement the existing and potential local supply systems. The need for supplementing the existing supplies of most of the communities within the District was concluded from investigations conducted in conjunction with the 1969 Needs and Proposals report.

These investigations indicated that, of the 98 communities in the Council, only two communities had existing supplies capable of meeting projected 1990 demands, and only 17 communities outside of the communities served by the Metropolitan District Commission (MDC) reported potential supplies which, together with the existing supplies, could meet the 1990 demands.

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[1] Inventory of Water and Sewer Facilities, May 1967, Metropolitan Area Planning Council and Massachusetts Department of Commerce and Development, by Camp, Dresser & McKee, Consulting Engineers.

Projected Needs and Current Proposals for Water and Sewer Facilities, July 1969, Metropolitan Area Planning Council, by Camp, Dresser & McKee, Consulting Engineers.

Alternative Regional Water Supply Systems for the Boston Metropolitan Area, February 1971, Metropolitan Area Planning Council, by Camp, Dresser & McKee, Consulting Engineers.

The supplemental water systems discussed were developed along criteria and design guidelines chosen to be sufficiently generalized to permit use throughout the District, yet detailed enough to produce systems which were technically sound. The efficient development of a water supply system to meet the projected demands of the communities within the Council District will require further detailed studies of the most favorable alternatives presented in this study. All systems were developed without regard to institutional constraints. Particular emphasis was placed on the development of subdistrict systems which would serve a portion of the Council District through the utilization of local resources.

Five individual subdistricts were established as follows: the Charles River Subdistrict, the Concord River Subdistrict, the Ipswich River Subdistrict, the Neponset River Subdistrict, and the North River Subdistrict. A plan of the subdistricts is shown on Plate No. 7.

The supplemental needs of the individual communities were determined by comparing projected demands with the estimated safe yield of the existing and potential community supplies. Needs were assessed in accordance with the study policy that all local potential supplies were to be developed.

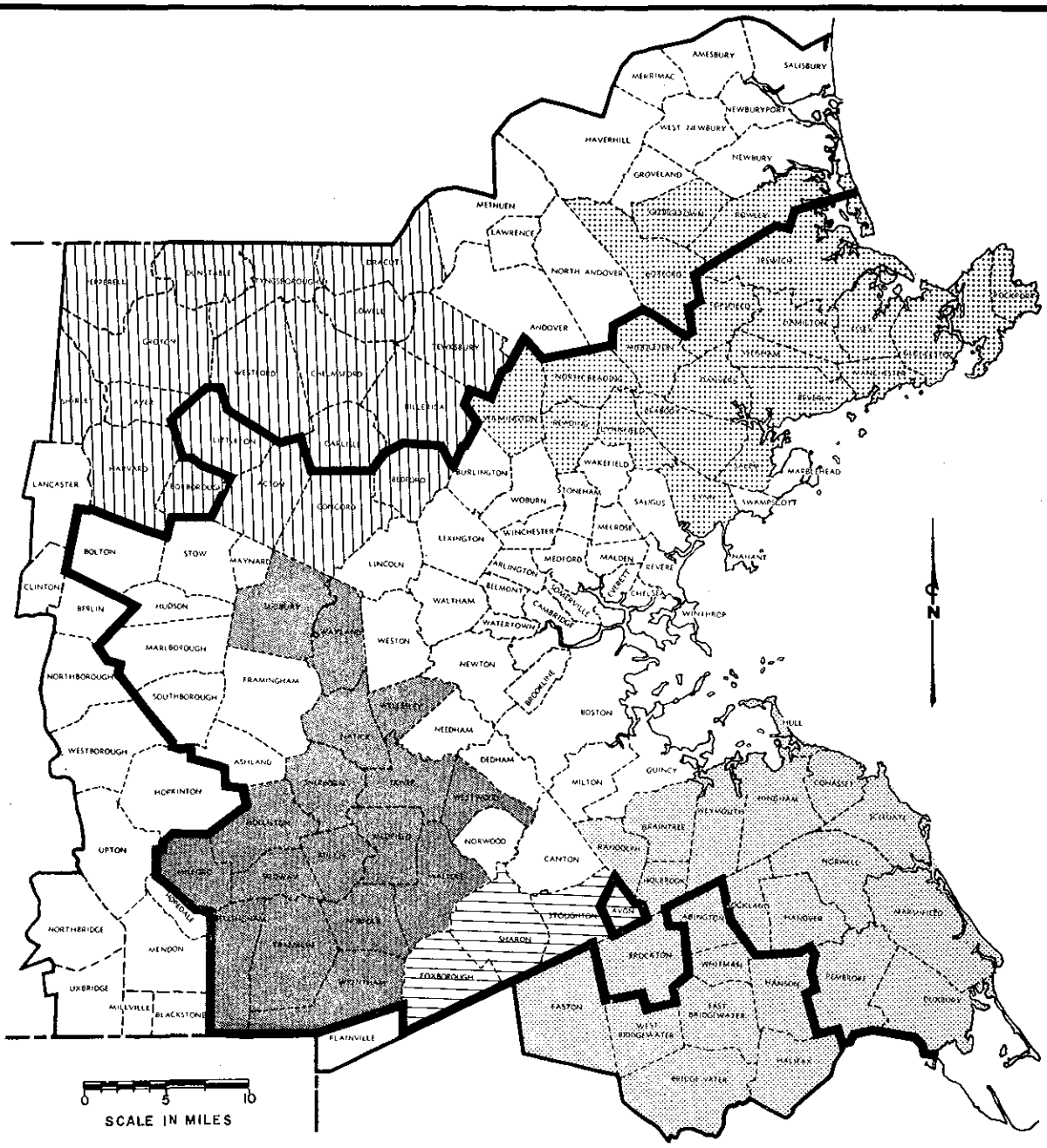
The needs may change in time as additional potential local supplies are discovered, or potential supplies must be abandoned.

It is emphasized that all potential groundwater sources must be fully explored, and development seriously considered even though the water is of quality that will require treatment.

B. Subdistrict Water Systems

The majority of the supplies to be developed to supply the subdistrict system will be surface supplies with either on or off stream reservoirs. It is imperative that before any of these alternatives are adopted, studies be conducted to investigate fully the environmental implications of these diversions.

1) Ipswich River Subdistrict: Two of the communities listed below have adequate existing supplies to meet their projected 1990 demands. An additional six communities have potential supplies which could adequately supplement their existing supplies through 1990. However, the potential supplies in five of the communities and the existing supplies in one of the communities make use of the Ipswich River.



LEGEND

- IPSWICH RIVER SUBDISTRICT
- CONCORD RIVER SUBDISTRICT
- CHARLES RIVER SUBDISTRICT
- NEPONSET RIVER SUBDISTRICT
- NORTH RIVER SUBDISTRICT

NOTE:

FROM ALTERNATIVE REGIONAL WATER SUPPLY SYSTEMS FOR THE BOSTON METROPOLITAN AREA, PREPARED FOR THE METROPOLITAN AREA PLANNING COUNCIL, BY CAMP, DRESSEN AND MCKEE, FEBRUARY 1971.

NORTHEASTERN UNITED STATES WATER SUPPLY STUDY

MAPC SUBDISTRICT AREAS

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

Beverly	Ipswich	Reading
Boxford*	Lynn	Rockport
Danvers	Lynnfield	Rowley*
Essex	Manchester	Salem
Georgetown*	Middleton	Topsfield
Gloucester	North Reading	Wenham
Hamilton	Peabody	Wilmington

*Not in Council District

The Ipswich River does not have the capacity to meet these collective demands. Unless the Ipswich River is supplemented, it will be unable to supply sufficient additional yield to even the communities which now pump from it. Through the construction of three new off-stream reservoirs, together with a diversion system from the Merrimack River, the Ipswich River can be developed to adequately supplement the existing and potential supplies of the communities in the Ipswich River Subdistrict. The Merrimack River is the only possible source which would permit diversion to the Ipswich during dry periods, thus reducing the size of the off-stream reservoirs required. The longer the period of diversion, the smaller the size of the reservoirs required to produce the same yield. Under present conditions, the diversion works would be located above the City of Lowell in the Town of Tyngsborough with water being transmitted about 17.6 miles to Lubber Brook in Wilmington, a tributary of the Ipswich. If the quality of the water in the Merrimack River was upgraded, the diversion works could be moved downstream to Andover, thus decreasing the length of the raw water transmission main.

Diversions would then be made from the Ipswich River at three general locations. At the first location, diversions would be made to a proposed 1800 million gallon (mg) regional reservoir in Lynnfield and to the existing Lynn and Peabody Reservoirs. The second diversion would occur downstream off Route 1 in Topsfield and would supply the proposed 1800 mg Topsfield reservoir. This new reservoir would be operated in conjunction with the existing facilities of the Salem and Beverly Water Supply Board. The third diversion would be located in Ipswich. Water would be pumped to the proposed 2800 mg Ipswich Reservoir.

2) Concord River Subdistrict: None of the MAPC communities in this subdistrict will be able to adequately meet their projected 1990 demands. However, the communities in the Concord River Subdistrict

can also be supplied by the Merrimack River. This subdistrict includes four MAPC communities, Acton, Bedford, Concord and Littleton, and 13 communities adjacent to the Council District.

These communities would take their supply at the same location as the diversion works proposed for the Ipswich River Subdistrict mentioned above. The two pumping facilities may, in fact, be combined. If, however, both subdistrict systems are developed, it may be necessary to develop either additional storage facilities or a special working schedule to eliminate combined diverting during short periods of extreme low flows and thereby degrading water quality. The need will depend to a large degree on the number of the communities outside the MAPC District which would be supplied by the Concord River Subdistrict system.

3) Charles River Subdistrict: The third subdistrict considered includes the 17 communities in or adjacent to the Charles River watershed and listed below:

Bellingham	Milford	Walpole
Dover	Millis	Wayland
Franklin	Natick	Wellesley
Holliston	Norfolk	Westwood
Medfield	Sherborn	Wrentham
Medway	Sudbury	

Five of these communities can develop potential supplies to adequately meet their projected 1990 demands. The communities in this subdistrict have been subdivided into two groups, the Upper and the Middle Charles River Groups. By developing the abundant potential local supplies of Franklin and Milford and interconnecting the individual systems, the six communities in the Upper Charles River Group can adequately meet their projected 1990 demands. The 11 communities in the Middle Charles River Group can extend the adequacy of their systems by grouping together similar to the Upper Charles River Group.

However, unless the MDC is extended to supply Sudbury, Medfield, Norfolk and Dedham, the combined 1990 demands cannot be met even if all potential supplies are developed. Following the completion of the MAPC study, the NEWS study requested the opinion of the U. S. Geological Survey (USGS) concerning the hydraulic relationship of the well field proposed for the Middle Charles River Group and the River. The USGS replied they felt the proposed well fields were directly linked to the nearby river. With such a link, the well field in essence would be drawing from river flow, particularly in low flow periods. Low flow

conditions in the Charles River at present are a critical factor in the river's water quality. It was felt that any substantial decrease in flow caused by withdrawals for water supply would increase water quality problems. Thus, the NEWS study proposed communities listed as middle Charles to be served by connection to the regional system.

4) Neponset River Subdistrict: Only the town of Sharon in this subdistrict, consisting of Avon, Foxborough, Sharon and Stoughton, can develop supply adequate through 1990. The remaining three subdistrict communities will require an outside supplementing source of supply. The projected 1990 demand of the Neponset River Subdistrict can be adequately met through the development of Ponkapoag Pond as a water supply reservoir. By raising the level of the Pond some 19 feet, adequate storage capacity can be provided to receive flood flows pumped from the Neponset River. Water would be pumped from the Neponset River only during periods when the flow exceeds 25 cubic feet per second (cfs). During dry periods, pumping will be permitted only over a few months of the year. In order to provide sufficient yield, it will be necessary to provide pumping capacity greatly in excess of the estimated safe yield of the system.

5) North River Subdistrict: The fifth subdistrict system investigated would provide supplemental supply to communities located south and southeast of Boston. This North River Subdistrict includes the 15 communities located in the MAPC District, listed below, plus the communities in the Old Colony Planning Council.

Braintree	Holbrook	Randolph
Cohasset	Hull	Rockland
Duxbury	Marshfield	Scituate
Hanover	Norwell	Stoughton
Hingham	Pembroke	Weymouth

Cohasset is the only member community which can develop supplies adequate through 1990. However, providing all of the communities develop their potential supplies, the North River could be developed to supply all of the communities in the subdistrict well beyond the year 1990 with the exception of the towns of Braintree, Weymouth, Randolph and Holbrook. While these communities could be supplied by the North River, it would be more realistic to supplement the supplies of these communities from the MDC, since they are remote from the North River, near the existing MDC system, and their demands would decrease the North River's period of adequacy. The only source that will be

available to supplement the North River once the demands exceed its yield is the MDC, and these four communities would have to be connected to the MDC eventually.

Development of the North River for water supply purposes will require the construction of an on-stream storage reservoir located in the present tidal reach of the North River, a water treatment plant, and pumping and transmission facilities. It is recognized that an impoundment within the tidal reaches of the North River will affect the ecology of the estuary. Early estuarine studies should be made to determine the implications of ecological changes."

6) Summary: Certain groups of communities (particularly those outside Metropolitan Boston) can satisfy their present and projected 1990 needs without relying directly on the MDC. However, they cannot do so unless the MDC supplies certain key communities such as Sudbury, Medfield, Norfolk, Dedham, Braintree, Weymouth, Randolph and Holbrook. It, therefore, becomes apparent that any concept of regional supply for the eastern Massachusetts - Rhode Island Study Area depends on firming up the existing regional system, i.e. the MDC. This is the specific problem addressed by the present survey report.

Also by 1990, many communities not served by the MDC will collectively require water in addition to that available in their immediate watersheds. The development of institutions and physical systems to meet with this regional problem is critical. By 2020, the MDC will also require additional water from a large regional source. These two problems are the subjects of on-going studies.

16. Expected Expansion of the Regional System Service Area

Because potential new water supply sources within the Eastern Massachusetts area are rapidly becoming exhausted, communities are forced to look to regional concepts in water resource development as a means of meeting their future water supply needs. The MDC system represents the largest system in Massachusetts, and for this reason is expected to be called upon to expand its service area considerably by the year 1990.

Under present Massachusetts state Legislation, the MDC system is required to permit any municipality within 10 miles of the State House in Boston to become a member upon application. The MDC is further bound by the same legislation to allow any other municipality within 15 miles of the State House which could be reasonably serviced by the MDC to become, upon application, a member. Any non-member municipality with the approval of the Massachusetts Department of Public Health can be furnished water by the MDC.

In an attempt to determine what communities might be serviced by the regional system in 1990, four groups of municipalities were identified. These are listed below and shown on Plate No. 5.

1) Cities and towns presently serviced by the MDC.

2) Municipalities who cannot meet their future demands from local sources and who have no other reported feasible alternative but to join the MDC system.

3) Communities with a number of reported feasible alternatives including joining the MDC system.

4) Those cities and towns who can meet their future demands from local sources or from other regional systems not including the MDC system.

The MDC system presently is made up of 32 member communities, 25 of which are wholly served. The MDC also supplies water to 10 non-member communities which draw from either the Chicopee Aqueduct in the Springfield area or from the Wachusett-Sudbury reservoir system. These cities and towns, listed in Table 9, obtain water from the MDC because there simply are no other feasible sources of water supply available to them. Therefore, with the exception of Peabody, it has been assumed that all additional future water demands originating from

these communities will be met completely by the MDC system. Peabody's additional demand may be met by further development of the Ipswich River.

The remaining communities in the study area were then investigated to determine if they can meet their 1990 water demand locally and then, if not, whether it is feasible for them to join the MDC system. The communities listed in Table 10 have no other reported feasible alternative to meet their additional future water demands other than joining the MDC system. Because they all can be reasonably served by the MDC, these cities and towns are included in the potential 1990 service area.

The third category of communities are listed in Table 11. These cities and towns have a number of feasible alternatives including connection to the MDC system. Other alternatives available to the municipalities include development of the Merrimack, Ipswich and North Rivers as well as ground water resources in some cases.

Those communities not anticipated to join the MDC system by 1990 are shown on Plate No. 5. Based on a review of these municipalities' 1990 water supply needs, it appears adequate local resource is available or entrance to another regional system is a more feasible solution.

The 1990 water demands on the Quabbin - Wachusett Reservoirs (MDC system) were then estimated for the three groups of communities which may be serviced. Supply demand estimates, as described in Appendix B, were derived using both population and industrial output forecasts. Population increases were combined with estimates of future per capita usage to provide supply needs domestic, commercial and public usage. Industrial output forecasts using a water use per dollar output analysis allowed the estimation of supply needs for heavy water using industry. Both estimates were then combined to give total future water requirements.

Once the supply requirements were established, the additional development necessary to meet these needs was determined. This was accomplished by subtracting safe yields of existing and anticipated supply sources from the total estimated needs. Using this methodology, the existing MDC's service area 1990 water demand was estimated to be about 410 million gallons per day (mgd). If the cities and towns with no other reported alternative were to join the MDC, total demand for 1990 was estimated to be about 441 mgd. If all communities noted as including the MDC as an alternative source were serviced, then 519 mgd would be needed in 1990.

Based on the investigations conducted in this report then the 1990 water supply needs to be met by the MDC could vary from a minimum of 410 mgd to a possible maximum of about 519 mgd. Although it is possible that all communities described as having other potential sources may elect to join the MDC system, it is unlikely. Based on efforts observed by this group, it appears that certain communities are willing and planning to develop the local resource to meet their needs. Providing additional supplies to non-MDC communities is part of the problem addressed by on-going NEWS studies. In this report, 1990 demands on the regional system estimated for presently served communities and those with no other reported option were used for planning purposes.

TABLE 9

COMMUNITIES PRESENTLY BEING SERVICED
BY THE M.D.C.

FULLY SUPPLIED MEMBERS:

Arlington	Malden	Quincy
Belmont	Marblehead	Revere
Boston	Medford	Saugus
Brookline	Melrose	Somerville
Chelsea	Milton	Stoneham
Everett	Nahant	Swampscott
Lexington	Newton	Waltham
Lynnfield Water District	Norwood	Watertown
		Winthrop

PARTIALLY SUPPLIED MEMBERS:

Cambridge	Peabody
Canton	Wakefield
Needham	Weston
	Winchester

NON-MEMBERS SUPPLIED:

Clinton	Leominster	Southborough
Chicopee	Marlborough	South Hadley, F.D. #1
Framingham	Northborough	Wilbraham
		Worcester[1]

Total Estimated 1990 Demand	450 MGD
1965 Safe Yield[2]	335 MGD
Anticipated Expansion of Local Sources	5 MGD
1990 Deficit	110 MGD

[1] On an emergency basis only.

[2] Includes 300 MGD Safe Yield of Quabbin-Wachusett System.

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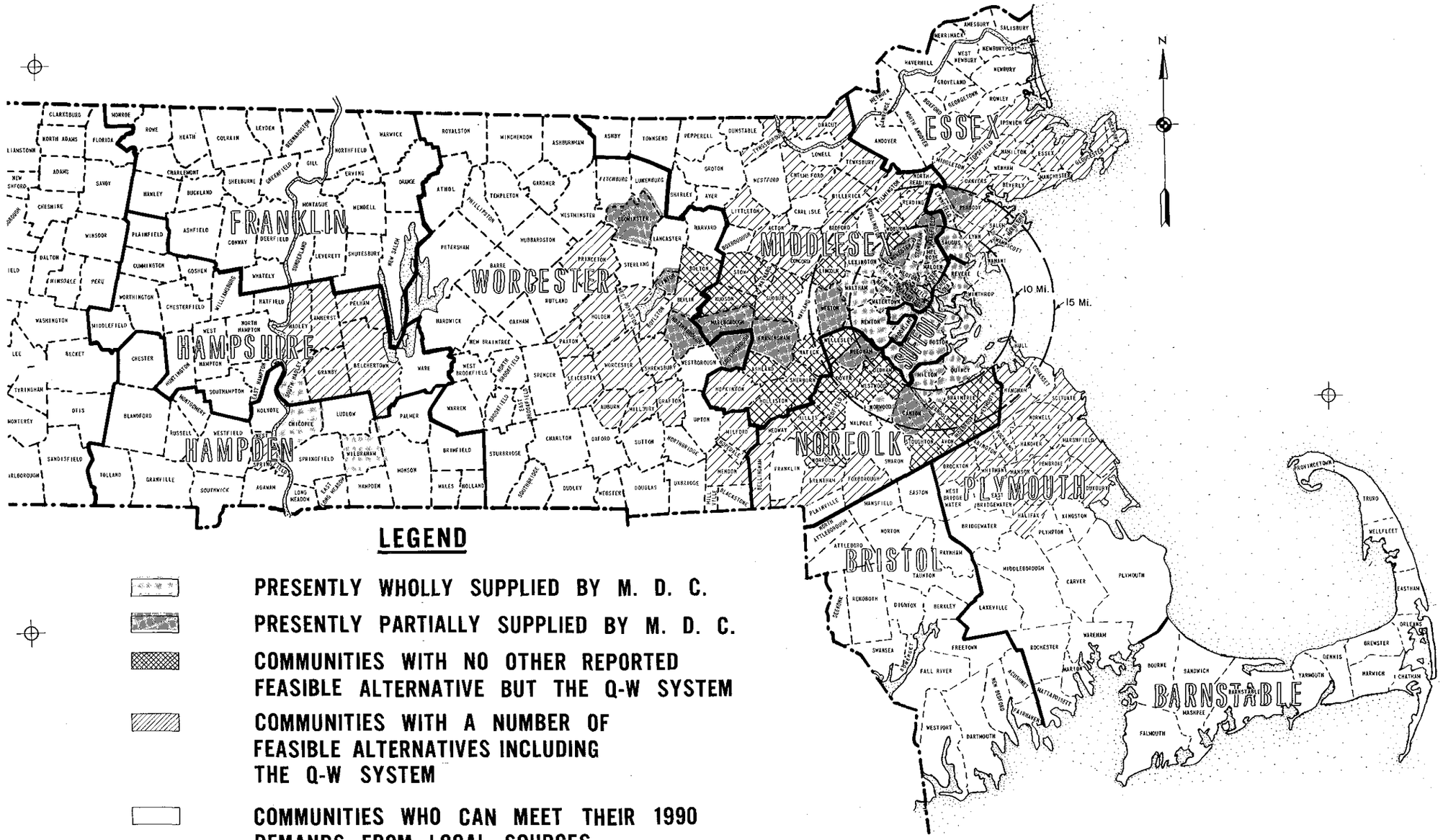


LEGEND

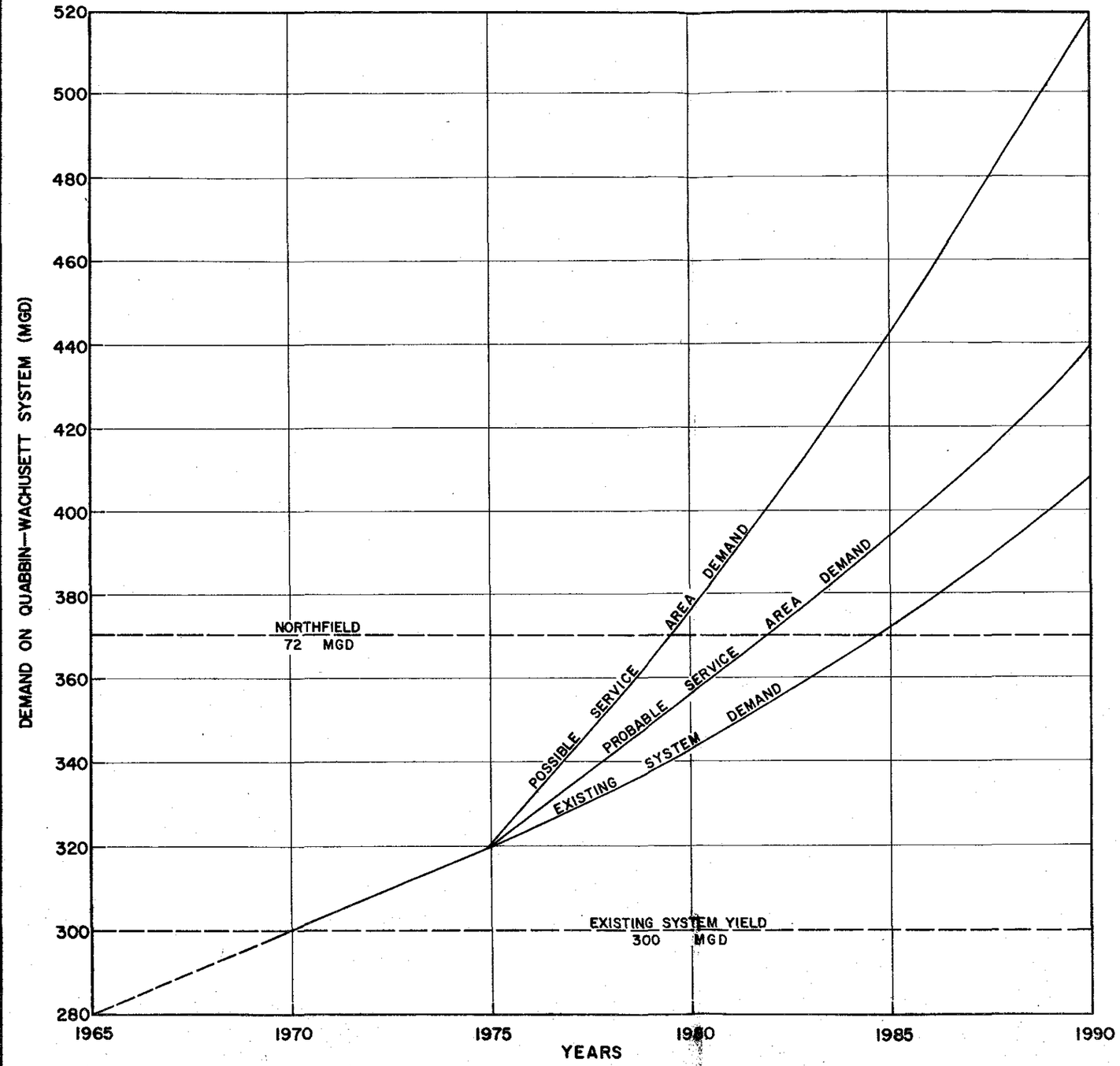
- PRESENTLY WHOLLY SUPPLIED BY M. D. C.
- PRESENTLY PARTIALLY SUPPLIED BY M. D. C.
- COMMUNITIES WITH NO OTHER REPORTED FEASIBLE ALTERNATIVE BUT THE Q-W SYSTEM
- COMMUNITIES WITH A NUMBER OF FEASIBLE ALTERNATIVES INCLUDING THE Q-W SYSTEM
- COMMUNITIES WHO CAN MEET THEIR 1990 DEMANDS FROM LOCAL SOURCES OR OTHER REGIONAL SYSTEMS
- EXISTING Q-W SERVICE AREA
- PROBABLE 1990 Q-W SERVICE AREA
- POSSIBLE 1990 Q-W SERVICE AREA

NORTHEASTERN UNITED STATES
WATER SUPPLY STUDY
QUABBIN – WACHUSETT
WATER SUPPLY SYSTEM
EXISTING AND FUTURE SERVICE AREA

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORP OF ENGINEERS
WALTHAM, MASS.

PLATE 7

CORPS OF ENGINEERS U. S ARMY



LEGEND:

——— HISTORICAL DEMAND

——— PROJECTED DEMAND

NORTHEASTERN UNITED STATES
WATER SUPPLY STUDY

ESTIMATED DEMAND ON
QUABBIN WACHUSETT SYSTEM

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORP OF ENGINEERS
WALTHAM, MASS.

PLATE 8

TABLE 10

COMMUNITIES WITH NO OTHER REPORTED OPTION

Ashland	Millis
Avon	Natick
Bolton	Norfolk
Braintree	Randolph
Dedham	Sherborn
Dover	Stoughton
Holbrook	Stow
Holliston	Sudbury
Hudson	Wellesley
Lincoln	Westwood
Maynard	Weymouth
Medfield	Woburn

Total Estimated 1990 Demand	74 MGD
1965 Safe Yield	39 MGD
Potential Local Sources	4 MGD
1990 Deficit	31 MGD

TABLE 11

COMMUNITIES WITH OTHER OPTIONS INCLUDING THE M.D.C. SYSTEM

IPSWICH RIVER:

Beverly	Ipswich	Peabody
Danvers	Lynn	Reading
Essex	Lynnfield	Rockport
Gloucester	Middleton	Salem
Hamilton	North Reading	Topsfield
		Wilmington

Estimated 1990 Demand	58 MGD
1965 Safe Yield	47 MGD
1990 Deficit	11 MGD

CONCORD RIVER:

Acton	Concord
Bedford	Littleton

Estimated 1990 Demand	12 MGD
1965 Safe Yield	5 MGD
1990 Deficit	7 MGD

MERRIMACK RIVER:

Billerica	Dracut
Chelmsford	Tewksbury
	Tyngsborough

Estimated 1990 Demand	22 MGD
1965 Safe Yield	12 MGD
1990 Deficit	10 MGD

TABLE 11 (cont'd)

NORTH RIVER:

Abington	Hanson	Pembroke
Brockton	Hingham	Rockland
Duxbury	Hull	Scituate
Halifax	Marshfield	Whitman
Hanover	Norwell	

Estimated 1990 Demand	39 MGD
1965 Safe Yield	28 MGD
1990 Deficit	11 MGD

CHARLES RIVER:

Bellingham	Medway
Foxborough	Wrentham

Estimated 1990 Demand	9 MGD
1965 Safe Yield	5 MGD
1990 Deficit	4 MGD

MILL RIVER:

Hopedale	Mendon
Hopkington	Milford

Estimated 1990 Demand	6 MGD
1965 Safe Yield	2 MGD
1990 Deficit	4 MGD

TABLE 11 (cont'd)

WORCESTER AREA:

Auburn	Holden	Princeton
Berlin	Leicester	Shrewsbury
Boylston	Millbury	West Boylston
Grafton	Paxton	Worcester

Estimated 1990 Demand	47 MGD
1965 Safe Yield	26 MGD
1990 Deficit	21 MGD

COLLEGE AREA:

Amherst	Hadley
Belchertown	Pelham
Granby	South Hadley, F. D. #2

Estimated 1990 Demand	10 MGD
1965 Safe Yield	4 MGD
1990 Deficit	6 MGD

WEST SPRINGFIELD:

Estimated 1990 Demand	7 MGD
1965 Safe Yield	3 MGD
1990 Deficit	4 MGD

TOTAL ESTIMATED 1990 DEMAND	210 MGD
TOTAL 1965 SAFE YIELD	132 MGD
TOTAL 1990 DEFICIT [1]	78 MGD

[1] Deficit shown is expected to be met by local resource development.

17. Capability of System to Meet Future Needs

A. Source

The estimated yield from the existing MDC sources of supply is about 300 mgd. In 1971, the average daily demand of all communities serviced by the system was about 322 mgd. At present then, withdrawals from the system exceed the available dependable yield. The most striking example of this demand in excess of supply situation is at Quabbin Reservoir, the main storage facility of the system. From a low pool elevation of 495 feet (full pool 530 feet) the reservoir has been unable to replenish its storage.

Forecast demands on the system for 1990 indicate an additional increment of 141 mgd of yield will be necessary unless water use practices of the serviced population are altered dramatically.

The MDC as a result of their analysis have reported to the Massachusetts State Legislature the next step in providing the supply necessary to meet future needs is the diversion via the Northfield Mountain [1] Project. At a NEWS meeting held in Boston, Massachusetts, in May 1970, local, State and Federal officials agreed that the Northfield Mountain Project was a viable element in any regional water supply plan.

If the yield from Northfield Mountain is made available, the total dependable yield available to the system would be about 372 mgd. Based on the forecast demands, this project would meet supply needs to about 1984. In order to meet the short-range 1990 needs then an additional source of supply will be needed.

In this report, the potential of diverting water from the Millers River Basin, a tributary of the Connecticut, is being investigated. Depending on the method of development employed, this source could produce 76 mgd of additional supply.

Development of the Northfield Mountain Project as described in this report then could add about 25 percent to the existing system yield. This addition, when combined with the Millers River Basin yield, would allow adequate supplies within the serviced communities to about 1990.

B. Transmission Facilities

Although the intent of this Interim Report of Survey was to investigate new sources of supply to meet future needs, a preliminary analysis of the MDC's transmission facility was also conducted. The purpose of

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[1] Subject of a companion NEWS report.

evaluating the transmission facilities was not to include any needed improvements as recommendations for authorization, but rather to present a full picture of the system's present capability.

In order to determine the adequacy of the major transmission aqueducts, the peak demands for the system had to be estimated. Variations in water demands due to seasonal weather changes have always been important considerations in the design of water supply systems in the northeastern United States and particularly in New England. Historically, summer periods have promoted exceptionally high water demands which quite often last for several weeks. In most cases, these peak demands must be met by the water supply storage reservoirs, since storage within the distribution system itself cannot usually be economically constructed to handle these peak loads.

The ratio of the maximum day demand to the average daily demand is directly related to the type and character of the development within the community or communities to be served. The present MDC system, as described earlier, services 32 member communities within the greater Boston area. Twenty-five of the communities depend wholly upon the system to supply their water needs, while the remaining seven communities make maximum use of their own sources and only rely upon the MDC system to supply their peak demands. The 25 wholly supplied communities range from completely residential in character to the inner core cities with industrial and commercial development. During the recent drought of the 60's, the ratio of the maximum day demand to the average daily demand for the city of Boston reached a high of 1.24, while the ratio for the total 25 communities reached 1.65. This difference has been attributed to the effect of the suburban communities peak demands upon the system. If the MDC is called on to expand its service area, it will be adding suburban communities which are largely residential in nature. Thus, the maximum daily demand ratio can be expected to increase above the present high figure of 1.65. The amount of increase will, of course, depend on what portion of the total water demand upon the system the new members demand represents.

To determine what increase, if any, the transmission facilities would have to supply by 1990, peak demand characteristics of a number of eastern Massachusetts communities were examined. Based on this investigation, it appeared a maximum day ratio of 1.70 to average daily demand represented a reasonable value for planning purposes. A comparison of this figure to other historic and projected maximum day data for large metropolitan systems in the Northeastern United States was then made and proved to be comparable.

Applying the maximum day ratio to demands forecast in the Boston Metropolitan area, it appears the present transmission facilities from Wachusett Reservoir to the Boston City tunnel system may be inadequate. This inadequacy can be primarily attributed to the limiting carrying capacity of the Hultman Aqueduct.

At present, the Metropolitan District Commission has under way a large scale (one million dollar) investigation of its water supply system. Included in this investigation will be an examination of the future courses of action which the MDC may pursue with regard to supply, demand and conveyance facilities. One of the major study elements will be the adequacy of the system's aqueducts. The results of this investigation will describe problem areas and corrective actions needed.

SECTION VII

DESCRIPTION OF THE PROJECT

19. General

Early in 1966, the Western Massachusetts Electric Company, the Connecticut Light and Power Company and the Hartford Electric Light Company filed an application for permission to build a pumped storage hydroelectric facility atop Northfield Mountain in Franklin County, Massachusetts. Permission to build the facility was given and construction commenced in 1966 and is scheduled for completion in 1973. When completed, the Northfield Mountain Project will have a generating capacity of one million kilowatts and will cost an estimated $140 million.

In the initial application made by the power companies to the Federal Power Commission, the potential of adding a municipal water supply function to the facility was recognized. This multiple use would be achieved by utilizing the pumping and storage facilities to supply Connecticut River water during periods of high flow to Quabbin Reservoir. Water from Quabbin would then be supplied to serviced municipalities, both within the Connecticut River Basin and to out-of-basin communities in the Boston Metropolitan area.

Following the power companies' proposal to use power facilities as a diversion device, the Metropolitan District Commission filed legislation with the Massachusetts State Legislature regarding use of Northfield Mountain for a dual water supply use. This legislation was adopted by the Commonwealth of Massachusetts in Chapter 669 of the Acts, 1967, and provided $25 million in funds for the necessary water supply diversion facilities.

In 1969, the MDC filed additional legislation with respect to the Northfield Mountain Proposal. This legislation requested an additional $20 million for the diversion facilities' construction, changed the control flow upon which the diversion would be based to a more favorable gaging location downstream and allowed an opportunity for the MDC to explore other potential diversion locations besides Northfield. When

this additional legislation was presented to the Massachusetts Legislature, a considerable amount of local Connecticut River Basin opposition was voiced on the bill. In response to this protest, the Legislature ordered a special study commission to study the issues raised by the dissenting voices and report their findings on the diversion.

The findings of this special study commission were reported to the Massachusetts Legislature in May 1970. In brief, the special study commission approved the diversion plan, although a further supplementary report by three of the legislative members of the Commission raised the question of radioactive pollution from a nuclear power plant being constructed in Vernon, Vermont, about ten miles upstream from the Northfield Mountain intake. The Massachusetts Advisory Commission on Radiation presented its findings on the radioactive danger to the joint Massachusetts Senate - House Committee on Urban Affairs. These findings conclude that even with the Vermont plant in operation, the Metropolitan Water System will not be harmed by diverting Connecticut River water.

The Special Study Commission submitted proposed legislation containing provisions reflecting the above and other conclusions. Prior discussions between the MDC and the electric utilities had produced a preliminary draft of an agreement containing provisions not usually included in agreements to which the Commonwealth of Massachusetts is a party. These provisions included payments to reimburse the utility for costs of constructing the diversion structures needed to store and divert the water from their installation, reimbursement for their expenses in insurance and local taxes, and provisions for the referral of disagreements to arbitration procedures. The Special Study Commission included provisions in its proposed legislation to provide for these aforesaid matters. However, this legislation was not enacted by the Massachusetts Legislature. In the legislation which was enacted as Chapter 766 of the Acts of 1970, however, provisions expressly limiting the quantity and location of the diversion were included. In view of this, the MDC is currently preparing a new draft of an agreement designed to arrive at a mutually satisfactory arrangement with the utility companies.

To date no agreement has been reached on this element of the project. Discussions held with officials of the MDC, however, indicate an agreement can be reached on this present impasse.

20. Facilities Required and Project Operation

A. Hydroelectric Facilities and Operation

The Northfield Mountain hydroelectric project has been constructed in Northfield and Erving, Massachusetts. The location of the project, shown on Plate No. 9, is about 9 miles downstream from the New Hampshire - Vermont - Massachusetts state boundaries, about 49 miles and 75 miles upstream from Springfield, Massachusetts, and Hartford, Connecticut, respectively.

The pumped storage project consists of a high level storage reservoir on Northfield Mountain, underground pump-turbine facilities and low level storage in the Turners Falls pool. The high level reservoir consists of a system of dams and spillways arranged to provide a 17,000 acre-foot storage about 800 feet above the Turners Falls pool. The pump - turbine facilities, consisting of 4 - 250,000 KW units, are connected to the upper reservoir by a 31 foot diameter, concrete lined penstock excavated in the rock. A 40 foot high and 26 foot wide horseshoe tunnel connects the pump-turbines to the Turners Falls pool. A plan of the facilities is shown on Plate No. 10.

New storage in the Turners Falls pool would be provided by raising the dam to elevation 185.0 mean sea level. The Montague section would have bascule gates and the Gill section would have hinged flash boards. The two sections would be connected by a new dam on the island consisting partially of bascule gates and partially flash boards.

The Northfield Mountain project will be operated principally for power purposes. When low cost, base load power is available, water would be pumped and when high value, peaking power is needed, electric energy would be generated. Base load power is usually available nights and weekends. Peaking power is usually needed on weekdays for periods in the morning, afternoon and early evening. Present planning would pump the Upper Reservoir full each weekend, generate each day and partially refill each night.

1) Northfield Mountain Power House - The four 250,000 KW units, each capable of pumping 3,000 cfs (average 2,500 cfs) would be operated individually either to supply the needed power or to utilize the low cost energy available. The total maximum generation discharge would be 18,000 cfs when all units were operating. The total maximum pumping with all units running would be 12,000 cfs (average 10,000 cfs). The power company's proposed pumping operation would utilize storage in Turners Falls pool and be independent of Connecticut River flow.

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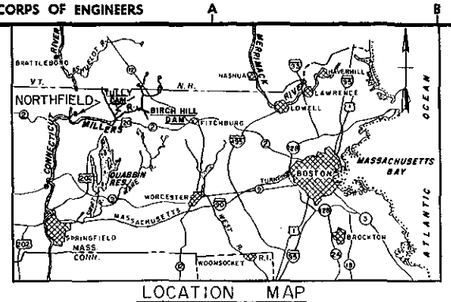
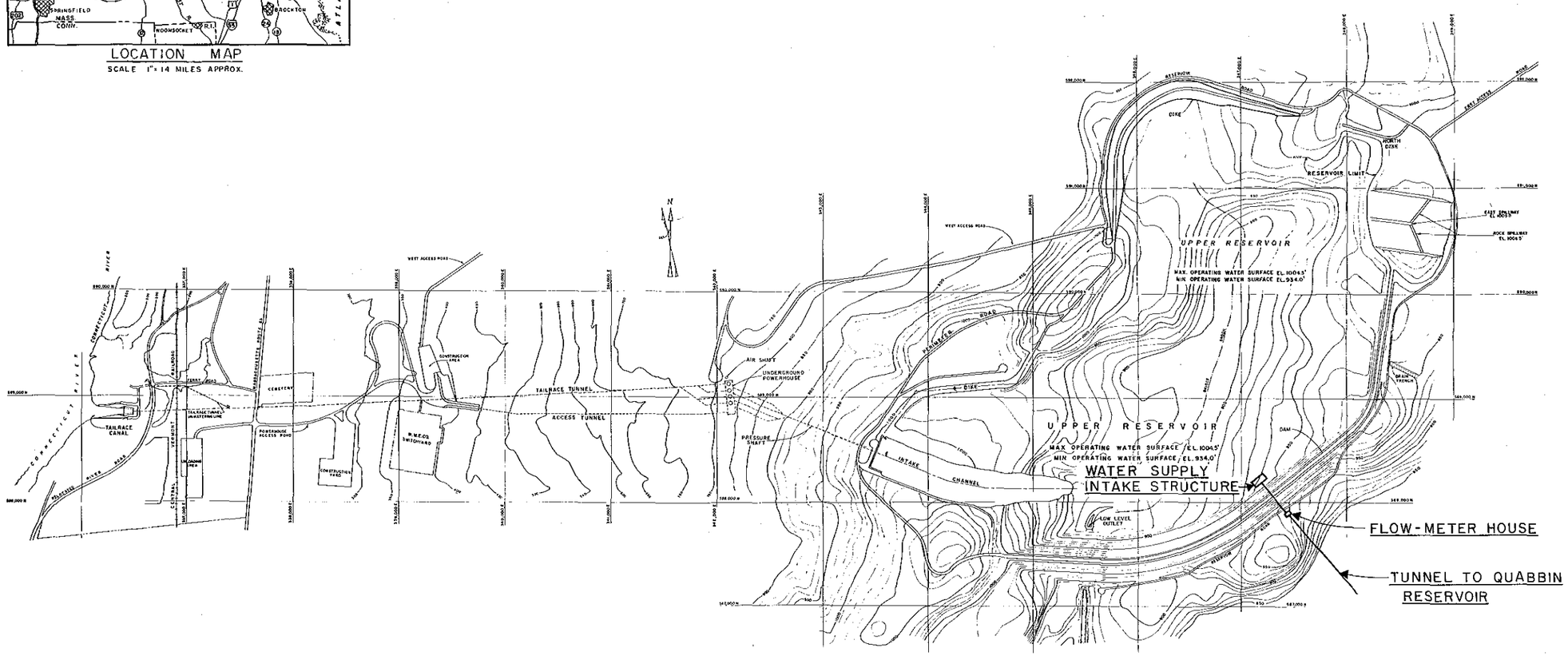


LOCATION MAP

SCALE 1" = 14 MILES APPROX.



GRAPHIC SCALE

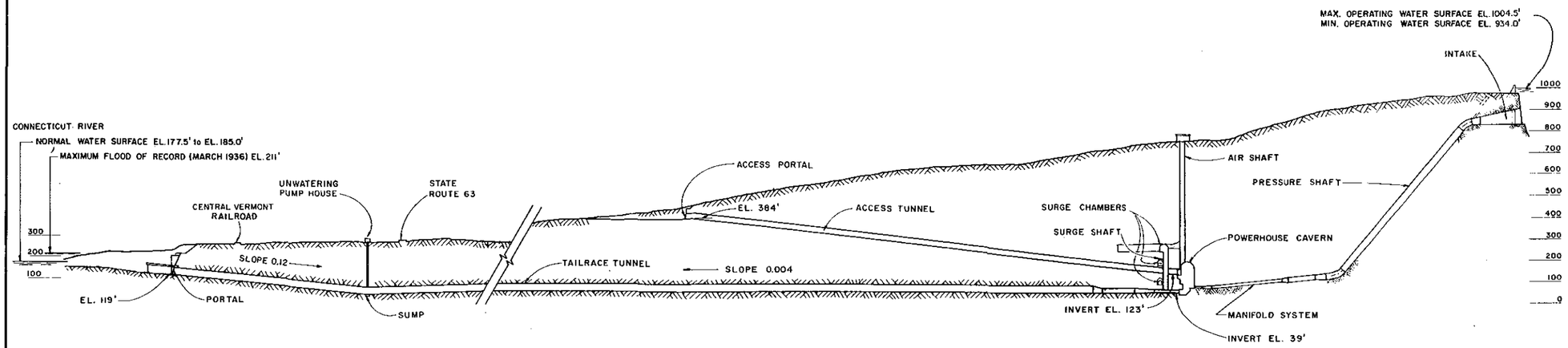
1" = 400' 400' 0 400' 800'

NORTHEASTERN UNITED STATES
WATER SUPPLY STUDY

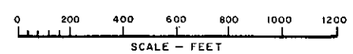
NORTHFIELD MOUNTAIN
PUMPED STORAGE PROJECT

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

PLATE 9



SECTION



1" = 200'

NOTE:
ELEVATIONS REFER TO USGS MEAN SEA LEVEL DATUM

NORTHEASTERN UNITED STATES WATER SUPPLY STUDY

SECTION THROUGH POWER HOUSE AND
WATER CONDUITS
NORTHFIELD MT. PUMPED STORAGE PROJECT

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
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2) Upper Reservoir - The total capacity of the upper reservoir is 17,000 acre-feet of which 12,750 acre-feet would be usable. The power company's operations would fill this reservoir each weekend, use water during the week and partially refill each night. For safety, a small spillway would permit overflow of local inflow (about 1/2 square mile drainage area) to the Millers River. A larger spillway at higher level would discharge to Four Mile Brook in the event of an operational failure which continued pumping with a full reservoir.

3) Turners Falls Pool - This pool would perform two separate functions, storage for Northfield Mountain and pondage for Turners Falls. The storage created by the new bascule gates and flashboards would be reserved for Northfield Mountain. Thus, 12,750 acre-feet of water would be in storage in the Turners Falls pool when the Upper Reservoir was empty and 12,750 acre-feet of storage would be available in the Turners Falls pool when the Upper Reservoir was full. To maintain storage available in Turners Falls pool, the Applicants would operate the bascule gates during generation and pumping in such a manner that outflow at Turners Falls equals reservoir inflow from all sources other than Northfield Mountain and that downstream discharges will be unchanged. The bascule gates would be raised to retain generation water and lowered during pumping to maintain storage available. The only change expected from Turners Falls generation from this operation will be a slight increase in electric energy by reason of the larger head available at times when the Turners Falls pool was storing water for Northfield Mountain.

B. Water Supply Facilities and Operation

As described earlier, the electric utilities have made an offer to the Metropolitan District Commission (Boston) to include provisions for water supply diversions to Quabbin Reservoir. In order to include this water supply function, three modifications to the pumped storage facilities are necessary. These are:

1) Raising the upper reservoir located on Northfield Mountain about 4 feet to provide about 1,150 acre-feet of additional storage capacity.

2) Provision of head works at the upper reservoir for the diversion aqueduct to Quabbin Reservoir.

3) About 9.8 miles of connecting aqueduct and outlet facilities at Quabbin Reservoir.

The first two items necessary for diversion have been essentially completely constructed at the upper reservoir on Northfield Mountain by the electric utility construction forces. A plan of these facilities is shown on Plate No. 9.

The third item necessary for water supply diversion is presently in preliminary design stages by engineers at the MDC. At present, plans indicate water would be diverted from the upper reservoir through an eight foot diameter steel pipe constructed in the east dike of the Northfield Mountain upper reservoir. Water would be withdrawn at an average rate of 375 million gallons per day and delivered to an intake shaft of the Northfield - Quabbin tunnel aqueduct. A plan of the aqueduct alignment is shown on Plate No. 11.

The intake down shaft would be a scroll type configuration with a diameter of 16 to 18 feet. Water would be conveyed from a maximum upper reservoir pool elevation of 1004 feet msl in this vertical shaft to the aqueduct at elevation 300 feet msl.

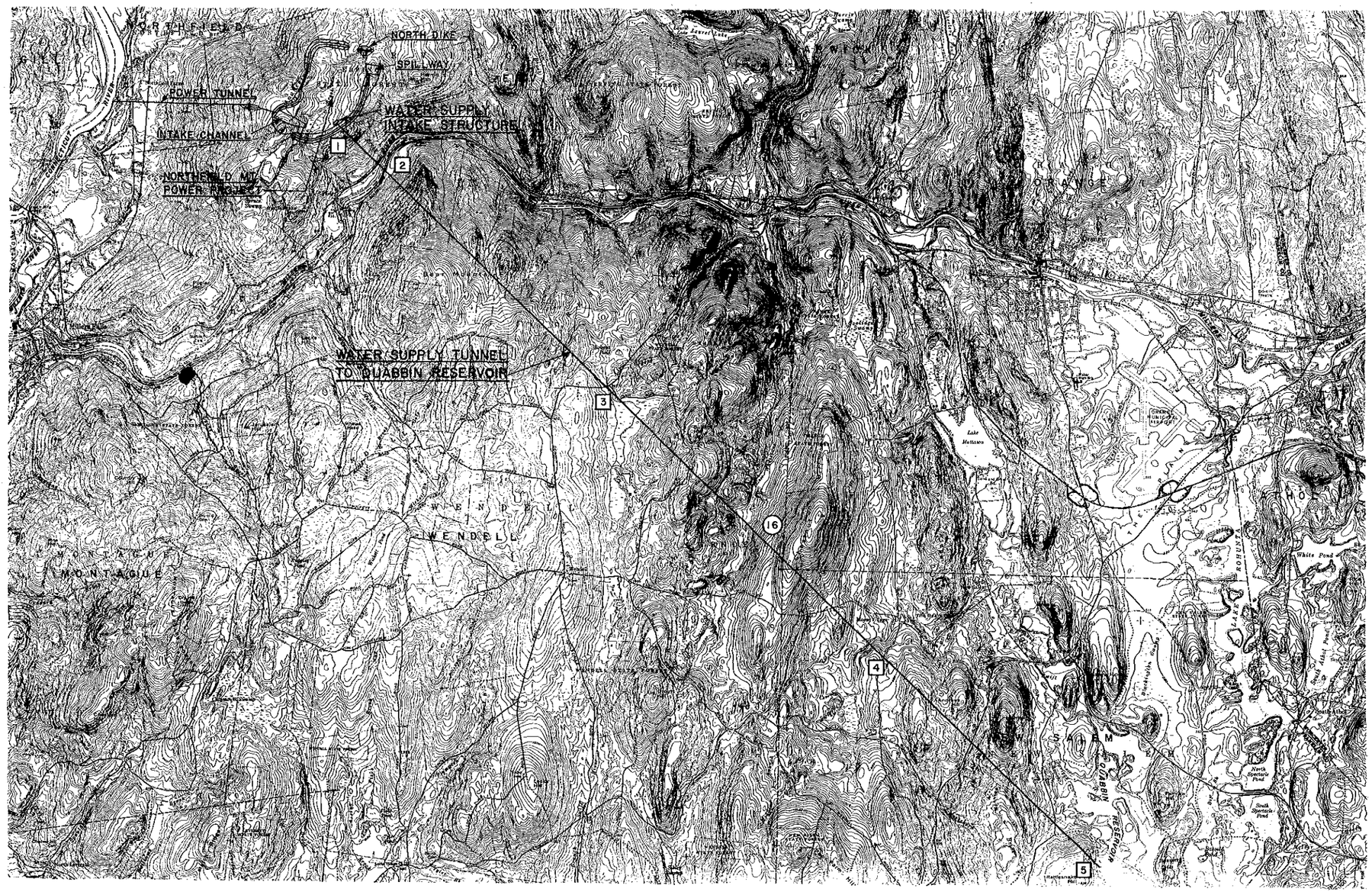
The aqueduct would be a 10 foot finished diameter tunnel with a reinforced concrete liner. From the downtake shaft, the aqueduct would run about .53 miles to the vicinity of the south bank of the Millers River. At the Millers, a 10 foot diameter construction shaft would be excavated.

Continuing to Quabbin, the aqueduct would be driven about 3.0 miles to the vicinity of Bullard Hill. In this tunnel reach, the aqueduct would rise from the 300' elevation at the Millers River to elevation 440'. A second construction shaft would be provided at this location as shown on Plate No. 11.

From Shaft No. 3, the tunnel would continue about 6.2 miles to the uptake shaft located in Rattlesnake Hill adjacent to Quabbin Reservoir. At Rattlesnake Hill, an uptake shaft would be driven from elevation 440 to elevation 500. At elevation 500, the tunnel would be enlarged from ten to 30 feet in width in a 150 foot long transition zone. Flow entering Quabbin from the transition zone would be conveyed in a 30 foot wide channel cut to the main channel of the Middle Branch of the Swift River.

In operating the project for water supply purposes, the electric utilities would extend their pumping operation about 1-1/2 hours per day to pump about 1,150 acre-feet (375 mg) of water to the upper reservoir each day when Connecticut River flow is in excess of 17,000 cfs at Montague City USGS gaging station. On a long term average, flow at Montague

CORPS OF ENGINEERS U. S ARMY



LEGEND

(16) TUNNEL ALINEMENT NUMBER

[3] SHAFT NUMBER AND APPROXIMATE LOCATION

GRAPHIC SCALE

1" = 2000' 2000' 0 2000' 4000'

NORTHEASTERN UNITED STATES
WATER SUPPLY STUDY

NORTHFIELD MOUNTAIN
WATER SUPPLY PROJECT

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

PLATE II

City exceeds 17,000 cfs about 58 days during the spring months of March, April and May, the principal diversion period.

Water diverted to the upper reservoir would be stored temporarily and diverted to Quabbin Reservoir at a rate of about 580 cfs through head gates, aqueducts and outlet works. In order to utilize the facility for water supply, the operating agency must design and construct the connecting aqueduct and pay the electric utilities for the $2 million already expended for construction completed at the upper reservoir. In addition to construction costs, charges for off peak electric energy used for the extra pumping necessary to provide the volume of water to be diverted would also be incurred.

Although all of the operational details have not been planned to date, the effect of the extra pumping necessary for water supply is expected to be spread over a full 24 hour period. This spreading of the extra pumping effect can be attained by bascule gate operation at the Turners Falls dam.

21. Water Treatment Required

The quality of the Connecticut River, as is the usual case of most large river systems, varies with the upstream municipal and industrial waste discharges, river flow, velocity, time of year and geomorphology of the region. At present, the general classification of the Connecticut River in the vicinity of this project's diversion intake is Class C. The adopted future classification of the river reach is B.

Water quality in the vicinity of, and upstream from, the Northfield Mountain intake has been sampled for a varying number of years by the Environmental Protection Agency, by State Health Departments, by an electric utility and as part of this report under contract.[1] Results of this monitoring indicate that treatment for bacteriological and biological control prior to its direct use as a water supply would be necessary. A summary of data collected in the vicinity of the pumped storage intake is given in the following table:

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[1] See Appendix D and Appendix G.

TABLE 5

WATER QUALITY DATA [1]
CONNECTICUT RIVER AT NORTHFIELD, MASSACHUSETTS

	Unit	Maximum	Minimum	Mean
Physical				
Color	Units	60	9	26
Odor	--	--	--	--
Temperature	°C	32.5	--	16.5
Turbidity	Jackson Units	143	1.0	23.0
Microbiological				
Coliform Organisms	MF/100 ml	60,000	40	5,775
Fecal Coliforms	MF/100 ml	380	0	89
Inorganic Chemicals				
Alkalinity	mg/1	54	12	28
Ammonia	mg/1	1.1	0	.096
Arsenic	mg/1	.06	0	.017
Barium	mg/1	.02	.007	.014
Boron	mg/1	.029	.004	.016
Cadmium	mg/1	.02	.001	.004
Chloride	mg/1	45	3.0	7.9
Chromium, hexavelent	mg/1	.006	0	.002
Copper	mg/1	.024	0	.010
Dissolved Oxygen	mg/1	14.8	2.2	9.2
Fluoride	mg/1	.31	.05	.126
Hardness	mg/1	58	20	37.4
Iron	mg/1	.079	.005	.035
Lead	mg/1	.003	.0002	.015
Manganese	mg/1	.009	.0003	.005
Nitrates plus Nitrites	mg/1			
pH	--	8.6	2.0	7.1
Phosphorus	mg/1	1.0	.01	.10
Selenium	ug/1	.01	.01	.01
Silver	ug/1	.40	.07	.264
Sulfate	mg/1	22	3.0	9.3
Total Dissolved Solids	--	--	--	--
Uranyl Ion	--	--	--	--
Zinc	mg/1	.7	.12	.17

[1] Based on STORET Data, compiled by the Environmental Protection Agency.

TABLE 5 (cont'd)

	Unit	Maximum	Minimum	Mean
Organic Chemicals				
Carbon chloroform extract	ug/l	159.0	39.0	89.3
Cyanide	mg/l	.02	0	.01
MBAS	mg/l	.09	.02	.05
Oil and Grease	--	--	--	--
Pesticides				
Aldrin	ug/l	.00	.00	.00
Chlorodane	ug/l	.00	.00	.00
DDT	ug/l	.01	.00	.0009
Dieldrin	ug/l	.022	.000	.007
Endrin	ug/l	.025	.000	.0035
Heptachlor	ug/l	.00	.00	.00
Heptachlor Epoxide	ug/l	.001	.000	.0001
Herbicides 2,4-D plus 2, 4, 5-T plus 2, 4, 5-TP	ug/l	.00	.00	.00
Radioactivity				
Radium - 226	pc/l	--	--	--
Strontium - 90	pc/l	3.1	.3	1.23

If water drawn from the Connecticut River were to be used to directly feed water supply distribution systems, then at least complete conventional treatment would be required. In the Northfield Mountain diversion, however, water withdrawn from the river would be conveyed to storage at Quabbin Reservoir. Storage time[1] within Quabbin could provide an opportunity for natural purification processes, thus precluding extensive treatment prior to the introduction of the river water to Quabbin.

There are a number of questions on the "treatment plant" capacity which Quabbin possesses. To date, the reservoir has not had large demands placed upon it. The present feeder streams, the Swift and Ware Rivers, are free of high oxygen demanding materials, industrial and municipal pollution, and other sources of pollution. Therefore, the streams that feed Quabbin are low in coliforms, oxygen demand, turbidity and all the other water quality parameters which are used in judging the suitability of a water supply.

The continuing high quality of the reservoir's drainage basin streams and the resulting supply are a testimony to the Metropolitan District Commission's watershed management program. Thus with the exception of color, little is required of Quabbin's treatment plant capacity.

The addition of Connecticut River water to Quabbin presents a different situation for the reservoir. Quality of Connecticut River water, due to both man-made influences, such as waste discharge and natural phenomena, such as bank erosion, is inconsistent then with the present reservoir feeder streams. It can be expected, therefore, that Quabbin's "treatment plant" capability will be tested with the addition of the Connecticut River water.

At present, no one knows with certainty exactly what the reservoir's "treatment plant" capacity is. Preceding the actual diversion, additional studies, conducted by both the Metropolitan District Commission and the Environmental Protection Agency, are planned. Included in these planned studies will be observation of water quality parameters within the upper reservoir of Northfield Mountain and bench scale models of Quabbin Reservoir water mixed with Connecticut River water. The results of these investigations should add more hard data on the potential response of Quabbin to diverted waters.

All investigators agree that any deleterious impact, if any, on Quabbin water quality would develop slowly, thus allowing a period of observation and monitoring in the prototype reservoir itself. Since maximum

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[1] See Appendix D for results of hydrodynamic studies of Quabbin Reservoir.

dilution of the lower quality river water with reservoir water may be desirable, the option of including a dual outlet system to different legs of the reservoir has been considered. Under this plan, water would be conveyed from Northfield Mountain to Quabbin. Depending upon characteristics of the receiving water body, such as pool elevation quality, etc., the diverted flow could be split between the Middle Branch or West Branch of the reservoir. To provide for this future flexibility, if needed, the Northfield - Quabbin Aqueduct would include a tunnel stub heading toward the West Branch of the reservoir. If, in the future after diversion, the water quality monitoring program indicated a deterioration of water quality, a tunnel leg could be constructed to the West Branch of Quabbin Reservoir, thus insuring maximum dilution and flexibility in diversion operations.

In summary, then, water quality data analyzed in this report indicates no water treatment would be necessary prior to the diversion of Connecticut River water to Quabbin. This conclusion is based on the recognition that within Quabbin Reservoir a capability for natural purification processes exist. An exact quantification of this capability, however, is not possible. To insure, then, that these capabilities are not overtaxed, a series of investigations prior to the diversion coupled with observation and monitoring after diversion is necessary.

22. Waste Treatment Required

As described in the previous section, water quality data collected from the Connecticut River indicates the river can be used as a supply source after reservoir storage detention and adequate measures for disinfection. The river itself, however, is subject to waste loads from both municipal and industrial waste discharges, many of which are presently untreated. The high dilution flows during diversion periods considered in this study act to reduce the concentrations of these pollutants. If pollution loads increase unchecked in the future, however, there is no assurance that this dilution effect of the river will be sufficient to produce an adequate quality water at the intake.

Recent reports by the Environmental Protection Agency,[1] as well as studies conducted as part of this investigation, have documented the location and amounts of waste discharges entering the Connecticut River above the Northfield intake.

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[1] Comprehensive Water and Related Land Resources, Connecticut River Basin, Appendix D, Water Supply and Water Quality.

From the Connecticut River headwaters to the introduction of the Upper Ammonoosuc River in Northumberland, New Hampshire, the river is free of major sources of organic pollution. Above this confluence, only a few smaller communities contribute untreated municipal waste. From the Upper Ammonoosuc to the intake, however, large amounts of industrial and municipal wastes are discharged to the river. The following table illustrates the total waste measured in BOD_5 to the river in 1960 from both industrial and municipal sources upstream of the proposed diversion intake.

TABLE 6

WASTE LOADS[1] TO CONNECTICUT RIVER BASIN STREAMS

1960

Pounds Per Day BOD_5

Stream	Municipal	Industrial
Upper Ammonoosuc	255	154,000
Israel	250	--
Johns	230	--
Ammonoosuc	975	1,670
Passumpsic	1,660	--
Wells	--	120
Mascoma	895	4,100
Sugar	1,870	8,615
Ashuelot	2,240	5,360
White	650	750
Ottaquechee	170	--
Black	1,085	910
Williams	85	--
Sacketts Br.	--	2,020
Saxtons R	--	400
West	135	--
Connecticut	5,145	3,710
TOTALS	15,645	181,655

[1] Upstream of Northfield Mountain intake.

Of the totals shown in Table 6, only about 1% of the load was removed in 1960. Since that date, several municipal treatment plants have been constructed and are now operating. The impact of these plants, however, has not decreased to a significant degree the waste loads in the Connecticut River.

Pollution loads from the upstream rivers and brooks are subject to the natural purification processes of the river itself. Studies conducted as part of this report, however, reveal major sources of pollution presently exist in close upstream proximity to the diversion intake. The largest single pollution source upstream is the Ashuelot River.

Waste discharges into the Ashuelot originate from both municipal and industrial sources. Included in the industries now discharging into the river are woolen mills, leather factories and paper product industries. Based on an average over the past ten years, over 8% of the Connecticut River flow at the proposed diversion intake is flow from the Ashuelot.

The Environmental Protection Agency, in cooperation with the New Hampshire Water Supply and Pollution Control Agency and the Vermont Division of Water Supply and Pollution Control, has established an implementation schedule for abatement of all point sources of pollution upstream from the diversion intake at Northfield. This implementation schedule calls for secondary waste treatment facilities to be constructed and in operation by 1976. Adherence to this established schedule is vital to the quality of the Connecticut River water which is to be diverted for water supply purposes. If the schedule is not adhered to, the potential for increased pollution loads hindering the use of the river as a water supply source is a strong possibility.

23. Multi-Purpose Applications

As noted in the description of the project facilities, the majority of the construction required for the water supply diversion would be a deep rock tunnel aqueduct. The possibility of incorporating other allied water uses is, therefore, quite limited on the diversion facility itself.

Construction of the aqueduct and outlet facilities would necessitate the establishment of haul and construction support roads. Following construction, these roads would provide limited access for recreation, hiking, camping, hunting, and fishing. Because Quabbin Reservoir

acts as a primary reservoir for communities in the Chicopee area, however, it is uncertain as to the extent which these activities would be allowed by the responsible State Agency.

At present, recreational activities on the receiving storage reservoir for the diverted Connecticut River flow, namely Quabbin, are limited. Under sanitary rules and regulations established by the Massachusetts Department of Public Health, bathing in the Metropolitan District Commission's storage and distribution reservoirs is prohibited.

Under special rules and regulations, the use of boats at Quabbin Reservoir for fishing purposes is permitted. Three boat mooring areas are maintained by the MDC on the reservoir and outboard motor boats are rented during the fishing season. In addition, shore fishing is permitted on the reservoir from three locations. Although full attendance records at these controlled recreation locations are not maintained, the reservoir Superintendent estimated that the facilities provided opportunities for 250,000 visitor days in 1971.

The volume depletion of Quabbin Reservoir, anticipated if additional sources are not made available, will cause environmental damage to the reservoir. One form this damage may take is the reduction of the managed fisheries program in the reservoir. If this occurred, the present recreational usage of the reservoir would undoubtedly suffer. The provision of additional volume to the reservoir through the diversion project thus will preclude some of the recreational opportunities lost.

Recently, a number of fish and game clubs, watershed associations and other groups have requested that the reservoir and its watershed be opened further to recreational pursuits. In response to these requests, the MDC has stated they are willing to consider specific proposals in conjunction with approval of the health authorities. It appears then that increased opportunity for recreational usage can be anticipated. The role which the diversion project itself would play in any increased usage would lie in its potential for preventing damage to the reservoir and loss of these future recreation opportunities.

24. Monitoring Program

Throughout the history of the Metropolitan District Commission water supply system, a policy of strict watershed management has been used as the first line of defense in maintenance of good quality water. Now, for the first time, water from a watershed not directly or

indirectly controlled by the MDC will be introduced into the main storage reservoir of the system.

The Connecticut River's water quality is subject to many factors, both natural and man-made. To insure then that the introduction of this water will not impair the existing good quality reservoir water, it is imperative that a carefully designed monitoring program be established.

Within the detail of this report, it is not possible to determine totally the full requirements for such a monitoring program. That degree of detail belongs rightfully in the design phase of the project.

Even without the benefit of such detailed analysis, however, it is apparent that monitoring programs must be established at least in three locations. These are: 1) in the Connecticut River upstream of the diversion intake such that representative samples of river water to be withdrawn can be evaluated; 2) in the upper reservoir of Northfield Mountain so that water to be diverted to Quabbin Reservoir can be tested and analyzed; and 3) within Quabbin Reservoir itself such that any potential impact of the diverted flow on the reservoir or on the water quality delivered to consumers can be readily recognized and dealt with.

Provisions for these monitoring activities should be fully prepared and operational before the actual diversion occurs to provide background data and operational experience.

SECTION VIII

ESTIMATES OF FIRST COSTS AND ANNUAL CHARGES

25. First Costs

The total estimated cost of the water supply facilities at the Northfield Mountain upper reservoir, connecting tunnel aqueduct to Quabbin Reservoir and outlet works is $46,815,000, based on July 1974 price levels. Estimates of costs for the already completed upper reservoir works, including the raising of the dikes and intake tower, were supplied by the Metropolitan District Commission. Tunnel and outlet costs are of feasibility detail and developed by members of the New England Division. Estimates of construction costs were prepared utilizing a computerized tunnelling program [1] which costed both the machine tunnelling method (MOLE) and the conventional drill and blast method with the costs shown assuming the MOLE technique. All costs were based on the input of the assumed geologic conditions which controlled the design functions, with labor, equipment and material rates being costed on the basis of ENR quarterly reports including a 5 percent profit and a 25 percent overhead margin. No allowance has been made in the computer program for cost of headworks other than the discharge structure at Quabbin Reservoir. The estimated costs for engineering and overhead are based on knowledge of the site and experience on similar projects. A summary of construction costs for the project elements is presented in Table 8.

A. Available Geologic Data

Geologic information pertinent to the project was obtained from a literature survey correlated with available data from the design of the Northeast Utilities pumped power project and preliminary geologic investigations conducted by MDC along the proposed route. No exploratory data was available; however, strength tests conducted

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[1] A computer program for estimating costs of hard rock tunnelling (COHART) prepared by Harza Engineering Co., 400 West Madison Street, Chicago, Illinois - May 1970, for the Office of High Speed Ground Transportation, Urban Mass Transportation Administration, Department of Transportation, Washington, D. C., 20591, (Modified by NED).

on rock cores for the Northfield Mountain Project were utilized. Indicated rock structure and conditions are those depicted on a Preliminary Geologic Structure Section along the proposed Northfield - Quabbin Tunnel dated March 7, 1972, prepared by MDC (not included). Rock formations crossed by the tunnel alignment are comprised of approximately 85 percent hard, gneissic varieties and 15 percent softer schistose types. Inflow estimates and conditions of the rock structure (RQD) were estimated from known properties of similar rock formations on other projects. The rock formations and their assumed engineering properties are shown on Tables C-1 and C-2 in Appendix C. Critical geologic structures such as fault lines and buried valleys whose conditions and limits are unknown and assumed to be moderately severe and have been costed accordingly.

B. Proposed Tunnel Alignment

The proposed alignment, shown on Plate No. 11, represents the scheme shown on an April 1972 Plan by the MDC Construction Division entitled, "Quabbin Water Diversion Facilities -- Plan of Borings," File Cont. C-390 G 3.36 P.M. All stationing is based on a NED profile used for the computer program.

Four shaft locations selected by MDC were located and are described as follows:

Shaft 1. Located at the upper reservoir of the Northfield Power Project. Coordinates N 587,465.785 and E 347,405.915 at Station 15+00. This shaft is costed as an 18-foot, 8-inch finished diameter shaft having a 12-inch minimum thickness concrete lining with an invert elevation of 300 and a top elevation of 950 m.s.l. Two excavation schemes were estimated using a conventional and mole system with the excavated material being removed through Shaft 2. Cost estimates shown are for the MOLE technique.

Shaft 2. Located adjacent to the easterly banks of the Millers River at approximately Station 45+00. Tunnel invert elevation is at 300 m.s.l. with a ground surface elevation of 440 m.s.l. Shaft 2 is designed as a 14-foot finished diameter with a 12 inch thick lining in accordance with MDC criteria. Shaft 2 will service the tunnel west to Shaft 1 (Station 15+00) and east to Shaft 3 (Station 200+00). Disposal of all material is considered to be within a radius of two miles of the shaft requiring a disposal area of approximately two acres 30 feet deep.

Shaft 3. Located adjacent to Depot Road at Station 200+00, this shaft is 520 feet deep with a tunnel invert at elevation of 440 m. s. l. Shaft diameter is 14 feet, finished diameter, with a 12-inch thick lining. Shaft 3 will service the tunnel easterly to Shaft 4 (Station 385+00) and all material removed from Shaft 3 will be disposed of within two miles of the shaft in a two acre area approximately 30 feet deep.

Shaft 4. Located east of the Swift River and south of Morse Village, the shaft has a depth of 370 feet with an invert at elevation 440 m. s. l. This shaft has a 14-foot finished diameter with a 12-inch thick concrete lining. Shaft 4 will service the tunnel section between Stations 385+00 and 530+00. Disposal of material in this section is costed for a two acre area, 30 feet deep within two miles of Shaft 4.

Shaft 5. Located at Rattlesnake Hill on the East Branch of the Quabbin Reservoir, the shaft is 90 feet deep with an invert elevation of 440 feet m. s. l. A horizontal cut section at elevation 530 serves as a discharge apron and varies from a 14-foot width at the tunnel shaft to a 30-foot wide discharge apron 150 feet distance at the edge of the reservoir. It is considered that excavation at Shaft 5 will be disposed of within a 1 mile radius of the shaft.

In view of the lack of specific subsurface data, Shafts 1 through 4 are considered as being driven wet and requiring full ring steel supports for the first 100-foot depth. The remaining portion of the shaft would be supported by rock holts with a temporary wire mesh. In all cases, the required support in the first 100-foot depth is assumed to require full support equal to a tunnel in the same conditions. Below 100 feet the loading is assumed as 1/2 the stresses sustained by a tunnel in the same formation. Costing of shafts assumes that for safety reasons all supports will be installed as the excavation progresses and material costs will include preformed steel ribs with blocking and lagging in the upper 100 feet and 1-inch diameter rock bolts with wire mesh and grouting in lower section of the shaft. All costs of pumping and air conditioning in shaft construction are considered negligible.

The tunnel section, as designed by MDC, is costed as a 10-foot finished diameter tunnel with an 8-inch thick concrete lining operating at a head of approximately 475 feet with an overall length of 51,700 feet. All haulage will be done by train with a maximum slope occurring between Shaft 2 and 3 of .009 percent. Two potential fault zones and one crushed zone on the proposed alignment are costed as being done by conventional tunnelling methods with water inflows of up to 500 g. p. m. These severe assumptions require that the mole method

be modified for 1000 feet at each of these areas at an additional cost of reset up at 25 percent of the initial mole setup.

C. Tunnel Cost Estimate

A computerized estimate of construction cost for mole and conventional excavation was based on the proposed design and assumed geologic conditions along the alignment shown on Plate No. 11. Costs were based on a 5 percent profit margin and a 25 percent overhead margin with a regional cost factor of 1.2. A 1.2 factor is considered applicable for areas with a labor market having reasonable union controls and not particularly suited to underground construction or mining. Cost indices for labor, equipment, and materials are based on Engineering News Record (ENR) values for the month of July 1974.

All costs for ventilating and air conditioning were based on mean underground temperature of 55° F at the heading and the warmest eight hour daylight temperature at the ground surface of 75° based on records at Turner Falls, Massachusetts.

All structural design in the tunnel and shafts was based on the assumed geologic conditions and the proposed design by MDC. No costs are assumed for headworks or C.I. helical vanes at Shaft 1, or special structures or plugs in Shaft 2 for water supply operation. Noticeable increases will occur in segments 16, 17 21, 22, 24, and 25 where the tunnel intersects assumed faults and crushed zones in the rock. Fault zones are carried as a warning on Table 6 due to the assumed crushed conditions of the rock.

Disposal costs were computed on an area basis at a circumferential distance from the most appropriate shaft. Cost of land for disposal represents a real estate estimate of the approximate values of land for the section involved. Muck disposal configuration has been programmed to minimize construction activities within the reservoir areas. This has been done to reduce work traffic in the area of the headworks construction and to minimize contamination of the existing reservoirs.

A summary of construction costs for tunnel and shaft works by mole construction is shown on Table 7.

TABLE 7

NORTHFIELD MOUNTAIN TO QUABBIN RESERVOIR AQUEDUCT COSTS

Tunnel Cost Estimate

Labor		18,284,000
Equipment		4,116,000
Materials		4,227,000
	Sub-total	26,627,000

Shaft Cost Estimate

Labor		3,167,000
Equipment		1,175,000
Materials		630,000
	Sub-total	4,972,000

Sub-total	31,599,000
Contingencies	6,320,000
	37,919,000

26. Annual Charges

Average annual costs, summarized in Table 8, are based on interest rates of 5.875 percent for Federal and non-Federal costs. Investment costs for the project are amortized over a 50-year economic life. Annual charges for use of the facility and the power necessary to operate the diversion were supplied by the Metropolitan District Commission.

The Facilities Charge includes all items attributable to the water supply operation of the Northfield Mountain Pumped Storage Project. Such costs as the men required to operate the pumps and gates, maintenance work on the facility, heating and lighting of the facility, and part of original investment were considered in determining the Facilities Charge which was tentatively agreed to by the two parties involved, the Metropolitan District Commission and Northeast Utilities.

The Power Charge is the annual electric power costs required on an average basis to develop a yield of 72 MGD from the project. These costs were also tentatively agreed to by the MDC and Northeast Utilities.

TABLE 8

SUMMARY OF FIRST COSTS AND ANNUAL CHARGES

(1972 Price Level)

not really; update to 1974 P.L.

FIRST COSTS	
Water Supply Works - Upper Reservoir Northfield Mountain (Constructed)	$ 2,000,000
Tunnel Aqueduct - Northfield Mountain to Quabbin Reservoir	37,919,000
Outlet Works - Quabbin Reservoir	483,000
Total Direct Cost	$ 40,402,000
Engineering and Design[1] 9.2%	3,533,000
Supervision and Administration (7.5%)	2,880,000
Total Project First Cost	$ 46,815,000
Interest During Construction	4,126,000
Investment	$ 50,941,000

ANNUAL CHARGES	
Interest and Amortization	$ 3,176,000
Facilities Charge[2]	241,000
Power Charge[2]	666,000
Total Annual Charges	$ 4,083,000

[1] Does not include upper reservoir works which have already been constructed.

[2] At the Northfield Mountain Hydroelectric Facility.

SECTION IX

PROJECT IMPACT ANALYSIS

24. General

A. Background

This section of the report will deal with an evaluation of the social impacts which the construction of the proposed water supply project would have. The objectives are to determine and evaluate the potential beneficial contributions as well as neutral or adverse effects which the project's development may have. These effects are evaluated in both the source and service area. Impacts are quantified and translated into dollar values where possible. In areas where impacts are not quantifiable, the effects of diversion are discussed so that the reader will be aware of all the ramifications of implementing the projects. Every effort has been made to consider all significant effects of the proposed diversion, for even the more subtle changes to a stabilized community can have important and long lasting implications.

A data baseline was first established so that changes which would occur without the proposed diversion could be measured. The baseline data in the short term are merely extrapolations of existing trends. For example, it has been assumed that in-and-out migration patterns will continue, that no major economic shifts will occur and that existing regulatory policies and jurisdictional lines will remain unchanged. Beyond the short term projections, anticipated development became less clear. Social expectations tempered by judgmental decisions have produced as reasonable projections as possible. Specifically, population, water use, and development expectations were taken from available master plans of cities and towns affected. Where no such data were available, projections of economic activity were estimated.

Impacts directly from constructing the project were based on engineering plans and site maps. To relate construction activities to impact categories, estimates were made of labor demands and capital expenditures as well as the physical alterations to specific sites relating to human activity.

In evaluating the projects, guidelines given in Senate Document 97 were followed. In addition, the proposed Water Resources Council guidelines [1] were followed and benefits as well as losses were evaluated on a three account system. The guidelines were established under the premise that the over-all purpose of water and land replanning is to reflect society's preference for attainment of the three objectives defined as:

1) To Enhance the National Economic Development by increasing the value of the nation's output of goods and services and improving the national economic efficiency.

2) To Enhance Environmental Quality by the management, conservation, preservation, creation, restoration, or improvement of the quality of certain natural and cultural resources and ecological systems.

3) To Enhance Regional Development through increases in a region's income; increases in employment; distribution of population within and among regions; improvements in the region's economic base, and educational, cultural, and recreational opportunities; and enhancement of its environment and other specified components of regional development.

A complete accounting of relevant beneficial and adverse effects are presented as they relate to the above social objectives.

Beneficial and adverse effects are measured in monetary terms for the national economic development objective and the regional income component of the regional development objective and for some social factors.

Other beneficial or adverse effects are measured in non-monetary terms for components of the environmental quality, for the non-income components of the regional development objective, and for most social factors. Estimating these beneficial and adverse effects is undertaken in order to measure net changes with respect to particular objectives that are generated by the project. The beneficial and adverse effects on social factors are also displayed in the system of accounts.

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[1] Federal Register, Volume 36, No. 245, Part II, Water Resources Council - Proposed Principles and Standards for Planning Water and Related Land Resources.

Thus, there are beneficial and adverse effects for national economic development, environmental quality, and regional development objectives and beneficial and adverse effects on social factors. These are measured in quantitative units or qualitative terms appropriate to a particular effect.

The multi-objectives are not mutually exclusive with respect to beneficial or adverse effects, and decisions as to the selection of the recommended plan have been made by considering the difference in the effects of the alternative plans.

B. Parameters Used in the Benefit/Cost Analysis

WRC ?

1) Discount Rate - A discount rate of 5-7/8 percent was used throughout the computations. This is a rate furnished by the United States Office of Management and Budget. The rate reflects the average price being paid for money borrowed by the government.

Impacts were estimated on a year by year basis into the future. The capital dollar values were brought back to year 0 using present worth single payment factors to get a capital dollar value at year 0. These capital dollar values at year 0 were then amortized over the life of the project to put them into annual dollar values.

2) Project Life - A 50-year project life was selected as best fitting the circumstances of type of projects under consideration. Although the projects under consideration will not meet Eastern Massachusetts' needs 50 years into the future, it is expected that they will remain operative and be contributing to the system at least up to 50 years in the future. Consideration was given to using a somewhat longer project life, but such a course of action would contribute little for three reasons. First, projections of population and water consumption become extremely uncertain when carried into so distant a future. These projections are a basis for loss and benefit computations. As a matter of fact, loss totals enjoying a high degree of confidence end about 1990. Second, future technology, an unknown quantity, may very well make new sources of water supply competitive with the system as we now know it. Third, calculations beyond 50 years yield very little in the way of dollar amounts when figures are brought back to present worth. For instance, a $1.00 value at year 51 is worth only $0.06 when brought back to year 0. The $1.00 at year 100 is worth only $0.004 when brought back to year 0.

The year 1976 was selected as the year in which the project could possibly go into operation. This is year 0 in the 50-year economic life.

3) Price Level - The price level established for this study was based on the prevailing prices in 1974. No changes in this price level were considered during the life of the project. This assumption, although not supportive by historical record, should not lead to any erroneous conclusions because, in general, the rate of price level increases in the past has tended to be uniform among the various facets of the economy. There is no reason to suspect that the rate of price level change in the donor area, receiver area, or New England region would vary significantly from the national average.

Benefits and adverse effects of the project have been determined by comparing the conditions expected with the plan to the conditions expected without the plan. In other words, impacts are defined as deviations from the no-project baseline. The term "no-go situation" in the following paragraphs is defined as the state of affairs which will prevail if the existing water supply system is not augmented with additional water from any source. The "go situation" conversely is the situation which will exist if the particular alternative in question is implemented. The no-go situation, therefore, becomes a baseline for comparison of the various alternatives.

C. Elements Included in Analysis

1) General - A contract was negotiated with a private concern to make a study and report on the social and economic impacts of diverting water from the Millers and Connecticut River Basins into the Eastern Massachusetts water supply system. The report[1] which evolved from this study is included in this report as Appendix F. This work, which can best be described as a case study, first established the existing socio-economic framework in which the proposed water supply development will be acting. After establishing this baseline situation, the contractor then determined the positive and adverse effects which could be expected if the water supply developments were to be constructed.

Budgeting and time constraints on the study made it impossible to do a complete economics analysis under contract. The contract was negotiated midway through the NEWS Study and final alternative plans had not been decided upon; in fact, results of the study could have changed the direction of the investigation. With this in mind, it was decided that the money

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[1] Identification and Assessment of Social and Economic Impacts of the Connecticut and Millers River Basin Diversions - Abt Associates, Inc., June 1972.

spent under contract would be used to the best advantage if an intensive study were made on the Northfield Mountain Project and on one specific alternative on the Millers River Basin. The contract work was then used as the basis of in-house study of further alternatives and evaluations under the other two accounts. Regional Development was selected as the account to be addressed by the study.

This approach worked out very well. Impacts on the receiver area depend primarily on the quantity and timing of deliveries to the system. It makes little difference where the water comes from. If the study had taken a drastic change of direction and some different source of water emerged as a better alternative, the contract work would have been a valuable reference; because although values would change, the methodology would be no less valid.

2) Economic Loss Categories - Economic losses estimated in this report as a result of supply shortage may be described either as one time events or happenings on an annual basis. In the former category belong all losses connected with investment projects undertaken to either permanently increase the supply of water available to an area or to permanently decrease the consumption rate. Once such investment projects are undertaken, the losses that formerly resulted will not be experienced again unless the shortage grows more severe. Altogether, seven types of concrete losses were analyzed in this study. The Contractor gathered information in the field and made numerous telephone inquiries. He also relied heavily on collected data and methodologies developed under a study for Resources for the Future, Inc.[1]

LOSS TYPE 1

Annual Loss Categories: Industrial Sector.

Two major subheadings fall in this category:

(1) Business losses resulting from forced slowdowns or shutdowns in production due to drought; and

(2) Disparate costs, like dry-hole wells, cloud seeding, and water conservation programs. The magnitude of these losses was

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[1] Drought and Water Supply, Russell et al, Johns Hopkins Press, Copyright 1970.

estimated first at lost value added for shutdowns and forced slowdowns, and then as the costs of the various "other" projects.

LOSS TYPE 2

Annual Loss Categories: Municipal Sector.

The subheadings distinguished here include:

(1) Lost Revenue on water not sold (the prevailing price of water times the shortage computed as the difference between potential demand and available supply);

(2) Emergency Supply Costs, based on interviews with water systems managers and press accounts;

(3) Other, the "costs of redistributing the town's available water in a desired pattern as in hiring spray trucks to cart river water to thirsty trees and shrubs," and certain investment projects which ought to be classified as permanent losses; for example, the costs of "a well for a town swimming pool . . . . . efforts to find new groundwater sources, etc." For the purpose of this study, the "Municipal Other" category is treated as an annual cost because it has been impossible to split apart this category into its appropriate investment and annual components.

(4) Tree Losses, these losses reflect the town's inability to water trees as a result of shortage.

LOSS TYPE 3

Annual Loss Categories: Revenues Lost to Municipal Sector.

Included here were the losses of municipal revenue on water that the town was not able to sell because of the restrictions. Markup margins on water purchased from the Metropolitan District Commission (MDC) were estimated on the basis of a telephone survey of the sample town's water departments. Not included here are the revenues lost by the MDC system itself; this category includes only the markup lost by the client municipalities.

LOSS TYPE 4

Annual Loss Categories: Commercial Sector.

As in the industrial sector losses include:

(1) Business Losses, and

(2) Projects aimed at reducing consumption. This section consists of non-manufacturing establishments, including firms engaged in trade and services.

LOSS TYPE 5

Annual Loss Categories: Domestic Sector.

The only subheading falling in this category consists of sprinkling losses, the losses of consumer surplus resulting from a complete or partial ban on lawn sprinkling.

LOSS TYPE 6

Permanent Losses: Industrial Sector.

The only heading here reflects the claimed costs of all permanent water-use adjustments . . . . . (such as) cooling towers for the recirculation of cooling water; wells drilled to increase the plant's independent supply capability; process-water recirculation systems; additions to existing dams; new dams; installations of air-cooled window air-conditioners, and others.

LOSS TYPE 7

Permanent Losses: Domestic Sector.

Like industries, certain households made emergency investments in order to shield themselves from the effects of drought. There appears to have been no domestic investments undertaken to control consumption (i. e., recycling), and investments which were undertaken to provide new, independent sources of water appear not to have been profitable. This implies fairly large losses for this sector.

Permanent Losses: Other Sectors.

Investments of varying profitability were undertaken by sectors outside of the industrial and the domestic sectors, however, these investments

were quite small. It was felt that they would be best handled as annual impacts.

One aspect of these losses deserves special consideration. Can losses for a number of firms be summed up and expressed as losses for the industrial sector as a whole? For example, in a hypothetical situation where a serious labor shortage exists, losses of value-added in industries forced to restrict operations due to water shortage may be cancelled by gains in value-added by industries which profitably hire the labor released. In this study, it has been assumed that all value-added is lost when a firm is forced to shut down its operations. It is possible to look at the entire system shortage and make a series of alternative assumptions by which people and resources can be transferred either to non-water-dependent production units or to production units outside the shortage area. In this way the system losses can be, in fact, less than the full losses of firms suffering the shortage; therefore, in instances where we are working with estimates of the cost of shortage in the region, no benefits are reaped from stimulation occurring in non-shortage areas or in non-water using activities outside the region as a consequence of the slowdown.

3) Socio-Economic Impact Categories - Impact categories used to measure effect of the project's construction are shown in Table 9. The measures they include, because of lack of data, are in some cases at too fine a level of detail. The categories shown, however, were used to the greatest extent possible in attempting to define socio-economic impacts in both the Connecticut River Basin and the Boston Metropolitan Region.

4) National Economic Development - The National Economic Development (NED) objective is enhanced by increasing the value of the nation's output of goods and services and improving the national economic efficiency. Entries under this account can, of course, be either positive or negative. Any item under this account will be carried under one or both of the other two accounts (Regional Development and/or Environmental Quality). The converse is not true. An example is in order.

Suppose an item, say a paper product, is not manufactured in the region of a proposed project because of a drought situation. This would create a loss in the regional economy. If the lost production were made up elsewhere in the United States, then there would be no loss in the NED account. If, on the other hand, the paper product was a specialty of the region that was effected and could not be manufactured elsewhere, then the loss would

TABLE 9

SOCIO-ECONOMIC IMPACT MEASUREMENT

Impact Categories	Suggested Measures	Units	Time Period
1. Land Use	Net change in the percent distribution of acres devoted to industrial, commercial, agricultural, residential & recreational uses.	Percent	Long
	Net change in land use caused by the various physical diversion facilities (e.g., dams, pipelines, tunnels).	Acres	Short & Long
	Net change in the amount of land available for development.	Acres	Long
2. Population	Net changes in the age, income, race and ethnicity distributions of the local population, particularly in the donor areas.	Percent	Short & Long
3. Municipal Finance	Loss of assessed valuation as a percent of community total.	Percent	Long
	Increase in assessed valuation resulting from improved water service.	Dollars	Long
	Net change (gain/loss) in tax revenue resulting from improved water service.	Dollars	Short & Long
4. Commercial Activity	Net change over normal trends in gross wholesale and retail sales of those facilities affected by availability of water resources.	Dollars	Short & Long
	Net number of businesses located (displaced) by a facility	Number	Short & Long

TABLE 9 (cont'd)

5. Housing	Net change (increase/decrease) in number of housing units by number of bedrooms by price (OR).	Number	Short
	As a percent of community's total stock in the receiver area.	Percent	Short
6. Education	Net change in amount of classroom and other educational space required for projected change in school-age population resulting from in- and out-migration.	Sq. Ft.	Short & Long
	Net changes in cost of teacher and other education staff required for projected change in school-age population resulting from in- and out-migration.	Dollars	Short & Long
	Net change in cost of providing school services because of changes in busing.	Dollars	Short
	Use of facilities for educational programs.	Day/Yr.	Short
7. Leisure Opportunities	Net change in the total number of acres of parks and playgrounds in the Study Area.	Acres Visitor Days	Short & Long
	Net change in the extent to which planned recreation space meets American Society of Planning Officials planning standards relating types of space to population characteristics.	Percent	Short
8. Cultural Opportunities	Total number of churches, historical sites or other cultural institutions taken.	Number	Short
	Cost of relocating churches, historical sites and other cultural institutions, minus compensating payments.	Dollars	Short
	Increase in locational amenities (e.g., improved site planning, additional parking, etc.) as a result of relocation.	No. of Improvements	Short

TABLE 9 (cont'd)

9. Transportation	Net change in travel time as a result of facilities from major residential areas to activity centers: health, commercial, recreation, employment, education, cultural	Min./Trip x Trips/ day	Short
10. Municipal Services	Net change in cost of providing water, sewerage, and garbage service and other municipal services.	Dollars	Short & Long
	Net change in residential insurance rates.	Percent	Long
11. Security	Number of positive and negative statements about the opportunities for system failure, as revealed by a content analysis of local news media.	Number	Short & Long
12. Community Image	Changes in property values adjacent to supply facilities	Dollars	Short & Long
	Number of positive and negative statements about the community as revealed by a content analysis of local news media.	Number	Short & Long
13. Community Cohesiveness	Total number of community, regional, statewide and national groups taking a position (making a public statement) for or against the project.	Number	Short
14. Citizen Involvement	Total number of community, regional, statewide and national groups involved in the planning of the project, times the level of their involvement, according to the following scale of increasing involvement: 1. Attendance at hearing; 2. Citizen opportunity to critique plans at public meetings; 3. periodic workshop planning sessions with community representatives; 4. community advocate planner participated on equal basis with technical staff in all planning activities; 5. appointment of arbitrative hearing officer who makes final decision in case of dispute between community & Army Engineers.	Weighted No.	Short

TABLE 9 (cont'd)

15. Institutional Involvement	Total number of jurisdictions involved in the totality of the construction process for a water supply facility.	Number	Short & Long
	Number of applications submitted to the MDC for water supply service by cities and towns; disposition and frequency of refusal.	Number	Short & Long
16. Economic Stability	Net change in income resulting from construction and related activities.	Dollars	Short & Long
	New increase in private investment.	Dollars	Short & Long
17. Real Income	Net change in per capita income.	Dollars	Short & Long
	Net change in tax assessments.	Dollars	Short & Long
	Net change in regional net income.	Dollars	Short & Long
18. Employment	Number and type of jobs created/lost.	Number	Short & Long
19. Industrial Activity	Change (increase/decrease) in number of industrial establishments.	Number	Short & Long
	Change in productivity indices.	Dollars	Short & Long
20. Agricultural Activity	Change (increase/decrease) in number of farm acres.	Number	Short & Long
	Change in production per acre.	Dollars	Short & Long

occur in the NED account as well as the regional account. Following the logic further, if other manufacturers outside the region manufactured the product but were operating to capacity, then they could not take up the lost production. The lost production would not be made up in the United States and the loss would be to the region as well as the NED account. The same logic can be applied to an item which is part of the environmental quality account.

It is quite possible that only a part of a regional or environmental account entry will appear in the NED account. Example, a loss in the region that will be only partially mitigated elsewhere in the country.

In this study, as described earlier, seven economic loss categories were used to determine the economic impact of water shortages. All of these categories express losses to the regional development.

Upon examining the losses in each category, it was decided that losses in four of the categories; Municipal Emergency Supply and Other, Municipal Lost Revenue, Domestic Losses and Domestic Investment would be carried 100% into the NED account. It was decided that the remaining three; Industrial Business Losses and Other, Commercial Losses, and Industrial Investment would net out to zero (mitigated in full by the national economy). Industrial Investments are assumed to operate at no loss; therefore, losses were 0 in both accounts.

Based on the above procedure, then, the method for determining NED losses was to remove Commercial Losses and the Industrial Business Losses and Other from total Regional Economy Losses.

5) Environmental Quality - In assessing the impact of the project on the environment, contractor services as well as in-house personnel were used extensively. An evaluation was made of the project's impact on the Connecticut River estuary; on the Connecticut River; on the environment of the receiving water storage reservoir, i. e., Quabbin; and the Boston Metropolitan Region. Full descriptions of these investigations are included later, and in Appendices D and E.

6) Regional Development - In assessing the impacts which the project's implementation might have on regional development, a subdivision into two groupings of communities was required. This subgrouping was necessitated because any impact of the diversion on Connecticut River Basin communities (or source area) would be keyed to

the withdrawal of water from the basin. On the other hand, communities supplied by the water would experience a separate set of impacts from any of the alternatives.

A determination thus was made as to what, in fact, were the supplier and receiver communities sub-groups. It was decided that only the communities directly affected by the project would be considered as suppliers. It became clear that social and economic impacts in the Connecticut Basin would be most significant for site-specific activities. Communities such as Deerfield and Leominster would probably be slightly affected by the project, however, not to a point that could be quantified or even speculated upon reasonably. Greenfield, Erving, Royalston, Warwick, Athol, Winchendon, and Orange are the only communities that would be noticeably affected by this project and projects in the Millers River Basin. Environmental studies presented in this report indicate that downstream communities on the Connecticut River, as well as the Connecticut River estuary, would not be significantly affected from an environmental or ecological standpoint. On this basis, it was decided not to include these communities among the suppliers. A complete listing of all communities examined as potential suppliers is given in Table 10.

Receiver communities are defined as present recipients of the Metropolitan District Commission Water Supply System plus those communities which will have no other reported engineering option than to join the system to meet their 1990 water supply needs. The sixty-six receiver communities are given in Table 11.

28. Evaluation

A. Regional Development Account

1) General

As described earlier, impacts from the implementation of the project on the regional development within the study area received considerable attention. Included in this analysis was an assessment of the project's impact on the socio-economic objectives of communities both within the basin (or suppliers) from which water would be diverted as well as communities which would be supplied by the diverted flow (or receivers).

To impose some rational structure of the impact analysis, the study was structured in a matrix fashion. The project together with the baseline "no-go scenario," was considered with respect to each relevant impact category shown in Table 9. By considering the project in this fashion, an evaluation of the project's economic and social change and the no project baseline was possible.

Obviously, not every possible combination is equally important. In some cases, the magnitude of change in a given impact category is so small as to be insignificant. In others, a forecast change may be small but long-lived, thus overshadowing a larger but more ephemeral effect. Generally, the effort was made to distinguish short- and long-term changes for each impact category as it relates to communities. Short-term has been defined as the five-year term required for construction. Thus, impacts so accounted are project-specific. Long-term encompasses changes falling outside that limit and related less to the specific works proposed than to the shortage/availability of a quantity of water equal to that diverted. In both cases the definitions apply without regard to real time; that is, the five-year period begins to run whenever construction commences.

If implementation of the project is delayed an inordinate period of time, then the impacts as described, of course, became less valid. A delay of 10 years, for example, would place communities served by the regional system in a precarious water supply situation.

The total number of communities examined totalled eighty-four. Of this number, eighteen were considered potential suppliers or municipalities from whom water would be diverted. The balance of sixty-six municipalities or communities which would use the water were considered as receivers. A listing of the municipalities included in the supplier and receiver sub-groups is given in Tables 10 and 11.

Insofar as possible, profiles of sample communities were built in the same format as impact categories described in Table 9. Over the short term, baselines are merely a continuation of trends noted in the profiles. For example, it has been assumed that in- and out-migration patterns will continue, that no catastrophic economic shifts will occur and that existing regulatory policies and jurisdictional lines will remain unchanged. Over a time horizon extended to fifty years, however, anticipated development is less clear. However, the study made use of the best projections available. Specifically, population, water use, and development expectations have been taken from the available Master Plans of cities and towns affected. Where no such data were available, projections of economic activity were developed. In all cases, impacts are defined as deviations from the no-project baseline.

TABLE 10

SUPPLIER COMMUNITIES

Ashburnham	Northfield
Athol	Orange
Deerfield	Petersham
Erving	Phillipston
Gardner	Royalston
Gill	Templeton
Greenfield	Warwick
Hubbardston	Wendell
Montague	Westminster
New Salem	Winchendon

TABLE 11

RECEIVER COMMUNITIES

Fully Served Members

Arlington	Malden	Quincy
Belmont	Marblehead	Revere
Boston	Medford	Saugus
Brookline	Melrose	Somerville
Chelsea	Milton	Stoneham
Everett	Nahant	Swampscott
Lexington	Newton	Waltham
Lynnfield	Norwood	Watertown
		Winthrop

Partly Served Members

Cambridge	Wakefield
Canton	Weston
Needham	Winchester
Peabody	

Served Non-Members

Clinton	Lancaster	Northborough
Chicopee	Leominster	Southborough
Framingham	Marlborough	South Hadley
		Wilbraham

Communities with No Other Option

Ashland	Hudson	Sherborn
Avon	Lincoln	Stoughton
Bolton	Maynard	Stow
Braintree	Medfield	Sudbury
Dedham	Millis	Wellesley
Dover	Natick	Westwood
Holbrook	Norfolk	Weymouth
Holliston	Randolph	Woburn

2) Methodology

Because individual treatment of each of the eighty-six communities (source and receiver) affected by the proposed projects was never considered feasible within the dollar and time constraints of the study, it was necessary to limit the number investigated. Therefore, a computerized clustering exercise was performed which grouped communities according to sixteen descriptors:

(1) Present Population
(2) Projected Population
(3) Population Growth
(4) Population Density
(5) Employment
(6) Median Income
(7) Present Water Demand
(8) Projected Water Demand
(9) Status of M. D. C. Service (served, non-served)
(10) Total Industrial Demand
(11) Restrictions on Consumption (yes, no)
(12) Supplier or Receiver
(13) Future M. D. C. Member
(14) Present M. D. C. Member
(15) Served Non-Member
(16) Have No Option

Next, one element from each of the sixteen resulting clusters was chosen for further study. In the subsequent data gathering effort, it became clear that not every sample community had the data required to establish competent socio-economic profiles, or more importantly, Master Plans from which to extract expectations of future development. Supplier towns, with the exception of Greenfield, were particularly data-poor. Indeed, they were omitted from a second clustering program which was then run for only the sixty-six receivers.

It appeared from preliminary work that long-term economic impacts were going to be most important in receiver communities. Therefore, the variables chosen for the second clustering program were restricted to economic factors suggestive of uniform economic structure. The outputs of this second program are as follows:

CLUSTER 1.

Elements: Arlington, Revere*, Saugus, Winthrop, Weymouth

Representative and Descriptors:

Revere*

Low-income area
Urban/Boston satellite, North
Largely residential
Commercial economy
Stagnant or little growth potential
Low water user
MDC receiver

CLUSTER 2.

Elements: Belmont*, Brookline, Milton, Swampscott, Lincoln, Lexington, Newton, Nahant, Needham, Wellesley

Representative and Descriptors:

Belmont*

High-income area
Urban/Boston suburb or satellite
Residential
Commercial economy
Moderate growth rate
Low water user
MDC receiver

CLUSTER 3.

Elements: Boston*, Cambridge, Maynard

Representative and Descriptors:

Boston*

Low-income to poor area
Urban/city core
Increasingly less residential
Mixed economy; larger proportion commercial
Stagnant to negative growth rate
High water user
MDC receiver

CLUSTER 4.

Elements: Chelsea, Everett, Peabody*, Clinton, Chicopee, Ashland, Woburn

Representative and Descriptors:

Peabody*

Low-income area
Urban independent/North Shore
Highly industrial
Moderate growth rate
High water user
MDC receiver (very small % of total consumption)

CLUSTER 5.

Elements: Lynnfield, Marblehead, Weston, Winchester, Southborough, Dover, Holbrook, Medfield*, Stowe, Westwood

Representative and Descriptors:

Medfield*

Moderate or middle-income area
Rural/Southwest of Boston
Largely residential
Mixed economy; moderately industrial
Stagnant or low growth potential
Low water user
Not an MDC receiver

CLUSTER 6.

Elements: Malden, Medford*, Somerville, Stoneham, Lancaster, Watertown

Representative and Descriptors:

Medford*

Moderate or middle-income area
Urban/Boston satellite or suburb
Residential
Economy mostly commercial
Stagnant or low growth potential
High Water user
MDC receiver

CLUSTER 7.

Elements: Melrose, Marlborough, Wilbraham, Holliston, Hudson, Randolph*, South Hadley, Millis, Stoughton

Representative and Descriptors:

Randolph*

Moderate to middle-income
Urban independent/South of Boston
Moderately residential
Mixed economy - highly industrial
High growth potential
Low water user
Not an MDC receiver

CLUSTER 8.

Elements: Wakefield, Norwood, Framingham, Natick*, Leominster

Representative and Descriptors:

Natick*

High-income area
Urban independent/West of Boston
Moderately residential
Mixed economy - highly industrial
Moderate growth potential
High water user
Not an MDC receiver

CLUSTER 9

Elements: Canton, Avon, Bolton, Sherborn, Sudbury, Northborough*, Norfolk

Representative and Descriptors:

Northborough*

Moderate or middle-income area
Rural/West of Boston
Largely residential
Mixed economy - mostly industrial
High growth potential
Moderate water user
MDC receiver

CLUSTER 10.

Elements: Quincy, Waltham, Braintree*, Dedham

Representative and Descriptors:

Braintree*

High-income area
Urban/South of Boston
Moderately residential
Industrial economy
High growth potential
Moderate water user
Not an MDC receiver

The subgroup of supplier communities selected for close examination were limited to seven: Greenfield, Erving, Royalston, Warwick, Athol, Winchendon, and Orange. These municipalities were chosen because early in the investigation it became clear that social and economic impacts in the Connecticut Basin would be most significant for site-specific activities, remote suppliers like Deerfield and Leominster were eliminated. Though a case could be made for examining towns downstream on the Connecticut, it was felt that the environmental studies under way would point out any important changes for these communities. From the social and economic standpoint, analysis by community outside the immediate diversion area would not have been fruitful, or even possible.

The backbone of the analysis was the projection of economic and residential activity for the receiver area from 1970 to 2020. Of the sixty-six communities total, none but a very few had themselves done any significant forecasting.

As noted above, the basic strategy was to build clusters on the basis of key economic indicators. In this way, information could be used in our analysis that could not have been obtained for all sixty-six cities in a reasonable time. While most work actually proceeded on the 66-city level, values for certain variables were estimated for cluster sample cities only and then assumed to apply also to other communities in the same cluster. Thus, when a variable could not be feasibly collected for all receivers, an estimate was made for a representative city in each cluster and assumed that its value was shared by all other members of its cluster.

Even so, information was not easy to come by, especially for the very distant years, 1990 - 2020. As is usually the case for projective studies, some very general numbers were available for the far end of the time horizon; projections prepared for New England, or at best for eastern Massachusetts. The application of such general information to particular localities has been a risky venture, however sensitively done.

Thus, the implication is that estimates presented later are likely to be far more meaningful for larger groups of jurisdictions studied (i. e., for clusters, or for the aggregate of all receivers) than for any one cluster element. This is especially true for the years near the 2020 time horizon. Accordingly, loss estimates are not presented for each individual receiver since such displays of data would be likely to contain very large errors. In a cluster, on the other hand, errors are likely to cancel, and the results for the cluster as a whole are likely to be far more reliable.

Finally, to fill out impact categories related to project - specific changes, use was made of historical data from two case study communities. In the supplier area, the Town of Northfield and its responses to a very much larger construction project at Northfield Mountain (Northeast Utilities) was used as an upper bound on similar types of changes anticipated for the alternative projects. In the receiver area, interview data provided by the Chairman of the Planning Board in Stoughton established the dimensions of change to be expected in the event of widespread water shortages resulting from a situation caused without a project being implemented. This community is generally conceded to be the most deprived of potential M. D. C. water customers and offers a good example - though admittedly over a very brief period compared to the fifty-year life attempted here - of the trends to be expected in other communities equally deprived by a failure to provide for projected demands.

In the course of data collection, some contact, direct or by telephone, was established with all seventeen sample cities and towns. In most cases, specific water-related agencies or elected officials were successfully sought out.

Conversations about the major issues of the water supply problem in metropolitan Boston and diversion plans were held with residents of both supplier and receiver areas; roughly ten in each area, half being sidewalk encounters and the others more structured interviews with private individuals known to have an interest in the project. In addition, five planning officials were approached as spokesmen for their respective

constituencies in eastern and western Massachusetts. Four were members of local Planning Boards and one headed a county planning office. Other noteworthy sources included: 1. Northeast Utilities, 2. Maine Yankee, 3. The Metropolitan Area Planning Council, and 4. The Commonwealth's Office of Regional Affairs (Department of Community Affairs), Department of Education (Research and Development), Department of Natural Resources (Division of Water Resources, Division of Water Pollution Control), Department of Public Works, Division of Employment Security (Research Department) and Department of Public Health.

3) Impact on Supplier Area

The impact categories shown in Table 12 present forecasted changes in the supplier communities. The data shown represent total impacts for the sum of individual towns actually affected. Qualitative data which is keyed by superscript letter to following sections, however, is generally applicable to all eighteen communities examined as suppliers.

It should also be noted that it has not been possible to go much beyond the short term limits of construction and deal quantitively with impacts on suppliers. Baseline projections are simply not available after 1990 and forecasted impacts are directly related to construction in most every case. Unfortunately, then, assumptions have had to be made to fill more gaps than desired, but by working within ranges, it is believed gross errors have netted out.

/a/ Land Use

Approximately 30 acres would be slated for land taking under this project. Thus land use changes are minimal.

Since existing uses are almost entirely limited to undeveloped open space and since acquisition is likely to mean controlled access, the natural character of the taking area will be preserved. In any event, the service population for the project is extremely small and significant principally in the eyes of personally affected individuals.

Apart from the recreation issue, the development potential of the host towns with the project is not thought to be threatened. Given what the towns themselves must recognize as severe geographic disadvantages for industrial growth, it is highly improbable that the sites needed to implement the diversions would ever have appreciable economic value. Their value is chiefly scenic.

TABLE 12

IMPACTS ON SUPPLIERS

Impact Category	Measures Applied to: Greenfield, Royalston, Athol, Erving Warwick, Winchendon, Orange	Northfield	No Project
1. LAND USE /a/	Net change, % distribution, by use; industrial, commercial, agricultural, residential, recreational; estimated from topo sheets	0	0
	Net use change, in acres; assuming change for all land taken as an upper limit	30 acres (Wendell, New Salem)	0
	Net change in developable land, percent of land taken	Negligible	0
2. POPULATION /b/	Net change in age, race, ethnicity distribution of local populations	None	0
	Total divergence from baseline trend	0	0
3. MUNICIPAL FINANCE /c/	Loss of assessed valuation, % of total, $130,747,427 upper limit	0	0
	Increased assessed valuation from improved water service	N. A.	N. A.
	Net change (gain/loss) in tax revenue resulting from improved water service	N. A.	N. A.
4. COMMERCIAL ACTIVITY /d/	Net change over normal trends in gross wholesale and retail sales of those facilities affected by availability of water resource	0	0
	Number of businesses displaced by facilities	0	0
5. HOUSING /e/	Net change in number of housing units. Any relocations expected to be inside supplier area	None	None

N. A. = not applicable

TABLE 12 (cont'd)

Impact Category	Measures Applied to: Greenfield, Royalston, Athol, Erving, Warwick, Winchendon, Orange	Northfield	No Project
6. EDUCATION /f/	Net change in amount of classroom space required for projected change in school-age population resulting from in-migration, upper limit	1 primary classroom	0
	Net change in cost of teacher and other staff required for projected change in school-age population resulting from in-migration; average salary @ $8,000/annum	+$8,000	0
	Net change in cost of providing school bus services because of changes in housing	U	0
	Use of facilities for educational programs, upper limit, days/year	7	0
7. LEISURE /g/ OPPORTUNITIES	Net change in total number of acres of parks and playgrounds	0	0
	Net change in extent to which planned recreation space meets American Society of Planning Officials planning standards	N. A.	N. A.
8. CULTURAL OPPORTUNITIES	Total number of churches, historical sites, or other cultural institutions taken	0	0
	Cost of relocation	0	0
	Increase in locational amenities, range	1	0
9. TRANSPORTATION /h/	Net change in travel time as a result of facilities construction	0	0
10. MUNICIPAL SERVICES	Net change in providing water, sewerage, garbage service and other municipal services	None	None
	Net change in residential insurance rates	N. A.	N. A.

U = data unobtainable at this level of detail

TABLE 12 (cont'd)

Impact Category	Measures Applied to: Greenfield, Royalston, Athol, Erving, Warwick, Winchendon, Orange	Northfield	No Project
11. SECURITY	Number of positive and negative statements about the opportunity for system failure (new facilities)	N. A.	N. A.
12. COMMUNITY IMAGE /i/	Changes in property values adjacent to supply facilities, per holding; totals small in view of limited takings		0
	Number of positive and negative statements about communities as revealed by content analysis of local news media	0	0
13. COMMUNITY COHESIVENESS (See /i/)	Total number of community, regional, statewide and national groups taking a position for or against the project	5-10	0
14. CITIZEN INVOLVEMENT (See /i/)	Total number of community, regional, statewide and national groups involved in planning of the project, times the level of their involvement, according to the following scale: 1. Attendance at hearing. 2. Citizen opportunity to critique plans at public meetings. 3. Periodic workshop planning sessions with community representatives. 4. Community advocate planner participated on equal basis with technical staff. 5. Appointment of arbitrative hearing officer (5 x 8)	0	0
15. INSTITUTIONAL INVOLVEMENT	Total number of jurisdictions involved in the totality of the construction process for water supply facilities	(2 towns M. D. C. *State*) 4	0
	Number of applications submitted to the M. D. C. for water supply service; disposition and frequency of refusal	N. A.	N. A.

TABLE 12 (cont'd)

Impact Category	Measures Applied to: Greenfield, Royalston, Athol, Erving, Warwick, Winchendon, Orange	Northfield	No Project
16. ECONOMIC STABILITY (See /d/)	Note change in local economic activity resulting from construction and related activities; 100 x $7,000 x 2 = value added in dollars	1,400,000	0
	New increase in private investment	0	0
17. REAL INCOME	Net change in per capita income; Net change in tax assessments per individual taxpayer Net change in regional income	No significant change anticipated	
18. EMPLOYMENT (See /b/)	Number and type of construction jobs opened; substitution effects not accounted for.		
	P: professional S: skilled U: unskilled	30P 170S 300U 500	0
	Secondary employment (.2 - .4 times total jobs)	100	
19. INDUSTRIAL ACTIVITY	Change in number of industrial establishments	0	0
	Change in productivity indices	None	None
20. AGRICULTURAL ACTIVITY	Change in number of farm (productive) areas, upper limit	20	0
	Change in production per acre	0	0

/b/ Population

Beyond the labor influx associated with construction of the project, it is highly unlikely that current downward population trends will be reversed. In the decade between 1960 and 1970, no town in the immediate supplier area registered appreciable growth; and Winchendon, Athol and Orange experienced net outmigrations of better than 250 persons each. The principal determinant of any population changes related to the diversions proposed will be the recreation issue. Should the development of recreational facilities take place, it is possible that the supplier area could see a slight increase in residential population, though probably only on a seasonal basis.

Construction-phase labor demands will have at least a temporary effect on suppliers, however. About 300 unskilled construction workers, 170 skilled, and 30 professional people would be employed directly on the project.

To determine how the combined incomes of that work force would be distributed, the experience during construction of the Northfield Mountain Hydroelectric facility was utilized. Though the project was very much larger -- $90 million, employing a total of some 3,700 persons -- the tasks required, (such as tunneling, concreting, carpentry iron working, pipe fitting, etc.), are of much the same nature as will be required on the diversion works, and project labor is likely to be drawn from the same sources. In a post-audit of the labor force assembled for construction of the pumped storage project,[1] Clark points out that of the 3,368 people employed in the crafts, fully 84% were hired locally; that is, only 16%, or 477 men moved into the area to obtain project work.[2] The great majority already lived within commuting distance and spent their paychecks locally. Indeed, aside from those immigrants who established temporary addresses for the term of their employ (principally hard rock miners from North Carolina, New York State and other extra-regional areas who were supporting families left behind), salaries were

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[1] "The Labor Force Associated with the Northfield Pumped-Storage Hydroelectric Project and Its Effects on the Surrounding Communities," Frank Clark, University of Massachusetts, January 1971.

[2] The reverse is true for supervisory personnel. Of 355 persons so employed, roughly 60% were immigrants moving to the area for the duration of the project. Most often families were settled in a population center near the project site or in trailer parks in nearby New Hampshire. In terms of spending, however, the same general patterns apply to "wage" staff as to the field force.

introduced to the economics of Central Massachusetts and southermost New Hampshire and Vermont. Thus, apart from the purchase of meals and incidentals, the salaries of both professionals and the field force were spent within the immediate region but outside the borders of the towns sharing the construction site. As for rents, the largest portion of temporary residents was set up in Greenfield or Montague, Massachusetts rooming houses, housing closer to the construction site being virtually unavailable.

Thus, if the Northfield Mountain water supply project is a "union job" and that is the supposition, the same commutation and spending patterns are likely to apply, though at reduced levels.

/d/ Commercial Activity

With a wide distribution of labor, salary spending should be well diffused, with no one city or town experiencing more than marginal increases in commercial activity. The alternative diversion projects may absorb whatever labor surplus is created by the completion of the Northfield Mountain pumped storage facility and maintain the employment status quo. Of course, since scheduling is uncertain, unemployment conditions at the time of construction are unknowable, and it is possible that the water supply project will come too late to prevent an employment sag caused by the demobilization at Northfield or offer only substitution effects -- paying salaries obtainable elsewhere in a time of full employment. At present, however, unemployment in Massachusetts is in excess of the national average with a rate of 7.5% compared to the national figure of 5.9%. In the immediate vicinity of the project in Greenfield, Athol, and Gardner, unemployment is even higher than the State total, with figures of 10.1, 7.7, and 8.5%, respectively. Unless, then, employment opportunities prior to construction alleviate these high unemployment totals, construction activities would provide substantial opportunities for employment. In any event, the diversion construction could well absorb the fifty-odd local hard rock miners trained at the hydroelectric facility.

Beyond the salaries generated, short-term economic impacts also encompass the monies paid to local residents through land acquisition. Neither the magnitude nor the distribution of such payments in readily available.

Again, as with salaries, benefits to the regional economy rather than to individuals are to be reckoned not just in terms of dollar totals, but by their fluidity. Clearly, when a land seller receives dollars for his land, it makes a difference to the community whether he saves the money, reinvests it or spends it.

Long-term economic implications for suppliers center largely around the extent to which the volumes of water diverted affect industries now located in the area. As for the first issue, comments made by industry spokesmen at the public meeting held at Athol in late October 1972 indicate a concern for maintaining flows in the Millers River[1] adequate for process purposes. However, it seems safe to conclude that no industrial enterprise will be jeopardized by high flow skimming operations on the Connecticut River and/or its tributaries. In fact, at least in the purely economic sense, the marginal value of the water to be diverted is zero. As such, it must be considered "surplus" and no tangible loss to the local economy.

/e/ Housing

During the construction period of the project, there will be an increased demand for rental housing. Probably, established urban centers at Greenfield, Gardner and Athol or Brattleboro and Keene and Hinsdale (trailers) will absorb whatever non-resident labor force appears and that towns nearer construction sites will not be affected. In no event is the stimulation of new housing construction foreseen. Housing prices and property values may rise for the term of construction but suffer setbacks when the project is completed. Since Greenfield has been identified as an area in which the housing market is sensitive, trends there should be observed as Northfield and Vermont Yankee at Vernon wind down. Adjustments will be required for any data collected to reflect the very much smaller labor force (about 500 as compared with 3,700) anticipated for this construction job.

/f/ Education

From the experience of a dozen different towns surveyed by Northeast Utilities for effects on school populations,[2] only in one, Hinsdale, was overcrowding attributed to worker influxes. It should be kept in mind, however, that the nuclear generating station at Vernon, Vermont, and increased business activity in Brattleboro account for much of that effect and obscure the influence of Northfield. Other school systems either had no marked increase in enrollments or cited natural growth rather than project in-migration as the cause of crowding.

As a conservative estimate of impacts felt in the supplier area sample of seven communities, we have used one primary classroom or about

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[1] Subject of a separate report.

[2] Bernardston, Deerfield, Erving, Gill, Greenfield, Hinsdale (N.H.), Leyden, Montague, Northfield, Orange, Warwick, Winchester (N.H.)

twenty youngsters. Noting that Greenfield appears to be a primary response area, we have located the demand there and estimate an average teaching staff expenditure of $8,400.

Busing data were not available. However, because the numbers of new school-age children to be served under the situation caused by construction activities is so small and because their distribution would likely be more general than we have assumed -- that is not just in Greenfield alone -- any change in busing costs would be extremely small.

/g/ Transportation

Impacts here are certain to be of a temporary nature. The bulk of construction is to take place below the surface with only occasional access shafts at ground level. Mobility patterns in the resident population may change to some degree, but the dominantly rural nature of the area will make such disruptions infrequent.

The construction contemplated will have almost negligible effects by comparison with the recent highway work on Route 2. Heavy trucking will be required for the removal of spoil to fill areas and the delivery of equipment, but intelligent planning can avoid traffic congestion and hazards to residents. Commutation patterns for the work force will have an appreciable effect on the traffic volumes of major arteries. Locations and magnitudes can be reckoned only after the distribution of labor has been established.

/h/ Community Image and Cohesiveness

Impacts forecasted for this category are very small. No physical separation of populations is involved, apart from temporary road closings. No aesthetically undesirable structures are planned, save in the sense that any alteration of the natural scene may be thought of by some as undesirable. Yet, it is in this category that the supply areas themselves feel themselves to be the most injured. Their perceptions of loss are very large, and some commentary seems appropriate.

In terms of standard socio-economic categories like population, density, employment, ethnicity, mobility, etc., and particularly in terms of attitudes, the immediate diversion environs are so homogeneous as to be spoken of as an entity.

Because of the nature of the project under consideration, it is revealing to examine the source of the unanimity. Inhabitants feel that the construction of Quabbin Reservoir in the late 1930's was shock to the cultural and economic life of the area from which it has never fully recovered. As the testimony of several local people at the Orange Hearing indicated, many of the residents consider themselves refugees from the Quabbin site.

Residents of the supplier towns feel themselves to be threatened once again. That is the root of their common cause and the most important cohesive factor in their alliance against the diversion proposed. The social psychology operating here is transference; water for Boston means the bureaucratic machinery of the water supply agency, which in turn means wanton despoliation of all that local residents hold dear, and that means a repetition of the upheaval brought by Quabbin.

From the impact assessment standpoint, then, even the relatively minor changes brought about by implementation of the diversions will have two principal effects: (1) demonstrate to suppliers that their impotence has not changed in thirty-odd years and (2) draw the circle of opposition even more closely together, further alienating it from the political system dominated by Eastern interests. Supplier communities will feel themselves to have been bested yet again and withdraw into a smoldering hostility.

4) The "No Go" Scenario

In the event that the Northfield Mountain Diversion is not implemented, the single most important impact in the supplier region will be at Quabbin itself. Biological studies have determined that in the event of a near-complete drawdown, the ecologic viability of the reservoir would be endangered. Moreover, as the water area shrinks, the likelihood of odors and exposure of the unsightly bottom area grows. The recreational opportunities at Quabbin are, therefore, considerably diminished, not to mention the consequences for the receivers of Quabbin water which may change perceptibly in color and taste.

Less dramatic are the direct economic and social impacts on suppliers. First, local stimuli caused by construction activity will be zero. Whatever buffer effect the project might have had on the labor fallout at Vernon and Northfield and on unemployment in the region will be lost. Whatever dollar gains might have been realized by local economies as a result of labor force spending and landtaking costs will be foregone. It should also be pointed out that the difference between tax revenues collected on property not taken and any payments made in lieu of taxes should implementation proceed could be counted as "savings." As noted above, however, revenue data have not been made available and it can only be assumed that the amounts involved are quite small.

Finally, if the project was not implemented, whatever monetary value might accrue to the surplus waters not diverted would be returned locally. This eventuality is highly unlikely, however, because there is no reason to foresee the development of new water-dependent industry in the immediate donor area, at least in the 1975 - 1990 time frame.

5) Impacts on Receiver Area

In the receiver area, which totals sixty-six communities listed in Table 11, impacts brought about by implementation of the project can be expressed in two different ways. First, losses both with and without diversions can be totalled and compared to the costs of providing additional water from the proposed project. This comparison then provides a basis for assessing the economic efficiency of the project.

Included in the loss totals are industrial, city emergency, city revenue, commerce, sprinkling, business investment and domestic investment losses. However, these loss figures say nothing of the ways in which such losses might be allocated by the various industries and municipalities. An assessment of the potential methods which could be used to allocate these losses (utilizing the socio-economic impact categories given in Table 9) is the second method used to express losses in the receiver areas.

To measure the economic losses, a computer simulation model was developed. The model as developed investigated the consequences of a water shortage using as an information base results of a study[1] conducted during the sixties' drought in Massachusetts.

Four major sectors of the communities' economy were differentiated: industrial, commercial, municipal and domestic. A fifth sector was also

[1]Drought and Water Supply, C. S. Russell, D. G. Arcy and R. W. Kates, for Resources for the Future.

used and was comprised of various miscellaneous impacts which could not be conveniently accomodated in any of the above economic sectors. In the analysis, special care was taken to prevent double accounting of losses, that is, to make sure losses were counted in only one sector. For example, the MDC and local water departments lose considerable revenue from not being able to sell the water that is unavailable. Since this loss is charged to the MDC and local municipal sectors, the cost of the water not available to the other sectors cannot be charged as a loss to those sectors as well. Their losses should include all the damages in excess of what it would have cost them to purchase the desired amount of water.

To test the impact of water shortages, assumptions regarding the water system facilities to both average runoff and drought conditions similar to those experienced in the sixties were made. Losses associated with both runoff conditions were then calculated. Two major types of losses were distinguished: those experienced annually as a consequence of a shortage and those losses which are experienced once and for all given a certain shortage level. In the latter category belong all losses connected with investment projects undertaken to either permanently increase the supply of water available to a sector or to permanently decrease the consumption rate of the sector. Once such investment projects are undertaken, the losses that may result may not be experienced again unless the shortage grows more severe. For example, a home owner faced with a water shortage could develop an on-lot supply well to use for his lawn and shrubs. Once this investment is made, he has shielded himself from effects of shortage in future years.

Altogether seven types of losses were analyzed for their response to water shortage. These are: Annual Losses for the Industrial, Municipal, Revenues Lost to Municipal; Commercial and Domestic Sectors, and Permanent Losses for the Industrial and Domestic Sectors.

The results of the losses which may be expected with the two assumed hydrologic runoff conditions are given in Table 13 for the project. A full description of the methodology for the evaluation is given in Appendix F.

Utilizing the information contained in Table 13, a benefit/cost analysis was made for the project. In developing the benefit/cost ratio shown, a discount rate of 5-7/8 percent and a 50-year project life was used. The losses were estimated on a year by year basis into the future.

TABLE 13

LOSSES PREVENTED BY IMPLEMENTATION OF NORTHFIELD MOUNTAIN [1] PROJECT

(1972 Dollars) Millions of Dollars

Year	Industrial	City Emergency	City Revenue	Commercial	Sprinkling	Business Investment	Domestic Investment	Total
				Normal (Average) Runoff Conditions				
1982 [2]	.326	.740	1.747	.165	.429	0	1.689	5.096
1990	.620	1.347	3.522	.333	.745	0	.423	6.990
2000	.950	1.911	5.475	.568	1.068	0	.384	10.355
2010	.235	.723	3.294	.275	.455	0	-.053	4.930
2020	.012	.499	3.059	.245	.359	0	.022	4.195
				Drought Runoff Conditions (Sixties Drought)				
1978 [2]	.570	1.362	2.824	.284	.800	0	6.064	11.905
1979	1.454	3.393	7.024	.721	1.994	0	30.832	45.420
1980	1.211	2.762	5.715	.598	1.626	0	.186	12.097
1990	.620	1.347	3.522	.333	.745	0	.103	6.670
2000	.395	.923	3.441	.282	.531	0	.099	5.474
2010	.235	.723	3.294	.275	.455	0	-.253	4.730
2020	.012	.499	3.059	.245	.359	0	-.335	3.838

(1) Based on a proportion of yield made available from this project and the Millers River Basin Alternatives. Tables in Appendix F, thus are modified by the ratio 72/120.

(2) Years shown are the dates when restrictions would be necessary based on criteria described in Appendix F.

The capital dollar losses were then brought back to year 0 using present worth single payment factors to get a capital dollar value at year 0. These capital dollar values were then amortized over the life of the project to put them into annual dollar values. The loss figures on an annual basis were then compared with the annual costs[1] of the alternative projects yielding the benefit/cost ratio. These ratios are shown in Table 14. As illustrated, the benefit/cost ratio varies from 1.2 1.9 for average rainfall - runoff conditions, with the assumed drought condition superimposed on the water supply system.

Based on this analysis, then, the project would provide an economically justified protection for the receiver communities.

TABLE 14

REGIONAL DEVELOPMENT OBJECTIVE

BENEFIT/COST RATIO[2]

NORTHFIELD MOUNTAIN DIVERSION PROJECT

Normal Runoff (Average)	Sixties Drought Runoff
1.2	1.9

As stated earlier, impacts on the receiver areas as the result of water shortages can be expressed two ways. The first, described in the previous sections, counts economic losses which could occur with water use restrictions. The categories included in those totals encompass industrial, city emergency, city revenue, commercial, sprinkling, business investment and domestic investment losses. However, the dollar losses shown do not illustrate how such losses might be allocated. For example, of the more than two million dollars in municipal revenues not collected in 1990 as a result of water shortage, there is no way of knowing whether it would be recreation or education budges that suffer.

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[1] Shown in Table 8.

[2] Based on a prorated by yield average of losses prevented by both Northfield Mountain and the Millers River Basin water supply projects.

In an attempt to allocate these economic losses, the impact categories described in Table 9 were utilized. Using these categories, Table 15 was constructed. As shown in Table 15, impact category 6 lists loss in classrooms not built as one possible expression of total dollar loss. Similarly, housing units not built are but an alternative manifestation of losses in the private sector. Therefore, to avoid double accounting, the impacts set out in categories 5 and 6 should not be summed with those in other categories.

Still, some quantification of these two important social impacts, as well as those in categories 1 and 7 - 15, was necessary, if only to provide order of magnitude estimates.

To provide the estimates for these categories, an examination was made of the experience of an actual community already beset by the kinds of problems anticipated in the event of prolonged water shortage. Principally, "soft data" related to social impacts were the objective. How does a community respond to the dislocations of water use restrictions? Do citizens get more involved in planning when crisis conditions are sustained over a long period? How quickly does population growth slow in response to water-use and building restrictions? An extended interview with Stoughton's Planning Board Chairman produced both background and impact information.

Stoughton is an industrial - residential community in the Brockton Standard Metropolitan Statistical Area. The town's population of about 25,000 is growing at a rate of more than 40% every decade, and shows no signs of a downward turn. The principal constraint on continuing growth may be an acute shortage of water. Presently, municipal supplies come from five town wells; two recently completed standpipes with capacities of 10 and 2 million gallons, respectively, give Stoughton about 14 million gallons of total storage. The severity of ongoing shortages are indicated by a complete ban on outside watering in effect for several years and a one-year freeze on the issuance of building permits which was lifted last year.

The town has been searching for water since 1955. First, an extensive drilling effort at producing well sites was tried. When the results were negative, consulting engineers were engaged to search for new groundwater sources; results, negative or unacceptable because of high iron content. Last year, a grant of $1.5 million funded a project to clean or replace defective distribution piping. In addition, $150,000 was spent on a connection with Brockton and Canton water supplies. This, however, is seen as only a temporary measure because these two towns can

terminate the arrangement at will, whenever their capacities are strained. In general, admission to the MDC system is viewed as the only permanent solution. Formal application has been made, but even favorable action means a delay of possibly 8 - 10 years before Quabbin - Wachusett water becomes available.

The consequences of water deprivation have been felt across a wide range of community activities. The following paragraphs, keyed to Table No. 15 discuss the impact of the 1960's drought and the continuing water shortage on the Town of Stoughton, Massachusetts.

/a/ Land Use

Although no shifts in the allocations of land use type have occurred, development in the industrial category has been nearly stopped by water shortage. Interestingly, though a building ban prevented "new starts" on residential housing for a year, the rush to develop after the ban was lifted has more than wiped out any deficit.

/b/ Population

While data projections for longer terms show population deficits for deviations from the "enough supply" situation, it does not appear that population growth is sensitive to short-term controls and constraints. Stoughton's in-migration continued despite the building ban and shows signs of growing even more quickly now that new housing construction has begun again.

/c/ Municipal Finance

Because finding water has been a top town priority, other municipal services have suffered. A sidewalk program has been indefinitely postponed and only minimal roadway maintenance and construction has occurred. Generally, expenditures have been cut as revenues from expected property taxation have dwindled. Estimates range as high as $1,000,000 in tax losses with increases in assessments covering the deficit. The cost of water has doubled in the past two years and the municipal debt as of January 1, 1970 stood at $7,516,000 or $320 per capita. Until a mutual help agreement was reached with Easton and Sharon, adequate fire protection was a critical concern.

/d/ Commercial Activity

In the time observed by the interviewee, there have been no perceptible consequences for either retail or wholesale trade.

TABLE 15

IMPACTS ON RECEIVERS
NORMAL RUNOFF CONDITIONS

Impact Category	Measures Applied to Receiver Area (66 elements)	Northfield	No Project
1. LAND USE /a/	Net change, % distribution, by use; industrial, commercial, agricultural, residential, recreational	No Change	No differential change; general retardation in industrial and residential growth
	Net use change, in acres, for land taken	N. A.	N. A.
	Net change in developable land, as % of land taken	N. A.	N. A.
2. POPULATION /b/	Net divergence from unconstrained baseline trend of: 2,893,100 in 1990; 4,057,800 in 2020;	2,893,100 3,689,800	2,769,600 3,384,700
	Net change in age, race, ethnicity distribution	0	0
3. MUNICIPAL FINANCE /c/	Net change in revenue resulting from water service, 1990 2020	$2,762,000 [1] $15,573,000	$5,870,000 $18,762,000
	Emergency water expenditures, 1990 2020	$1,056,000 $4,980,000	$2,245,000 $5,542,000
4. COMMERCIAL ACTIVITY /d/	Net change (losses) over normal trends; 1990 2020	$261,000 $2,044,000	$555,000 $2,313,000
	Number of businesses displaced by facilities	N. A.	N. A.
5. HOUSING /e/ Stoughton	Net change in number of new housing units; upper limit (Average decrease 125 units per year)	0	-3750 units per year

N. A. = not applicable U = data unobtainable for calculations at this level of detail

[1] All dollar figures are 1972 price level.

TABLE 15 (cont'd)

Impact Category	Measures Applied to Receiver Area (66 elements)	Northfield	No Project
6. EDUCATION /f/	Net change in amount of classroom space required for projected change in school age population; order of magnitude estimate	0	30, twenty-room schools, or 600 rooms not built
	Net change in cost of teaching staff required for projected change in school population (average salary/year = $10,000)	0	900 staff, or $9 million not spent in salaries
	Net change in cost of providing school bus services because of changes in housing	0	U
	Use of facilities for educational programs; upper limit, days/year	20	0
7. LEISURE OPPORTUNITIES	Net change in total number of acres of parks and playgrounds	0	0
	Net change in extent to which planned recreation space meets American Society of Planning Officials standards	N. A.	N. A.
8. CULTURAL OPPORTUNITIES	Total number of churches, historical sites, or other cultural institutions taken	N. A.	N. A.
	Cost of relocation	N. A.	N. A.
	Increase in locational amenities; fountains, pools, etc.	20-30	0
9. TRANSPORTATION	Net change in travel time as a result of facilities construction	N. A.	N. A.
10. MUNICIPAL SERVICES (See /c/)	Net change in providing water, sewerage, garbage service or other municipal services	0	0
	Net change in residential insurance rates	0	0

TABLE 15 (cont'd)

Impact Category	Measures Applied to Receiver Area (66 elements)	Northfield	No Project
11. SECURITY /g/	Number of positive and negative statements about the opportunity for system failure	10-20, principally related to radiological hazards of diverting waters downstream of Vernon, Vermont Yankee outfalls	Episodic concern for prolonged and widespread water shortage caused by Quabbin depletion
12. COMMUNITY /h/ IMAGE	Changes in property values adjacent to supply facilities	N.A.	N.A.
	Number of positive and negative statements about communities as revealed by content analysis of local media (average 20/year/community); order of magnitude estimate	0	c. 600 Increasing negative comment as watering restrictions put into effect
	Sprinkling losses, 1990 2020	$584,000 $2,937,000	$1,242,000 $3,328,000
13. COMMUNITY /h/ COHESIVENESS	Total number of community, regional, statewide and national groups taking a position for or against; average of 4 per community concerned; 3 in favor 1 opposed	90 in favor 30 opposed	100 in favor
14. CITIZEN /h/ INVOLVEMENT	Total number of community, regional, statewide and national groups involved in planning of the project X		
	Level of involvement on the following scale: 2 x 60 x 3 1. Attendance at hearing 2. Citizen opportunity to critique plans at public meetings 3. Periodic workshops planning sessions with community representatives 4. Community advocate planner participated on equal basis with technical staff 5. Appointment of an arbitrative hearing officer	360	360

TABLE 15 (cont'd)

Impact Category	Measures Applied to Receiver Area (66 elements)	Northfield	No Project
15. INSTITUTIONAL INVOLVEMENT	Total number of jurisdictions involved in the totality of the construction process for water supply facilities;	No primary sites, connections only; upper limit, 1990 15	N. A.
	Number of applications submitted to M. D. C. for water supply service, disposition and frequency of refusal; upper limit, 1990, 23 "no option" communities 5 actual petitioners (Bedford, Burlington, Reading, North Reading, Wilmington) 2 additional communities	30, increasing frequency of admission	30, decreasing frequency of admission
16. ECONOMIC /i/ STABILITY	Net change in local economic activity; value added deviation from unconstrained supply level of		
	$ 446,000,000 in 1990	$364,800,000	$364,800,000
	$1,398,000,000 in 2020	$903,400,000	$903,400,000
	Net increase in private investment	0	0
17. REAL INCOME	Net change in per capita income		
	Net change in tax assessments per individual taxpayer		
	Net change in regional income;		
	Total concrete losses, 1990	$5,481,000	$11,650,000
	Total concrete losses, 2020	$29,708,000	$34,149,000
	Total domestic investment losses, 1990	$331,000	$705,000
	2020	$1,200,000	$1,169,000

TABLE 15 (cont'd)

Impact Category	Measures Applied to Receiver Area (66 elements)	Northfield	No Project
18. EMPLOYMENT	Number and type of jobs saved/lost	0	U Employment falls at about the same % as value added
19. INDUSTRIAL ACTIVITY	Change in number of industrial establishments Change in productivity	0	U Declines as revealed by declines in value added
	Total industrial investment losses, 1990 2020	$487,000 $2,974,000	$1,034,000 $3,036,000
20. AGRICULTURAL ACTIVITY	Change in number of farm acres, upper limit	N. A.	N. A.
	Change in production per acre	Water used for agricultural purposes is not drawn from public supplies.	

/e/ Housing

Since the lifting of the building ban, over 500 rental units have been built and occupied. The demand for housing has lowered the vacancy rates significantly and stimulated the construction of 3,000 apartment units and the planned development of 3,000 more. Before the ban went into effect, issuances of building permits had declined an average of about 130 units per year for two successive years.

/f/ Education

Two primary schools of twenty-six classrooms each have been completed in the past two years (September 1970 and 1971) to accomodate a swelling elementary-age school population. A much-needed junior high has been put off -- an effect attributed to the "extraordinarily high expenditures of finding water." As a result, the present junior high is expected to go into double sessions this coming fall.

/g/ Security

As the search for water has become "business as usual," citizens appear to have developed some tolerances for the inconvenience of watering bans. However, their latent insecurity about adequate supplies for fire protection and general domestic consumption have made water shortage a perennial political issue on which concern can focus. As noted above, the prevailing attitude is that "everything will be all right" once MDC admission is secured and the burden of water planning can be shifted to the Commission.

/h/ Community Image

Despite the general slowdown in industrial development and its second order consequences on town revenues, the average citizen perceives the water supply problem in terms of his own inability to water outdoors. Lawns and shrubbery are a waste of money, says the homeowner, and the town looks poorer for it. A general feeling of discouragement and frustration has set in and the desireability of Stoughton as a residential community has been adversely affected. So far no monetary reflections of this malaise have developed and property values are as yet unchanged by water shortage.

/i/ Economic Stability

Economic development has been hurt because water using industries have been turned away. This has "slightly decreased" the stability of the town

because the tax base has not expanded quickly enough to keep up with demands on local revenues. Wages and prices have remained in phase with the rest of the state, but taxes have increased.

/j/ Industrial Activity

No Stoughton industries have left because of water shortage, but new industries (chemical plant, refinery) have gone elsewhere. Presently, only non-manufacturing, non-processing firms are permitted to locate in town, and a $40 million industrial park is now two years behind in its development schedule.

Using data collected in the Stoughton case study, adjustments were made to reflect forecasts of impacts on the receiver area. In every case, values were multiplied by a factor of thirty: twenty-four "no option" communities for whom prolonged water shortages could be expecially severe and six others, roughly one out of every three now "partially-served" or served non-members. Since the impact estimates produced in this manner are undoubtedly high, no separate account was taken of communities already fully served. That is, for example, the thirty, twenty-room schools not built because of slowed population growth in the "no go" situation represent a system maximum whether or not it is precisely the "no option" or "partially served" communities which fail to erect them.

One further note should be made regarding Table 15. The data shown with the exception of the values presented for the seven loss categories described earlier were not adjusted for the yield[1] of the project. Since the other data is qualitative, it was felt adjustments to further refine the information was not warranted. In addition, the With Diversion Project column reflects a satisfied condition, that is, water demands are met. To meet water demands, however, another supply project would be needed. That other project, the Millers River Basin development, is the subject of a separate, but companion report.

Social impacts, then, in the receiver area are principally "shadow costs" of losses generated by water shortage. As municipal efforts turn to finding new sources, building bans to hold the line on new demand are a likely eventuality. Second-order effects of expenditures on water searching manifest themselves as slowed school building programs, poorer municipal services (especially fire protection) and a general malaise in the development plans of the subject towns. Moreover, it appears that citizens are likely to become discouraged and frustrated as they see their lawns dry up during watering bans. In many ways, these

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[1] In the analysis conducted the Northfield Mountain and Millers River Basin development were evaluated for their aggregate impact on receiver communities. See Appendix F.

feelings are reflected in attitudes about the desirability of their town as a place to live and work. The net result is stagnating growth, hostility toward the communities which snare the industries unable to locate in a water-deprived town, and a growing dependence on MDC admission as the ultimate solution to water shortage.

Short-term, project-specific impacts on receiver areas are seen as virtually non-existent. Remembering that no actual water deliveries from the Connecticut Basin would be made short of five years from the start of construction, economic impacts perceived in the MDC service area would not be water-related. For example, it might be that certain portions of the supervisory and office labor force required for construction might come from cities and towns incidentally served by the MDC. Or, it is possible that equipment required for construction or permanent installation may bring revenues to a jurisdiction classified as a receiver. However, such stimuli are likely to be very small indeed because the dichotomy between supplier and receiver areas is nearly perfect.

Long-term impacts -- those generated by the availability of that yield increment provided by the diversions -- are more tangible. In a general sense, receiver areas will continue to develop along the optimistic lines suggested by their respective Master Plans.[1] Therefore, interruption of service is not expected to occur and industry, especially, can be free of nagging doubts about the risks of water use restrictions. Developers of residential housing slated for existing MDC service communities and those expected to join before 1990 are not likely to take their investments elsewhere as a result of threatened water shortages.

With respect to the water supplied itself, receiver communities benefit from implementation of the diversions in two specific ways. First, exceptionally high water quality will not change. Households and industrial establishments accustomed to minimally treated upland water supplies will not be required to tolerate or compensate for waters of lower quality until such time as even the Connecticut diversions become inadequate to meet demand. This will be particularly important to manufacturers using large amounts of water for purposes other than cooling and those to whom deferred investments in treatment and recycling are desirable. Likewise, homeowners will not have to search for other sources of supply and sustain the cost of sprinkling losses. Moreover, it is unlikely that MDC members will be subjected to the large price hikes that may be associated with the restrictions imposed earlier under a no-go condition.

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[1] These documents uniformly assume unconstrained water supplies in their development of growth expectations.

B. National Economic Development Account

The National Economic Development (NED) objective is enhanced by increasing the value of the nation's output of goods and services and improving national economic efficiency. Components of the NED objective include:

a) The value to users of increased outputs of goods and services resulting from a plan. For example, the projects reported upon in this study would reduce descriptions of economic activity due to water supply shortages, thus leading to direct increases in productivity from water and land development that contribute to national output.

b) The value of output resulting from external economics. In addition to the value of goods and services derived by users of outputs of a plan, there may be external gains to other individuals or groups. For example, the projects included in this study would maintain a viable economy in receiver communities. Such maintenance of a strong economy in the northeast would then benefit the nation as a whole.

In the assessment of the Northfield Mountain project's impact on the NED account, much reliance was placed on the economic loss categories described earlier. This is not to say that some of all of the social impacts described in the section on Regional Development do not carry into the NED account. The reader should be cautioned, however, that the economic losses described in the following paragraphs are not all inclusive of losses which may be sustained without the availability of additional supply.

In evaluating the economic losses prevented by implementation of any of the alternative projects, seven loss categories were examined. These are: Annual Losses to the: industrial, municipal-emergency, municipal-lost revenue, commercial and domestic sectors; Permanent losses to industrial and domestic sectors.

Upon examining the losses in each category, it was decided that losses in four of the categories, municipal-emergency, municipal-lost revenue, domestic annual losses and investment, represented losses to the nation as a whole. These four categories, therefore, were carried fully from the Regional Development account into this account.

The remaining three loss categories investigated, industrial business losses, commercial losses and industrial investment losses, were felt

to more represent regional rather than national losses. That is, elements in these three categories which suffered losses in the region could be replaced by increased business activity in other parts of the nation.

Based on the four loss categories considered affecting the NED objective, a benefit/cost ratio for the project was constructed and is presented in Table 16.

As illustrated, the benefit/cost ratio for the project varies under normal (or average) hydrologic runoff conditions from 1.1 to 1.7 simulated sixties drought conditions.

Based solely on economic losses, then, construction of the project would prevent more losses to the national economic development objective than the costs of implementing the project. In addition, as stated earlier, these economic benefit/cost ratios do not reflect the social impacts to the nation which might be occassioned by water shortages. If these social impacts, described under the Regional Development account, are also considered as affecting the nation as a whole, then the effects of water shortage on the National Economic Development account are multiplied.

TABLE 16

NATIONAL ECONOMIC DEVELOPMENT OBJECTIVE

BENEFIT/COST RATIO[1]

NORTHFIELD MOUNTAIN DIVERSION PROJECT

Normal Runoff (Average)	Sixties Drought Runoff
1.1	1.7

C. Environmental Quality Account

1) General

From the outset of this report, efforts have been made to determine the impact of the Northfield Mountain water supply diversion element on the environment. An evaluation was made of the project's impact on the Connecticut River estuary, on the Connecticut River downstream from the point of diversion and on the environment of the receiving water storage reservoir, i.e., Quabbin.

[1] Based on a pro-rated by yield average of losses prevented by both Northfield Mountain and the Millers River Basin water supply projects.

To conduct these investigations, both in-house capability of the New England Division's Environmental Resources Section, as well as contractor personnel, were utilized. The following sections describe in summary the efforts of this integrated multi-discipline team of both Corps of Engineer personnel and services from two environmental consulting firms. More detailed descriptions of the studies are given in Appendices E and F.

2) Possible Environmental Impacts of Diversion on the Connecticut River Estuary

In evaluating the possible environmental impacts which might occur within the Connecticut River estuary, contractor services were utilized extensively. Recognizing that this project's proposed diversion rates are small in comparison to the total river flow and that other proposals for diversion were also being considered in the Millers River Basin, it was decided to test effects[1] which might occur with a large range of postulated diversion rates.

The range of postulated diversion rates tested varied from 600 cfs to 4000 cfs with adherence to a minimum control flow at Montague City of 17,000 cfs and 12,000 cfs, as measured at the U. S. Geological Survey gaging station. Only the 17,000 cfs control flow rate has been approved by the Massachusetts Legislature.

The use of the large range of postulated diversion rates, i.e., 600 to 4000 cfs, with corresponding control flow rates of 17,000 and 12,000 cfs, thus were adopted to allow a full investigation of any potential impacts on the estuary. For example, if the larger postulated diversion rates were tested and limited impact predicted, then the lower diversion rates could be expected to exhibit even less of an impact. This, in fact, is what the results of the study concluded as summarized in the following paragraphs. A complete description of the study is given in Appendix E.

a) Changes in river temperature due to diversion should not exceed 0.61° F under the worst case postulated (i.e. 12,000 cfs at Montague City and 4,000 cfs diversion). Although many biological effects of temperature elevations are well known, in most cases the effects resulting from such a small temperature increment are too small to quantify.

Biological evaluations were made using a 2° F temperature rise in the estuary. The rationale for choosing this temperature rise is twofold. First, biological changes could not be predicted on much less than a

[1] Possible Effects of Various Diversions From the Connecticut River Estuary. Essex Marine Laboratory, Inc., May 1972. Prepared for the New England Division, Corps of Engineers.

2° F increment of change, and secondly, it would be only an academic exercise to try to refine predictions at a smaller increment of change if, in fact, no significant changes would occur at the 2° F increment. As it turns out, even a 2° F temperature rise would not cause a serious impediment to diversion plans as far as the ecological balance of the estuary is concerned. Keeping in mind that the calculated temperature rise is less than 1/3 the value used in biological evaluation (.61° F vs. 2° F), the reader is advised of the apparent conservative nature of the biological evaluation that is summarized in the following paragraphs.

Among the known biological effects of increased temperature, the following may be expected, but it should be kept in mind that even if deleterious, the small change in temperature will result in too small a magnitude of change to be cause for alarm.

All of the conclusions regarding temperature and biological change are based on the worst condition tested, i.e., 4000 cfs diversion with 12,000 cfs at Montague City.

(1) Change in the Time and Location of Shad Spawning - Calculations indicate that a 2° F temperature rise in the river water would have caused spawning to occur 3.4 days earlier in 1967 and 3.6 days earlier in 1968. It is postulated that the most severe postulated diversion conditions would have an insignificant effect on shad spawning.

(2) Shad Egg Size, Abundance, Development Time and Mortality - Shad spawning success in general will not be greatly influenced by any of the postulated diversion. After diversion, temperatures would still remain well within normally occurring variations; and since spawning occurs well above salinity intrusion, any changes in salinity patterns will not affect spawning.

(3) Effects of Survival of Larvae of Shad and Resident Fish Species - Temperature rise and salinity changes that would be brought about by postulated diversion are not expected to affect the egg or larval survival development or growth of any of the fish species tested.

(4) Adult Fish Populations - Some adult fish could feel an effect of the diversion as a result of shifting (in time) of the availability of a food supply. Food generally becomes available as temperatures exceed 40° F. A 2° F temperature rise would have caused this 40° F temperature to be reached 4.3 and 6.8 days earlier in 1969 and 1970, respectively. Since some adult fish winter in coves and do not move out into the river until temperatures reach 40° F in the coves, they may

arrive in the river up to a week after the food supply begins to develop. This assumes that water temperature in the coves would not be influenced by the 2° F temperature rise in the river. More information is needed in this area to draw any definite conclusions, but no problem of significant proportions is anticipated.

(5) Homing Ability and Timing of Arrival of Adult Shad - Adult shad appear to have no homing problems even during extreme low flow springs. Diversion will not reduce flows during these extreme low flow conditions so that it is logical to assume that the shad's homing will not be impaired by diversion. Historically, it has been found that shad tend to enter the estuary when temperatures reach 40° to 43° F. Diversion would cause these temperatures to be reached somewhat earlier, but no problem is anticipated.

(6) Microbiological Population - Because of the paucity of data in some critical areas of basic biology, deemed pertinent considering the postulated diversion, no absolute predictions can be made regarding the ultimate fate of microorganisms in the estuary. Since temperature and salinity rise are so small (2° F and a few mg/l) at any given point and since these changes develop over a period of time, no significant qualitative or quantitative alterations of bacterial populations are to be expected in the short run (a few years). Beyond this span any prediction would be speculative.

(7) Invertebrates - 48 recurring species of invertebrates have been identified in 60 months of sampling. Of these, four species are dominant. A 2° F temperature increase can be expected to increase the metabolic activity and probably advance sexual maturity slightly in each of the above species. However, since considered diversions will not be made during summer low flow, high temperature situations, these species are not put under any undue stress. Temperatures after diversion will still be well within the limits of naturally occurring variation, and only minimal adverse effects are to be expected.

b) Freshet conditions should continue throughout the estuary if no diversion takes place when flows are less than 17,000 cfs at Montague City. The duration of freshet will be shortened by 2 to 4 days at both the onset and cessation of freshet in a normal year with diversion. If 12,000 cfs were considered as a control flow, then freshet conditions would be shortened by 3 to 9 days at both the onset and cessation of freshet in a normal year.

c) At a 12,000 cfs controlling flow at Montague City, minor reversals of current may occur in the lower estuary. These should not be sufficient to cause a biologically significant intrusion of salt water from Long Island Sound.

d) Under either controlling flow regime, changes in salinity distribution would be too small to have measurable biological effects.

3) Possible Environmental Impacts of Diversion on the Connecticut River

a) General

The Connecticut River itself is the largest river basin within New England. The river drains an area of 11,265 square miles of which about 7,200 square miles are located upstream of the proposed diversion intake.

Downstream from the intake, the river flows south for about 63 miles prior to the tidal portion of the basin. In this downstream reach, the river flows through rural as well as highly populated centers such as Springfield, Chicopee, and Holyoke, Massachusetts, and Hartford, Connecticut.

Historically, the Connecticut River has supported major runs of anadromous fishes, including American shad, alewives, blueback herring, rainbow smelt, sturgeon, and Atlantic salmon. Though the first four of these species still complete their annual migrations for spawning within the lower reach, all were eliminated from the upper portion subsequent to dam construction. The Atlantic salmon has been entirely eliminated. A sport fishery does exist throughout the river's length; however, it reaches peak importance along the tributaries, which receive annual stockings of trout to maintain a "put-and-take" sport fishery. Present efforts are being expended to restore anadromous fish to the entire watershed through construction of fish passage facilities at obstructions not having these structures and through re-introduction of salmon. Pollution abatement within the entire watershed is expected to lead to restoration of high quality aquatic resources and their utilization.

Within the vicinity of the diversion intake, anadromous fish species are not now found; however, approximately 25 resident species have been collected within this reach. Three of these species are important sport fishes (yellow perch, bullhead and small-mouth bass).

As described earlier, the diversion for water supply purposes would withdraw about 580 cfs from the river and this flow would then be

conveyed to Quabbin Reservoir. Diversions would only be made contingent on a minimum control flow of 17,000 cfs as measured at the U. S. Geological Survey gaging station at Montague.

Based on long-term stream flow records maintained at the Montague City gage, the amount of water to be withdrawn would be about 1% of the average annual run-off from the river. A plot of the proposed withdrawal effect on the long-term average monthly hydrograph is shown on Plate No. 12. In addition, the maximum decrease in river stage caused by the diversion would be about 0.2 feet at Montague City or about .05 feet at the Thompsonville, Connecticut gage.

b) Change in Concentrations of Nutrients

Based on data developed by the University of Massachusetts as part of a research grant, ammonia-nitrogen loads in the Connecticut River at Northfield for 1963 - 1965 were 3,800 pounds per day. Downstream at Thompsonville, Connecticut, loads for the same period were recorded as 35,900 pounds per day. Phosphate-phosphorous at Northfield for 1963 - 1965 was estimated to be 6,700 pounds per day, while at Thompsonville, about 33,000 pounds per day were recorded.

The diversion from the Northfield Mountain would little affect nutrient levels downstream from the diversion. Maximum differences in concentration at Thompsonville for ammonia-nitrogen and phosphate-phosphorous would be less than .01 ppm.

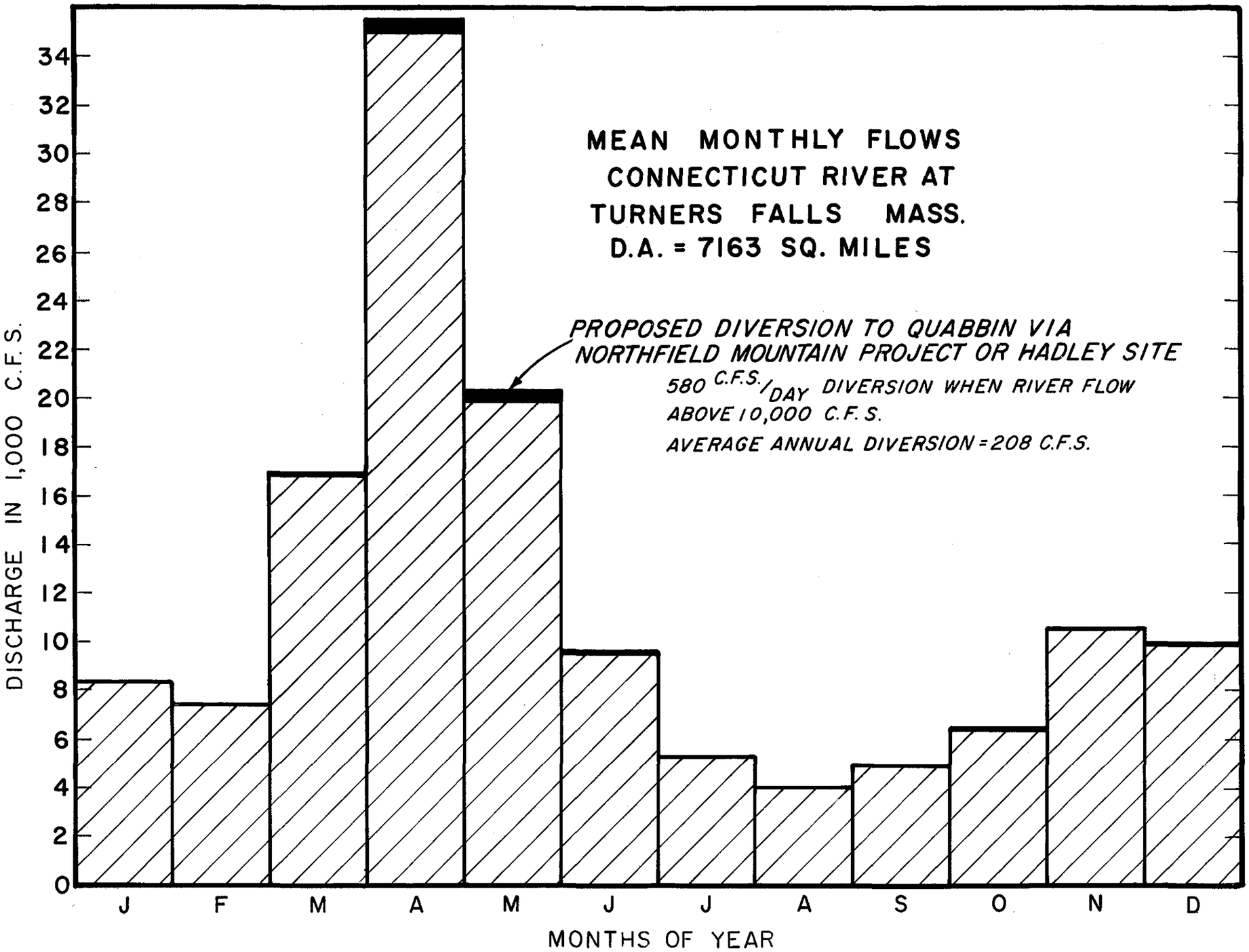
Since pollution abatement schedules call for installation of waste treatment facilities by 1976, the actual effect of diversion would be even less.

c) Change in Coliform Levels

Work conducted at the University of Massachusetts on this subject had among its conclusions, "A diversion of Connecticut River water at Northfield would reduce the flow and increase the coliform concentration. This seems reasonable since relatively coliform-free dilution water would be diverted. However, a reduction in flow at Northfield caused by the proposed rate of diversion would probably have no significant effect on coliform concentration at Enfield."

d) Effect on Downstream Wetlands

As stated earlier, the diversion at Northfield would lower river stages at Montague City 0.2 feet at a maximum. Downstream at Thompsonville,



NORTHEASTERN UNITED STATES
WATER SUPPLY STUDY

AVERAGE MONTHLY RUNOFF
CONNECTICUT RIVER AT TURNERS FALLS
AND
PROPOSED DIVERSION EFFECTS

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS

the stage reduction would be .05 feet. Minimal impacts to downstream wetlands are foreseen for these limited river stage reductions.

e) Effect on Planned Water Quality Improvements

Implementation schedules for waste treatment facilities on point sources of pollution have been established by the Environmental Protection Agency and the basin states. All plans for pollution abatement are based on meeting adopted water quality standards during low flow conditions. Since diversions considered in this project would only occur during high flow periods when flow is 17,000 cfs or greater at Montague City, no impact would occur to impair planned water quality goals.

f) Effect on Water Temperature

Studies conducted within the estuarine portion of the basin indicated a maximum of 0.06° F rise could be expected in the estuary following diversion of 600 cfs. Upstream in the mainstem of the Connecticut River, the maximum change in temperature which would be caused by the diversion and subsequent loss of dilution flow would be about 3%. No significant effect on water temperature is anticipated, therefore, from the diversion.

g) Change in Level of Groundwater Table

A meeting was held with the U. S. Geological Survey to determine the impact which the diversion may have on groundwater levels. In the opinion of the Geological Survey, no significant impact to groundwater levels is anticipated as a result of the diversion.

h) Effect of Diversion in Flood Flow Bottom Deposit Scouring

Based on studies by the University of Massachusetts, it was estimated sediment load transport efficiency of the Connecticut River just downstream from the diversion intake would be reduced approximately 3 percent. Downstream from the intake, flow from intervening drainage area would cause the reduction in efficiency to be even less.

i) Effect on Aquatic Life in Vicinity of Diversion Intake

Diversion of water from the Connecticut River to the Northfield Mountain upper reservoir may affect the aquatic life in the vicinity of the river intake. Fishes, phytoplankton and invertebrate organisms of all

life stages may be entrained and/or trapped at the pumping facility. This impact is not occasioned by the fact of the water supply diversion, but rather by the operation of the Northfield project for power production.

j) Effect on Downstream Navigation

Below Hartford, Connecticut, the river is used for both commercial shipping and recreational boating. Upstream from Hartford to Holyoke, the river is used for recreational boating, but sand bars and shallow water during low flow greatly impede navigational use.

Normal navigation season flow at Hartford is considered to be 3,750 cfs, while the upper limit is considered to be 66,000 cfs.

The diversion would not affect low flow navigation conditions. High flow conditions would be affected, but not in a negative manner. Instead, the reduction in flow from the diversion would be a minor benefit due to slightly lower velocities.

k) Effect on Flood Control

The Corps of Engineers is presently working with electric utility officials on an operational schedule of the Northfield Mountain project during flood periods. At present, a draft report presenting methods of operation is under review. It is anticipated that operation of the facility would not have a detrimental effect on flood control measures within the basin.

4) Possible Environmental Impacts of Diversion on Quabbin Reservoir

This study generated and evaluated extensive data on the Quabbin and Wachusett Reservoirs and the Connecticut and Millers Rivers systems, with the objective of making predictions on the impacts of diverting portions of these riverine systems into Quabbin Reservoir. Field and laboratory data included approximately 100 parameters, including chemical, physical, biological, and pesticides data. In addition, radiological data, hydrodynamic studies, fisheries information, and pollution abatement plans were considered and evaluated. Finally, other pertinent data available from both public and private sources, especially on the Connecticut River, were evaluated in the light of the objectives of this study. A summary of this evaluation is given in the following sections. A complete description of the study results is given in Appendix D.

Central to the evaluation was the development of a qualitative model of reservoir dynamics. If water of lower quality is introduced from a

river system into a receiver system, there will most likely be a loss in water quality in the receiver system. This loss of water quality is due to various materials in the water. These materials include molecules, ions, suspended inorganic materials, organic debris, and living organisms. One of the central problems of ecology today is to trace the flow of materials from the various compartments of an ecosystem.

a) Possible Impact on Water Quality

In this section, changes in water quality as a result of the proposed diversion are evaluated. The discussion is limited to the more important issues; no attempt is made to discuss all parameters. Subsequent sections will deal with broader ecological issues, and will include most of the biological parameters.

Diversion of Connecticut River water into Quabbin Reservoir in 1976 will initially increase the turbidity of the reservoir water. The final turbidity will depend upon (1) fallout of some material, (2) the relative dilution of Connecticut River water by ambient Quabbin volume, (3) transformations of materials, (4) the influence of ionic strength changes, and the influence of pH changes. Based on only preliminary data, the fallout of material could be significant after a residence time of 60 - 90 days. The dilution, however, can never exceed a factor of about 5 to 10, depending upon what volumes and how much mixing one considers. Also, water originating in the Connecticut River will be between 18 and 19% of the volume of the entire reservoir, depending on the availability of other diversions during the period 1980 to about 2000. Transformations may change the molecules or colloidal aggregates, but will not necessarily cause an elimination. Finally, the Connecticut River water will undergo a drop in specific conductance after it enters Quabbin; this will tend to stabilize the colloidal suspensions. If it is assumed that the Connecticut River will have an average turbidity of less than 25 during freshet flow, and that extremely high values are possible but infrequent occurrences, all factors considered above will tend to bring the final turbidity down to a lower value. While it cannot be predicted what this value will be, it will probably vary between 0.5 (present turbidity) and about 2. Thus, it may not meet future U. S. Public Health Service (1 JTU) standards for drinking water. The turbidity will probably not rise as much during the first two diversion cycles (years 1976 - 1978) because of the smaller relative proportion of total water originating in the Connecticut River.

Ions that form insoluble complexes (Mn, Fe, Ca) tend to precipitate out into the sediment if suitable anions are available. Such anions decrease

as the pH becomes more acid, and thus these ions will tend not to precipitate out as the Connecticut River waters mix with Quabbin waters. Depending on the quality of other waters introduced to the reservoir in the future, there may be a tendency to balance. However, it cannot be predicted what the trend will be over a two-decade period, because the exact proportions cannot be predicted and the long-range stability for pH values in all systems is unknown.

There are at least two major concerns on the possible deterioration of water quality that have ecological significance. One concerns oxygen depletion, and the other is the introduction of additional nutrients which can lead to eutrophication.

Available data suggests that Chemical Oxygen Demand (COD) values for the Connecticut River are about twice as high as the Quabbin stations. Both Connecticut River and Quabbin Reservoir waters maintain high 0_2 levels, and during the freshet flow periods are probably close to saturation. The concern here is an assessment of the potential depletion of 0_2 from Quabbin waters as a result of the proposed diversion.

COD represents a potential 0_2 consumption that is measured using a strong chemical oxidizing agent. Depending on the ease with which the material can be oxidized under natural conditions, the full COD may or may not be exerted upon the water.

If most of the COD is in particulate form (which is probably true for the Connecticut River) much of the material with a potential demand for oxygen could settle out either in the Northfield Pumped Storage Reservoir or in upper Quabbin Reservoir after diversion. Although settling reduces the COD of the water column, the potential oxygen demand is conserved in the mud. Moreover, the organic component of the sediment may be acted upon at the mud-water interface, and transformed into more easily oxidized compounds. Some materials in the diverted waters may interfere with biological activity in the mud-water interface and either inhibit or enhance the transformation processes. Seasonal turnover and wind effects can stir up these bottom deposits into the water column. These effects are intensified if the reservoir levels decrease. The resuspension of transformed organic muds can serve to deplete available oxygen quickly because COD that had accumulated over many years through the settling process is suddenly present in the water column. If the stirring of the bottom mud never occurs, then COD that is settled out may be buried in the anerobic sector of the mud and may never exert its 0_2 demand on the water.

Included in COD values are the oxygen demands of inorganic materials such as iron and manganese. These inorganic species can have high O_2 demands if they are in a chemically reduced state. However, in the Connecticut River, laboratory analysis shows that the iron is mainly Fe III and that the manganese may also be already oxidized.

All the above factors make it difficult to predict the impact of diverting Connecticut River waters with a higher COD into Quabbin Reservoir. Localized oxygen-depletion effects have been observed in the eastern arm of the reservoir. It is probable that similar effects will be observed after diversion in the northern part of the reservoir as well. The impact on the hypolimnion in the deeper part of the reservoir cannot be predicted at this time. Oxygen depletion will depend on a complex of biological and chemical processes in these aquatic systems. In conclusion, then, it is very possible that the proposed diversions may result in some localized oxygen depletions in the reservoir. The extent and magnitudes of such depletions cannot be predicted. As described earlier in the section on "Water Treatment Required" the impact on Quabbin must be carefully observed and monitored. If necessary, the option of diverting flow to more than one location within the reservoir can be exercised by extension of the tunnel stub described earlier.

A number of mechanisms can be expected to operate after the diversions of river waters. Much of the larger material will settle out, probably within hours and days. Many transformations can be expected, based on both inorganic and biological reactions. Detergents would be degraded, although no significant MBAS[1] levels were found. As the carbonates from the Connecticut River reach the more acid reservoir waters, equilibria will shift and some CO_2 will go off to the atmosphere. Organic materials including the CCE will probably be oxidized. Some NH_3 may also be oxidized, but most of it would be transformed by the biota. Color would decrease. This loss of color could be at least tenfold, based on evidence from the existing Ware River diversion. Finally, many highly insoluble organic materials, including hydrocarbon pesticides and organomercury compounds would tend to evaporate, as they reach the relatively large surface area of the reservoir.

The general trend will be towards an improvement in quality as the diverted water is retained in the reservoir. Whether the retention time within the reservoir before the Connecticut River water reaches the general position near the reservoir main water supply outlets is sufficient to cause recovery is unknown. However, the much longer

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[1] MBAS - Methylene blue active substances, found in most household detergents.

retention times to reach the Chicopee Valley water supply outlet could also allow for some recovery. It cannot be predicted that dilution with ambient reservoir volume will not restore the water quality alone. Some "fallout" of materials due to sedimentation, transformation and evaporation must occur to restore quality. The "treatment plant" capacity of the reservoir can probably handle some restoration of water quality. The magnitude of this capacity is now unknown. Because of its capacity to handle waters from the Ware River diversion with efficiency for 30 years of diversion, we may assume it has some reserve capacity. However, assuming that a loss of water quality occurs with some diversions of Connecticut River water, further deterioration will be checked if other sources of supply are added to the reservoir.

In summary, then, during the period prior to the Northfield Mountain diversion, the water quality will deteriorate as the volume in Quabbin Reservoir decreases. This loss of quality could progress to a dangerous point if the volume of hypolimnion waters is drastically reduced. Any losses in quality due to Connecticut River diversion must be judged in the light of water quality loss without diversion. Secondly, the volumes of water represented by Connecticut River origin will be relatively low during the first few diversions. This allows ample time to study the actual impact of diversion during a period of lower potential to cause a negative impact on water quality. Thirdly, future additions of water to Quabbin from other sources should improve the "treatment plant" capacity of the reservoir and thus an improvement in quality may take place. Also, it must be remembered that as the pollution abatement plans are implemented in the 1970's, the quality of riverine waters will improve. Finally, without even further sources of water inflow, Quabbin Reservoir is destined to deteriorate rapidly by the end of the century.

b) Possible Impact on Ecology

There can be little doubt that increased levels of nutrient chemicals will be detected in Quabbin Reservoir after the implementation of the Connecticut River diversion. However, not all nutrients can be expected to show such an increase in this time period. Phosphorus increases are possible, but not probable. Increases in available carbon, on the other hand, are quite probable if only due to the relatively high alkalinity of the Connecticut River. Also, the fact that fecal contamination of the Connecticut River does occur, increases the likelihood that complex organic molecules will be introduced into Quabbin and possibly into Wachusett where they will become part of the nutrient pool. The

future abatement of pollution in the Connecticut River will contribute significantly to the lowering of any such nutrient addition to the reservoir through diversion.

It is important to note that current nitrogen, phosphorus, and carbon levels in Quabbin are sufficient to support larger phytoplanktonic populations than presently exist. Increased levels of these nutrients do not necessarily mean, then, that higher concentrations of algae in Quabbin can be expected as a direct result of the diversion. It is quite possible, however, since nitrogen, phosphorus and carbon appear not now to be limiting, that the Connecticut River diversion may increase the levels in Quabbin Reservoir of some now unknown limiting growth factor, such as a vitamin. Additional studies on limiting growth factors in both Quabbin Reservoir and Connecticut River water is now under way by the MDC.

There is no reason to believe that undesirable algal species will be introduced into Quabbin Reservoir by either diversion. Any changes in the current algal populations in Quabbin will most likely be the result of the response of present populations in Quabbin to changing levels and kinds of nutrients brought about by the diversions.

The proposed diversion of Connecticut River waters into Quabbin Reservoir presents a good possibility of having an impact upon the maintained fisheries of Quabbin. Furthermore, in view of the fisheries management objectives of the Massachusetts Division of Fisheries and Game, the impact would be a negative impact. If it is assumed that undesirable species will be introduced into Quabbin Reservoir, then the consequences could be felt in several ways. First, the present managed ecological balance between species will be lost. Secondly, if the salmonid population is decimated by undesirable species competition, and a warm water fish population predominates, there is good likelihood that the number of angler trips by sports fishermen to Quabbin Reservoir will decline. This, in turn, will reduce the harvest and further influence ecological balance. The issue, then, is not a reduction of the standing crop of total fishes in Quabbin Reservoir, but the disruption of the present success in the management of a salmonid fisheries program. Studies on methods of excluding undesirable species and hence the consequences associated with their introduction are now being discussed by the MDC and the Massachusetts Division of Fish and Game.

Increased concentrations of organic molecules in Quabbin as a result of the Connecticut River system diversion may affect the dissolved oxygen content of Quabbin waters due to the oxygen demand of these molecules as discussed earlier. The magnitude of any overall decrease

in oxygen in the hypolimnion of Quabbin Reservoir, however, is not expected to cause significant changes in the present ecology of Quabbin Reservoir. Localized depletions of oxygen in Quabbin Reservoir have been periodically noted over the past half dozen years as a result of the present Ware River diversion. These depletions have been observed only in the southern part of the eastern arm of Quabbin, and have been short lived. The proposed diversions may be expected to produce similar, localized phenomena. The salmonid fisheries in Quabbin are not expected to be affected by any lowering of dissolved oxygen which is localized in the upper portion of the middle arm and in the eastern arm because they are typically found in the main body of Quabbin.

Because of the number of factors governing the disposition of pesticides in surface waters, it is not surprising that only small traces of pesticides were detected in this study. Similar findings are seen in the STORET retrieval data on the Connecticut River. Analyses for aldrin, BHC, DDT, dieldrin, endrin and other pesticides during the 1960's show little or no residues in the water. Finally, the findings of Lichtenberg et al. (1970) in a 5-year summary of pesticides in surface waters of the United States report only trace amounts (0.1 ppb) of pesticides in the Connecticut River.

A prediction with some certainty can be made about the ecological effects of pesticides in the proposed diversions. The Massachusetts Division of Fisheries and Game has data that indicate significant levels of DDT, endrin, dieldrin and PCBs in the tissues of lake trout taken from Quabbin Reservoir. These pesticides in lake trout reflect the expected concentrations by the food chain if traces of pesticides are already available in the reservoir ecosystem. Nor were the residues of DDT in fish from the Connecticut River (Lyman et al. , 1968) any higher than those reported for the fish in Quabbin Reservoir. While more extensive monitoring of the waters, muds, and biota of both the Connecticut River and Quabbin Reservoir for pesticides would increase the certainty of prediction, it is highly improbable that the proposed diversion will have any important environmental effects.

Similarly, the impacts of the proposed diversions into Quabbin or Wachusett Reservoirs are impossible to discuss in detail until such a time as the specific impacts discussed above can be more fully defined by future studies. On the basis of current data, the possibility of a degeneration in turbidity in Wachusett deserves some mention due to the importance of turbidity in any contemplated future treatment of

Wachusett waters prior to their final distribution to consumers. Further studies sponsored by the MDC are presently under way on possible impacts in both Quabbin and Wachusett Reservoirs.

A summary of impacts on Quabbin Reservoir, which may be brought about by the proposed diversion via Northfield Mountain, is shown in Table 17.

5) Possible Environmental Impacts Caused by Added Waste Load of Reservoirs

In keeping with the objectives of the Environmental Quality account, the impact which added waste loads, occassioned by the additional water supply, from the project was also investigated. To provide a measure of the added waste load impact, it was assumed that the environmental cost would be considered as the cost of bringing the quality of water back to its original state. Estimates of providing advanced waste treatment to the incremental water supplied was made. It was assumed 70% of this additional supply would be treated; the remaining 30% would be lost from the system through evaporation, irrigation and consumed process water. The estimated costs of providing the necessary treatment is 3.4 million dollars on an average annual basis.

Care should be exercised by the reader, however, in translating this treatment cost dollar total to the earlier Regional Development and National Economic Development Accounts analysis. Offsetting the costs in general of this additional treatment required is the revenue lost to the MDC system if additional supply is not made available. For example, at present, water rates ($120/mg) revenue lost (or not available) without additional supplies totals 3.2 million dollars on an average annual basis. Using the anticipated new rate ($160/mg) revenues not available would total about 4.2 million dollars on an average annual basis.

In an attempt to preclude confusion by the reader in the Regional Development or the National Economic Development Accounts, neither the added waste treatment costs nor the benefit derived by the system in selling the added water were included. Thus, the two earlier account assessments are in essence addressed to an examination of net costs and net benefits.

TABLE 17

SUMMARY OF PROBABLE IMPACTS OF THE PROPOSED DIVERSION ON QUABBIN RESERVOIR

Note: This summary does not predict the duration of the impact.

Description of Impact	Relative Probability Impact Will Occur			
	No significant change over existing conditions	Possible but Probability Low	Probable	Probability High
Increase in Nutrient Chemicals			C	
Increase in Eutrophication			C	
Modification of Present Equilibration			C	
Introduction of Undesirable Species				C[1]
Increase in Coliform Bacteria			C	
Increase in Human Pathogens		C		
Interference with Water Treatment at Quabbin			C	
Increase in Levels of Toxic Materials		C		
Increase in Levels of Radioactivity	C			
Increase in Levels of Pesticides	C			
Increase in Extent and magnitude of oxygen depletion			C	

C = Connecticut River Diversion

[1] Assuming exclusion devices were not employed.

6) Possible Environmental Impacts Caused by Construction of the Project

The preliminary design of the aqueduct and appurtenant structures of the Northfield Mountain Water Supply project precludes a detailed assessment of possible environmental impacts associated with the construction aspects of the project. If authorized, the project would undergo detailed design which could alter the preliminary design presented in this report. For example, tunnel shaft locations selected in this report may change which in turn would affect possible environmental impacts of such construction activities as tunnel spoil disposal, selection of haul roads and maintenance areas.

In response to the possible alterations in design and other followup action which might affect the environment, the Corps of Engineers requires four environmental impact statements for each project authorized. These separate statements are prepared for the Planning, Design and Construction phases and finally for the Operation and Maintenance stage. In all of the stages, projects are designed with the minimum disruption of the environment which is feasible.

This interim report of survey is a planning stage report. Detailed data, therefore, are not available on all environmental impacts which might be encountered during final design and prior to construction of the project. Sufficient information is available, however, to highlight possible areas of environmental concern which would be considered in the followup phases.

All work on the tunnel from Northfield Mountain to Quabbin Reservoir would be underground. Thus, the majority of the construction activity would not be visible or disrupting to the environment. Since the majority of the aqueduct route is in hard gneissic and other rock of good tunneling quality, the possibility of disrupting local ground water supplies is low. However, the Northfield hydroelectric facility experienced some limited disruption of individual supplies. Thus, this possibility should be assessed when the final route is selected.

Total rock spoil from aqueduct construction is estimated to be approximately 242,000 cubic yards. In the preliminary design, this quantity would require about 5 acres with a 30 foot depth. Spoil from the tunnel, however, is expected to be of good quality and some or all of the material may be recycled into other local construction projects such as road construction. This potential for recycling would depend on final design and other construction activities in the vicinity.

Surface construction activities are expected to be limited to the vicinity of the construction shafts and connecting haul roads to spoil areas if needed. Environmental impacts which should be considered in the followup phases include impact of maintenance areas, haul trucks and other associated construction needs.

In summary, detailed environmental impacts of the construction activities associated with the project cannot be fully described during the planning phase. Possible impacts, however, would be fully described in followup environmental studies conducted in the design, construction and operation and maintenance stages. Although all possible impacts cannot be quantified at this time, sufficient data exists which indicates no major adverse effects from the project. This conclusion is based primarily on the fact that the majority of construction activities would be underground. Surface construction activities may have potential impacts, but experience with similar projects indicates such impacts can be minimized through careful planning in the design and construction phases.

7) Possible Environmental Quality Enhancement

a) Environmental health of Quabbin Reservoir is presently in danger. Since 1970, water demands upon the Quabbin system have exceeded the safe yield of the Quabbin watershed. This means that on a long-term runoff basis, volume and level of Quabbin will decrease until existing inflows are augmented with new sources. To date, the reservoir has not recovered from the drought of the sixties, although 1972 and the winter of 1972 - 1973 was an excessively "wet year" and reservoir levels rose significantly.

Water quality conditions, algal growth patterns in the northern portions of Quabbin suggest that progression toward eutrophication is already taking place there. Water quality in the main body of the reservoir is still of a high quality; but if volumes decrease as projected over the years, the relative masses of high versus low quality water will shift toward an overall loss in water quality. Losses in volume will decrease the natural purification or "treatment plant" capacity and possibly the retention times of inflow waters. Losses in the hypolimnion volume will diminish the managed standing crop of salmonid fishes. The depletion of oxygen in the hypolimnion, whether partial or complete, depends a great deal on quantities of reducing agents in the water. Potential impacts on water quality are manyfold. Iron and manganese may be reduced to the ferrous and manganous state and released to the

water column. Sulfate may be reduced to hydrogen sulfide gas, resulting in obnoxious gas. In general, then, Quabbin may become unacceptable as a water supply.

When the waters from the Northfield diversion are introduced into the system, the yields of the system will again exceed the demand and levels of Quabbin will increase. With careful management and monitoring, eutrophication can be arrested and the reservoir will continue as a highly acceptable water supply source.

b) Environmental health in the communities to be serviced by the project would undoubtedly suffer without project implementation. Much has been stated previously of the economic and socio-economic impacts in the receiver area which would accompany construction of the project. Almost without exception, these impacts were of a positive nature, maintaining past progress in improving the quality of life. In addition to these economic and socio-economic gains in the receiver area, construction of the project should provide beneficial environmental impacts as well.

Therefore, the impact on the environment caused by the project can be viewed from two perspectives. First are those impacts on the estuary, Connecticut River and the receiving water bodies which would be caused by project implementation. The second perspective is the environmental impacts which would be prevented by project construction. In all cases, possible changes brought about by the project must be viewed in light of the environmental damage which could be expected without the project. Utilizing this approach, it appears environmental impacts expected with project implementation are less than could be expected without the project.

SECTION X

OTHER ALTERNATIVES

31. General

In this report, a wide range of alternatives to the Northfield Mountain Project was investigated. Included in these alternatives were other possible diversions, use of new technology as a means of augmenting existing supplies, non-structural approaches such as reduction of demand and the evaluation of the no-action alternative. A description of these alternatives and their potential as solutions to the existing problem, are given in the following paragraphs.

32. No Action

In the evaluation of this alternative, it was assumed that any failure to secure timely additional supplies for the service area will result in major economic and social losses to the entire planning region. To verify this assumption, a quantification of these impacts was necessary.

Estimates of impacts caused by a no-action policy can be expressed in two different ways. First, concrete losses without the diversion total $96 million to 1990 and $528 million to 2020, if average runoff conditions prevailed. Under drought conditions, concrete losses without diversion total $201 million to 1990 and $623 million to 2020.

As described in the previous section and Appendix K, categories included in these totals encompass industrial, city emergency, city revenue: commerce, sprinkling, business investment and domestic investment losses. However, economic losses in these categories say nothing of the ways in which the losses might be allocated. For example, of the approximately $3.5 million not collected in city revenue in 1990 by all receivers under a no-action policy, there is no way of knowing with certainty whether it would be municipal expenditures on recreation or schools that might suffer. In Section IX, this loss in revenue was expressed as 600 classrooms. Similarly, housing units not built are but an alternative manifestation of losses in the private sector.

sixty-six receiver communities, the experience of an actual municipality already beset by the kinds of problems anticipated in the event of prolonged water shortage was evaluated.

The town selected for examination was Stoughton, Massachusetts, an industrial - residential community in the Brockton S. M. S. A. An extended interview with Stoughton's Planning Board Chairman produced both background and impact information. Growth in the town has been steadily upward and shows no sign of a downward turn. The principal constraint on continuing growth may be an acute shortage of water.

The town has been searching for water since 1955 and results have been disappointing. The consequences of the resulting water deprivation have been felt across a wide range of community activities.

Although no shifts in the allocations of land use type have occurred, development in the industrial category has been nearly stopped by water shortage. Economic development has been hurt because water using industries have been turned away. This has slightly decreased the stability of the town because the tax base has not expanded quickly enough to keep up with the demands on local revenue. Wages and prices have remained in phase with the rest of the state, but taxes have increased. No Stoughton industries have left because of water shortage, but new industries have gone elsewhere. Presently, only non-manufacturing, non-processing firms are permitted to locate in town, and a $40 million industrial park is now two years behind in its development schedule.

While data projections estimated in this report show population deficits without the provision of additional supply, it does not appear, based on the Stoughton experience, that population growth is sensitive to short term controls and constraints. Stoughton's in-migration continued despite the building ban and shows signs of growing even more quickly now that new housing construction has begun again. Since the lifting of the building ban, over 500 rental units have been built and occupied. The demand for housing has lowered the vacancy rates significantly and stimulated the construction of 3,000 apartment units and the planned development of 3,000 more. Before the ban went into effect, issuances of building permits had declined for two successive years.

Because finding water has been a top town priority, other municipal services have suffered. A sidewalk program has been indefinitely postponed, and only minimal roadway maintenance and construction have occurred. Generally, expenditures have been cut as revenues

from expected property tax have dwindled. Estimates range as high as $1,000,000 in tax losses with increases in assessments covering the deficit. The cost of water has doubled in the past two years, and the municipal debt as of 1 January 1970 stood at $320 per capita. Until a mutual help agreement was reached with Easton and Sharon, adequate fire protection was a critical concern. A much needed junior high school has been put off -- an effect attributed to the "extraordinary high expenditures of finding water." As a result, the present junior high is now in double sessions.

As the search for water has become business as usual, citizens appear to have developed some tolerances for the inconvenience of watering bans. However, their latent insecurity about adequate supplies for fire protection and general domestic consumption have made water shortage a perennial political issue on which concern can focus.

Despite the general slowdown in industrial development and its second order consequences on town revenues, the average citizen perceives the water supply problem in terms of his own inability to water outdoors. Lawns and shrubbery are a waste of money, says the homeowner, and the town looks poorer for it. In turn, these feelings are reflected in attitudes about the desirability of the community as a place to live and work.

In addition to socio-economic impacts, a second major impact could occur with the no-action alternative. This second impact regards the probable deterioration in water quality within Quabbin Reservoir which could be caused by lowered reservoir volumes. As described in Section IX, Quabbin Reservoir presents a complex limnological situation. Some areas of the reservoir such as the northern sections appear to be progressing toward eutrophication. In the main reservoir body, however, quality is still high. If the pool volume decreases over the years as might occur with the no-action alternative, then there will be a shift towards an overall loss in water quality in the reservoir. Losses in volume will decrease the "treatment plant" capacity and hypolimnion volumes affecting water quality from both an environmental and public health standpoint.

Based on the evaluation of the socio-economic and environmental impacts, the no-action alternative has many disadvantages. Use of this alternative, therefore, does not offer a realistic solution to the short range needs of the study area.

31. Weather Modification

The primary source of the water used for public and private water supply in Massachusetts, as in most humid areas, is precipitation falling directly on the areas concerned. It follows then that if precipitation can be increased in a regulated manner, the water supply can also be increased. To this end, several major agencies such as the National Oceanic and Atmospheric Administration (NOAA), the United States Bureau of Reclamation, the American Meteorological Society, and the National Science Foundation are investigating ways of productively modifying natural precipitation patterns. The primary focus of research is in the area of cloud seeding. Other fields of interest are long-term seasonal precipitation forecasting and fog drip augmentation. Since little work has been done on the latter two, and what little has been accomplished is not applicable to the Massachusetts area, only the process of cloud seeding will be reviewed in this section.

A. Cloud Seeding

Simply stated, rain falls from clouds when water vapor in the clouds condenses around nuclei and forms rain drops large enough to overcome frictional resistance to falling. In technical terms, this process is the conversion of the water vapor from a state of colloidal stability to one of colloidal instability. The concept of artificially induced precipitation by cloud seeding refers to the introduction of particles of foreign substances, such as dry ice and silver iodide into clouds to serve as condensation nuclei. Theoretically, this action will result in condensation of the water vapor and consequent precipitation. In short, it is scientific rain making.

The testing of the engineering and economic feasibility of this theoretical process has been concentrated in experimental projects in the Rocky Mountain and Upper Great Plains regions. Evidence gained through NOAA research suggests that winter cloud systems over Lake Erie may be modified to produce additional precipitation. A cost benefit study was performed for the Connecticut River Basin, but this study was in design only with no actual experimental work involved. Most information regarding the potential of cloud seeding in the eastern United States is derived from commercial cloud seeding operations.

Some of the findings resulting from these studies and experiments are summarized below:

1) The state of the art is such that most researchers look upon the potential of increased precipitation through cloud seeding with

an air of cautious optimism. Study to date, however, has provided little more than a beginning to the solution of many of the problems involved in weather modification.

2) Cloud seeding is impractical during severe drought conditions when water shortages are most critical. The first requisite for cloud seeding is the presence of clouds, and droughts are notable for their lack of clouds. Present technology is not even remotely capable of producing clouds by weather pattern modification. During a temporary interruption of drought conditions, clouds may form over an area. Even under these conditions, however, cloud seeding would not appreciably alleviate water supply problems since most precipitation would be in all likelihood taken up immediately by plants and soil. It is apparent then that water shortages in periods of drought cannot be solved by cloud seeding. Any substantial seeding induced precipitation would have to be produced during non-drought conditions with abundant moisture in the atmosphere.

3) There are many problems that must be solved before substantial technological breakthroughs result. One of the most critical is the inability of researchers to satisfactorily define optimum cloud conditions and seeding techniques and to predict seeding results accurately. In other words, there is an inadequate understanding of the basic cloud processes which determine: a) the "seedability" of a cloud or cloud system, and b) the proper seeding treatment to stimulate rainfall production efficiently in a potentially seedable cloud.

Another problem is the possibility of undesirable effects of seeding. Indiscriminate seeding might increase soil erosion and sedimentation in streams through intensification of the normal rainfall rate of natural storms. There is the possibility also that artificial seeding of clouds might in fact reduce the natural rain producing capacity of the clouds.

4) Estimates of the feasibility of cloud seeding in the eastern part of the country, including New England, are vague and poorly defined. Most recent cloud seeding research has been conducted in the western states. Atmospheric scientists have cautioned that results of seeding experiments in one area of the country must be viewed with caution when applied to other areas characterized by different topography and climate. It is apparent that much research needs to be done in the eastern part of the country. There is data available for parts of this area from commercial cloud seeding operations. However, these operations were not performed under proper scientific and statistical control procedures and any data gathered in such a manner must be used and interpreted with care.

B. Conclusion

Research has continued to improve the state of the art of weather modification by cloud seeding and other means. At best, however, weather modification is still an inexact science. Studies are unable to predict optimum cloud conditions and seeding results with any degree of accuracy. It is the conclusion of this section, therefore, that at this time weather modification operations to augment water supplies in Massachusetts does not appear to be a viable solution to the immediate water supply problem.

32. Desalinization

Desalinization, the process in which brackish and salt water is converted to fresh, is currently being used in some parts of the world as a viable, economically feasible source of fresh water. This process thus was considered for its potential as a future alternative solution to the water supply needs of eastern Massachusetts.

The conversion of saline to fresh water is accomplished through four major processes: distillation-evaporation, membrane separation, crystallization, and chemical differentiation. A descriptive summary of each process is given below.

A. Distillation-Evaporation

In this process, water containing salt or other impurities is heated and vaporized. The water vapor, free from the salt and other solids which remain behind as the water boils, is then condensed and collected. The system is basically a simple one requiring only a source of heat energy to boil the water, a method of cooling the water vapor (condensation) and various kinds of plumbing and receptacles for the transfer and storage of the water.

Since distillation, by its nature, results in the complete separation of the water vapor from the dissolved salts of the influent, the process produces fresh water of exceptional purity. Because this method removes the water from the salt, rather than vice versa, the quality of the influent is not critical and the system works equally well on water with a high salt content as an only slightly brackish water. For these reasons, among others, distillation is the oldest and best-known process of desalinization.

B. Membrane Separation

Desalinization by the membrane process is based upon the ability of thin membranes to pass molecule of pure water and retain the ions of salts and other dissolved solids. There are three basic variations to this concept: a) electrodialysis, b) transport depletion, and c) reverse osmosis. The first two variations depend on the electrical properties of the ions involved, while the third depends on a pressure differential existing across the membrane. Of these three variations, the electrodialysis process is the most well established, with many commercial installations throughout the world.

In contrast to distillation, the membrane process separates the salt from the water rather than the water from the salt. Each stage of the electrodialysis process removes slightly less than 50% of the dissolved solids in the water being treated. The more saline water, the more stages are needed and hence more energy is consumed. For this reason, electrodialysis and other variations of the membrane process are more economical when used with brackish water with a salinity of between 5,000 - 10,000 mg/l, as opposed to more saline water. The water can then be refined in stages to the desired degree of purity.

C. Crystallization

This process relies primarily upon the fact that as water freezes, the ice crystals reject ions of salt. Saline water is frozen and the crystals of pure ice are then skimmed or removed for later use from the still liquid brine. A second method of separation by crystallization employs the hydrate process which is the formation of a crystalline substance by the combination of water with low molecular weight, hydrocarbons or their derivatives. Like ice crystals, these hydrates reject salt ions. It takes less energy to freeze water than it does to boil it, thus this method has an advantage over distillation in that it consumes less energy. The crystallization process has not been widely used, however, and further research into its effectiveness is continuing.

D. Chemical

In this process either the water or the dissolved salts are made to undergo a chemical reaction which forms a substance which can be easily separated from the untreated water. Ion exchange, a method by which the saline water is passed through treated resin and the salt ions selectively removed, is the most widely used method of chemical desalinization.

The efficiency of ion exchange decreases with time as the "holes" in the resin become filled with salt ions. Once the resin is saturated, the operation must be closed down and the resin regenerated. For these reasons, the process has had only local exposure and small volume use.

E. Present Application

Sea water can be considered, for all intents and purposes, an unlimited source of fresh water once the technology of desalinization is refined to a point where it is economically feasible. To this purpose, the federal government, through the Office of Saline Water, has promoted extensive study and research into the problems of desalinization. Several model and testing plants and facilities have been constructed to aid in these

studies. The research to date concludes that of the four main processes discussed above, distillation and membrane separation are best suited to large capacity plants. Economical considerations dictate that distillation is best for sea water and electrodialysis for brackish water.

Presently more than 300 million gallons per day (mgd) of desalting capacity is installed world-wide. Plants are generally located in arid regions where conventional water sources are high cost or unavailable. Principal areas of use are in the Mid-East and Caribbean tourist islands. In the United States, desalting for municipal water supply has thus far been limited to smaller communities, relatively isolated from sources of conventional supply.

The largest municipal desalting plant in the United States is a 2.6 mgd distillation process in Key West, Florida. Largest in the world is a French-built, 30 mgd distillation plant, recently completed in Kuwait.

A distillation plant was recently proposed for San Louis Obispo and Santa Barbara Counties, California, which would have a capacity of 40 mdg. Construction on this plant which would have been the largest in the world was scheduled to begin in 1973, however, action on this plant has been recently suspended.

F. Costs of Desalinization

The cost of fresh water produced by desalinization depends upon the capacity of the plant, the type of process used and whether nuclear or fossis fuel is used. In general, the larger the plant capacity, the less the cost per unit of water. As has been mentioned previously, distillation is more economical for the desalting of sea water, while electrodialysis is better for brackish water. The water costs from nuclear fueled plants are approximately 10% less than from fossis fuel when used in large capacity (more than 100 mgd) plants.

The current cost of desalting is about one dollar per thousand gallons. This estimate is based upon an output capacity of 1 mgd, an amount representative of many plants currently in operation. Designs for the larger plants, such as for San Louis Obispo and Santa Barbara Counties, California, indicate costs in the vicinity of 73 cents per thousand gallons at the plant site. To this figure must be added delivery system costs.

G. Conclusion

Desalinization by numerous processes is already feasible in parts of the world when the natural water supply is either scarce or of poor quality. In these areas, the relatively high costs of water produced

by desalinization are justified. Research[1] has indicated that when larger capacity plants are designed and in production, the costs for desalting sea water could ultimately be reduced to approximately 50¢ per thousand gallons, in the size range of the Northfield Mountain Project, although the proposed California plant would produce water at 73¢ per thousand gallons at the plant site. Even at this reduced cost, however, desalinization is not competitive with present costs of developing natural surface and sub-surface water supplies. For example, costs of water from this report's recommended project is about 15¢ per thousand gallons.

Aside from the economic costs involved with desalinization, the Office of Saline Water is also investigating the potential hazards to the environment which might occur. In considering placement for any type of desalting plant, environmental factors are as important as any other factor. Pure water is not the only product. A plant will produce extremely concentrated brine as an effluent, plus any waste products from the power source, such as soot, heat, smoke, toxic gasses, etc. So far as brine is concerned, this brine from distillation plants is of high temperature, higher chloride content and may contain concentrations of copper, all of which may prove injurious to the environment. Special design procedures would be required in the cases of estuaries or areas with restricted water interchange, as many life forms present might be adversely affected. Two land methods of disposal have been studied: (1) evaporation to dryness; and (2) deep-well injection. Evaporation is expensive, though this is highly dependent on land costs, presently quite costly in urban areas. Injection method costs are estimated at 25 to 70 cents per 1,000 gallons of brine. Such costs must be added to plant production and distribution costs to arrive at a true cost of water from this technology. At present, the Office of Saline Water is investigating other methods of brine disposal.

The future of desalting in the northeast is described as follows by the Office of Saline Water:[2]

"Existing desalting operations are characterized by several constraining features. Among the most important are high total annual costs, relative to conventional water sources; the need for proof of large-scale plant operation; and the problem of brine disposal. In the future,

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[1] Based on data contained in memorandum from Office of Saline Water to New England Regional Coordinator, U. S. Department of the Interior, 17 August 1972, based on 1972 price levels.

[2] Ibid.

as technology is further developed, several of the constraints will be lessened, and desalting may prove to be an attractive supplement to water supply in coastal and estuarine areas of the Northeast United States. Desalting processes may also serve future use as an aid in control of water quality." As a result, this report concludes that desalinization not be considered at this time as a viable alternative source of water in eastern Massachusetts for the short-range water supply problems. When and if the technology and efficiency of this process is refined so that it is economically and environmentally competitive with other methods of supplying water, its feasibility can be re-evaluated.

33. Importation

During the crisis years of the sixties' drought, many newspaper and periodical articles pondered the possibility of diverting water from extra-regional sources as a solution. One of the major basins often mentioned as a water supply source for the Northeast was the Saint Lawrence. As an alternative to developing local resources to meet future water needs, an investigation was made regarding the feasibility of diverting Saint Lawrence flow to meet future needs.

The Saint Lawrence River Basin is an impressive basin, both in its size and the annual runoff from its watershed. The drainage area is about 295,000 square miles at Ogdensburg, New York, which includes over 95,000 square miles of water surface area, most of which is in the five Great Lakes. Storage capacity within the lakes regulates the flow in the river to a large degree. The long term average discharge at Ogdensburg is about 240,000 cubic feet per second (155,000 mgd). From a review of these statistics, it is apparent that the basin, if developed, could meet the forecast supply demands for all of southeast New England.

Engineering studies were conducted to assess various methods and quantities of development from the basin. Cost estimates were prepared for projects which would service all of the Northeast through the year 2020. Construction costs for such facilities were estimated to be as high as 8.5 billion dollars, excluding any necessary water treatment costs. Water delivered from such an undertaking would cost substantially more than similar volumes made available from local resource potential.

In addition to the high cost of water, this alternative also has several other major disadvantages. First, the nature of the project would not allow stage development. Thus, large expenditures of funds would be required for distant long range needs. Second, since the basin is international, negotiations with Canada would have to be held and a treaty consummated prior to diversion. Assuming that Canada would be favorable to such negotiations, at best, any treaty would be in the distant future.

Based on the results of investigations conducted as part of this report, the importing of water to meet short-range water supply needs does not present a viable alternative for the southeastern New England Region.

34. Waste Water Reuse as a Municipal Supply

Waste water reuse, especially in industrial process application, has been economically successful in many sections of the country. The Bethlehem Steel Company in Baltimore, Maryland, currently uses about 120 mgd of treated municipal waste from Baltimore and uses this effluent in its quenching and cooling processes. The Dow Chemical Company uses treated sewage from the City of Midland, Michigan for use in its cooling water and fire protection system. In Amarillo, Texas, effluent from the municipal sewage treatment is used as cooling water and boiler make-up water for industries located in that city.

Other uses to which treated waste water has been applied include irrigation of both crop land and lawns, as a fresh water barrier against salt water intrusion, and in some cases as a source of supply for formation of recreation lakes and ponds.

Direct reuse of waste water effluent as a public water supply, however, has not been utilized to a large degree. Advanced waste treatment research and development programs at the Federal level are continuing and pilot plant studies such as the noted Lake Tahoe project are apparently meeting with success in producing a high quality effluent.

The current Drinking Water Standards do not apply to direct reuse of reclaimed water for drinking. In a series of recent articles, the Division of Water Supply Programs, Environmental Protection Agency, (formerly Public Health Service) have described a number of potential health programs which could occur with the use of renovated waste water. As stated in these articles, recent public repercussions from birth defects caused by thalidomine and from the side effects of other

new drugs, underscore the responsibility that health officials have in introducing or promoting the use of reclaimed waste water as a domestic source.

Health officials feel that many questions remain unanswered which must be fully investigated if renovated waste water is to be considered for drinking water purposes. Research considered vital was described in an article [1] prepared by the Director and Deputy Director, Division of Water Supply Programs. In their article, it was stated that "before development of intimate personal-contact uses of renovated waste waters, one needs to:

A. Initiate studies on viruses for:

1) Development of improved viral detection and enumeration methodology.

2) Exploration and definition of the basic properties of enteric viruses.

3) Provision of knowledge on transmission of viruses through the aquatic environment.

4) Definition of the impact of viral disease on man through associated epidemiological studies.

5) Development of technology for the positive removal and inactivation of viruses.

B. Investigate the potential problems from bacteria and other microorganisms in reclamation systems.

C. Identify and define the potential health effects of organic and other chemicals not removed by reclamation plants and subject to build-up, and develop techniques to identify and measure readily the concentrations of such chemicals.

D. Dispel the cloud that hangs over the whole subject of reliability for wastewater-treatment-plant operation. Reclamation plants for direct reuse must have fail-safe processes, back-up facilities, alternate means for disposal, continuous monitoring, and bioassay, and they must be operated in an atmosphere that demands reliability. State programs responsible for the operation of wastewater treatment plants

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[1] Lang, W. N. and Bell, F. A., "Health Factors and Reused Waters," Journal American Water Works Association, April 1972.

will require upgrading. Pilot and field-scale testing will be required for the validation of processes and practices prior to their widespread use.

E. Use common sense. Renovated wastewater should not be used for the ultimate personal use -- as a drinking-water supply -- until there is no other practical choice; and then, hopefully, the minimum research will have been completed and the use will be carefully operated and controlled. Meanwhile, in water-short areas, the renovation and reuse of wastewaters for industrial, limited irrigation, and other low human-contact purposes should be investigated and advanced.

The future of direct wastewater reuse, particularly in industrial applications, seems promising. Future water demand forecasts for industrial usage used in this report, in fact, anticipates greater recycling of water in the industrial sector. For example, industrial output projections of Standard Industrial Classification (SIC), category No. 28, Chemicals and Allied Products, indicate a 750% increase by 1990. Thus, if no recycling beyond that presently practiced were implemented, then anticipated water supply needs for this industry would increase over sevenfold. Future industrial supply estimates developed for this report, however, recognize many pressures are being exerted which should alter present industrial water use practices. In the SIC 28 category, described earlier, the possible changes in use practices were estimated to require a 370% increase in supply rather than the 750% which might be expected based on output forecasts.

Use of renovated waste water as a regular domestic supply, however, requires full results of proposed research. Until such research is completed, wastewater reuse as a municipal water supply is not a viable alternative to meet short-range supply needs.

35. Ground Water Resources

A study[1] of the ground water resources of Massachusetts was prepared for the Corps of Engineers by the United States Geological Survey. The study was based upon analysis and interpretation of available data and did not include any new exploratory work. The objectives of the study included an estimate of the area extent and sustained yield of principal aquifer reservoirs which might be used for supplementing municipal and industrial water supplies. The cost of producing the water was also estimated.

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[1] This investigation was conducted as part of the feasibility study of potential engineering alternatives in the study area.

A. Occurrence of Ground Water

A water bearing strata of rock material is called an aquifer. The principal aquifers underlying Massachusetts are of three types: 1) Stratified drift, layers of sand and gravel commonly interbedded with some silt and clay; 2) till, a non-stratified, poorly sorted mixture of clay, sand, gravel and boulders; 3) crystalline metamorphic and igneous bedrock. Till and bedrock aquifers yield small amounts of water, suitable only for domestic supplies. Only those aquifers occurring in stratified drift have the potential capacity to sustain large withdrawals of water.

Geologic reports and well logs were studied to determine the distribution and thickness of stratified drift deposits in Massachusetts. Deposits were found about everywhere in the state, but were most extensive in the valleys and outwash plains of the east and southeast area.

B. Hydrologic Parameters

In order to evaluate the aquifers as potential sources of water supply, their water transmitting and storage characteristics were studied. Permeability values, in gpd/sq. ft. were assigned to various lithologies such as gravel, sand and gravel and coarse - medium - fine sand on the basis of the relationship between grain size and permeability. The transmissibility, in gpd/ft., of a lithologic unit was then determined by multiplying the thickness of the unit by its permeability value. Coefficients of transmissibility and storage were also calculated from controlled pumping and drawdown tests at wells sunk in the aquifers.

The saturated thickness of the aquifers was mapped where data was available. The thickness was determined by subtracting the elevation of the base of the aquifer from the water table elevation. The saturated thickness of stratified drift, although not necessarily indicative of the presence of permeable zones, has been found by investigators to be a useable favorability guide for a general analysis of the ground water withdrawal potential. One further indicator of the water content of a ground water reservoir is the percentage of surface stream flow which is contributed by ground water. This portion of stream flow is termed base flow or ground water runoff. Analysis of past records indicates that average annual base flow of a given stream is approximately equal to Q-60 (stream flow equalled or exceeded 60% of the time) in a year of normal climate and equal to Q-70 in a dry year. The Q-70 flow is considered an index to the amount perennially available for consumptive use without depletion of storage.

The hydrologic criteria described above were applied to the principal aquifer reservoirs of Massachusetts. In this manner the capability of these reservoirs to serve as alternate sources of water supply could be evaluated. The rates of withdrawal from the aquifers were estimated by assuming the following conditions:

1) No recharge occurs for 200 days in dry years and all the water produced during this period is from ground water storage -- it is assumed that reservoirs capable of sustaining withdrawals under these conditions could continue producing forever;

2) The configurations of the reservoirs were idealized to form elongated rectangles;

3) A system of dewatering wells, 24" in diameter and spaced 2,000 feet apart for 2 mgd yields and 1,000 feet apart for 1 mgd yields, was hypothesized to aid in planning and cost estimates;

4) These wells were assumed to have no drawdown attributed to partial penetration, thinning of the reservoir, nor well losses;

5) Available drawdowns in the wells were limited to two thirds of the saturated thickness for water table conditions and to the top of the producing reservoir for artesian conditions;

6) Current withdrawals of ground water were included as a part of the estimated withdrawals.

The results were then tabulated by area and rate of withdrawal in mgd/sq. mile and total withdrawal in mgd.

C. Conclusions

The survey of ground water resources indicated that the aquifers in Plymouth County and parts of Cape Cod have the capacity to sustain long term, large magnitude withdrawals. The water demand on Cape Cod is increasing at a fast rate; therefore, this area is not considered in this report. The Plymouth County area studied comprises 300 square miles and its estimated safe yield is 300 mgd. This estimated rate exceeds the required quantity established as a goal at this study. Thus, it was concluded that the Plymouth County area could offer a viable alternative source of water supply for eastern Massachusetts.

Cost estimates for the necessary resource development were then prepared. Major development items included in these estimates were land

acquisition, cost of ground water well development, water treatment facilities, pumping installations and connecting aqueduct system to the metropolitan service area. The estimated construction cost for the ground water development per million gallons per day (mgd) capacity is about 1.2 million dollars. Costs for the Northfield Mountain Project on the other hand are estimated to be about 600,000 per mgd capacity. Annual costs of ground water development which include interest and amortization; maintenance, repair and operating cost; and major replacement costs are estimated to require charges of about 30¢ per 1,000 gallons produced. Annual costs for Northfield Mountain would require about 15¢ per 1,000 gallons produced.

In addition to the economic costs associated with development of the ground water alternative, there are also potentially significant environmental and socio-economic impacts. For example, land taking activities associated with sanitary protection of the various wells may be substantial. Preliminary estimates of necessary land acquisition for the wellfield development indicate 1,000 to 1,500 acres of land would be necessary. This compares quite unfavorably with the 30 acres estimated to be required for the Northfield Mountain Project.

Connecting pipelines between wells in the wellfield and transmission facilities to point of use would require a large amount of surface construction. Such extensive surface construction would have an impact on the environment in the vicinity of the wellfield and transmission facilities. Since portions of the aqueduct systems would pass through heavily urbanized areas, disruption would be expected to be extensive.

Since all water developed from the wellfield would have to be pumped to the consumer, this alternative would utilize large amounts of electricity. Thus, depending on the method used to provide this power, impacts on the environment may be expected. The Northfield Mountain Project would utilize off peak power; therefore, no additional potential environmental damage would accrue because of power requirements.

On the basis, then, of cost comparisons and potential socio-economic impacts, use of ground water does not appear to offer an attractive alternative to the proposed project.

38. Dual Water Supply Systems

An alternative which has been receiving attention of late has been the use of dual water supply systems. In these systems, a hierarchy of

water supply would be established whereby higher quality supplies could be used to furnish a potable source for drinking, cooking, dishwashing, cleaning, bathing and laundering. All other uses could be furnished by a second supply of lesser quality.

Two general methods have been suggested for such a dual system. The first is the possibility of recycling at the point of usage. Under this scheme, drinking, washing and bathing water would undergo treatment and then be further utilized as toilet flush water and outdoor uses. It is estimated that such a system could reduce domestic water use by as much as 50%.

Various systems for in-house reuse or for outdoor usage have been proposed and some are being marketed on a small scale.

Advantages to this system beyond potable water consumption reduction is the reduction in sewage water volume, sewer pipe and pumping requirements. Capital cost outlay for such a system based on limited cost data would be over twice as expensive as water delivered from this report's recommended project. Other disadvantages to this alternative lie with its limited application and accompanying operational experience, potential problems of odor and other aesthetic considerations. Health officials, in general, have not expressed their acceptance or rejection of such systems. However, their general apprehension on introducing less than potable water into the home environment could also reasonably be expected with regard to any system of this nature.

The second method which has been suggested for delivering higher and lower quality water for various uses would require a second distribution system. This second distribution system would carry river water or even sea water to supplement the high quality primary supply source.

Two methods of providing the second (lower quality) distribution system could be employed. The first would involve installation of the entire system immediately. The second, and more practical, method would be on an incremental approach wherein secondary systems are installed in new or replacement buildings above a certain size. The second approach was evaluated in this report. With this approach, water consumption is only reduced at a given time by the building construction that utilizes secondary systems.

To estimate costs for such a system, a report on the New York City area prepared as part of the NEWS Study was utilized. Based on the results of that investigation, preliminary capital cost estimates for

such a dual system would be about 6.5 million dollars per mgd saved. The Northfield Mountain project recommended in this report is estimated to cost about $600,000 per mgd. Therefore, it is quite apparent that use of a dual supply distribution system as an alternative would be an extremely expensive alternative.

In summary, then, use of dual water supply systems does not offer an alternative to the recommended project in this report. Of the two methods, the system which would recycle water at the point of usage holds the more promise for future application.

39. Other Diversion Sites

In addition to the Northfield Mountain Diversion proposal described in this report, a number of other diversion possibilities were also evaluated. These other possible sources included diversions from: the mainstem Connecticut River at other than the Northfield Mountain location; other tributaries of the Connecticut River; the mainstem of the Merrimack River and the Sudbury River, a tributary of the Merrimack, formerly used by the MDC.

A. Other Connecticut River Basin Alternatives

The possibility of diversions from the Millers River sub-basin appears to offer a viable companion source which when combined with the yield of the Northfield Mountain Project would allow the system to meet its short and medium range needs. Development of the Millers River is the subject of another Interim Report of Survey.

Alternative methods of diversions from the Connecticut River Basin, such as the Deerfield River or another location on the Connecticut River, could provide an equivalent yield to that of this report's recommended project. Development of either of these proposals, however, would be more expensive than either Millers River proposals or Northfield Mountain. Aside from economic costs, neither alternative appears to present any clear cut advantage from either an environmental or socio-economic standpoint. It appears then that development of these alternative sources would offer an opportunity for providing the necessary short-range water supply needs. Their development, however, would be more expensive and would not offer any advantage over the project recommended in this report.

B. Merrimack River Basin Alternatives

1) Merrimack River Mainstem

As an alternative to further diversions from the Connecticut River Basin, the potential of developing the Merrimack River mainstem was also investigated. Based on studies to date, use of the Merrimack River, to meet future needs, holds promise. Use of the river to meet immediate needs, however, does not appear to offer an alternative from either an economic or public health standpoint.

At present, the physical, chemical and bacteriological quality of the river is poor. For years the river has been subject to major discharges of municipal and industrial wastes. Because of these discharges, the Merrimack is often characterized as one of the ten most polluted rivers in the United States.

Even with the existing pollution load, the mainstem river is now used as a water supply for the Cities of Lowell and Lawrence. Water treatment facilities for both municipalities are conventional; however, taste and odor problems are experienced periodically at both locations.

Pollution abatement programs to implement secondary waste treatment facilities on point sources of pollution are under way by State and Federal agencies. Costs of these plants are estimated to be 235 million dollars. Upon completion of the abatement programs scheduled for 1976, the river will be improved as a water supply source.

A recent report by the Corps of Engineers,[1] in cooperation with the Environmental Protection Agency, investigated the feasibility of various alternatives for upgrading treatment processes beyond the planned implementation schedule. Cost estimates of the various alternatives ranged from 668 to 1108 million dollars. All of these plans would further enhance the quality of the river for use as a water supply source.

At present, the NEWS study is performing an Interim Report of Survey on those waste water treatment alternatives reported upon in the waste water feasibility report. The objective of this task is the evaluation of the various alternatives for their effectiveness in meeting the goals of the 1972 Water Quality Act. As a companion effort to the waste water element, investigations in survey detail on the river's potential for water supply development are also under way.

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[1] "The Merrimack: Designs for a Clean River," North Atlantic Division, Corps of Engineers, September 1971, Northeastern United States Water Supply Report.

In summary, at present, the Merrimack River Mainstem in Massachusetts is generally of poor quality. Alternative methods of treating the waste water discharges were assessed in a feasibility report by the NEWS Study. Followup survey detail investigations on alternative waste water treatment techniques and methods for developing water supply facilities are presently under way.

Based on studies to date, use of the Merrimack River to meet future water supply needs holds promise. Use of the River to meet immediate needs within the study area does not appear to offer an alternative to this report's recommended project from either an economic or public health standpoint.

2) Sudbury River

In 1846, the Cochituate Reservoir (previously Long Pond and presently Lake Cochituate) was acquired and developed to meet Boston's water needs through diversions from a subdivision of the Sudbury River watershed.

In 1872, the Sudbury River Act was passed which authorized the diversion of a portion of the Sudbury River waters to the Boston Water System. Subsequent to this Act, a series of reservoirs were construced by the Boston Water System and later by the Metropolitan Water District to develop the watershed. Construction on the last reservoir in the basin was completed in 1898 and a total of 75.2 square miles of drainage area was controlled.

In 1947, in response to the availability of supply from Quabbin Reservoir and the higher quality supply from this source, the Massachusetts Legislature transferred control of a number of the reservoirs to the Department of Conservation. The reservoirs transferred represented about 50 square miles of drainage area and were subsequently developed for recreational usage and their water supply use discontinued.

With its available supplies unable to meet its short range needs, the Metropolitan District Commission has reevaluated the potential which the full Sudbury system may have. Based on initial studies, it appears an additional 40 million gallons per day may be made available through flood skimming techniques.

The Sudbury Basin waters, however, have a number of water quality problems. Thus, to provide the potential yield, water treatment facilities would be necessary. Preliminary cost figures for needed facilities are estimated to be about 43 million dollars. In addition, transmission and pumping facilities may be necessary.

In order to fully estimate the potential and costs for redeveloping the Sudbury system, the MDC is preparing to initiate detailed investigations.

In summary, the "redevelopment" of the Sudbury River Basin could add an attractive increment to the available water supplies for this report's study area. Based on preliminary cost estimates, this increment is expected to cost about twice that of this report's recommended project. Yet to be determined as part of the MDC further study are the environmental and socio-economic advantages and shortcomings.

C. Conclusion

Alternative development of the Connecticut or Merrimack Rivers was evaluated as methods of meeting short range water supply needs forecast. Although either river basin offers opportunities, their development would be more expensive than the proposed project. In addition to economic considerations, use of the heavily polluted Merrimack River does not appear to offer an attractive alternative from a water quality standpoint for immediate supply needs.

The Sudbury system plan needs further study for a full assessment of its potential. If the Sudbury "redevelopment" plan were to be found attractive and constructed, however, it would be fully compatible with this report's recommended project.

38. Water Demand Control

The NEWS Study, cognizant of the narrow margin separating available yield and consumer demand, conducted studies on methods available to alleviate this critical water supply situation. Two general approaches to the problem were investigated: the first considered various methods of increasing the supply available to the system. The second approach described in this section was investigation of methods whereby demand could be curtailed.

A. Components of Demand

1) General

Water demand can be classified into four main categories. These are Domestic, Public, Commercial and Industrial. Nationally, of water withdrawn from public systems, 47 percent is delivered to domestic consumers; 13 percent to public uses; 18 percent to commercial; and 23 percent to industrial applications. A description of uses to which water is applied in the various categories is given in the following paragraphs.

2) Domestic

Domestic use, for purposes of this study, includes that water used by the consumer both within his home and that used by him for allied residential uses such as lawn sprinkling and car washing. In house uses of water include drinking, bathing, cooking, washing, and carrying away of wastes.

Total domestic water use in the United States amounts to approximately 73 gpcd. Few studies have been conducted regarding the composition of this demand; however, the U.S.G.S. reports domestic water in Akron, Ohio, was used in the following proportions:

TABLE 18

Domestic Water Use	
Carrying away of wastes	41%
Bathing	37%
Cooking and Washing	9%
Drinking	5%
Clothes Washing	4%
Lawn Sprinkling	3%
Car Washing	1%
Total	100%

3) Public

Public or municipal use on a national basis accounts for about 28 gpcd of the average 157 gpcd supplied by public water utilities. Water used in this category is delivered to municipal facilities such as administration buildings, schools, hospitals, golf courses and other facilities used by the community at large. The water delivered in this category, of course, reacts to number and type of services provided. In Boston, for example, with a large number of hospitals and other institutions, it is reported 38 percent of total water use falls within this category. In Wellesley, a suburb of Boston, only 9 percent is recorded as public.

4) Commercial

A significant portion of all water delivered from public supply systems is used by commercial establishments. Nationally, it is estimated about 28 gpcd are used for this purpose. Within this category, is included department stores, restaurants, hotels, laundries and other service elements which serve the general public. No breakdown of water delivered to the commercial sector was available for the Boston Metropolitan area, but it is estimated 850,000 commuters travel daily to the City of Boston. Water supplied to these commuters for their needs while "temporary residents" cannot help but be a significant share of the water supplied to the City.

5) Industrial

Many industrial establishments obtain their water supply from public utilities. Of the average 157 gpcd recorded in the United States, 36 gpcd were used in industrial plants. The water withdrawn by these industries is used for three principal reasons: cooling water; boiler water or water used for the generation of steam and process water, which is water that comes in contact with the product being manufactured.

Available records on industrial use which record individual community usage are limited. On a state-wide basis, about 100 mgd or 13 percent of the publicly supplied water was drawn for industrial use in 1968. Within the MDC service area, a recent telephone survey conducted by the NEWS Study indicated about 8 percent of water withdrawn was used for industrial. On this basis, then, Massachusetts and the MDC service area are not heavily industrial water users if compared to the national percentage of 23 percent.

B. Methods of Controlling Demand

There are basically five methods which have been suggested as effective in controlling demands on water supplies. These are:

a) Changing from flat-rate to metered supply
b) Increasing the price of metered supply
c) Imposing of restrictions on water use
d) Utilization of water saving devices
e) Public water conservation education programs

Each of these methods outlined above are described in the following sections as they might apply to the demand forecasts prepared for this report.

1) Metering

The installation of meters which measure the amount of water used by a consumer have been shown to be effective in varying degrees in reducing demand for water supply. With metering, the customer is now charged for the quantity of water used, instead of being charged a flat rate for a period of time regardless of quantity used. Most of the studies conducted regarding the effects of metering indicate domestic in-house use is relatively in-elastic, but lawn sprinkling use and some industrial applications apparently are affected.

Use of metering then appears to present a good opportunity for conservation of a resource. In the Boston area, however, application of this technique to reduce demand is quite limited. Most municipalities in eastern Massachusetts already meter extensively. For example, the MDC system is presently 96 percent metered. Complete metering, therefore, would affect only 4 percent of service connections in this system and not, therefore, affect to any significance water supply demands forecast in this study.

2) Pricing Effects on a Metered Supply

a) General

A number of articles have appeared in recent years in water supply and water resource professional journals regarding the impact of price increases on water demand. All of these articles attempt to quantify the constraining influence which pricing may have upon demands. In these articles, a number of various pricing techniques have been suggested for administration of price hikes. These include general increases in price levels, seasonal pricing and increasing block rates for varying usage of water. Aside from the administrative technique employed, however, the objective of the articles is to define impact of price increases on demand. Generally, the authors, however, are forced to base conclusions on a generally incomplete and sporadic empirical data base. In the following paragraphs, a brief description of some of the major empirical studies is given. Following the study descriptions, an application of the empirical data findings to the eastern Massachusetts forecast demand is made for both the domestic and industrial water components. Finally, an attempt is made to correlate the results

of the empirically derived data to the local water supply system experiences. Although the data presented later is applicable to general pricing increases, the conclusions are felt to apply regardless of administrative technique selected.

In 1957, H. F. Seidel and E. R. Baumann[1] prepared a statistical analysis of various water works data. In their analysis, the authors derived an elasticity coefficient of 1.0 for certain price levels and a lower, inelastic coefficient for lower price levels. The authors, however, noted that they remained skeptical that a rate adjustment has the prompt, proportional effect on water use which the elasticity coefficients suggest. They stated their review revealed that most rate adjustments are moderate enough and water use habits sufficiently stable to consign the rate factor to a "distinctly minor role as an influence on fluctuations in water use."

Linaweaver, Geyer and Wolff,[2] during the years 1961 - 1966, conducted studies to determine patterns of residential water use and factors influencing this use. The results were then used to determine design criteria for water supply systems. These studies were sponsored by the Technical Studies Program of the Federal Housing Administration, and were in cooperation with sixteen water utilities in various climatic regions. Both residential and apartment areas were studied. Climate, economic level of consumers, and pricing systems were considered and concluded as having in that order the major influences on water use.

The economic level of the consumer was considered to influence water use for several reasons. A consumer in a higher valued area is likely to have more water using appliances which increase the overall domestic use. A second reason advanced is that a higher-priced house usually has a larger lawn which will increase the sprinkling demand. Climate is a major factor influencing sprinkling use when there is a lack of precipitation, but it has little effect on in-house use.

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[1] Seidel, Harris F. and Baumann, E. Robert, "A Statistical Analysis of Water Works Data for 1955," Journal of the American Water Works Association, XLIX, No. 12 (December 1957).

[2] Linaweaver, F. P., Jr., Geyer, John C., and Wolff, Jerome B., A Study of Residential Water Use, Washington: Department of Housing and Urban Development Report TS-12, February 1967.

The cost of water also influences the demand. Based on their findings, the authors conclude that cost does not influence in-house water use to a great extent, but would decrease sprinkling use.

Howe and Linaweaver,[1] using the results of the Residential Water Use Study,[2] studied the effect of water pricing in residential areas. Included in the results of this study was the formation of two equations which, according to the study, described the relation of price on use.

The domestic in-house demand was considered best expressed by the following linear equation:

$$g = 206 + 3.47v - 1.30p$$

where g = gallons per day per dwelling unit
v = market value of dwelling unit in thousands of dollars
p = price per 1000 gallons in cents

By use of this equation, the authors concluded that the effect of price on demand and the price elasticity of domestic use could be determined.

Based on their use of this equation, Howe and Linaweaver next concluded that domestic in-house use represented a demand relatively inelastic with respect to pricing changes.

Effect on summer sprinkling demands by pricing was considered as described by the following equation:

$$g = 3657\, r^{0.309}\, p^{-0.93}$$

where $r = b(w - 0.6s)$

and p = price per 1000 gallons in cents
b = irrigable area in acres surrounding dwelling unit
w = average summer potential evapotranspiration in inches calculated by the Thornthwaite method about 10" in the eastern United States
s = summer precipitation in inches

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[1] Howe, Charles W. and Linaweaver, F. P. Jr., "The Impact of Price on Residential Water Demand and Its Relation to System Design and Price Structure," Water Resources Research, III, No. 1 (1967).

[2] Linaweaver, F. P. Jr., Geyer, John C., and Wolff, Jerome B. A Study of Residential Water Use, Washington: Department of Housing and Urban Development, Report TS-12, February 1967.

From use of this equation, it was determined that the sprinkling demand was responsive to price change. The Howe and Linaweaver work indicated, then, that residential water demand is dependent on the price charged. Typical in-house demands exhibited a price elasticity of -0.23,[1] e.g., a 10% increase in price will reduce demand by 2.3%, while the price elasticity for sprinkling demands was 0.93. Sprinkling use is, therefore, more strongly affected by price change than domestic use. The authors felt that pricing could be used as an effective tool to decrease average day demands and increase revenue.

Because of the different industrial water use requirements and variations in plant process flexibility, a single elasticity coefficient for all industrial use is probably unattainable. Research in this field appears quite limited. One small scale study, however, has been undertaken within Massachusetts and the results of this study are described in the following paragraph.

Coefficients of elasticity for water demand response to pricing changes were studied by Stephen J. Turnovsky.[2] This study was primarily directed to the question of the response of individuals to an uncertain supply of water. From data collected from a sample of Massachusetts towns, the coefficient of elasticity derived for household use was around 0.3, and for industrial demand, about 0.5.

c) Application of Prior Study Conclusions to Eastern Massachusetts

As described in the previous paragraphs, both Howe-Linaweaver and Turnovsky have developed equations and price elasticity based on empirical data which suggest the influence which pricing may have on demand. In an attempt to determine the significance of these relationships to current water demand in eastern Massachusetts, a computer program using these relationships was developed for communities serviced by the MDC.

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[1] based on a house market value of $20,000 and cost of water at 40¢/1000 gallons.

[2] Turnovsky, Stephen J., "The Demand for Water: Some Empirical Evidence on Consumers Response to a Commodity Uncertain in Supply," Water Resources Research, V, No. 2 (April 1969).

Once the computer program had been developed, a series of hypothetical price increases were imposed on the existing municipal rate structures. The effect of these increases on both domestic and in-house use and lawn sprinkling requirements are shown in the following table:

TABLE 19

Effect of Hypothetical Water Supply Rate Increases on MDC Demand, Theoretical Decrease

Price Increase ¢/1000 gals	Domestic Demand	Lawn Sprinkling Demand	Industrial[1] Demand	Total
5	4.3	1.2	1.4	6.9
10	8.6	2.1	2.7	13.4
15	13.0	2.9	4.1	20.0
20	17.3	3.5	5.4	26.2
30	21.6	4.1	8.3	34.0
40	25.9	4.6	10.7	41.2
50	34.5	5.3	13.7	53.5

d) Discussion

As illustrated in Table 19, price adjustments would appear to offer an alternative to development of supplemental water supplies. Theoretically, a price increase of 50¢ per 1,000 gallons could be expected to reduce domestic or in-house demands by about 34 mgd and a corresponding decrease in lawn sprinkling demand by about 5 mgd. Industrial water use demands are indicated to react by decreasing almost 14 mgd. The total theoretical decrease on the system then with such a price increase would be about 53 mgd.

On the basis of the theoretical equations then pricing would appear to be a valuable tool for conservation of the water resource. A number of questions, however, arise concerning the direct application of these forecast decreased demands to the water supply situation at hand.

[1] does not include partially serviced communities

First, the empirical data used in the derivation of the domestic use equations, although the most extensive to date is far from all inclusive. Data used was derived from 21 areas nationwide, which contained about 5000 dwelling units. None of the test areas were located within Southeastern New England, although data available from the Middle Atlantic States was used.

In the analysis of industrial water demand reaction data utilized was quite limited, and other research in this area is almost non-existent. Development of any hard policy conclusions based on such sketchy information is, therefore, uncertain at best.

Second, the derivation of the empirical equations for domestic use was based on a "static" view of cost versus use. That is, the data employed was not an observation of a group of communities actual reaction to pricing changes. Rather the equations were developed by using a number of communities, which for a given point in time, had different water use with their individual rate structures. For example, Community A in 1970 used 100 gpcd at a cost of 20¢ per thousand gallons; Community B in the same year recorded an average use of 50 gpcd at a cost of 40¢ per thousand gallons. Based on the approach used by Howe and Linaweaver, the expected decrease in use from Community A with a price increase to 40¢/1000 gallons would be 50 gpcd. Whether the use of such a "static" scenerio to predict dynamic conditions is valid is unknown.

That the equations may not indeed reflect the dynamic situation which would occur with a price increase is particularly suspect with actual operating experience in the Boston Region. For example, in the Boston Region, the MDC increased wholesale prices for its water from $40 to $80 per million gallons in 1954, and $80 to the current $120 per million gallons in 1962. Neither of these price increases was accompanied by a decrease in per capita demand on the system, in fact, demand increased on the system.

To further evaluate the dynamic impact of pricing in an actual operating experience, a survey was made of a privately owned water company which recently applied a 24¢ per 1000 gallons to its water rates. This rate increase raised the cost of water to the consumer from $1.00 to $1.24 per 1000 gallons. The two communities serviced by the company are principally residential, thus the rate increase based on the empirical equation should be expected to result in a demand decrease or, in any event, a decrease in the rate of increase. The company reports,

however, that instead of experiencing a decrease in per capita usage, it experienced a 5 gpcd increase, an increase in excess of that reported in years prior to the price increase.

Based on the actual operating experiences of these utilities within Metropolitan Boston, it appears that any arbitrary adoption of the empirical equation as a forecast tool with respect to water demand carries a large degree of uncertainty.

Third, all of the studies upon which the pricing - demand relationship was developed have been basically economic studies. No attempts have been made to evaluate or quantify cost to the consumers from either environmental quality or social considerations. Nothing systematic is known about such losses, in spite of the widespread occurrence of drought and shortage in recent years.

Both the social and environmental costs of reducing water demand may outweigh the gains derived from institution of such a policy. Whether, in fact, the costs would outweigh the benefits is unfortunately unknown.

In summary, use of increased water supply prices as a method to conserve a resource may have merit. Yet to be determined, however, are data to support the theoretical impact such increases would have upon the demand within New England. Also unknown with this approach are the social and enviromental costs which would be borne by the consumer. It appears then that much work remains to be done on this approach, such that it can be evaluated as a viable alternative to increased supply.

3) Imposing of Restrictions on Water Use

Historically, water utilities have used water use restrictions as a "safety factor" against depletion of supply during a drought. In general, however, most water utilities attempt to avoid restrictions whenever practical. Public reaction to such restrictions, however, is almost always unfavorable, and many examples of such public disapproval can be found in newspaper clippings during the recent sixties' drought.

Imposition of restrictions on water use could not fail to interrupt the existing and planned life styles of communities serviced by a water supply system. As described in the appendix on socio-economic impacts, restrictions on water use, depending on its degree, would

have far reaching social and economic costs. On the basis of costs which would be incurred with a restriction policy, it does not appear to offer a viable alternative.

4) Utilization of Water Saving Devices In-House

Much of the recent increase in municipal water supply by individual consumers has been attributed to the adoption of multiple toilet facilities; water using devices such as automatic clothes and dish washers; and shower installations. Variation in water use between brand names differ markedly. For example, automatic home washers for an 8 pound load require from 32 to 59 gallons per load, while toilets vary from 3.2 to 8 gallons per usage. Information on the impact of domestic water saving appliances on in-house use is limited and variable in quality.

An article[1] presented last year in the American Water Works Association demonstrated possible water savings which could be brought about by adoption of presently available appliances for toilet, clothes washing and shower use. In this article, the authors sought to determine whether the residential consumer would financially benefit by adopting the most up-to-date water using appliances. Varying replacement strategies as a function of costs were assumed. Based on their findings, the authors conclude that there doesn't appear to be current financial incentives for adoption of water saving appliances. They do note, however, that conversely economic costs to consumers from utilizing water saving appliances do not seem great. Presumably, their conclusion refers to replacement costs when currently used appliances wear out. The authors suggest that complete replacement of appliances with water saving models might reduce domestic water use by 32 percent.

A second study[2] of water conservation measures for the Office of Water Resources, U. S. Department of the Interior, also contains some information on water saving devices. In this study, it was noted that

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[1] Howe, Charles W. and Vaugham, William J., "In-House Water Savings," Journal of the American Water Works Association, Vol. 64, No. 2, (February 1972).

[2] Hittman Associates, Inc., "Main C. Computerized Methodology for Evaluation of Municipal Water Conservation Research Programs," No. HIT-409, Columbia, Maryland, August 1969.

increasing use of water by automatic dish and clothes washers over the years has been occasioned by a rise in required performance standards. Thus, customer desires are reflected in the increased water use.

A third study [1] recently completed for the Washington Suburban Sanitary Commission provides a brief review on the effectiveness of water saving measures and the relationship of their use to rate-making policy formulation. In this report, the authors state, "A major deficiency in the data reported by all investigators to date is that it refers to isolated uses of specific appliances and fixtures, but does not reflect actual use conditions. For example, reducing the water requirement of a toilet from 5 to 3 gallons per flush may be assumed to produce a corresponding decrease in water demand for that particular use. If the modification required to accomplish this reduction, however, interferes with the flushing action of the toilet, then the result may be an increased number of flushes which partially or completely nullifies the expected savings."

In reference to the suggestion that 32 percent of the domestic water use could be saved by adoption of water saving devices, the authors state, "Such a result implies, of course, no reduction in the actual or perceived efficiency of operation of any of the appliances or futures. In the latter instance, the net reduction in water use is more difficult to predict; however, it should be somewhat less than 32 percent."

Statements made at a number of progress meetings suggested that use of incentives such as subsidies or tax concessions and revision of plumbing codes to require water saving devices would result in substantial water savings.

In general, however, the same questions which burden analysis of price as a demand moderation measure also apply to use of water saving devices. Regardless of managerial technique used to implement use of such devices (i.e., subsidy, tax concessions, etc.) the question still remains as to the effectiveness and impacts on water use which may occur. Research conducted to date has been limited and supporting evidence to prove or disprove possible water savings is lacking. In addition, socio-economic impacts which might occur with a general requirement that older appliances be replaced with the water saving

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[1] Boland, John J., Hanke, Steve H., and Church, Richard L., An Assessment of Rate-Making Policy Alternatives for the Washington Suburban Commission, Prepared for the Washington Suburban Sanitary Commission, September 1972.

models has not been addressed at all. Environmental impacts generated as a spinoff of producing the new replacement models may also be significant and must be included in any analysis.

In summary, adoption of water saving devices as a method of conserving water supply may have merit in the long run. At present, however, supporting data to measure the impacts of either requiring new housing units or replacement by older housing with water saving appliances is not available. Without this data, evaluation of potential savings as an alternative course of action to the recommended project cannot be documented.

5) Public Water Conservation Education Programs

Historically, the water supply industry has not advocated wide scale public water conservation, except in communities where supply or distribution systems were inadequate to meet demand. Recently, however, increased awareness of the need to protect and enhance the environment has required a review of this earlier policy.

At present, two[1] major metropolitan supply systems have adopted a water conservation policy during a time of water surplus. In the past year both utilities have promoted expanded voluntary customer water conservation through a public education program.

Bill inserts and information handbooks on water saving measures have been distributed widely. In addition, speeches to individuals, schools and clubs have been employed to inform the public of why the water resource should be used properly and what they can do to help conserve water. Results of the education programs are now being evaluated for their effectiveness.

The Washington utility which has the longest experience record reports results have been encouraging to date; however, major reductions in per capita usage have not been observed.

In addition to voluntary conservation measures, the two utilities are also considering the use of regulatory powers to conserve water. Regulatory measures under consideration include, for example, price increases, utilization of water saving household appliances and

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[1] Washington Suburban Sanitary Commission and East Bay Municipal Utility District. Note: both utilities service populations of about 1.1 million each.

restriction of lawn sizes. All such measures, however, are being carefully evaluated by the utilities because of the many questions, described in earlier sections, which surround use of such devices.

In summary, adoption of public water conservation programs as a management tool has received attention of late. Results on water use modification of the voluntary conservation programs now under way are limited. However, based on the Washington area experience, no major decrease in per capita usage has been observed.

39. Re-examination of the Swift and Ware Rivers Downstream Release Schedules

At the time diversions were contemplated from the Connecticut River Basin, via the Swift and Ware Rivers, Massachusetts applied to the Secretary of War for authority to make the proposed diversions. After hearing arguments pro and con from Massachusetts and Connecticut, the Secretary permitted diversion of the flood waters of the Ware in excess of 85 million gallons per day between 15 October and 15 June and prohibited the taking of any water except during that period.

With regard to the Swift River, the Secretary permitted diversion of all waters of the Swift except enough to maintain a flow therein of 20 million gallons per day (mgd) or 31 cubic feet per second (cfs). The Secretary did require that during the period from 1 June to 30 November there shall be released from the impounding dam 71 mgd (110 cfs) whenever the flow of the Connecticut River at Sunderland, Massachusetts is 4650 cfs and 45 mgd (70 cfs), when the flow is more than 4650 and less than 4900 cfs.

These findings of the Secretary of War regarding operational schedules for the diversions were later made a part of the Supreme Court Decision, dated March 1931, in the suit between Connecticut and Massachusetts. Since the date of that decision, diversions from the Swift and Ware Rivers have been accomplished under the Secretary of War findings.

During the progress of the NEWS Study, an interested citizens' group suggested the setting aside of the Swift River diversion limitations with the objective of retaining presently scheduled releases within Quabbin Reservoir. The citizen group further suggested any diminution of flow in the Connecticut River could be made up by releases from existing

Corps of Engineers' flood control reservoirs. In keeping with this suggestion, an examination was made of the potential which such re-scheduling might have on the short-range supply problems.

The drainage area of the Swift River controlled by the Quabbin Reservoir totals 186 square miles. The long-term average annual runoff from the watershed is 187 mgd (289 cfs) of which 32 mgd (50 cfs) has been released downstream in compliance with the existing downstream release schedule.

Thus, the maximum addition to the existing water supply system which could be achieved through re-scheduling would be 32 mgd (50 cfs). To provide this increment, however, all downstream releases would have to be terminated. Such a complete cessation of downstream releases with the subsequent "drying up" of the river reach downstream is, of course, impracticable. The question then raised is what level is practicable. A recent study[1] completed for the entire Connecticut River Basin recommends an instantaneous discharge rate, from power reservoirs on the Connecticut River of 0.20 cubic feet per second per square mile of upstream watershed. An application of this criteria to Quabbin Reservoir, for example, would result in a downstream release requirement of 24 mgd (37 cfs). Adoption, then, of such a modified operational schedule could result in an additional 8 mgd being made available. This increment of yield, however, would not begin to meet the short-range needs of this report's study area which are estimated to total an additional 141 mgd. In short, then, a re-examination of downstream release schedules with the objective of conserving such releases for water supply has merit. However, based on the requirement of maintaining a viable river environment downstream from Quabbin, the opportunity for reducing downstream releases does not offer an alternative.

The spring runoff which occurred in 1972 was of longer duration and of greater magnitude than is usually experienced. As a result, diversions from the Ware River, in compliance with the operation schedule described earlier, were forced to cease even though flows in excess of 85 mgd were still occurring. This event triggered a suggestion to the NEWS Study that if the 15 June to 15 October no diversion constraint were lifted, large additional supplies of water could be made available to Quabbin.

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[1] Comprehensive Water and Related Land Resources Investigation, Connecticut River Basin, Connecticut River Basin Coordinating Committee, June 1970.

A computer test was made to determine the impact of the 15 June to 15 October constraint. The results of the computer simulation indicated that only an additional 2.6 mgd might be made available if the 4 month no diversion period currently in effect was terminated.

In the Ware River, as in the case of the Swift River, a re-examination of downstream release schedules may have merit. However, terminating the 15 June to 15 October diversion period constraint does not offer an alternative to this report's recommended project.

SECTION XI

CONCLUSIONS AND RECOMMENDATIONS

NORTHFIELD MOUNTAIN WATER SUPPLY PROJECT

40. Conclusions

This report has investigated and assessed all aspects of the water supply situation within the study area. The Metropolitan District Commission (MDC) Boston, is the largest regional system in New England, supplying about two million people in 1970. The MDC relies upon surface water as its supply source, and the present estimated safe yield of these sources is 300 million gallons per day (mgd). In 1971, the average daily delivery of water from this system was about 322 mgd. Thus, at present, available safe yield of the largest regional system in New England has been outstripped by rising supply demands.

The land area encompassed by this study falls within the boundaries of the so-called "megalopolis" which extends from Boston, Massachusetts to Washington, D. C. Latest population estimates for the Massachusetts study area forecast increases from 5.5 million in 1970 to 6.7 million by 1990, and 8.4 million by the year 2020.

Estimates of future water requirements within the region and on the existing regional system demonstrate the need for additional supply. Development of a single regional system to meet 1990 needs of all communities within the study area was not found to be an attractive approach, either from an economic or resource utilization viewpoint.

Based on a review of the area's 1990 water supply needs, it is concluded, that the MDC system, as it exists at present, will require additional supply. In addition, studies reveal about 24 communities which may require admission to the system to satisfy their short range (1990) needs.

The estimated total demand for 1990 for presently serviced and other needy communities on the existing regional (MDC) supply sources is calculated to be about 441 mgd. Future demand forecasts were derived using both population and industrial output projections. In general, although some modification of consumer and industrial water usage patterns are included in these estimates, no major modifications or shifts in usage patterns are included.

In order to meet the 141 mgd additional demand, a large number of alternatives were investigated to determine their environmental and socio-economic impacts. Alternatives to the Northfield Mountain project included no action, desalination, groundwater development, waste water reuse, other diversion sites, re-regulation of existing supply sources, local resource development and controlling the water supply demand. Based on the investigations conducted, it is concluded that the Northfield Mountain supply project offers an attractive opportunity for providing early relief to the short range needs.

In the evaluation of the Northfield Project, particular attention was given to the impacts on downstream water users which implementation might cause. All of the investigations indicated minimal downstream effects could be expected with operation of the project.

On the other hand, implementation of the project would provide protection against water shortages and associated socio-economic losses. Estimates of economic losses prevented when compared to project costs demonstrate the economic efficiency of the project. With respect to the Regional Development objective, the project would provide a benefit/cost ratio of 1.2 under average runoff conditions; and under a hypothetical drought situation, the ratio was estimated to be 1.9. In the National Economic Development account, the benefit/cost is estimated to be 1.1 under normal and 1.7 under drought runoff conditions.

In assessing the Environmental Quality Impact, the Connecticut River Estuary, the river itself and the receiving water body at Quabbin Reservoir were examined to determine what changes would accompany the project's implementation. In general, minimal changes can be expected in the river and estuary downstream of the diversion intake. These minimal impacts forecast are due to the relatively small diversion volumes compared with river flow. Within Quabbin Reservoir, the diverted flow may have impacts depending to a large degree on the pollution abatement steps taken. For example, the present waste loads may provide opportunities for localized algae growth or oxygen depletion. The Metropolitan District Commission is currently investigating certain chemical and physical parameters to better define the probable impacts on the reservoir.

Based on all investigations conducted, it is concluded that resources are available within the region which can be developed from both economical and environmental viewpoints. Development of these resources through the Northfield Mountain Project and a companion project (subject of another report) offers a means of meeting supply

needs through 1990. The availability of the resources and the opportunity for their development provides an optimistic outlook for the region at least in the short run.

In addition to the conclusion that the Northfield Mountain Project should be implemented, it is also felt that concurrent investigations on water demand and its makeup should be conducted.

For example, detailed breakdown of water use or demand by consumers is not readily available. Although use, on a per capita basis, is readily available, data on how and by whom the water is used is not well documented. Increased per capita demands are, of course, a reflection of the nation's rising standard of living, but the breakdown of this demand into various use categories is poorly understood. A clearer understanding of the breakdown would permit the most efficient long range use of water supply resources.

Household items, which are undoubtedly contributing to increased water usage, include clothes and dish washing machines; multiple toilet facilities, and installation of shower facilities. Among these appliances, a wide range of water requirements per usage is needed. A search of available literature indicates these wide variances in water requirements may not be occasioned by economic or environmental efficiency objectives, but rather the result of independent design criteria. It appears then a rationalization of criteria used in design of water using appliances may offer opportunities for reduction of longer range water needs upon the public supply systems. The true measure of this opportunity would require extensive investigation, including the various appliances' efficient water needs; the impact which re-design would have on consumers; identification of incentives necessary to achieve full use of such devices, such as use of plumbing regulations, subsidies, and the effect which such potential in-house savings may have on future, particularly long range, water demands.

A second area worthy of investigation regards the impact which restructuring of pricing policy as a conservation measure for long range needs may have. Studies conducted to date indicate increases in cost of water supplied to the consumer may decrease use of water by the individual. Data developed to date on this pricing/use reaction has been limited. Thus, any theoretical anticipated decrease in water use caused by a price hike must be viewed as speculative.

In addition, none of the work has addressed the question of whether such price increases would in fact be beneficial or detrimental to the socio-economic objectives of the public water supply consumer.

For example, if water rates were raised substantially in excess of the economic costs of delivering the water, the rate increase would in effect be a tax placed upon the consumer; consequently, questions of equity then arise. In short, the use of pricing as a conservation tool is an unproven venture, given the present "state of the art" concerning its potential benefits and possible shortcomings.

During the course of the study, at a number of informal progress and formal public meetings, it became evident that the general public was apathetic with regard to its water supply systems. At three public meetings held in the Boston metropolitan region, the area which could be supplied water from this report's recommended project, less than 50 people attended each of the meetings. It appears that the public takes its present good quality and available water as unlimited. This attitude can be attributed, in part at least, to the continuing availability of supply made available by the efforts of the local and regional water supply agencies. The question arises, however, whether such casual public concern over their water resources is a healthy state of mind. Many conservation groups at the NEWS meetings characterized this lack of public concern as leading to misuse of the resources through waste. There is no evidence to substantiate this charge in the study region. However, an education program to inform the public about their supply system, its limits and future, is in consonance with good management practice. The development of such an educational program, therefore, not only within the study area of this report, but nation-wide, should be considered as part of any water supply plan.

Throughout the conduct of this study, a number of groups, primarily conservation oriented, have advocated the re-cycling of waste water for water supply uses. In some cases, such as in certain industrial processes, effluent from waste treatment facilities can be utilized. The use of such waste water effluent, regardless of the degree of waste water treatment, as a source of supply for municipal systems is not sanctioned at this time. Echoing the position of the Division of Water Supply, Environmental Protection Agency, State and local health officials and professional water supply engineers, any application of reused water as a municipal supply would require a considerable amount of research on associated potential health hazards. Since, in many regions, less than desirable sources may be needed in the future, it is imperative such research be accelerated.

As part of the legislation establishing the NEWS Study, the Secretary of the Army, acting through the Chief of Engineers, was authorized

to prepare a plan to meet the long-range water needs of the Northeastern United States. Such plans were to be prepared in cooperation with Federal, State and local agencies and were "to provide for appropriate financial participation from States, political sub-divisions and other local interests." In keeping with these study objectives, the NEWS Study has conducted investigations on institutional and financial options for implementation of the various projects. These investigations were conducted by public administration consultants[1] as well as by in-house NEWS personnel.

Five major institutional options that encompass a full range of alternatives for centralization/decentralization of control and financing within the northeast, including Southeastern New England, were investigated. The five options are:

> Local Initiative/Federal Planning -- A continuation of present institutional arrangements and trends
>
> Strengthened Systems of Local Initiative -- Regional water supply councils established on the base of major metropolitan systems
>
> State/Federal Leadership -- Federal planning and state construction and management of major new water supply sources (wholesale only)

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[1] "Organizational, Legal, and Public Finance Aspects of Water Supply for Southeastern New England and the Metropolitan Area of New York City - Northern New Jersey - Western Connecticut," prepared by the Institute of Public Administration, New York, New York, July 1972, for the North Atlantic Division, Corps of Engineers.

"Legal, Institutional and Cost Sharing Requirements for Implementing Water Supply Projects in the Northern New Jersey - New York City - Western Connecticut Metropolitan Area," prepared by Booz-Allen Public Administration Services, Inc., June 1973, for the North Atlantic Division, Corps of Engineers.

"Water Supply Cost-Sharing Alternatives," prepared by Linton, Mields and Coston, unpublished, for the North Atlantic Division, Corps of Engineers.

"Institutional Analysis, Southeastern New England," prepared by Linton, Mields and Coston, unpublished, for the New England Division, Corps of Engineers.

Federal Initiative -- Federal planning, construction and management of new water supply sources (wholesale only)

Intergovernmental Water Resources Corporation -- Corporation established by the three state to manage wholesale water supply development and operation for the entire area.

The options range from decentralized control and financing (as represented by the Local Initiative/Federal Planning Option) to a highly centralized option represented by the Intergovernmental Water Resources Corporation.

On the basis of all investigations, it was concluded that existing State institutions can operate the Northfield Mountain Project and the overall regional system which would be augmented by implementation of the project.

As described earlier, the legislation which spawned the NEWS Study instructed the Corps of Engineers that any plans "shall provide for appropriate financial participation by the States, political subdivisions thereof, and other local interests." In response to this directive, the NEWS Study also conducted a number of investigations[1] on financial options for implementation of the various projects.

As described in the cited references, the provision of water supply in the northeastern part of the United States has historically been a local (non-federal) function. In each of the states investigated, numerous water supply utilities, both public and privately owned, furnish water to small communities, large cities and metropolitan regions. The methods of financing these utilities are many and varied; however, a general rule which fits all is that local benefiting jurisdictions share among themselves the major costs of water supply development and operating costs.

Present Federal cost-sharing policies for water resources development have been developed by the Congress and by administrative decisions. The Congress establishes general policy in two ways. The first is through formal statements of cost-sharing policy contained in legislative acts covering broad programs such as flood control and water quality control. The second way is by Congress repeatedly authorizing Federal agencies to carry out specific programs or

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[1] op cit., page

activities, and including cost sharing arrangements in the authorizations. When this is done consistently over a period of time, it is usually considered that a firm congressional policy has thus been established.

The legislation establishing the Northeastern United States Water Supply Study (NEWS) falls into the latter method of policy making described above. In addition, the Northfield Mountain Water Supply Project is one of the first authorization documents to be submitted under the NEWS legislation; therefore, any action taken on this project cannot be considered as an adoption of a general policy.

Federal interest in water supply, evident for more than half a century, began with a focus on the water short areas of the American West. Since the mid-1950's, water supply and related water problems in the Northeast have received increasing attention in Congressional hearings, bills, and speeches, and reports from the President's Executive Office.

Generally, the rationale for the involvement of Federal cost sharing in water supply development and distribution has been based upon two arguments:

1) The inability of the local utilities to secure adequate or reasonable credit

2) Increased public demand for water facilities

In 1955, the Housing Amendments Act, Title II, established a program for public facility loans to assist states and municipalities (esp. with populations under 10,000) to provide water, sewage and other facilities.

In 1958, the Water Supply Act provided authority for the Corps and the Bureau of Reclamation to include storage for immediate and future water supply uses in federal navigation, flood control, irrigation or multi-purpose water supply projects.

In 1961, Amendments to the Water Supply Act of 1958 authorized 30 percent Federal grants to assist in meeting costs of establishing and maintaining adequate measures for prevention of water pollution. This legislation also contained authority for Federal Agencies (Corps and Reclamation) to include capacity in reservoirs to be used for anticipated future water supply demands. Prior to this point (1958 Act), contracts had to be entered into for that portion of the supply

allocated to future demands and reasonable assurances obtained for repayment. This was changed in 1961 to resolve the problem which occurred where projects could provide capacity for future municipal and industrial demands, but no entity yet existed to contract for such future use.

In 1965, four significant pieces of water legislation were passed:

> The Rivers and Harbors Act of 1965 (89-298) authorizing the NEWS Study to plan a system of reservoirs, aqueducts between major basins, and treatment facilities.
>
> The Water Resources Planning Act which called for multi-purpose river basin plans. (The NEWS Study, for example, would incorporate river basin plans into its regional plan).
>
> The Housing and Urban Development Act of 1965, which provided Federal matching grants of 50 percent for water and sewer and treatment facilities. This legislation was aimed primarily at encouraging orderly development and serving immediate growth needs. Note, the conference report amended out the use of these funds for treatment facilities.
>
> The Rural Water Facilities Act cited lack of available credit to finance new rural water systems and was justified partially as a result of the Housing and Urban Development Act which was serving primarily urban communities.

In summary, the provision of water supply in the northeastern part of the United States has historically been a non-Federal function. Federal interest in the nation's water supplies began with a focus on water short areas in the west. Since the mid-1950's, however, national interest in the form of several legislative acts has also included the large urban population in the northeast. Federal cost sharing in water supply activities includes many forms such as 50% grants for certain facility development as well as long term loans for construction of water supply storage. In all cases, operation and maintenance costs are borne by non-Federal interests.

Financial options investigated as part of this study included options such as modifications to the Water Supply Act of 1958 as well as the possible use of grants. Each of these methods have their own

advantages and disadvantages with regard to meeting the requirements of the NEWS Act. However, on the basis of all investigations conducted, it is concluded that the general provisions of the Water Supply Act of 1958 should be utilized in financing the Northfield Mountain Water Supply Project.

In summary then, the Northfield Mountain Water Supply Project would be an important supply increment in the regional plan for the metropolitan Boston area and appears compatible with the short and long range water resource development objectives of the region. Included in the regional plan for the Boston area would be one of the Millers River Basin alternatives described in a companion report. Also, there is the possibility of utilizing the South Sudbury River and/or the Merrimack River for future demands. Studies may find that certain measures designed to conserve and moderate water demand should be implemented to reduce the size of needed long range water supply developments. For the region as a whole, water resources are available which can be developed efficiently from both an environmental and economic viewpoint to meet the water demands. Sources include the Merrimack, Taunton, North and Connecticut River Basins, together with local groundwater sources. The future view of the area, therefore, can be described as optimistic. However, a continuing planning program, dynamic in nature, must be pursued to insure adequate, safe, dependable water supplies are available when necessary.

Recommendations

The water supply needs of the metropolitan Boston area are both of an immediate critical and regional nature, such that it is within the national interest for the Federal government to participate in assuring the adequacy of the region's water supply system. The Northfield Mountain Water Supply Project would be an important supply increment in the regional plan for the metropolitan Boston area and appears compatible with the short and long range water resource development objectives of the region.

Accordingly, the Division Engineer, New England Division, recommends that the Federal Government participate in the design and construction of the water supply component of the Northfield Mountain Pumped Storage Project as well as the conveyance facilities from Northfield Mountain to Quabbin Reservoir.

Consideration was given to the institutional arrangements necessary to operate this project and the expanded regional water supply system. From these investigations, the Division Engineer concludes that existing State institutions can operate this project and the overall regional system in light of objectives set forth in Title I of Public Law 89-298.

Investigations on cost sharing options by the Federal Government in regional water supply projects were also conducted in accord with directives set forth in Public Law 89-298, Title 1. These studies indicate that a larger Federal participation than presently authorized in funding of water supply projects may be warranted. Thus, in order to assure adequate water supply for the eastern Massachusetts Metropolitan Center, the Division Engineer recommends that the provisions of the Water Supply Act of 1958, with certain modifications, should be used. The modification which is necessary to make the 1958 Act responsive to the current supply needs is a deletion of the stipulation that only costs of storage in flood control reservoirs apply under the law. This modification, however, would not apply to any treatment facilities which may be needed. Such treatment facilities are considered a non-Federal interest cost.

The Division Engineer also recommends that studies be conducted by the Federal Government to define the potential impacts which measures designed to conserve and moderate water demand may have on long range supply needs. These studies would include an assessment

of the impacts which such measures may have on the consumer as well as on needed future supplies. Such investigations would be designed to provide data applicable nationally.

The Division Engineer supports the position of the Environmental Protection Agency that "water quality standards be adopted as soon as practicable for intrastate waters which are presently unclassified, and approved standards on interstate waters be met."

The Division Engineer further recommends that water quality in the Connecticut River, in the upper reservoir at Northfield Mountain and in Quabbin Reservoir, be monitored by responsible Federal and State authorities to insure the safety and purity of the water.

He further recommends that the projects be authorized subject to the condition that local interests, prior to construction, furnish assurances satisfactory to the Secretary of the Army that they will:

A. Institute with the State of Connecticut agreements pursuant to the diversions contemplated in the recommended project.

B. Reimburse to the United States the entire amount of the construction cost including interest during construction. Such reimbursement shall be repaid within the life of the project, but in no event to exceed 50 years after the project is first used for water supply purposes, except that no payment need be made with respect to facilities designed for future water supply until such supply is first used, and (2) no interest shall be charged on such cost until such supply is first used, but in no case shall the interest free period exceed ten years. Limits on the cost of a project which may be allocated to future water use and the interest rate used for purposes of computing interest during construction and interest on the unpaid balance shall be determined as specified in the Water Supply Act of 1958.

C. Hold and save the United States free from damages due to the construction works, or changes to water rights.

D. Continue to operate and maintain existing public use, access, and landing facilities for recreational boats at Quabbin Reservoir, open to all on equal terms.

E. Provide public access to those areas which may have recreation development potential occasioned by construction activity in accord with local health regulations.

F. Agree to cost share under provisions of P. L. 89-72, should suitable opportunities for recreation development materialize during the post authorization phase.

G. Operate and maintain all features of the project after its completion in accordance with regulations prescribed by the Secretary of the Army including allowances for major replacements.

H. Investigate and institute those measures found practicable to enhance the conservation and wise use of the water resources used for supply.

I. Provide a mechanism through which communities can be reimbursed for taxes lost through acquisition of land necessary for this project.

J. Initiate a continuing Public Education Program designed to inform the public on the need for wise use and conservation of their water supply resource.

K. Insure that communities within the Commonwealth which require additional short range supply are eligible for admittance to the water supply system.

JOHN H. MASON
Colonel, Corps of Engineers
Division Engineer

NADDE (25 Oct 1974) 1st Ind
SUBJECT: Northfield Mountain Water Supply Project Survey Report

DA, North Atlantic Division, Corps of Engineers, 90 Church Street, New York, New York 10007 5 November 1974

TO: HQDA (DAEN-BR/Resident Member) Kingman Bldg., Ft. Belvoir, Va. 22060

I concur in the conclusions and recommendations of the New England Division Engineer.

James L. Kelly
JAMES L. KELLY
Brigadier General, USA
Division Engineer