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August 1992

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New England Division

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The study provides preliminary information on the evaluation of the alternative of using upstream storage in the Connecticut River Basin to augment flows on the Connecticut River with the purpose of maintaining an average daily flow of 4,900 cubic feet per second (cfs) at Montague City, Massachusetts from June through November. Maintaining flows at or above 4,900 cfs will relieve the Massachusetts Water Resources Authority/ Metropolitan District Commission of releasing additional water from Quabbin Reservoir, thereby increasing the amount of water potentially available to the water supply system. The data and analysis contained in this report is intended to provide the Massachusetts Water Resources Authority with sufficient information to determine if further investigation of the flow augmentation alternative is warranted.

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May 29, 1992

Mr. Joseph Ignazio
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Dear Mr. Ignazio:

The MWRA Waterworks Division has reviewed the draft report, Connecticut River Flow Augmentation Study, which your staff has prepared on the potential for increases in MWRA storage at Quabbin Reservoir through release changes at Corps flood storage reservoirs upstream.

Based on these initial findings - the long list of potential environmental impacts, the estimated cost of the project and the small increase in yield projected for our supplies, MWRA has concluded that continued study of this proposal is not warranted at this time.

We will review carefully all comments received on the draft report and ask that you include them verbatim in the Final Report. Thank you for investigating this innovative idea.

Very truly yours,

William A. Brutsch
Director, Waterworks Division

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Section 22, Massachusetts Water Resources Authority
Connecticut River Flow Augmentation Study

Final Report

Department of the Army
Corps of Engineers, New England Division
Waltham, Massachusetts

August 1992

EXECUTIVE SUMMARY

The purpose of this investigation is to evaluate the use of upstream storage in the Connecticut River Basin, principally Corps flood control reservoirs, to augment Connecticut River flows at Montague City, Massachusetts, thereby decreasing the amount of time the flows are below 4,900 and 4,650 cubic feet per second (cfs).

Massachusetts Law, Acts of 1927, requires releases from Quabbin Reservoir to maintain a flow at all times of at least 20 million gallons per day (mgd) on the Swift River at Bondsville, Massachusetts. In addition the War Department in 1929 in the interest of navigation on the Connecticut River, required that between June 1 and November 30, a flow of 70 cubic feet per second (about 45 mgd) be released from Quabbin whenever the flow at the United States Geological Survey gage at Montague City, Massachusetts becomes less than 4,900 cubic feet per second (cfs) and a flow of 110 cfs (about 71 mgd) be released whenever the flow at the Montague gage is 4,650 cfs or less.

Daily flow data at the Montague gage from 1904 to 1990 was examined in order to determine the percent of the time from June 1 to November 30 the flows are less than 4,900 cfs. Flow duration analysis based on 87 years of record indicate that during the June to November time period, daily flows are less than 4,900 cfs approximately 38 percent of the time and less than 4,650 cfs 34 percent of the time.

In order to maximize potential savings at Quabbin this study assessed providing flow augmentation to maintain a flow of 4,900 cfs at the Montague gage. A general relationship between the required additional volume of flow at the Montague gage to maintain a flow of 4,900 cfs and the potential savings in required releases at Quabbin was developed. This general relationship shows that a large amount of flow augmentation volume would be required in order to effect the maximum savings at Quabbin. For example, in 1964 approximately 675,000 acre-feet of volume would have been required in order to save required releases from Quabbin of approximately 7,000 million gallons that would have been triggered by flows less than 4,900 cfs and in 1963, approximately 560,000 acre-feet of volume would have been required in order to save required releases from Quabbin of approximately 5,800 million gallons. These numbers illustrate the high release requirement placed on Quabbin during a drought period as a result of the War Department Permit. They also illustrate the need to consider the cumulative effect of successive years of low inflow in order to design an alternative with enough reservoir storage to be able to provide sufficient flow augmentation volume during a drought period.

The general relationship developed for this study does not consider the potential loss of savings in Quabbin releases through subsequent reservoir spilling. If this study were to proceed further the flow augmentation alternative could be factored into the system safe yield model to estimate the increased system yield due to savings in required releases from Quabbin.

A reconnaissance level analysis of flood control storage capacity of the nine Corps of Engineers flood control reservoirs upstream of the Montague gage indicated that a limited amount of seasonal encroachment for flow augmentation storage could be considered at seven of the reservoirs during the months of June, July and August. This shorter time period, June to August instead of June to November, eliminates consideration of the fall flood threat and thus allows for a slightly greater allowable seasonal use of flood control storage.

The seven reservoirs are: Union Village Dam, North Hartland Lake, North Springfield Lake, Ball Mountain Lake, Townshend Lake, Otter Brook Lake, and Tully Lake. During the June to August time period summer pools are normally maintained at all the reservoirs except for Union Village. The summer pool capacity at the reservoirs is 7,870 acre-feet. The amount of empty storage in the reservoirs above the summer pool is the summer flood control capacity. The total summer flood control capacity at the reservoirs is between the normal summer pool elevation and spillway crest, a total of 280,350 acre-ft at the seven reservoirs. The hydrologic analyses assessed the allowable encroachment into the summer flood control capacity and determined 22,340 acre-feet of capacity might be used for flow augmentation storage. The total capacity available for flow augmentation storage is the summer pool capacity plus the allowable encroachment into summer flood control capacity and was determined to be 30,210 acre-feet. Storage of flow augmentation water would result in an increase in pool elevation and surface area and a decrease in summer flood control capacity at the reservoirs.

The allowable seasonal flow augmentation storage capacity at the reservoirs in the June to August time period of 30,210 acre-feet is significantly less than the volume needed to maintain a flow of 4,900 cfs at the gage all the time.

Analysis of flow data from 1957 to 1989 indicated that if the 30,210 acre-feet had been available for release in the June to August time period, potential annual savings in required releases from Quabbin would have ranged from 150 to 810 million gallons with a median savings of 400 million gallons. If 30,210 acre-feet had been available for release in August, potential annual savings in Quabbin required releases would have ranged from 0 to 630 million gallons with a median savings of 350 million gallons. The days of flow augmentation would have ranged from 0 to 14 with a median of 7 days.

A ten year low flow analysis of inflows and outflows indicated that the flow augmentation pool at six of the seven projects could be filled by August 5 when filling began on June 1. The flow augmentation pool at Tully Lake would not fill under this scenario. In higher flow years the pools would fill more rapidly and releases might be possible earlier. Further studies should address the possibility of beginning filling of some of the reservoirs in May. Once filling of the flow augmentation pool is completed, flow releases could be made from one reservoir or from several reservoirs simultaneously in order to make up the required flow

volume to keep the Montague gage from falling below 4,900 cfs. Release of augmentation flows from Corps reservoirs would need to be coordinated with the hydropower interests on the river as the river is dispatched on a daily basis by New England Power Exchange on anticipated water availability and electric demand.

Potential impacts associated with storing and release of water at the Corps Reservoirs in the June to August time frame for flow augmentation include impacts to water quality, wetlands, fisheries, wildlife, historic properties, recreation, agriculture, and hydropower. These impacts would be a result of filling the reservoir pools above the normal summer level and then releasing all of the stored water for flow augmentation. Reconnaissance level analysis indicated that mitigation of these impacts may limit storage at several of the reservoirs and/or require other mitigation. Conversely, flow augmentation during low flow periods in the summer might have some positive effects on downstream aquatic life, water quality and recreation.

Recreation facilities at the projects that might be impacted by water storage and release include roads, parking lots, picnic areas, boat ramps, swimming beaches, comfort stations, ballfields and a camping area. Loss of the use of these facilities would result in a loss of recreational opportunities at the reservoirs. The value of the lost recreational benefit is based on the expected decrease in reservoir visitors and the estimated value of a visit. It is anticipated that attendance at the seven projects during May, June, July and August would decline from a combined estimate of 507,633 visitors to 227,317 visitors, a drop of 280,317 visitors or 55 percent. Recreation value of the projects is estimated to drop from about $2,000,000 to $900,000 a loss of $1,100,000 annually.

If this alternative were to be considered further, detailed environmental studies would be required. Preparation of a Federal Environmental Impact Statement might be required depending on the final configuration of the alternative. Public hearings would be held as part of the process for determining whether the public interest is best served by water supply or by recreation.

The basic authority permitting the United States to store water for municipal and industrial water supply purposes is contained in the Water Supply Act of 1958. The Act also stipulates that the local beneficiary must pay for such storage. The annual cost of the seasonal flow augmentation storage is based on water storage pricing policy established by Corps regulations and is estimated at about $1,400,000. A large portion, about $1,100,000, of this annual cost is attributable to the lost recreation benefits at the projects.

Data and analysis presented in this report should provide the Massachusetts Water Resources Authority with sufficient information to determine if further investigation of the alternative to use Corps of Engineers reservoirs for flow augmentation is warranted.

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COMMENTS RECEIVED ON DRAFT REPORT

On June 4, 1992 the draft report was sent to appropriate Federal, State, regional, and local organizations for review. Comments were received on the draft report from the following organizations:

Federal

United States Department of the Interior
Fish and Wildlife Service
New England

State

State of Vermont, Agency of Natural Resources,
Department of Environmental Conservation,
Water Quality Division

Regional

Connecticut River Valley Flood Control Commission

Connecticut River Watershed Council, Inc.

Franklin County Commission

Joint River Commissions,
Vermont Connecticut River Watershed Advisory Commission and
New Hampshire Connecticut River Valley Resource Commission

Water Supply Citizens Advisory Committee on the
Massachusetts Water Resources Authority Long Range Water
Supply Program

Upper Valley Lake Sunapee Regional Planning Commission

Other

New England Power Pool, New England Power Exchange

Northeast Utilities

Commenting organizations concurred with the Massachusetts Water Resources Authority (MWRA) position that further study of this alternative is not warranted because of the potential environmental and economic impacts, and low yield identified in the draft report. Comments included remarks about typographic and minor information changes, impacts associated with the alternative, and the scope of study. Comment letters are included in Appendix H. Remarks are summarized below.

- United States Fish and Wildlife Service expressed concern regarding potential impacts on wildlife and downstream aquatic life during reservoir filling. They noted that the alternative would result in significant adverse impacts to the environment of the Connecticut River Basin.

- The State of Vermont, Agency of Natural Resources noted the numerous environmental and safety issues associated with the alternative were substantial and costly to the State of Vermont.

- The Connecticut River Watershed Council agreed with the MWRA decision to discontinue study of the flow augmentation alternative. The Council was concerned about the impacts on the Swift and Chicopee Rivers, the impacts during reservoir filling on downstream salmon and shad populations and impacts to the recreational use of the river.

- The Franklin County Commission noted the conclusion to abandon future efforts in light of environmental and economic costs seems well advised.

- The Connecticut River Valley Flood Control Commission concurred with the MWRA's position that the flow augmentation alternative is not a viable option at this time. It is their policy to maintain flood control capacity at flood control structures in the Connecticut River Basin. Further more, the recreational, environmental and economic impacts outweigh the benefits.

- The Joint River Commission remarks included reference to the protection of the Connecticut River in New Hampshire under The New Hampshire Rivers Management and Protection Program and the potential impact on recreational facilities discussed in the report.

COMMENTS RECEIVED ON DRAFT REPORT (continued)

- The Water Supply Citizen Advisory Committee (WSCAC) concurred with MWRA's conclusion that no further study be done of changes in Corps of Engineers management of Connecticut River flows. WSCAC had hoped for a institutional/policy study, including a detailed analysis of the relationship between hydropower operation on the Connecticut River and Quabbin releases. WSCAC position is that manipulation of the Connecticut River flows should not be seen as a source for incremental water to the MWRA system, unless this result is achieved through improved management of the present legislated release requirements, or through a more environmentally aware management scheme by the hydro utilities.

- The Upper Valley Lake Sunapee Regional Planning Commission agreed with the MWRA decision not to pursue the matter further. They were concerned about the impacts to local communities near the flood control projects.

- NEPEX and NEU provided minor report corrections

The Corps' staff reviewed comments on the draft report, incorporating typographic and minor information changes suggested in comment letters. Although, impacts identified in the letters were also identified in the draft report, the calling out of specific areas of concern by the commenting organizations reinforces the study findings. The Connecticut River Basin serves many interests and it is difficult to satisfy all concerns.

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TABLE OF CONTENTS

		Page
I.	INTRODUCTION	
	Study Authority	1
	Background	1
	Purpose and Scope	2
	Prior Corps Investigations of Release Requirements	3
II.	CONNECTICUT RIVER	
	General Description	4
	Development above Montague	5
	Hydropower	9
	Future Development	12
III.	FLOWS AT MONTAGUE	
	General	13
	Daily Flows	13
	Flow Augmentation	15
IV.	FLOW AUGMENTATION WITH CORPS RESERVOIRS	
	Available Seasonal Storage	17
	Filling Schedule	19
	Release Schedule	19
	Increase in Water Retained in Quabbin Reservoir	20
V.	ENVIRONMENTAL IMPACTS	
	Water Quality	21
	Biological Resources	22
	Archaeological and Historical Resources	24
VI.	ECONOMIC IMPACTS	
	Recreation	25
	Agriculture	26
	Hydropower	27
	Drought Water Supply	28
VII.	PRICE OF WATER	29
VIII.	LEGAL ISSUES	30

TABLE OF CONTENTS (continued)

Page

IX. DROUGHT AND DROUGHT RECOVERY YEARS 31

X. SUMMARY ASSESSMENT OF THE USE OF STORAGE IN CORPS RESERVOIRS FOR FLOW AUGMENTATION 32

REFERENCES 35

APPENDIXES

Appendix A - Hydrology Appendix
Appendix B - Water Quality Appendix
Appendix C - Environmental Appendix
Appendix D - Historic and Archaeological Appendix
Appendix E - Economic Appendix
Appendix F - Listing of Hydropower Licenses and Reservoirs
Appendix G - Selected Correspondence
Appendix H - Comments on Draft Report

LIST OF TABLES

		Page
TABLE 1	Major Tributaries of the Connecticut River	5
TABLE 2	Dams and Reservoirs on the Connecticut River	6
TABLE 3	Non-Federal Reservoirs above Montague with Storage Capacity in Excess of 7,000 acre-feet	7
TABLE 4	Corps Flood Control Reservoir above Montague	8
TABLE 5	FERC Licensed Projects on the Main Stem Connecticut River	10
TABLE 6	FERC Licensed Projects on the Deerfield River	10
TABLE 7	Mean Monthly Flows, Connecticut River at Montague City, Massachusetts, 1904-1990	14
TABLE 8	Connecticut River at Montague City, Massachusetts, Monthly Discharge and Charge in Upstream Reservoir Contents, Water Year 1989 to 1990	14
TABLE 9	Quabbin Flow Release Requirements	15
TABLE 10	Flow Augmentation Storage Capacity at Corps of Engineer Reservoirs	18
TABLE 11	Impact of Flow Augmentation Storage on Summer Pool Elevations, Summer Pool Surface Area and Summer Flood Control Capacity	18
Table 12	Historic Properties Overview	24
Table 13	Impacts to Recreational Features at Projects	26
Table 14	Major Hydropower Projects Downstream of Corps Reservoirs	27
Table 15	Price Determination	29

LIST OF FIGURES

		Follows Page
FIGURE 1	Connecticut River Basin Map	2
FIGURE 2	Montague Gage, Daily Flows, 1933	14
FIGURE 3	Montague Gage, Daily Flows, 1941	14
FIGURE 4	Montague Gage, Daily Flows, 1964	14
FIGURE 5	Montague Gage, Daily Flows, 1976	14
FIGURE 6	Montague Gage, Daily Flows Range, 1931 to 1989	14
FIGURE 7	Montague Gage, Flow Duration Curve, June 1 to November 30, 1957 to 1989	16
FIGURE 8	Frequency Analysis of volume of water required to maintain Montague gage above 4,900 cfs, June to November, 1957 to 1989	16
FIGURE 9	Relationship between volume of water saved in Quabbin and required additional volume at Montague gage	16
FIGURE 10	Frequency Analysis of water saved in Quabbin using 30,210 ac-ft of Corps storage, 1957 to 1989	20

I. INTRODUCTION

STUDY AUTHORITY

Authority for the Section 22 "Planning Assistance to States", program is contained in the Water Resources Development Act of 1974, Public Law 93-251, as amended. This section authorizes the Corps to cooperate with the States in the preparation of plans for the development, utilization and conservation of water and related land resources. Section 319 of the Water Resources Act of 1990, Public Law 101-640, authorizes the Secretary of the Army to collect from non-Federal entities, fees for the purpose of recovering fifty percent of Section 22 program costs.

The Massachusetts Water Resources Authority and the New England Division of the Department of the Army, Corps of Engineers (NED) entered into a Cost Sharing Agreement in March 1991 under the Section 22 program to conduct a reconnaissance level investigation of flow augmentation on the Connecticut River at Montague City, Mass.

BACKGROUND

The Massachusetts Water Resources Authority (MWRA), supplies water to approximately 2.4 million people in 46 municipalities in eastern and central Massachusetts, including the Boston metropolitan area. The MWRA was created in 1985 by the Massachusetts Legislature to carry out the water supply distribution and planning, former functions of the Metropolitan District Commission (MDC). Quabbin Reservoir, located in western Massachusetts within the Connecticut River Basin, is the main storage reservoir for the MWRA/MDC water supply system. (See Figure 1)

Quabbin Reservoir, located on the Swift River, discharges to the Chicopee River, a major tributary to the Connecticut River Main Stem. The reservoir has a water storage capacity of 412 billion gallons (1,280,200 acre-feet) and a drainage area of approximately 186 square miles. Water is withdrawn from Quabbin through the Chicopee aqueduct and the Quabbin-Wachusett tunnel to the MWRA/MDC water supply system. There is also an outlet at Windsor Dam from which water is released to the Swift River and an emergency spillway.

Quabbin Reservoir, completed in 1939 is required by Massachusetts Law, Chapter 321, Acts of 1927 and a 1929 Department of War Permit to release water from the impounding dam into the Swift River. The Massachusetts Law requires releases from Quabbin to maintain flow at all times of at least 20 million gallons per day (mgd) on the Swift River at Bondsville. The War Department Permit, in the interest of navigation on the Connecticut River, requires that between June 1 and November 30, a flow of 70 cubic feet per second (about 45 mgd) be released for Quabbin whenever the flow at the United States Geological Survey gage at Montague City, Massachusetts becomes less than 4,900 cubic feet per second (cfs) and a flow of 110 cfs (about 71 mgd) be released whenever the flow at the Montague gage is 4,650 cfs or less.

In February of 1989, when Quabbin Reservoir levels were below normal, the MWRA sent a letter to the New England Division Corps of Engineers (NED), asking how the Corps might utilize storage in the Connecticut River flood control reservoirs to help the MWRA\MDC water supply system. (See Appendix G, Correspondence, letter of February 17, 1989.) This letter sparked subsequent meetings and correspondence regarding a possible NED Section 22 study to assist the MWRA with assessing alternatives to decrease the volume of water released from Quabbin. Three possible alternatives were discussed.

- Storage and release of water from upstream Corps flood control reservoirs to replace releases from Quabbin to the Swift River required by the War Department Permit, the gallon for gallon alternative.

- Storage and release of water from upstream Corps flood control reservoirs to maintain a minimum flow of 4,900 cfs at Montague City, Massachusetts on the Connecticut River, thereby preventing triggering of the War Department Permit flow releases to the Swift River, the flow augmentation alternative.

- Reduction in Quabbin's required water release to the Swift River during an extreme water emergency.

The MWRA suggested the scope of work for the Section 22 investigation focus on the flow augmentation alternative, as this option would not require modifications to the established statutory or regulatory release requirements.

In March 1991, the NED and the MWRA entered into a Cost Sharing Agreement to conduct the Section 22 Study.

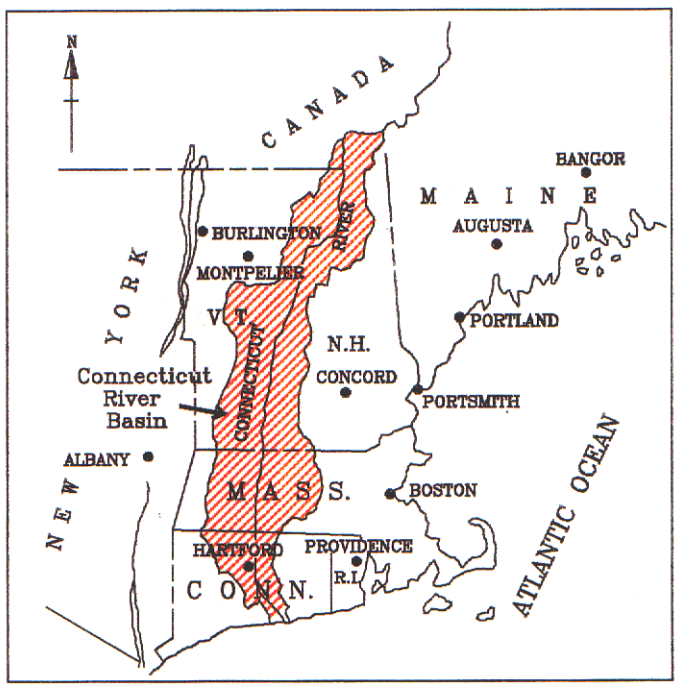
PURPOSE AND SCOPE

The purpose of this study is to evaluate the use of upstream storage in the Connecticut River Basin, including Corps flood control reservoirs to augment Connecticut River flows at Montague City, Massachusetts to increase the amount of time the flows are above the trigger 4,900 cfs and 4,650 cfs flows, thereby reducing the volume of water released from Quabbin to the Swift River during the annual June 1 to November 30 period.

The study describes the existing flows regime at the USGS gage at Montague City, Massachusetts, identifies reservoirs and dams constructed since establishment of the required Quabbin releases, and discusses possible future changes due to the Federal Energy Regulatory Commission (FERC) hydropower licensing.

CORPS OF ENGINEERS

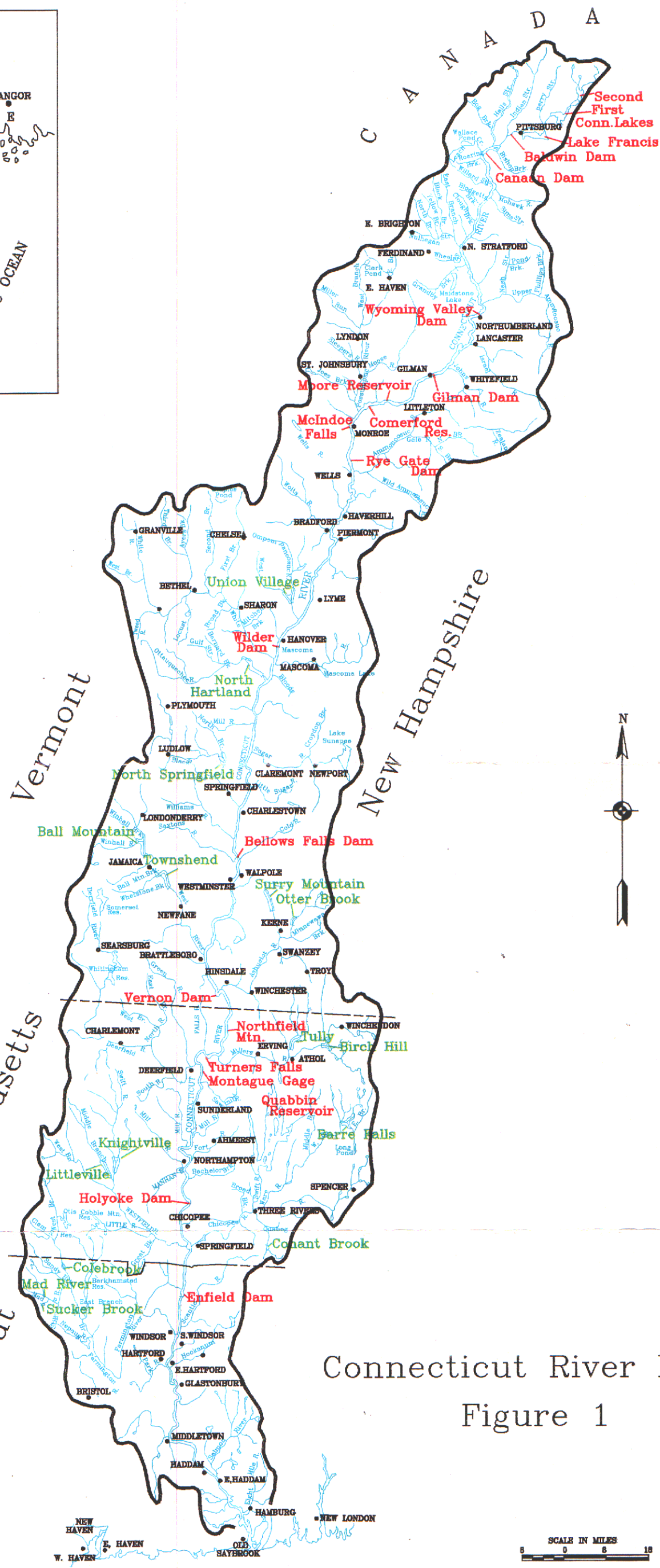
U.S. ARMY



LOCATION MAP

SCALE IN MILES

40 0 40 80



Connecticut River Basin

Figure 1

The study reviews existing Connecticut River Basin information to identify existing projects with significant storage. General relationships between the required additional water volume to maintain the Montague City gage at 4,900 cfs during the June to November period and the volume of water saved in Quabbin are developed.

The study focuses on identification of potential flow augmentation storage at the Corps flood control reservoirs and environmental and economic impacts and costs associated with this storage.

The Corps reservoir flow augmentation alternative is dependent on seasonal (June through November) flow variations, and on the Corps' ability to utilize storage at the reservoirs without compromising the facilities' primary flood control purpose.

The impacts on the Swift River due to the flow augmentation alternative are not addressed as part of this study. The MWRA would study these impacts if further investigation of the Corps reservoir flow augmentation alternative is warranted.

The data and analysis contained in this study is intended to provide the MWRA with sufficient information to determine if further investigation of the flow augmentation alternative is warranted.

PRIOR CORPS INVESTIGATIONS OF RELEASE REQUIREMENTS

In February 1982, NED completed a report entitled a "Hydrologic Assessment of Downstream Flow Requirements at Quabbin Reservoir and Ware River Intake". The purpose of this study was to develop objective hydrologic reference information, not to advocate any particular stream flow regime.

Hydrologic data was presented for the "gallon for gallon alternative" in which Corps flood control reservoirs in the upper Connecticut River Basin might be used to replace additional releases from Quabbin Reservoir. The study found that, on an average annual basis, Quabbin releases 20 mgd to satisfy Massachusetts minimum flow statutory requirements, and an additional 10 mgd to satisfy War Department Permit navigation flow requirements. The study determined, based on the data record from 1904-1979, that the maximum year release requirement from Quabbin to make the additional War Department flow releases was 23,800 acre-feet (7,758 million gallons). Data presented indicated storage equivalent to one-half inch of runoff at seven of the Corps reservoirs in the upper Connecticut River Basin would total 23,450 acre-ft. The report did not address the impacts to the authorized flood control purpose of the Corps reservoirs, the additional costs associated with creating a new or enlarged seasonal pool at the Corps reservoirs, the impacts associated with modifying the existing discharge patterns, nor the legal issues associated with modifying the mandated Quabbin release requirements.

II. CONNECTICUT RIVER

GENERAL DESCRIPTION

The main stem Connecticut River rises in the Connecticut Lakes adjacent to the Canadian Border, follows a general southerly course for about 404 miles to its mouth on Long Island Sound at Saybrook, Connecticut. In the first 29 miles below its source, the river flows entirely within the State of New Hampshire, then for a distance of about 238 miles, between New Hampshire and Vermont, through Massachusetts for 67 miles and finally through Connecticut for 70 miles. (See Figure 1)

The lower 60 mile reach of the river to approximately 8 miles above Hartford is tidal. The Connecticut River is navigable from Long Island Sound to Hartford. There is an existing Federal navigation project called "Connecticut River Below Hartford" and an inactive Federal navigation project called "Connecticut River Above Hartford". The inactive project would have involved work in the river's reach from Hartford to Holyoke, Massachusetts.

The Connecticut River Basin is the largest in New England. The basin has a total drainage area of 11,250 square miles of which 114 are in Quebec, 3,046 in New Hampshire, 3,928 in Vermont, 2,726 in Massachusetts and 1,436 in Connecticut. The average annual precipitation over the entire basin is about 43 inches and occurs as rain and snow. The longest and most severe drought in the history of the region occurred from 1961 to 1966. The average annual runoff in the basin is about 23 inches or slightly over one-half of the average precipitation. (USACOE-NED, 1983) The average annual stream flow for the basin is 1.7 cfs per square mile of drainage area. (USACOE-NED, 1991)

The Connecticut River is fed by numerous streams and rivers entering from the east and west. The fifteen largest tributaries, with watersheds greater than about 200 square miles and an aggregate area equal to about 58 percent of the total basin area are listed in Table 1.

Montague gaging station, a United States Geological Survey (USGS) water stage recording gage, is located on the Connecticut River main stem at Montague City, Massachusetts approximately 1,000 feet downstream from the Deerfield River. The Connecticut River drainage area at the gage is 7,860 square miles which represents 70 percent of the total basin area. Flows at the gage are made up of flows that pass Turners Falls dam on the main stem (91.1 percent of the drainage area), flows from the Deerfield river (8.4 percent of the drainage area) and flows from the Falls River (0.5 percent of the drainage area).

The first 12 tributaries listed in Table 1 enter the Connecticut main stem above the Montague gage and represent an aggregate area equal to about 4,670 square miles or 59 percent of the drainage area above the Montague gage.

Table 1. Major Tributaries of the Connecticut River

Name	State	Drainage Area (sq.mi.)
1. Upper Ammonoosuc River	NH	254
2. Passumpsic	VT	507
3. Ammonoosuc	NH	402
4. White River	VT	712
5. Mascoma River	NH	194
6. Ottauquechee	VT	222
7. Sugar River	NH	275
8. Black River	VT	204
9. West River	VT	423
10. Ashuelot River	NH	421
11. Millers River	NH&MA	392
12. Deerfield River	VT&NH&MA	664
13. Chicopee River	MA	721
14. Westfield River	MA&CT	517
15. Farmington River	MA&CT	609

DEVELOPMENT ABOVE MONTAGUE

There has been considerable development throughout the 1900's of reservoirs and dams on the Connecticut River and its tributaries for flood control, hydroelectric power, recreation and water supply. Table 2 lists dams and reservoirs on the Connecticut River main stem.

The primary purpose of dams on the Connecticut River main stem is hydropower production. Second Connecticut Lake, First Connecticut Lake, Murphy Dam provide storage for the downstream hydropower production and are used to augment flows on the Connecticut River when natural inflows have diminished. Moore and Comerford Dams have large storage capacity in their impoundments and are generally used during peak demand periods. McIndoes is operated almost continuously in conjunction with Moore and Comerford and used to reregulate flows on the Connecticut. Wilder, Vernon and Bellows Falls and Turners Falls are operated generally as peaking stations on a daily cycle. Northfield Mountain, a pumped storage project, is also operated to provide power during weekday peak demand periods. Water is pumped to the upper reservoir during off peak hours at night or on weekends.

Table 2. Dams and Reservoirs on the Connecticut River

Name	Drainage Area (square miles)	Reported Usable Storage (acre-feet)
Second Conn. Lake	45	11,600
First Conn. Lake	83	76,400
Murphy Dam	87	99,300
Baldwin	b(1)	b
Canaan	381	ng(2)
Wyoming Valley	b	b
Gilman Paper Co. Dam	1,514	ng
Moore Dam	1,600	114,000
Comerford Dam	1,635	29,400
McIndoes Falls	2,210	9,800(3)
Rye Gate Dam	2,215	590
Wilder Dam	3,375	13,350
Bellows Falls Dam	5,414	7,476
Vernon Dam	6,266	18,300
Northfield Mtn.	0	17,240
Turners Falls Dam	7,163	14,000
Holyoke Dam	8,309	4,000
Enfield Dam	9,661	ng

(1) b - breached
(2) ng - negligible
(3) gross storage

There are approximately 12 non-Federal reservoirs or lake systems above Montague having usable storage capacities greater than 7,000 acre-feet. Table 3 lists these reservoirs and the date they became operational. The largest storage reservoir on the Connecticut River above Montague is Moore Dam, operational in 1957 and owned by the New England Power Company. The largest storage reservoir on a tributary to the Connecticut is Harriman Reservoir on the Deerfield River, operational in 1924 and also owned by New England Power Company.

Table 3. Non-Federal Reservoirs above Montague with Storage Capacity in Excess of 7,000 acre-feet.

Name	Drainage Area (sq. mi.)	Reported Usable Storage (acre-feet)	Date Operational
Connecticut River			
Second Conn. Lake	45	11,600	1914
First Conn. Lake	83	76,400	1915
Murphy Dam (Lake Francis)	170	99,300	1940
Moore Dam	1,600	114,000	1957
Comerford Dam	1,635	29,400	1930
Wilder Dam	3,375	13,350	1950
Bellows Falls Dam	5,414	7,476	1928
Vernon Dam	6,266	18,300	1909
Northfield Mtn.	0	17,240	1972
Turners Falls Dam	7,163	14,000	1905
Mascoma River			
Mascoma Lakes	182	24,400	na(1)
Sugar River			
Lake Sunapee	46	19,800	na
Deerfield River			
Somerset	30	57,400	1913
Harriman	184	116,000	1924
Bear Swamp/Fife Brook	250	9,200	1974
Total Storage		627,866	

(1) na - not available

There are nine Federal Corps flood control reservoirs above Montague in the Connecticut River Basin. Table 4 lists these reservoirs and their date of construction. The Corps reservoirs store water during high runoff events to prevent flooding downstream, then release the water as soon as possible after the event.

Table 4. Corps Flood Control Reservoirs above Montague

River/ Name	Drainage Area (square miles)	Flood Control Storage (1) (acre-feet)	Equivalent Runoff (inches)	Date Completed
Ompompanoosuc River Union Village, VT	126	38,000	5.6	1950
Ottauquechee River North Hartland, VT	220	68,750	6.0	1961
Black River North Springfield,VT	158	50,000	5.9	1960
West River, Ball Mountain, VT	172	52,600	6.0	1961
West River Townsend, Vt	278	32,800	5.8	1961
Ashuelot River Surry Mountain,NH	100	31,700	5.9	1941
Otter Brook Otter Brook, NH	47	17,600	7.0	1958
Millers River Birch Hill, MA	175	49,900	5.3	1941
East Branch Tully River Tully Lake, MA	50	20,600	8.3	1949

(1) Summer Flood Control Capacity

HYDROPOWER

There are many hydropower projects on the Connecticut River and its tributaries. Many of these are operated to meet the region's electric demands under regional power pool agreements. New England Power Exchange (NEPEX), the operating arm of New England Power Pool, manages hydroelectric generation. NEPEX adds or subtracts electric power production based on demand changes through each day and through the seasons based on the most economic mix of available nuclear, coal, oil, natural gas and hydropower electric generating resources. NEPEX schedules hydropower generation based on electric demand and considers river hydrology, reservoir levels and regulatory constraints on reservoir elevations and releases. NEPEX directs hydropower plants on the Connecticut River and its tributaries when to pond water and when to generate electricity. NEPEX has a computer model which it uses to dispatch hydropower production on the Connecticut River. During lower river flows, water is ponded and hydroplants used to provide for peak electrical demand Monday through Friday.

Hydropower projects are licensed under the authority of the Federal Power Act. Licensing and relicensing considers both power and other developmental purposes such as navigation, flood control, water supply and nondevelopment purposes such as energy conservation, protection and mitigation of damage to and enhancement of fish and wildlife habitat, the protection of recreational opportunities and preservation of other aspects of environmental quality. (FERC, April 1991). Recently, establishing minimum flows to be maintained below projects has become an important component of the licensing procedure. FERC licenses include a statement which require the project operator to maintain minimum flow release or inflow, whichever is less, below a project. The minimum flow release is established after investigation of stream flows and uses including fish and wildlife requirements. Occasionally minimum flow release requirements are established on a seasonal basis. At this time the U.S. Fish and Wildlife Service expects the project proponent will conduct flow and fishery studies. If the proponent does not wish to undertake these studies, the Fish and Wildlife Service will request a minimum flow release below a project of 0.5 cubic feet per second per square mile (cfsm). (USFW, telecom, John Warner, October 1991.)

A review and compilation of information provided by the Federal Energy Regulatory Commission (FERC, September 1991) indicated there are over a hundred Federal Energy Commission (FERC) licenses for hydropower projects on the Connecticut River and its tributaries. A list of projects on the Connecticut River Main Stem and on tributaries above Montague including storage, operational date and license expiration date is provided in Appendix F. The hydropower projects that impact directly on the flows at Montague are those on the main stem Connecticut River and Deerfield River. Information on these projects are presented in Table 5 and Table 6.

Table 5. FERC Licensed Projects on the Main Stem Connecticut River

Project Name	Usable Storage ac-ft	FERC Project No	Operational Date	License Expiration
Murphy Dam (Lake Francis)	99,300	7188	1940	X(3)
Baldwin	ng(1)	7962	breached	2037
Canaan	ng	7528	1943	2009
Wyoming Valley	na(2)	7960	breached	X
Gilman Paper Co	ng	2392	1941	X
Moore Dam	114,000	2077	1957	2001
Comerford Dam	29,400	2077	1930	2001
McIndoes Falls	na	2077	1931	2001
Rye Gate Dam	590	8011	1990	E(4)
Wilder Dam	13,350	1829	1950	2018
Bellows Falls Dam	7,476	1855	1928	2018
Vernon Dam	18,300	1904	1909	2018
Northfield Mtn.	17,240	2485	1972	2018
Turners Falls Dam	14,000	1889	1905	2018
Holyoke Dam	4,000	2004	1950	1999

(1) ng - negligible
(2) na - not available
(3) X - application pending
(4) E - exemption

Table 6. FERC Licensed Projects on the Deerfield River

Project Name	Usable Storage ac-ft	FERC Project No	Operational Date	License Expiration
Somerset Dam	57,345	2323	1913	1993
Searsburg Dam	197	2323	1922	1993
Harriman Dam	103,375	2323	1924	1993
Sherman Dam	1,359	2323	1927	1993
Deerfield No. 5 Dam	118	2323	1974	1993
Bear Swamp Pumped Storage	5,100	2669	1974	2020
Fife Brook Dam	4,600	2669	1974	2020
Deerfield No. 4 Dam	432	2323	1912	1993
Deerfield No. 3 Dam	200	2323	1912	1993
Gardner Falls Dam	190	2334	1904	1993
Deerfield No. 2 Dam	300	2323	1913	1993

The Turners Falls Dam is situated on the Connecticut River about 3 miles upstream of the Montague gage. The dam is comprised of the Gill and Montague Spillways and diverts water to the canal that runs alongside the river. Two hydropower stations are situated on the canal. The Turners Falls pool behind the dam is approximately 20 miles long extending to Vernon Dam in Vermont and has a usable storage volume of about 14,000 acre-feet. Reservoir storage is used on a daily basis during low flow periods to maximize hydropower output. The main tributaries to the pool are the Millers and the Ashuelot Rivers. The tailrace of the Northfield Mountain Pumped storage project is located approximately 5 miles above the Turners Fall Dam.

Daily discharges from Turners Falls power stations and dam are based on inflows to the project and the region's electric demands. When inflow conditions at Turners Falls are less than 10,000 cfs, hydropower generation is operated on a daily pond and release cycle as directed by NEPEX

Turners Falls, as well as the upstream projects Vernon Dam, Bellows Falls Dam, and Wilder are licensed through 2018. These projects currently are required by FERC to release a minimum flow of 0.2 cfsm or inflows whichever is less. A release of 0.2 cfsm at Turners Falls Dam is 1,433 cfs. When these projects are relicensed in 2018, twenty six years from now, it may be that a higher minimum flow release may be stipulated. A minimum flow release of 0.5 cfsm at Turners Falls equates to a minimum flow of 3,582 cfs. Whether the minimum flow release is 1,433 cfs or something else and whether other additional flow releases may be required on weekends that might increase flows at the Montague gage will depend on the regulatory climate in 2018.

The mouth of the Deerfield River is located about 1,000 feet upstream of the Montague gage. Several hydroelectric developments control the river's flow patterns. These projects are operated similarly to the Connecticut River projects to provide peaking power and operational reserve capacity to NEPEX Typically, the Deerfield River hydroelectric stations are dispatched as needed to satisfy peak demand Monday through Friday and a few hours on Saturdays. When the flows in the river are sufficient the stations are operated on a more continuous basis. (NEP,1991)

The Deerfield River projects, except for Fife Brook and Bear Swamp which are licensed through 2020, are currently involved in licensing procedures as established under FERC regulations. (NEP, December 1991) Relicensing of the Deerfield River project may alter the shape of the monthly and annual flow duration curves for the Deerfield River. New England Power is proposing a minimum flow for the Deerfield River Project of 0.31 cfsm. The Deerfield No. 2 Dam, approximately 13.2 miles from the mouth, is the most downstream project with a drainage area of 505 square miles or 76 percent of the Deerfield River drainage area. The proposed minimum flow release at this dam is 157 cfs (0.31 cfsm). The current release requirement at this dam is an average daily minimum flow of 100 cfs (0.2 cfsm). The proposed minimum release of 0.31 cfsm corresponds

to the estimated median August flow on the Deerfield River under unregulated conditions. (NEP, December 1991, Volume 1, Table B-5) Because the Deerfield River represents only 8.4 percent of the drainage contributing to the Montague gage and because the proposed change represents a flow increase of just 57 cfs, impact on the annual flow duration curve at Montague will probably be minor.

FUTURE DEVELOPMENT

Review of information for this report did not identify any major water resources projects planned for the Connecticut River above Montague. However, in May of 1992, the New Hampshire legislature voted the entire length of the Connecticut River in New Hampshire into the State's Rivers Management and Protection Program. This program was created by the NH State legislature in 1988 as a response to the increasing and competing demands placed on the State's Rivers. The purpose of the program is to protect the State's significant river resources. Once a river or river segment is designated and classified under the program, state law establishes protection measures related to dams, water quality and quantity, waste disposal and recreational use. Nomination of a river can be made by any New Hampshire citizen or organization and the New Hampshire Legislature must adopt a bill that designates the river into the program.

III. FLOWS AT MONTAGUE

GENERAL

The Connecticut River drainage encompasses 7,860 square miles north of the Montague gage. Typical of rivers in this region flow is highest in the spring (March, April, May) and lowest in the summer and early fall (July, August, September). (See Table 7.)

Runoff from precipitation events, groundwater flow, releases from reservoir storage and wastewater discharges contribute to the monthly volume of flow that passes the gage. The majority of the flow at the gage is from runoff and groundwater flow. Some portion of the flow in a month may be from reservoir storage. In general, large headwater reservoirs store water primarily for hydropower purposes and release this water into the river when natural flows have diminished. Corps' flood control reservoirs store water during high runoff events to prevent downstream flooding and release this water as soon as possible. The potential impact of monthly change in reservoir storage volume on flow volumes at the gage for a recent water year 1989 to 1990 is summarized in Table 8 for illustrative purposes only. The change in reservoir storage volume for any given month varies from year to year. Detailed analysis of the potential impact of changes in upstream reservoir storage on flows at Montague should be considered if further studies are conducted. The volume of flow passing the gage also includes discharges from upstream municipal wastewater treatment facilities. Contribution from municipal wastewater facilities is estimated to be about 36 mgd (56 cfs) or a volume of 111 acre-feet/day. (Estimate based on data provided by USGS, written communication, 1991.)

DAILY FLOWS

Data on daily flows at the Montague gage is reported by USGS. The daily flow is reported in cubic feet per second and represents the mean discharge value for that day.

Daily flow data for the gage was reviewed by year. Selected years of data, 1933, 1941, 1964, and 1976 for the June 1 to November 30 time period are presented in Figures 2, 3, 4, and 5, respectively for illustrative purposes. Data for 1933 is included to depict low monthly stream flows in July; 1941 is included to depict low monthly stream flows in June; 1964 represent a year of low monthly stream flows for June through October; and 1976 represents a year of high stream flow in August.

Review of data by year indicated a large range in magnitude of flow that may be experienced on any given day. Figure 6 depicts the range and median of daily flows observed at the gage from 1931 to 1989. The median flow is the middle value when the daily observations are placed in order from smallest to largest in magnitude.

Review of the daily flow data by day of the week indicated a weekly cycling with higher flows occurring during week days and lower flows occurring on Sundays. This weekly cycling can be seen in Figures 2, 3, 4 and 5. The reason for this cycling occurring is principally due to hydropower regulation of the river.

TABLE 7. Mean Monthly Flows,
Connecticut River at Montague City, Mass.,
1904-1990
(source of data USGS, September 1991)

Month	Mean Monthly Flow (cfs)
January	10,590
February	10,350
March	20,780
April	38,940
May	23,690
June	11,480
July	6,591
August	5,527
September	5,932
October	8,265
November	12,150
December	12,190

TABLE 8. Connecticut River at Montague City, Mass.,
Monthly Discharge and Change in Upstream Reservoir Contents,
Water Year 1989 to 1990.

Year	Month	Total Discharge (acre-feet)	Change in Upstream Reservoir Contents (acre-feet) (1)	Potential Impact on Volume at Gage (2) (Percent)
1989	Oct	1,043,088	19,472	-1.9
1989	Nov	1,243,636	-6,313	0.5
1989	Dec	562,850	-85,629	15.2
1990	Jan	673,309	-12,608	1.9
41990	Feb	991,736	-34,720	3.5
1990	March	2,299,835	47,103	-2.0
1990	April	1,902,744	102,011	-5.4
1990	May	1,674,248	25,310	-1.5
1990	June	786,288	4,571	-0.6
1990	July	569,534	-34,509	6.1
1990	August	1,140,298	-27,013	2.4
1990	September	338,658	-29,756	8.8

(1) Data from the USGS Water Resources Data for New Hampshire and Vermont 1990 and Water Resources Data for Massachusetts 1990. The reservoirs included in this analysis were 1) the hydropower reservoirs, First and Second Connecticut Lakes, Lake Francis, Moore and Comerford, Somerset and Harriman Reservoirs 2) the flood control reservoirs Union Village, North Hartland, North Springfield, Ball Mountain, Townsend, Surry Mountain, Otter Brook, Birch Hill and Tully Dam and 3) Sunapee Lake and Mascoma Lakes used for recreation, water supply and hydropower purposes.
(2) Change in upstream reservoir contents divided by total discharge at gage and multiplied by -1. Presented for illustrative purposes only.

Figure 2. Montague gage, daily flows, 1933

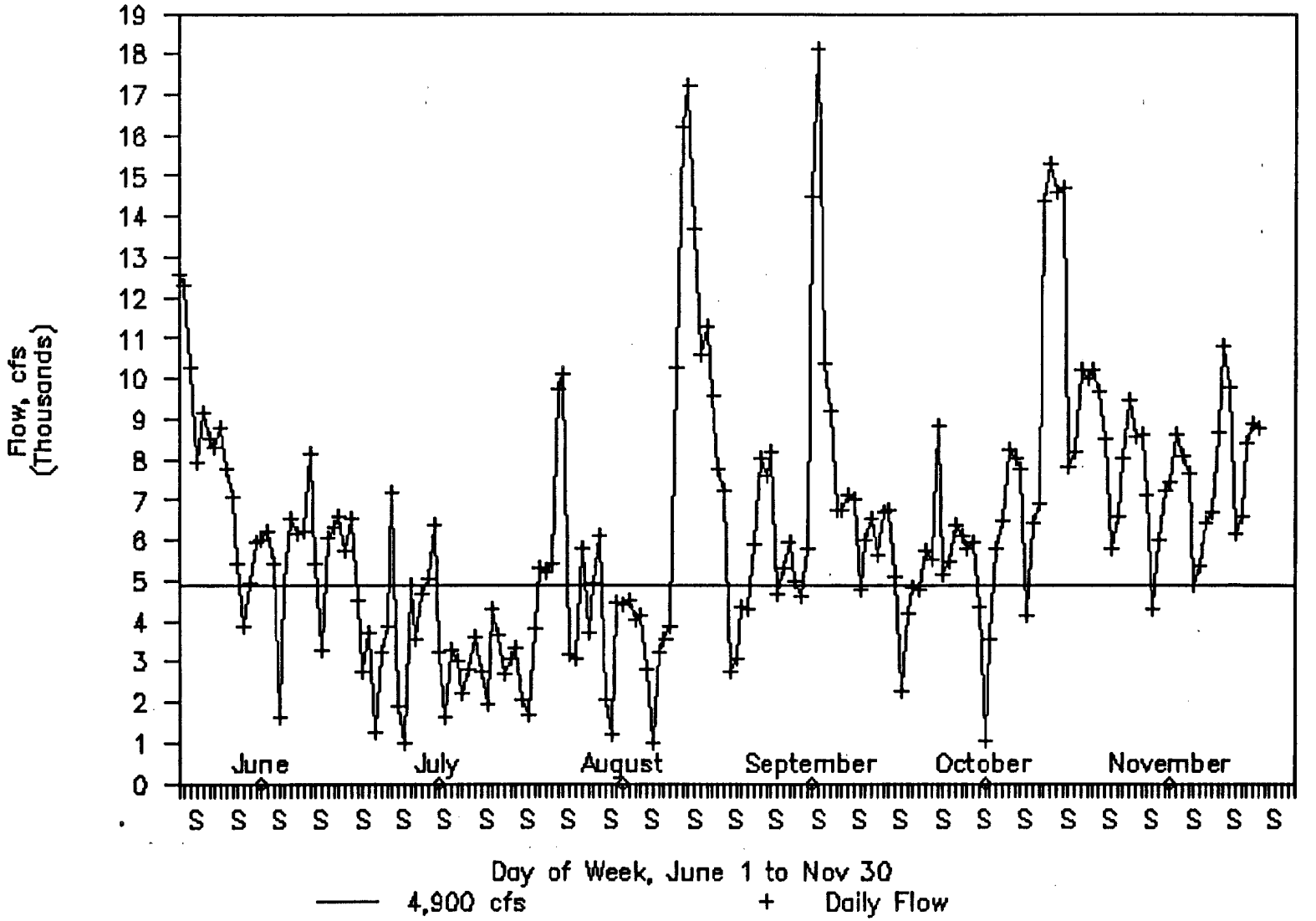


Figure 3. Montague gage, daily flows, 1941

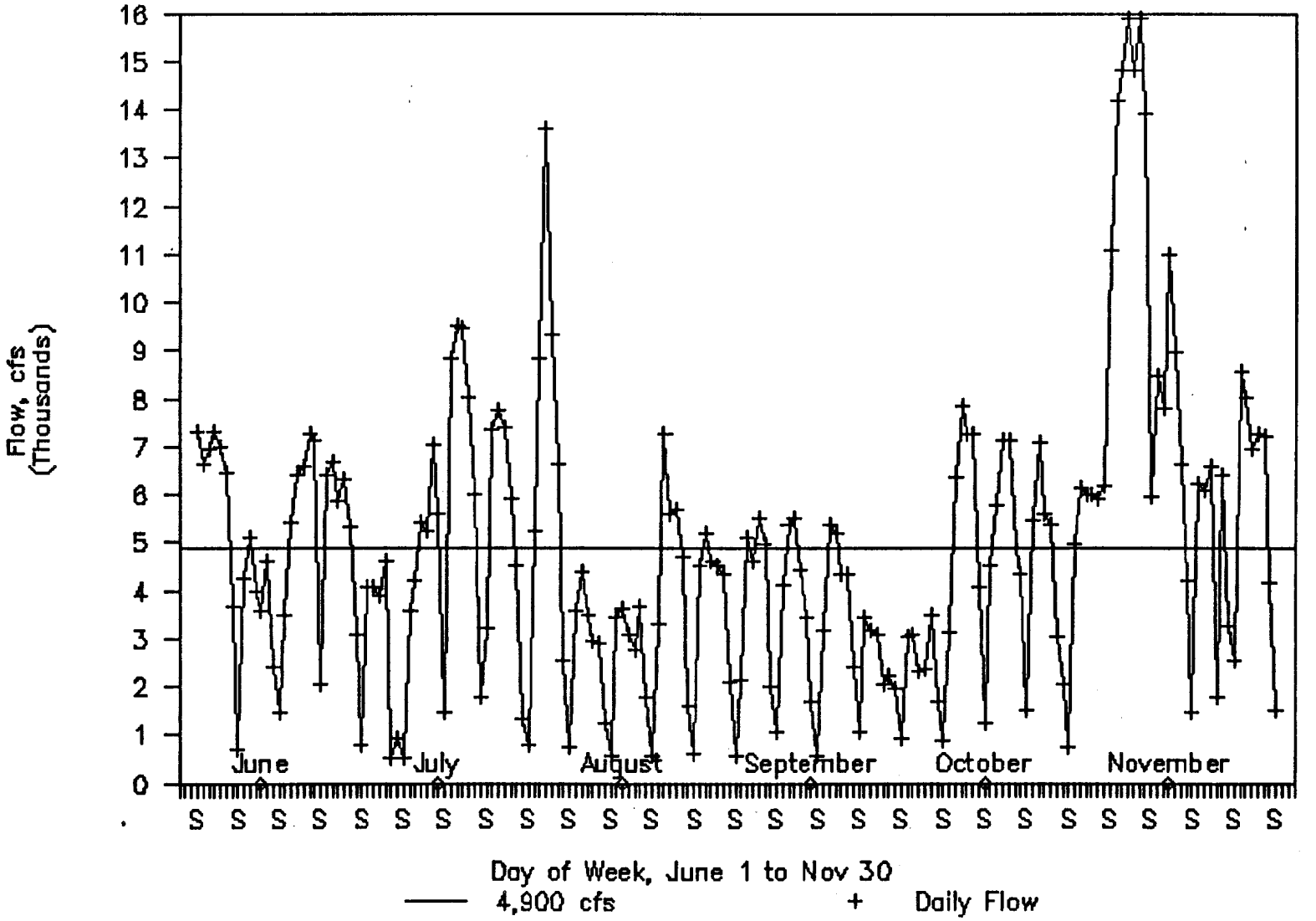


Figure 4. Montague gage, daily flows, 1964

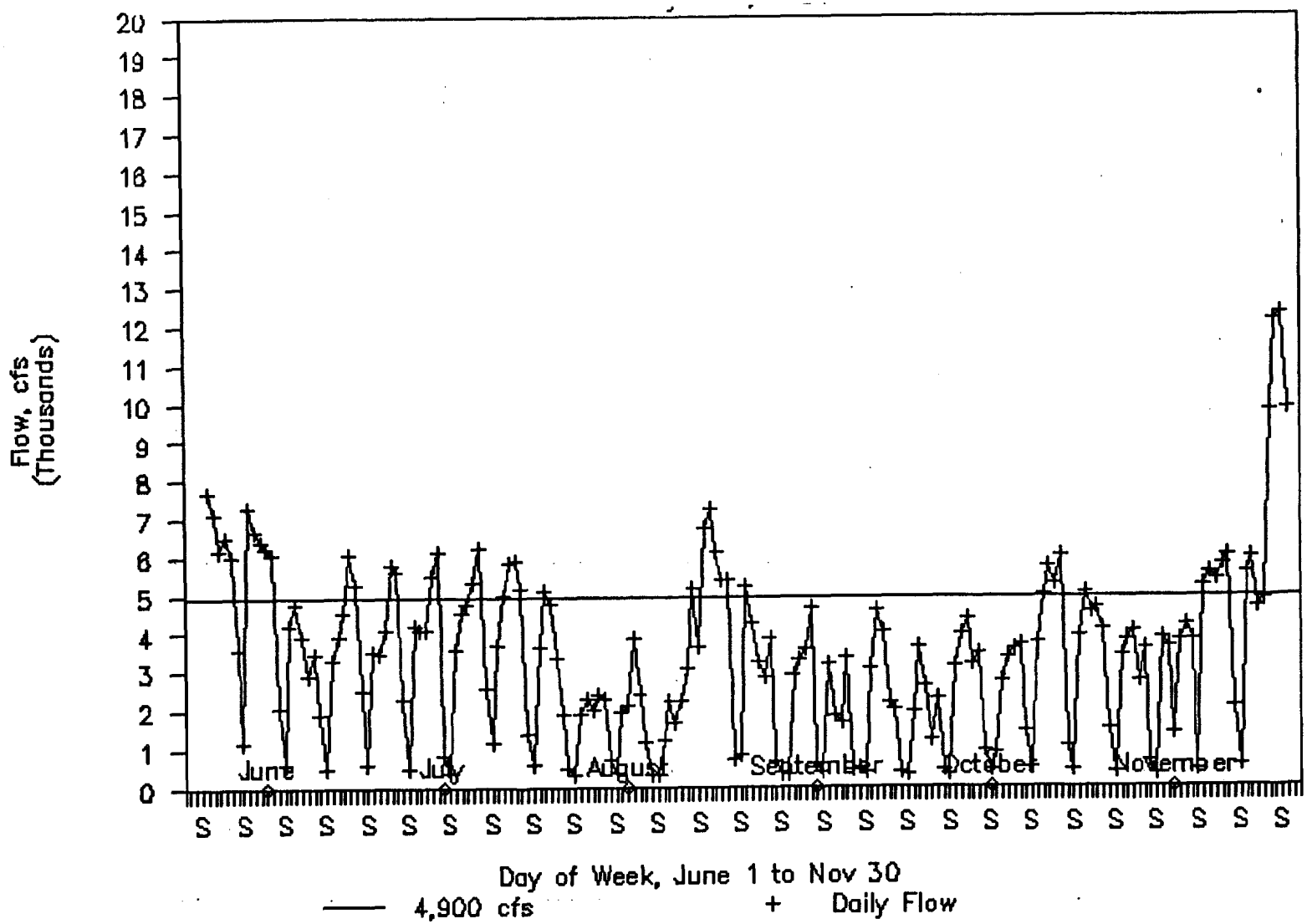


Figure 5. Montague gage, daily flows, 1976

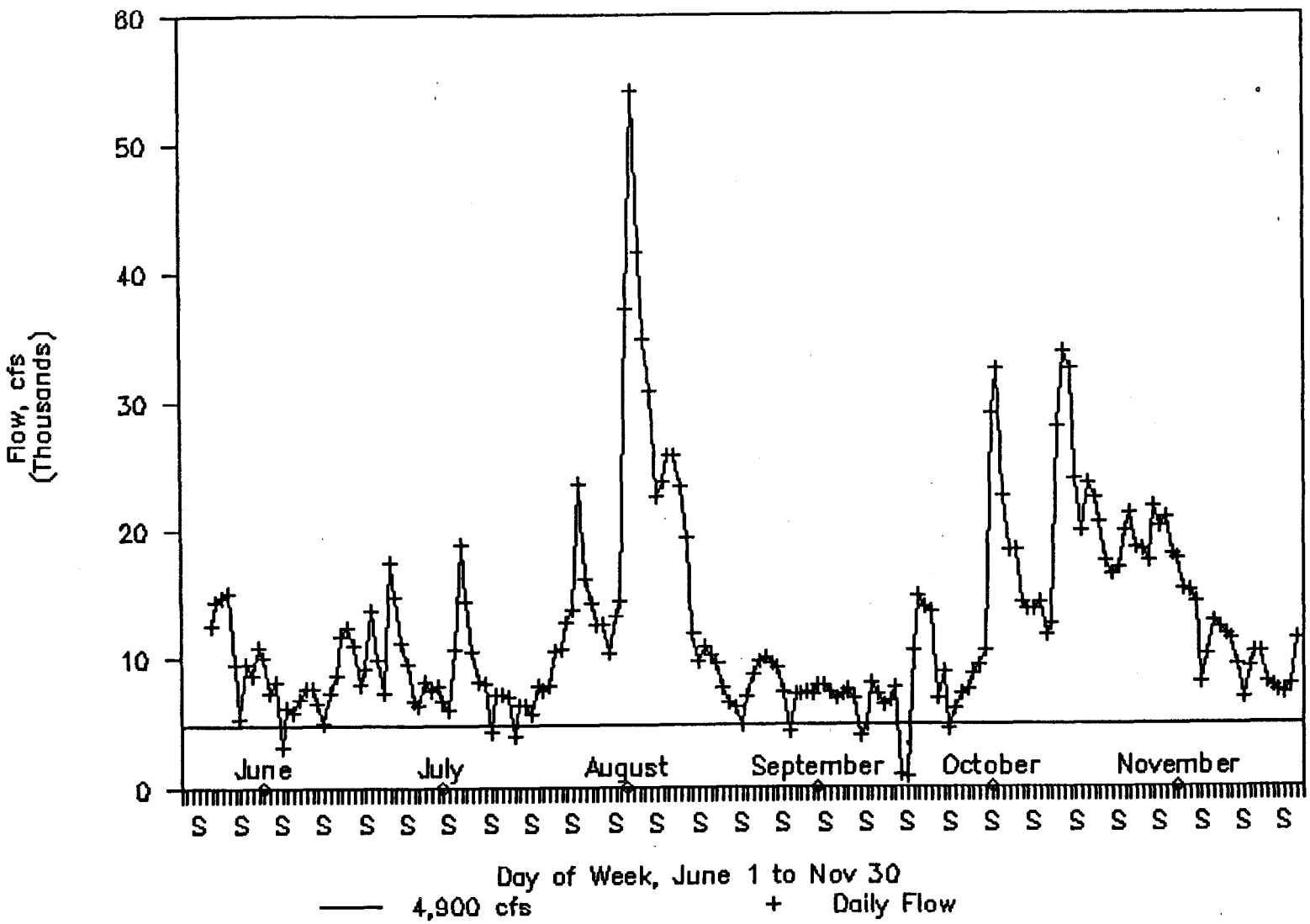
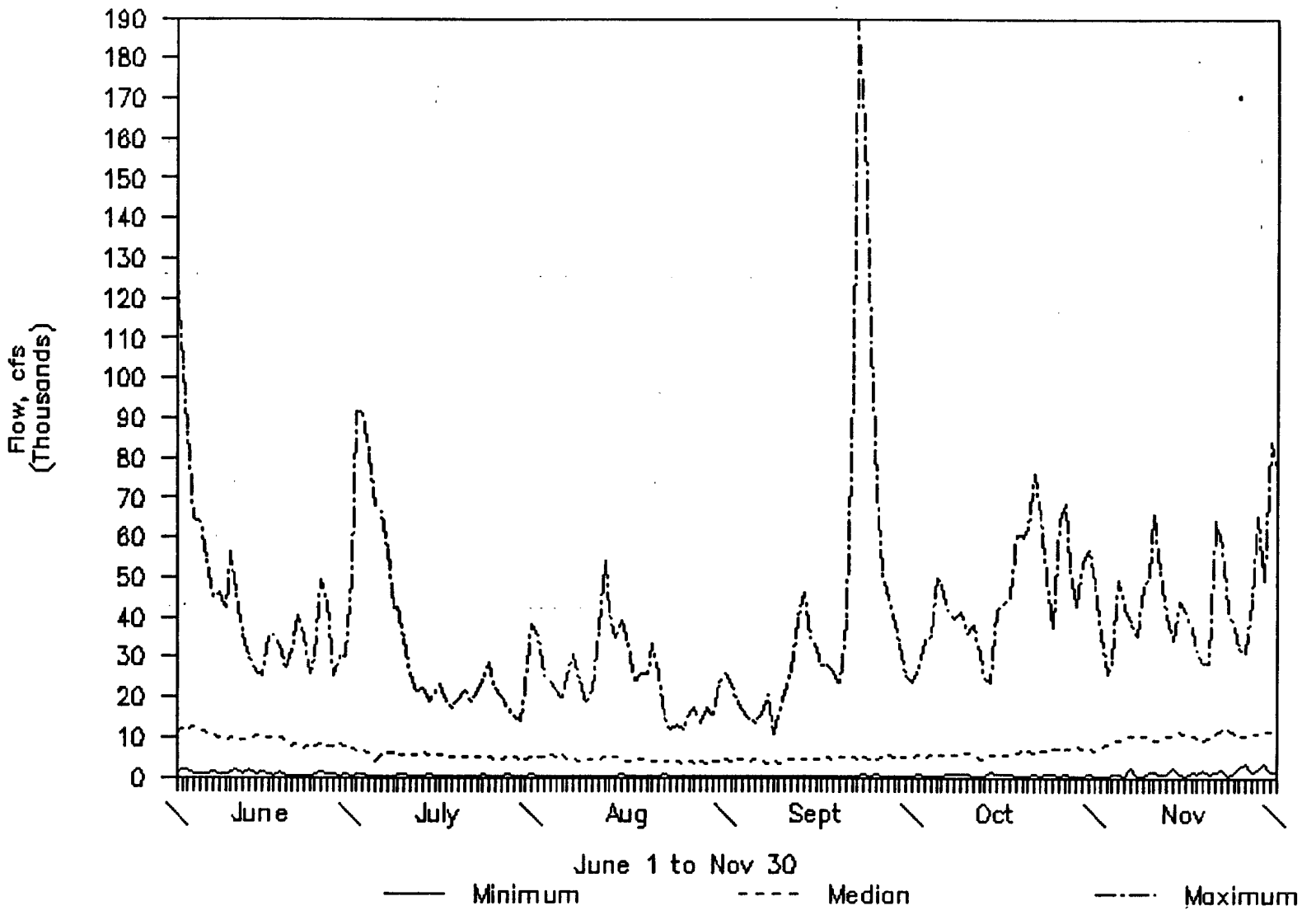


Figure 6. Montague gage, daily flows range, 1931 to 1989



FLOW AUGMENTATION

Quabbin Reservoir, completed in 1939 is required by Massachusetts Law, Chapter 321, Acts of 1927 and a 1929 Department of War Permit to release water from the impounding dam into the Swift River. The Massachusetts Law requires releases from Quabbin to maintain flow at all times of at least 20 million gallons per day (mgd) on the Swift River at Bondsville. The War Department Permit, in the interest of navigation on the Connecticut River, requires that between June 1 and November 30, a flow of 70 cubic feet per second (about 45 mgd) be released for Quabbin whenever the flow at the United States Geological Survey gage at Montague City, Massachusetts becomes less than 4,900 cubic feet per second (cfs) and a flow of 110 cfs (about 71 mgd) be released whenever the flow at the Montague gage is 4,650 cfs or less. (See Table 9.)

TABLE 9. Quabbin Flow Release Requirements

Montague Flow June 1 to November 30	Quabbin Release	Release Increase Above 20 mgd
greater than 4,900 cfs	20 mgd	0 cfs
less than 4,900 cfs and greater than 4,650 cfs	70 cfs (45 mgd)	39 cfs (25 mgd)
equal or less than 4,650 cfs	110 cfs (71 mgd)	79 cfs (51 mgd)

The amount of time the gage falls below 4,900 cfs in the June to November time period and the differential between 4,900 cfs and actual flow varies from year to year. At times when flows are well below 4,900 cfs a large volume of augmentation flow at the gage would be required in order to effect a savings in required releases at Quabbin. At other times when flows are closer to 4,900 cfs a smaller volume of augmentation flow would be required to effect the same savings in required releases at Quabbin.

Daily flow data at the gage from 1904 to 1990 was examined in order to determine the percent of time from June 1 to November 30 the flows are less than 4,900 cfs. Flow duration analysis based on 87 years of record indicate that during the June to November time period, daily flows are less than 4,900 cfs about 38 percent of the time and less than 4,650 cfs 34 percent of the time. (See Appendix A, Figure A-3, for flow duration curve.) Thus additional flow releases of 25 mgd, 4 percent of the time and 51 mgd, 34 percent of the time results in an average annual additional required flow release from Quabbin of 3,350 million gallons (10,300 acre-feet).

Daily flow data at the gage from 1957 to 1989 was also examined. This time period includes the 1960's drought and operation of the most recent large hydropower storage project, Moore Reservoir operational in 1957. Flow duration analysis indicates a very slight decrease, about two percent, in the amount of time flows are less than 4,900 cfs. Daily flow data from 1957 to 1989 was used to calculate seven day running average flow values at the gage. Flow duration analysis of this data indicated that the percent of time flow was less than 4,900 cfs at the gage was about the same as for daily flow values. (See Figure 7.)

Daily flow data from 1972 to 1989 was also examined because the Northfield Mountain pumped storage project became operational in 1972. Flow duration analysis indicated flows are higher during this time period, with daily flows below 4,900 approximately 28 percent of the time. (See Appendix A, Figure A-3, for flow duration curve.) This time period, 1972 to 1989, does not include the sixties drought.

Daily flow duration curves provide information on the average conditions over the historic record and do not illustrate the variation in yearly flow durations. In order to assess the variations in required yearly flow augmentation volumes an analysis was made of 33 years of record from 1957 to 1989. Analysis of daily flows indicates that 675,000 acre-feet of additional volume would have been needed in the June to November time period to prevent the flows at Montague from dropping below 4,900 cfs 100 percent of the time, and approximately 250,000 acre-feet of additional volume would have been required fifty percent of the time. This frequency analysis is presented in Figure 8.

In order to maximize potential savings at Quabbin this study assessed providing flow augmentation to maintain a flow of 4,900 cfs at the Montague gage. A general relationship between the amount of water saved in required releases at Quabbin and the required flow augmentation volume was developed.

This general relationship is presented in Figure 9 and shows that a large amount of flow augmentation volume would be required in order to effect the maximum savings in required releases at Quabbin. For example, in order to save required releases from Quabbin of approximately 7,000 million gallons (mg) that would have been triggered in 1964 by flows less than 4,900 cfs, approximately 675,000 acre-feet of volume would have been needed. In 1963 to save required releases from Quabbin of approximately 5,800 mg that would have been triggered by flows less than 4,900 cfs, approximately 560,000 acre-feet of volume would have been needed. These numbers illustrate the high release requirement placed on Quabbin during a drought period as a result of the War Department Permit. They also illustrate the need to consider the cumulative effect of successive years of low inflow in order to design an alternative with enough reservoir storage to be able to provide this much flow augmentation volume during a drought period.

The general relationship developed does not consider the potential loss of savings in Quabbin releases through subsequent reservoir spilling. If this study were to proceed further the flow augmentation alternative could be factored into the system safe yield model to estimate the increased system yield due to savings in required releases from Quabbin.

Figure 7. Montague gage, Flow Duration Curve, June 1 to November 30, 1957 to 1989

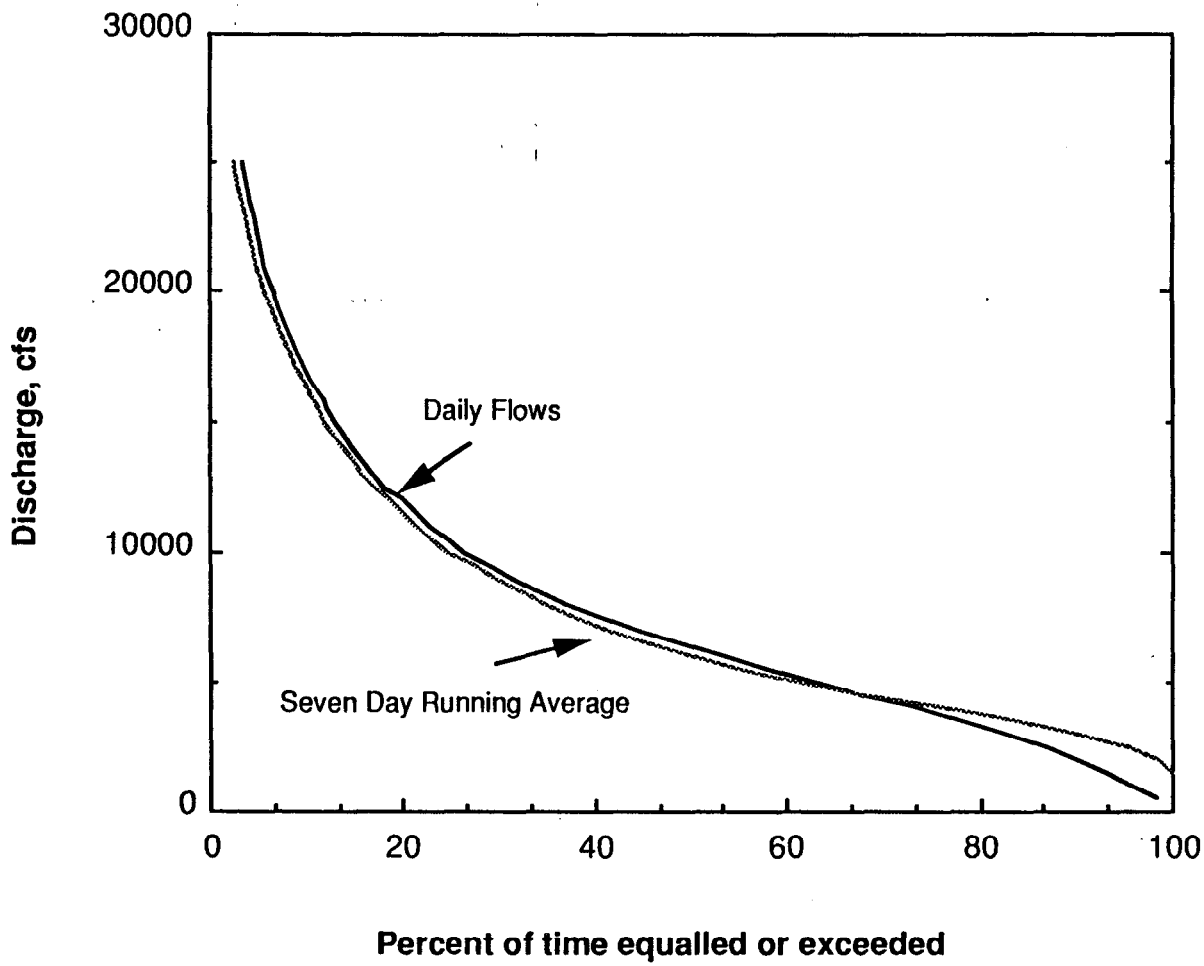


Figure 8. Frequency Analysis of volume of water required to maintain Montague gage above 4,900cfs, June to November, 1957 to 1989

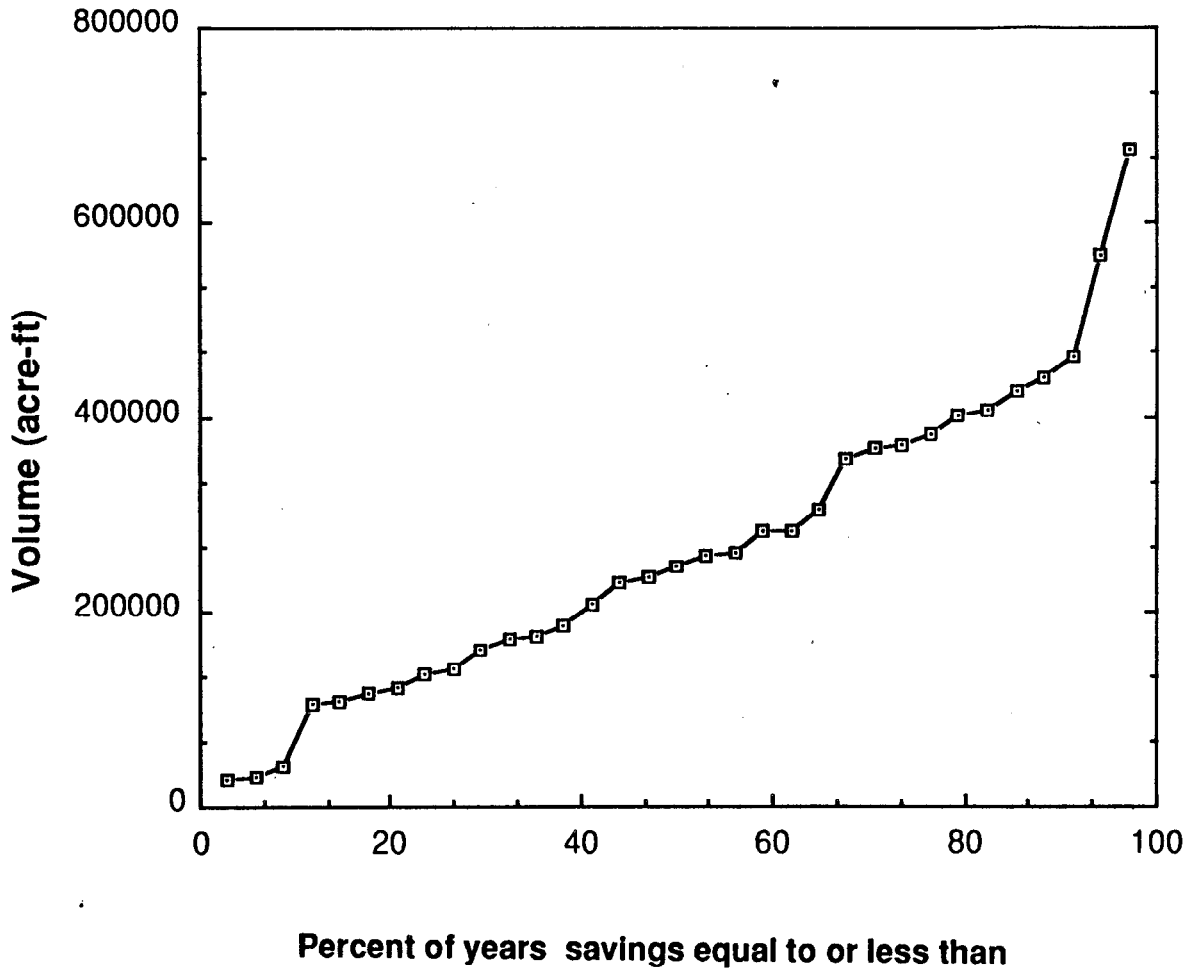
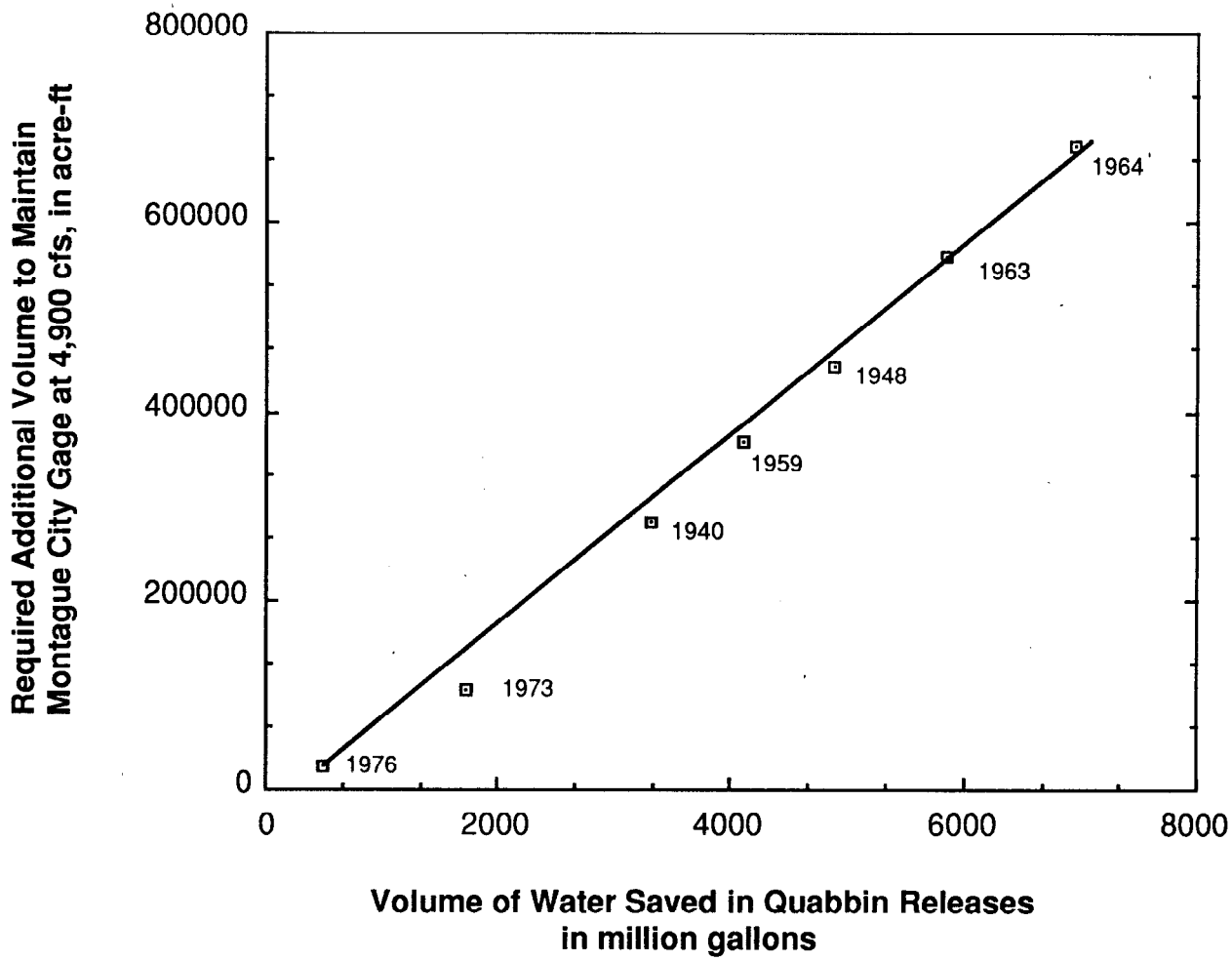


Figure 9. Relationship between volume of water saved in Quabbin and required additional volume at Montague gage



IV. FLOW AUGMENTATION WITH CORPS RESERVOIRS

The following is a reconnaissance level review of the alternative of using Corps of Engineer Reservoir storage capacity to augment flows on the Connecticut River, thereby decreasing the amount of time the daily flows are below 4,900 and 4,650 cfs at the Montague gage.

AVAILABLE SEASONAL STORAGE

There are nine Corps of Engineers flood control reservoirs above the Montague gage: They are Union Village Dam, North Hartland Lake, North Springfield Lake, Ball Mountain Lake, Townshend Lake, Surry Mountain Lake, Otter Brook Lake, Birch Hill Lake, and Tully Lake. Each of the projects was assessed from a hydrologic point of view to determine the amount of seasonal storage capacity that might be used to provide for flow augmentation on the Connecticut River from June 1 to November 30 without infringing on the flood control purposes of the reservoirs.

Preliminary assessment indicated Birch Hill and Surry Mountain should be dropped from further study. Birch Hill was dropped because of limited flood control storage. Surry Mountain was dropped because of its location with respect to the City of Keene and the limited downstream channel capacity.

The remaining seven reservoirs were analyzed using the HEC-1 "Flood Hydrograph Package" as a tool to determine the allowable encroachment into flood control storage. Encroachment was determined based on historic floods, as well as, the Corps of Engineers standard project flood. This analysis is presented in Appendix A.

Initially a storage and release time period of June 1 through November 30 was considered. As this 6 month time period provided a somewhat limited volume of flow augmentation storage capacity (about 24,000 acre-feet), it was decided to shorten the filling and storage time period to June 1 through August 31. This shorter time period eliminates consideration of the fall flood threat and thus allows for a slightly greater use of reservoir capacity for flow augmentation.

During the June to August time period summer pools are maintained at all the reservoirs except for Union Village. The summer pool capacity at the reservoirs is 7,870 acre-feet. The amount of empty storage in the reservoirs above the summer pool is the summer flood control capacity. The total summer flood control capacity at the reservoirs is between the normal summer pool elevation and spillway crest, a total of 280,350 acre-ft at the seven reservoirs. The hydrologic analyses assessed the allowable encroachment into the summer flood control capacity and determined 22,340 acre-feet of capacity might be used for flow augmentation storage. The total capacity available for flow augmentation storage is the summer pool capacity plus the allowable encroachment into summer flood control capacity and was determined to be 30,210 acre-feet. This information is presented by reservoir in Table 10. Storage of flow augmentation water will result in an increase in pool elevation and surface area and a decrease in summer flood control capacity at the reservoirs. This information is presented in Table 11.

Table 10. Flow Augmentation Storage Capacity at Corps of Engineers Reservoirs

Project	Summer Pool Capacity (acre-feet)	Encroachment into Summer Flood Control Capacity (acre-feet)	Flow Augmentation Storage Capacity (acre-feet) (1) (2)
Union Village	0	4,030	4,030
North Hartland	2,350	4,690	7,040
North Springfield	500	4,550	5,050
Ball Mountain	2,000	3,500	5,500
Townshend	800	2,590	3,390
Otter Brook	720	1,280	2,000
Tully	1,500	1,700	3,200
Total	7,870	22,340	30,210

(1) For the time period June 1 to August 31, only.
(2) Only considers impacts to flood control capacity

Table 11. Impact of Flow Augmentation Storage on Summer Pool Elevation, Summer Pool Surface Area and Summer Flood Control Capacity

Project	Increase in Summer Pool Elev. (feet)	Increase in Summer Pool Surface Area (acres)	Decrease in Summer Flood Control Capacity (percent)
Union Village	65	190	11
North Hartland	19	135	7
North Springfield	17	314	9
Ball Mountain	29.5	70	7
Townshend	16	176	8
Otter Brook	13	92	7
Tully	7	320	8

FILLING SCHEDULE

The next analysis performed was to determine if the flow augmentation storage could be ready if filling was constrained to a June 1 starting date. The June 1 staring date was chosen to avoid compromising flood control storage required in May. Also Ball Mountain and Townsend Lakes are restricted to low pool elevations until June to allow for downstream passage of Atlantic salmon smolt. A low flow analysis was performed using ten year frequency low inflow and outflow criteria. Using this criteria all the reservoirs except Tully Lake were available to provide flow augmentation by August 5. In higher flow years the reservoirs should be available sooner for flow augmentation.

The filling analysis was also done using an outflow criteria of 0.2 cfsm. This outflow criteria resulted in only two of the seven projects, North Hartland and Townshend, filling in the June to August time period and these two filled by June 30. (See Table A-6, Appendix A.)

Beginning filling of reservoirs in June was selected to be conservative from a flood control and hydrologic point of view. However, restrictions of flows at this time may trigger additional flow releases from Quabbin. Monthly flow duration curves indicated that on average flows are less than 4,900 cfs 13 and 46 percent of the time in June and July, respectively. Analysis of the impact of filling on flows at the gage would be required if further studies were conducted. Also it may be possible to consider beginning filling some of the reservoirs in May. However, as noted above, Ball Mountain and Townshend Lakes could not be filled sooner because of the downstream passage of Atlantic salmon smolt. Filling in May would require detailed evaluation during any further studies.

RELEASE SCHEDULE

In a low flow year, water would be available for release from the reservoirs in August. In higher flow years flow releases may be possible from June through August.

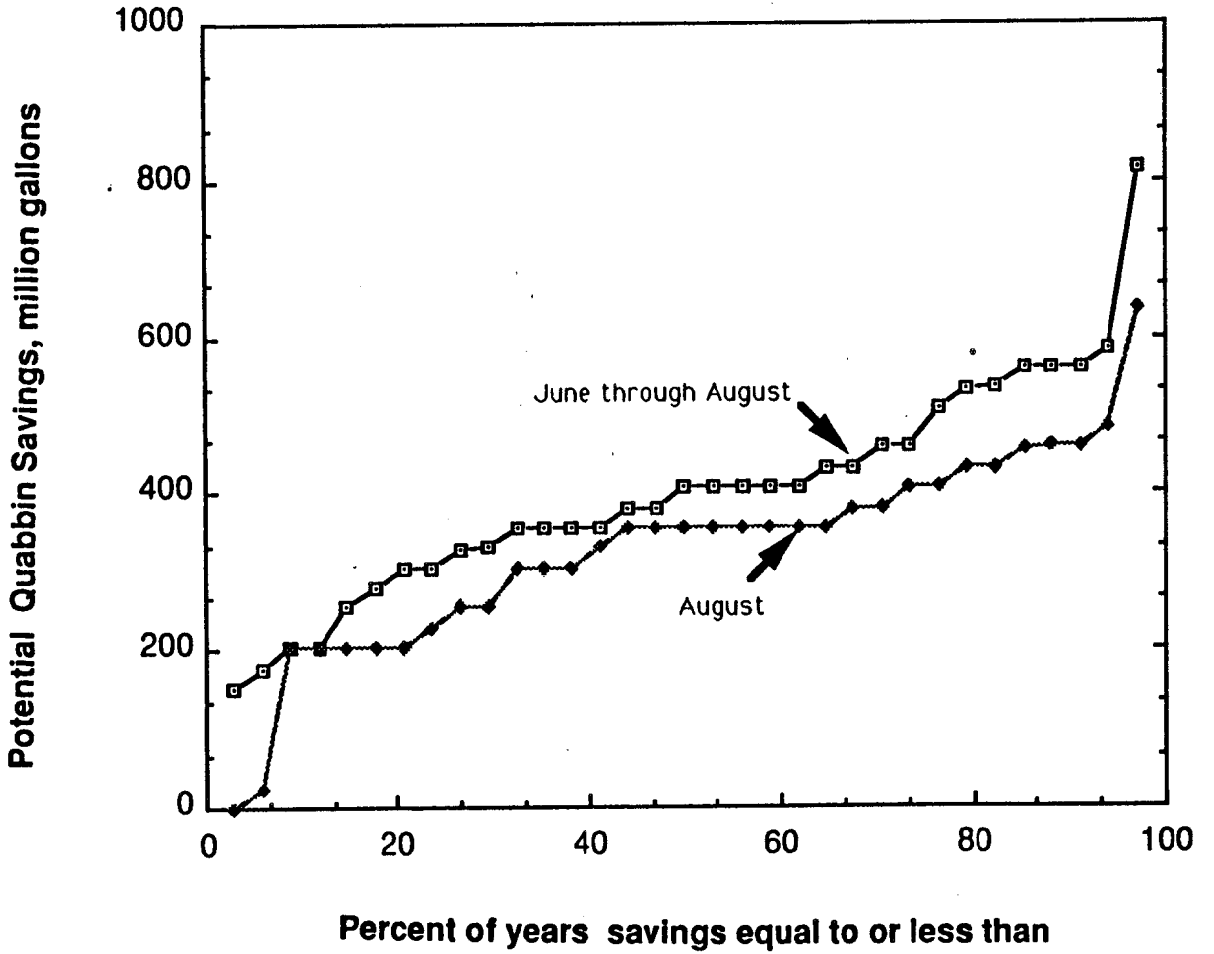
Flow releases could be made from one reservoir or from several reservoirs simultaneously in order to make up the required flow volume to keep the gage from falling below 4,900 cfs. The nondamaging downstream channel capacities at the reservoirs range from 600 cfs to 9,500 cfs. The timing and volume of releases would vary depending on when flows are needed at the Montague gage. Estimates of travel times from the reservoirs to Montague at a release rate of 100 cfs range from about 34 hours for Otter Brook to about 10 hours for Tully. Times along the Connecticut River were provided by NEPEX and estimates could vary widely, depending on flow conditions. (See Appendix A.) Release of augmentation flows from Corps reservoirs would need to be coordinated with the hydropower interests on the river to obtain forecast flows and to ensure flows would not be captured in hydropower pools at Wilder, Bellows Falls, Vernon or Turners Falls.

INCREASE IN WATER RETAINED IN QUABBIN RESERVOIR

The number of days of flow augmentation provided by the total volume of 30,210 acre-feet depends on the magnitude of the difference between the actual daily flows and 4,900 cfs. The daily flows at the Montague gage from 1957 to 1989 were analyzed in order to assess the range in yearly flow augmentation afforded by 30,210 acre-feet of storage. The time period, 1957 to 1989, includes the sixties drought. The most recent large hydropower storage reservoir became operational in 1957.

Analysis indicated that if 30,210 acre-feet had been available for release in August the decrease in required Quabbin releases would have ranged from 0 to 630 million gallons with a median savings of 350 million gallons. The days of flow augmentation would have ranged from 0 to 14 with a median of 7 days. If the 30,210 acre-feet had been available for release in the June to August time period the decrease in required Quabbin releases would have ranged from 150 to 810 million gallons with a median savings of 400 million gallons. A frequency analysis of this data is presented in Figure 10.

Figure 10. Frequency Analysis of Water Saved in Quabbin using 30,210 ac-ft of Corps Storage, 1957 to 1989



V. ENVIRONMENTAL IMPACTS

WATER QUALITY

The Corps flow augmentation alternative could impact water quality at and downstream from the reservoirs. A reconnaissance level review and analysis of these impacts is presented in Appendix B. Impacts in reservoir pools include possible increases in nutrients, metals, color, turbidity, suspended sediments, algae production and sedimentation. Temperature changes and decreases in dissolved oxygen levels are also expected to occur in these pools. Potential impacts downstream of the projects include increases in turbidity, color, suspended sediments and metals, as well as possible temperature and dissolved oxygen changes. None of these impacts initially appear to be so severe as to definitely preclude storing the proposed amount of water at any of the projects with the exception of Union Village, and possibly Tully.

Currently, no summer pool is maintained at Union Village. Tributaries to the reservoir contain high concentrations of heavy metals including iron, copper and mercury. These metals wash into tributaries in runoff from upstream tailings piles at abandoned copper mines. Sediment studies conducted upstream of the dam indicate these sediments contain elevated metal levels. A summer pool maintained at the reservoir has the potential to cause a release of metals from the sediments to the water column and could possibly cause toxic metal concentrations.

At Tully, degradation caused by extensive inundation of vegetation and a large increase in hydraulic residence time, presents the potential for significant impacts on water quality.

Water quality degradation in downstream releases due to effects of increases storage has been mentioned above. However, flow augmentation releases may benefit downstream water quality during drought or low flow periods.

Before water storage at the reservoirs could be undertaken, detailed investigations at each reservoir would be required in order to better assess impacts on water quality at and of the downstream reservoirs.

BIOLOGICAL RESOURCES

The Corps flow augmentation alternative could impact the vegetation, wildlife, and fisheries at and downstream of the reservoirs. A reconnaissance level review and analysis of these impacts is presented in Appendix C.

Impacts on vegetation include a total inundation of about 750 acres of upland and 500 acres of wetland habitat at the reservoirs. Much of this area is inundated periodically for short periods of time (less than two weeks) under current operating protocol for flood control storage. Most of these flood control events occur prior to or after the growing season. Over the years, reservoir operation has selected for vegetation that is somewhat tolerant of this inundation. However, prolonged inundation by the flow augmentation pool during the growing season would probably kill most woody upland and wetland vegetation. Emergent wetland vegetation occurring in the reservoirs would also probably be killed or severely damaged by submergence during the growing season. Submerged aquatic plants growing in existing recreation pools or riverine habitat could also be severely impacted, if submerged for prolonged periods below the euphotic zone. Fluctuating water levels would prevent significant colonization of higher pool levels by emergent or aquatic vegetation. Loss of vegetative cover could lead to increased erosion when no pool is maintained. Increased slumping of embankments could also occur.

Of the seven reservoirs the greatest impact on wetlands would occur at Tully where flow augmentation storage would inundate about 275 acres of forested, scrub-shrub wetland, and emergent wetland. In addition, Tully Lake may contain a rare state listed aquatic plant "the tiny cow lily". If the plant is still present in Tully its presence may preclude augmentation storage above the existing summer pool.

Most of the areas that would be inundated provide good to excellent wildlife habitat. Although most wildlife using these areas would shift to alternative habitat as the reservoirs were filled, some mortality due to dispersal related stress would probably occur. Loss of woody cover would probably result in a long-term decline in habitat carrying capacity for many species. At most reservoirs, loss of submerged macrophyte communities and associated invertebrates would reduce existing habitat value for migrating waterfowl.

Most of the reservoirs support some type of fisheries. Augmentation storage would disturb spawning and nursery habitat for largemouth bass and other warmwater fish at most of the reservoirs. Increased water level fluctuations associated with the alternative could cause increased stranding of eggs and juveniles. Loss of cover and invertebrate prey provided by submerged aquatic plants would also affect fish populations. Inundation of spawning and nursery habitat would have a significant impact on an excellent largemouth bass fishery at North Springfield. At Union Village maintaining a pool at the project would severely affect the existing put and take trout fishery and rearing habitat for Atlantic salmon.

A large population of brook floater, a freshwater mussel, and candidate species for inclusion on the Federal list of threatened and endangered species, is present in the West River, about 2,000 to 3,000 feet downstream of Townshend Lake. A second brook floater population is reportedly present about 4.5 miles downstream of the dam. Based on field observations, a release of about 90 cfs, or inflow if less would be required to avoid significant impacts to the brook floater population situated downstream of the dam.

Outflow from the reservoirs would be reduced below normal levels during reservoir filling in June. This would result in loss of some downstream riverine habitat, and could adversely effect fish and aquatic invertebrate populations. In some instances (Ball Mountain and North Hartland), excellent downstream trout fisheries could be affected. Conversely, flow augmentation during low flow periods in the summer might have some positive effects on downstream aquatic life. Periodic releases for flow augmentation would result in some stranding of aquatic life downstream of the dam. In-stream flow studies to determine acceptable minimum flows and ramping rates would be required to minimize impacts.

A program is underway in the West River Basin to restore Atlantic salmon. The Corps recently completed a study which recommended several measures to enhance downstream passage of smolts and upstream passage of adults at Townshend and Ball Mountain Lakes. Upstream passage of adults at both projects will be provided by capture facilities situated downstream of of Townshend Lake. Downstream passage of smolts through Ball Mountain and Townshend will be enhanced by maintaining low pool stage until June 1. The flow augmentation alternative should have no impact on the salmon restoration efforts as filling of the reservoirs would not begin until June 1.

If the flow augmentation alternative were to be considered further, detailed environmental studies would be required. Preparation of a Federal Environmental Impact Statement might be required depending on the final configuration of the alternative. Detailed environmental studies required would include the following:

- field surveys to more precisely quantify wetland impacts;
- habitat based analysis, such as the U.S. Fish and Wildlife Service Habitat Evaluation Procedure (HEP), to quantify fish and wildlife resource impacts and aid in development of a mitigation plan;
- in-stream flow studies to establish acceptable outflows during reservoir filling and ramping rates;
- and in addition to impacts at Corps Reservoirs, there would also be a need to consider the impacts of decreased releases from Quabbin Reservoir on the Swift, Ware, and Chicopee Rivers.

ARCHAEOLOGICAL AND HISTORICAL RESOURCES

The Corps flow augmentation alternative could impact historic properties at the projects. A reconnaissance level review and analysis of these impacts is presented in Appendix D.

Historic properties include historic as well as prehistoric sites. Sites identified within the proposed flow augmentation pools at the reservoirs are listed in Table 12. Based on existing data, Ball Mountain is identified as containing a prehistoric site eligible for the National Register of Historic Places. An erosion monitoring program at a known archaeological site is currently ongoing at Ball Mountain Lake, as a result of the development of fish passage facilities for Atlantic salmon.

Table. 12 Historic Properties Overview

RESERVOIR	HISTORIC SITES	PREHISTORIC SITES
Union Village	Four historic sites; two farm/residences; one industrial/farm/residence; one mill site	None identified; however, several areas of low to high prehistoric site sensitivity
North Hartland	Three historic sites; all early to mid 19th century farm/residences	Two field sites identified; low to moderate prehistoric site sensitivity
North Springfield	Nine historic sites; seven farm/residences; one sawmill one blacksmith shop	Several areas of low to moderate prehistoric site sensitivity
Ball Mountain	Two historic sites; one school; one farm/residence	Two prehistoric sites; two areas with moderate prehistoric site sensitivity
Townshend Lake	Four historic sites; three farm/residences; one seasonal camp	One prehistoric site; Several small areas with low to moderate prehistoric site sensitivity
Otter Brook	Four historic sites; all farm/residences	Several areas of moderate to high prehistoric site sensitivity
Tully Lake	No known historic sites; however, no studies have been performed for this area	Several areas of prehistoric site sensitivity

The presence of historic properties at the sites does not preclude the use of the reservoirs for storage, however any site on Corps property is subject to Section 110 of the National Historic Preservation Act of 1966, as amended, which directs Federal agencies to assume responsibility for preservation of historic properties which are owned or controlled by the agency. Also, the Corps is required to undergo a National Historic Preservation Act Section 106 review for any proposed action. Section 106 requires an agency to identify historic properties that may be affected by a Federal action, determine if they are significant (i.e. National Register eligible) and determine if the action will have an affect on the resources. If historic properties will be affected by a proposed action then they should be avoided or mitigation for adverse impacts provided. This must all be coordinated with the appropriate State Historic Preservation Officer.

If further studies are conducted additional research would be needed to determine what sites would be impacted by inundation and erosion.

VI. ECONOMIC IMPACTS

The Corps flow augmentation alternative could have impacts on recreation, agriculture, hydropower and water supply for drought contingency. A reconnaissance level review and analysis of these impacts is presented in Appendix E.

RECREATION

The seven reservoirs and associated lands offer recreational opportunities such as hiking, hunting, snowmobiling, camping, bird watching, ball playing, picnicking, fishing, boating and swimming. Recreational features that support these activities will be inundated as a result of raising the reservoir pool to elevations above the summer pool elevations. Although normal flood storage may cause a short disruption in use, in a matter of days, these features are usually available again. Potentially inundated features include roads, parking lots, picnic and camping areas, boat ramps, beaches and comfort stations. (See Table 13) Inundation of these features as well as the drawdown of the pool during flow releases will eliminate swimming and boating and limit picnicking at the reservoirs. Beaches at North Hartland and Townshend Lakes are the only public beaches in their local area.

It is anticipated that combined reservoir visitation would decline from an estimate of 507,633 to 227,317, a drop of 280,317, or about 55 percent.

Recreation value, as determined through the unit day methodology (See Appendix E), is estimated to drop from $2,000,000 to $900,000, a loss of about $1,100,000 annually.

Table 13. Impacts to Recreational Features at the Projects

Water storage impacts on	Union Village	North Hart.	North Spring.	Ball Mtn.	Townshend	Otter Brook	Tully
roads	yes(1)				yes(3)	yes	
parking lots		yes			yes	yes	
picnic areas	one small area				yes	70 sites and two shelters	
camping area							yes
boat ramp		yes	yes		yes	yes	yes
beach		yes	yes		yes	yes	
comfort stations or septic system					yes	yes	yes
other			yes(2)		ballfield	ballfield	

(1) Inundate road providing access to east side of river
(2) Ascutney Mountain Audobon Society maintains a nature trail that offers opportunities for bird watching overlooking the wetlands at northern end of the reservoir. Inundation of the wetland will limit this activity.
(3) Access road to picnic area and ballfield will be flooded

There is also the possibility that flow augmentation may benefit recreational opportunities on the Connecticut River. However, as the number of days of flow augmentation provided by Corps Reservoir storage is estimated to range from 0 to 14 days, the benefit is expected to be minor compared to the lost recreation at the Corps Reservoirs.

AGRICULTURE

The Corps currently leases land at North Springfield that is used to grow corn and hay. With storage this land would be inundated and lost to production. The loss in profitability of these lands would need to be included as a cost of water storage. This loss is estimated to be $24,200 annually.

HYDROPOWER

There is a 4 megawatt hydroproject at North Hartland Reservoir that uses the existing reservoir pool to generate power. An agreement for this use was entered into between the United States Government and Vermont Electric Cooperative in 1983. The turbine is rated for operation between 422 and 435 feet NGVD. The proposed pool fluctuation for flow augmentation at North Hartland is 390 to 448 feet NGVD, thus the alternative will impact on hydropower generation at the project. The median hydropower output at North Hartland for the last five years for June, July, August was 821, 411, and 374 megawatt hours, respectively. In addition, 4 megawatts of summer capacity would be lost. The total replacement energy and additional capacity expenses would be approximately $56,210 and $53,000. (Letter from Vermont Electric Cooperative, February 19, 1992.)

There are six major hydropower projects located downstream of Corps reservoirs considered for flow augmentation storage. These are Wilder Falls, Bellows Falls, Vernon Falls, Turners Falls and Cabot, and Holyoke.

Table 14. Major Hydropower Projects Downstream of Corps Reservoirs

Dam	Capacity	Location
Wilder	39 megawatts	Downstream of Union Village
Bellows Falls	45 megawatts	Downstream of Union Village, North Hartland, North Springfield
Vernon Falls	26 megawatts	Downstream of Union Village, North Hartland, North Springfield, Ball Mountain, Townshend, Otter Brook
Turners Falls and Cabot	6 megawatts and 53 megawatts	Downstream of Union Village, North Hartland, North Springfield, Ball Mountain, Townshend, Otter Brook, Tully
Holyoke	42 megawatts	Downstream of Union Village, North Hartland, North Springfield, Ball Mountain, Townshend, Otter Brook, Tully

Water storage for flow augmentation could affect the ability of hydropower companies located downstream of the reservoirs to generate electricity. Hydropower is usually used during daily peak periods. Reduction in river flows in the early summer may require the generation of electricity by other more costly methods. However, releases in the late summer may allow for additional hydropower generation lowering the overall electricity generation cost.

New England Power Pool was contacted regarding this issue and their response indicated that the alternative would not produce any additional hydropower, whereas a plan capturing spring runoff water (April and May) for release in the summer would result in additional hydropower. (NEPOOL Letter of April 6, 1992; Telecom B. Blumeris, Corps and J. Ginnetti, NEPOOL, April 9, 1992; Corps letter of April 16, 1992.)

There is also one hydropower project at Quabbin (operated by the MWRA/MDC) and six hydropower projects on the Chicopee River (operated by Northeast Utilities and other interests). These projects would be affected by decreased required releases from Quabbin as a result of the flow augmentation alternative. However, as required Quabbin releases would be decreased for a limited number of days and decreases would be small (either 39 or 79 cfs) the impact on hydropower production is expected to be small. (Telecom, February 5, 1992, Charles Mannie, Northeast Utilities.)

Hydropower impacts should be included in additional studies, if future study of this alternative is undertaken.

DROUGHT WATER SUPPLY

Over the next several years drought contingency water supply studies will be conducted for many of the Corps reservoirs. The drought contingency studies will identify local water supply agencies that may be able to use the storage at a reservoir during a drought emergency.

Of the seven reservoirs considered for flow augmentation, the reservoir most likely to be used by a local community for drought water supply is Otter Brook, by the City of Keene. There has been potential interest by the City in withdrawing water from Otter Brook below the dam. Also the Corps plans to pursue drought studies at North Springfield in the future.

Storage of water for flow augmentation at the reservoirs would not preclude the use of the reservoirs for local water supply during a drought emergency. An arrangement could be made that would allow the local need to be satisfied before release of water for flow augmentation.

VII. PRICE OF WATER

The basic authority permitting the United States to store water for municipal and industrial water supply purposes is contained in the Water Supply Act of 1958. (See Section VIII, Legal Issues.) The Act also stipulates that the local interest, in this case the MWRA, must pay for such storage. The annual cost of seasonal flow augmentation storage is based on water storage pricing policy established by Corps regulations.

The derivation of price to be charged for seasonal storage is presented in Appendix E and summarized in Table 15. The cost includes the full cost of foregone benefits (1), compensation of losses to others, and operation and maintenance costs (O&M) specific to flow augmentation storage. In addition, joint O&M costs at the reservoirs are assessed for the number of days the contract would be in effect. This period is estimated to be 90 days.

Table 15. Price Determination

Category	Annual Cost	Daily Cost	Contract Cost
New O&M	$63,000	$700	$63,000
Joint O&M	$220,500	$600	$54,000
Foregone Benefits			
Recreation (1)	$1,100,000		$1,100,000
Compensation to Others			
Agriculture	$24,200		$24,200
Hydropower	$109,210		$109,210
Total			$1,350,410
		SAY	$1,400,000

The annual cost of flow augmentation storage for pricing purposes is estimated at about $1,400,000. A large portion, about $1,100,000, of this annual cost is attributable to the lost recreation benefits at the projects.

VIII. LEGAL ISSUES

Authorization for Seasonal Storage - The basic authority permitting the United States to store water for municipal and industrial water supply purposes is contained in the Water Supply Act of 1958. In this act, Congress declared "the Federal government should participate and cooperate with states and local interests in developing such water supplies in connection with the construction, maintenance and operation of Federal navigation, flood control, irrigation, or multiple purpose projects".

In this case, the increase in water supply in the MWRA/MDC system would be indirect, however the goal of the project and the net result of the flow augmentation alternative is to participate and cooperate with local interests in the development of water supply. The Act also stipulates that the local interest, in this case the MWRA, must pay for such storage.

The Act also requires that any modifications to project operation must be consistent with authorized project purposes and law. The seven reservoirs considered in this study were originally authorized by Congress as single purpose flood control projects. However, recreation was developed under the authority of the Flood Control Act of 1944 at these projects. This act authorizes development and operation of recreational facilities when such use is determined by the Chief US Army Corps of Engineers not to be contrary to the public interest. The proposed augmentation alternative would impact on the recreational use of the reservoirs. The important issue will be whether the need for increased water supply outweighs the public interest in recreation. Resolution of this issue would require public hearings on the matter and coordination with the Office of the Chief of Engineers in Washington.

Consistency with Federal and local Laws - A variety of Federal laws and regulation would need to be considered prior to implementation of the proposed augmentation plan. However, due to the doctrine of Federal supremacy, the Federal government is not required to adhere to state and local laws or regulations, unless such immunity has been waived. In the case of water regulation no such waiver has been granted. It is, however, the policy of the Federal government to conform as much as practicable, to substantive state and local requirements. The MWRA, as the potential local sponsor, would be required to meet procedural requirements stipulated in these laws or regulations. A list of applicable Federal and state laws is provided in Appendix C. If the augmentation scheme were to be considered further it would be necessary to ascertain the nature of riparian impacts of the alternative in light of local statutory and common law.

IX. DROUGHT AND DROUGHT RECOVERY YEARS

If the flow augmentation alternative were confined to drought years, the difference between 4,900 cfs and the actual daily flow might be high, thus the Corps reservoir storage might be utilized in fewer days providing fewer days of savings in required flow releases at Quabbin. For instance in August of 1964, approximately 30,000 acre-feet of storage would have provided about four days of flow augmentation. Also it may be difficult to fill Corps reservoir storage in the June to August time frame in drought years depending on flow release requirements at the reservoirs.

In drought recovery years when flows may be higher, the difference between 4,900 cfs and the actual daily flow might be lower, thus the Corps reservoir storage might be utilized over a greater number of days. Reduced triggering of additional required releases to the Swift River during a drought recovery period might increase Quabbin's pool elevation at a faster rate.

Confining the use of Corps reservoir storage to drought or drought recovery years would probably not reduce the identified impacts at the projects because filling of storage and release of storage would still be required for several years in a row. The price of water would also remain the same, as it is determined on an annual basis.

X. SUMMARY ASSESSMENT OF THE USE OF STORAGE IN CORPS RESERVOIRS FOR FLOW AUGMENTATION

A reconnaissance level analysis of flood control storage capacity of the nine Corps of Engineers flood control reservoirs upstream of the Montague gage indicated that a limited amount of seasonal encroachment for flow augmentation storage could be considered at seven of the projects during the months of June, July and August. The seven projects are: Union Village Dam, North Hartland Lake, North Springfield Lake, Ball Mountain Lake, Townshend Lake, Otter Brook Lake, and Tully Lake. Analysis indicated the allowable seasonal flow augmentation storage capacity at the projects in the June to August time period is 30,210 acre-feet.

A ten year low flow analysis of inflows and outflows indicated that the flow augmentation pool at six of the seven projects could be filled by August 5 when filling began on June 1. The flow augmentation pool at Tully Lake would not fill under this scenario. In higher flow years the pools would fill more rapidly. Further studies should address the possibility of beginning filling of some of the reservoirs in May.

In a low flow year, water would be available for release from the reservoirs in August. In higher flow years flow releases may be possible from June through August. Once filling of the flow augmentation pool is completed, flow releases could be made from one reservoir or from several reservoirs simultaneously in order to make up the required flow volume to keep the Montague gage from falling below 4,900 cfs. Release of augmentation flows from Corps reservoirs would need to be coordinated with the hydropower interests on the river as the river is dispatched on a daily basis by New England Power Exchange based on anticipated water availability and electric demand.

Analysis indicated that if 30,210 acre-feet had been available for release in August, potential annual savings in Quabbin required releases would have ranged from 0 to 630 million gallons with a median savings of 350 million gallons. The days of flow augmentation would have ranged from 0 to 14 with a median of 7 days. If the 30,210 acre-feet had been available for release in the June to August time period, potential annual savings in releases from Quabbin would have ranged from 150 to 810 million gallons with a median savings of 400 million gallons.

Impacts associated with storing and release of water at the Corps reservoirs in the June to August time frame include impacts to water quality, wetlands, fisheries, wildlife, historic properties, recreation, agriculture, and hydropower. Reconnaissance level analysis indicated that these impacts may limit storage at several of the reservoirs and/or require mitigation. Conversely, flow augmentation during low flow periods in the summer might have some positive effects on downstream aquatic life and water quality.

Impacts identified that may limit water storage and/or require mitigation are listed below, however detailed assessment of all impacts would be required if this alternative were to be considered further:

- at Union Village Dam water quality concerns due to releases of metals to the water column from sediments;
- at North Hartland Lake agreement between the Corps and the Vermont Electric Cooperative relative to hydropower generation at the existing pool elevation;
- At North Springfield Lake inundation of spawning and nursery habitat could have a significant adverse impact on an excellent largemouth bass fishery;
- at Townshend Lake presence of a rare freshwater mussel, the brook floater, a candidate Federal threatened and endangered species below Townshend;
- at Townshend Lake impacts on a beach, parking lot and boat ramp which provides the only local opportunity for swimming and boating;
- at Otter Brook Lake impact on a parking lot, picnic area, boat ramp, and beach;
- at Tully Lake inundation and possible degradation of approximately 275 acres of wetlands and the possible presence and impact on a population of the tiny cow lily, a rare state-listed aquatic plant;
- and at Tully Lake degradation caused by inundated vegetation and large increase in hydraulic residence time present the potential for impacts on water quality;
- at Tully Lake impact on small camping area and boat ramp.

The annual cost of the seasonal flow augmentation storage is based on water storage pricing policy established by Corps regulation and is estimated at about $1,400,000. A large portion, about $1,100,000, of this annual cost is attributable to the lost recreation benefits at the projects.

If this alternative were to be considered further detailed environmental studies would be required. Preparation of a Federal Environmental Impact Statement might be required depending on the final configuration of the alternative. Public hearings would be held as part of the process for determining whether the public interest is best served by water supply or by recreation.

It is apparent that with the limited flow augmentation volume that could be provided at the Corps reservoirs a more practical approach from a hydrologic point of view is the gallon for gallon alternative discussed in the Corps 1982 report. This alternative is to make the required additional flow releases from Corps reservoirs instead of from Quabbin. However, this approach would require a letter from MWRA to NED requesting review and modification of the War Department Permit requirements and would require detailed study of the release requirements and the impacts of modifying the requirements.

Data and analysis presented in this report should provide the Massachusetts Water Resources Authority with sufficient information to determine if further investigation of the alternative to use Corps of Engineers Reservoirs for flow augmentation is warranted.

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APPENDIX A

HYDROLOGY APPENDIX

APPENDIX A

TABLE OF CONTENTS

Paragraph	Subject	Page
1	INTRODUCTION	
	a. Background	A-1
	b. Purpose	A-1
	c. Scope of Work	A-1
2	DESCRIPTION	
	a. Connecticut River Basin	A-2
	b. Quabbin Reservoir	A-2
	c. Downstream Flow Requirements	A-2
	d. Corps of Engineers Reservoirs Flood Control Operations	A-3
	(1) Union Village Dam	A-3
	(2) North Hartland Lake	A-3
	(3) North Springfield Lake	A-3
	(4) Ball Mountain Lake	A-5
	(5) Townshend Lake	A-5
	(6) Otter Brook Lake	A-5
	(7) Tully Lake	A-5
3	DETERMINATION OF SUPPLEMENTAL STORAGE AVAILABILITY	
	a. General	A-5
	b. General Corps Policy	A-6
	c. Flood Analysis (June - November)	A-6
	d. Flood Analysis (June - August)	A-7
4	FILLING/RELEASE SCHEDULE	
	a. General	A-11
	b. Filling Schedule	A-11
	c. Release Schedule	A-12
	d. Travel Time	A-14
5	CONNECTICUT RIVER FLOWS	A-14
6	INCREASE IN WATER RETAINED IN QUABBIN RESERVOIR	A-18
7	SUMMARY	A-21

LIST OF TABLES

Table	Title	Page
A-1	Quabbin Reservoir Pertinent Data	A-2
A-2	Corps of Engineers Flood Control Projects In The Connecticut River Basin Above Montague City Gage	A-4
A-3	Historic Floods and Standard Project Floods - HEC-1 Analysis	A-8
A-4	Maximum Pool Levels Experienced Since Construction (June - August)	A-9
A-5	Assessment of Available Seasonal Storage at Corps of Engineers Reservoirs (June - August)	A-10
A-6	Filling/Release Schedule	A-13

LIST OF FIGURES

Figure	Title	Page
A-1	Schematic of Travel Times 100 & 200 cfs	A-15
A-2	Connecticut River Travel Times	A-16
A-3	Flow Duration Curves (June - November)	A-17
A-4	Monthly Flow Duration Curves (June, July, August)	A-19
A-5	Water Savings at Quabbin Reservoir	A-20
A-6	Frequency Analysis of Potential Savings	A-22

LIST OF PLATES

Plate	Title
A-1	Connecticut River Basin
A-2	Reservoir Filling
A-3	Reservoir Drawdown
A-4	Travel Times
A-5	Reservoir Area & Capacity Curves

APPENDIX A
HYDROLOGIC ANALYSIS
FOR SECTION 22, RECONNAISSANCE INVESTIGATION
CONNECTICUT RIVER FLOW AUGMENTATION

1. INTRODUCTION

a. Background. In 1982 NED conducted a study considering the possible use of Corps of Engineers reservoirs to meet existing Quabbin Reservoir requirements for increased stream flow to the Connecticut River. The study was conducted under Section 22 authority at the request of the Massachusetts Office of Environmental Affairs.

The objective of the 1982 study was to determine the relative increase in safe yield from Quabbin Reservoir that might result from the use of seasonal storage at Corps reservoirs. This storage would be used to replace additional flow requirements from Quabbin Reservoir at times of low flow on the Connecticut River.

b. Purpose. Although the current study is to build on the previous study, focus has been redirected to the determination of possible Connecticut River flow augmentation with the use of Corps reservoirs. By augmenting riverflows during the June to November time period, additional releases from Quabbin Reservoir would be made less frequently.

c. Scope of Work. Following is a summary of the major analysis conducted for the current study:

Determination of supplemental storage available at Corps reservoirs which may be used for flow augmentation of the Connecticut River. Determination of the supplemental storage was based on impacts to flood control only.

Develop possible reservoir filling and release scenarios which could be used as a guide any year.

Analysis of Connecticut River flows at the Montague City gage for the period of concern (June - November).

Determine a relationship between amount of volume available for augmentation and increase in water retained in Quabbin Reservoir.

2. DESCRIPTION

a. Connecticut River Basin. The Connecticut River Basin, the largest basin located almost entirely in New England is shown on plate A-1. With a total drainage area of 11,250 square miles, it extends in a southerly direction from the Canadian Border in the State of New Hampshire to Long Island Sound in Connecticut. The drainage area at the Montague City gage, a pertinent location for this study, is 7,865 square miles. The main stem of the Connecticut River is over 400 miles in length. It has a total fall of about 2,650 feet, and one half of this total fall in the initial 30 miles from its origin.

b. Quabbin Reservoir. This reservoir is located in the Chicopee River watershed in central Massachusetts. It is part of the MWRA MDC system of water supply to Metropolitan Boston along with Wachusett, Sudbury and three Framingham reservoirs. The Metropolitan District Commission (MDC) Water Supply Study of July 1983 reports an adopted safe yield value of 300 mgd for the entire system excluding the Sudbury Reservoir. The Quabbin Reservoir has been in operation since 1942, and has a usable capacity of 416 billion gallons (1,280,200 acre-feet) equivalent to 129 inches of runoff from its 186-square mile watershed. The reservoir has sufficient storage capacity to regulate all watershed runoff so the dependable water supply yield is equal to the long term average annual runoff from the watershed minus reservoir evaporation and downstream releases. Long term average annual runoff of the Quabbin watershed is about 203 mgd (314 cfs), and average annual lake evaporation has been estimated at 15 mgd (23 cfs). Pertinent data on Quabbin Reservoir is listed in table A-1.

TABLE A-1

QUABBIN RESERVOIR
PERTINENT DATA

Drainage Area	186 square miles
Average Annual Runoff	203 mgd (314 cfs)
Water Surface Area	38 square miles

c. Downstream Flow Requirements. The Massachusetts Legislature requires releases be made from Quabbin Reservoir to insure the flow of the Swift River is a minimum of 20 mgd at all times. In addition, in the interest of

navigation on the Connecticut River, a permit issued by the Department of War in 1929 requires releases from Quabbin Reservoir between June 1 and November 30 of 70 cfs (about 45 mgd) when flows at the Montague City gage becomes less than 4,900 cfs and releases of 110 cfs (about 71 mgd) whenever the flow at Montague is 4,650 cfs or less.

d. Corps of Engineers Reservoirs/Flood Control Operations. The Corps of Engineers operates and maintains nine flood control reservoirs in the Connecticut River Basin upstream of the Montague City gage (location where flows are measured to determine required releases at Quabbin). The projects are operated for flood control along the main stem of the Connecticut River and its individual tributaries. Pertinent data of the reservoirs are contained in table A-2.

In the 1982 study, it was determined that 2 of 9 projects be ruled out. Due to its limited flood control storage (5.3 inches of runoff), Birch Hill Dam should not be considered. The Surry Mountain project is also ruled out due to its location with respect to the city of Keene and the limited downstream channel capacity. A brief description of the seven reservoirs considered for this study follows. Locations of these projects are shown on plate A-1.

(1) Union Village Dam. This project, completed in June 1950, is located in east-central Vermont on the Ompompanoosuc River at Union Village, about 4 miles upstream of the confluence of the Ompompanoosuc and Connecticut Rivers. The project has no permanent pool, a drainage area of 126 square miles, and 38,000 acre-feet of storage for flood control only.

(2) North Hartland Lake. This project, completed in June 1961, is located in east-central Vermont on the Ottauquechee River, 1.2 miles west of North Hartland, about 1.3 miles upstream of the confluence of the Ottauquechee and Connecticut Rivers. The project has a drainage area of 220 square miles, a permanent pool of 215 acres, and 68,750 acre-feet of available storage for flood control. In 1985, the project was retrofitted to allow for installation of a non-Federal hydropower generating plant.

(3) North Springfield Lake. This project, completed in September 1960, is located in east-central Vermont on the Black River, 3 miles northwest of North Springfield, Vermont, and about 8.5 miles upstream of the confluence of the Black and Connecticut Rivers. The reservoir has a drainage area of 158 square miles, a permanent pool of 100 acres, and 50,000 acre-feet of available storage for flood control.

TABLE A-2
CORPS OF ENGINEERS FLOOD CONTROL PROJECTS
IN THE CONNECTICUT RIVER BASIN
ABOVE MONTAGUE CITY GAGE

Project Name	Tributary Stream	Drainage Area (sq. mi.)	Flood Control Capacity ** (ac-ft)	Equivalent Runoff (inches)	Growing Season Channel Capacity (cfs)
Union Village	Ompompanoosuc R.	126	38,000	5.6	2,400
North Hartland	Ottauquechee R.	220	68,750	6.0	6,000
North Springfield	Black R.	158	50,000	5.9	3,500
Ball Mountain	West R.	172	52,600	6.0	5,000
Townshend	West R.	106(net)	32,800	5.8	9,500
Surry Mountain*	Ashuelot R.	100	31,200	5.9	800
Otter Brook	Otter Brk.	47	17,600	7.0	650
Birch Hill*	Millers R.	175	49,900	5.3	2,000
Tully	Tully R.	50	20,600	8.3	600

* Ruled out of the study
** Summer Flood Control Capacity

(4) Ball Mountain Lake. This project, completed in October 1961, is located in southeastern Vermont on the West River at Jamaica and Londonderry, about 29 miles upstream of the confluence of the West and Connecticut Rivers. The reservoir has a drainage area of 172 square miles, a seasonal pool which varies from 25 feet (winter) to 65 feet (summer) and 52,600 acre-feet of available storage for flood control at the summer pool.

(5) Townshend Lake. This project, completed in June 1961, is located in southeastern Vermont on the West River at Townshend, about 19.5 miles upstream of the confluence of the West and Connecticut Rivers. The reservoir, located downstream from Ball Mountain, has a net drainage area of 106 square miles, a permanent pool of 95 acres, and 32,800 acre-feet of available storage for flood control.

(6) Otter Brook Lake. Placed in operation in September 1958. Otter Brook Lake is located in Keene, New Hampshire on Otter Brook, a tributary of the Branch River, which in turn is a tributary of the Ashuelot River. The dam is 2.7 miles above the confluence of Otter and Minnewawa Brooks, which form the Branch River. The reservoir has a drainage area of 47 square miles, a recreation pool of 80 acres, and 17,600 acre-feet of available storage for flood control and recreational purposes.

(7) Tully Lake. This project, completed in September 1959, is located in Royalston on the East Branch Tully River, about 23.6 miles above the confluence of the Millers and Connecticut Rivers. The reservoir has a drainage area of 50 square miles, a recreation pool of 280 acres, and 20,600 acre-feet available storage remaining for flood control.

3. DETERMINATION OF SUPPLEMENTAL STORAGE AVAILABILITY

a. General. The primary purpose of Corps reservoirs is flood control; therefore, any seasonal encroachment must not have a significant impact on flood control capability. It has been concluded, in past studies, that flood control storage requirements are generally somewhat less during June and July than during the fall hurricane and spring snowmelt seasons. It is, therefore, conceivable that a small amount of storage might be used to retain late spring runoff for release later in the summer. In order to quantify an amount of storage that might be available, the following information was gathered and analysis conducted.

b. General Corps Policy. The main purpose of Corps reservoirs is flood control. However, small deviations in project operation are considered if such deviations do not impact the primary function. The Digest of Water Resources Policies and Authorities (EP 1165-2-1), dated 15 February 1989, states that " ... 15 percent of total storage capacity allocated to all authorized Federal purposes or 50,000 acre-feet, whichever is less, may be allocated from the storage serving authorized purposes to storage serving municipal or industrial supply within the Chief of Engineers discretionary authority." Any reallocation of storage above 15 percent of the total storage of a project would require Congressional reauthorization of the project.

It is recognized that the reallocated storage would not specifically serve a municipal or industrial water supply; however, it would be used to increase available water at an existing municipal water supply reservoir. Therefore, 15 percent of total storage was considered an upper limit for the purposes of this study. Each reservoir was evaluated with various increments of lost flood control storage (up to 15 percent) to determine the maximum acceptable encroachment into flood control.

c. Flood Analysis (June Through November). The 6-month time period from June through November was analyzed because this is when increased Quabbin releases are required. Critical historic floods that occurred during this timeframe were analyzed as well as the Corps of Engineers Standard Project flood. The historic floods that were analyzed for this timeframe were the September 1938 and November 1927 events. In addition, since the reservoirs would be impacted for a considerable time (6 months), historic floods that have occurred outside this timeframe (March 1936 and April 1987) were analyzed. It is recognized that these two flood events were associated with some snowmelt; however, an analysis provides important information as to individual reservoir response to a major flood event.

To facilitate the analysis, the September 1990 version of the HEC-1 "Flood Hydrograph Package" was used as a tool to aid in determining possible available storage at the 7 selected reservoirs. The available inflow hydrographs for the historic events were routed through individual reservoirs using HEC-1 with varying initial encroachments into flood control storage of 0, 0.5, and 1 inch of runoff, respectively.

The results of these routings were used as a guide to determine the likely upper limit for the use of a 6-month

seasonal storage. Table A-3 displays summary results of the HEC-1 analysis. Again, it is noted that the March 1936, and April 1987 flood occurred outside the period of interest. The November 1927 flood, was a major Upper Connecticut Basin event but little data are available. It is noted however, that a recurrence of this flood would result in 0.4 inch of available storage at Union Village. With consideration of historic flood data available and analysis of the results presented in table A-3, it was determined that for a prolonged period of time (6 months) 0.5 inch of encroachment into flood control would be a reasonable limit. This value is in agreement with the results of the 1982 study, and would represent about 24,000 acre-feet of available storage.

d. Flood Analysis (June Through August). Since the intent of this study is to determine the amount of storage available for flow augmentation, it is apparent (in analysis discussed in paragraph 3c) that storage provided by Corps reservoirs would be somewhat limited. Therefore, it was decided to shorten the impacted period of time from June through August and determine if additional storage could be provided, if this shorter time period were considered.

The period of record since construction of the selected reservoirs was analyzed. Table A-4 was developed to show maximum pool levels experienced for the months of June, July, and August, from the time each project was constructed. The total storage utilized during these storms is also shown along with unused remaining storage available to spillway crest. It should be noted that the June 1984 flood was a large event with rare frequency of occurrence, particularly within the Ashuelot River watershed. The impact of those storms in each reservoir was significant; however, there was considerable storage remaining in most reservoirs.

The final encroachment allowable into flood control was determined by analyzing the information shown in table A-4 with the final attainable encroachment shown in table A-5. This table presents the increase in storage allowable over the present summer pool, and the elevation and area increases brought by the additional storage. Two important factors in the determination of allowable encroachment were the remaining reservoir storage available for flood control operations, and the total reservoir storage capacity. This final allowable volume was selected based on engineering judgement along with consideration for past experienced floods, remaining available storage, and Corps policy criteria mentioned in section 3b of this appendix. The supplemental storage is determined to be a total of 22,340 acre-feet, which added to the existing summer levels in the seven reservoirs, brings

TABLE A-3

CORPS OF ENGINEERS RESERVOIRS

HISTORIC FLOODS AND STANDARD PROJECT FLOODS

HEC-1 ANALYSIS

PROJECT	ENCR	NOVEMBER 1927			MARCH 1936			SEPTEMBER 1938			APRIL 1987			SPF		
		AVAILABLE STORAGE (r.o)	AVAILABLE STORAGE (ac-ft)	PEAK* OUTFLOW (cfs)	AVAILABLE STORAGE (r.o)	AVAILABLE STORAGE (ac-ft)	PEAK* OUTFLOW (cfs)	AVAILABLE STORAGE (r.o)	AVAILABLE STORAGE (ac-ft)	PEAK* OUTFLOW (cfs)	AVAILABLE STORAGE (r.o)	AVAILABLE STORAGE (ac-ft)	PEAK* OUTFLOW (cfs)	AVAILABLE STORAGE (r.o)	AVAILABLE STORAGE (ac-ft)	PEAK* OUTFLOW (cfs)
UNION VILLAGE	0	0.4"	3,000	0	N / A			N / A			3.8"	25,500	0	0	0	12,100
	0.5	0	0	700							3.3"	22,500	0	0	0	18,000
NORTH HARTLAND	0	N / A			0	0	7,700	2.8"	32,834	0	2.9"	34,472	0	0	0	7,900
	0.5				0	0	8,000	2.3"	27,600	0	2.2"	26.250	0	0	0	10,800
NORTH SPRINGFIELD	0	N / A			0	0	4,600	2.3"	19,600	0	3.0"	25,600	0	0	0	7,700
	0.5				0	0	4,600	1.8"	15,700	0	2.5"	21,200	0	0	0	9,600
BALL MOUNTAIN	0	N / A			0	0	4,000	2.1"	20,090	0	0	0	3,700	0	0	5,200
	0.5				0	0	5,500	1.7"	15,590	0	0	0	4,800	0	0	12,200
TOWNSHEND	0	N / A			0.4"	2,250	0	1.9"	11,040	0	0	0	7,400	0	0	14,600
	0.5				0	0	1,600	0.6"	3,750	0	0	0	10,700	0	0	17,900
OTTER BROOK	0	N / A			0	0	1,300	0	0	1,100	0	0	1,100	0	0	1,300
	0.5				0	0	1,400	0	0	1,000	0	0	1,200	0	0	2,000
TULLY LAKE	0	N / A			0.5"	1,325	0	0.2	500	0	3.5	9,325	0	0	0	900
	0.5				0	0	200	0	0	300	2.6	6,925	0	0	0	1,700

* Peak Outflow - This term is defined as the maximum project outflow during the flood event and does not represent controlled releases which would be made following the event.

TABLE A-4

CORPS OF ENGINEERS RESERVOIRS

HIGHEST POOL LEVELS EXPERIENCED

DURING THE MONTHS OF JUNE, JULY AND AUGUST

Project	Month/Year	Storage Utilized Runoff (inches)	Storage Utilized Total (percent)	Storage Remaining* Runoff (inches)
Union Village	June 1984	2.3	40	3.3
(1950-1991)	July 1973	1.8	33	3.8
	Aug 1955	0.4	7	5.2
North Hartland	June 1984	3.3	55	2.7
(1962-1991)	July 1973	3.0	50	3.0
	Aug 1976	1.3	21	4.7
North	June 1984	3.8	64	2.1
Springfield	July 1973	3.9	66	2.0
(1962-1991)	Aug 1976	1.4	24	4.5
Ball Mountain	June 1984	4.4	75	1.6
(1962-1991)	July 1973	3.5	59	2.5
	Aug 1976	2.8	47	3.2
Townshend	June 1984	4.0	68	1.8
(1962-1991)	July 1973	2.3	41	3.5
	Aug 1976	1.0	18	4.8
Otter Brook	June 1984	5.7	82	1.3
(1958-1991)	July 1986	1.5	20	5.5
	Aug none above 11% full			6.2 min.
Tully	June 1984	5.0	61	3.3
(1951-1991)	July 1975	0.8	10	7.5
	Aug none above 10% full			7.5 min.

*Storage remaining is the difference between the storage utilized and total storage at spillway crest elevation

TABLE A-5

ASSESSMENT OF AVAILABLE SEASONAL STORAGE *

AT CORPS OF ENGINEERS RESERVOIRS

JUNE-AUGUST

Project	Summer Pool			Total Allowable Storage **						
	Elev. (ft NGVD)	Volume (ac-ft)	Area (acres)	Addit. R.O. (inches)	Addit. Storage (ac-ft)	Total R.O. (inches)	Total Storage (ac-ft)	Elev. (ft NGVD)	Area (acres)	Remaining Available Flood Control Storage (inches)
Union Village	420	0	0	0.6	4,030	0.6	4,030	485	190	5.0
North Hartland	425	2,350	215	0.4	4,690	0.6	7,040	444	350	5.4
North Springfield	467	500	100	0.54	4,550	0.6	5,050	484	414	5.3
Ball Mountain	870.5	2,000	75	0.38	3,500	0.6	5,500	900	145	5.4
Townshend	478	800	95	0.45	2,590	0.6	3,390	494	271	5.2
Otter Brook	701	720	70	0.51	1,280	0.8	2,000	714	162	6.2
Tully	641	1,500	305	0.63	1,700	1.2	3,200	648	625	7.1
		TOTAL			22,340 (ac-ft)		30,210 (ac-ft)			

* The only impacts addressed were to flood control. Other impacts would need to be evaluated before the feasibility of this plan is determined.

** For the period of June, July and August only

the available storage to 30,210 acre-feet. In 5 of 7 reservoirs under consideration (Union Village, North Hartland, North Springfield, Ball Mountain, and Townshend), the allowable storage was in the order of 10 percent of their total storage capacity. Due to their relatively larger available storage capacity, the two other reservoirs (Otter Brook and Tully Lake) might provide 11 and 15 percent of their total storage capacity, respectively. These are preliminary estimates for these reconnaissance level studies, and would be subject to further review and refinement along with more detailed flood analysis including refined computer modeling during further study efforts.

These encroachments into the reservoir represent an upper limit which would not have a significant impact on the flood control.

4. FILLING/RELEASE SCHEDULE

a. General. Based on supplemental storage findings shown in table A-5, and using the 1 June to 30 August time period, the following possible filling and release schedule was developed. Due to time limitations, it is expected that the filling and release operation be scheduled to only one event per year.

b. Filling Schedule. To determine the time required to fill the reservoirs a low flow frequency analysis was conducted at each reservoir. This analysis was made by analyzing data at the gages downstream of the projects and facilitated by the use of the entire period of record of low flow data from USGS "WATSTORE" data base.

Low flow frequency analyses were conducted to determine the 10-year frequency low flows for various durations. Depending on the required volume to fill at each reservoir, 30, 60, or 90-day, 10-year low flow values were used to compute project inflows. The 10-year frequency low flow was believed to be sufficiently conservative and demonstrated a high confidence that the reservoir would be able to be filled during low flow periods. Two criteria were assumed for project outflows during reservoir filling. The 7-day, 10-year (7Q10) low flow for the June - August period was assumed as the first criteria in each reservoir. In addition to the 7Q10 criteria, the suggested minimum flow, by other agencies of 0.2 csm was also considered for outflow rates during the filling time. These values were assumed or project inflow, whichever was less, and filling times computed. Table A-6 shows the filling time schedule for both the 7Q10 and the 0.2 csm outflow rates. In addition, reservoir

filling is shown graphically on plate A-3. As can be seen, if an outflow criteria of 0.2 csm were adopted, reservoirs would not be able to be filled in time to have all their supplemental storage available for augmentation. As stated previously, the above analysis assumes the reservoirs would begin filling in June.

It is determined that under the 7Q10 criteria, it is possible to have 6 of 7 reservoirs ready to augment flows in the Connecticut River for the timeframe projected. If the second criteria of outflow (0.2 csm) were used for the filling schedule, most reservoirs would be unable to reach the supplemental volume desired in the time period under consideration. The assumed 7Q10 outflow criteria for two reservoirs (North Hartland and Townshend) is greater than the 0.2 csm suggested outflow rate; therefore, the 0.2 csm release rate was not considered.

Two concerns arise when the filling scheduled is considered as starting in June. This is the first month when additional releases are required from Quabbin. Restriction of flow at this time would further increase the need for flow augmentation. June was selected to be conservative in determining reservoir filling times. It is, however, conceptually possible to start filling during the month of May. Since May flows are higher, it is concluded that the filling process would take less time if started during May. By observing the filling schedules depicted in plate A-3, it can be concluded that if the filling process started in May, three reservoirs (North Hartland, Ball Mountain, and Townshend) would take less than 30 days to be filled, and would be ready for drawdown by the beginning of June. Tully Lake would take less than 46 days to be filled, and ready for release by the middle of June. The three additional reservoirs (Union Village, North Springfield, and Otter Brook) would take less than 60 days, and ready for release by the end of June.

c. Release Schedule. Various reservoir outflow rates were assumed to determine possible time required to lower pool levels to normal.

Plate A-4 depicts drawdown time versus pool elevations. The rates shown are only an illustration of the time the supplemental storage would last if released at a specific rate. It does not indicate, however, a limiting flow rate. Higher or lower rates may be utilized based on seasonal needs. Larger release rates would, obviously, result in faster usage of the supplemental storage. This information was included as an aid, and to provide information as to rate

TABLE A-6

CONNECTICUT RIVER FLOW AUGMENTATION

CORPS OF ENGINEERS RESERVOIRS

FILLING/RELEASE SCHEDULE

	10 Year Low Flow Criteria *					0.2 csm Criteria **			
PROJECT NAME	INFLOW DURING FILLING (cfs)	OUTFLOW DURING FILLING (cfs)	OUTFLOW DURING FILLING (csm)	INFLOW MINUS OUTFLOW (cfs)	COMPLETE FILLING BY...	INFLOW DURING FILLING (cfs)	OUTFLOW DURING FILLING (cfs)	INFLOW MINUS OUTFLOW (ac-ft)	FILLING COMPLETE BY
UNION VILLAGE	43	15	0.12	28	AUG 3	43	25	18	* * *
N. HARTLAND	113	60	0.27	53	JUL 5	113	44	69	JUNE 30
N. SPRINGFIELD	57	24	0.15	33	AUG 1	57	32	25	* * *
BALL MOUNTAIN	71	29	0.17	42	JUL 4	71	34	37	* * *
TOWNSHEND	127	56	0.2	71	JUNE 26	127	56	71	JUNE 26
OTTER BROOK	11	2	0.04	9	AUG 5	11	9	2	* * *
TULLY	11	1	0.02	10	AUG 30	11	10	1	* * *

* Outflow data determined by 7Q10 criteria

** Outflow data determined by 0.2 csm for fish and wildlife protection

*** Reservoir will not fill to desired volume within the Jun-Aug period.

of reservoir drawdown and likely supplemental flows available. Additional information concerning individual reservoir area and capacity relationships is shown on plate A-6.

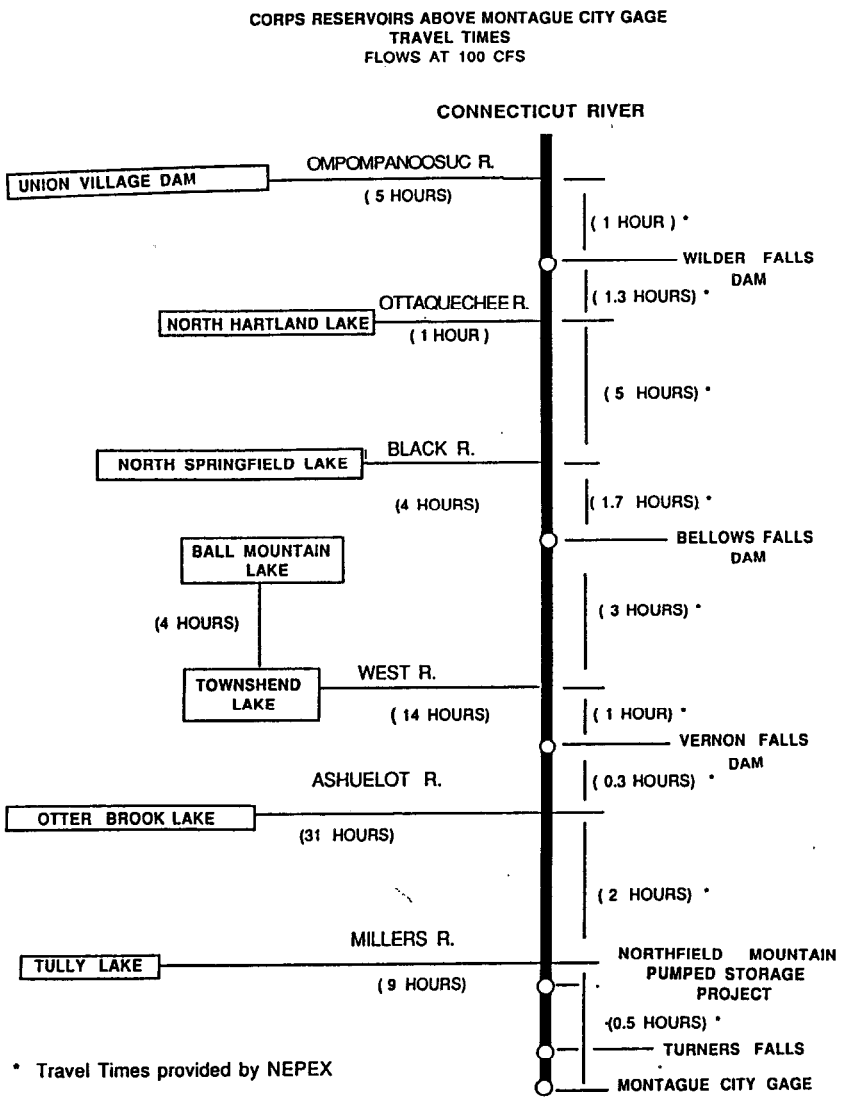
d. Travel Time. Different assumed flow rates were analyzed to estimate travel time from each reservoir to the confluence with the Connecticut River. Travel times, as shown in plate A-5, were computed based on solving Manning's equation for various assumed release rates and with the computed average slope, and an assumed channel width. Computed travel times along individual tributaries to the Connecticut River for 100 and 200 cfs are shown on figure A-1. Also shown on figure A-1 are travel times along the Connecticut River which are used by New England Power Exchange (NEPEX) to establish power release rates and generation.

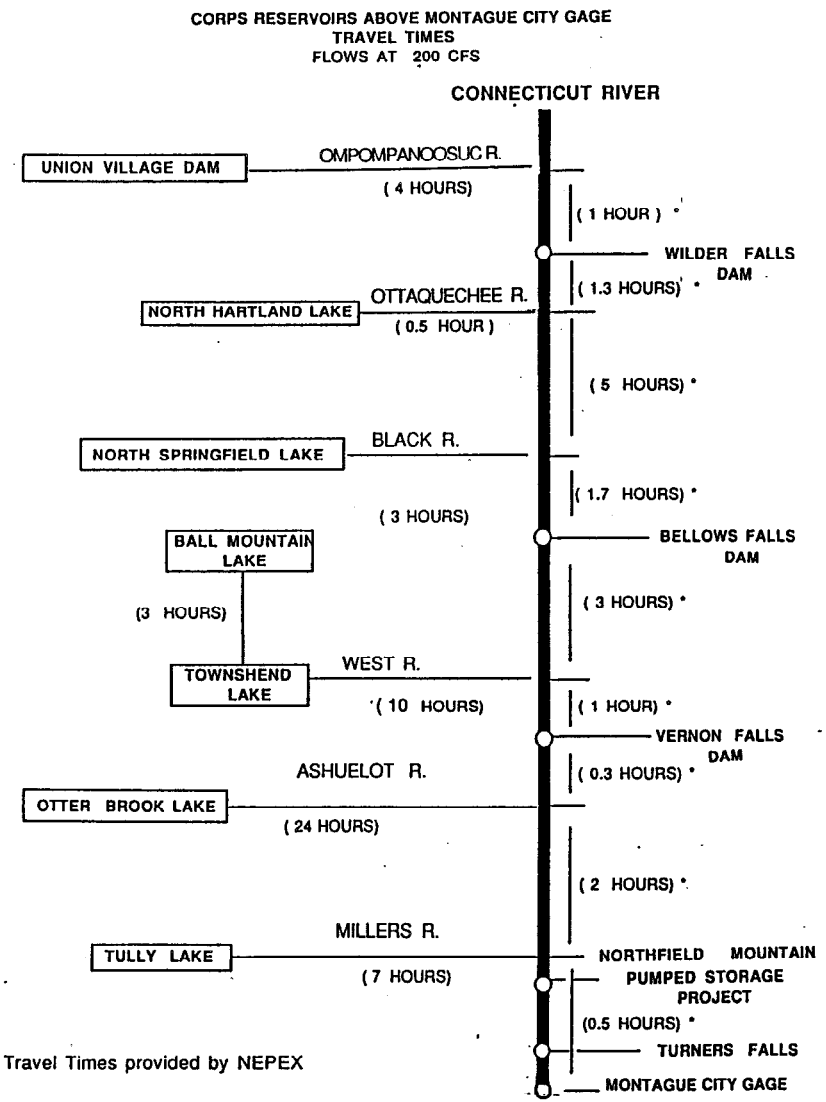
Figure A-2 shows a schematic of the Connecticut River with tributaries and pertinent locations for the current study. Also shown on figure A-2 are travel times along the Connecticut River, as reported by NEPEX, and travel times for an assumed velocity of 2 fps. The 2 fps velocity was selected to give a range that could be more realistic for low flow conditions. As can be seen, there is considerable variation in times reported by NEPEX and those associated with a 2 fps velocity.

5. CONNECTICUT RIVER FLOWS

Flows have been measured at Montague City from 1904 to present. Drainage area at the gage is 7,865 square miles. As stated previously, additional releases are required from Quabbin when low flows are experienced along the Connecticut River between 1 June and 30 November. When flows at the Montague gage drop below 4,900 cfs, required releases from Quabbin are 70 cfs. When flows drop below 4,650 cfs, required releases are 110 cfs. In order to quantify the Connecticut River flow region, a flow duration curve was developed using the USGS "WATSTORE" daily values file. The flow duration curve for the June to November time period is shown on figure A-3. This curve is a graphic presentation of magnitude of riverflow versus percent time during the selected season without regard to sequence of occurrence. Several curves are shown on figure A-3. One represents the entire period of record (1904 to 1990); others represent selected timeframes. A time period from 1957 to 1989 was analyzed because the last large hydropower storage reservoir was constructed and filled in 1956. This period, therefore, represents all aspects of reregulation of riverflows due to hydropower storage operations. Another curve, presented for information purposes only, is for the period from 1972 to

FIGURE A-1
SCHEMATIC OF TRAVEL TIMES
100 & 200 CFS





CONNECTICUT RIVER TRAVEL TIMES
MILE 274 TO 119

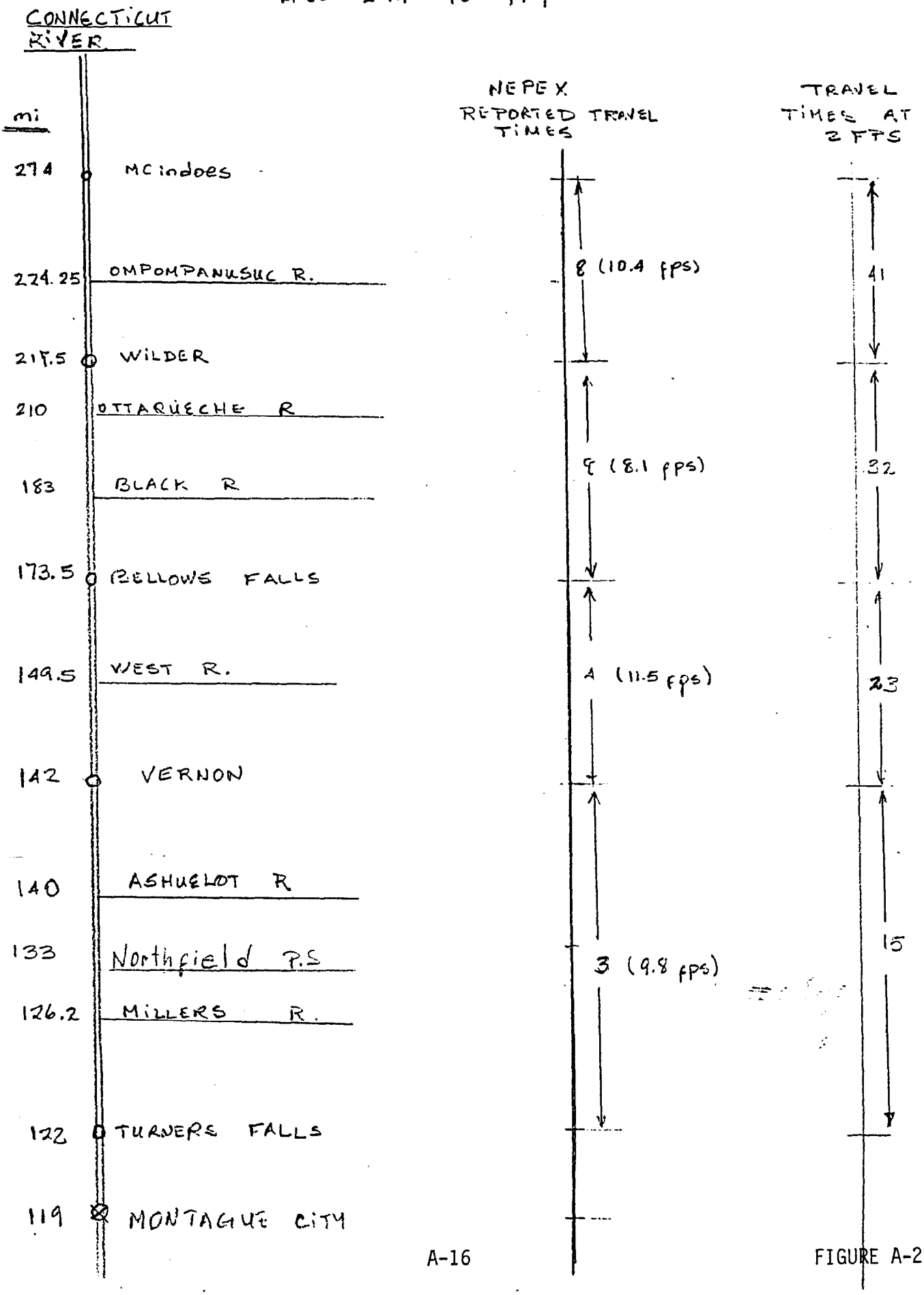


FIGURE A-2

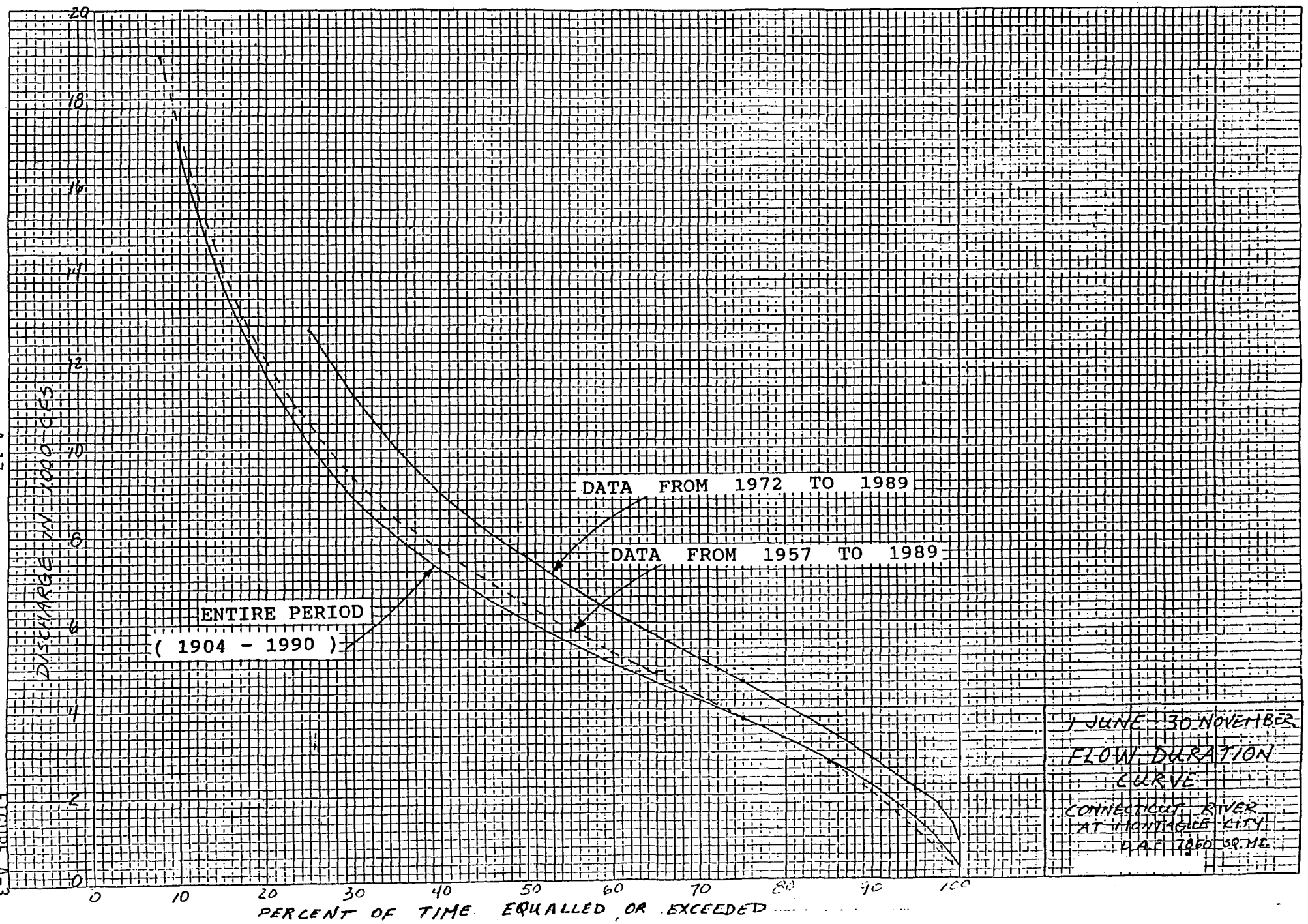

DISCHARGE IN 1000 CFS
20
18
16
14
12
10
8
6
4
2
0
0
10
20
30
40
50
60
70
80
90
100
PERCENT OF TIME EQUALLED OR EXCEEDED
DATA FROM 1972 TO 1989
DATA FROM 1957 TO 1989
ENTIRE PERIOD
(1904 - 1990)
1 JUNE - 30 NOVEMBER
FLOW DURATION
CURVE
CONNECTICUT RIVER
AT MONTAGUE CITY
D.A. 1860 SQ. MI.

FIGURE A-3

1989, and presents flows for the post Northfield Mountain Pumped Storage Project. These flows are considerably higher than the first two time periods analyzed. The 1972 to 1989 time period does not include the sixties drought.

Curves for the two time periods, 1904 to 1990, and 1957 to 1989, are quite similar with flows being less than 4,900 cfs about 36 to 38 percent of the time. Flows are less than 4,650 cfs about 34 percent of the time.

Shown on figure A-4, are monthly flow duration curves for June, July, and August, depicting the monthly flow regime that could be expected during times of flow augmentation. August is a critical month with flow less than 4,900 cfs about 64 percent of the time.

6. INCREASE IN WATER RETAINED IN QUABBIN RESERVOIR

The additional volume of 30,210 acre-feet to be stored in the Corps Reservoirs will provide varying savings in the Quabbin Reservoir releases. This savings depends on the number of days that flows of the Connecticut River fall between 4,900 and 4,650 cfs plus the number of days the flows fall below 4,650 cfs. As an example, in a dry year such as 1964, during June through August, the gage dropped below 4,650 cfs for 58 days, and between 4,650 and 4,900 cfs for 3 days. In a wet year, such as 1940, releases needed dropped to only 6 days in the 3-month period.

Figure A-5 presents a general relationship between the savings in required releases at Quabbin versus the additional volume required to maintain the Connecticut River at Montague City at or above 4,900 cfs for the June to November period. This general relationship shows that a large amount of flow augmentation volume would be required in order to effect the maximum savings in required releases at Quabbin. This relationship does not consider the potential loss of these savings through subsequent reservoir spilling. If this study were to proceed further the flow augmentation alternative could be factored into the system safe yield model to estimate the increased system yield due to savings in required releases from Quabbin.

The number of days of flow augmentation provided by the total volume of 30,210 acre-feet varies, depending on the magnitude of the difference between the actual flows and 4,900 cfs. Daily flows at the Montague gage from 1957 to 1989 were analyzed in order to assess the range in yearly flow augmentation afforded by 30,210 acre-feet of storage. The time period, 1957 to 1989, includes the sixties drought. The last large hydropower storage reservoir became operational in 1957.

Analysis indicated that if 30,210 acre-feet had been available for release in August, potential savings in

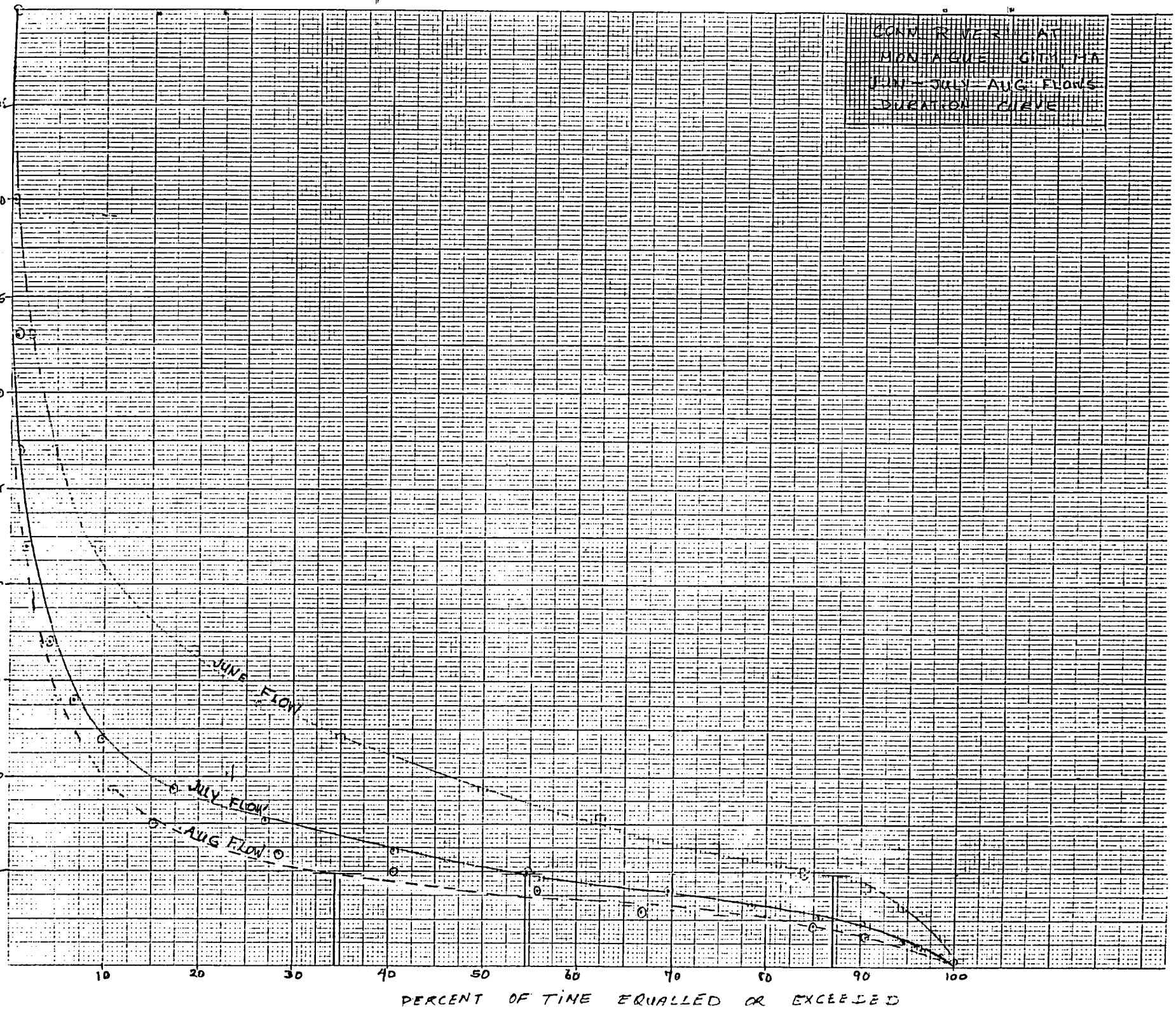


FIGURE A-4

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ADDITIONAL VOLUME WITHIN THE CONNECTICUT RIVER BASIN
TO MAINTAIN MONTAGUE CITY GAGE ABOVE 4900 CFS (1,000 AC-FT)

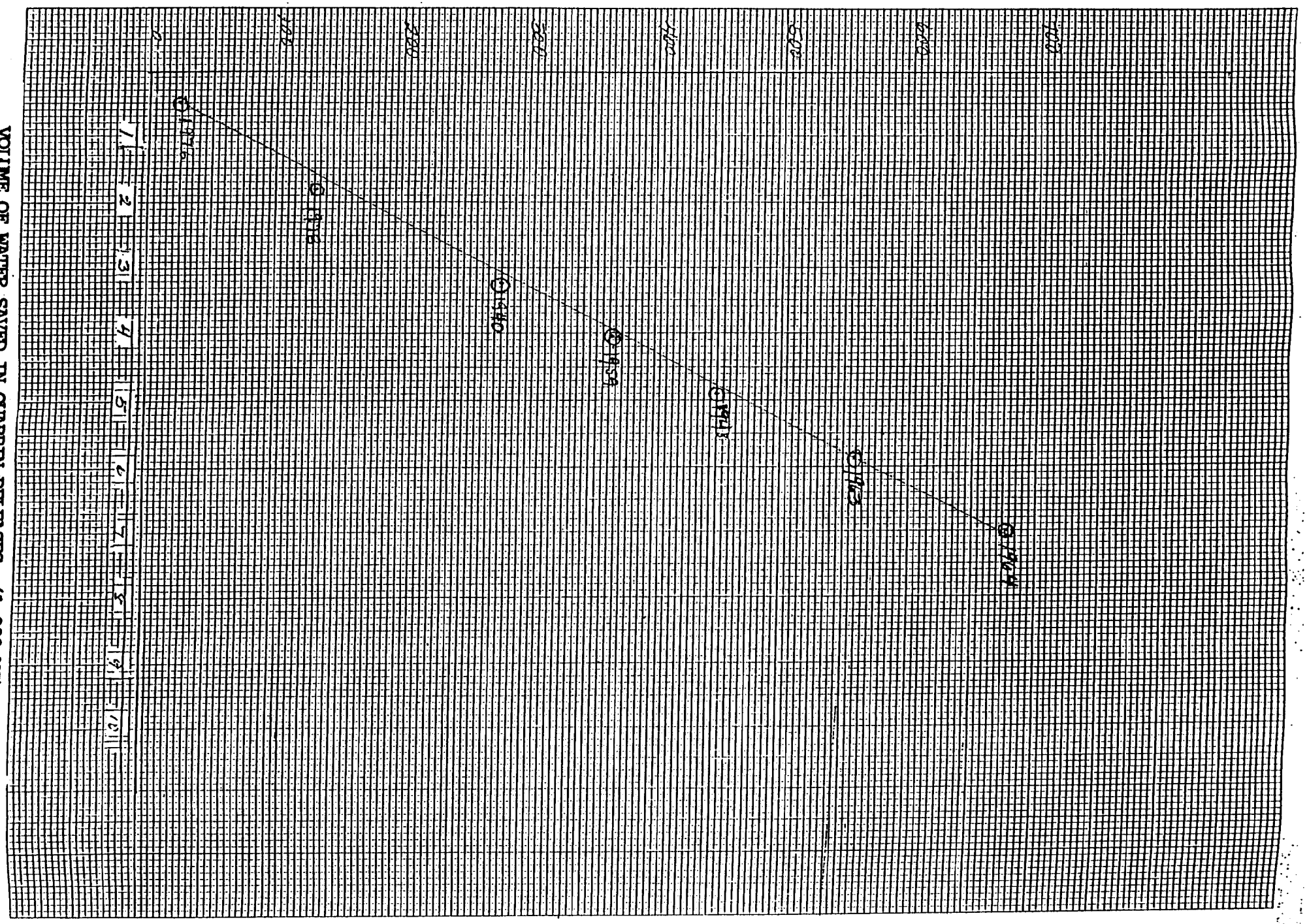


FIG A-5

FIGURE A-5

Quabbin releases would have ranged from 0 to 630 million gallons with a median savings of 350 million gallons. The days of flow augmentation would have ranged from 0 to 14 with a median of 7 days. If the 30,210 acre-feet had been available for releasing in the June to August time period, potential savings in releases from Quabbin would have ranged from 150 to 810 million gallons with a median savings of 400 million gallons. A frequency analysis of this data is presented in figure A-6.

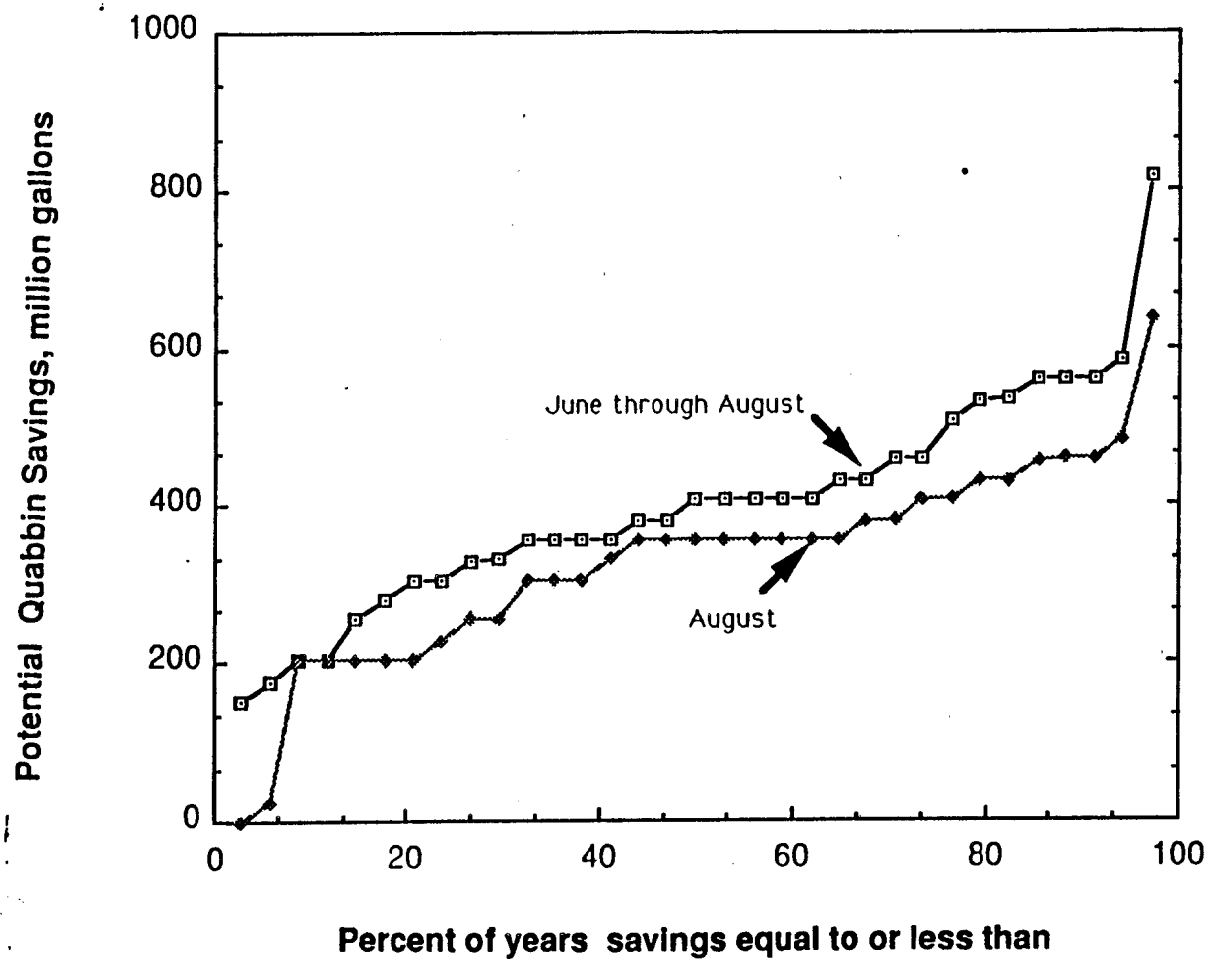
7. SUMMARY

From the hydrologic analysis, it can be concluded that the seven reservoirs studied could provide seasonable storage for flow augmentation of the Connecticut River. It was determined that a total of 22,340 acre-feet could be added to the existing summer levels in the seven reservoirs, bringing available storage to 30,210 acre-feet. Determination of these volumes is based on flood control requirements only. The use of these increments of reservoir storage would not significantly impact flood control capability of Corps reservoirs. Additional hydrologic analysis would be required during feasibility studies, further quantifying impacts to flood control capability. It is not believed, however, that these studies would significantly affect allowable seasonal volumes reported herein.

With an assumed outflow determined by the 7Q10 criteria during the filling process, it is feasible to fill 6 of 7 reservoirs to the level of supplemental storage determined in a 2-month time period.

Although the purpose of this study was to reduce required additional releases from Quabbin Reservoir as much as possible, it is evident that only minimal flow augmentation would be available through the use of Corps reservoirs (i.e., there would not be sufficient storage to have a significant effect on Connecticut River flows for the entire 3-month period).

FIGURE A-6 Frequency Analysis of potential Quabbin Savings using 30,210 ac-ft of Corps Storage, 1957 to 1989



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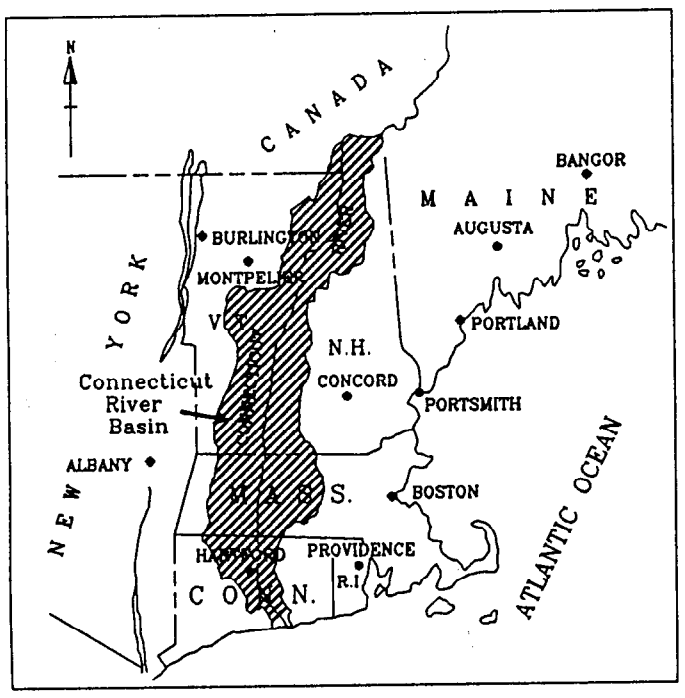
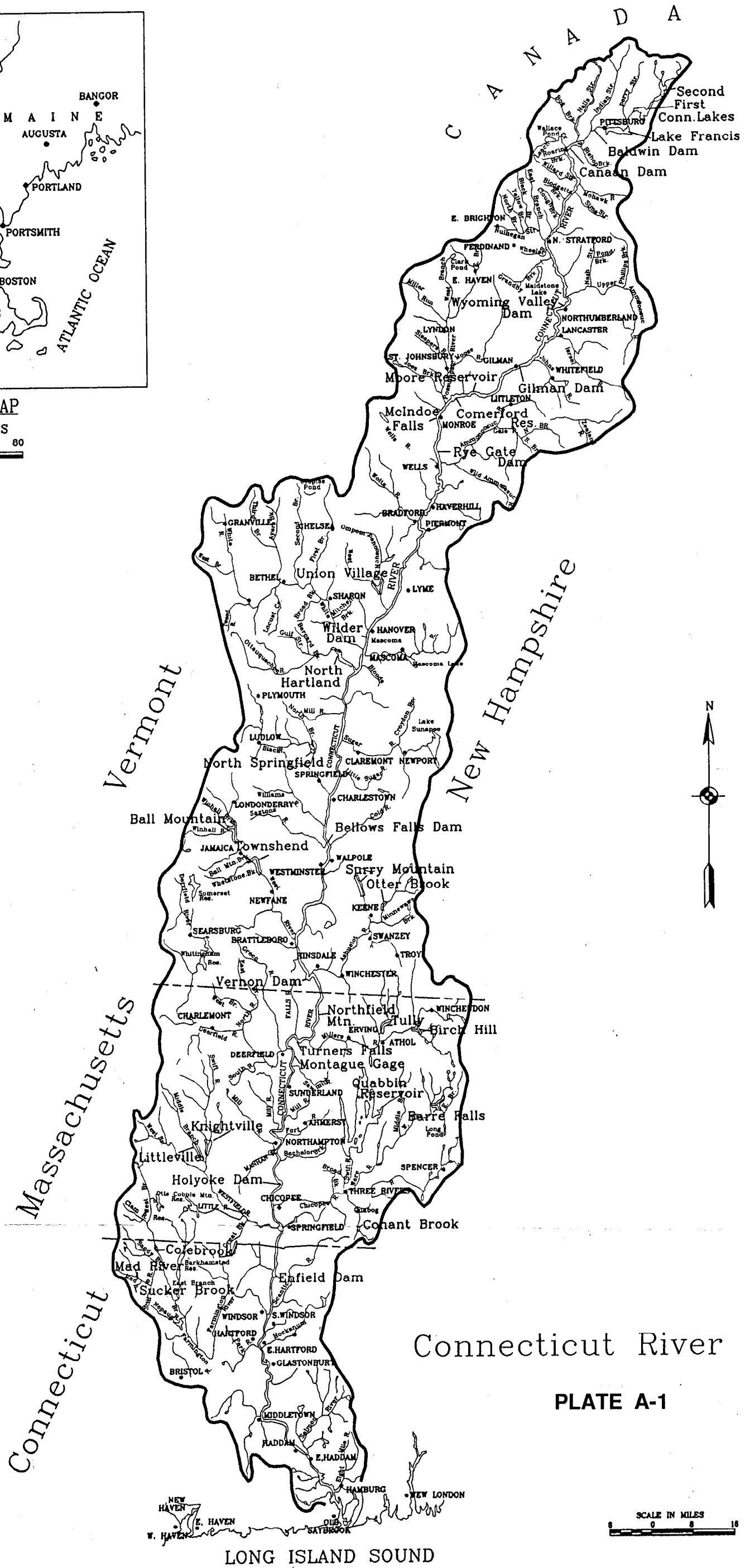


LOCATION MAP

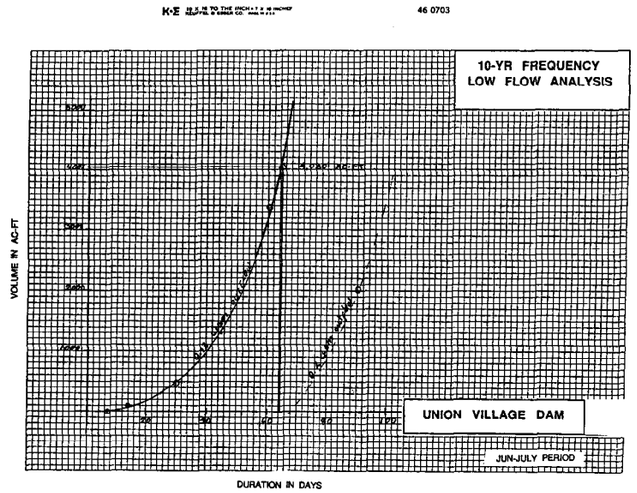
SCALE IN MILES

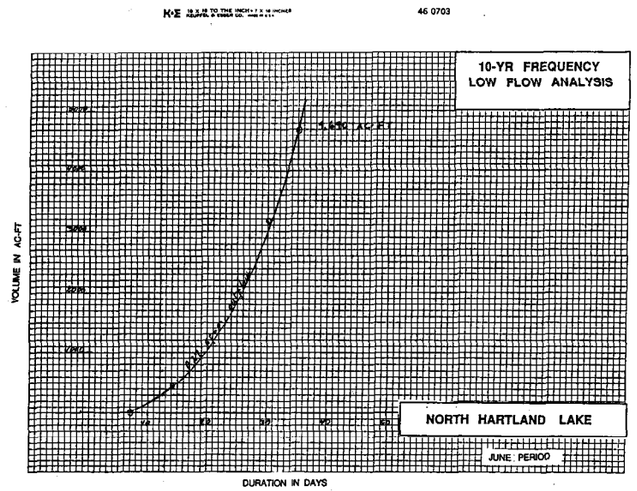
40 0 40 80

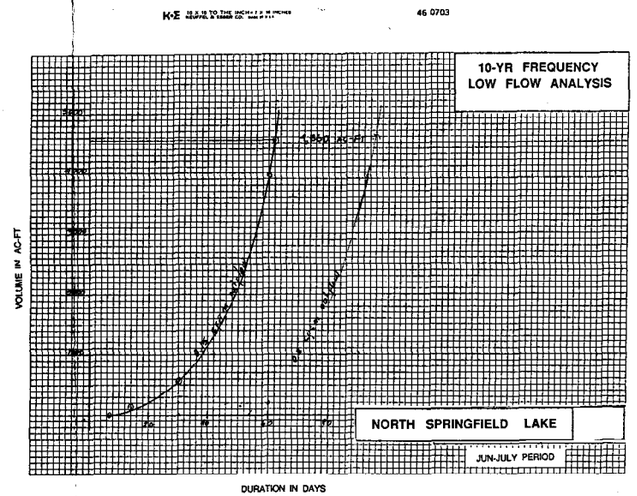


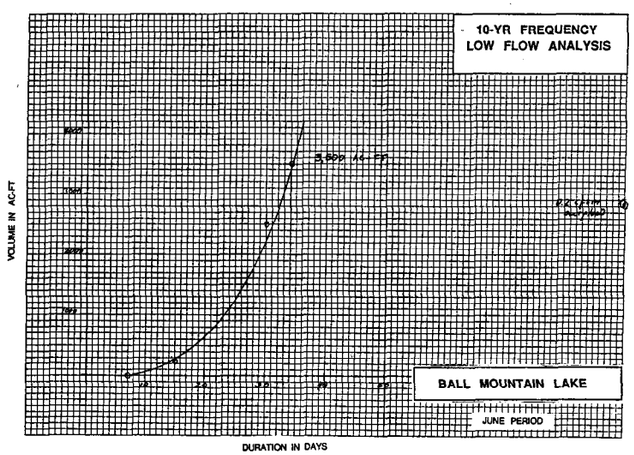
Connecticut River Basin

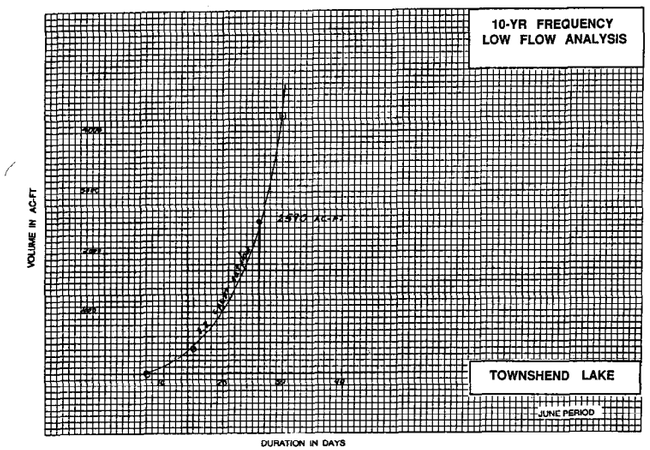
PLATE A-1

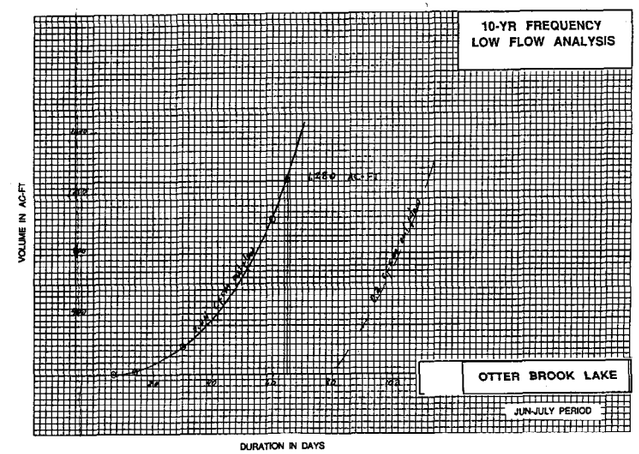


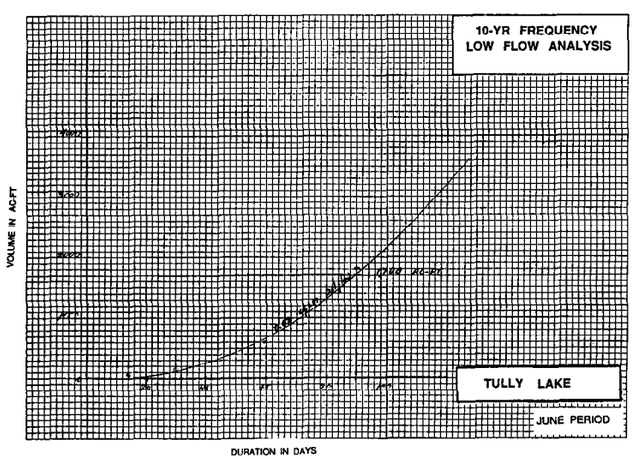












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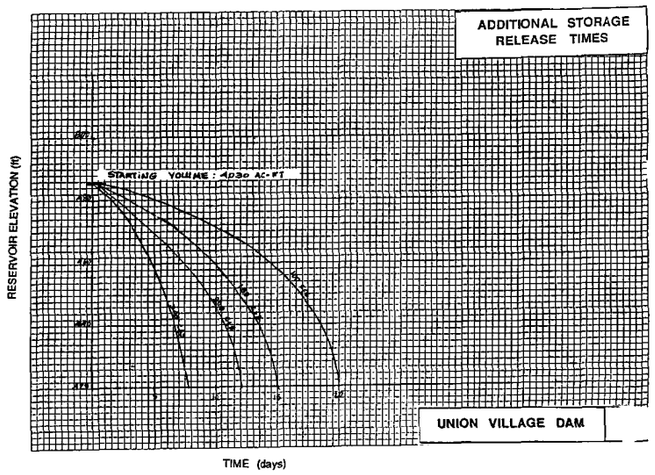
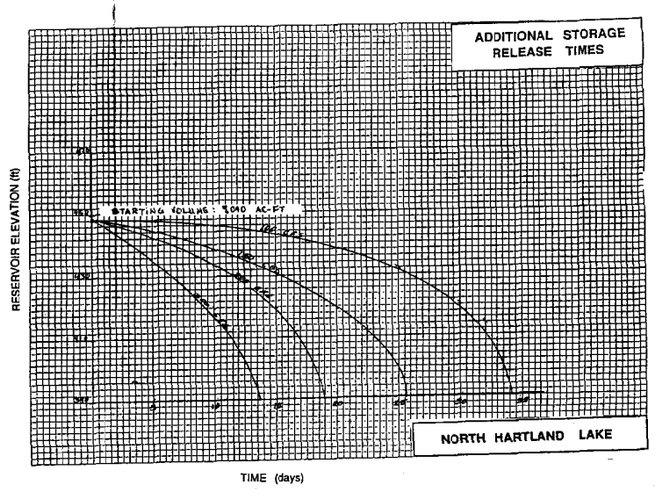
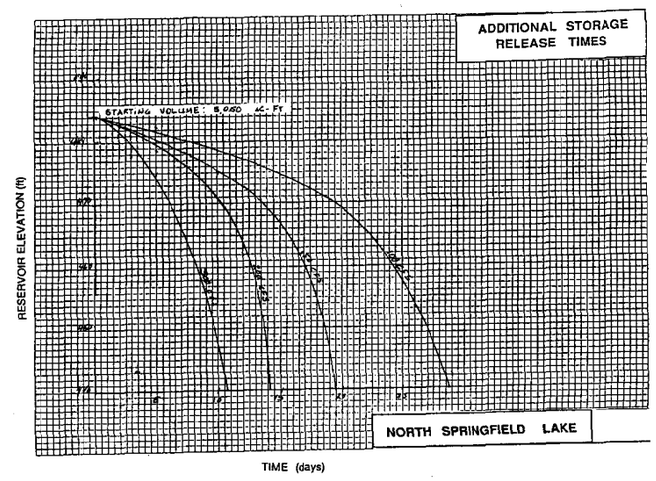
SECTION 22, MWRA
CONNECTICUT RIVER
FLOW AUGMENTATION STUDY

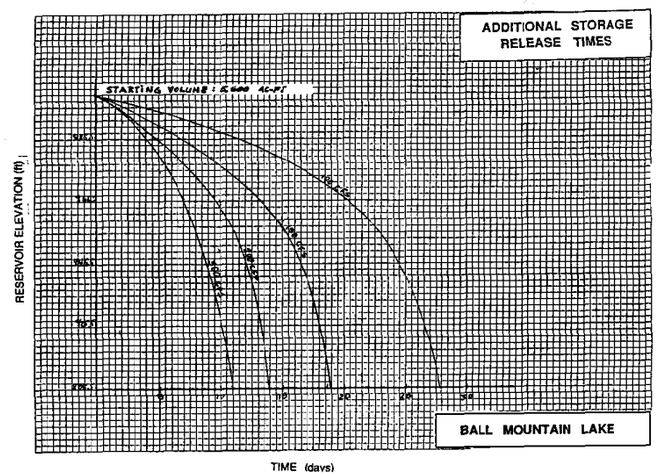
RESERVOIR FILLING

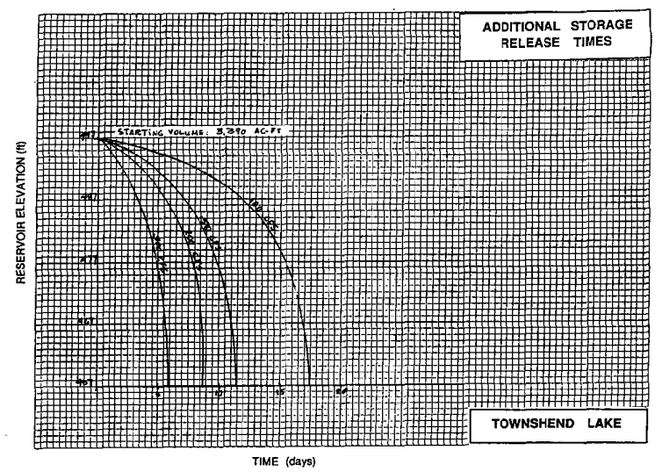
PLATE A-2

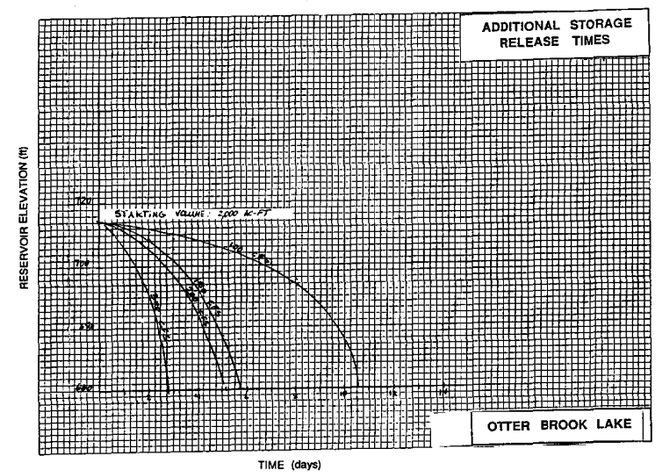


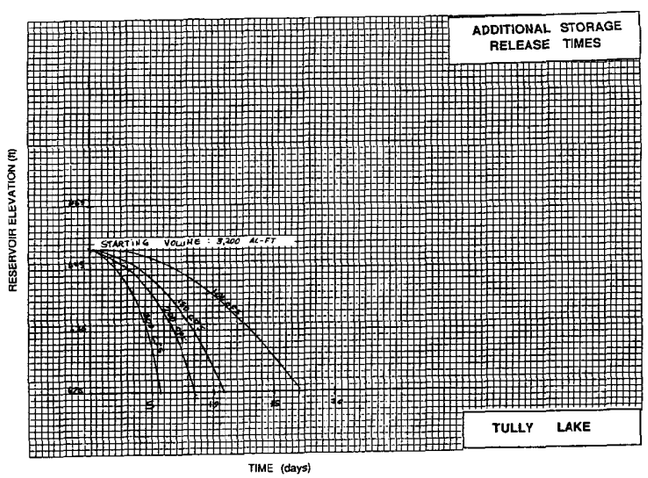












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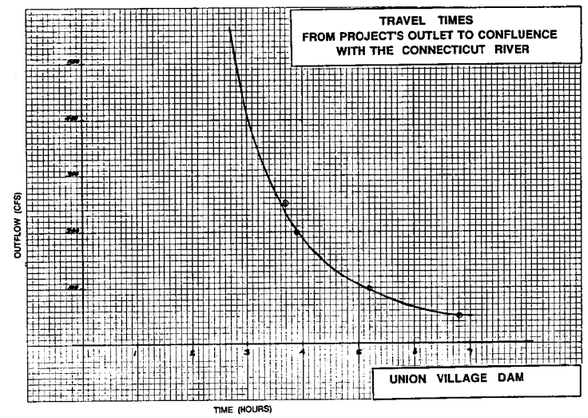
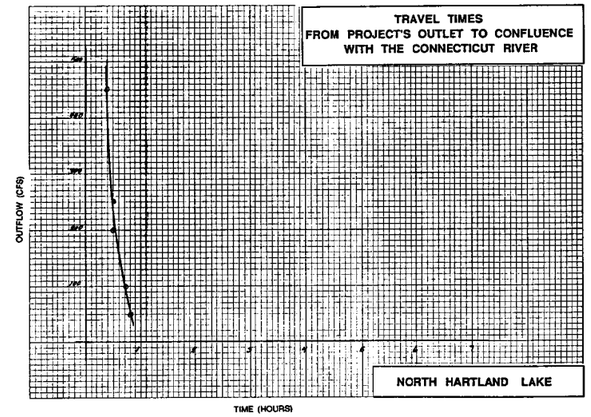
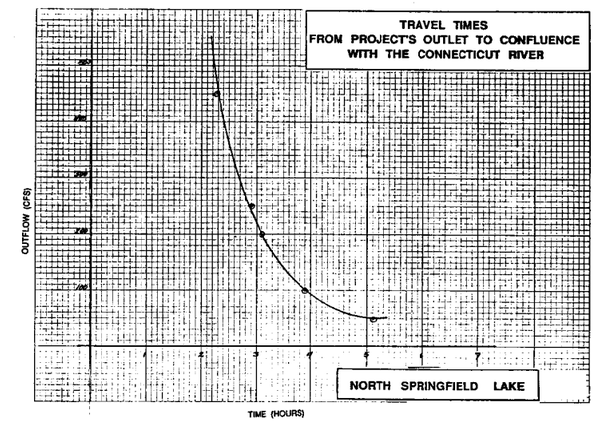
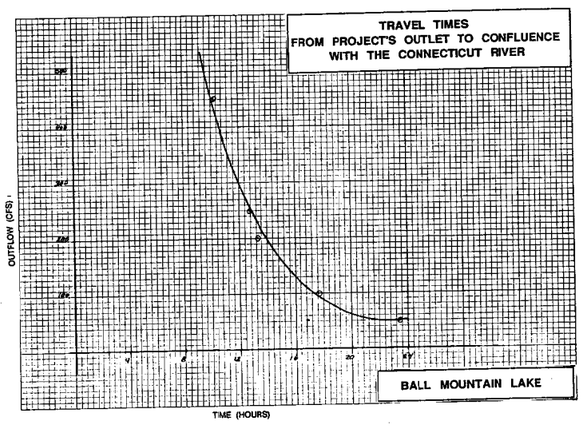
RESERVOIR DRAWDOWN

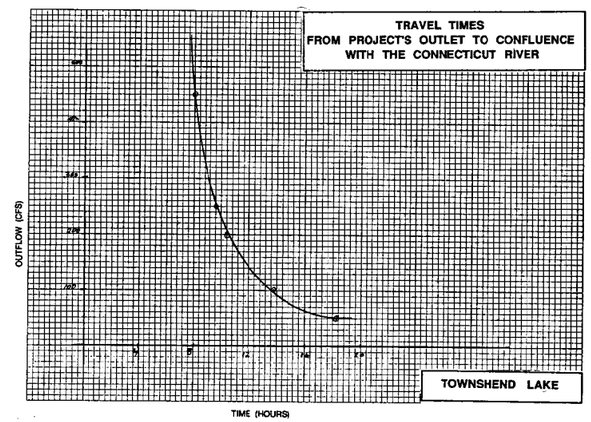
PLATE A-3

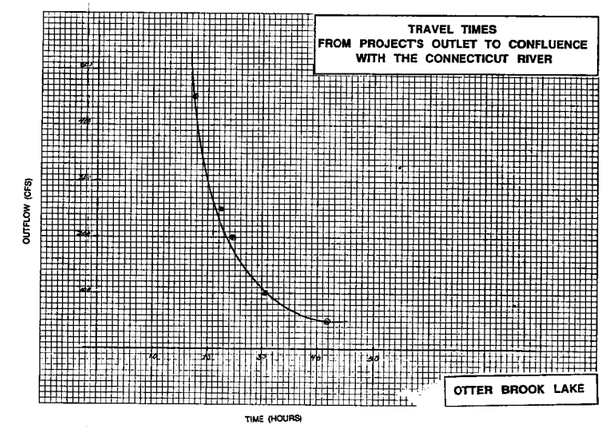


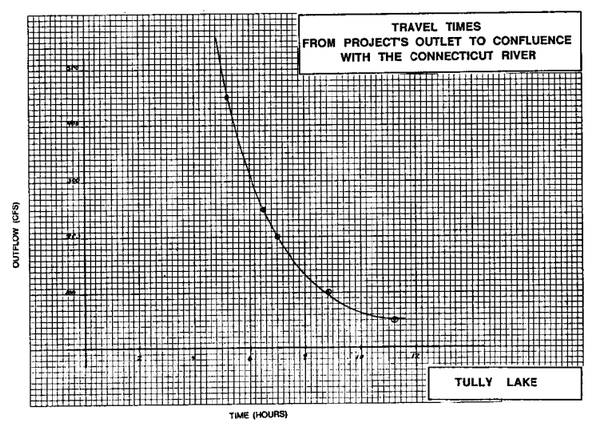












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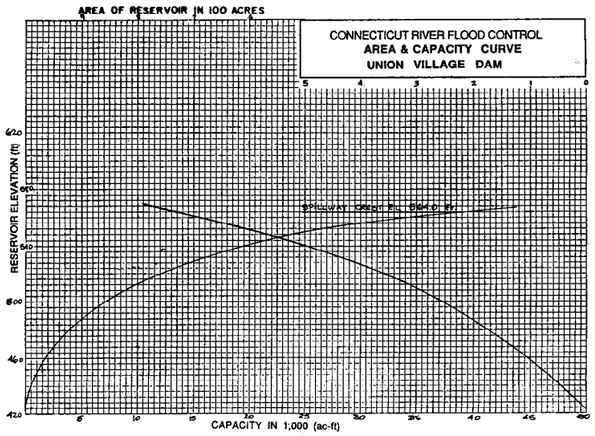
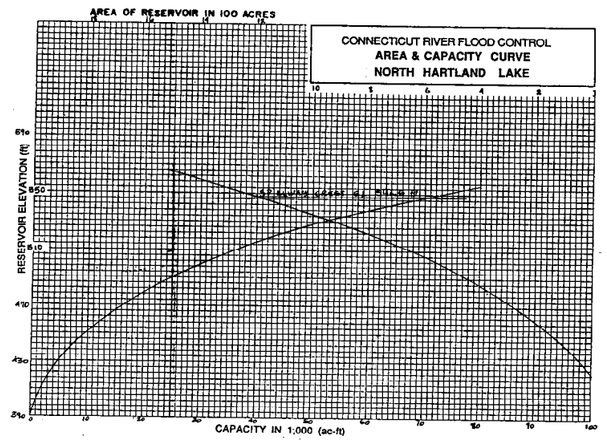
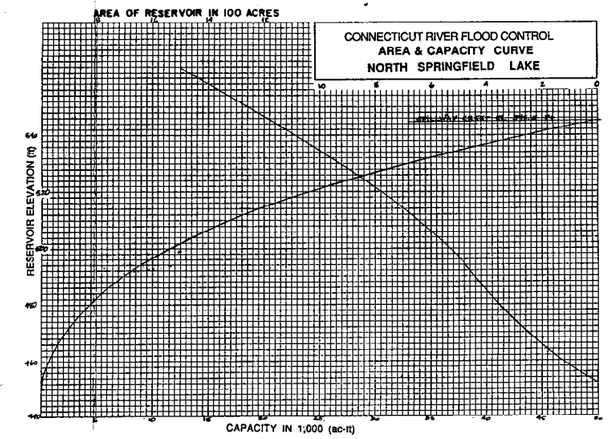
TRAVEL TIMES



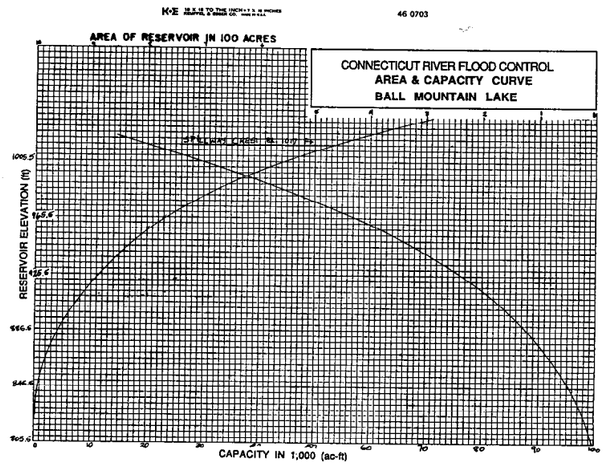
CONNECTICUT RIVER FLOOD CONTROL
AREA & CAPACITY CURVE
UNION VILLAGE DAM



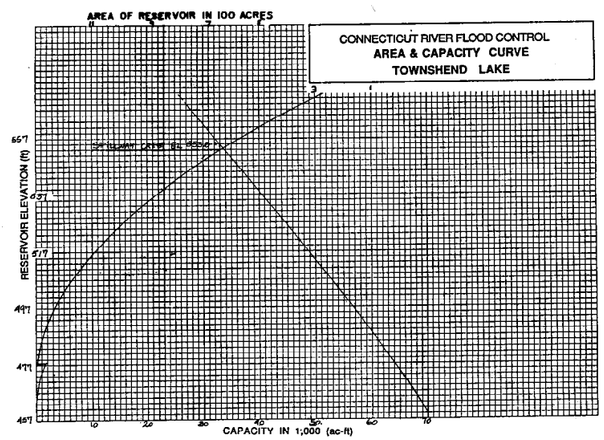
CONNECTICUT RIVER FLOOD CONTROL
AREA & CAPACITY CURVE
NORTH HARTLAND LAKE



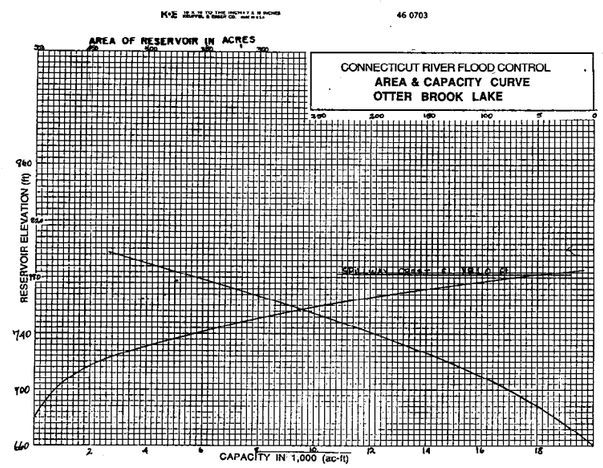
CONNECTICUT RIVER FLOOD CONTROL
AREA & CAPACITY CURVE
NORTH SPRINGFIELD LAKE



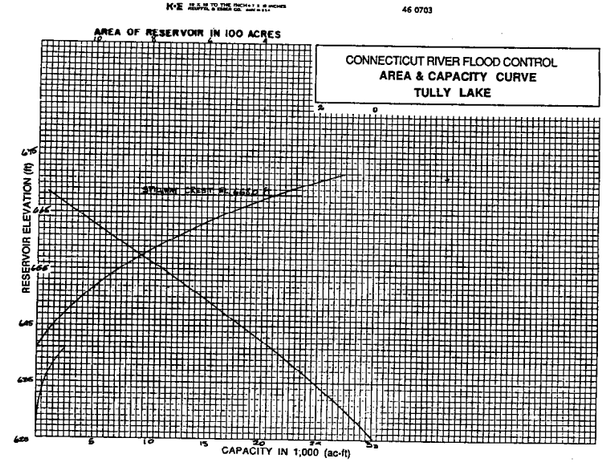
CONNECTICUT RIVER FLOOD CONTROL
AREA & CAPACITY CURVE
BALL MOUNTAIN LAKE



CONNECTICUT RIVER FLOOD CONTROL
AREA & CAPACITY CURVE
TOWNSHEND LAKE



CONNECTICUT RIVER FLOOD CONTROL
AREA & CAPACITY CURVE
OTTER BROOK LAKE



CONNECTICUT RIVER FLOOD CONTROL
AREA & CAPACITY CURVE
TULLY LAKE

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CONNECTICUT RIVER
FLOW AUGMENTATION STUDY

AREA & CAPACITY CURVES

PLATE A-5

APPENDIX B

WATER QUALITY APPENDIX

APPENDIX B

TABLE OF CONTENTS

Paragraph	Subject	Page
1	SUMMARY	B-1
2	WATER QUALITY CLASSIFICATIONS	B-2
3	GENERAL EFFECTS OF SIGNIFICANTLY ADDITIONAL STORAGE ON WATER QUALITY	B-2
4	UNION VILLAGE DAM	
	a. Location	B-4
	b. Watershed Land Use	B-4
	c. Water Quality Classification	B-5
	d. Existing Water Quality Conditions	B-5
	e. Effects of Additional Storage on Water Quality	B-5
5	NORTH HARTLAND LAKE	
	a. Location	B-6
	b. Watershed Land Use	B-6
	c. Water Quality Classification	B-6
	d. Stratification Patterns	B-6
	e. Trophic Status	B-6
	f. Existing Water Quality Conditions	B-6
	g. Effects of Additional Storage on Water Quality	B-7
6	NORTH SPRINGFIELD LAKE	
	a. Location	B-7
	b. Watershed Land Use	B-7
	c. Water Quality Classification	B-7
	d. Stratification Patterns	B-7
	e. Trophic Status	B-8
	f. Existing Water Quality Conditions	B-8
	g. Effects of Additional Storage on Water Quality	B-8

Paragraph	Subject	Page
7	BALL MOUNTAIN LAKE	
	a. Location	B-8
	b. Watershed Land Use	B-8
	c. Water Quality Classification	B-9
	d. Staratification Patterns	B-9
	e. Trophic Status	B-9
	f. Existing Water Quality Conditions	B-9
	g. Effects of Additional Storage on Water Quality	B-9
8	TOWNSHEND LAKE	
	a. Location	B-10
	b. Watershed Land Use	B-10
	c. Water Quality Classification	B-10
	d. Stratification Patterns	B-10
	e. Trophic Status	B-10
	f. Existing Water Quality Conditions	B-10
	g. Effects of Additional Storage on Water Quality	B-10
9	OTTER BROOK LAKE	
	a. Location	B-11
	b. Watershed Land Use	B-11
	c. Water Quality Classification	B-11
	d. Stratification Patterns	B-11
	e. Trophic Status	B-11
	f. Existing Water Quality Conditions	B-11
	g. Effects of Additional Storage on Water Quality	B-12
10	TULLY LAKE	
	a. Location	B-12
	b. Watershed Land Use	B-12
	c. Water Quality Classification	B-12
	d. Stratification Patterns	B-13
	e. Trophic Status	B-13
	f. Existing Water Quality Conditions	B-13
	g. Effects of Additional Storage on Water Quality	B-13
11	EFFECTS ON QUABBIN RESERVOIR	B-13
12	CONCLUSION	B-14
13	REFERENCES	B-15

APPENDIX B

WATER QUALITY EVALUATION
SECTION 22 RECONNAISSANCE INVESTIGATION
CONNECTICUT RIVER FLOW AUGMENTATION

1. SUMMARY

The following evaluation is a preliminary assessment of expected water quality conditions if significant additional storage were to be maintained at Union Village Dam and North Hartland, North Springfield, Ball Mountain, Townshend, Otter Brook and Tully Lakes to augment flows in the Connecticut River as requested by the Massachusetts Water Resources Authority (MWRA). Augmenting Connecticut River flows would lessen the amount of required Quabbin Reservoir releases (see Appendix A, Hydrologic Study), and would ultimately help to sustain Quabbin storage and preserve the quality of its waters.

Water quality in the above reservoirs and their tributaries is relatively good, usually meeting or exceeding applicable State water quality standards. The proposed increases in storage at these reservoirs would impact water quality, and negative effects may be significant at some of the projects. In this initial investigation, however, none of these impacts appear to be so severe as to definitely preclude storing the proposed amounts of water at any of these projects with the exception of Union Village Dam. Creation of an impoundment during warm weather months at Union Village Dam is not recommended unless definitive information becomes available showing acid mine drainage from abandoned copper mines in the watershed would cause no significant water quality problem in the proposed impoundment. In the absence of a definitive study, source control through cleanup and stabilization of the abandoned mines may be the only likely way to address this concern. Other potential impacts at all projects are as follows: (a) the possibility of increased nutrients, algae production and sedimentation and lower dissolved oxygen levels in the pools, and (b) increases in color, turbidity, metals, and suspended sediments in the pools and their downstream releases. Temperature may increase near surface waters of the lakes and decrease near the bottom. Discharge temperature could either increase or decrease depending on whether releases are made over a weir or from the bottom, respectively. In addition, existing septic systems at Otter Brook and Tully Lakes would have to be relocated since the proposed increases in pool levels would inundate these facilities.

This evaluation is based on existing water quality data, and a more detailed analysis of water quality and sediments would be necessary if the reconnaissance study proceeds to the feasibility phase. Further study must address changes in reservoir stratification and the need for reservoir clearing and would include, at a minimum, additional water and sediment sampling, sediment column studies, and temperature and dissolved oxygen numerical modelling for each Corps project.

2. WATER QUALITY CLASSIFICATIONS

Corps reservoirs being evaluated for this study include Union Village, North Hartland, North Springfield, Ball Mountain, Townshend, Otter Brook, and Tully, and are located in the Upper Connecticut River Basin as shown in figure B-1. These reservoirs and their tributaries are rated as class B waters by their appropriate State standards, except parts of the Ottauquechee River above North Hartland Lake and portions of Black River both upstream and downstream from North Springfield Lake, which are rated class C.

Class B waters have high aesthetic value with no objectionable physical characteristics. These waters are designated an acceptable habitat for aquatic life and wildlife and for primary and secondary recreation. In addition, they are suitable for public water supply following adequate treatment, irrigation and other agricultural uses, and compatible industrial cooling and process uses.

Class C waters, according to the Vermont Water Resources Board, are suitable for aquatic life and wildlife, secondary contact recreation, irrigation of crops not used for human consumption without cooking, and compatible industrial uses.

The above classifications represent the goals for a particular water body which may not always be met by observed water quality data.

3. GENERAL EFFECTS OF SIGNIFICANTLY ADDITIONAL STORAGE ON WATER QUALITY

Reservoir ecosystems are extremely complex and it is difficult to predict exactly what will happen to water quality and aquatic life when storage capacity is significantly increased at a reservoir. Generally, water quality in an enlarged impoundment and its downstream releases is expected to degrade due to the effects of newly inundated acreage, a deeper and larger pool, longer hydraulic residence times, and larger fluctuations in pool elevation throughout each year. Table B-1 identifies existing and proposed pool

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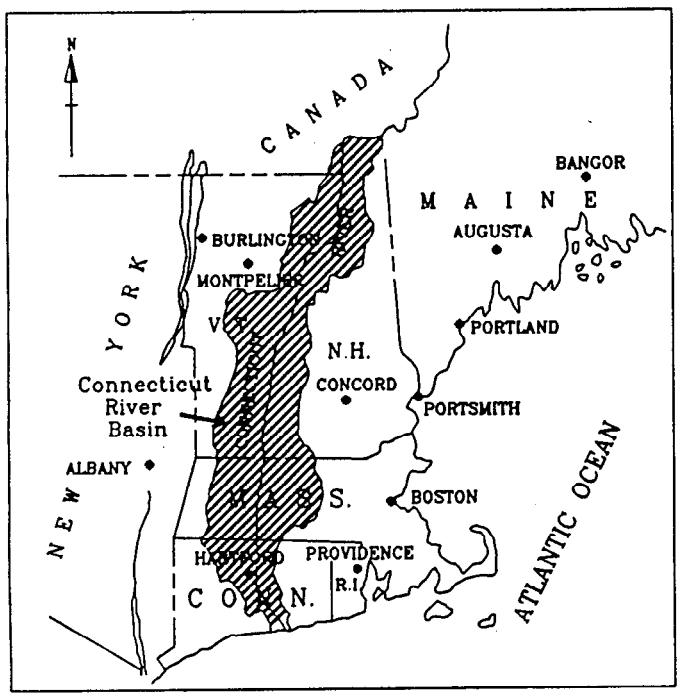
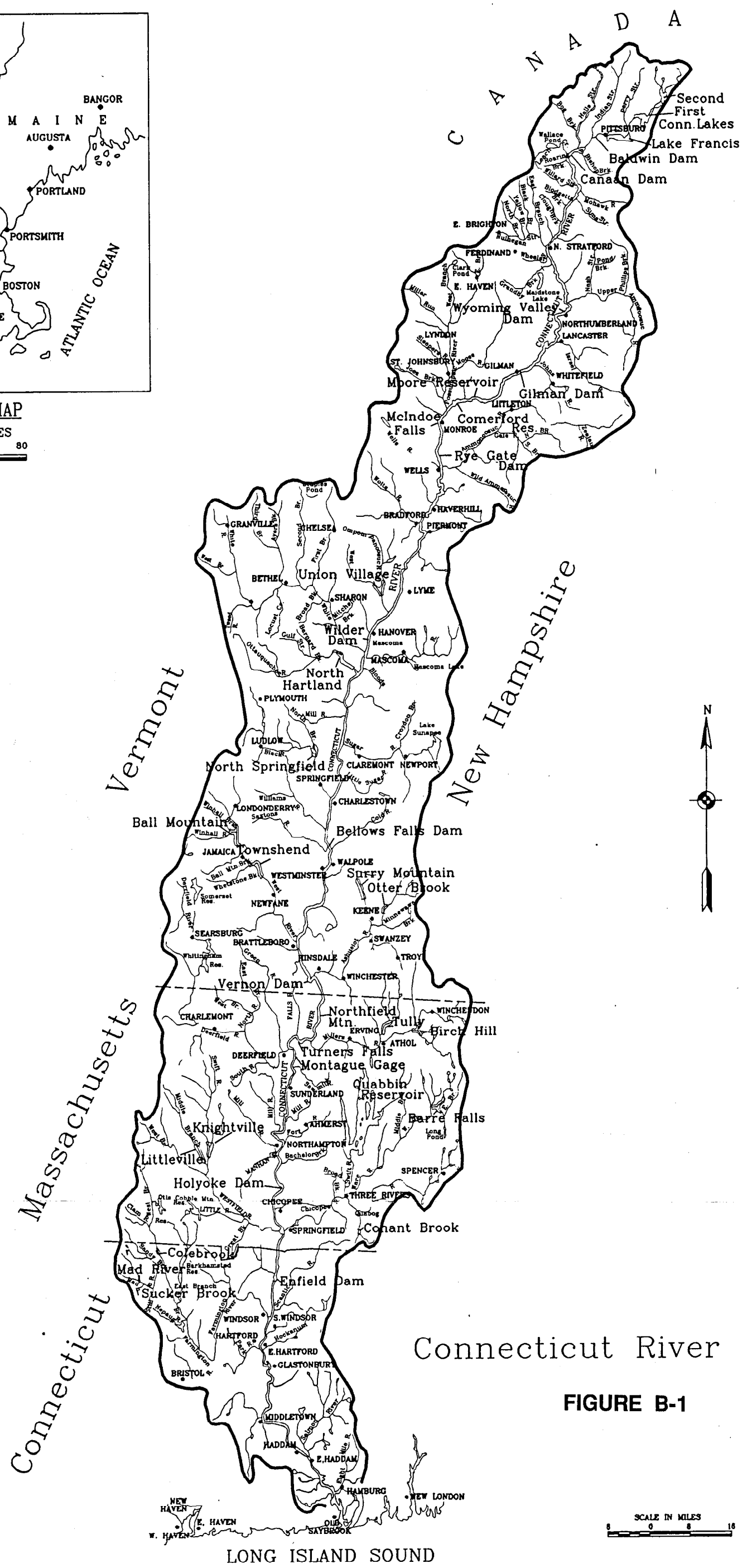


LOCATION MAP

SCALE IN MILES

40 0 40 80



Connecticut River Basin

FIGURE B-1

TABLE B-1
CONNECTICUT RIVER FLOW AUGMENTATION STUDY
WATER QUALITY EVALUATION

PROJECT	WNTR PL	EXIST. SUMMER POOL			PROPOSED POOL			PROPOSED INCREASE		
	ELEV FT, NGVD (DEPTH FEET)	ELEV FT, NGVD (DEPTH FEET)	GROSS STORAGE AC-FT	AREA ACRES	ELEV FT, NGVD (DEPTH FEET)	GROSS STORAGE AC-FT	AREA ACRES	FEET ABOVE SUMMER POOL	GROSS STORAGE AC-FT	AREA ACRES
UNION VILLAGE	440 (20)	420 (0)	0	0	485 (65)	4030	190	65	4030	190
NORTH HARTLAND	425 (35)	425 (35)	2350	215	444 (54)	7040	350	19	4690	135
NORTH SPRINGFIELD	467 (15)	467 (15)	500	100	484 (32)	5050	414	17	4550	314
BALL MOUNTAIN	830.5 (25)	870.5 (65)	2000	75	900 (94.5)	5500	145	29.5	3500	70
TOWNSHEND	478 (21)	478 (21)	800	95	494 (37)	3390	271	16	2590	176
OTTER BROOK	701 (18)	701 (18)	720	70	714 (31)	2000	162	13	1280	92
TULLY	636 (11)	641 (16)	1500	305	648 (23)	3200	625	7	1700	320

level, storage, and surface area at each Corps project under evaluation.

With an increase in storage at these projects causing surface area increases ranging from 70 acres at Ball Mountain to 320 acres at Tully Lake, significant shoreline vegetation and organic sediment will become inundated from June until August when the original pool is again maintained. Inundation of vegetated lands and organic sediments affect water quality by causing a decay of organic material; thereby, releasing nutrients and metals to overlying waters. This could lead to increases in color and suspended sediments, and because of additional nutrients, a greater susceptibility to localized algae blooms. These effects can be reduced by clearing and grubbing the inundated area; however, clearing and grubbing make soil more susceptible to erosion, and may cause sloughing of embankments. Large fluctuations in water surface elevations between winter and the proposed summer pools could also cause sloughing of embankments during drawdown events. Some eroded material would discharge downstream, but most would settle in the lake, increasing sedimentation in the lake and, also, color and suspended sediments in downstream releases.

While removal of trees and stumps is recommended, a one time clearing and grubbing event may not eliminate all vegetation, as herbaceous plants will establish themselves each spring when the lands are not yet inundated. Nutrient releases from herbaceous plants have been shown to be significant in comparison to woody plants in other watershed studies (Ball, 1975). Amounts of nutrients released and their effects on water quality will differ for each reservoir depending on the amount of inundated acreage, type of vegetation, and trophic status of the lake. Additional sediment sampling and sediment column tests would be required to better define potential nutrient and metal uptake from newly inundated lands and to set final clearing and grubbing requirements.

Enlarging pool volume and depth increases hydraulic residence times and reduces flushing action in the impoundment. Waters will tend to warm near the surface, especially when low level releases are made which draw water only from the bottom, coolest part of the lake. Consequently, thermal stratification patterns would strengthen with lower water temperatures near the bottom and increasing dissolved oxygen depletion in the bottom waters. Sediments in areas devoid of oxygen become chemically reduced causing ammonia, phosphorus, manganese, iron, and other heavy metals to become soluble and diffuse into the overlying waters. Furthermore, higher water

temperatures at the surface, longer residence times, and increased nutrients can promote algae blooms in the lake. On the other hand, larger pool volumes and longer residence times would tend to attenuate some of the anticipated water quality effects and promote settling of suspended materials from the water column helping to minimize increases in turbidity, color and suspended solids in the impoundment and downstream discharges. This would also lead to increased sedimentation in the pool.

The filling and release of additional storage at each reservoir would also have some effect on the quality of its downstream discharges. The filling and release schedule is presented in Appendix A, the Hydrologic Study. The filling process would begin in June and end sometime between mid-June to early August, depending on inflows. The minimum release during filling would be the 7-day, 10-year low flow estimated for the months of June through August. As a natural minimum flow of that season, this release should provide downstream water quality comparable with naturally experienced conditions. Once each pool reaches its proposed maximum storage elevation, reservoir releases would be maintained equal to inflow, except when low flow conditions call for greater releases to be made for augmentation. Water quality degradation in downstream releases due to effects of increased storage has been previously discussed. However, flow augmentation releases may actually benefit downstream water quality during drought or low flow periods by creating greater aquatic habitat, entraining more dissolved oxygen, and cooling water temperatures. If releases are made from the bottom they may be cooler, if made over a weir, they may be warmer.

Mathematical water quality modelling would be required for each project to better define expected temperature and dissolved oxygen regime of impoundments and discharge. Additional water sampling would also be necessary. This is especially important since none of these projects have selective withdrawal capability.

4. UNION VILLAGE DAM

a. Location. Union Village Dam is located on the Ompompanoosuc River, four miles upstream from its confluence with the Connecticut River in Thetford, Vermont (see figure B-2).

b. Watershed Land Use. The watershed is mostly forest, with some open fields, and fewer marshlands. The region is sparsely populated with mostly agricultural development and

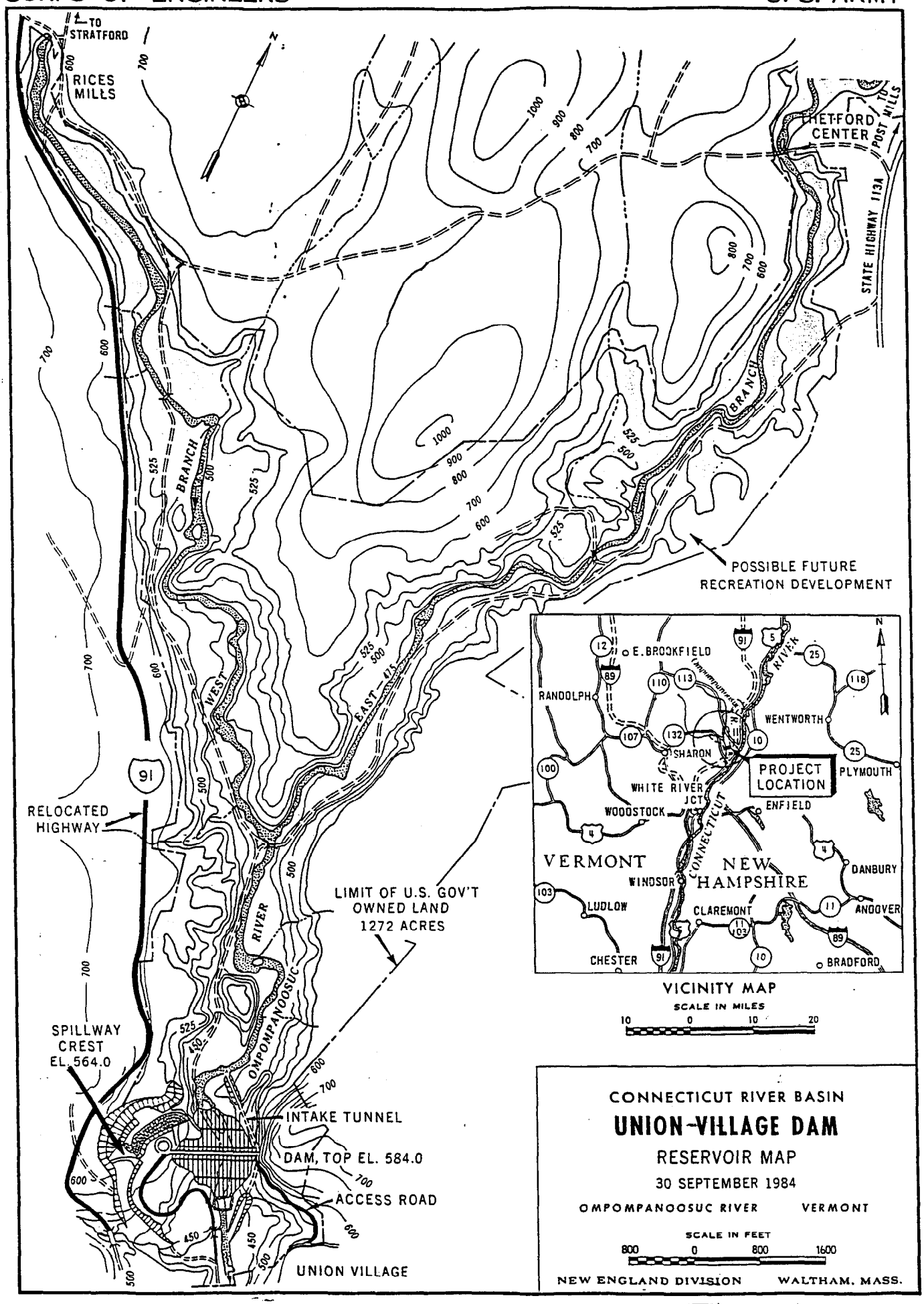

TO STRATFORD
RICES MILLS
CHETFORD CENTER
TO POST MILLS
STATE HIGHWAY 113A
WEST BRANCH
EAST BRANCH
OMPOMPANOOSUC RIVER
POSSIBLE FUTURE RECREATION DEVELOPMENT
RELOCATED HIGHWAY
LIMIT OF U.S. GOV'T OWNED LAND 1272 ACRES
SPILLWAY CREST EL. 564.0
INTAKE TUNNEL
DAM, TOP EL. 584.0
ACCESS ROAD
UNION VILLAGE
E. BROOKFIELD
RANDOLPH
WENTWORTH
SHARON
PLYMOUTH
PROJECT LOCATION
WHITE RIVER JCT
ENFIELD
WOODSTOCK
VERMONT
NEW HAMPSHIRE
CONNECTICUT RIVER
WINDSOR
DANBURY
LUDLOW
CLAREMONT
ANDOVER
CHESTER
BRADFORD
VICINITY MAP
SCALE IN MILES
10 0 10 20
CONNECTICUT RIVER BASIN
UNION-VILLAGE DAM
RESERVOIR MAP
30 SEPTEMBER 1984
OMPOMPANOOSUC RIVER VERMONT
SCALE IN FEET
800 0 800 1600
NEW ENGLAND DIVISION WALTHAM, MASS.

FIGURE B-2

some lumber and paper industries. In the past, copper mining was a major industry in the area. Acid mine drainage from tailings of abandoned copper mines located within the watershed is a major concern to water quality.

c. Water Quality Classification. The Ompompanoosuc and its tributaries are rated class B by the Vermont Water Resources Board. Upstream and downstream waters are further designated as cold water fish habitats.

d. Existing Water Quality Conditions. The waters contain high concentrations of heavy metals including iron, copper and mercury, especially during times of heavy rainfall when runoff from mine tailings carries metals into the river. During significant runoff events, water in the river actually turns a reddish color.

e. Effects of Additional Storage on Water Quality. Currently, no summer pool is maintained at Union Village Dam. The proposed flow augmentation will create a 65-foot deep pool (El. 485 feet) with a gross storage of 4,030 acre-feet. The change in seasonal pool level would only be 45 feet as a 440-foot NGVD winter pool (45-foot depth) is normally maintained to prevent the gates from freezing. However, since vegetation is dormant, biological activity is minimal, and the pool is not normally stratified during winter, the most significant effects on water quality will be due to the change in summer storage from 0 to 4,030 acre-feet (65-foot pool depth). Predicted mean hydraulic retention times for the proposed pool in July and August would be approximately 25 and 36 days, respectively. There is no weir at this project, and releases are made from the bottom of the pool.

Aside from the anticipated general water quality degradation as previously described in item 3, increasing the pool at Union Village Dam raises a major water quality concern because of acid mine drainage in the watershed. Since pH in these waters is usually fairly significant, metals concentrations in storm runoff would likely precipitate and accumulate in the sediments of the rivers and proposed impoundment. Sediment studies of the West Branch Ompompanoosuc River indicate sediment containing elevated metal levels is present in the riverbed upstream from the dam (Colorado School of Mines Research Institute, 1984). With a large pool volume during warm months, increases in hydraulic retention times will induce more settling. If the proposed pool stratifies, anaerobic or low dissolved oxygen conditions in the bottom of the pool can cause significant amounts of heavy metals from the sediments to become soluble in the overlying waters. In this event, the pool and its downstream releases could

possibly contain toxic metal concentrations. Consequently, a more detailed water quality and sediment study should be conducted, as discussed in section 3, to determine if storing water at Union Village Dam has detrimental effects on water quality. It is likely that the only solution to the acid mine drainage would be source control including cleanup and stabilization of the upstream abandoned mines.

5. NORTH HARTLAND LAKE

a. Location. North Hartland Lake is located on the Ottauquechee River, 1.5 miles upstream from its confluence with the Connecticut River in North Hartland, Vermont (see figure B-3).

b. Watershed Land Use. The watershed is mostly forest, with some open pasture lands, and fewer marshlands. The region is scarcely populated and predominant development within the watershed is residential. Recreation, tourism, agriculture and manufacturing are major industries in the area. Several waste water treatment plants discharge upstream from the reservoir. Of the 1,100 acre reservoir area about 60 percent are forested, 25 percent - open pasture land, and 15 percent - marsh or water.

c. Water Quality Classification. The Ottauquechee River and its tributaries are rated class B by the Vermont Water Resources Board in most reaches except upstream from Dewey's Mills Dam (4 miles upstream of North Hartland dam) where waters are class C due to waste water treatment plant discharges. Waters in the lake and downstream from the dam are further designated as warm water fish habitats.

d. Stratification Patterns. The lake exhibits weak thermally induced density stratification patterns which form, break up, and reform during summer. Because of the intermittent nature of stratification and a tendency for cold aerated inflows to travel along the bottom of the lake, there is minimal dissolved oxygen depletion in depths of the lake.

e. Trophic Status. The lake is borderline mesotrophic/oligotrophic with nutrient levels at or below the generally accepted threshold levels for supporting algal blooms in an impoundment. Chlorophyll a measurements are at very low levels as generally found in oligotrophic lakes.

f. Existing Water Quality Conditions. The waters of North Hartland Lake have elevated levels of mercury and aluminum, and are also highly colored. The heavy metals and color levels are probably due to natural conditions in the watershed.

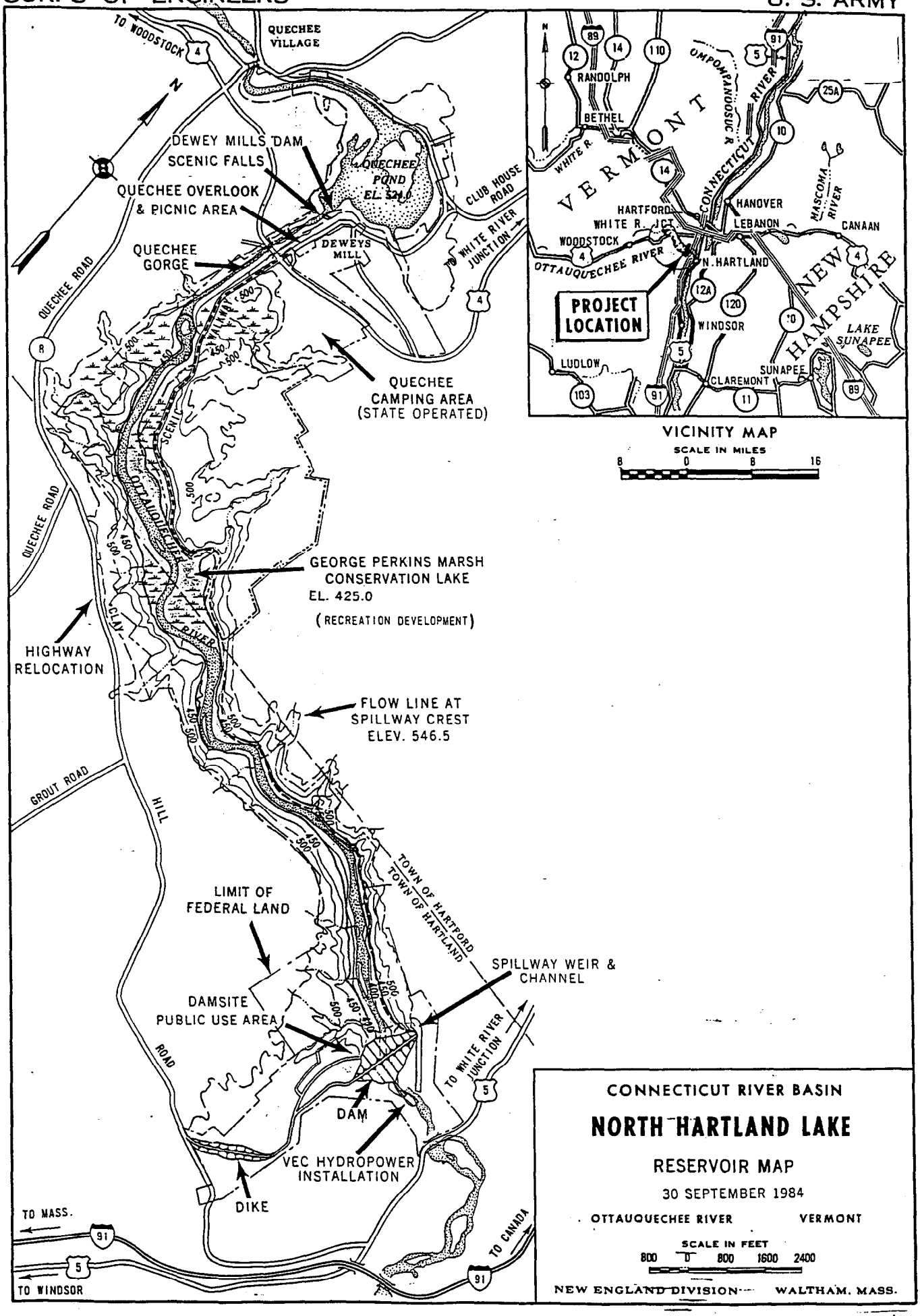

TO WOODSTOCK
QUECHEE VILLAGE
N
DEWEY MILLS DAM
SCENIC FALLS
QUECHEE OVERLOOK & PICNIC AREA
QUECHEE POND EL. 524.0
CLUB HOUSE ROAD
TO WHITE RIVER JUNCTION
QUECHEE GORGE
DEWEYS MILL
QUECHEE ROAD
QUECHEE CAMPING AREA (STATE OPERATED)
GEORGE PERKINS MARSH CONSERVATION LAKE EL. 425.0
(RECREATION DEVELOPMENT)
HIGHWAY RELOCATION
FLOW LINE AT SPILLWAY CREST ELEV. 546.5
GROUT ROAD
HILL
LIMIT OF FEDERAL LAND
TOWN OF HARTFORD
TOWN OF HARTLAND
SPILLWAY WEIR & CHANNEL
DAMSITE PUBLIC USE AREA
ROAD
DAM
VEC HYDROPOWER INSTALLATION
DIKE
TO MASS.
TO WINDSOR
TO CANADA
VERMONT
NEW HAMPSHIRE
RANDOLPH
BETHEL
WHITE R.
UMPOMPANOOSUC R.
CONNECTICUT RIVER
HARTFORD
WHITE R. JCT.
HANOVER
LEBANON
CANAAN
MASCOMA RIVER
WOODSTOCK
OTTAUQUECHEE RIVER
N. HARTLAND
PROJECT LOCATION
WINDSOR
LAKE SUNAPEE
LUDLOW
CLAREMONT
SUNAPEE
VICINITY MAP
SCALE IN MILES
8 0 8 16
CONNECTICUT RIVER BASIN
NORTH HARTLAND LAKE
RESERVOIR MAP
30 SEPTEMBER 1984
OTTAUQUECHEE RIVER
VERMONT
SCALE IN FEET
800 0 800 1600 2400
NEW ENGLAND DIVISION
WALTHAM, MASS.

FIGURE B-3

g. Effects of Additional Storage on Water Quality. The proposed flow augmentation will increase the summer pool level by 19 feet from 425 to 444 feet NGVD, with an increase in gross storage from 2,350 to 7,040 acre-feet. Mean hydraulic retention times estimated for July and August would increase from 7 and 10 days for the existing pool to 22 and 30 days for the proposed pool, respectively. Surface area will change from 215 to 350 acres. Normal releases are made from the lake bottom through hydropower facilities at the site. Water quality degradation, due to inundated vegetation and erosion, would probably be minor since the large increase in lake volume would dampen the effects of additional nutrients, suspended sediments, turbidity, color, and sedimentation. Increased algae production should also be minor, based on trophic status, low nutrient levels, and the relatively moderate increases in retention times. Trophic status should not change much and waters in the lake and downstream releases are expected to remain of good quality. This should be confirmed through the detailed study outlined in section 3.

6. NORTH SPRINGFIELD LAKE

a. Location. North Springfield Lake is located on the Black River, 8.7 miles upstream from its confluence with the Connecticut River in Springfield, Vermont (see figure B-4).

b. Watershed Land Use. The watershed is mostly rural and undeveloped forest land. Agricultural activity is minimal and mostly consists of dairy land and poultry and egg production. Of the 1,200 acre reservoir area about 50 percent are open fields, 15 percent are marshland, and the remaining 35 percent are wooded. Within the reservoir, 137 acres of open fields are leased for hay and corn production. Vegetation around the lake is one third trees, grass and brush and two thirds marsh and open water.

c. Water Quality Classification. Black River and its tributaries are rated class B by the Vermont Water Resources Board in all reaches except upstream from Ludlow, Vermont to its junction with North Branch, and downstream from North Springfield Lake discharge to the Connecticut River which are rated class C. Waters in the lake and in some reaches downstream from the dam are further designated as warm water fish habitats. In fact, North Springfield Lake is one of the best large mouth bass habitats in southeast Vermont.

d. Stratification Patterns. The lake exhibits weak to moderate thermally induced density stratification patterns; however, occasionally it can exhibit stronger stratification

patterns. Good dissolved oxygen levels are usually present throughout the water column.

e. Trophic Status. Nutrient data and chlorophyll a measurements collected at North Springfield Lake are fairly low indicating an oligotrophic waterbody.

f. Existing Water Quality Conditions. Inflow waters to North Springfield Lake have low pH, but pH levels in the pool and its discharges are high. This is indicative of significant buffering action in the lake. Also, a very high quality fishery exists in the lake suggesting excellent water quality; however, sedimentation has been reducing quality of the fishery in recent years.

g. Effects of Additional Storage on Water Quality. The proposed flow augmentation will increase the pool level by 17 feet from 467 to 484 feet NGVD, with an increase in gross storage from 500 to 5,050 acre-feet. The present pool is controlled by a weir, and releases can be made over the weir or from the pool bottom using the flood control gates. Mean hydraulic retention times estimated for July and August would change significantly from 2 and 3 days for the summer pool to 20 and 30 days for the proposed pool, respectively, an increase of between 18 and 27 days. Surface area will also increase significantly from 100 to 414 acres. Water quality degradation due to inundated vegetation and erosion would occur; however, it may be fairly minor since the large increase in lake volume would attenuate the effects of additional nutrients, suspended sediments, turbidity and color. Sedimentation, however, would likely increase at a more rapid rate. Increased algae production should also be minor, or at least localized, as the lake is oligotrophic and has low nutrient levels. The high quality fishery in the lake could be damaged or destroyed by warmer water temperatures and the significant increase in pool level. Detailed water quality analysis would be required to confirm preliminary judgements as outlined in section 3.

7. BALL MOUNTAIN LAKE

a. Location. Ball Mountain Lake is located on the West River, 29 miles upstream from its confluence with the Connecticut River in Jamaica and Londonderry, Vermont (see figure B-5).

b. Watershed Land Use. The watershed is mostly wooded with some open fields, and few marshlands. Of the 810 acre reservoir area 74 percent - wooded, 16 percent - open fields for grazing and hay production, and 10 percent - open water. A camping area is located at the upper end of the project.

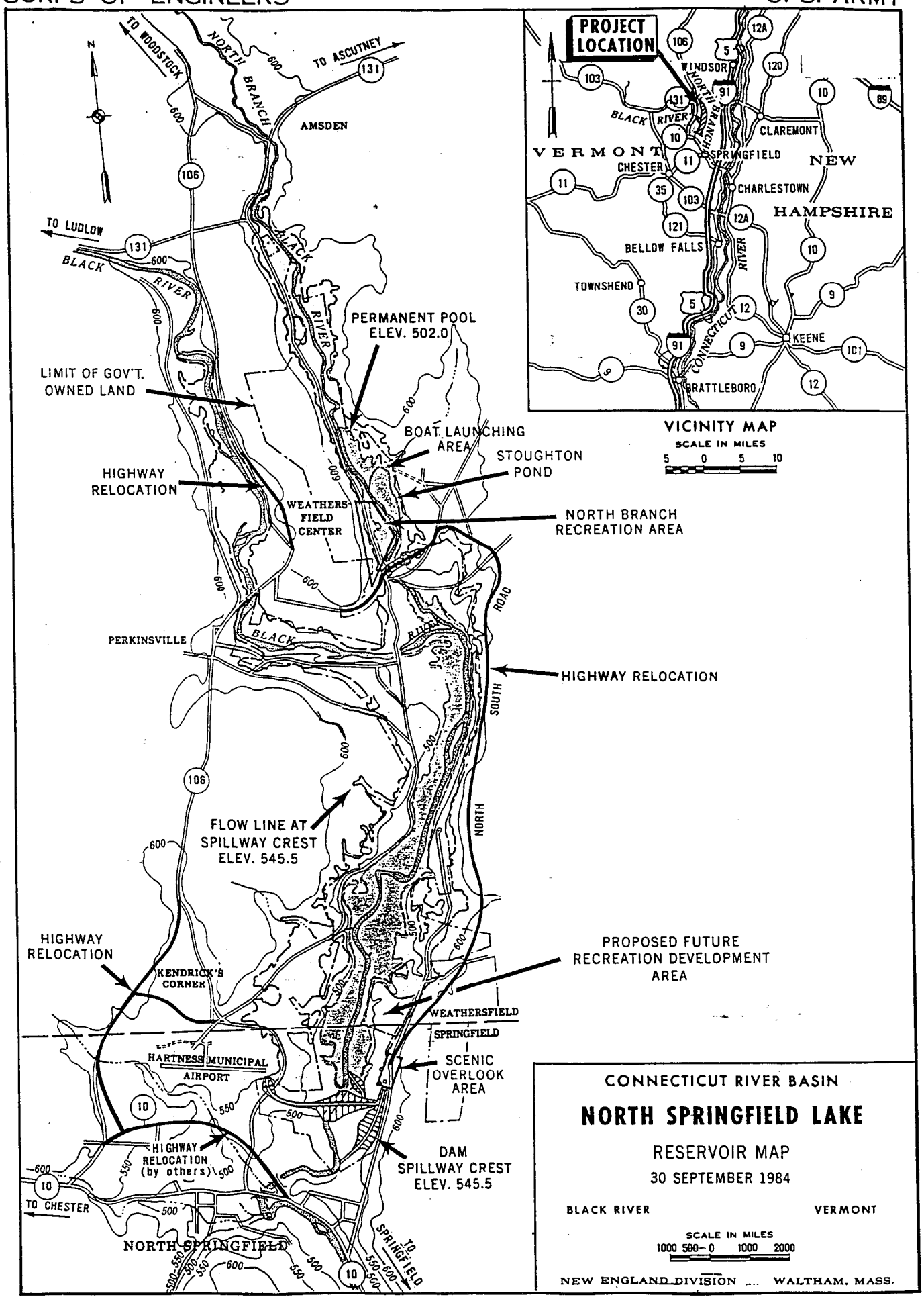

PROJECT LOCATION
VERMONT
NEW HAMPSHIRE
WINDSOR
CLAREMONT
SPRINGFIELD
CHESTER
CHARLESTOWN
BELLOW FALLS
TOWNSHEND
KEENE
BRATTLEBORO
BLACK RIVER
NORTH BRANCH
CONNECTICUT RIVER
VICINITY MAP
SCALE IN MILES
5 0 5 10
TO WOODSTOCK
TO ASCUTNEY
TO LUDLOW
AMSDEN
PERMANENT POOL ELEV. 502.0
LIMIT OF GOV'T. OWNED LAND
BOAT LAUNCHING AREA
STOUGHTON POND
HIGHWAY RELOCATION
WEATHERS FIELD CENTER
NORTH BRANCH RECREATION AREA
PERKINSVILLE
HIGHWAY RELOCATION
SOUTH ROAD
NORTH
FLOW LINE AT SPILLWAY CREST ELEV. 545.5
HIGHWAY RELOCATION
KENDRICK'S CORNER
PROPOSED FUTURE RECREATION DEVELOPMENT AREA
WEATHERSFIELD
SPRINGFIELD
HARTNESS MUNICIPAL AIRPORT
SCENIC OVERLOOK AREA
HIGHWAY RELOCATION (by others)
DAM SPILLWAY CREST ELEV. 545.5
TO CHESTER
NORTH SPRINGFIELD
TO SPRINGFIELD
CONNECTICUT RIVER BASIN
NORTH SPRINGFIELD LAKE
RESERVOIR MAP
30 SEPTEMBER 1984
BLACK RIVER
VERMONT
SCALE IN MILES
1000 500 0 1000 2000
NEW ENGLAND DIVISION ... WALTHAM, MASS.

FIGURE B-4

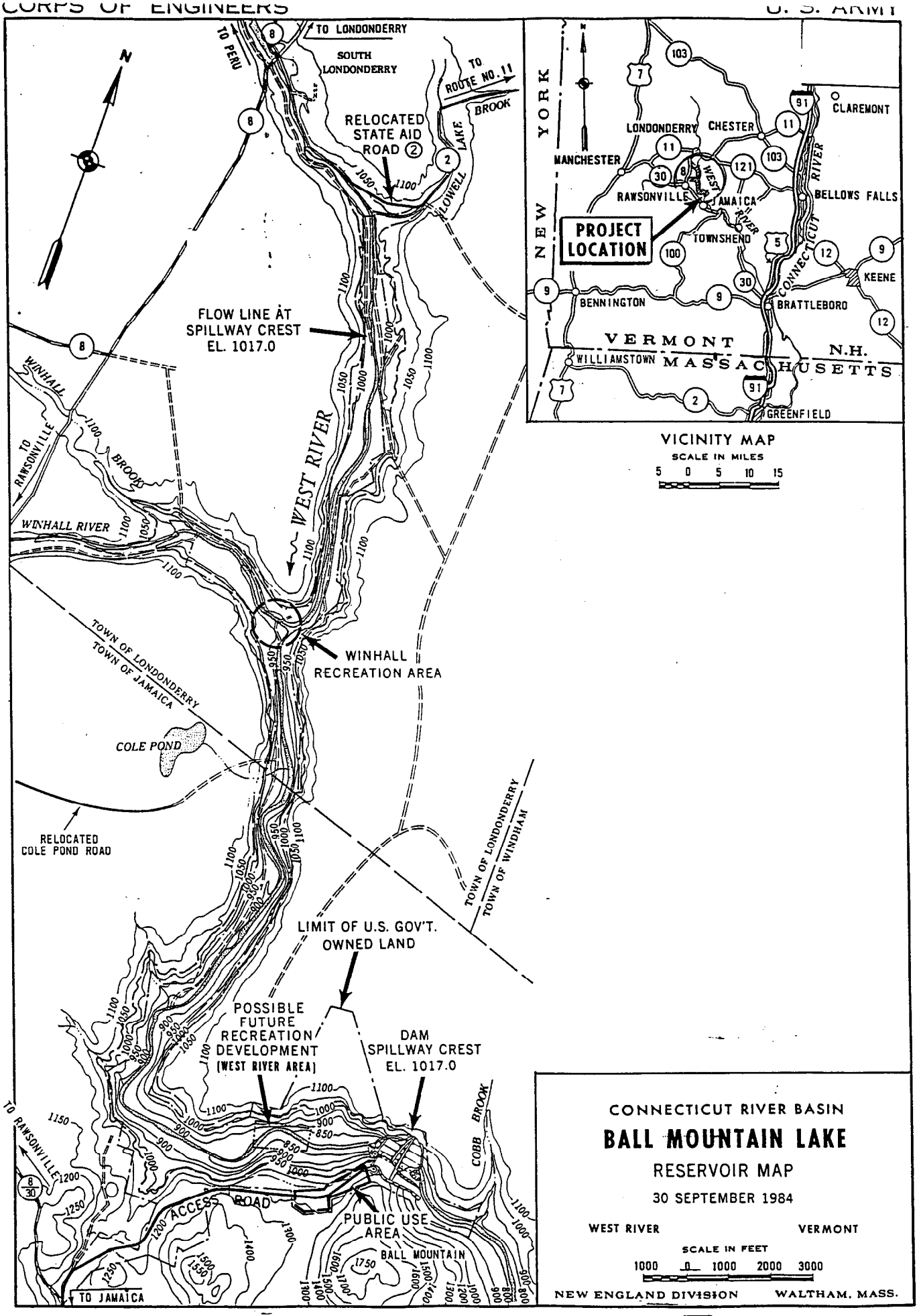

TO LONDONDERRY
SOUTH LONDONDERRY
TO PERU
TO ROUTE NO. 11
BROOK
LAKE
LOWELL
RELOCATED STATE AID ROAD ②
FLOW LINE AT SPILLWAY CREST EL. 1017.0
WEST RIVER
WINHALL
BROOK
TO RAWSONVILLE
WINHALL RIVER
TOWN OF LONDONDERRY
TOWN OF JAMAICA
WINHALL RECREATION AREA
COLE POND
RELOCATED COLE POND ROAD
TOWN OF LONDONDERRY
TOWN OF WINDHAM
LIMIT OF U.S. GOV'T. OWNED LAND
POSSIBLE FUTURE RECREATION DEVELOPMENT (WEST RIVER AREA)
DAM SPILLWAY CREST EL. 1017.0
COBB BROOK
TO RAWSONVILLE
ACCESS ROAD
PUBLIC USE AREA
BALL MOUNTAIN
TO JAMAICA
NEW YORK
LONDONDERRY
CHESTER
CLAREMONT
MANCHESTER
RAWSONVILLE
JAMAICA
WEST RIVER
BELLOWS FALLS
PROJECT LOCATION
TOWNSHEND
CONNECTICUT RIVER
KEENE
BENNINGTON
BRATTLEBORO
VERMONT
N.H.
WILLIAMSTOWN
MASSACHUSETTS
GREENFIELD
VICINITY MAP
SCALE IN MILES
5 0 5 10 15
CONNECTICUT RIVER BASIN
BALL MOUNTAIN LAKE
RESERVOIR MAP
30 SEPTEMBER 1984
WEST RIVER
VERMONT
SCALE IN FEET
1000 0 1000 2000 3000
NEW ENGLAND DIVISION
WALTHAM, MASS.

FIGURE B-5

c. Water Quality Classification. West River and its tributaries are rated class B by the Vermont Water Resources Board. Waters in the lake and in some reaches downstream from the dam are further designated as cold water fish habitats. However, the large differences in depth and area between the summer and winter pool prevent maintenance of a lake environment suitable for fish.

d. Stratification Patterns. The lake exhibits weak to moderate thermally induced density stratification patterns which form, break up, and reform during the summer. Because of the intermittent nature of stratification and a tendency for cold aerated inflows to travel along the bottom of the lake, there is minimal dissolved oxygen depletion in the depths of the lake.

e. Trophic Status. The lake is borderline mesotrophic/oligotrophic with nutrient levels at or below the generally accepted threshold levels for supporting algal blooms in an impoundment.

f. Existing Water Quality Conditions. The waters of Ball Mountain Lake are of good quality usually meeting or exceeding State standards. Minor concerns are low pH, and high color and iron levels probably due to natural conditions in the watershed.

g. Effects of Additional Storage on Water Quality. The proposed flow augmentation will increase the summer pool level by 29.5 feet from 870.5 to 900 feet NGVD, with an increase in gross storage from 2,000 to 5,500 acre-feet. Mean hydraulic retention times estimated for July and August would increase from 8 and 10 days for the existing summer pool to 22 and 26 days for the proposed pool, respectively. Surface area will change from 75 to 145 acres. There is no weir at this project, and releases are made from the bottom of the pool using the flood control gates. Water quality degradation caused by newly inundated vegetation and erosion would probably be minor since the large increase in lake volume would dampen the effects of additional nutrients, turbidity, color, suspended sediments, and sedimentation. Increased algae production should also be minor, and localized, based on low nutrient levels and projected retention times of the lake. Trophic status is also not expected to change very much. The large fluctuation from the winter to proposed pool of 69.5 feet, however, will make it even more difficult to maintain a good fishery. Preliminary findings would need to be confirmed by a detailed investigation as outlined in section 3.

8. **TOWNSHEND LAKE**

a. Location. Townshend Lake is located on the West River, 19.1 miles upstream from its confluence with the Connecticut River in Townshend and Jamaica, Vermont (see figure B-6).

b. Watershed Land Use. The watershed is mostly wooded with little agricultural land except in the flood plains adjacent to the rivers. About 75 of the 735 acres of reservoir area are leased for hay production with no plowing or fertilization.

c. Water Quality Classification. West River and its tributaries are rated class B by the Vermont Water Resources Board. Waters in the lake, upstream and downstream from the project are further designated as cold water fish habitats.

d. Stratification Patterns. Although no profile sampling has been conducted at Townshend Lake, the lake most likely exhibits weak thermally induced density stratification patterns which form, break up, and reform during the summer, based on other reservoirs of similar size and conditions. Good dissolved oxygen levels are usually present throughout the entire water column.

e. Trophic Status. The lake is borderline mesotrophic/oligotrophic with low nitrogen levels but phosphorus levels are usually close to or just above the generally accepted threshold levels capable of supporting algae blooms in an impoundment.

f. Existing Water Quality Conditions. The waters of Townshend Lake are of good quality usually meeting or exceeding State standards. Minor concerns are low pH, and high levels of color and iron probably due to natural conditions in the watershed. Turbidity levels are occasionally high, especially during times of high runoff.

g. Effects of Additional Storage on Water Quality. The proposed flow augmentation will increase the summer pool level by 16 feet from 478 to 494 feet NGVD, with an increase in gross storage from 800 to 3,390 acre-feet. The present pool is controlled by a weir, and releases can be made over the weir or from the pool bottom using the flood control gates. Mean hydraulic retention times estimated for July and August would increase from 2 and 2.5 days for the existing summer pool to 8 and 11 days for the proposed pool, respectively. Although the change in surface area would almost triple from 95 to 271 acres, water quality degradation

due to inundated vegetation and bank erosion would probably be minor since the large increase in lake volume would dampen the effects of additional nutrients, suspended sediments, turbidity, color and sedimentation. Increased algae production should also be minor, based on trophic condition, fairly low nutrient levels and projected residence times in the lake. These preliminary estimates need to be confirmed as outlined in section 3.

9. **OTTER BROOK LAKE**

a. Location. Otter Brook Lake is located on Otter Brook in Keene, New Hampshire, 2.4 miles upstream from its junction with the Branch which flows 2.5 miles to the Ashuelot River and eventually into the Connecticut River (see figure B-7).

b. Watershed Land Use. The watershed is mostly rural with relatively little residential and agricultural, and no industrial development. No known point source discharges from industries or municipalities empty into the rivers upstream from Otter Brook Lake.

c. Water Quality Classification. Otter Brook and its tributaries are rated class B by the New Hampshire Water Supply and Pollution Control Commission. These waters are further designated as warm water fisheries, and have cold water put and take fishery management during spring.

d. Stratification Patterns. The lake exhibits weak to moderate thermally induced density stratification patterns which form, break up, and reform during the summer. DO decreases significantly from the surface to bottom waters showing low to anaerobic levels in the deepest parts of the lake. Phosphorus and ammonia levels increase near the bottom of the lake, especially where the waters are anaerobic.

e. Trophic Status. The lake is borderline mesotrophic/oligotrophic with low nutrient levels. Nitrogen measurements occasionally exceed threshold concentrations capable of supporting algae blooms in an impoundment; however, phosphorus exceedances are very rare. Nuisance algae blooms have never been observed in Otter Brook Lake.

f. Existing Water Quality Conditions. The waters of Otter Brook Lake are of high quality, usually meeting or exceeding their class B requirements. Minor areas of concern include low pH, and high color, iron and manganese levels which probably originate from natural sources in the watershed.

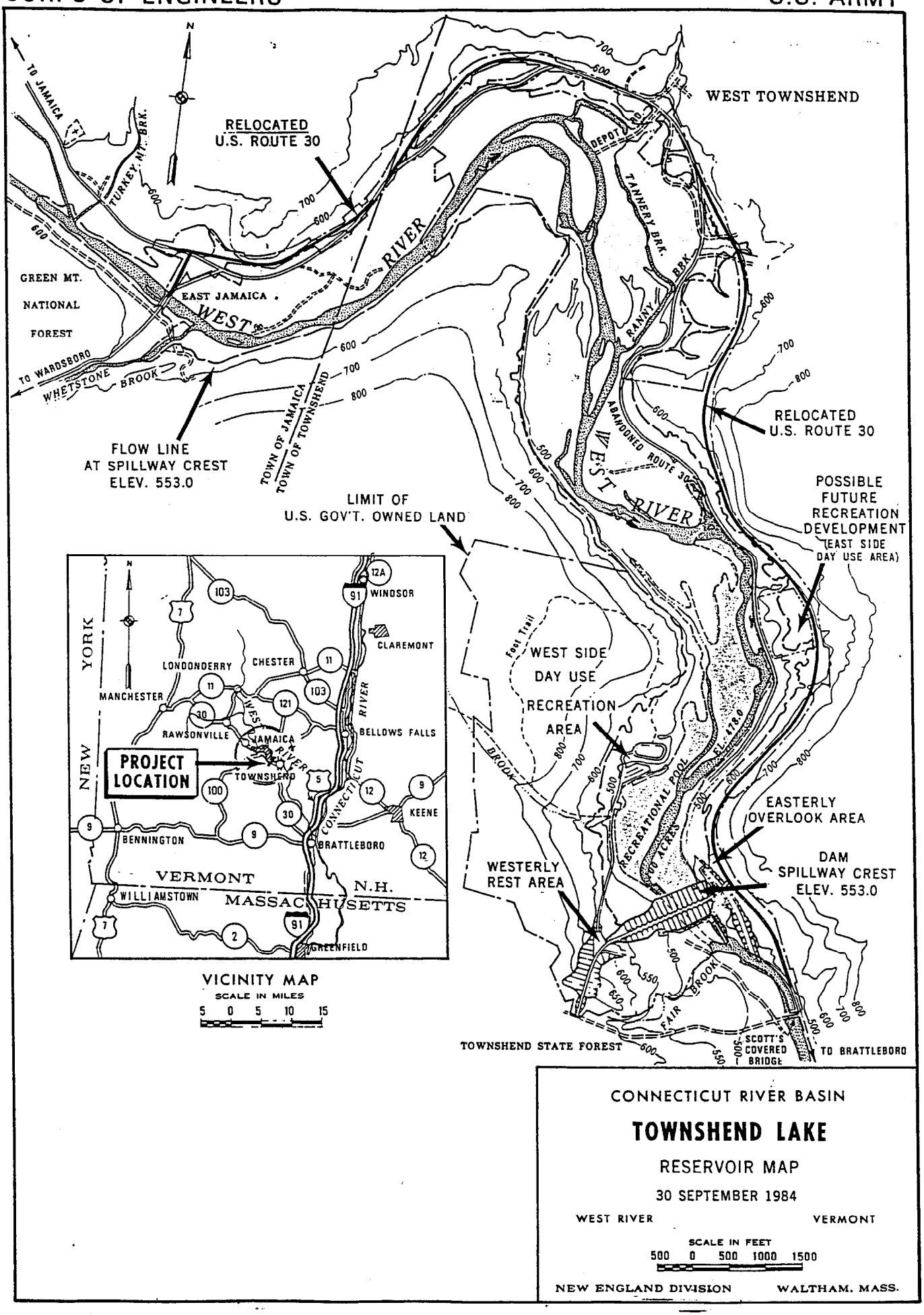
g. Effects of Additional Storage on Water Quality. The proposed flow augmentation will increase the pool level from 701 to 714 feet NGVD, with an increase in gross storage from 720 to 2,000 acre-feet. The present pool is controlled by a weir, and releases can be made over the weir or from the pool bottom using the flood control gates. Mean hydraulic retention times estimated for July and August would increase significantly by 23 to 29 days from 13 and 17 days for the existing summer pool to 36 and 46 days for the proposed pool, respectively. Surface area would more than double from 70 to 162 acres. Water quality degradation due to inundated vegetation, bank erosion, and increased retention times would probably be minor since the large increase in lake volume would dampen the effects of higher water temperatures, and additional nutrients, suspended sediments, turbidity, color and sedimentation. Although residence times would increase significantly, increased algae production should be minor, and localized, as trophic status is not likely to change much and nutrients levels should remain fairly low. In addition, the recreation area septic system would have to be relocated as the leach field's perforated pipe invert elevations of 714.2 feet NGVD are close to the proposed pool elevation of 714 feet. Detailed investigation would be required to refine water quality conclusions as explained in section 3.

10. **TULLY LAKE**

a. Location. Tully Lake is located on the East Branch of the Tully River in Royalston and Athol, Massachusetts, about 3.9 miles above its junction with Millers River which feeds the Connecticut River (see figure B-8).

b. Watershed Land Use. The watershed is primarily wooded, with many swamps and marshes, a few small lakes, and relatively little open agricultural or pastoral lands occupying the remainder of the watershed. The Corps leases 1,150 of the 1,320-acre reservoir area to the Massachusetts Department of Natural Resources for recreation, fish, wildlife, and forestry resources management. The watershed is rural with no industrial and relatively little residential development. No known point source discharges empty into the rivers upstream from the lake.

c. Water Quality Classification. The entire length of the East Branch Tully River and its tributaries are rated class B by the Massachusetts Division of Water Pollution Control. These waters are further designated as warm water fisheries, and provide acceptable cold water fish habitat until early summer.



CONNECTICUT RIVER BASIN

TOWNSHEND LAKE

RESERVOIR MAP

30 SEPTEMBER 1984

WEST RIVER VERMONT

SCALE IN FEET

500 0 500 1000 1500

NEW ENGLAND DIVISION WALTHAM, MASS.

FIGURE B-6

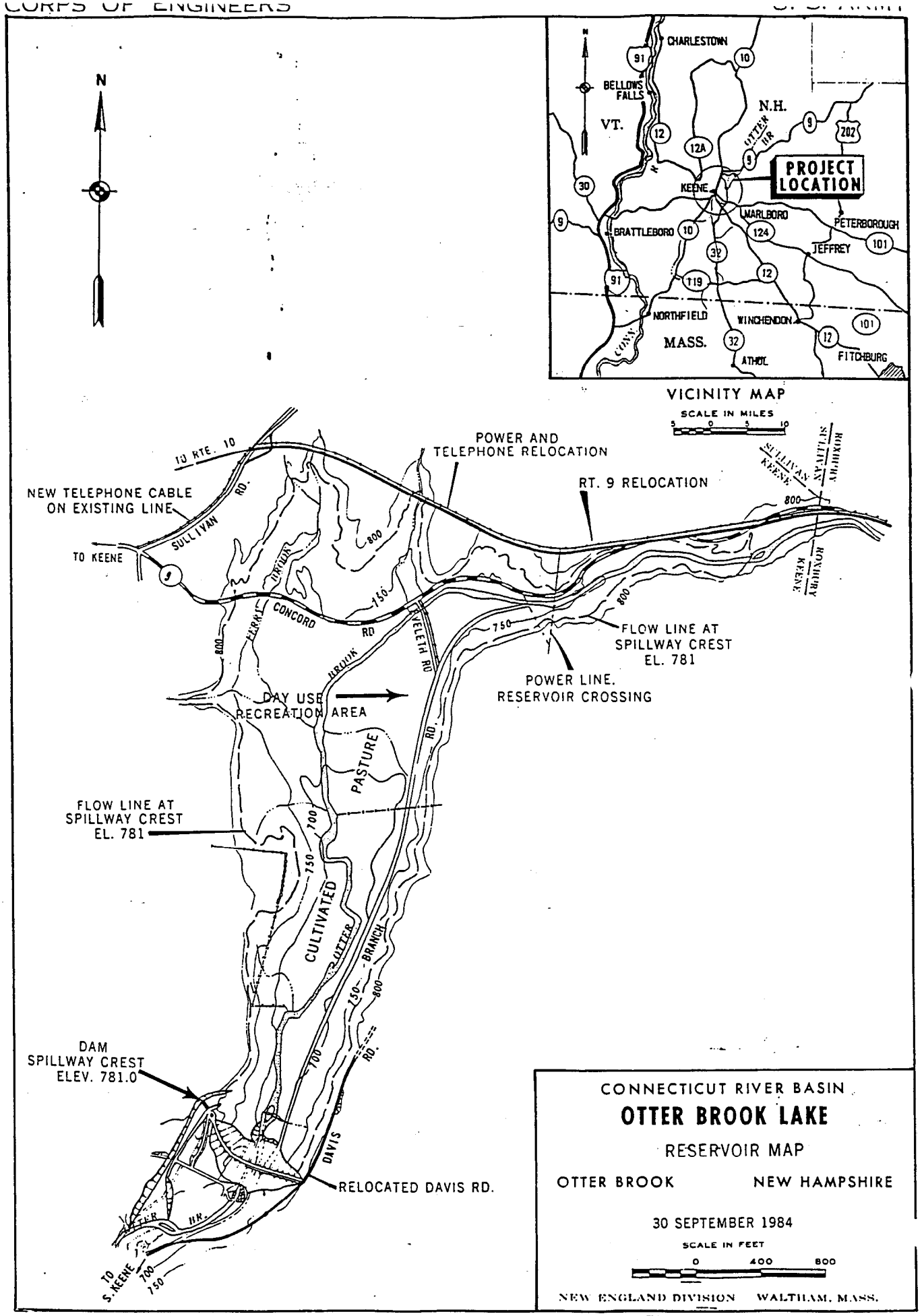

N
CHARLESTOWN
BELLOWS FALLS
VT.
N.H.
OTTER BR
PROJECT LOCATION
KEENE
MARLBORO
PETERBOROUGH
BRATTLEBORO
JEFFREY
NORTHFIELD
WINCHENDON
MASS.
ATHOL
FITCHBURG
VICINITY MAP
SCALE IN MILES
TO RTE. 10
POWER AND TELEPHONE RELOCATION
RT. 9 RELOCATION
NEW TELEPHONE CABLE ON EXISTING LINE
SULLIVAN RD.
TO KEENE
CONCORD RD
FERRY BROOK
VELETH RD
FLOW LINE AT SPILLWAY CREST EL. 781
POWER LINE. RESERVOIR CROSSING
DAY USE RECREATION AREA
PASTURE
CULTIVATED
OTTER BRANCH
DAVIS RD.
DAM SPILLWAY CREST ELEV. 781.0
RELOCATED DAVIS RD.
TO S. KEENE
CONNECTICUT RIVER BASIN
OTTER BROOK LAKE
RESERVOIR MAP
OTTER BROOK NEW HAMPSHIRE
30 SEPTEMBER 1984
SCALE IN FEET
0 400 800
NEW ENGLAND DIVISION WALTHAM, MASS.

FIGURE B-7

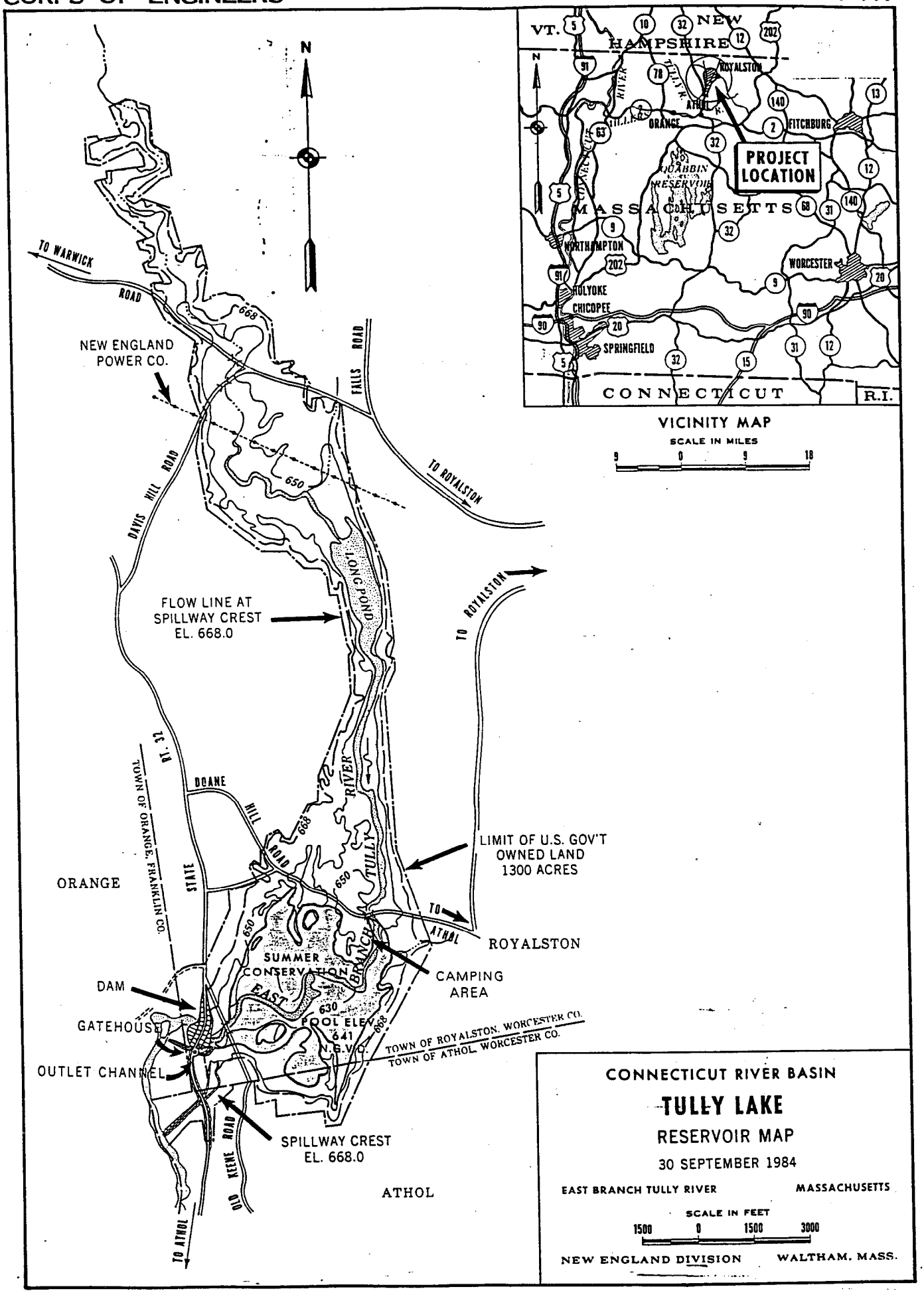

N
TO WARWICK ROAD
NEW ENGLAND POWER CO.
FALLS ROAD
TO ROYALSTON
DAVIS HILL ROAD
LONG POND
FLOW LINE AT SPILLWAY CREST EL. 668.0
TO ROYALSTON
RT. 32
TOWN OF ORANGE, FRANKLIN CO.
DOANE HILL ROAD
STATE
ORANGE
EAST BRANCH TULLY RIVER
LIMIT OF U.S. GOV'T OWNED LAND 1300 ACRES
TO ATHOL
ROYALSTON
SUMMER CONSERVATION
CAMPING AREA
DAM
GATEHOUSE
POOL ELEV. 641 N.G.V.D.
TOWN OF ROYALSTON, WORCESTER CO.
TOWN OF ATHOL, WORCESTER CO.
OUTLET CHANNEL
SPILLWAY CREST EL. 668.0
OLD KEENE ROAD
ATHOL
TO ATHOL
VT.
NEW HAMPSHIRE
ROYALSTON
ATHOL
ORANGE
FITCHBURG
PROJECT LOCATION
QUABBIN RESERVOIR
MASSACHUSETTS
NORTHAMPTON
WORCESTER
HOLYOKE
CHICOPEE
SPRINGFIELD
CONNECTICUT
R.I.
VICINITY MAP
SCALE IN MILES
9 0 9 18
CONNECTICUT RIVER BASIN
TULLY LAKE
RESERVOIR MAP
30 SEPTEMBER 1984
EAST BRANCH TULLY RIVER
MASSACHUSETTS
SCALE IN FEET
1500 0 1500 3000
NEW ENGLAND DIVISION
WALTHAM, MASS.

FIGURE B-8

d. Stratification Patterns. The lake exhibits moderate thermally induced density stratification patterns which form, break up, and reform during the summer. Dissolved oxygen measurements show low to anaerobic levels in the hypolimnium, indicating a lack of mixing of the waters.

e. Trophic Status. The lake is mesotrophic with low to moderate nutrient levels. Nuisance algae blooms have never been observed in Tully Lake.

f. Existing Water Quality Conditions. The waters of Tully Lake are of good quality, often meeting or exceeding their class B requirements. Minor areas of concern include low pH, and high color, iron and manganese levels which probably originate from natural sources in the watershed.

g. Effects of Additional Storage on Water Quality. The proposed flow augmentation will increase the summer pool level by 7 feet from 641 to 648 feet NGVD, with an increase in gross storage from 1,500 to 3,200 acre-feet. There is no weir at this project and releases are made from gates located at the bottom of the pool. Mean hydraulic retention times estimated for July and August would increase significantly by 26 to 35 days from 24 and 32 days for the existing summer pool to 50 and 67 days for the proposed pool, respectively. Surface area will more than double from 305 to 625 acres. With a change in surface area of this magnitude relative to the increase in storage, some degradation caused by inundated vegetation and bank erosion could occur, including increases in suspended sediments, nutrients, turbidity, color, and sedimentation. Increased algae production could be significant and there may be a possibility of nuisance algae blooms, based on trophic status, nutrient conditions, and large increases in projected residence times of the lake. In addition, the recreation area septic system would have to be relocated as the leach field invert elevation of about 651 feet NGVD is close to the proposed pool elevation (648 feet NGVD). As explained in section 3, a detailed investigation would be required to refine the above water quality conclusions.

11. EFFECTS ON QUABBIN RESERVOIR

The Quabbin reservoir is a class A waterbody from which moat waters are diverted to Wachusett Reservoir and on to metropolitan Boston (see figure B-1). Water from the reservoir is rated class A by the Massachusetts Division of Water Pollution Control, and requires no treatment other than chlorination for drinking water supply. Full pool elevation is 530 feet Metropolitan Water Supply Commission Datum

(MWSC). The Metropolitan District Commission study of Quabbin Reservoir (1983) recommends a minimum pool elevation of 490 feet MWSC, to prevent adverse effects on water quality and aquatic life. Below this elevation, water quality would not likely meet the class A and drinking water standards, and treatment would be required. According to the above study, the lowest experienced pool level is 495.7 feet MWSC which occurred in 1967 during a well-recognized drought period.

The MWRA is required by the Commonwealth of Massachusetts to release water from the Quabbin to maintain a flow of 20 mgd at Bondsville on the Swift River. When flows fall below 4,900 cfs at the U.S. Geological Survey Montague City gaging station on the Connecticut River, 70 cfs must be released from the Quabbin. In addition, when flows are less than 4,650 cfs at the Montague gage, the Quabbin must release 110 cfs. These last two releases are required by the Department of War (1929), and additional information is provided in the Hydrologic Study, Appendix A, of this report. By increasing storage at Corps projects, flow augmentation in the Connecticut River would help to keep readings at the Montague gage above 4,900 cfs more often. This, in turn, would not invoke the higher release rates from Quabbin as often; thereby, helping to keep its pool level above 490 feet during low flow periods. Reduced flows downstream from Quabbin Reservoir on the Swift River could impact water quality there. This has not been evaluated by the Corps for this report, but should be considered by the Massachusetts Water Resources Authority.

12. CONCLUSION

Storing additional water at the selected Corps reservoirs to augment flow in the Connecticut River would have some impact on water quality of the reservoirs and downstream releases. For the most part, these impacts would be minor, except at Union Village Dam where acid mine drainage may cause a severe water quality problem in the proposed impoundment. A more detailed study of the water and sediments at Union Village Dam would have to be performed to make sure acid mine drainage does not impair water quality. This would likely result in the requirement of source control involving cleanup and stabilization of abandoned upstream mines. Minor water quality degradation at all projects include decreases in dissolved oxygen in the pool; and increases in nutrients resulting in a greater potential for localized algae blooms, increases in sedimentation in the impoundment, and possible increases in turbidity, color, suspended sediments, and metals in the pool and downstream releases. Temperature may increase near the surface of the lakes and decrease near the

bottom. Discharge temperature could either increase or decrease depending on whether releases are made over a weir or from the bottom of the pool, respectively. Increased fluctuations in pool levels would also heighten bank erosion and may interfere with maintenance of fisheries. This is more likely to occur at projects with significant changes from winter to proposed summer pool levels, such as Union Village Dam and Ball Mountain Lake. Disregarding Union Village Dam, water quality degradation would probably be most noticeable at Tully Lake based on its projected trophic status and nutrient conditions, and extremely large increases in hydraulic retention times. This evaluation is based on existing water quality data and reservoir information. Detailed water and sediment data would have to be collected and analyzed to provide a more conclusive evaluation of expected water quality conditions due to the proposed increase in storage at all projects under evaluation. Numerical modelling of temperature and dissolved oxygen would be required to define changes to stratification patterns and releases. Column studies would be needed to examine sediment nutrient release.

13. REFERENCES

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APPENDIX C

ENVIRONMENTAL APPENDIX

TABLE OF CONTENTS

		Page Number
I.	INTRODUCTION	C- 1
II.	ENVIRONMENTAL RESOURCES	C- 1
	A. Union Village Dam	C- 1
	B. North Hartland Lake	C- 3
	C. North Springfield Lake	C- 4
	D. Ball Mountain Lake	C- 5
	E. Townshend Lake	C- 7
	F. Otter Brook Lake	C- 8
	G. Tully Lake	C- 9
III.	POTENTIAL ENVIRONMENTAL AFFECTS OF USING CORPS RESERVOIRS FOR FLOW AUGMENTATION	C-10
	A. General Impacts	C-10
	B. Impacts at Specific Reservoirs	C-11
	1. Union Village Dam	C-11
	2. North Hartland Lake	C-12
	3. North Springfield Lake	C-12
	4. Ball Mountain Lake	C-12
	5. Townshend Lake	C-13
	6. Otter Brook Lake	C-13
	7. Tully Lake	C-14
IV.	RECOMMENDED FEASIBILITY-LEVEL STUDIES	C-14
V.	APPLICABLE FEDERAL AND STATE LAWS AND REGULATIONS	C-15

I. INTRODUCTION

This report discusses the potential environmental affects of using existing U.S. Army Corps of Engineers (Corps) Reservoirs to augment Connecticut River flow at the Montague City, Massachusetts USGS gage. The study was funded jointly by the Corps and Massachusetts Water Resources Authority (MWRA) under the Corps' Section 22 "Planning Assistance" program.

Interest in augmenting flow at the Montague gage stems from a 1929 War Department Permit which imposed the following release requirements on the MWRA's Quabbin, Massachusetts Reservoir:

a. From the period June 1 to November 30, if flows on the Connecticut River at the Montague gage are between 4650 cfs and 4900 cfs, Quabbin Reservoir must release 70 cfs per calendar day.

b. From the period June 1 to November 30, if flows on the Connecticut River at the Montague gage are below 4650 cfs, Quabbin Reservoir must release 110 cfs per calendar day.

Flow augmentation using Corps reservoirs would be aimed at maintaining flows at the Montague gage above the mandated levels (i.e. 4650 or 4900 cfs) during June, July, and August.

Preliminary hydrologic screening determined that it may be possible to use storage capacity at seven Corps flood control reservoirs to augment flow at the Montague gage. Information about proposed augmentation storage at these projects is presented in Table 10 and 11 of the Main Report (see Figure 1 of Main Report for location map). Storage for flow augmentation would probably commence in June. Discharges to augment flow at the Montague gage would occur during June, July, and August.

II. ENVIRONMENTAL RESOURCES

A. Union Village Dam

The Union Village Dam is located on the Ompompanoosuc River in the town of Thetford, Vermont. The dam is located about 4 miles upstream of the confluence of the Ompompanoosuc and Connecticut Rivers. The project area encompasses about 1,300 acres, including 740 acres situated below spillway crest. The project is normally operated as a "dry-bed reservoir", with no permanent summer conservation pool. During the winter a 50 acre pool (440-ft NGVD) is maintained to prevent freezing of control gates. Storages for flood control operations typically occur several times each year, usually in spring and fall. Storages above the elevation of the proposed augmentation pool (485-ft NGVD) have occurred numerous times since the project became operational in 1950. The reservoir area includes

the confluence of the main branch and east Branch Ompompanoosuc Rivers. An abandoned copper mine is present on the main branch of the Ompompanoosuc, about 6 miles upstream of the Union Village dam. Over the years a substantial amount of metal rich tailing has washed downstream from the mine and been deposited in the reservoir.

Most of the project area (ca. 800 acres) is forested. The remainder consists of scrub-shrub wetlands, oldfield, and pasture. Forested upland communities are dominated by eastern hemlock, white pine, and northern hardwoods (American beech, sugar maple, and yellow birch). Associated species include northern red oak, basswood, white ash, and black cherry.

Most of the 190 acres situated within the dry-bed reservoir which would be inundated by the augmentation pool is upland vegetated with shrubs and herbaceous vegetation. About 40 acres between 460 and 485-ft NGVD is forested. About 75 acres at lower elevation is scrub-shrub wetland.[1] Predominant species in the wetlands include willows, red osier dogwood, gray birch, and alder. Little emergent wetland vegetation is present. About two-thirds of the scrub-shrub wetland is normally flooded by the winter pool.

The project area provides excellent wildlife habitat. Mammals present include white-tail deer, black bear, snowshoe hare, New England cottontail, red and gray squirrel, red fox, woodchuck, skunk, raccoon, muskrat, beaver, and mink. A large white-tail deer wintering yard in present on the west side of the Ompompanoosuc, within the reservoir area (but above 485-ft NGVD). Numerous species of birds inhabit the project area. These include osprey, wild turkey, and ruffed grouse. Waterfowl seldom occur in the project area, except during the winter and spring, when a pool is normally present.

The Ompompanoosuc River and its tributaries support both warm and cold water fisheries. The Vermont Department of Fish and Wildlife stocks the river with rainbow, brown, and brook trout on a put and take basis. Other species present include smallmouth bass, largemouth bass, yellow perch, chain pickerel, bullhead, dace, suckers, shiners, and burbot. Atlantic salmon fry have been stocked in the east branch of the Ompompanoosuc, including the Union Village dam reservoir area, since 1989. Fry survival is good, and a substantial number of smolts are likely to migrate seaward from the project area each spring.

Except for occasional transients, no federal or state listed rare, threatened, or endangered species are known to occur in the project area.

The project area provides opportunities for hiking, hunting, fishing, swimming, and snowmobiling. Facilities present include a riverside swimming beach, picnic area, and restrooms.

Notes:

1: Estimates of wetland area presented in this report are based on U.S. Fish and Wildlife Service National Wetlands Inventory maps and/or analysis of Corps aerial photographs taken in the spring of 1985. Additional studies would be needed to fully categorize and quantify wetland resources.

B. North Hartland Lake

North Hartland Lake is located in south central Vermont, in the towns of Hartland and Hartford. The dam is located on the Ottauquechee River, about 1.3 miles upstream of the confluence of the Ottauquechee and Connecticut Rivers. The project encompasses about 1,728 acres, including 1,100 acres situated below spillway crest. The reservoir is situated in a narrow valley and has a maximum length of about 5 miles at spillway crest. The Ottauquechee passes through a deep, scenic gorge (Quechee Gorge) at the upper end of the reservoir. A 215 acre pool is maintained at 425-ft NGVD throughout the year for recreation and to facilitate hydropower production. Maintaining the pool in winter also prevents control gates from freezing. Storages for flood control operations typically occur several times each year, usually in spring and fall. Storages above the elevation of the proposed augmentation pool (444-ft NGVD) have occurred about 35 times since the project became operational in 1962.

Most of the project area is forested. Predominant species present in mature upland forests are white pine, Eastern hemlock, sugar maple, American beech, and yellow birch. White birch and butternut hickory are also common along steep slopes. Secondary growth on abandoned pasture lands is dominated by aspen, gray birch, white ash, and red pine.

The proposed augmentation pool would inundate about 135 acres not normally flooded by the recreation pool. Most of this area is vegetated with herbaceous vegetation or is mudflat. Some trees, however, are present above 435-ft NGVD. About 20 acres of emergent or scrub-shrub wetland is present. Alder and willow predominate in the scrub-shrub wetlands.

The project area provides habitat for a variety of wildlife species. Mammals present include white-tail deer, snowshoe hare, New England cottontail, gray and red squirrel, red fox, fisher, weasel, skunk, raccoon, muskrat, beaver, and mink. Numerous species of birds inhabit the project area, including osprey, ruffed grouse, woodcock, and migrating waterfowl.

Predominant fish species present in North Hartland Lake include white sucker, brown bullhead, golden shiner, and yellow perch. The lake supports a poor largemouth bass fishery, possibly due to water level fluctuations caused by operation of an associated hydropower facility. The Vermont Department of Fish and Wildlife stocks the Ottauquechee River with rainbow, brown, and brook trout on a put and take basis. An excellent trout fishery is present in the Ottauquechee downstream of lake.

Except for occasional transients, no federal or state listed rare, threatened, or endangered species are known to occur in the project area.

The project area provides opportunities for hiking, hunting, fishing, swimming, boating, and snowmobiling. Facilities present include a swimming beach, boat ramp, picnic area, ballfield, restrooms, and a campground operated by the state of Vermont.

A non-federal hydropower facility is present at the North Hartland Dam. The facility consists of a conduit leading from the dam outlet to penstocks and a powerhouse capable of generating 4 MW. The facility was not designed to operate with greater than a 45-ft head, and shuts down when pool elevation exceeds 435-ft NGVD.

C. North Springfield Lake

North Springfield Lake is located on the Black River in the town of North Springfield, Vermont. The dam is located about 8.7 miles upstream of the confluence of the Black and Connecticut Rivers. The project encompasses about 1,790 acres, including 1,200 acres situated below spillway crest. A 100 acre permanent pool is maintained at 467-ft NGVD. The pool has a maximum depth of about 15 feet. Storages for flood control typically occur several times each year, usually in spring and fall. Storages above the elevation of the proposed augmentation pool (484-ft NGVD) have occurred about 35 times since the project became operational in 1962.

Uplands in the project area are a mix of open areas, oldfield, and forest. Forested areas are dominated by eastern hemlock, white and red pine, scotch pine and Norway spruce, white birch, aspen, and northern hardwoods (American beech, sugar maple, and yellow birch). Open and oldfield areas are vegetated with gray birch, aspen, white pine, red maple, blue beech, Spirea spp., and herbaceous vegetation.

About 20 acres of emergent and scrub-shrub wetland occurs adjacent to the permanent pool, mostly at the northern end of the reservoir. Species present include willow, bulrush, smartweed, cattail, burreed, arrowhead, pickerelweed, water plantain, sedges, and grasses. Stands of submerged aquatics such as water celery and pondweed are also present.

Upland and wetland areas within the reservoir provide habitat for a variety of wildlife species. Mammals present include white-tail deer, black bear, New England cottontail, gray and red squirrels, red fox, skunk, raccoon, muskrat, beaver, mink, and river otter. About 150 muskrat are trapped from the upper impoundment area yearly. Numerous species of birds, including osprey and ruffed grouse, inhabit the project area. The reservoir provides good habitat for migratory waterfowl, including Canada goose, mallard, black duck, green-winged teal, American goldeneye, common merganser, and wood duck.

North Springfield Lake supports an excellent, self sustaining largemouth bass population. Bass spawn in shallow sandy areas around the perimeter of the lake during May and June. Aquatic bed and emergent wetlands provide nursery areas. Other fish present in the lake include brown bullhead, yellow perch, shiners, suckers, sunfish, and rock bass. Brown trout, fallfish, chubs, suckers, yellow perch, brown bullhead, and smallmouth bass are found in the Black River downstream of the lake.

Except for occasional transients, no federally or state listed rare, threatened, or endangered species are known to occur in the project area.

The project area provides opportunities for hiking, hunting, fishing, swimming, boating, snowmobiling, cross country skiing, and trail bike riding. Facilities present include a swimming beach, a boat ramp, a picnic area, restrooms, and an interpretive nature trail maintained by the Ascutney Mountain Audobon Society. The nature trail overlooks wetlands at the northern end of the reservoir. The lake offers an excellent bass fishery.

D. Ball Mountain Lake

Ball Mountain Lake is located on the West River in the towns of Londonderry and Jamaica, Vermont. The dam is located about 29 miles upstream of the confluence of the West and the Connecticut Rivers, and 9.5 miles upstream of the Corps Townshend Lake flood control dam. The project encompasses about 1,790 acres, including 1,200 acres situated below spillway crest. A 75 acre conservation pool is maintained at 870.5-ft NGVD during the summer and early fall (June thru early October). The pool has a maximum depth of about 65 feet. Storages for flood control operations typically occur several times each year, usually in spring and fall. Storages above the elevation of the proposed augmentation pool (900-ft NGVD) have occurred numerous times since the project became operational in 1962.

No vegetation occurs below the normal Ball Mountain Lake summer conservation pool level. The area between 871 and 890-ft NGVD is well vegetated with grasses, willows and other low shrubs. The reservoir is forested above 890 NGVD. Predominant species include sugar maple, red maple, white birch, yellow birch, red oak, American beech, white ash, aspen, red spruce, and white pine.

The Ball Mountain Lake project area provides habitat for a variety of wildlife species. Mammals present include white-tail deer, black bear, New England cottontail, gray and red squirrels, red fox, skunk, raccoon, muskrat, beaver, mink, and river otter. The reservoir provides good waterfowl habitat. Species present include common merganser, mallard, canvasback, cormorant, Canada goose, and hooded merganser. Other birds present include osprey and ruffed grouse.

Ball Mountain Lake supports a poor warmwater fishery, probably due to rapidly fluctuating water levels which preclude development of emergent or submerged aquatic vegetation. Game fish found in the lake include brown trout, rainbow trout, and perch. Rainbow trout are stocked by the Vermont Department of Fish and Wildlife on a put and take basis. An excellent brown trout fishery is present in the West River downstream of the dam. Other species present downstream of the dam include rainbow trout, fallfish, common shiner, dace, white sucker, and Atlantic salmon (fry, parr, and, smolt).

A program is underway to restore Atlantic salmon in the West River basin (the river is ranked third among Connecticut River tributaries with respect to potential production of wild salmon smolts). Large numbers of fry have been stocked in the basin yearly since 1987, about 50 percent of these upstream of Ball Mountain Lake. Fry survival to the yearling parr stage is generally excellent, and thousands of smolts are likely to migrate seaward each year during late April and May.

Virtually all adult Atlantic salmon migrating to the upper Connecticut River are captured at the Holyoke Dam and retained for propagation purposes. Some fish are released above Holyoke, however, and in recent years a few salmon have entered the West River. At least one salmon was seen in the pool immediately downstream of Townshend Lake in May of 1990 and two unconfirmed sightings were reported from the West River in 1991. Adult salmon are currently unable to reach Ball Mountain Lake due to the Townshend Lake dam. Eventually at least 550 salmon are projected to return to the river annually.

The Corps has recently completed a study which recommends several measures to enhance passage of smolts and adult salmon at Ball Mountain and Townshend Lakes. Upstream passage of adults at both projects will be provided by a capture facility situated downstream of Townshend Lake. Downstream passage of smolts through Ball Mountain Lake will be enhanced by lowering the pool stage to 25-ft during the smolt outmigration season (late April through June). This protocol has been followed informally since 1989.

With the exception of transients, no federally or state listed rare, threatened, or endangered species are known to occur at Ball Mountain Lake. A population of brook floater (Alismidonta varicosa), a freshwater mussel, and "candidate" species for inclusion on the Federal list of threatened and endangered species, is present in the West River, about 5 miles downstream of the lake. The eastern pearl mussel (Margaritera margartifera) a proposed threatened species in Vermont, is found at the same location.

The project area provides opportunities for hiking, hunting, fishing, and camping. Facilities present include a campground, a picnic area, restrooms, and hiking trails. Little swimming, boating or fishing currently occurs on Ball Mountain Lake. Excellent trout fishing is found in the West River downstream of the dam, and in some sections of the river upstream of Ball Mountain Lake.

The Corps provides controlled releases (1500 cfs) from Ball Mountain Lake for whitewater canoeing and kayaking each year. Prior to 1990, controlled releases were typically made during two weekends in the spring (late April and early May) and during Columbus Day weekend in October. The releases provide outstanding white water conditions between Ball Mountain and Townshend Lakes, and attract hundreds of white water enthusiasts each year. National White Water Canoeing Championship races were frequently held in the West River during one of the spring release weekends. Since the fall of 1990, there has been an informal agreement between the Corps, U.S. Fish and Wildlife Service, Vermont Department of Fish and Wildlife, and the Appalachian Mountain Club to have only one spring release, dedicated for recreational purposes. Races were held elsewhere in 1991, and are not currently scheduled to be held at Ball Mountain Lake in future years.

E. Townshend Lake

Townshend Lake is located on the West River in the towns of Townshend and Jamaica, Vermont. The dam is located about 19.5 miles upstream of the confluence of the West and the Connecticut Rivers, and 9.5 miles downstream of the Corps Ball Mountain Lake flood control project. The Townshend Lake project encompasses about 1,230 acres, including 553 acres situated below spillway crest. A permanent 95 acre conservation pool is maintained at 478-ft NGVD by a weir. The pool has a maximum depth of about 21 feet. Storages for flood control operations typically occur several times each year, usually in spring and fall. Storages above the elevation of the proposed augmentation pool (494-ft NGVD) have occurred numerous times since the project became operational in 1962.

The reservoir area is forested above about the 494-ft stage. Predominant species include red maple, sugar maple, white birch, yellow birch, red oak, American beech, white ash, aspen, red spruce, and white pine. Scrub-shrub vegetation dominated by alder is common along the margins of the normal recreation pool. Extensive emergent wetlands dominated by grasses and sedges are present at the head of the pool. A moderate amount of submerged aquatic vegetation is present in the conservation pool.

Wetland and forested areas within the reservoir provide habitat for a variety of wildlife species. Mammals present include white-tail deer, New England cottontail, gray and red squirrels, red fox, skunk, raccoon, muskrat, beaver, mink, and river otter. The reservoir provides habitat for numerous birds. Waterfowl present include common merganser, mallard, canvasback, cormorant, Canada goose, and hooded merganser.

Townshend Lake supports a limited warmwater fishery. Species found in the lake include brown and rainbow trout (stocked), yellow perch, large and smallmouth bass, sunfish, and bullhead. Species present in the West River downstream of the dam include brown trout, rainbow trout, fallfish, common shiner, blacknose dace, bass, and white sucker.

As discussed above for Ball Mountain Lake, efforts are underway to restore Atlantic salmon in the West River basin. At least one adult salmon was seen immediately downstream of Townshend Lake in May of 1990 and two unconfirmed sightings were reported from the West River in 1991. The Townshend Lake dam currently blocks salmon access to about 80 percent of potential spawning habitat in the West River basin. The Corps has recently completed a study which recommends construction of capture facility several hundred feet downstream of the dam. Captured salmon will be trucked upstream of Ball Mountain or Townshend Lake. The facility is expected to be operational in 1993.

A large population of brook floater, a freshwater mussel, and "candidate" species for inclusion on the Federal list of threatened and endangered species, is present in the West River, about 2,000 - 3,000 feet downstream of the dam. A second brook floater population is reportedly present about 4.5 miles downstream of the dam.

With the exception of transients, no other Federally or state listed rare, threatened, or endangered species are known to occur in the vicinity of Townshend Lake.

The project area provides opportunities for swimming, boating, hiking, fishing, hunting, fishing, and snowmobiling. Recreational facilities present at Townshend Lake include a swimming beach, ballfield, drinking water, picnic area, hiking trails, restrooms, and boat ramp.

F. Otter Brook Lake

Otter Brook Lake is located in the town of Keene, New Hampshire. The lake is located on Otter Brook, about 2.4 miles above its confluence with the Branch River and 4.9 miles above the Branch-Ashuelot River confluence. A 70 acre recreation pool is maintained during the summer at 701-ft NGVD. During the winter, the pool is raised to 703-ft NGVD to prevent the outlet works from freezing. Storages for flood control typically occur several times each year, usually in spring and fall. Storages above the elevation of the proposed augmentation pool (714-ft NGVD) have occurred numerous times since the project became operational in 1962. The project area includes 582 acres, including 374 acres situated below spillway crest.

Uplands in the project area are mostly forested with mixed hardwood and softwood stands. Predominant species include white pine, eastern hemlock, northern red oak, hickory, and aspen.

About 25 acres of vegetated wetland habitat is present in the project area. These include about 20 acres of forested or shrub/scrub wetland and 5 acres of emergent wetland. Forested wetland is dominated by red maple Associate species include swamp white oak, yellow birch, ironwood, and American yew, speckled alder, and black ash. Willow, alder, and Spirea spp. are predominant in scrub-shrub areas. Submerged and emergent aquatic vegetation is well developed along the margins of the reservoir. Species present include pickerelweed, broadleaf arrowhead, bladderwort, spikerush, water lilies, pondweed, bullrush, purple loosestrife, speckled alder, and Spirea spp. Dominant species in riparian areas along Otter Brook are American elm, black ash, red maple, alder, big tooth aspen, and quaking aspen.

Wetland and forested areas within the project area provide habitat for a variety of wildlife species. Mammals present include white-tail deer, eastern cottontail, snowshoe hare, gray and red squirrels, red fox, skunk, raccoon, beaver, fisher, mink, muskrat, and woodchuck.

Fish present in Otter Brook Lake included chain pickerel, yellow perch, pumpkinseed sunfish, brown bullhead, golden shiner, largemouth bass, and rock bass. Otter Brook is stocked with rainbow trout on a put and take basis. Warmwater species in the brook include white suckers, fallfish, common shiner, and blacknose and longnose dace. American eel occur downstream the dam.

With the exception of occasional transients, no Federally or state listed or proposed threatened or endangered species are known to occur in the project area.

Otter Brook Lake provides opportunities for swimming, boating, hiking, hunting, and fishing. Facilities present include a swimming beach, boat ramp, large picnic area, parking lot, and changing house/comfort station.

G. Tully Lake

Tully Lake is located in the towns of Royalston and Athol, in central Massachusetts. The lake is located on the East Branch of the Tully River, about 3.9 miles above its confluence with the Millers River. At present a 300 acre recreation pool is maintained during the summer at elevation 641-ft NGVD. A 78 acre winter pool is maintained at 636-ft NGVD to prevent the outlet works from freezing. Storages for flood control operations typically occur several times each year, usually in spring and fall. Storages above the elevation of the proposed augmentation pool (648-ft NGVD) have occurred numerous times since the project became operational in 1949. The project area includes 1263 acres, including 1,130 acres situated below spillway crest. Long Pond, a 40 acre natural lake (elevation 647-ft NGVD), is present within the reservoir area.

Uplands in the project area are mostly forested. Predominant species present include white pine, northern red oak, red maple, and gray birch. Other species present include white ash, white oak, black cherry, eastern hemlock, yellow birch, red spruce, and aspen.

About 355 acres of vegetated wetlands are associated with Tully Lake and Long Pond. These include about 205 acres of forested, and 105 acres of scrub-shrub emergent wetland. Forested wetlands are dominated by red maple and gray birch. Common species in scrub-shrub wetlands include willow, sweet pepperbush, alder, meadowsweet, and dogwood. About 45 acres of submerged and emergent aquatic vegetation is present in Tully lake, Long Pond, and the Tully River. The most common submerged aquatic species is coontail. Common emergent species include pickerelweed, sedges, grasses, and softstem bullrush.

Wetland and forested areas within the project area provide habitat for a variety of wildlife species. Mammals present include white-tail deer, eastern cottontail, gray and red squirrels, red fox, skunk, raccoon, beaver, mink, river otter, muskrat, and woodchuck. Over 100 species of birds are known to occur in the project area. Game birds and waterfowl present include woodcock, ruffed grouse, black duck, and mallard.

Tully Lake and Long Pond support good warmwater fisheries. Species present include chain pickerel, yellow perch, brown bullhead, largemouth bass, and sunfish. The East Branch of the Tully River and a tributary stream (Lawrence Brook) are stocked with brook and rainbow trout on a put and take basis. Warmwater species present in Tully River include white suckers, fallfish, common shiner, and blacknose and longnose dace.

With the exception of occasional transients, no Federally listed or proposed threatened or endangered species are known to occur in the project area. A rare State-listed plant, the tiny cow lily (Nuphar pumila), may occur in Long Pond. The last record of the cow lily in Long Pond was in 1950, however, and a survey would be required to determine if the plant is still present.

Tully Lake provides opportunities for boating, fishing, hunting, hiking, camping, picnicking and hunting. Facilities present include two boat ramps, a picnic area, and a small walk-in campground. Two scenic waterfalls (Doane Falls and Spirit Falls) are present in the project area.

III. POTENTIAL ENVIRONMENTAL AFFECTS OF USING CORPS RESERVOIRS FOR FLOW AUGMENTATION

A. General Impacts

Implementation of the proposed augmentation plan at all seven reservoirs would inundate about 750 acres of upland and 500 acres of wetland habitat. Much of this area is inundated periodically under current operating protocol. Frequency and duration of inundation varies widely with pool-stage, but vegetation is typically inundated only for short periods (i.e. < 2 weeks) during flood events a few times each year. Most of these events occur prior to or after the growing season. Over the years this flooding regime has selected for vegetation that is somewhat tolerant of inundation. Despite this, prolonged inundation by the augmentation pool during the growing season, would probably kill most woody upland and wetland vegetation present below the maximum augmentation pool level. Emergent wetland vegetation occurring in the reservoirs would also probably be killed or severely damaged by submergence during the growing season. Submerged aquatic plants growing in conservation pools or riverine habitat could also be severely impacted, if submerged for prolonged periods below the euphotic zone. Fluctuating water levels would prevent significant colonization of higher pool levels by emergent or aquatic vegetation.

At most reservoirs, loss of vegetative cover could lead to increased shoreline erosion when no pool was maintained.

Most of the areas that would be inundated provide good to excellent wildlife habitat. Although most wildlife using these areas would shift to alternative habitat as the reservoirs were filled, some mortality due to dispersal related stress would probably occur. Loss of woody cover within the reservoir would probably result in a long-term decline in habitat carrying capacity for many species. Eggs and nestling of many birds species would be vulnerable to inundation if filling commenced in May. Loss of submerged macrophyte communities and associated invertebrates would reduce reservoir habitat value for migrating waterfowl.

Augmentation storage would disturb spawning and nursery habitat for largemouth bass and other warmwater fish at most of the reservoirs. Increased water level fluctuations associated with the plan would increase stranding of eggs and juveniles. Loss of cover and invertebrate prey provided by submerged aquatic plants would also affect fish populations.

The augmentation pools would inundate recreational facilities at most reservoirs. These include 4 swimming beaches, 6 boat ramps, and 1 picnic area. In most instances the recreational facilities could not be easily replaced.

Outflow from the reservoirs would be reduced below normal levels during reservoir filling. This would result in loss of some downstream riverine habitat and could raise stream water temperature. More frequent changes in outflow from the dams would increase stranding of downstream aquatic life, unless changes in flow were made gradually. In some instances (Ball Mountain Lake, North Hartland Lake), excellent downstream trout fisheries could be affected. Conversely, properly managed flow augmentation during low flow periods in the summer might be beneficial to downstream aquatic life and water quality. In-stream flow studies are needed to determine acceptable minimum flows and ramping rates. At most projects it is unlikely that release of 7Q10 flows during reservoir filling would be acceptable from an environmental standpoint. A release rate of 0.2 to 0.5 cfsm is more likely to be acceptable, but would need to be verified by field studies.

A discussion of reservoir specific impacts at each of the seven Corps reservoirs under study is presented in the next section. Potential impacts on water quality and archaeological resources are discussed in Appendices A and D.

B. Impacts at Specific Reservoirs

1. Union Village Dam

The proposed augmentation pool would flood about 190 acres of vegetated habitat, including about 75 acres of scrub-shrub wetland and 40 acres of forested uplands.

About 2 miles of riverine habitat would be inundated. This would severely affect the existing put-and take trout fishery and rearing habitat for Atlantic salmon. Augmentation storage early than in June would impair downstream migration of Atlantic salmon smolts.

The augmentation pool would flood a small picnic area and flood a road providing access to the east side of the reservoir.

Outflow from the augmentation pool might be somewhat cooler than outflow under current operating (run-of-the-river) protocol. This would have a beneficial impact on downstream cold water (trout) fisheries. If anoxic conditions were to arise in the reservoir, release of metals from sediments could have an adverse impact on aquatic life in the reservoir and in the Ompompanoosuc downstream of the dam.

2. North Hartland Lake

The proposed augmentation pool would inundate about 135 acres not flooded by the normal recreation pool. This includes about 20 acres of wetland habitat. Most of the remaining area is upland habitat vegetated with herbaceous vegetation or mudflat.

Water level fluctuations caused by the augmentation scheme would further degrade the already marginal bass fishery in the lake.

Reduced outflow from the lake during filling could adversely affect an excellent downstream trout fishery.

The augmentation pool would flood the only locally available swimming beach, a boat ramp, and a parking lot. Operation of the existing hydropower facility downstream of the dam would be curtailed when pool levels rise above 435-ft NGVD.

3. North Springfield Lake

The proposed augmentation pool would inundate about 314 acres not flooded by the normal recreation pool. This includes about 20 acres of emergent and scrub-shrub wetland. Most of the remaining area that would be inundated is upland vegetated with shrubs, scattered trees, and herbaceous vegetation. Submerged macrophytes would also be impacted.

Inundation of spawning and nursery habitat would have a significant adverse impact on a excellent largemouth bass fishery.

The augmentation pool would inundate a swimming beach and a boat ramp. Opportunities for bird watching along the Audobon Society nature trail would be curtailed due to flooding of adjacent wetlands.

4. Ball Mountain Lake

The proposed augmentation pool would inundate about 70 acres not flooded by the normal conservation pool. Virtually all of this area is upland. About half the area flooded is forested. No vegetated wetlands would be flooded.

The proposed regulation scheme would have little impact on the already poor Ball Mountain Lake warmwater fishery. The augmentation plan would have no impact on the Atlantic salmon restoration efforts, unless filling of the reservoir did not commenced before June 1. Filling prior to June 1 would have a significant adverse effect on smolt outmigration. This would not be permissible since Atlantic salmon restoration is an authorized project purpose at both Ball Mountain Lake and Townshend Lake.

Curtailment of outflow from the lake during filling could impact an excellent downstream trout fishery and Atlantic salmon rearing habitat.

The proposed augmentation plan would have no significant impact on recreational resources.

5. Townshend Lake

The proposed augmentation pool would inundate about 176 acres not flooded by the normal recreation pool. These include about 90 acres of emergent wetland and about 50 acres of forested uplands.

Inundation of spawning and nursery habitat would have an adverse impact on warmwater fish populations. The augmentation plan would have no impact on the Atlantic salmon restoration efforts, provided that filling of the reservoir did not commence until after June 1. Maintaining higher pool stages prior to June 1 would have a significant adverse effect on smolt outmigration.

Implementation of the augmentation plan would result flood a large swimming beach, boat ramp, two parking areas, and the access road to the picnic area. The beach is the only public beach in the area.

Implementation of the augmentation plan could impact a population of brook floater, a rare freshwater mussel (and potential Federally listed threatened or endangered species) found in the West River 2,000 to 3,000 feet downstream of Townshend Lake. Of principal concern is the possibility that rapid reductions in outflow from the dam will dewater mussel habitat, and result in mortality of stranded mussels due to overheating and desiccation.

Based on field observations, a minimum release of about 90 cfs (or inflow into the reservoir, if less) would be required during filling of the reservoir to avoid significant impacts on the brook floater population situated downstream of the dam. In addition, any reductions in flow below 200 cfs would have to be made gradually to avoid stranding. Monitoring would need to be conducted to insure that this protocol is adequate to protect the population.

6. Otter Brook Lake

The proposed augmentation pool would inundate about 92 acres not flooded by the normal recreation pool. These include about 25 acres of emergent, forested, or scrub-shrub wetland.

Inundation of spawning and nursery habitat would have an adverse impact on existing self-sustaining warm water fish populations.

The proposed 714-ft NGVD augmentation pool would inundate a large swimming beach, boat ramp, a parking area, and a changing house/comfort station. A leachfield situated at 715-ft NGVD would probably have to be relocated.

7. Tully Lake

The proposed augmentation pool would inundate about 320 acres not normally flooded by the recreation pool. This includes about 275 acres of forested, scrub-shrub wetland, and emergent wetland. About 1.5 miles of riverine habitat would also be flooded.

Augmentation storage could impact a population of the tiny cow lily, a rare state-listed aquatic plant. Prior to implementation of the plan, a detailed survey of Long Pond would be needed to determine if the plant is still present. Its presence would probably preclude use of Tully Lake for augmentation storage.

The proposed augmentation pool would inundate two boat ramps and a small campground. A septic system located at 651-ft NGVD would probably have to be relocated.

IV. RECOMMENDED ADDITIONAL STUDIES

Before the proposed augmentation plan were implemented, an Environmental Impact Statement (EIS) would probably be required. An EIS, rather than an Environmental Assessment (EA) would be required due to the likely significant adverse impacts on wetlands and socio-economic resources. Preparation of an Environmental Assessment, rather than EIS would be appropriate only if the augmentation plan was revised so that impacts to wetland and socio-economic resources were substantially reduced. Due to the cumulative nature of the impacts, preparation of separate EIS's or EA's for individual projects would not be appropriate.

Studies required as part of the EIS process would include:

- Field surveys to more precisely quantify wetland impacts.
- A habitat based analysis, such as the U.S. FWS Habitat Evaluation Procedure (HEP), to quantify fish and wildlife resource impacts and aid in development of a mitigation plan.
- In-stream flow studies to establish acceptable minimum flows during reservoir filling and ramping rates.
- Water quality modelling studies at all reservoirs. In addition, detailed studies would be required at Union Village to determine if toxic levels of contaminants would be released from inundated reservoir sediments.
- Archaeological surveys to identify significant historical properties.

In addition to impacts at Corps Reservoirs, the EIS would need to consider the impacts of reduced releases from Quabbin on the Swift, Ware, and Chicopee Rivers. As part of the EIS process, alternatives to flow augmentation, such as water conservation, would need to be considered.

V. APPLICABLE FEDERAL AND STATE LAWS AND REGULATIONS

A variety of Federal Laws and Regulations would need to be considered prior to implementing the proposed augmentation plan. These include the following:

A. Federal Statutes

1. Preservation of Historic and Archaeological Data Act of 1974, as amended, 16 U.S.C. 469 et seq.

2. Clean Air Act, as amended, 42 U.S.C. 7401 et seq.

3. Clean Water Act of 1977 (Federal Water Pollution Control Act Amendments of 1972) 33 U.S.C. 1251 et seq.

4. Endangered Species Act of 1973, as amended, 16 U.S.C. 1531 et seq.

5. Federal Water Project Recreation Act, as amended, 16 U.S.C. 460l-12 et seq.

6. Fish and Wildlife Coordination Act, as amended, 16 U.S.C. 661 et seq.

7. Land and Water Conservation Fund Act of 1965, as amended, 16 U.S.C. 460l-4 et seq.

8. National Historic Preservation Act of 1966, as amended, 16 U.S.C. 470 et seq.

9. National Environmental Policy Act of 1969, as amended, 42 U.S.C. 4321 et seq.

10. Watershed Protection and Flood Prevention Act, as amended, 16 U.S.C. 1001 et seq.

11. Water Supply Act of 1958, as amended

B. Federal Executive Orders

1. Executive Order 11988, Floodplain Management, 24 May 1977 amended by Executive Order 12148, 20 July 1979.

2. Executive Order 11990, Protection of Wetlands, 24 May 1977.

3. Executive Order 11514, as amended by E.O. 11991, Protection and Enhancement of Environmental Quality

4. Executive Order 11593, Protection and Enhancement of the Cultural Environment.

C. State and Local Laws or Regulations

Due to the doctrine of federal supremacy, the federal government is not required to adhere to state and local laws or regulations, unless such immunity has been waived. In the case of water regulation no such waiver has been granted. It is however, the policy of the federal government to conform as much as practicable, to substantive state and local requirements. At this time it is unclear if the MWRA, as a "local sponsor", would be required to meet procedural requirements stipulated in these laws or regulations.

State regulations that may be applicable include:

1. Massachusetts:

   a. Wetland Protection Act (310 CMR)

   b. Surface Water Quality Standards (314 CMR 4.0)

   c. Massachusetts Environmental Protection Act (301 CMR 11.0)

   d: Interbasin Transfer Act (313 CMR 4.0)

   e: Massachusetts Historical Commission (950 CMR 70.0)

2. New Hampshire:

   a. Surface Water Quality Standards (RSA 485-A: 8, I,II,III; Env-Ws 430-432)

   b. Wetlands Board Regulations (RSA 483-A, Env-Wt 100-800)

   c. Endangered Species Act (RSA 212-A)

   d. Plant Protection Act (RSA 217-A)

3. Vermont:

   a. Wetland Protection Law (10 V.S.A, Section 905 (A)(7-9))

   b. Regulation of Stream Flow (10 V.S.A, Chapter 41)

   c. Water Quality Standards (10 V.S.A, Chapter 47)

   d: Vermont Endangered Species Law (10 V.S.A., Chapter 123)

APPENDIX D

HISTORIC AND ARCHAEOLOGICAL APPENDIX

TABLE OF CONTENTS

INTRODUCTION.....D-1

METHODOLOGY.....D-1

CULTURAL BACKGROUND: THE PREHISTORIC PERIOD, 12,000-300 B.P.....D-2

I. General Settlement Pattern Variability in Southeastern Vermont: 12,000-300 B.P.....D-2

A. General Site Locational Data: The Ompompanoosuc River Watershed and Union Village Dam.....D-5

B. General Site Locational Data: The Ottauquechee River Watershed and North Hartland Lake.....D-6

C. General Site Locational Data: The Black River Watershed and North Springfield Lake.....D-7

D. General Site Locational Data: The West River Watershed and Ball Mountain Lake.....D-7

E. General Site Locational Data: The West River Watershed and Townshend Lake.....D-8

II. Prehistoric Site Information: Otter Brook Lake Project Area, Keene, New Hampshire.....D-8

III. Prehistoric Land Use and Settlement Patterns in Central Massachusetts and Tully Lake.....D-9

CULTURAL BACKGROUND: THE HISTORIC PERIOD.....D-11

A. Union Village Dam.....D-11

B. North Hartland Lake.....D-12

C. North Springfield Lake.....D-14

D. Ball Mountain Lake.....D-16

E. Townshend Lake.....D-17

F. Otter Brook Lake.....D-19

G. Tully Lake.....D-19

CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER STUDY.....D-20

REFERENCES.....D-23

TABLES

TABLE D-1 Historic Properties Overview.....D-22

INTRODUCTION

The Massachusetts Water Resources Agency requested a reconnaissance level study of Connecticut River flow augmentation through the storage of water at Army Corps of Engineers flood control projects. This study is funded under the Section 22 "Planning Assistance to the States" program (PL 93-25). This survey provides a reconnaissance level review of historic properties in the following Corps project areas: Union Village Dam, North Hartland Lake, North Springfield Lake, Ball Mountain Lake, Townshend Lake, Otter Brook Lake and Tully Lake. Recommendations for further investigations are outlined in this report.

METHODOLOGY

Since this is a reconnaissance level investigation, this report is principally a review of existing literature available on the Corps project areas. Specific information relating to historic properties that would be inundated by the proposed storage for the Connecticut River flow augmentation is included.

Cultural Resource Management Studies have been completed by New England Division for nineteen Corps flood control reservoirs. These archaeological reconnaissance surveys were prepared as part of the Corps' management responsibilities on Federally owned property under Sections 106 and 110 of the National Historic Preservation Act of 1966, as amended, and implementing regulations (36 CFR Part 800). Archaeological Reconnaissance surveys for the following project areas under investigation for this study, have been completed by New England Division: Union Village Dam (1986); North Hartland Lake (1986); North Springfield Lake (1982); Ball Mountain Lake (1982 and 1984); and Townshend Lake (1986). In addition, at Otter Brook Lake, a Cultural Resource Reconnaissance for Construction of Recreation Facilities at the Day Use Area of Otter Brook Dam, Keene, New Hampshire, was completed in 1978. This report provides a overview of the Otter Brook Lake project area. No studies have been completed to date at Tully Lake. However, a archaeological reconnaissance/intensive survey of the Birch Hill Dam in Royalston, Templeton and Winchendon, Massachusetts (1990), provided an overview of prehistoric land use and settlement patterns for Central Massachusetts that is applicable for the Tully Lake project area, as well as historic background information for Templeton and Royalston. Addition information on these cultural resource management reports can be found in the references section of this appendix (page D-23).

Since the information contained in the reports was site specific, the information presented in this appendix has been taken directly, and in most cases, except for summary paragraphs, word for word from these reports.

CULTURAL BACKGROUND: THE PREHISTORIC PERIOD, 12,000-300 B.P.

The cultural background for the prehistoric period is essentially the same for all project areas in Vermont. Therefore, this information will be presented in a general format, with more specific locational information for each project area presented under separate headings. Cultural Resource Management studies have been completed for Union Village, North Hartland, North Springfield, Ball Mountain and Townshend dams (Thomas and Bourassa 1986a; Thomas and Bourassa 1986b; Thomas and Bourassa 1986c; Thomas etal. 1982a; Thomas etal. 1982b). All material presented in this appendix for these project areas has been taken directly from these reports.

I. General Settlement Pattern Variability in Southeastern Vermont: 12,000-300 B.P.

The regional environment has undergone a number of major changes since the last glacier retreated from the Northeast. In turn, variations in the climate and vegetation of the Connecticut Valley, the southern New England Uplands and the Green Mountains have influenced the ability of people to utilize the area's resources.

The first environmental period that we can consider corresponds with the final events of the glacial retreat from the Champlain and Connecticut Lowlands after about 12,500 B.P. For a time, the ice margins were probably not too far north, and the environmental characteristics of the glacially scoured landscape were not advantageous for human occupation. A large glacial lake, Lake Hitchcock, filled the Connecticut Valley. There is no evidence of human occupation in Vermont at this early period and certainly the conditions were not conducive for any lengthy stay.

By about 10,500 years ago the glacial lakes had drained. Subsequently, spring melt waters from the mountains eroded channels into the outwash and lacustrine deposits left by Lake Hitchcock and deposited alluvial sediments along these channels as well. The valley bottoms were open at first, crossed by numerous small streams, and initially covered with low tundra vegetation. The climate was cold and dry.

The tundra of the post-glacial period was fairly rapidly intruded upon by thickets of alder, poplar, birch and willow. As the climate began to ameliorate, becoming somewhat warmer, although remaining dry, spruce and fir began to appear. Eventually, the forest cover became extensive and a spruce parkland-open spruce woodland probably blanketed the landscape. Beginning with this period, lower valley portions of the Green Mountains and New England Uplands probably supported limited populations of musk-ox, mastodon, mammoth and moose-elk. Herds of caribou are also predicted.

The locations of known Paleo-Indian sites (ca. 9,000-10,000 B.P.) in the Hudson River corridor and in the Champlain Valley suggest that the movement of hunting bands was primarily north-south, and restricted to the more lush environs. In short, band movement tended to ignore the rugged uplands. It

could be hypothesized that the distribution of sites will be linearly arranged up the Connecticut Valley, and in the bottomlands along the lower reaches of its major tributaries. The Whipple Site, located along the Ashuelot River in Swanzey, New Hampshire, is the only currently known Paleo-Indian site in one of the upper Connecticut River's tributaries.

Although quantities of arboreal vegetation increased, the uplands of southeastern Vermont probably remained a less attractive area in terms of exploitable resources. It is not impossible that archaeological sites dating to roughly 9,000 B.P. will be encountered in upland valley, however, the frequency of such an occurrence is expected to be very low.

The spruce, fir, birch woodland that had replaced the tundra reached its maximum extent by roughly 10,200 B.P. in the lowlands and had begun to encroach on the mountains by at least 9,500 B.P. Larch and alder were present in low percentages in the wet lowlands, and other deciduous trees, beech, oak, ash and maple, began to appear on the better drained bottomland areas and low hills in the Champlain and Connecticut Valleys. It seems probable that the increasing diversity, density and predictability of floral species at this time provided a greater subsistence potential for animals and birds, and thus people as well. This is the period, when other animal species began to migrate from the south and establish themselves in favorable habitats. Moose, black bear, beaver, lynx, porcupine, snowshoe rabbit, red squirrel, grouse, mice, voles, lemmings and ultimately deer and wolf are examples. The larger fauna had disappeared, but caribou may have still been present. The carrying capacity of the New England Upland, and particularly of the Green Mountains, is expected to have remained relatively low.

In the lowland regions of Vermont by 9,000 B.P., amounts of spruce and fir had decreased, and pine and birch moved towards a maximum. By approximately 7,900 B.P., these high frequencies of pine and birch were tapering off, and areas dominated by beech especially, as well as hazel and oak, had begun to occur more frequently. Between 9,500 and 7,900 B.P., the environmental changes in the New England Uplands probably lagged behind those taking place in the region's lowlands, but the exact nature of the transition is unclear. Bands of hunters coming to Vermont from the oak-dominated forests to the south or west may have had to adopt new exploitation strategies in order to obtain necessary resources, even in this period of increasing environmental productivity. That they did adapt seems apparent. It is suggested, however, that movements into the uplands would have been exploratory, and only the most prolific areas are likely to have attracted aboriginal foraging parties during the warmer seasons of the year. In eastern Vermont, the archaeological data are lacking, but the presence of what may be an Early Archaic site (9,500-7,800 B.P.) on the shore of an upland pond in northwestern New Hampshire suggests that people were venturing out of the bottomlands here as well.

Between 7,900 and 3,000 B.P., the regional climate was generally warm and dry, the most stable period in post-glacial times occurring between 5,500 and 3,500 B.P. This warming trend, allowed the gradual expansion of an oak-hemlock and then oak-hickory forest from the south. Nut trees and fruit shrubs became

more plentiful. While the animal populations may have increased also, coincident with vegetation increases, the increased carrying capacity of the biomass might have supported less visible populations, such as mice, voles and insects.

Despite the lag in the establishment of this warming trend in upland areas, the increased availability of subsistence resources at higher altitudes, as well as the increased length of the frost-free season, allowed new regional patterns of settlement and exploitation to occur. Large upland regions were now available for subsistence exploitation. By 5,000 or 6,000 B.P. (Middle to Late Archaic), therefore, bands of hunters and gatherers began to take a persistent interest in once marginal areas. The expansion of diversified, southern vegetation types to higher elevations created potential for exploiting the mountain sides. Even along the valley margins, areas once passed over were increasingly utilized. This trend is reflected, archaeologically, in the relatively large numbers of Late Archaic (5,000-3,500 B.P.) sites found in upland zones, particularly adjacent to lakes and ponds, throughout western Vermont. Limited data from the southern section of the New England Uplands, as well as from the Green Mountains, suggest a similar pattern here as well. As in other periods, the more favorable environs, major streams and broad wetlands rich in fauna, were also exploited from adjacent areas.

Although use of upland resources may have remained seasonal, with a reconcentration of bands in the lower reaches of major valleys during the winter, the increased floral productivity throughout the region provided for a greater flexibility in the location of sites and in the exploitation of faunal and floral foods. As a result, annual settlement patterns may have shifted to encompass all of the Connecticut River valley, as well as the more favorable habitats in the New England Uplands and Green Mountains. Therefore, the presence of sites dating from roughly 6,000-3,500 B.P. is to be expected in all areas encompassed by Corps flood control projects.

At about 3,000 B.P., the climate began to cool. The return of spruce and fir at higher elevations and on north-facing slopes indicates that a cooler climate prevailed. Deciduous trees such as oak and hickory became more restricted to lower elevations, particularly in the valley bottoms and on south and west-facing hillsides. The distribution, and perhaps the diversity of game species may also have become somewhat constricted.

Seemingly, throughout Vermont, the upland regions were nearly abandoned by foraging bands between roughly 2,800 B.P. and 1,900 B.P. (Early Woodland Period), with groups tending to remain in the relatively more prolific lowlands.

The climate seems to have stabilized about 1,500 B.P. Subsequently, a slight warming trend occurred. Beginning at about this time, the Champlain Lowland (and perhaps the middle Connecticut River valley) apparently witnessed a gradual population increase. By 1,400-1,200 B.P. (Middle Woodland Period), extensive settlements could be found in the lower reaches of all major rivers in the Champlain basin. A similar pattern may be true of the Connecticut Basin

as well. It is suggested that such population growth would have been sufficient to have overtaxed the natural resources had these groups remained exclusively in the lowlands. Therefore, a new diversified strategy gradually evolved. During some seasons, groups may have congregated in those lowland areas where fish, plant and game species were dense and varied. At other seasons, fairly large communities may have broken up into small bands or employed specialized task groups in order to better obtain dispersed food sources. By roughly 1,000 B.P. groups may have begun again to regularly utilize the uplands of Vermont, at least on a seasonal basis.

The introduction of maize into New England about 900 years ago (Late Woodland Period) did not cause an immediate change in this seasonal pattern of resource exploitation, although new variables were introduced and shifts in the annual cycle may have occurred over time, due to the restrictions imposed by the need to plant and harvest. Ultimately, the subsistence cycle did combine generalist strategies of late fall, winter, and spring hunting and fishing, with summer planting, harvesting and nut gathering.

It is very likely that the Corps' project areas were part of a hunting/fishing/trapping territory exploited at this time by the Squakheag (Sokoki) community whose horticultural fields were located on the Connecticut River bottomlands to the east. Events in the period following European settlement in southern New England and New York altered these settlement and exploitation patterns dramatically.

In summary, throughout the entire time span of prehistory, from 12,000 to 300 years ago the regional environment went through periods of tremendous change. Furthermore, there is little doubt that these fluctuations forced human populations to adapt their exploitation strategies to meet such changing conditions in the region's resources. As a result, there were periods when the floral and faunal communities in the uplands of east-central Vermont many have been only marginally tapped, and others when resources in the entire Connecticut River basin made up a significant portion of several groups' subsistence base. Such shifts in cultural patterns should be reflected in archaeological sites throughout the region, including those in the Corps project area.

A. General Site Locational Data: The Ompompanoosuc River Watershed and Union Village Dam

The archaeological data which have been presented warrant the conclusion that for significant periods in the prehistoric past aboriginal populations have made frequent use of eastern Vermont. At this point, however, we are unable to answer major questions related to the primary resources which were exploited or the seasonality of settlement. There are also questions related to social networks and the degree of interaction between groups who tended to aggregate in different regions.

Hemenway's Vermont Historical Gazetteer (1871:1093), reports that "the first settlers, in 1764, found abundant evidence that this section of country had been inhabited by a numerous tribe of Indians previous to the war. In the southern part of town, near the [Connecticut] river was their old camping ground, and a small clearing where they raised corn. Arrows and other utensils were found in many places near the river." Despite this "abundant evidence", the campsite has never been accurately located, and no sites along the Connecticut River or the Ompompanoosuc River in Thetford have been identified.

There is a reference to a site in Norwich, Vermont, on the bank of the Connecticut River, near the mouth of the Ompompanoosuc, and described as an Indian burying ground. Upstream in Strafford, a site is located on a tributary of the West Branch of the Ompompanoosuc River. A petroglyph was found above Lake Fairlee. All of the other reported sites in Orange County, except for one, are situated along the Connecticut River, or just upstream from the confluence of the Connecticut with a tributary. Most of these sites are in Newbury and Bradford. On the New Hampshire side of the Connecticut, two steatite (soapstone) quarries were reported as were five other sites. Little is known about most of these sites.

When all of this information is considered together, it seems probable that the Ompompanoosuc River watershed, could easily have been part of the annual exploitation territories of groups whose primary residential centers were located in the Connecticut Valley. In summary, that part of the Ompompanoosuc River watershed within the Corps project area is likely to contain a number of significant prehistoric sites. They will vary considerably in their size, content, age, structure and function. The Cultural Resource Management Study completed at Union Village Dam in 1986 did not identify any prehistoric sites within the study area. However, the investigation did identify areas of prehistoric site potential. Within the proposed 485 ft. NGVD storage pool, there are areas of low, moderate and high prehistoric site sensitivity.

B. General Site Locational Data: The Ottauquechee River Watershed and North Hartland Lake

Only one prehistoric site is known to be located along the Ottauquechee River (VT-WN-57). It is situated near Quechee Gorge and was excavated during the summer and fall of 1985 by archaeologists from the University of Massachusetts, Amherst. It is a small site (estimated size: 15 x 7 m) which contains a few hearths and scatters of lithic debitage produced from stone tool manufacture or tool resharpening. No diagnostic tools were recovered.

There is a blocked-end tubular pipe at the Smithsonian Institution, Washington, D.C., that was found in Woodstock, Vermont during the late nineteenth century. This type of artifact is usually associated with burials dating from the Early Woodland Period, or about 2,500 B.P. The Ottauquechee River is the major waterway in Woodstock and, therefore, it is likely that the people who left this artifact behind both lived and traveled along the Ottauquechee River.

There are a few known sites along the Connecticut River near the Ottauquechee River. The People's Site (VT-WN-9) is located in North Hartland. Again, site age is presently unknown. A large, multicomponent site (VT-WN-2) with artifacts dating to at least the Late Archaic and Late Woodland Periods is located in Hartland. Another site, described as containing a small scatter of flakes and fire-cracked rocks (VT-WN-50), was found on the Connecticut River floodplain below the confluence of the White and Connecticut Rivers.

From these reports and local histories, there are four known sites located in or near the Ottauquechee River watershed. It is apparent from this evidence, however incomplete, that prehistoric groups did exploit resources in the Ottauquechee River valley, and that prehistoric sites are likely to be found in the Corps project area.

The Cultural Resource Management Study of North Hartland Lake Dam identified two field sites within the proposed 444 ft. NGVD elevation storage pool (FS-WN-15, FS-WN-16). In addition, several areas of low to moderate prehistoric archaeological site sensitivity were identified. These areas have the potential to contain prehistoric sites.

C. General Site Locational Data: The Black River Watershed and North Springfield Lake

Based on research performed in 1982 for the Cultural Resource Management Survey (Thomas etal.), there are no known prehistoric sites within the Black River watershed. Based on the general settlement pattern described above, however, the Black River watershed is likely to contain a number of significant prehistoric sites.

The archaeological reconnaissance investigation completed as part of the above survey, did not identify any prehistoric sites within the study area. However, the investigation did identify areas of prehistoric site potential. Within the proposed 484 ft. NGVD storage pool, there are areas with low and moderate archaeological sensitivity. These areas have the potential to contain prehistoric sites.

D. General Site Locational Data: The West River Watershed and Ball Mountain Lake

Based on research performed in 1982 for the Cultural Resource Management Survey (Thomas etal.), there were no known prehistoric sites within the West River watershed. Based on the general settlement pattern described above, however, the West River watershed was considered likely to contain a number of significant prehistoric sites.

The archaeological reconnaissance investigation completed as part of the above survey, identified two areas of moderate prehistoric site sensitivity within the area under investigation for this flow augmentation study.

Additional testing was performed at these two areas as part of a proposal to construct a hydroelectric facility at Ball Mountain Dam (Thomas 1982). This study identified a prehistoric site VT-WD-31 and a mid-19th century farmstead. Additional archaeological testing would be necessary to determine if these sites are significant (i.e. National Register eligible). The report also recommended additional testing at a small terrace in the reservoir that was actively eroding. This area was tested in 1984, and prehistoric site VT-WD-36 was identified. Due to the nature of the site and its excellent integrity, VT-WD-36 was considered eligible for the National Register of Historic Places.

E. General Site Locational Data: The West River Watershed and Townshend Lake

To date, little is known about most of the reported sites in the West River watershed but some preliminary observations are possible. The known sites in the West River watershed vary in size, topographic location and content. Large, multicomponent sites (containing artifacts from several time periods) are found near the mouth of the West River and along the Connecticut River. These may be residential base camps. The only known multicomponent site in the watershed, which, from the density of lithic material collected to date, has been used repeatedly over thousands of years, is in Jamaica. Several small sites, which appear to contain very few artifacts (from preliminary sampling) are located on a variety of landforms along the West River and its tributaries. (Most were located during the reconnaissance survey for Ball Mountain Dam, so are in Jamaica and Londonderry. It is conceivable that the pattern may extend to other parts of the watershed.) The majority of these occur on level areas near the river. Many of these sites appear to contain low artifact densities and probably represent occupations of limited duration and activities. Therefore, we can conclude that sites are not only located on floodplains and at the confluence of streams with main stem, but also on higher terraces, that may have offered different resources, vantage points or other yet unknown attraction.

In summary, the West River watershed and the Townshend Lake Dam project is likely to contain a number of significant prehistoric sites. The reconnaissance study identified several small areas of low to moderate archaeological site sensitivity within the proposed 425 ft. NGVD storage pool. In addition, one prehistoric was identified in the reservoir (VT-WD-41). Additional site evaluation of VT-WD-41 will be required before it can be determined if the site is eligible for inclusion on the National Register of Historic Places.

II. Prehistoric Site Information: Otter Brook Lake Project Area, Keene, New Hampshire

There are no known prehistoric sites within the reservoir boundaries. The nearest recorded sites (as of 1978) are on the Ashuelot River, within the town of Swanzey, New Hampshire, approximately 8 km. southwest of the project.

Ethnohistoric data indicates that the Otter Brook Lake area was within the territory of the Algonkian Pennacook Confederacy centered in the vicinity of Concord, New Hampshire, though Connecticut Valley groups may have also exploited the area. An Amerindian trail, the "Winigegwoh", may have passed up the Otter Brook valley to Highland Lake, in Stoddard, New Hampshire.

The Otter Brook Lake project area may be characterized as typical New England upland terrain, with steep slopes above narrow watercourses with highly variable flow. Archaeological sites in such an environment may be expected to be small and single component in nature, reflecting probable seasonal exploitation of resources. In a general sense, a large majority of known prehistoric sites are found on well drained to excessively drained soils, on slopes of less than 15%, and close to reliable supplies of fresh water. Orientation relative to prevailing winds and proximity to a varied base of exploitable resources are other contributing factors.

Within the boundaries of the Otter Brook Lake project area, prehistoric archaeological resources would be expected on those locations having well drained floodplain soils and where flooding was not especially frequent, or upon isolated areas of less than 15% slope on the hills above Otter and Ferry Brooks. General wildlife and vegetation suitability of soils indicate that areas near the southern portion of the reservoir probably provided a slightly richer and more diverse exploitable environment than those near the northern part of the reservoir. With the exception of limited wetland and stream environments in the valley, prehistoric habitat probably consisted mainly of hardwood-conifer woodland, as it does today.

Based on the reconnaissance survey prepared in 1978 (Wilson and Teltser), the most probable locations for prehistoric archaeological resources appear in small areas on Otter Brook and near the confluence of Otter and Ferry Brooks. This investigation identified several areas of moderate to high archaeological site sensitivity along Otter Brook. These areas have the potential to contain prehistoric sites. Portions of these areas would be inundated by the proposed storage reservoir at elevation 714 ft. NGVD.

III Prehistoric Land Use and Settlement Patterns in Central Massachusetts, and by Inference, Tully Lake

1. Paleo-Indian Period (12,500-10,000 B.P.) - The first inhabitants of this region came into the area following the retreat of the Wisconsin glacier northward. Paleo-Indian groups utilized a nomadic hunting and gathering subsistence strategy and are believed to have been organized in small groups. Paleo-Indian sites in the northeast are usually situated near existing lakes, proglacial freshwater lakes, inland saltwater invasions and major riverine locales. Upland bluffs or ridge tops are also cited as site locations often used by Paleo-Indian groups. Available information on Paleo-Indian sites and fluted point finds indicates a strong correlation with major rivers in southern New England. There are two confirmed and numerous unconfirmed Paleo-Indian period sites in Central Massachusetts.

2. Archaic Period (10,000-3,000 B.P.) - Due to the poorly represented archaeological record for the Archaic Period in Central Massachusetts, settlement patterns are difficult to reconstruct. By about 9,500 B.P., the environment of southern New England was characterized by a mixed pine-hardwood forest (MHC 1985). The settlement and subsistence systems of the Early Archaic were probably focused on seasonal abundant resources. This pattern persists throughout subsequent temporal ecosystems, which are characterized by extreme fluctuations in the availability of most wild foods. Little information is known about the subsistence economy and use of smaller and non-riverine environments by Early Archaic inhabitants of the region. The Early Archaic Period (10,000-7,500 B.P.) is represented by at least ten sites in Central Massachusetts.

An intensive exploitation of riverine resources is indicated by the Middle Archaic Period (7,500-5,000 B.P.). Large, often multicomponent, sites have been found along major rivers and fall lines in Massachusetts and New Hampshire. Archaeological sites from this period have also been discovered along small waterways. These are typically smaller depositions, with evidence of shorter term occupations for task specific activities (fishing, nut gathering). In Central Massachusetts, there are 22 known Middle Archaic sites.

Late Archaic/Transitional Archaic Period (5,000-2,500 B.P.) sites have been identified adjacent to swamps, riverine/marsh zones, and upland areas, as well as adjacent to streams and brooks. Site types range from large habitation sites with cremation burials to small episodes of stone tool manufacturing and maintenance. These groups utilized a wide variety of environmental zones, such as major river floodplains, tributary streams and associated riverine/marsh environments.

The Transitional Period (3,600-2,500 B.P.) in New England is marked by the presence of steatite (soapstone) vessels and smoking pipes. This period represents the first use of heavy vessels and implies an increasing sedentism. The use of steatite is considered to be a transitional step towards the manufacture of ceramic vessels.

The growth of human populations during the late Archaic/Transitional Period is implied by the large number of sites documented from this period with southern New England. At least 87 sites are known for Central Massachusetts from this period.

3. Woodland Period (3,000-450 B.P.) - During the Woodland Period ceramics were introduced, populations became increasingly sedentary, and at some point before A.D. 1100 domesticated plants appeared. Long distance trade in lithics (stone tools) increased in intensity, and developing specialization in subsistence tasks is inferred by the appearance of task specific sites. The Early Woodland Period (3,000-1,600 B.P.) is poorly represented in the uplands of Central Massachusetts with only 13 known sites from this period.

Middle Woodland Period (1,600-1,000 B.P.) sites are frequently located near falls and on major rivers. Occupations dating to this time period are often

found as components of large reoccupied sites. Information concerning the exploitation of ponds, riverine marshlands, and small tributaries is largely undocumented for this period. Only ten sites are known to date to the Middle Woodland Period in Central Massachusetts.

By about A.D. 1100, horticulture was introduced to the Northeast. Horticulture has been postulated as an important impetus for the development of nucleated village settlement patterns in the Great Lakes area, but changes stimulated by horticulture in Central Massachusetts have remained unstudied. Late Woodland Period (1,000-450 B.P.) sites are found as components of large sites along major rivers.

4. Contact Period (450-300 B.P.) - The period of Native American contact with Europeans (1550-1700 A.D.) is largely undocumented in the archaeological record for Central Massachusetts. In historic accounts, Contact Period villages have been mentioned as occurring along major rivers. None of these villages have been located to date.

There are no known prehistoric sites in the Tully Lake project area. However, based on the general settlement pattern described above, the area is likely to contain a number of significant prehistoric sites. The sites would probably be small, single component sites on terraces overlooking riverine and marshland areas. Based on a site visit to the area, there are several areas of high, moderate and low archaeological site sensitivity within the proposed 648 ft. NGVD storage pool. These areas have the potential to contain prehistoric sites.

CULTURAL BACKGROUND: THE HISTORIC PERIOD

A. Union Village Dam

1. Thetford, Vermont

Thetford, situated in the southeast corner of Orange County, is bounded on the north by Fairlee and West Fairlee, on the east by the Connecticut River, which separates it from Lyme, New Hampshire, on the south by Norwich, and on the west by Strafford.

Thetford was one of 60 towns chartered in 1761 by Benning Wentworth, Governor of New Hampshire, to John Phelps and sixty-one others, mostly from Hebron, Connecticut. The first settler arrived in 1764, and was soon joined by others; at least 50 families were settled before the Revolutionary War. The floodplains of the Connecticut River were settled first. Threats of British and Indian raids caused much alarm until the end of the Revolutionary War. After the war, the western part of town, including the Ompompanoosuc River valley, was quickly settled.

Thetford's population rose rapidly. The early generations of residents were mostly subsistence farmers, with potash and maple sugar being likely cash crops. By the turn of the nineteenth century, water-powered mills were in use at several sites along the Ompompanoosuc River, creating the nuclei for the future village of Post Mills, Thetford Center, Rice's Mills and Locke's Mills (Union Village). Many small mills operated in Thetford's villages until the 1870s. By then, fire, flood and outside competition had put most of these factories out of business. Farming, especially dairy farming, once more became the occupation of the majority of town residents. In the first half of the twentieth century, Thetford's population remained relatively low, but stable. Summer camps were established on some of the major water bodies. Fewer crops were raised, but dairy cows increased in number. The last quarter century has brought rapid growth to Thetford's population. The transformation from rural farming community to rural bedroom community has been very rapid. Improved transportation after completion of Interstate 91 in the early 1970s has put the Hanover-Lebanon-White River Junction area within easy of Thetford's quiet hills.

2. Historic Sites Within the Proposed Storage Reservoir for the Flow Augmentation Study (el. 485 ft. NGVD)

There are eight historic sites within the limits of the proposed storage reservoir for this study. Two of these sites, post 1900-farm/residences (HS 6, HS 7) were destroyed during dam construction, while a pre-1858 farm site (HS 22) has been wholly disturbed by operation of a gravel pit. One of the sites was Buzzell's Bridge (HS 10), of which little more is known. There are, therefore, four historic sites within the proposed project area that require further archaeological evaluation: HS 9, a pre-1877 farm/residence; HS 20, a mid-nineteenth century industrial and farm/residence site; HS 21, a pre-1858 farm/residence; the precise location of HS 44, Waterman's Mill (c.1795) is not known. All of these sites would require additional sub-surface testing to determine their significance (i.e.. eligibility for the National Register of Historic Places).

B. North Hartland Lake

1. Hartland, Vermont

Hartland (originally Hertford) is bounded on the north by Hartford, on the east by the Connecticut river, which separates it from Plainfield, New Hampshire, on the south by Windsor and West Windsor and on the west by Woodstock.

The original town of 25,350 acres was chartered on July 10, 1761 to Samuel Hunt and his associates in 71 shares by the Governor of New Hampshire. The town was re-chartered to Oliver Willard and his associates on July 23, 1766 by New York. The town now covers 29,912 acres. The original name of Hertford was changed to Hartland in 1782 to end the confusion of having neighboring towns with nearly identical names.

Hartland was settled shortly after the end of the French and Indian War. After a period of initial settlement and subsistence farming, commercial livestock farming became established and continued as the major economic base of the town throughout its history. Emphasis shifted from hogs and sheep to dairying about the year 1880.

Available water power on the Connecticut and Ottauquechee Rivers and several smaller tributary brooks ran a number of small mills and factories. Many of these businesses, including saw mills, grist mills, tanneries, and woolen mills processed these products. Livestock and processed goods from Hartland were sent to Boston for distribution.

Floods on the Connecticut and its tributaries washed away several dams and mills, including the dam and locks at Sumner's Falls, in the mid-nineteenth century. The coming of the railroad had already begun to make river travel less practical, so the locks were not rebuilt. some of the mills were not rebuilt, either. But, despite the loss of some small industry and the loss of inhabitants to the new frontier of the western lands, Hartland maintained its commercial farms. Ninety-four percent of Hartland's acreage was in farms in 1850; 84 percent was still in farms in 1935. Dairy farming became the livelihood in this later period, replacing sheep and hogs in popularity and profitability.

Hartland has been experiencing a slow growth in population since the 1930s. Part of this is due to the popularity among certain wealthier classes of people, of buying and restoring fine old country houses. The rest is probably due to a renewed interest in rural living and to Hartland's proximity to the rapidly expanding Hanover-Lebanon-White River Junction region.

2. Hartford, Vermont

This town of 27,000 acres is bounded on the north by Norwich, on the east by the Connecticut River, which separates it from Lebanon, New Hampshire, on the south by Hartland, and on the west by Pomfret. Hartford was the first township east of the Green Mountains to be granted by Governor Benning Wentworth of New Hampshire after the close of the French and Indian War. Hartford was chartered on July 4, 1761 to John Baldwin and 61 others who were residents of Windham and Lebanon, Connecticut.

The history of Hartford has been shaped by its geography. It is located at the junction of the Connecticut and White Rivers, which were two major water-based highways in prehistoric and early historic times. It continued to be a crossroads as first turnpikes in 1803, railroads in the mid-nineteenth century, then interstate highways in the twentieth century crossed paths in Hartford. This phenomenon caused Hartford to be an oddity among Vermont towns in that the great waves of emigration to the Midwest and West that drastically decreased most towns' populations in the nineteenth century did not greatly affect Hartford's population. It also helped Hartford to develop from an agricultural community to an industrial and marketing center. Hartford, or

more specifically White River Junction, remains a major distribution center for the upper Connecticut Valley region of Vermont and New Hampshire. It is quite possible that the early proprietors foresaw these economic opportunities, as Hartford was the first township east of the Green Mountains to be chartered after the French and Indian War.

3. Historic Sites Within the Proposed Storage Reservoir for the Flow Augmentation Study (el. 444 ft. NGVD)

There are six historic sites within the limits of the proposed storage reservoir for this study. Three of these sites (HS 1, HS 2, HS 3), early to mid-nineteenth century farm/residences, were destroyed during construction of the Corps dam. HS 6 was a farm/residence dating from the early to mid-nineteenth century. HS 7 was a early to mid-nineteenth century farm/residence. Little is known about HS 8, a residence constructed prior to 1855. Historic sites, 6, 7 and 8 would all require sub-surface archaeological testing to determine their significance.

C. North Springfield Lake

1. Springfield, Vermont

The earliest Euro-American settlement of Springfield is said to have occurred in 1752, when John Nott constructed a log home for his family in the lower Black River valley near the Black River's confluence with the Connecticut River. In the following year, eleven men established homesteads nearby.

The clearing of the Crown Point Military Road in 1759-1760 occurred too late to aid the British in their conflict with the French, but the section of road extending from its eastern terminus at the Connecticut River into the interior of present day Vermont served to stimulate settlement of the Springfield area. In any event, population growth in the locale only accelerated as the area became a more secure place in which to live after 1763, when the French finally departed from Canada and the alarming Indian raids ceased.

The initial Euro-American settlement of the area presently occupied by Springfield Village occurred in 1774, when William Lockwood built a cabin and sawmill at the location which came to be known as "Lockwood's Mills". Other mills were raised in various parts of the town on sites which afforded sufficient water power. The establishment of subsequent mills along the Black River served to concentrate Springfield's population at the Village, which evolved into a regional industrial center in the 19th century. Industries important in the Village's early 19th century growth included saw, grist, turning, fulling and cotton and wool weaving mills, tanneries, a lead pipe factory, blacksmith shops and machine shops. The machine shops proved to be the forerunners of the large machine tool factories which have dominated Springfield industry since the late 1800s.

Outside the industrial center, Springfield's development has been dominated by dispersed farms, with croplands in the broader valley bottoms and dairying in the steeper areas.

2. Weathersfield, Vermont

Weathersfield is bounded on the east by the Connecticut River, on the south by Springfield, on the west by Baltimore and Cavendish and on the north by Windsor and West Windsor. The town was first granted by New Hampshire's Governor Benning Wentworth to a group of Connecticut speculators in 1761, then regranted to the same proprietors by the New York governor in 1772. It was finally organized as a town in 1778 as part of the independent republic of Vermont.

Records indicate that a number of European colonists passed through the territory that would become the town of Weathersfield before 1769. The Crown Point Military Road was completed through Weathersfield in 1760. Settlement began in 1769, but growth was slow until 1780. The town experienced its greatest period of growth from 1780-1830, when salable agricultural surpluses and the Connecticut River traffic supported a growing population. From 1820-1900, agricultural activities were supplemented by a number of small industrial concerns that primarily processed locally available raw materials, including wool, soapstone, lumber and lime. the village of Perkinsville grew as the site of many of these industrial concerns.

From 1820-1840, sheep were the focus of agricultural activity. Sheep raising in town was encouraged by the presence of William Jarvis, the former U.S. consul in Portugal who first imported Merino sheep into the United States and who resided in Weathersfield. By 1900, the industrial activity in Perkinsville had declined. By 1910, the town's prosperity depended on dairying and the developing machine tool industry in adjacent towns. Weathersfield became a bedroom community for workers in those towns.

3. Historic Sites Within the Proposed Storage Reservoir for the Flow Augmentation Study (el. 484 ft. NGVD)

In 1959-1961, the North Springfield flood control project necessitated the removal of approximately 30 residential structures in and near Perkinsville. There are 14 historic sites within the limits of the proposed storage reservoir for this study. Four of these sites were destroyed during road, dam and restroom construction. Historic Site (HS) 11, was a cemetery. The graves were reinterred during dam construction. Seven of these sites were farm/residences, one was a sawmill and HS 21 was a blacksmith shop. These nine sites require additional field evaluation with sub-surface testing to determine their eligibility for the National Register.

D. Ball Mountain Lake

1. Jamaica, Vermont

Jamaica is bounded on the north by Londonderry and Windham, on the east by Townshend, on the south by Wardsboro, and on the west by Stratton and Winhall. The present town includes portions of six grants made by the governor of New York from 1767-1782. The charter for the town of Jamaica was issued in 1780 by the Vermont General Assembly to Colonel Samuel Fletcher and 67 associates.

Twelve families had settled in Jamaica before 1780 when the town was chartered. Most early settlers located in the southeastern corner at the junction of the West River and Wardsboro Brook, where the first village developed. Jamaica village in the center of town had a topographic advantage over the east village, and became the "central place", providing services and goods to surrounding farms and hamlets. Potash was the only marketable product at first. Merino sheep raising brought a certain prosperity in the years before the Civil War.

An active non-farming economy developed on the West River and the various streams as the readily available timber and water power were exploited. The number of sheep and mills both declined after the Civil War. Unlike other towns in the region, Jamaica never developed as a dairying community. The population decreased steadily from 1860-1920, was from 1920-1950, decreased markedly in the decade from 1950-1960, and has increased slowly but steadily since then. Tourism, both summer and winter, provides the main economic base today.

2. Londonderry, Vermont

Today Londonderry is bounded on the north by the towns of Landgrove, Weston and Andover, on the east by Windham, on the south by Jamaica, and on the west by Landgrove and Winhall. In 1770, the governor of New York granted the town of Kent to James Rogers; it included the territory of Londonderry and neighboring Windham. Rogers was a Tory sympathizer during the Revolution, so his lands were confiscated. In 1792, the eastern part of town, which the Vermont legislature had chartered to Samuel Fletcher, Edward Aiken, Joseph Tyler and others in 1780, was removed to form the town of Windham. In 1795, a portion of Windham was reannexed to Londonderry to form the present boundaries.

First attempts at settlement were made in 1770 by Colonel James Rogers and several friends. The Vermont legislature chartered the town in 1780. Two villages, Londonderry and South Londonderry, developed. South Londonderry was the northern terminus for the West River Railroad which opened in 1880. The economy has relied on agriculture, lumbering, small mills, and summer homes and tourism. The town's population grew rapidly until 1830, then, after a small decline, climbed to an 1860 high of 1367. From 1860 to 1930 the population decreased as farms were abandoned. The population increased slowly from 1930 to 1970, and sharply from 1970 to 1980, when a new high of 1510 people was

recorded. Twentieth century growth is due in part to the establishment of new small industries in adjacent towns, and to the development of a large skiing industry.

3. Historic Sites Within the Proposed Storage Reservoir for the Flow Augmentation Study (el. 900 ft. NGVD)

There were 11 historic sites within the limits of the proposed storage reservoir for this study. Seven of these sites were destroyed by dam and reservoir construction. One site, a cemetery was removed during construction. Pratt's Bridge (HS 8) was still standing as of 1982, but currently only the abutments remain. There are two sites within the proposed project area that require further archaeological evaluation: HS 10, Pratt's Bridge School; and HS 11, a 19th century farm/residence. Both of these sites would require additional sub-surface testing to determine their National Register eligibility.

E. Townshend Lake

1. Townshend, Vermont

The original town of Townshend, containing 23,040 acres, was chartered in 1753 to John Hazeltine and 63 others by Benning Wentworth, Governor of New Hampshire. The area was increased to 28,050 acres in 1840 by the annexation of the small town of Acton. Acton was chartered by Vermont to Moses Johnson and 32 others in 1782, and was known as Johnson's Gore. Acton was incorporated in 1801, with representation to the legislature through Townshend.

Although Colonel Hazeltine and his associates received a charter for Townshend in 1753, the dangers of frontier life during the French and Indian War delayed colonization until the hostilities drew to a close in 1760. The first few inhabitants spread out along the West River and lived in log huts surrounded by small clearings.

By the turn of the 19th century, the population had increased significantly, and two villages and two smaller hamlets became nodes of economic and social activity for this rising agricultural and lumber manufacturing town. West Townshend was the earliest established node, although it would later be replaced in importance by the East Village, which was the church and school center of the community as well as the town's geographic center. Many small mills were located along the West river or its major tributaries. Ever present were saw and grist mills, tanneries, and cloth dressing establishments. Frequent freshets and occasional major floods caused problems for farmer and mill owner alike. Fires also took their toll, burning mills, churches and schools at least four times in the 19th century.

The economic base of the community for a greater part of its history has been forest and agricultural products. Sheep and cattle (for dairy and beef) have each taken their turn as the primary farm stock. Since the Civil War,

cattle have been more numerous than sheep, but the number of all livestock has declined steadily into the second half of the 20th century. Grains, potatoes, orchard products and maple sugar rounded out the agricultural yield. The saw and grist mills, tanneries and fulling mills processed these forest and agricultural products for local use and export.

Townshend experienced its peak population from 1820 to 1860. The population steadily declined until the mid-20th century. After 1860, there was some farm abandonment and consolidation of farms. Many acres reverted to woodland.

From the 1950s to the present, the town has experienced some small growth in population. Vacationers, retirees and commuter families have become part of the community. Recreation has become part of the economic base of Townshend.

2. Jamaica, Vermont

Jamaica is bounded on the north by Londonderry and Windham, on the east by Townshend, on the south by Wardsboro, and on the west by Stratton and Winhall. The present town includes portions of six grants made by the governor of New York from 1767-1772. The charter for the town of Jamaica was issued in 1780 by the Vermont General Assembly to Colonel Samuel Fletcher and 67 associates.

Twelve families had settled in Jamaica before 1780 when the town was chartered. Most early settlers located in the southeastern corner at the junction of the West River and Wardsboro Brook, where the first village developed. Jamaica village in the center of town had a topographic advantage over the east village, and became the "central place", providing services and goods to surrounding farms and hamlets. Potash was the only marketable product at first. Merino sheep raising brought a certain prosperity in the years before the Civil War. An active non-farming economy developed on the West River and the various streams as the readily available timber and water power were exploited. The number of sheep and mills both declined after the Civil War. Unlike other towns in the region, Jamaica never developed as a dairying community. The population decreased steadily from 1860-1920, was stable from 1920-1050, decreased markedly in the decade from 1950-1960, and has increased slowly but steadily since then. Tourism, both summer and winter, provides the main economic base today.

3. Historic Sites Within the Proposed Storage Reservoir for the Flow Augmentation Study (el. 494 ft. NGVD)

There were five historic sites within the limits of the proposed storage reservoir for this study. One of these sites was destroyed during dam construction. There are three farm/residence sites and one former seasonal camp; three dating to the mid-19th century, and late-19th century, and one that was constructed c. 1785. These four sites would require additional sub-surface investigations to determine their National Register eligibility.

F. Otter Brook Lake

1. Keene, New Hampshire

Keene was first settled by Europeans in 1736, was abandoned and resettled in the late 1740s, and gradually shifted from a primarily agricultural town in the 18th century to a major manufacturing and commercial center of southern New Hampshire. Though the center of population in Keene was to the west of Otter Brook Lake, several historic sites existed within the reservoir boundaries. Land use included upland farming and small industrial sites on the brook. Nearly a dozen dwellings and two industries existed within the reservoir boundaries during the late 19th century.

2. Historic Sites Within the Proposed Storage Reservoir for the Flow Augmentation Study (el. 714 ft. NGVD)

Three historic sites are located within the limits of the proposed storage reservoir for this study. All three sites were farm/residences; two dating from the mid-19th century and one from the early 20th century. These sites would all require further sub-surface archaeological investigations to determine site significance.

G. Tully Lake

1. Royalston, Massachusetts

Royalston is located in northern Worcester County; bounded by Winchendon to the east, Warwick to the west, Orange, Athol, Phillipston and Templeton to the south, and New Hampshire to the north. The Royalshire grant was established in 1752, but Euro-American settlement was delayed until c. 1762, due to native hostilities. The grant was incorporated as the town of Royalston in 1765. Dispersed 18th and early 19th century agricultural settlement developed along Lawrence Brook and the Tully River meadowlands. An early 19th century civic/commercial focus developed at Royalston Center, while a small mill and manufacturing complex grew at Doane Falls. Textile manufacturing, initiated in 1813, persisted at South Royalston in the southeast through the 19th and early 20th centuries. Agricultural abandonment in the 19th century was ultimately followed by the loss of the South Royalston industrial base in the mid 20th century. Some modern suburban growth has extended into the southern part of Royalston from Athol, and pressures for exurban development, particularly on hilltop sites with good views, is likely to intensify.

2. Templeton, Massachusetts

Templeton, located in the hill country of northern Worcester County, is bounded by Royalston to the northwest, Winchendon to the northeast, Gardner to the east, Phillipston to the west, and Hubbardston to the southwest.

The Massachusetts General Court, in 1728, awarded Templeton land to a group of former soldiers of the 17th century war against the Narragansett Indians and their descendants in an early grant known as Narragansett No. 6. In 1762, Templeton was finally incorporated, after settlement efforts stalled during the French and Indian War. The town remained primarily agricultural throughout the remainder of the 18th century and for most of the 19th and early 20th centuries. Large scaled industries, including textile manufacturing and woodworking, established factories in Templeton during the early and late 19th century. After 1860, population began a decline, which continued during the early 20th century as farm families abandoned farmsteads no longer economically viable. Today Templeton retains a highly rural character with its center village largely intact.

3. Historic Sites Within the Proposed Storage Reservoir for the Flow Augmentation Study (el. 648 ft. NGVD)

The Tully Lake project area has not yet been the subject of a archaeological reconnaissance survey. Therefore, it is unknown if historic sites are present within the project area. However, certain conclusions can be inferred from the town histories. Any sites which may be present would most likely be agricultural (farm/residences), or small industrial sites, such as saw or grist mills. It is likely that these sites would be present as historical archaeological sites, which would require sub-surface investigations.

CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER STUDY

A summary of the historic properties within the limits of the flow augmentation reservoirs at the project areas is illustrated in Table D-1. All project areas either contain known prehistoric sites or have prehistoric site potential. All reservoirs would inundate historical archaeological sites. While little information exists for Tully Lake, it is likely that given the environmental variables that exist at the area, that there is the potential that the storage reservoir could impact historic and prehistoric archaeological sites.

If this Section 22, MWRA Connecticut River Flow Augmentation Study should proceed to a further stage of planning, then additional research would need to be performed to determine what sites with the Corps project areas will impacted by inundation and erosion.

– Any project on Corps property is subject to Section 110 of the National Historic Preservation Act (NHPA) of 1966, as amended, as part of the Corps' management responsibilities on Federally owned property. Section 110 states that: a)"The heads of all Federal agencies shall assume responsibility for the preservation of historic properties which are owned or controlled by such agency."; b)"Each Federal agency shall establish a program to locate, inventory, and nominate to the Secretary of the Interior all properties under

the agency's ownership or control, that appear to qualify for inclusion on the National Register. Each Federal agency shall exercise caution to assure that any such property that might qualify for inclusion is not inadvertently transferred, sold, demolished, substantially altered, or allowed to deteriorate significantly."

In addition, prior to implementation, any undertaking proposed by the Corps is required to undergo a NHPA Section 106 review. Section 106 requires an agency to identify historic properties that may be affected by a Federal action, determine if they are significant (i.e., National Register eligible) and determine if the action will have an effect on these resources. If significant historic properties will be affected by a proposed action, then they must be avoided or the Corps must mitigate for adverse effects. This will all be coordinated with the appropriate State Historic Preservation Officer (SHPO).

TABLE D-1
HISTORIC PROPERTIES OVERVIEW

RESERVOIR	HISTORIC SITES	PREHISTORIC SITES
Union Village	Four historic sites; two farm/residences; one industrial/farm/residence; one mill site	None identified; however, several areas of low to high prehistoric site sensitivity
North Hartland	Three historic sites; all early to mid 19th century farm/residences	Two field sites identified; low to moderate prehistoric site sensitivity
North Springfield	Nine historic sites; seven farm/residences; one sawmill one blacksmith shop	Several areas of low to moderate prehistoric site sensitivity
Ball Mountain	Two historic sites; one school; one farm/residence	Two prehistoric sites; two areas with moderate prehistoric site sensitivity
Townshend Lake	Four historic sites; three farm/residences; one seasonal camp	One prehistoric site; Several small areas with low to moderate prehistoric site sensitivity
Otter Brook	Four historic sites; all farm/residences	Several areas of moderate to high prehistoric site sensitivity
Tully Lake	No known historic sites; however, no studies have been performed for this area	Several areas of prehistoric site sensitivity

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APPENDIX E

ECONOMICS APPENDIX

APPENDIX E

TABLE OF CONTENTS

ITEM	Page No.
INTRODUCTION	E-1
ECONOMIC ASSESSMENT	
Operation and Maintenance	E-1
Recreation	E-1
Hydropower	E-3
Drought Water Supply	E-5
Summary	E-6
PRICE OF WATER	
Operation and Maintenance	E-7
New Cost	E-7
Joint Use Cost	E-7
Foregone Benefit	E-9
Compensation to Others	E-9
Price Limit on Cost of Water Storage	E-9
Summary	E-11
REGIONAL EFFECTS	E-12

List of Tables

Table No.		Page
E-1	Reservoir Visitors	E-2
E-2	Recreation Rating - Existing Conditions	E-2
E-3	Foregone Recreation Value	E-3
E-4	Downstream Hydropower on the Connecticut River	E-3
E-5	Downstream Hydropower on the Chicopee River	E-4
E-6	Agricultural Land Loss	E-5
E-7	Flow Augmentation Storage	E-8
E-8	Annual Operation and Maintenance Cost	E-8
E-9	Updated Construction Costs	E-10
E-10	Price Determination	E-11

INTRODUCTION

The purpose of the economic analysis is to provide an evaluation of the cost of flow augmentation water storage in the Connecticut River for the Massachusetts Water Resources Authority (MWRA). The economic analysis is performed at the reconnaissance level of detail. A price for water storage is developed based upon Corps criteria set forth in ER 1105-2-100, Chapter 4, Section VII. Water storage cost is developed at the January 1992 level of prices. This appendix also includes an assessment of regional effects associated with water storage at Corps Reservoirs.

ECONOMIC ASSESSMENT

Water storage and release at Corps Reservoirs to augment flows on the Connecticut River to decrease releases from the MDC/MWRA system imposes a direct cost on the Corps in the form of higher operation and maintenance cost, but may also impose costs on other members of society as recreation is displaced, the cost curves of hydropower companies are changed, operators of local water districts seek water from other sources during drought periods and agricultural land is flooded. In determining project cost, all costs irrespective of to whom they occur, need to be accounted for. Corps benefit evaluation procedures for water supply projects established in ER 1105-2-100, Chapter 6, Section II, requires an evaluation of external effects. Some of the effects may be positive such as lowering the cost of power generation (economy) and some may be negative such as reducing recreation availability (diseconomy).

Operation and Maintenance

The storage and release of water at Corps Reservoirs for flow augmentation requires additional raising and lowering of gates. Gate operation is estimated to cost approximately $100 per day. For the purposes of this analysis it is assumed as a worst case that operation would be required every day during the June to August time period. Total annual operation and maintenance cost for the seven reservoirs is estimated at $63,000.

Recreation

Storage at Corps reservoirs would reduce existing summer use at these sites. The reservoirs currently provide swimming, picnicking, fishing, boating, camping and bird watching. Water storage and release for flow augmentation will eliminate swimming, boating and limit picnicking at the reservoirs during June, July and August. Also the parks would not be open in May because of the amount of work involved in setting up the beaches for a short use period. Reservoir visitation for 1991 and the percent decrease in Reservoir visitation which is expected with flow augmentation storage is shown in Table E-1. It is anticipated that attendance would decline from a combined estimate of 507,633 visitors to 227,317 visitors, a drop of 280,317 visitors or 55 percent

The value of a visit is developed using the unit day value methodology for valuation of recreation experience. Recreation sites are rated based on the number of activities available, other sites nearby, extent of crowding, accessibility of the site, and site esthetics. The rating points are then converted to 1992 dollars using a scale developed by the Corps. The value of a visit is shown for each of the reservoirs in Table E-2. The value varies from $3.80 at Union Village to $4.24 at North Hartland, Townsend and Tully Lakes.

Recreation value is then determined for each site by multiplying the number of site visits by the value per visit. This result is shown in Table E-3. Recreation value, as determined through the unit day methodology, is estimated to drop from about $2,000,000 to $900,000 a loss of $1,100,000 annually.

The decline in recreation value is based entirely on a reduction in site visitation. In addition to reducing the number of user days (visits), water storage will also reduce the value of a user day. This reduction in value will be addressed in any future investigations.

Table E-1. Reservoir Visitors (1)

Reservoir	Without Storage	With Storage	Decrease	Percent Decrease
Union Village	41,133	20,567	20,567	50
North Hartland	68,067	34,033	34,033	50
North Springfield	32,033	25,627	6,407	20
Ball Mountain	107,200	96,480	10,720	10
Townshend	94,600	9,460	85,140	90
Otter Brook	110,367	27,592	82,775	75
Tully	54,233	13,558	40,675	75
Total	507,633	227,317	280,317	55

(1) Without storage based on 1991 monthly visitation data at the sites for May, June, July and August.

Table E-2. Recreation Rating - Existing Conditions

	Union Vill.	North Hartland	North Spring	Ball Mtn.	Towns.	Otter Brook	Tully
Recreation Experience	8	8	8	8	8	8	8
Availability of Opportunity	3	8	3	3	8	3	8
Carrying Capacity	7	5	5	7	5	5	5
Accessibility	12	12	12	12	12	12	12
Environmental Quality	6	10	10	10	10	10	10
TOTAL	36	43	38	40	43	38	43
USER DAY VALUE	$3.80	$4.24	$3.91	$4.01	$4.24	$3.91	$4.24

Table E-3. Foregone Recreation Value

Project	Without Project	With Project	Foregone Value
Union Village	$156,307	$78,153	$78,153
North Hartland	$288,603	$144,301	$144,301
North Springfield	$125,250	$100,200	$25,050
Ball Mtn.	$429,872	$386,885	$42,987
Townshend	$401,104	$40,110	$360,994
Otter Brook	$431,534	$107,883	$323,650
Tully	$229,949	$57,487	$172,462
Total	$2,062,619	$915,019	$1,147,597
SAY	$2,000,000	$900,000	$1,100,000

Hydropower

There are five major hydropower projects located downstream of Corps reservoirs considered for flow augmentation storage. These are Wilder Falls, Bellows Falls, Vernon Falls, Turners Falls and Holyoke. Installed capacity at these projects is listed in Table E-4.

Table E-4. Downstream Hydropower on the Connecticut River

Dam	Capacity
Wilder	39 megawatts
Bellows Falls	45 megawatts
Vernon Falls	26 megawatts
Turners Falls and Cabot	59 megawatts
Holyoke	42 megawatts

Water storage for flow augmentation could affect the ability of hydropower companies located downstream of the reservoirs to generate electricity. Hydropower is usually used during daily peak periods. Reduction in river flows in the early summer may require the generation of electricity by other more costly methods. However, releases in the late summer may allow for additional hydropower generation lowering electricity generation cost.

New England Power Pool was contacted regarding this issue and their response indicated that the alternative would not produce any additional hydropower, whereas a plan capturing spring runoff water (April and May) for release in the summer would result in additional hydropower. (NEPOOL Letter of April 6, 1992; Telecom B. Blumeris, Corps and J. Ginnetti, NEPOOL, April 9, 1992; Corps letter of April 16, 1992.)

There is also a 4 megawatt hydroproject at North Hartland that uses the existing reservoir pool to generate power. An agreement for this use was entered into between the United States Government and Vermont Electric Cooperative in 1983. The turbine is rated for operation between 422 and 435 feet NGVD. The proposed pool fluctuation for flow augmentation at North Hartland is 390 to 448 feet NGVD, thus the alternative will impact on hydropower generation at the project. The median hydropower output at North Hartland for the last five years for June, July, August was 821, 411, and 374 megawatt hours. In addition, 4 megawatts of summer capacity would be lost. The total replacement energy and additional capacity expenses would be approximately $56,210 and $53,000. (Letter from Vermont Electric Cooperative, February, 19, 1992.)

Decreased releases at Quabbin as a result of the flow augmentation alternative could also impact on hydropower at or downstream of Quabbin. The MWRA/MDC operates a hydropower project at Windsor Dam with a capacity of 1.1 megawatts. The maximum efficiency of operation is 100 to 108 cfs (65 to 75 MGD). (Telecom, MDC, Tom Barron and B.Blumeris, September 18, 1991.) On days when the Corps maintains the gage above 4,900 cfs required releases at Quabbin would drop from either 71 mgd (110 cfs) or 45 mgd (70 cfs) to 20 mgd (31 cfs). This would result in a loss of hydropower production at the dam. However, because of the limited number of flow augmentation days provided by the alternative this impact is expected to be small.

Downstream of Quabbin on the Chicopee River there are four hydropower projects. These are listed in Table E-5. These projects would be impacted by decreased releases of water from Quabbin however, because the maximum decreased release as a result of the alternative would be 51 mgd (79 cfs) the impact on the projects is expected to be small.

Table E-5. Downstream Hydropower on the Chicopee River

Dam	Capacity
Red Bridge Station	3.6 megawatts
Collins	1.25 megawatts
Putts Bridge Station	3.2 megawatts
Indian Orchard Station	3.7 megawatts
Chicopee Falls	2.17 megawatts
Dwight Station	1.5 megawatts

Drought Water Supply

Over the next several years drought contingency water supply studies will be conducted for many of the Corps reservoirs. The drought contingency studies will identify local water supply agencies that may be able to use the storage at a reservoir during a drought emergency. Of the seven reservoirs considered for flow augmentation, the reservoir most likely to used by a local community for drought water supply is Otter Brook by the City of Keene. There has been potential interest by the City in withdrawing water from Otter Brook below the dam. In FY 92 the Corps plans to pursue drought studies at North Springfield. The flow augmentation alternative would be modified so as not to preclude the use of these reservoirs for local drought storage.

Agriculture

The Corps currently leases land at North Springfield Reservoir that is used to grow corn and hay. With storage this land would be inundated and lost to production. The loss in profitability of these lands would need to included as a cost of water storage. This loss is estimated to be $24,200 annually. The derivation of this loss is shown in Table E-7.

Table E-6. Agricultural Land Loss

Reservoir	Acreage	$/acre	Value
North Springfield			
hay	121	$166	$20,100
corn	16	$256	$4,100
Total	137		$24,200

Summary

Briefly summarizing, the social cost of flow augmentation storage includes increased O&M costs at seven Corps Reservoirs, lost recreation at the seven Corps Reservoirs, hydropower generation loss at North Hartland, increased costs of local water districts to obtain water during drought periods, and lost profitability from agricultural leases at Corps Reservoirs.

New O & M		$63,000
Recreation Loss		$1,100,000
Hydropower Loss		$109,200
Agriculture Loss		$24,200
	Total	$1,296,400
	SAY	1,300,000

PRICE OF WATER

The price of water to be charged to the MWRA is calculated in accordance with ER 1105-2-100, Chapter 4, Section 7. The price to be charged for changes in project operations require the non-Federal sponsor to be responsible for (1) all new construction and operation costs; (2) a share of joint use operation, maintenance and replacement cost; (3) benefits foregone; (4) compensation to others for induced losses in their operations; and (5) payment of one-half the difference between the local sponsor's (MWRA) least costly alternative and the sum of items 1 through 4 above.

There is an upper limit to the price to be charged which is the cost for permanent reallocation of storage. This would be the updated cost of storage developed using the "Use of Facilities" cost allocation procedure described later.

Operation and Maintenance

The storage and release of water at Corps Reservoirs for flow augmentation requires additional raising and lowering of gates. Gate operation is estimated to cost approximately $100 per day. For the purposes of this analysis it is assumed as a worst case that operation would be required every day during the June to August time period. Total annual operation and maintenance cost for the seven reservoirs is estimated at $63,000.

New Cost

There would be no new construction cost, but there would be new operations cost as a result of flow augmentation storage. The storage and release of water will have direct and separable cost on the operation of gates. This cost as discussed above, is estimated to be $63,000.

Joint Use Cost

A share of joint use, operation, maintenance, replacement, and major rehabilitation (OMR&R) cost is calculated based on the "Use of Facilitates" cost allocation procedure discussed below and described in ER 1105-2-100, Page 4-55.

The ratio of acre-feet devoted to flow augmentation storage to total acre-feet available will be used to allocate joint costs to the flow augmentation storage activity. Table E-7 relates acre-feet required for flow augmentation to total acre-feet available at each reservoir in the study. The percentage of total storage that would be available for flow augmentation storage is obtained by dividing acre-feet available for this storage by total acre-feet of available storage.

Joint use cost is project cost that cannot be separated by type of project benefit. The derivation joint use cost is shown in Table E-8. This cost is obtained by deducting from total O & M cost (Column 1) that is specific to recreation (Column 2). The result is shown in Column 3. The portion of joint maintenance to be allocated to flow augmentation storage (Column 4) is based on its proportionate share of total storage.

Table E-7. Flow Augmentation Storage

Project	Flow Augmentation Storage (acre-feet)	Total Storage (acre-feet)	Ratio
Union Village	4,030	38,000	0.106
North Hartland	7,040	71,100	0.099
North Springfield	5,050	50,500	0.100
Ball Mtn.	5,500	54,600	0.101
Townshend	3,390	33,600	0.101
Otter Brook	2,000	18,300	0.109
Tully	3,200	22,000	0.145
Total	30,210	288,100	0.105

Table E-8. Annual Operation and Maintenance Cost

Project	Total Cost	Recreation Cost	Joint Cost	Proportionate Share
Union Village	$243,600	$0	$243,600	$25,800
North Hartland	$318,900	$55,500	$263,400	$26,100
North Springfield	$379,800	$61,800	$318,000	$31,800
Ball Mtn.	$366,700	$97,700	$269,000	$27,200
Townshend	$305,100	$33,400	$271,700	$27,400
Otter Brook	$356,300	$67,400	$288,900	$31,500
Tully	$381,100	$31,700	$349,400	$50,700
Total				$220,500

Foregone Benefit

At the sites being analyzed there would be recreation benefits forgone. The reservoirs involved in the flow augmentation study were built as single purpose flood control with recreation added at a later date. The additional pool required for water storage to augment river flows does reduce recreation opportunities at these reservoirs. This loss was estimated above at $1,100,000 annually.

Compensation to Others

In addition to the loss in recreation there would be agricultural production lost. The net revenue from this operation would be counted as a cost of water storage. This loss is estimated to be $24,200, annually.

Also hydropower will be lost at North Hartland Reservoir. This loss is estimated at $109,200 annually.

Price Limit on Cost of Water Storage

The price limit on the cost of seasonal storage to the MWRA will be the highest of benefits foregone, the replacement cost or the updated cost of storage. Replacement cost is not applicable as the seasonal storage is not impacting on the flood control function of the reservoirs. The updated cost of storage requires updating the original construction cost of the reservoirs.

In determining the updated cost of construction, all specific costs are deducted from total construction cost with the result multiplied by the ratio of reallocated storage to total usable storage space. The Engineering News Record (ENR) Construction Cost Index is then used to update to present day price levels. These indices are used to update the three cost categories of (1) relocations, (2) buildings, grounds and utilities, and (3) permanent operating equipment. Land value will not include any enhancement caused by the project. Costs will be indexed from the midpoint of the physical construction period to the beginning of the fiscal year in which the contract for the reallocated storage is approved. As this report is at the reconnaissance level of detail the ENR price level for the year of construction completion was used to update total construction cost to current prices.

The updated construction cost for each reservoir is shown in Table E-9. The original construction cost is updated by a factor obtained from the ENR to obtain the construction cost in 1991 dollars (Column 3). Construction costs in current dollars is then annualized at the repayment rate for FY 92, 8 1/8 %. The repayment period is 30 years as required by ER 1105-2-100, Chapter 4, Section VII. The share of annual construction cost allocated to flow augmentation storage is based on its proportionate share of total storage as shown in Table E-7.

Table E-9. Updated Construction Cost

Reservoir	Original Const. Cost	PL Factor	Updated Const. Cost (1991 $)
Union Village	$4,000,000	9.60	$38,400,000
North Hartland	$7,300,000	5.78	$42,000,000
North Springfield	$6,800,000	5.94	$40,000,000
Ball Mtn.	$11,000,000	5.78	$64,000,000
Townshend	$7,400,000	5.78	$43,000,000
Otter Brook	$4,357,923	6.23	$27,000,000
Tully	$1,666,752	9.92	$17,000,000

	Annual Const. Cost	Annual Const. Cost Share
Union Village	$3,451,300	$365,800
North Hartland	$3,774,800	$373,700
North Springfield	$3,595,100	$359,500
Ball Mtn.	$5,752,100	$581,000
Townshend	$3,864,700	$390,335
Otter Brook	$2,426,700	$264,510
Tully	$1,527,900	$221,500
Total		$2,556,345
		SAY $2,600,000

Summary

The derivation of price to be charged to the MWRA is summarized in Table E-10. The MWRA would be charged the full cost of foregone benefits, compensation of losses to others, and costs specific to flow augmentation storage. Joint O & M cost would only be assessed for days when the contract was in effect. Daily cost is determined by dividing annual cost by 365 to obtain daily cost. The MWRA would be charged the daily cost for the number of days that the contract was in effect. This period is estimated to be 90 days.

Table E-10. Price Determination

Category	Annual Cost	Daily Cost	Contract Cost
New O&M	$63,000	$700	$63,000
Joint O&M	$220,500	$600	$54,000
Foregone Benefits			
Recreation	$1,100,000		$1,100,000
Compensation to Others			
Agriculture	$24,200		$24,200
Hydropower	$109,210		$109,210
Total			$1,350,410
		SAY	$1,400,000

Regulations require that the price for seasonal storage include an amount equal to one-half the savings to the MWRA. The savings is the difference between specific costs (new costs, benefits foregone and compensated losses to others) and the MWRA's least costly alternative. This amount is then added to new cost, joint O&M, benefits foregone and compensated losses to others, to determine price. As lower cost alternatives exist for the MWRA, this sum would be negative and thus is omitted from the price calculation.

The annual cost of flow augmentation storage for pricing purposes is estimated to be about $1,400,000. This is below the limit set by the updated construction cost of $2,600,000. The price would be determined on an annual basis and updated for each year of the flow augmentation storage contract with the MWRA.

The estimated median savings in Quabbin releases is 350 million gallons for a annual cost of about $4,000 per million gallons (mg).

A report recently published by the MWRA indicates that the cost of obtaining water from alternative sources would range from $500 to $1,600 per mg. (MWRA, Program Briefing and Recommendations to the Board of Directors, January 24, 1990) This is well below the price of flow augmentation alternative. Additionally, the yield from these alternatives ranges from 38 to 120 million gallons per day which is well above the savings in releases from the flow augmentation alternative.

REGIONAL EFFECTS

The reduction in number of visits to seven Corps Reservoirs would result in a reduction of spending in these localities. As a consequence of this initial reduction; sales, income and employment in the region would decline. However, the Corps estimates that approximately 75 % of these visitors live within the region. Because so much of the reservoir usage is local, the impact on the local economy from a reduction in visitors is expected to be small.

APPENDIX F

LISTING OF HYDROPOWER LICENSES AND RESERVOIRS

List of Hydropower Projects on Connecticut River Main Stem

River	Poject Name	Gross Storage acre-feet	FERC Project No.	Operational Date	License Expiration
Connecticut	Murphy Dam - Lake Francis	99,300	7188	1940	X
Connecticut	Baldwin	16	7962	breached	2037
Connecticut	Canaan	200	7528	1943	2009
Connecticut	Wyoming Valley	1700	7960	breached	X
Connecticut	Gilman Paper Co Dam	705	2392	1941	X
Connecticut	Moore Dam	200,000	2077	1957	2001
Connecticut	Comeford Dam	46,800	2077	1930	2001
Connecticut	McIndoe Falls (fifteen miles falls)	9,800	2077	1931	2001
Connecticut	Rye Gate Dam	4,940	8011	1990	E
Connecticut	Wilder Dam	34,600	1892	1950	2018
Connecticut	Bellows Falls Dam	26,900	1855	1928	2018
Connecticut	Vernon Dam	40,000	1904	1909	2018
Connecticut	Northfield Mountain PS	17,240	2485	1972	2018
Connecticut	Turners Falls Dam	19,400	1889	1905-1915	2018
Connecticut	Holyoke Dam	26000	2004	na	1999
Connecticut	Enfield Dam (Windsor Locks)	na	8404	1902	2029

Data compiled in part from information provided by Federal Energy Regulatory Commission, September 1991
X = Application pending
E = Exemption, permit has no expiration date
na = information not available

List of Hydropower Dams on the Upper Connecticut Tributaries, includes Conneticut Tributaries above Montague City, Mass with drainage areas greater than 100 square miles and reservoirs with storage of 50 acre-ft or greater

River	Project Name	Gross Storage acre-feet	FERC Project No.	Operational Date	License Expiration Date
Nulhegan	no project identified				
Upper Ammonoosuc	Brooklyn	250	11128	na	X
Upper Ammonoosuc	Weston	275	7883	1987	2025
Israel	less than 50 ac-ft of storage at any hydoelectric project				
Passumpsic	East Barnet	136	3051	1984	E
Passumpsic	Great Falls	135	2839	1915	2019
Passumpsic	North Gage	70	2397	1921	1993
Passumpsic	Passumpsic	70	2400	1929	1883
Passumpsic	Pierce Mills	50	2396	1928	1993
Passumpsic	South Gage	na	2397	1921	1993
Ammonoosuc	Ammonoosuc	280	4609	1985	E
Ammonoosuc	Bethlem	116	7860	na	2027
Ammonoosuc	Woodsville	226	5307	1982	E
Wells	less than 50 ac-ft of storage at any hydoelectric project				
Waits	Bradford	54	2488	1982	E

Data compiled in part from information provided by Federal Energy Regulatory Commission, September 1991
X = Application pending
E = Exemption, permit has no expiration data
na = information not available

List of Hydropower Dams on the Upper Connecticut Tributaries, includes Conneticut Tributaries above Montague City, Mass with drainage areas greater than 100 square miles and reservoirs with storage of 50 acre-ft or greater

River	Project Name	Gross Storage acre-feet	FERC Project No.	Operational Date	License Expiration Date
Ompompanoosuc	less than 50 ac-ft of storage at any hydoelectric project				
White	Bethel Mills	50	9826	1941	E
Mascoma	less than 50 ac-ft of storage at any hydoelectric project				
Ottauquechee	N.Hartland, uses existing Corps pool		2816	1985	2021
Ottauquechee	Downers Mill	250	5195	1983	E
Ottauquechee	Taftsville	100	2490	1943	1993
Ottauquechee	West Dam	129	2787	1987	E
Ottauquechee	Dewey Mills	260	5313	1985	2032
Sugar	Caplan	65	3320	1986	E
Sugar	Coy Paper Co.	150	10898	1924	2031
Black	Cavendish	100	2489	1907	1993
Black	Fellows	60	9648	1990	2026
Williams	less than 50 ac-ft of storage at any hydoelectric project				
West	no project identified				

Data compiled in part from information provided by Federal Energy Regulatory Commission, September 1991
X = Application pending
E = Exemption, permit has no expiration data
na = information not available

List of Hydropower Dams on the Upper Connecticut Tributaries, includes Conneticut Tributaries above Montague City, Mass with drainage areas greater than 100 square miles and reservoirs with storage of 50 acre-ft or greater

River	Project Name	Gross Storage acre-feet	FERC Project No.	Operational Date	License Expiration Date
Ashuelot	Lower Robertson	63	8235	1987	E
Millers	Athol MFG	420	10163	1988	E
Millers	New Home	530	6096	1940	E
Millers	Nunts Pond	120	8012	1986	E
Millers	Tannery Pond	51	8895	na	E
Deerfield	Somerset Dam	57,345	2323	1913	1993
Deerfield	Searsburg Dam	282	2323	1922	1993
Deerfield	Harriman Dam	116,075	2323	1924	1993
Deerfield	Sherman Dam	1,707	2323	1927	1993
Deerfield	Deerfield No. 5 Dam	152	2323	1974	1993
Deerfield	Bear Swamp PS	5,100	2669	1974	2020
Deerfield	Fife Brook Dam	4,600	2669	1974	2020
Deerfield	Deerfield No. 4 Dam	432	2323	1912	1993
Deerfield	Deerfield No. 3 Dam	200	2323	1912	1993
Deerfield	Gardner Falls Dam	190	2334	1904	1993
Deerfield	Deerfield No. 2 Dam	342	2323	1913	1993

Data compiled in part from information provided by Federal Energy Regulatory Commission, September 1991
X = Application pending
E = Exemption, permit has no expiration data
na = information not available

APPENDIX G

SELECTED CORRESPONDENCE

April 16, 1992

Planning Directorate
Basin Management Division

Mr. James Ginnetti
New England Power Exchange
One Sullivan Road, P.O. Box 1310
Holyoke, Mass. 01041-1310

Dear Mr. Ginnetti:

Thank you for your letter response of April 6, 1992 regarding the hydropower impact of flow augmentation on the Connecticut River. As you are aware, the proposed alternative being evaluated is storage and release of approximately 30,210 acre-feet of water at seven Corps reservoirs in June, July and August, in such a manner, that Corps reservoir discharge when added to NEPEX forecast flow for the day would maintain the daily stream gage reading at Montague at 4,900 cfs.

In your letter (paragraph four) you state: "the proposal would require NEPEX to dispatch hydropower facilities to maintain a 4,900 cfs flow at Montague during August. This restriction would force NEPEX to dispatch less hydropower production during on peak hours when the energy is most valuable and more during off peak hours when the energy is worth less. This change would result in an economic penalty due to non-optimal dispatch of hydropower."

Mrs. Barbara Blumeris, of my staff, contacted you (telecom, April 9, 1992) regarding this paragraph and explained that:

- for the purposes of this study 4,900 cfs is assumed to be an average daily flow and
- the proposal is for NEPEX to pass the flow that would normally be released on a given day under current NEPEX operating policy plus the Corps flow augmentation volume for that day.

Based on our current understanding of your operations, it appears that the alternative as currently being studied should not create an economic impact. Any lost hydropower production due to water storage in June and July at Corps reservoirs should be made up by flow releases in August.

We request that you provide us with your opinion regarding the economic penalty issue in light of this additional information.

Thank you for your assistance in this matter.

Sincerely,

Joseph L. Ignazio
Director of Planning

NEPOOL

NEPEX

April 6, 1992

Mr. Joseph L. Ignazio
Department of the Army
Corps of Engineers
424 Trapelo Road
Waltham, MA 02254-9149

Dear Mr. Ignazio:

As you requested in your February 19, 1992 letter to me, I am writing to provide you with NEPEX's opinion regarding the Corps' reconnaissance investigation of using its reservoir storage to augment the flows on the Connecticut River as measured at Montague, Massachusetts during August.

The Corps' proposal, as described in your letter, would capture 30,210 acre-feet of water in June and July and store it at seven (7) of the Corps' reservoirs on the Connecticut River. This water would then be released in August to assist in maintaining a 4,900 cfs flow at the Montague gage. Your proposal would allow the Massachusetts Water Resources Authority (MWRA) to reduce the amount of water that it would otherwise be required to release from Quabbin Reservoir into the Connecticut River.

The water that the Corps would capture in June and July is water that riparian rightholders would use for hydropower production in those months. This proposal will reduce the total flow that those rightholders see in June and July, while increasing the amount of Quabbin water available to the MWRA.

This proposal would require NEPEX to dispatch the hydropower facilities to maintain a 4,900 cfs flow at Montague during August. This is substantially above the current requirement of 1,455 cfs. This restriction could force NEPEX to dispatch less hydropower production during on-peak hours when the energy is most valuable and more during off-peak hours when it is worth less. This change would result in an economic penalty due to this non-optimal dispatch of the hydropower.

For these reasons, NEPEX does not see any production or economic benefit resulting from this proposal. In fact, new operating restrictions emanating from this proposal could reduce the total hydropower production and the associated economic benefit.

New England Power Exchange One Sullivan Road/P.O. Box 1310/Holyoke, MA 01041-1310/(413) 535-4000/Fax (413) 535-4343

As an alternative to your current proposal, you may want to consider the possibility of storing additional water at the end of the Spring freshet for release in August. By capturing water that would otherwise be spilled, you could provide water to assist in maintaining a 4900 cfs flow at Montague during August while providing additional water for hydropower generation. This approach could benefit electric ratepayers in New England without jeopardizing the riparian rights of those on the lower Connecticut River during June and July.

Please call me on 413-535-4336 if you have any questions regarding this topic.

Sincerely,

James A. Ginnetti

James A. Ginnetti
Manager-NEPEX Operations

CORPSRES.JAG:dlh

cc: R. Chevalier, NUSCO
H. Sullivan, NEP
R. McEacharn, NEPEX
J. Read, NEPEX

April 3, 1992

Planning Directorate
Basin Management Division

Mr. Tom Lauritsen and
Mr. George Moulton
Joint River Commissions
Post Office Box 1182
Charlestown, NH 03603

Dear Mr. Lauritsen and Mr. Moulton:

Thank you for your letter of March 9, 1992 regarding the "Connecticut River Flow Augmentation Study" being conducted by the New England Division under our Section 22 program at the request of the Massachusetts Water Resources Authority (MWRA). This investigation is scheduled for completion in May of this year and we would be happy to provide you a draft copy of the report for your review prior to its public release. I believe that this draft report will provide the Joint River Commissions with the necessary information to reach a position relative to this flow augmentation concept. My staff will also be available to brief the Joint River Commissions on the results of this investigation.

As I discussed in my letter of November 1, 1991, the purpose of this reconnaissance level study is to explore the potential benefits and impacts of augmenting flows on the Connecticut River during the low flow months. The flow augmentation is desired by the MWRA to maintain a flow of 4900 cfs at the Montague City USGS stream flow gage, downstream of the confluence of the Deerfield River, to reduce the amount of required releases from Quabbin Reservoir, thereby increasing the amount of water available for water supply. The investigation will include an evaluation of utilizing small increments of storage at existing Corps of Engineers' flood control reservoirs to provide a partial source of augmentation flows. The results of this Section 22 investigation will provide information to the MWRA to determine whether or not they should proceed with further study of the feasibility of this alternative.

If you have any question concerning this investigation or if the Commissions require any additional information, please contact Mrs. Barbara Blumeris of my staff at (617) 647-8737.

Sincerely,

Joseph L. Ignazio
Director of Planning

Blumeris/ap/7737

cf:
Ms. Blumeris, 114S (lauritsen)
Mr. Kennelly, 114S
BMD File, 114S

Commonwealth of Massachusetts

Division of Fisheries & Wildlife

Wayne F. MacCallum, *Director*

27 March 1992

NHESP File: 91-367

Joseph L .Ignazio
Director of Planning
Department of the Army
424 Trapelo Road
Waltham, MA 02243

Re: Flow augmentation study
Tully Lake, Athol/Royalston, MA

Dear Mr.Ignazio:

Thank you for contacting the Natural Heritage and Endangered Species Program regarding rare species and ecologically significant natural communities in the vicinity of Tully Lake as described in your letter of 31 January 1992.

At this time we are aware of one rare species of plant in the vicinity of Tully Lake. This is the Tiny Cow Lily (*Nuphar pumila*), which has been documented to occur in Long Pond, north of Tully Lake. Please see the enclosed letter of 29 July 1991 for details.

Please note that this determination is based on the most recent information available in the Natural Heritage database, which is constantly being expanded and updated through ongoing research and inventory. Should new rare species information become available, this determination may be reconsidered. This evaluation does not consider the potential impacts to inland fisheries. To receive such an evaluation contact, Richard Keller, Aquatic Biologist, Field Headquarters, Division of Fisheries and Wildlife, Field Headquarters, Route 135, Westborough, MA 01581.

Please contact me or Jay Copeland, Environmental Reviewer, if you have any questions.

Sincerely,

Patricia Huckery-Tower
Assistant Environmental Reviewer

Enclosure

Division of Fisheries & Wildlife
Leverett Saltonstall Building,
Government Center, 100 Cambridge Street, Boston, MA 02202 (617) 727-3151

Commonwealth of Massachusetts

Division of Fisheries & Wildlife

Wayne F. MacCallum, *Director*

29 July 1991 NHESP File No. 91-367

Joseph L. Ignazio
Director of Planning
Department of the Army
424 Trapelo Road
Waltham, MA 02243

Project Name: Drought Contingency Plan
Proponent: Department of the Army, Waltham
Location: Tully Lake, Royalston

Dear Mr. Ignazio:

Thank you for contacting the Natural Heritage and Endangered Species Program regarding the project referred to above. At this time, we are aware of a rare state-listed plant which grows in Long Pond, north of Lake Tully. This is the Tiny Cow Lily (Nuphar pumila), which is listed as a Threatened species. However, the last citing of this lily was in 1950. You may wish to have Long Pond reexamined in order to confirm that this plant still exists. If so, we can be of assistance in suggesting someone who is experienced with this species.

This review concerns only Rare and endangered species or animals and plants and ecologically significant natural communities for which the Program maintains site-specific records. This review does not rule out the possibility that more common wildlife or vegetation might be adversely affected by the project, especially if it will modify currently undeveloped areas.

Please note that this evaluation is based on the most recent information available in the Natural Heritage database, which is constantly being expanded and updated through ongoing research and inventory. Should project plans change, or new rare species information become available, this evaluation may be reconsidered.

This evaluation does not consider the potential impacts to inland fisheries. To receive such an evaluation contact Mark Tisa, Assistant Director for Fisheries, Division of Fisheries and Wildlife, Field Headquarters, Route 135, Westborough, MA 01581.

Natural Heritage & Endangered Species Program
100 Cambridge Street, Boston, MA 02202 (617) 727-9194, (617) 727-3151

JOINT RIVER COMMISSIONS

Vermont
Connecticut River
Watershed
Advisory Commission

New Hampshire
Connecticut River
Valley
Resource Commission

March 9, 1992

Col. Philip R. Harris
Division Engineer
U.S. Army Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02254-9149

Dear Col. Harris,

The New Hampshire Connecticut River Valley Resource Commission and its Vermont counterpart, the Connecticut River Watershed Advisory Commission, are required by the terms of the legislative acts creating them to be concerned with any and all activities with potential impact on the northern Connecticut River Valley and its people.

The Commissions think that the feasibility study now being conducted by the Corps on behalf of the Massachusetts Water Resource Authority is a cause for such concern. It will eventually be both appropriate and necessary that the Commissions arrive at a position relative to this study and its possible implementation. This position must be consistent with the facts, the legal requirements of the various jurisdictions, the public interet of the Valley and New England in general, the integrity of the flood control system, and the environmental, ecological, economic and social well-being of the area in question.

In October 1991, Barbara Blumeris, Project Engineer, addressed the Joint Commissions at a meeting at Lake Morey Inn, Fairlee, Vermont on the broad outlines of the study. Upon reflection, this presentation raised more questions than it answered - not the fault of Ms. Blumeris. The Commissions realize that if a valid position is to be reached, it must be with the most complete understanding of the study and its implications for the future.

To this end, the Commissions request the following:

1. That the Corps provide them with copies of the proposed study, contracts, and any amendments or appendices;

2. That the Commissions be kept informed as the study develops;

3. That the Commissions be made a participant to the extent that study results be made available upon completion, and preferably before being made public, for purposes of comment.

P.O. Box 1182 • Charlestown, NH 03603 • (603) 826-4800

The Commissions have a major obligation to the present and future welfare of the northern Connecticut River Valley. This can best be accomplished in an atmosphere of complete understanding.

We appreciate your consideration.

Sincerely,

Tom Lauritsen, Chairman VT
Connecticut River Watershed
Advisory Commission

George Moulton, Chairman NH
Connecticut River Valley
Resource Commission

cc: Robert Varney, Commissioner
NH Dept. of Environmental Services

State of New Hampshire
Fish and Game Department

2 Hazen Drive, Concord, NH 03301
(603) 271-3421

Relay NH 1-800-735-2964

Donald A. Normandeau, Ph.D.
Executive Director

February 28, 1992

Joseph L. Ignazio
Director of Planning
Impact Analysis Division
Dept. of the Army
New England Division
Corps of Engineers
424 Trapelo Road
Waltham MA 02254-9149
attn: Michael Penko

Dear Mr. Ignazio:

The New Hampshire Fish and Game Department has reviewed the request by the Massachusetts Water Resources Authority (MWRA) to augment flows to the Connecticut River from Corp's owned reservoirs within that watershed. The Department is providing comments pursuant to the Fish and Wildlife Coordination Act (48 Stat. 401 as amended; 16 U.S.C. 661 et seq.), and RSA 206:9 and 206:10.

The MWRA's request is in response to a Supreme Court Order which requires the MWRA to release flows from Quabbin Reservoir, the major drinking water supply for the Boston area, when flows in the Connecticut River at Montague City MA drop below 71 million gallons per day. The MWRA is requesting flow augmentation from seven Corp's reservoirs within the Connecticut River watershed, which includes Otter Brook Lake in New Hampshire, to offset the Quabbin releases.

Your letter of January 31 states that the potential for significant impacts to wetlands could occur at reservoirs in Vermont and Massachusetts, however, it appears from the data that similar impacts to Otter Brook Lake would also occur. Also, any fluctuations of flows from the reservoir could have an adverse impact on the aquatic resources of Otter Brook below the reservoir.

The Fish and Game Department recommends that you thoroughly address the aforementioned impacts in the forthcoming Environmental Assessment.

Discover Wild New Hampshire

If you have any questions or need additional information please contact Ecologist, William Ingham, Jr. at (603) 271-2224.

Sincerely,

Donald A. Normandeau, Ph.D.
Executive Director

DAN/WCI
cc: William Ingham, Jr.
Carol Henderson

State of Vermont

Department of Fish and Wildlife
Department of Forests, Parks and Recreation
Department of Environmental Conservation
State Geologist
Natural Resources Conservation Council

AGENCY OF NATURAL RESOURCES
Department of Environmental Conservation
WATER QUALITY DIVISION
103 South Main Street
Building 10 North
Waterbury, VT 05671-0408

802-244-6951

February 28, 1992

Mr. Joseph L. Ignazio
Director of Planning
Department of the Army
New England Division
Corps of Engineers
424 Trapelo Road
Waltham, MA 02254-9149

Dear Mr. Ignazio:

This is in response to your letter of January 31, 1992 in which you indicated that the Corps was undertaking a reconnaissance level investigation of flow augmentation for the Connecticut River using five reservoirs located in Vermont, among others in New Hampshire. You requested comments regarding possible water quality impacts associated with using the reservoirs for flow augmentation to offset additional withdrawal from the Quabbin Reservoir in Massachusetts. You indicated that storage for flow augmentation would commence in May or June and that discharges to augment flow at the Montague gage would occur during June, July and August. A table was enclosed with your letter specifying the increased depths and pool area that would be associated with increased storage.

Before giving the broad concerns of the Water Quality Division, I would like to draw upon an excerpt of a statement submitted to Governor Dean by Mr. Arthur Silvester, Commissioner, Connecticut River Valley Flood Control Commission.

> "The 1982 study evaluated the storing of a half inch of run off at seven Flood Control dams located above the Montague City measuring gauge. These seven dams were:

Union Village	Vermont
North Hartland	Vermont
North Springfield	Vermont
Ball Mountain	Vermont
Townshend	Vermont
Otter Brook	New Hampshire
Tully	New Hampshire

The Corps has stated that storing one half inch of run off would be equal to 23,800 acre feet. The study further determined that this 23,800 acre feet of storage could be used to obtain an additional yield from Quabbin of 10 MGD under the worst drought conditions. The Appendix of this 1982 study goes on to state that "this investigation did not address the impacts to the authorized flood control purpose of this project."

Some possible environmental impacts are listed below.

Union Village Dam (Norwich and Thetford)
possible ecological impact;
possible increase in mosquito infestation;
increase of heavy metal content in sediments from copper mines upstream on Ompompanoosuc causing lower water quality;
possible impact on downstream historic sites.

North Hartland Dam (Hartland and Hartford)

negative impact on VT Electric Co-op Hydro operation;
negative impact on recreational facilities.

North Springfield Dam (Springfield and Weathersfield)
loss of 8 historic sites;
negative impact on Large Mouth Bass fisheries
loss of agricultural land;
adverse impact on recreational sites at drawdown.

Townshend Dam (Jamaica and Townshend)
seasonal inundation of beach, parking lot and boat launching site.

Ball Mountain Dam (Jamaica and Londonderry)
possible impact on fish restoration projects;
inundation of three prehistoric sites, including one that is eligible for the National Register."

In addition to transmitting the above concerns raised by Mr. Silvester, this Department would like to point to general concerns which apply to all the projects in question and which deserve further study.

Flooding In the event of a storm large enough to fill a reservoir with reduced storage capacity, downstream flooding will be greater. The increase will be largest in the portions of rivers just below the study dams which, of course, are in Vermont. The Corps should determine the downstream flooding and make this information available to this Agency and to the public. Such an evaluation, in addition to considering the reduced storage volume, should take into

account the normal range of discretion of the Corps to otherwise manipulate storage with special reference to the type of condition which occurred in April of 1987 when emergency spillways were overtopped on the West River.

Wetlands Substantial areas of wetland would be inundated by the proposal. The impact on these sites as a result of the proposal should be evaluated in the context of the functions and values protected by the Vermont Wetland Rules. This evaluation should include the functions which would be eliminated, the possible replacement of such wetland functions in areas at the new, fluctuating pond margin, and changes in vegetation and wildlife habitat. It should also evaluate the effect of storage and releases on downstream wetlands. Wetlands are known to be within the impoundments of the dams at North Hartland, North Springfield, Townshend and Union Village.

Turbidity Impoundment shoreline instability due to pond level fluctuation, and downstream streambank and streambed erosion resulting from augmentation releases need special evaluation along with the impact of the resultant sedimentation on all phases of fish and invertebrate life cycles both in the littoral zone of the impoundment and in the channel downstream of each impoundment.

Dissolved Oxygen Increasing the depth of impoundment waters may stratify or increase stratification resulting in oxygen-depletion in some sections of the impoundments. Heavy metals and nutrients which may have accumulated in the bottom sediments of the impoundment can be released back into the water column under oxygen-depleted conditions.

Fish and Wildlife Habitat Fish habitat is influenced by the depth, velocity and time of year in which the flow release and impounded flows occur. The reduced flow during storage may also have a significant impact on fish habitat and behavior in response to modifications of the seasonal flow regime. Special attention should be given to the potential influence of storage and flow augmentation on efforts to restore the Atlantic Salmon to the Connecticut River and its tributaries. Wildlife are especially dependent on the wetlands and the impact of any proposal should be evaluated on species typical of such sites.

Recreation Careful analysis of beneficial uses in the impoundments and downstream is essential. This includes impacts to existing recreation areas, impacts of augmentation releases to current scheduled releases for white water canoeing, the increased risks to wading fishermen during release periods, impacts to the aesthetics of impoundments (bathtub ring effect), effects on boating and boat launches, bathing houses, and associated wastewater disposal systems. Natural moderate to low summer flows are usually optimum for bathing. Proposed augmentation flows would occur during the hottest summer

months. This impact should receive analysis.

Dam Structure These earthen dams may not have been designed to hold water at the proposed levels for a sustained period of time. The effect of the higher water level of impoundment on the internal structure of the dams requires special consideration.

This is a brief summary of the concerns of this Division in relation to the proposed study. We have spoken with Mr. Arthur Silvester of the Connecticut River Valley Flood Control Commission who had mailed us a discussion paper on your project. He indicated the paper was unanimously endorsed by the three Vermont Commissioners. I am attaching a copy of this document, without specific comment by the Department at this time, so that you may be aware of the Commission's concerns.

In addition, if you have not already done so, I would recommend that you obtain the comments of the Connecticut River Watershed Advisory Commission which is an organization concerning bi-state issues on the Connecticut River between Vermont and New Hampshire.

Please do not hesitate to contact me if you should have any questions.

Sincerely,

David L. Clough, P.E.
Director, Water Quality Div.

DLC/SS/lq

cc: Arthur Silvester
Robert Michenfelder

Enclosure

ss\055-1100.92

Some Considerations Relating

to

Possible use of Flood Control Dams above Montague City Gauge for the storage of water for subsequent release into Quabbin Reservoir for the benefit of the Massachusetts Water Resources Authority

On 12 March 1991 the Massachusetts Water Resources Authority entered into an agreement with the U. S. Corps of Engineers to undertake a feasibility study for the diversion of Connecticut River water into the Quabbin Reservoir in order to maintain required flow levels from Quabbin into the Swift River during the time frame from June 1st to November 30th.

Some background information is necessary for an understanding of the many issues. The Chicopee River contains a watershed of some 721 square miles and it discharges into the Connecticut River at Chicopee. The river is formed by the confluence of three tributaries in Palmer, the three being the Swift, Ware and Quabog Rivers. Located at Barre, on the Ware River, is a vertical shaft through which water can be diverted to the underground aqueduct connecting the Quabbin and Wachusett Reservoirs.

In the early 1930's the Corps of Engineers determined minimum flow requirements from Quabbin into the Swift River. Massachusetts protested but Connecticut supported these requirements in order to insure navigation on the river below Hartford. The case ended up in the U. S. Supreme Court which in 1931 imposed the following flow requirements upon Quabbin.

1. Quabbin must maintain a minimum flow of 20 million gallons (equivalent to 31 cfs) in each calendar day on the Swift River at Bondsville.
2. From the period June 1st to November 30th if flows on the Connecticut River at the Montague Gauge are between 4650 cfs and 4900 cfs Quabbin Reservoir must release 70 cfs to the Swift River.
3. From June 1st to November 30th if flows on the Connecticut River at Montague Gauge are below 4650 cfs Quabbin Reservoir must release 110 cfs to the Swift River.

Summarizing the above statements: what the federal government is saying is that as the amount of water in the Connecticut River at Montague City declines Quabbin must increase its discharge into the Swift/Chicopee River system to insure navigation on the lower Connecticut River.

The bottom line is that water from Quabbin that is diverted to the Connecticut River is water that is not available to Boston and the other municipalities that feed out of the Massachusetts Water Resources Authority.

In the sixty years that have elapsed since the 1931 Supreme Court decision the amount of water mandated to be released by Quabbin into the Swift River has remained unchanged. What has changed is the gradual lowering of the water level at Quabbin. This evolutionary lowering of Quabbin is due in part to two primary causes. There is greater demand for water in the area served by the Massachusetts Water Resources Authority because of an increased population, and secondly, there is significant water loss due to fissures and cracks in the underground aqueduct serving the metropolitan district. Essentially it is the search for new water supplies that has led to such studies as A Hydrologic Assessment of Downstream Flow Requirements at Quabbin Reservoir and Ware River Intake, New England Division, Corps of Engineers, Waltham, Massachusetts, February 1982. and Flow Management Study of the Connecticut River, Initiated in March 1991.

The 1982 study evaluated the storing of a half inch of run off at seven Flood Control dams located above the Montague City measuring gauge. These seven dams were:

Union Village	Vermont
North Hartland	Vermont

North Springfield	Vermont
Ball Mountain	Vermont
Townshend	Vermont
Otter Brook	New Hampshire
Tully	New Hampshire

The Corps has stated that storing one half inch of run off would be equal to 23,800 acre feet. The study further determined that this 23,800 acre feet of storage could be used to obtain an additional yield from Quabbin of 10 MGD under the worst drought conditions. The Appendix of this 1982 study goes on to state that "this investigation did not address the impacts to the authorized flood control purpose of this project."

Some possible environmental impacts are listed below.

Union Village Dam (Norwich and Thetford)
- possible ecological impact;
- possible increase in mosquito infestation;
- increase of heavy metal content in sediments from copper mines upstream on Ompompanoosuc causing lower water quality;
- possible impact on downstream historic sites.

North Hartland Dam (Hartland and Hartford)
- negative impact on Vt. Electric Co-op Hydro operation (Corps of Engineers was non-committal about notifying Vermont Public Service Board);
- negative impact on recreational facilities.

North Springfield Dam (Springfield and Weathersfield)
- loss of 8 historic sites;
- negative impact on Large Mouth Bass fisheries;
- loss of agricultural land;
- adverse impact on recreational sites at draw down.

Townshend Dam (Jamaica and Townshend)
- seasonal inundation of beach, parking lot and boat launching site.

Ball Mountain Dam (Jamaica and Londonderry)
- possible impact on fish restoration projects;
- inundation of three prehistoric sites, including one that is eligible for the National Register.

The contract between the Corps of Engineers and the Massachusetts Water Resources Authority signed in March of 1991 requires that the feasibility study be completed within twelve months. The study intends to address "the possible storage volumes available at Corps reservoirs" and "identify the amount of seasonal encroachment which could be permitted." In a later section outlining coordination it is stated: "The Corps of Engineers shall coordinate with all appropriate Federal, State and local agencies throughout the study."

This particular contract study was probably being informally discussed and formulated in late 1990. It was approved by the Corps on 12 February 1991 and subsequently signed by the Massachusetts Water Resources Authority on 12 March 1991. The Connecticut River Valley Flood Control Commission did not learn of the proposed study until 21 June 1991 when a Connecticut member of the Commission passed around copies of the proposed feasibility study authorized by the Corps and the Massachusetts Water Resources Authority. For over three months to elapse between the time the study was approved and the Commission's awareness of what was afoot must certainly be considered a breach of the promised "coordination." This breach of coordination is further compounded by the fact that it was a fellow Commissioner who informed the Commission and not the Corps or the

Massachusetts Water Resources Authority. A question logically comes to the fore at this point. Is the Connecticut River Valley Flood Control Commission considered by the Corps and the Massachusetts Water Resources Authority an "appropriate" agency to be kept informed?

Regardless of this oversight there are other significant considerations. The Compact for the Connecticut River Valley Flood Control Commission states in part:- "The comprehensive flood control system should include dams and reservoirs controlling flood run off from approximately 25 per cent of the total drainage area of the Connecticut River above Hartford," Connecticut. The engineering study initiated by the Corps following World War II indicated the need for some 22 dams or reservoirs to insure the necessary protection for life and property. However, only 15 were built. The following dams were planned but never built.

Groton Pond on Wells River	Vermont	17.3 sq. miles	drainage area
Victory on Moose River	Vermont	66.0 sq. miles	" "
Bloomfield on Nulhegan River	Vermont	70.0 sq. miles	" "
Walpole on Cold River	N. H.	101.0 sq. miles	" "
Bethlehem Junct. on Ammonoosuc River	N. H.	90.0 sq. miles	" "
Franconia on the Ammonoosuc River	N. H.	30.0 sq. miles	" "
Swiftwater on Wild Ammonoosuc River	N. H.	59.0 sq. miles	" "

It is difficult to comprehend how the Corps not having built all the dams it was originally believed necessary for protection can now consider using seven of these existing facilities (5 of which are in Vermont) for the storage of water to accommodate the needs of the Massachusetts Water Resources Authority. Presumably this water will be impounded between June 1st and November 30th. In the event of a threatened flood the storage capacity of each of these seven dams is decreased. It has been argued that the likelihood of a flood in the six month time frame is minimal. Yet the most destructive flood in New England in modern times occurred in the first week of November (1927). To impinge upon the existing flood control capacity, to any extent however slight, does not appear in the public interest for either the upper or lower Connecticut valley. Both the Corps and the Connecticut River Valley Flood Control Commission are aware of the inadequacies of the Chicopee flood control devices because of the lack of funds to provide necessary maintenance. A hundred year flood is no respecter of the months on a calendar. If the Corps sanctions water storage for six months of the year in seven existing flood control dams and a hundred year flood occurs within the time frame when storage is taking place who will answer for the resultant loss in life and property damage? I cannot forget the damage I saw wrought by the 1927 Flood. Too many people today, in positions of decision making responsibility, look upon a hundred year flood as a statistical phenomenon and not an experience in human tragedy.

Certain of the five Vermont dams already contain amounts of impounded water either for the generation of electricity or for recreational purposes. The proposal under consideration by the Corps and the Massachusetts Water Resources Authority would thus add to the levels of water already impounded thereby further decreasing the space available for the storage of water in the event of a flood.

There is another consideration that needs to be addressed. Is it premature to arrive at a policy recommendation prior to the detailed findings of the Corps/ Massachusetts Water Resources Authority study? The writer thinks not. On the contrary, it appears important that both the Corps and the Massachusetts Water Resources Authority know the thinking of the Connecticut River Valley Flood Control Commission before they finalize and publicize their intended course

of action.

The Corps and the Massachusetts Water Resources Authority must not overlook the long simmering resentment that Vermont towns feel regarding the existence of these dams. At the time of inception, when these dams were constructed, the tax loss payments could properly be judged as equitable. Over thirty years have elapsed and the value of the land has increased ten fold, but the tax loss payments have remained constant. Many Vermont towns already feel they are being discriminated against for the benefit of the valley communities in Massachusetts and Connecticut. To add another function onto these dams will undoubtedly further increase local resentment.

There remains but one additional question to be considered, namely: does the Connecticut River Valley Flood Control Commission have the authority to determine whether flood control dams may be used for water storage that is neither flood control, hydro electric or recreational? The Compact does not address this issue. If the Corps has the ultimate power of decision and not the Flood Control Commission, then it nonetheless behooves the Commission to take a position either in support of or against the proposal. Given the seriousness of the issues involved, the public safety, the potential loss of lives and property, it would appear the Commission would be well advised to manifest its disapproval of the project.

As one reviews all the studies and other data available it would appear that the Massachusetts Water Resources Authority is looking for an expedient and cheap "quick fix". While it is certainly not in the purview of the Connecticut River Valley Flood Control Commission to suggest to the Massachusetts Water Resources Authority how it should solve its dilemma one wonders if it might not be appropriate for the Corps and the Massachusetts Water Resources Authority to construct a desalination plant in the Boston area instead of pursuing a course of action that can only jeopardize the lives and property of people living within the Connecticut River basin.

Arthur Silvester

Arthur Silvester

15 January 1992

State of New Hampshire
DEPARTMENT OF ENVIRONMENTAL SERVICES
WATER SUPPLY & POLLUTION CONTROL DIVISION
6 Hazen Drive, P.O. Box 95, Concord, NH 03302-0095
603-271-3504
TTY/TDD 225-4033
Relay Service for Deaf/Speech Impaired

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February 21, 1992

Joseph L. Ignazio
Director of Planning
Department of the Army
Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02254-9149

Dear Mr. Ignazio:

This is in response to your January 31, 1992 letter regarding flow augmentation by releases from Otter Brook Lake in Keene, New Hampshire. The brief description of the project has similarities to earlier proposals for use of this lake which we have already commented on. Therefore, the following comments may be redundant, but they are offered for your use.

A primary use of the Ashuelot River downstream of the reservoir is for receipt of wastewater from the Keene wastewater treatment facility. The river flow during dry periods is a key factor in the discharge permit held by the facility. Therefore, any project which alters the river flow must give consideration to its impact on the dilution capability of the river. Flow augmentation may have a beneficial impact in this regard, but the timing of releases could be important. Furthermore, the timing of water retention to fill the reservoir may also have an impact on the ability of the river to receive wastewater. Therefore, we strongly recommend that you give careful consideration to these factors when developing new operating rules for the reservoir. We look forward to the opportunity to review them when available.

We would also like to take this opportunity to commend the Corps for pursuing the public benefits of flow augmentation. In the spirit of public service you may also want to consider the benefits that would accrue if the overall low flow regime of the river at Keene could be enhanced. If low flow statistics such as the 7Q10 could be raised, it would have a significant benefit to the Keene facility which would minimize the city's expenditures for wastewater treatment.

Once again, thank you for the opportunity to comment. Please keep us informed as the project moves forward.

Sincerely,

Edward J. Schmidt, P.E., Ph.D.
Director

EJS:bdm
cc: J. Dabuliewicz
R. Nylander
R. Carter
R. Flanders

United States Department of the Interior

FISH AND WILDLIFE SERVICE
400 RALPH PILL MARKETPLACE
22 BRIDGE STREET
CONCORD, NEW HAMPSHIRE 03301-4901

February 20, 1992

Joseph L. Ignazio, Chief
Impact Analysis Division
Army Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02254-9149

Dear Mr. Ignazio:

This responds to your letter dated January 31, 1992 requesting comments on the proposed flow augmentation study of the Connecticut River for the Massachusetts Water Resources Authority at the Montague gauging station. Augmentation would occur through the manipulation of storage capacity at seven Corps reservoirs.

A number of Federally listed threatened and endangered species, and candidate species occur either within the watersheds associated with some of the Corps reservoirs or in the Connecticut River. Three Federally listed endangered species occur, in scattered populations, in or near the Connecticut River south of the Ottauquechee River and north of Brattleboro: the dwarf wedge mussel (*Alasmidonta heterodon*), Jesup's milk-vetch (*Astragalus robbinsii* var. *jesupi*) and northeastern bulrush (*Scirpus ancistrochaetus*). To date, there is one endangered bald eagle (*Haliaeetus leucocephalus*) nesting on an island in the Connecticut River, transient use of eagles during the spring, summer and fall seasons and winter use in areas of open water. The cobblestone tiger beetle, (*Cicindela margipennis*) Category 2 candidate species[1] is also found within this stretch of the Connecticut River. The brook floater (*Alasmidonta varicosa*), another Category 2 candidate species is found in scattered populations in the West River, down river of the Townshend Dam.

Sudden changes in water levels may affect these species. The flow augmentation study being conducted by the Army Corps of Engineers should include an assessment of how the proposed activity will affect both sessile and mobile organisms that live in the river or at the river's edge for all rivers of the study. Section 7 (a)(2) of the Endangered Species Act of 1973, as amended requires that the Federal agency funding, authorizing or carrying out an action, must insure that the action is not likely to jeopardize the continued existence of a listed species or result in the destruction or adverse modification of critical habitat. While Federal candidate species are not afforded protection under the Endangered Species

[1] Information is available which indicates that proposing to list as endangered or threatened is possibly appropriate but for which conclusive data are not currently available to support proposed rules.

Act, the U.S. Fish and Wildlife Service encourages their consideration in environmental planning. If unnecessary impacts to candidate species can be avoided, the likelihood that they will require the protection of the Act in the future is reduced.

We are available to assist the Corps in meeting their Endangered Species Act obligations pursuant to Section 7(a)(2). It may be advisable for our staff to schedule a meeting to discuss this project in light of the endangered species known to be present. A list of Federally designated endangered and threatened species in New Hampshire, Vermont, and Massachusetts is included for your information. Thank you for your cooperation and please contact Susi von Oettingen of this office at (603) 225-1411 for further consultation on this matter.

Sincerely yours,

Gordon E. Beckett

Gordon E. Beckett
Supervisor
New England Field Offices

Inclosures

CC: RO/FWE Reading File
M. Penko, COE
C. Fichtel, VTNHP
A. Cutko, NHNHI
A. Tappan, NHFG
Bob Paquin, Sen. Leahy's Office
RO/SE
John Warner, NEFO
File No. 320-43
FWE: SvonOettingen:2-20-92:834-4411

IN MASSACHUSETTS

Common Name	Scientific Name	Status	Distribition
FISHES:			
Sturgeon, shortnose*	Acipenser brevirostrum	E	Merrimack & Conn. Rivers & Atlantic coastal waters
REPTILES:			
Turtle, green*	Chelonia mydas	T	Oceanic straggler in southern New England
Turtle, hawksbill*	Eretmochelys imbricata	E	Oceanic straggler in Southern New England
Turtle, leatherback*	Dermochelys coriacea	E	Oceanic summer resident
Turtle, loggerhead*	Caretta caretta	T	Oceanic summer resident
Turtle, Atlantic ridley*	Lepidochelys kempii	E	Oceanic summer resident
Turtle, Plymouth red-bellied	Chrysemys rubriventris bangsi	E	Plymouth & Dukes Counties
BIRDS:			
Eagle, bald	Haliaeetus leucocephalus	E	Nesting: Worcester, Franklin and Hampshire Counties; entire state-migratory
Falcon, American peregrine	Falco peregrinus anatum	E	Nesting: Boston & Springfield; entire state-migratory
Falcon, Arctic peregrine	Falco peregrinus tundrius	E	Entire state-migratory
Plover, Piping	Charadrius melodus	T	Atlantic coast
Roseate Tern	Sterna dougallii dougallii	E	Atlantic coast
MAMMALS:			
Whale, blue*	Balaenoptera musculus	E	Oceanic
Whale, finback*	Balaenoptera physalus	E	Oceanic
Whale, humpback*	Megaptera novaeangliae	E	Oceanic
Whale, right*	Eubalaena spp. (all species)	E	Oceanic
Whale, sei*	Balaenoptera borealis	E	Oceanic
Whale, sperm*	Physeter catodon	E	Oceanic
MOLLUSKS:			
Mussel, Dwarf wedge	Alasmidonta heterodon	E	Hampshire County probably extirpated
INSECTS:			
Beetle, Puritan tiger	Cicindela puritana	T	Hampshire County (Conn. River Valley)
Beetle, northeastern beach tiger	Cicindela dorsalis dorsalis	T	Dukes County (beaches, Cape Cod south)
PLANTS:			
Small Whorled Pogonia	Isotria medeoloides	E	Hampshire, Essex, Hampden, Worcester, Middlesex Counties
Gerardia, Sandplain	Agalinus acuta	E	Barnstable County
Bulrush, Northeastern	Scirpus ancistrochaetus	E	Franklin County

* Except for sea turtle nesting habitat, principal responsibility for these species is vested with the National Marine Fisheries Service

Rev. 11-14-91

FEDERALLY LISTED ENDANGERED AND THREATENED SPECIES IN NEW HAMPSHIRE

Common Name	Scientific Name	Status	Distribution
FISHES:			
Sturgeon, shortnose*	Acipenser brevirostrum	E	Atlantic Coastal waters
REPTILES:			
Turtle, leatherback*	Dermochelys coriacea	E	Oceanic summer resident
Turtle, loggerhead*	Caretta caretta	T	Oceanic summer resident
Turtle, Atlantic ridley*	Lepidochelys kempii	E	Oceanic summer resident
BIRDS:			
Eagle, bald	Haliaeetus leucocephalus	E	Nesting: Coos County; entire state-migratory
Falcon, American peregrine	Falco peregrinus anatum	E	Current nesting: Coos, Grafton, and Carroll Counties; entire state-migratory
Falcon, Arctic peregrine	Falco peregrinus tundrius	E	Entire state-migratory
Plover, Piping	Charadrius melodus	T	Atlantic coast, migratory-historic nesting
Roseate Tern	Sterna dougallii dougallii	E	Atlantic coast
MAMMALS:			
Cougar, eastern	Felis concolor couguar	E	Entire state-may be extinct
Whale, blue*	Balaenoptera musculus	E	Oceanic
Whale, finback*	Balaenoptera physalus	E	Oceanic
Whale, humpback*	Megaptera novaeangliae	E	Oceanic
Whale, right*	Eubalaena spp. (all species)	E	Oceanic
Whale, sei*	Balaenoptera borealis	E	Oceanic
Whale, sperm*	Physeter catodon	E	Oceanic
MOLLUSKS:			
Mussel, dwarf wedge	Alasmidonta heterodon	E	Cheshire (Ashuelot River) Grafton & Sullivan Counties (Conn. River)
INSECTS:			
Beetle, Puritan tiger	Cicindela puritana	T	Extirpated (CT Rvr Valley)
Butterfly, Karner blue	Lycaeides melissa samuelis	PE[1]	Merrimack County
PLANTS:			
Jesup's milk-vetch	Astragalus robbinsii var. jesupi	E	Connecticut River Valley
Robbins cinquefoil	Potentilla robbinsiana	E	Coos County
Small Whorled Pogonia	Isotria medeoloides	E	Belknap, Strafford, Merrimack, Grafton, Carroll, Rockingham, Hillsborough Counties

* Except for sea turtle nesting habitat, principal responsibility for these species is vested with the National Marine Fisheries Service

[1] Proposed Rule anticipated Dec. 1991 or January 1992.

Rev. 11-14-91

FEDERALLY LISTED ENDANGERED AND THREATENED SPECIES IN VERMONT

Common Name	Scientific Name	Status	Distribution
FISHES:			
NONE			
REPTILES:			
NONE			
BIRDS:			
Eagle, bald	Haliaeetus leucocephalus	E	Entire state-migratory
Falcon, American peregrine	Falco peregrinus anatum	E	Current nesting: Rutland, Addison, Lamoille, Orleans, and Washington Counties
MAMMALS:			
Bat, Indiana	Myotis sodalis	E	Southwestern Counties
Cougar, eastern	Felis concolor couguar	E	Entire state-may be extinct
MOLLUSKS:			
Mussel, Dwarf Wedge	Alasmidonta heterodon	E	Windsor and Windham (Conn. River Valley)
PLANTS:			
Jesup's milk-vetch	Astragalus robbinsii var. jesupi	E	Connecticut River Valley
Small Whorled Pogonia	Isotria medeoloides	E	Chittenden County
Bulrush, Northeastern	Scirpus ancistrochaetus	E	Windham County

Rev. 11-14-91

VERMONT ELECTRIC GENERATION AND
TRANSMISSION COOPERATIVE, INC.
School Street
Johnson, Vermont 05656

(802) 635-2331

February 19, 1992

Barbara Blumeris
US Army Corps. of Engineers
Bldg. 114
424 Trapello Rd.
Waltham, MA 02254

Dear Ms. Blumeris

Per your request, I have investigated the impact on our generator output of raising the level of the pond at North Hartland during June, July and August. The turbine is rated for operation up to 435 feet, therefore raising the level above this point would preclude operation. The median output for June, July and August for the past five years are 621MWh, 411MWh and 374MWh, respectively. In addition, we would lose 4MW of summer capacity. The total replacement energy and additional capacity expenses would be approximately $56,210 and $35,000.

If the level were raised to 432 feet, we could still operate, with the level fluctuating between 432 and 435. This would have relatively little impact on output. There could be a benefit to maintaining this level if we could generate during emergency system conditions using stored water. This would allow North Hartland to be classified as a spinning reserve unit. This benefit has not yet been quantified.

Please let me know if you have any further questions.

Sincerely,

Daniel R. Crocket

Daniel R. Crocket
Engineering and Operations Manager

NEW HAMPSHIRE
NATURAL HERITAGE
INVENTORY

Helpline Tdd Relay
1-800-735-2964

February 13, 1992

Joseph Ignazio
Director of Planning
Department of the Army
New England Division, Corps of Engineers
424 Trapelo Road
Waltham, MA 02254-9149

Re: The use of Otter Brook Lake in Keene, NH to augment flow of the Connecticut River.

Dear Mr. Ignazio:

Thank you for consulting the New Hampshire Natural Heritage Inventory regarding the presence of rare plants, animals, and noteworthy natural communities (hereafter referred to as "elements") in the vicinity of Otter Brook.

The New Hampshire Natural Heritage Inventory, a program within the Department of Resources and Economic Development, collects and analyzes data on the status, location, and distribution of rare or declining native plant and animal species and exemplary natural communities in the state. Using our data base and map information system, the NHNHI also reviews private and public projects with regard to impacts on these species and communities.

On the 8th of January I responded to an inquiry by Judith L. Johnson of the Army Corps of Engineers regarding the Otter Brook Lake Drought Contingency Plan. Ms. Johnson requested information concerning the potential impact on any rare species or natural communities in the vicinity of Otter Brook Lake. We provided her with the following information:

The data base of the Inventory indicates that there is a 1972 record of Amphicarpaea bracteata var. comosa, commonly known as Hog-peanut, which is a State Threatened species. The species was found along Sullivan Road north of the project area. Hog-peanut is an upland species that would not likely be found on the borders of the lake. However, a field survey would be needed to verify the presence or absence of this or any other rare species in the project area.

Department of Resources and Economic Development
PO Box 856 CONCORD N.H. 03302-0856

603-271-3623

Portions of Otter Brook were surveyed by The Nature Conservancy staff in 1991 for the Federally Endangered dwarf wedge mussel (Alasmidanta heterodon). Although some suitable habitat was identified, no dwarf wedge mussels were found.

Although the project involving the use of Otter Brook Lake for flow augmentation of the Connecticut River would affect considerably more acrage than would the drought contingency, the data base indicates that no additional rare species or natural communities would be impacted.

Please note, this information on environmental elements is not the result of comprehensive field surveys. For this reason, the New Hampshire Natural Heritage Inventory cannot provide a definitive statement on the presence, absence, or status of species or natural communities in the area under consideration. It should also be noted that more data on this area may become available in the future as the inventory expands with ongoing fieldwork and research.

I hope this information will be helpful to you. Please contact us if you require further information regarding this or other projects.

Sincerely,

Rachel D Johnson

Rachel D. Johnson
Conservation Intern

12 FEB 1991 Kennelly/ap/7505

Planning Directorate
Basin Management Division

Ms. Cassie Thomas
Division of Capital Engineering
and Development
Massachusetts Water Resource Authority
Charlestown Navy Yard
100 First Avenue
Boston, Massachusetts 02129

Dear Ms. Thomas

Enclosed are six (6) signed original copies of the Cost Sharing Agreement for the Section 22, Planning Assistance to the States investigation of flow augmentation opportunities within the Connecticut River watershed.

Please sign and date each of the six originals and return three (3) copies to this office.

We look forward to working with you on this investigation. If you have any questions or require any additional information, please contact Mr. John Kennelly of my staff. Mr. Kennelly can be reached at (617) 647-8505.

Sincerely,

Enclosures
cf:

LRPB, 1145
BMD File, 1145 (MWRA-LT1)

Philip R. Harris
Colonel, Corps of Engineers
Division Engineer

United States Department of the Interior

FISH AND WILDLIFE SERVICE
400 RALPH PILL MARKETPLACE
22 BRIDGE STREET
CONCORD, NEW HAMPSHIRE 03301-4901

February 11, 1992

Mr. Joseph L. Ignazio
Director of Planning
New England Division
U S Army Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02254-9149

Dear Mr. Ignazio:

This is in response to your January 31, 1992 letter concerning a reconnaissance level study examining the possibility of using storage capacity at existing Corps reservoirs to provide low flow augmentation on the Connecticut River. We understand that you are undertaking this study for the Massachusetts Water Resources Authority under the Corps' Section 22 "Planning Assistance" program.

While we understand that this is a reconnaissance level study, the range of alternatives and environmental issues should be expanded to include, but not be limited to, the following items:

- Water quality effects in the reservoirs and on downstream waters.
- States rights issues associated with impounding waters in Vermont and New Hampshire to benefit Massachusetts.
- The role of water conservation as an alternative to flow augmentation.
- Environmental effects in Quabbin Reservoir associated with the expanded drawdown plan.
- Environmental effects on the Swift, Ware, and Chicopee Rivers as a result of reduced minimum flow releases.

The potential significant effects associated with these items should be evaluated with those that your staff has already identified.

Please provide us with a copy of your reconnaissance study when it is completed.

Questions concerning this letter should be directed to Mr. Vern Lang of this office at FTS 834-4411 or 603-225-1411.

Sincerely yours,

Gordon E. Beckett

Gordon E. Beckett
Supervisor
New England Field Office

MASSACHUSETTS WATER RESOURCES AUTHORITY
Charlestown Navy Yard
100 First Avenue
Boston, Massachusetts 02129

Telephone:
(617) 242-6000

September 27, 1990

Mr. Joseph L. Ignazio, Planning Director
Army Corps of Engineers
424 Trapelo Road,
Waltham MA 02254-9149

Dear Mr. Ignazio,

We have reviewed the final version of the Scope of Work for the Connecticut River flow augmentation study, dated September 19th 1990, and we find that with the exception of minor points it has incorporated all MWRA staff recommended changes to date. We anticipate that these minor changes can be made during the final contractual negotiations for this study, which we intend to proceed with immediately. Ms. Cassie Thomas of my staff has initiated the MWRA procurement process for this study, which we have entitled "Army Corps of Engineers Flow Management Study," and will be in touch with John Kennelly of your staff shortly to finalize details of the contract document and payment requirements.

We look forward to commencing work with the Corps on this study. Should you have any questions, please contact Ms. Cassie Thomas at (617) 242-7110.

Very Truly Yours,

William A. Brutsch
Director, Waterworks Division

KET/CORPSCP3

Ref. 332

Kennelly/ap/7255

Planning Directorate
Basin Management Division

Mr. William A. Brutsch, Director
Water Works Division
Massachusetts Water Resource Authority
Charlestown Navy Yard
100 First Avenue
Boston, Massachusetts 02129

Dear Mr. Brutsch

Enclosed for your review is the final draft of the Scope of Work for the investigation to determine the feasibility and associated impacts of utilizing storage in the upper Connecticut River watershed to increase the current yield at Quabbin Reservoir. The enclosed outline provides a description of the tasks which we feel are necessary to assess the feasibility of augmenting flows on the Connecticut River in order to reduce the volume of water required to be released from Quabbin Reservoir during the June 1 to November 30 period. This scope incorporates the comments and concerns which were addressed at the meeting between you and Messrs. Kennelly and Pronovost of my staff. We have prepared a project schedule and cost estimate and have determined that this investigation would cost approximately $130,000 and could be completed in one year.

When you have completed your review of the the Scope of Work please provide your comments or concerns to Mr. Kennelly of my staff. Once the scope has been finalized we can discuss what is required from the Massachusetts Water Resource Authority and the Corps of Engineers to execute an agreement to conduct this investigation. If you have any questions or require any additional information, please contact Mr. John Kennelly at (617) 647-8255. I look forward to working with you on this important study and hope to continue to assist the MWRA in meeting the growing needs of the metropolitan Boston area.

cf:
Mr. Kennelly, 112N
BMD File (JK #4 MWRALT1), 112N
Reading File
Plng Dir. File, 114N

Sincerely,

Joseph L. Ignazio
Director of Planning

Enclosure:

MASSACHUSETTS WATER RESOURCES AUTHORITY
Charlestown Navy Yard
100 First Avenue
Boston, Massachusetts 02129

Telephone:
(617) 242-6000

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Executive Director
Paul F. Levy

July 26, 1990

Mr. Joseph L. Ignazio, Planning Director
Army Corps of Engineers
424 Trapelo Road,
Waltham MA 02254-9149

Dear Mr. Ignazio,

Enclosed for your review are our proposed changes to the Corps' final draft of the Scope of Work for the Connecticut River Flow Augmentation Study, to be undertaken jointly by the Corps and the MWRA Waterworks Division. Most of the details of these proposed changes have been discussed by Cassie Thomas of Waterworks CEDD with John Kennelly of your staff. We hope that the changes are acceptable to you, since we are eager to proceed with the study. Once the Scope of Work is in final form, we understand that a Memorandum of Agreement will be drafted by the Corps for MWRA review and approval. Should you have any questions, please feel free to contact Ms. Thomas, who will be managing the project, at (617) 242-7110, ext. 4308.

Very Truly Yours,

William A. Brutsch
Director, Waterworks Division

MASSACHUSETTS WATER RESOURCES AUTHORITY
Charlestown Navy Yard
100 First Avenue
Boston, Massachusetts 02129

Telephone:
(617) 242-6000

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Executive Director
Paul F. Levy

February 14, 1990

Colonel Daniel M. Wilson
Dept. of the Army
New England Div., Corps of Engineers
424 Trapelo Road
Waltham, Mass. 02254-9149

Subj: Quabbin Reservoir Flow Modification Study - Corps proposal

Dear Colonel Wilson:

We have completed a review of the work proposed by the Corps for the study of alternative flow releases from Quabbin. The result of this analysis is that we would like the Corps to modify the proposed scope of work as detailed in the attachment.

In explanation of the requested changes you will recall that you had proposed to study three options:

Option 1 - Evaluate upstream storage required to replace releases from Quabbin Reservoir. Viewed as gallon for gallon option and would be much like the Corps 1982 study.

Option 2 - Determine the amount of storage required to effect 4,900 cfs maintenance of flows on the Connecticut River at the Montague gage.

Option 3 - Evaluate the impacts of lowering the downstream flow requirements required in the Supreme Court Decision during an emergency condition.

As detailed in the letter from John Shawcross of my staff on January 16, 1990, we received comments from a number of people on the proposed scope including the MDC Division of Watershed Management and the Water Supply Citizens Advisory Committee (WSCAC). Based on these comments and on our own analysis, we conclude that:

1. Options 1 and 3 would require modifications of the May 11, 1929 War Department permit in order to be implemented. Our impression is that there would be

sufficient public opposition to make this approach infeasible at present. However, we would be very interested in the results of this work if the Corps were able to conduct this work at Corps expense.

2. Option 2, in our opinion, would require the investigation of additional issues to those addressed in your proposed scope of work. The MWRA would be prepared to contribute towards the cost of this work provided a jointly agreed scope of work can be defined.

The attached proposed scope concentrates on Option #2. We apologize for the delay since you submitted your proposal last year. We are interested in this project and would be able to contribute to the Option 2 alternative. We may also be able to provide some staff assistance for parts of the work and wonder if this could be considered a partial contribution towards the MWRA cost amount?

When you have had a chance to review the attached scope, please contact me with the revised cost estimate and/or to arrange a meeting if you consider that necessary.

Very truly yours,

William A. Brutsch, Director
Waterworks Division

WAB:JS:mp

cc: J. Shawcross
T. Baron
M. Kempe

cedd/200
ref.128

MASSACHUSETTS WATER RESOURCES AUTHORITY
Charlestown Navy Yard
100 First Avenue
Boston, Massachusetts 02129

Telephone:
(617) 242-6000

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Executive Director
Paul F. Levy

January 16, 1990

Colonel Daniel M. Wilson
Dept. of the Army
New England Div., Corps of Engineers
424 Trapelo Road
Waltham, Mass. 02254-9149

Subj: Quabbin Reservoir Flow Modification
Study - Corps proposal

Dear Colonel Wilson:

This responds to your letter of August 31, 1989 on a study of alternative flow releases from Quabbin Reservoir to Mr. William A. Brutsch, Director, Waterworks Division MWRA. We have conferred with the Metropolitan District Commission (MDC), the Water Supply Citizens Advisory Committee (WSCAC) and others on your proposal. We received a number of responses with comments on where the emphases of the study should be placed. Key responses are attached.

We had hoped by this time to have synthesized the various ideas into one scope of work. However; this synthesis is going more slowly than expected due to loss of a key staff member (Amy Vickers). Therefore, I am sending the attached comments so that those on your staff interested in this subject can see the issues that have been raised. I have started a new Project Manager (Kathryn Thomas) working on this scope of work and hope within two or three weeks to have a single revised scope completed.

In any case, I will contact you early in February so we can decide how to move forward on this study.

Very truly yours,

John F. Shawcross, Director
Capital Eng. & Dev. Dept.,
Waterworks Division

JFS:mp
cc: W. Brutsch, Paul Pronovost, P. Corcoran,
S. Estes-Smargiassi, K. Thomas

cedd/180 (#128)

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
424 TRAPELO ROAD
WALTHAM, MASSACHUSETTS 02254-9149

REPLY TO ATTENTION OF
Planning Division
Basin Management Branch

August 31, 1989

Mr. William A. Brutsch, Director
Water Works Division
Massachusetts Water Resource Authority
Charlestown Navy Yard
100 First Avenue
Boston, Massachusetts 02129

Dear Mr. Brutsch:

Our office has completed a study outline and approximate cost estimate for the investigation you discussed with Mr. Ignazio and Mr. Pronovost of our Planning Division to determine the feasibility and associated impacts of modifying the current release requirements at Quabbin Reservoir. The enclosed outline provides a list and description of the individual tasks which we feel would be required to complete this effort. The study would address three release modification approaches; 1) making releases from upstream reservoirs to offset the required Quabbin releases, 2) augmenting flows to the Connecticut River from upstream storage reservoirs in order to maintain a minimum flow of 4900 cfs at the Montague gage, and 3) reducing the required releases from Quabbin Reservoir during an emergency drought situation. We have determined that this investigation would cost approximately $130,000 and could be completed in one year.

The Corps of Engineers has the authority to conduct this investigation under our Section 22 program. This program allows the Corps to provide planning assistance to the individual states and state agencies. This program has traditionally been 100 percent Federally funded, however, the President's budget submittal to Congress for fiscal year 1990 contained language that would require that all Section 22 investigations, starting after October 1, 1989, be cost-shared 50/50 with the local beneficiary. The status of this cost-sharing proposal for the Section 22 program is presently undetermined.

In the event that cost-sharing is not approved by Congress, it is unlikely that our office could complete this investigation in one fiscal year at 100 percent Federal funding. Current fiscal constraints would require that the investigation be completed over several fiscal years. Our office could expedite the completion of the study by separating appropriate study elements from the attached scope of work and completing them as 100 percent reimbursable work for others, with the remaining work items accomplished using our regular Section 22 program funds.

We look forward to discussing this study effort with you and your staff. If you have any questions or would like to arrange a meeting to further discuss this project, please contact Mr. John Kennelly of my staff. Mr. Kennelly can be reached at (617) 647-8255.

Sincerely,

Daniel M. Wilson
Colonel, Corps of Engineers
Division Engineer

Enclosure:

April 4, 1989

Planning Division
Impact Analysis Branch

Mr. William A. Brutsch, Director
Waterworks Division
Massachusetts Water Resources Authority
Charlestown Navy Yard
100 First Avenue
Boston, Massachusetts 02129

Dear Mr. Brutsch:

I am writing in response to your letter of February 17, 1989 concerning the potential use of storage at Connecticut River Basin Corps of Engineers flood control reservoirs to augment the water supply yield available to your system. Your request asks us to consider both short term (i.e. this spring) augmentation and longer term coordinated operation with Quabbin Reservoir.

The 1982 report cited in your correspondence was prepared by this office at the Commonwealth's request and was intended to provide hydrologic information on the potential opportunities to increase water supply yield at Quabbin Reservoir. I believe the report clearly outlines this hydrologic information and provides a basis for further study if warranted.

Further studies needed to determine the final feasibility of yield enhancement would at a minimum include review of the impacts of storage at the reservoirs, allied downstream flow needs such as hydropower and necessary institutional changes. The scope of these studies clearly exceed the time available to allow any storage in the reservoirs this spring.

To evaluate the longer term potential I have initiated a review of potential drought related water supply storage capabilities at Corps of Engineers reservoirs within the New England Division.

I have asked my staff to meet with you to discuss our respective responsibilities in examining this potential. They will contact Mr. Shawcross to arrange the meeting.

Sincerely,

Daniel M. Wilson
Colonel, Corps of Engineers
Division Engineer

cc:
Mr. Pronovost-113N
Mr. Ignazio-114N
Mr. Scully-113S
Mr. Reardon-112S
Mr. Finegan-115N
Mr. Andreliunas-106N
Mr. Manor-106S
Plng Div File
IAB File
Reading File

MASSACHUSETTS WATER RESOURCES AUTHORITY
Charlestown Navy Yard
100 First Avenue
Boston, Massachusetts 02129

Telephone:
(617) 242-6000

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Paul F. Levy

February 17, 1989

Colonel Daniel Wilson
Divisional Engineer
New England Division, Corps of Engineers
424 Trapelo Road
Waltham, Mass. 02254

Dear Colonel Wilson:

Paul Pronovost recently drew our attention to a 1982 Corps of Engineers report, "A hydrologic assessment of downstream flow requirements at Quabbin Reservoir and Ware River Intake." The report shows how changes in management of Corps of Engineers flood control reservoirs could augment the Connecticut River in summer to increase flow at the Montague City gage. This would limit the MWRA to releasing 20 mgd from Quabbin Reservoir instead of the higher flows required when the Connecticut River flow is reduced below 4900 cfs at Montague City.

Quabbin reservoir has less reserve of water than since the last major drought. We anticipate mandatory water restrictions in all the communities we supply. We are, therefore, interested in a possible saving of the excess releases from Quabbin which we understand could average more than 10 mgd this year.

Is it feasible:

(a) To use your flood control reservoirs this spring to help us this summer?

(b) Over the longer term, is it feasible to manage the flood control reservoirs to help the MDC/MWRA water supply system at Quabbin reservoir?

I would appreciate your early consideration of this matter and would be ready to participate in any discussions you may consider appropriate. John Shawcross, Director - Capital Engineering & Development of my staff, has been in contact with Paul Pronovost on this subject and is available to assist if necessary.

Very truly yours,

William A. Brutsch, Director
Waterworks Division

WAB:JS:m

cc: P. Levy, Executive Director, MWRA
I. Bhatti, Director, Watershed Management, MDC
P. Pronovost, Chief Impact Analysis Branch, Corps of Engineers, Waltham
M. Kempe, Resource Conservation & Management, Waterworks Div., MWRA
J. Shawcross, Director, Capital Eng. & Devlmt., Waterworks, Div., MWRA

cedd/894
ref.190

APPENDIX H

COMMENTS ON DRAFT REPORT

On June 4, 1992 the draft report was sent to appropriate Federal, State, regional, and local organizations for review. Comments were received on the draft report from the following agencies:

	Date of Comment Letter
Federal	
United States Department of the Interior Fish and Wildlife Service New England	July 8, 1992
State	
State of Vermont, Agency of Natural Resources, Department of Environmental Conservation, Water Quality Division	July, 7, 1992
Regional	
Connecticut River Valley Flood Control Commission	July 27, 1992
Connecticut River Watershed Council, Inc.	June 28, 1992
Franklin County Commission	June 22, 1992
Joint River Commissions, Vermont Connecticut River Watershed Advisory Commission and New Hampshire Connecticut River Valley Resource Commission	June 16, 1992
Water Supply Citizens Advisory Committee on the Massachusetts Water Resources Authority Long Range Water Supply Program	July 6, 1992
Upper Valley Lake Sunapee Regional Planning Commission	June 9, 1992
Other	
New England Power Pool, New England Power Exchange	June 24, 1992
Northeast Utilities	June 26, 1992

These comment letters are included in this appendix and are organized by date in ascending order.

The Connecticut River Valley
FLOOD CONTROL COMMISSION

~~[illegible]~~ • P.O. BOX 511 • GREENFIELD, MASSACHUSETTS 01302

(413) 773-3601 — Greenfield, Mass.

July 27, 1992

Ms. Barbara Blumeris
Corps of Engineers
424 Trapelo Road
Waltham, MA 02254

Dear Barbara:

At the quarterly meeting of the Flood Control Commission, concluded on June 19, 1992, the Commissioners voted unanimously to make the following statement in response to the Massachusetts Water Resources Authority study which the Corps had reported on:

> The Connecticut River Valley Flood Control Commission replies to the Corps regarding the MWRA study to the extent that we concur with the MWRA's opinion that it's not a viable option at this time and because it is our policy to maintain flood control capacity at the flood control structures. Furthermore, the recreational, environmental, and economic impacts outweight the benfits.
>
> The Corps completed the objectives of the study in a timely manner, it was factual and provided enough information for the MWRA to make a decision whether to pursue this alternative.

Thank you for your presentation at the quarterly meeting, Barbara.

Sincerely,

Pauline M. Smiaroski

Pauline M. Smiaroski
Executive Secretary

pms

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United States Department of the Interior

FISH AND WILDLIFE SERVICE
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22 BRIDGE STREET
CONCORD, NEW HAMPSHIRE 03301-4901

TAKE PRIDE IN AMERICA

July 8, 1992

Mr. Joseph Ignazio, Chief
Planning Directorate
U.S. Army Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02254

Dear Mr. Ignazio:

This is in response to your June 4, 1992 letter requesting our review of the draft report entitled "Section 22, Massachusetts Water Resources Authority, Connecticut River Flow Augmentation Study". The following comments are provided in accordance with the Fish and Wildlife Coordination Act (48 Stat. 401, as amended; 16 U.S.C. 661 et seq.).

The purpose of this study is to evaluate the alternative of using upstream storage in the Connecticut River Basin to augment flows on the Connecticut River with the purpose of maintaining an average daily flow of 4,900 cubic feet per second at Montague City, Massachusetts from June through November. The purpose of the project would be to increase the amount of water available to the Massachusetts Water Resources Authority.

Our review focused on the section dealing with environmental impacts. This section acknowledges that the project, as proposed, would have significant adverse impacts on the environment. The report recognizes that the inundation of hundreds of acres of uplands and wetlands would result in the loss of numerous acres of upland and wetland vegetation. The inundation and fluctuating water levels would impact not only the terrestrial and emergent vegetation, but would likely result in the loss of submerged aquatic vegetation, as well. This means that there would be a loss of habitat complexity for the entire river basin. The overall result of this loss, as pointed out in the report, would be a significant loss in habitat values for all types of wildlife: invertebrates, amphibians, reptiles, fish, birds, and mammals.

The report, however, does make several statements in an apparent attempt to lessen the significance of the impacts. One of these statements is that "...most wildlife ... would shift to alternative habitat as the reservoirs were filled ...." This is a fairly common misconception. Aside from the fact that many wildlife species are incapable of migrating any significant distance, the remaining habitats are likely populated with their own biotic community, many of which may already be at or near carrying capacity. Therefore, the migration of those species that are capable of doing so may only result in the degradation of wildlife values due to exceeding the carrying capacity of these alternative habitats.

The second statement that should be closely scrutinized is that "Conversely, flow augmentation during low flow periods in the summer might have some positive effects on downstream aquatic life." It is true that the flow augmentation may, in fact, increase the amount of available habitat during the low flow periods. However, this is not likely to have any real positive effects on aquatic life. The reason for this is that the outflow from the reservoirs would be reduced below normal levels earlier in the year. This would result in the loss of habitat during a very important time of year, causing a decline in the fish and aquatic invertebrate populations or a change in the biotic community. The resulting aquatic community likely would not be capable of taking advantage of the increased habitat later in the summer.

In summary, the implementation of the alternative described in this document would result in significant adverse impacts to the environment of the Connecticut River Basin. We understand that the Massachusetts Water Resources Authority has already concluded that continued study of this proposal is not warranted. We agree with this conclusion and recommend that this alternative be eliminated from further consideration. If you have any questions concerning this letter, please contact Philip Morrison at (603) 225-1411.

Sincerely yours,

Gordon E. Beckett

Gordon E. Beckett
Supervisor
New England Field Offices

State of Vermont

Department of Fish and Wildlife
Department of Forests, Parks and Recreation
Department of Environmental Conservation
State Geologist
Natural Resources Conservation Council

AGENCY OF NATURAL RESOURCES
Department of Environmental Conservation

WATER QUALITY DIVISION
Building 10 North

802-244-6951

July 7, 1992

Mr. Joseph L. Ignazio, Director of Planning
New England Division
Corps of Engineers
424 Trapelo Road
Waltham, MA 02254-9149

Dear Mr. Ignazio:

This is in response to your letter of June 4, 1992 with which you transmitted the "Massachusetts Water Resources Authority, Connecticut River Flow Augmentation Study".

After reviewing the report we agree with the conclusion of the Massachusetts Water Resources Authority that the continued study of this proposal is not warranted. From our point of view there are numerous environmental and safety issues, including those discussed in my letter of February 28, 1992, which would have to be overcome before such a proposal of flow augmentation of the Connecticut River by releases from flood control impoundments could be implemented. We agree with the preliminary findings that the impacts of such a proposal would be both substantial and costly to the State of Vermont.

We appreciate your efforts to keep the State of Vermont informed of your work on this topic and we would welcome early notification of the State of Vermont, Department of Environmental Conservation, the Connecticut River Flood Control Commission and the Connecticut River Watershed Advisory Commission in the future should such a proposal come up again.

Sincerely,

David L. Clough

David L. Clough, P.E.
Director, Water Quality Division

DLC/ss

cc: Arthur Silvester
Robert Michenfelder
Tom Lauritsen
George Moulton

WS CAC
WATER SUPPLY CITIZENS ADVISORY COMMITTEE
on the Mass. Water Resources Authority
Long Range Water Supply Program

138 Russell St. (Rte. 9)
P.O. Box 478
Hadley, Massachusetts 01035
(413) 586-8861

July 6, 1992

Joseph L. Ignazio
Director of Planning
New England Division, Corps of Engineers
424 Trapelo Road
Waltham, MA 02254

Re: Comments on Army Corps Study of Connecticut River Flows and Quabbin downstream releases.

At the WSCAC monthly meeting of June 18, 1992, Patricia Corcoran for MWRA and Barbara Blumeris for the U.S. Army Corps of Engineers stated that the recent Connecticut River flow study would not be continued by the MWRA into a second phase. This concludes for the present time another chapter in the review of the required downstream releases from Quabbin Reservoir and the possibility of reducing the frequency of the required supplemental releases by a manipulation of the flows in the Connecticut River.

WSCAC concurs with the MWRA's conclusion that no further study be done of changes in Corps of Engineers management of the Connecticut flows. However, we believe it is appropriate to review our own involvement in the investigation of the Quabbin Swift River releases and enter into the record a statement clarifying our position.

The phase I Corps study, just concluded, results from an earlier request by the MWRA Board to its staff to review the required Swift River releases and the interstate agreement which governs them - Short Range Policy #12 of the MWRA Long Range Water Supply Policy first adopted in November of 1986. An MWRA staff memo to the MWRA Board of June 12, 1988 concluded that the MWRA <u>not</u> pursue reducing the required releases because doing so "would certainly provoke a legal challenge by the State of Connecticut, and could conceivably reopen the Corps of Engineers permit to environmental review by the U.S. Fish and Wildlife Service."

During 1989 and 1990, WSCAC noted that Quabbin supplemental releases often resulted from weekend pumped-storage operations on the river which lower the readings at the Montague gage. The hydro-dams were mostly built on the Connecticut after the construction of Quabbin, and the minimum hydro-dam releases are much lower than the flow which triggers the supplemental releases from Quabbin. Following a meeting with Northeast Utilities, WSCAC suggested to MWRA that further Corps of Engineers study be done on the impact of the management of the hydro-dams and canals to determine if changes could result in a saving of water in Quabbin. It was also necessary to develop a way to insure that any increase in flows as a result of actions by the Corps be

allowed past the hydro-dams as they occurred, or there would be no benefit to Quabbin.

WSCAC also stated at that time, that it considered any recommended changes in river management which might result in more water being held in Quabbin as an increase in interbasin transfer from the Connecticut Basin and that environmental studies would be needed to assess the impact on the Swift and Chicopee Rivers. In effect, WSCAC was suggesting a study of the institutionally sanctioned controls on the river by hydro operators, and hoping that a Corps study would lead to a dialogue with those operators which might reduce the inappropriate Quabbin releases triggered by the weekend use of the river by the utilities.

WSCAC believed that a study by the Corps of its flood storage capacity would not be productive because the Corps, in a 1982 study, had already determined that it did not have enough storage to **substitute** for the Quabbin supplemental 50 MGD releases required during low flows (the gallon for gallon scenario), although an annualized average substitution could be met. We believed that a study of flows to control the gage reading at Montague, which would require manipulation of even greater volumes of water, would clearly be a waste of effort, for the goal would be impossible.

WSCAC commented on the Scope of Services which MWRA and the Corps produced for the study. One item in the scope was to collect data for a review of institutional controls on the Connecticut River which we supported. The study just issued, however, only identified the severe impact which hydro-operators had on the river during weekends, and rather went on to assess in detail the impact and cost of adjustments in storage in the Corps flood control dams. The study demonstrated little water savings were possible for Quabbin, and that there would be significant loss of flood storage capacity for the Corps dams. WSCAC's hopes for an institutional/policy study were dashed!

WSCAC has recommended that the MWRA seek direct access to the Montague gage readings to more sensitively manage, in a more timely fashion, the supplemental releases from Quabbin. We also encouraged a seven day-a-week operation of the Winsor Dam facilities to insure that Quabbin's supplemental releases were operated on a real-time basis and not on a Monday morning catch-up schedule resulting from delayed notification of the Montague gage readings. These recommendations would optimize Quabbin releases and river flows. However, we do regard drought emergencies as a separate case, and believe the Authority, with the support of the Corps, should begin serious discussions with the Connecticut River power utilities to plan for maximizing Quabbin water during an extended drought or during an emergency.
A review of streamflows and release requirements is a normal part of the Federal Energy Regulatory Commission relicensing process for hydro facilities. FERC relicensing of the hydro-facilities on the Connecticut will not take place for two decades.
FERC relicensing has most often of late resulted in increased

downstream releases which could help to alleviate the problem. In the future, if adjustments to Connecticut hydro-release flows are considered, then concomitant studies of impacts on the Quabbin potable supply and the downstream Swift/Chicopee reaches should also be undertaken.

WSCAC's position has become quite clear. Manipulation of the Connecticut River flows should not be seen as a source for incremental water to the MWRA system, unless this result is achieved through improved management of the present legislated release requirements or through a more environmentally aware management scheme by the hydro utilities. WSCAC agrees that the present Corps study should fall of its own weight. However, we believe more can be done to orchestrate improved management by utilities of the Connecticut flows and downstream releases at Winsor Dam.

Thenkyou for the opportunity to comment.

Sincerely yours,

Eileen R. Simonson
William G. Elliott
Co-directors, on behalf of WSCAC

CONNECTICUT RIVER
Watershed Council Inc.

Headquarters: 125 Combs Road, Easthampton, MA 01027 (413) 584-0057
Upper Valley Office: P.O. Box 189, Plainfield, NH 03781 (603) 675-2518
Lower Valley Office: 118 Oak Street, Hartford, CT 06106 (203) 293-0227

June 28, 1992

Joseph L. Ignazio, Director of Planning
New England Division
U.S. Army Corps of Engineers
424 Trapelo Road
Waltham, MA 02254-9149

Re: Connecticut River Flow Augmentation Study

Dear Mr. Ignazio,

The Massachusetts Council of the Connecticut River Watershed Council would like to offer the following comments on the Draft Report of the Connecticut River Flow Augmentation Study conducted by the U S Army Corps of Engineers for the Massachusetts Water Resources Authority. The CRWC has been dedicated to the protection and enhancement of the Connecticut River and its tributaries for 40 years. For this reason we have followed this study with considerable interest.

The study provides much useful data, however, MWRA's discontinuation of the study has merit, not only for economic reasons, but more importantly because of serious environmental impacts on the Connecticut River and its tributaries, and the corresponding effects on the Swift and Chicopee Rivers.

Of particular concern about the proposal, is the holding back of Connecticut River water during late spring and early summer while the reservoirs are filling, after peaking during the spring freshet. The Connecticut River is now experiencing its best season for salmon and shad restoration. Reduced flows during critical seasons to retain water upstream, could have an adverse impact on the water temperatures and water quality necessary for promoting anadromous fish. Recently, the U. S. government passed the Conte River Refuge bill to protect and enhance the fish habitat of the Connecticut River. Although releases from the upper dams would increase during the low flow period, a higher flow during the early season may be more ecologically significant.

We believe the Swift River releases would need to be revisited from the standpoint of environmental requirements. Reduced releases from Quabbin into the Swift River could result in water quality and water temperature problems and have an adverse impact on the trout fisheries below Quabbin; therefore, a complete EIR would be necessary. During the FERC relicensing process for dams on the Chicopee River, the Fisheries and Wildlife recommendations have been increased for base aquatic flow to protect fish habitat. Currently the requirement for the Swift River is at 20 mgd plus the Army Corps releases which

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average 10 mgd. If the requirement of .36cfsm, or August median unregulated flow, recommended for the Chicopee River aquatic base flow, were adopted for the Swift River, this could increase significantly the minimum release from Quabbin and negate the savings realized from flow augmentation by the ACOE. In fact, an MWRA staff summary, June 1988, has suggested that the aquatic base flow could be set at a even a higher rate than .36cfsm.

During the past twenty years there has been substantial improvement in the water quality of the Connecticut River. This has led to increased recreation on the river. A change in regime as proposed has shown that there would be severe economic and environmental impacts on recreational use of the river. Members of the CRWC have long championed the educational opportunities that the diversity of the riverine environment allows, including some threatened or endangered species and important shoreline habitat. In addition, the project would impact a number of historic sites. The loss of these resources due to inundation would diminish the value of some of the most important assets in New England.

Therefore, because of possible environmental degradation of the Connecticut River and its tributaries, we concur with the MWRA decision to discontinue the ACOE study of flow augmentation of the Connecticut River for purposes of reducing Quabbin releases to the Swift River. We urge the MWRA to continue its conservation programs which have proved successful in meeting the demand for MWRA drinking water supply. In addition, the protection and enhancement of local sources available to MWRA communities will do far more to mitigate future demand than flow augmentation.

Sincerely yours,

Dona D. Motts

Dona D. Motts,
CRWC Trustee

Mason M. Phelps

Mason Phelps,
CRWC Trustee

Alice R. Clemente

Alice Clemente
CRWC Mass. Chairman

xc: Doug MacDonald & Wm. Brutsch, MWRA
Gordon Beckett, USFWS
Ilyas Bhatti, MDC
Terry Blunt, DEM
Walter Bickford, Mass. MCW
Maria Van Dusen, Riverways
Larry Bandolin, Conte Ref.
George Moulton, NH Com.
Peter Richardson, Vt.

6.26

Rec'd 6-30-92

Mr. Joseph Ignazio

Report looks good! No major comments noted. Minor comments/corrections noted on pages 4, 5, 10, 36.

If possible, I'd appreciate a copy of FINAL.

thanks,

Chuck Nimmer

NEPOOL

NEPEX

June 24, 1992

Mr. Joseph L. Ignazio
New England Division
Corps of Engineers
424 Trapelo Road
Waltham, MA 02254-9149

Attn:Planning Directorate
Basin Management Division

Dear Mr. Ignazio:

Enclosed you will find my comments on the draft report entitled "Section 22, Massachusetts Water Resources Authority, Connecticut River Flow Augmentation Study".

Thank-you for the opportunity to comment on this draft report.

Sincerely,

Jim Ginnetti

James A. Ginnetti
Manager-NEPEX Operations

Enclosure

New England Power Exchange One Sullivan Road/P.O. Box 1310/Holyoke, MA 01041-1310/(413) 535-4000/Fax (413) 535-4343

NEPEX COMMENTS ON THE DRAFT REPORT ENTITLED

"SECTION 22, MASSACHUSETTS WATER RESOURCES AUTHORITY CONNECTICUT RIVER FLOW AUGMENTATION STUDY"

1. Page 5, last paragraph: McIndoes is misspelled.

2. Page 6, in Table 2: McIndoes is misspelled. Footnote (3) does not exist. Bellows Falls is misspelled.

3. Page 7, in Table 3: Bellows Falls is misspelled.

4. Page 9, first paragraph: The New England Power Exchange (NEPEX) is the operating arm of the New England Power Pool (NEPOOL).

5. Page 10, Table 5: Bellows Falls is misspelled. McIndoes is misspelled. The Usable Storage at McIndoes is 9,800 acre-feet according to Table 2.

6. Page 27, Table 14: Installed capacity at Vernon is 26 MW not 260 MW.

7. Page 27, Table 14: The hydropower capability of Turners Falls should be identified as Turners Falls/Cabot. The generators at Turners Falls total only 6 MW. The generators at Cabot Station, which is at the end of the canal fed by Turners Falls reservoir, total 53 MW.

8. Page 36, sixth reference: Northeast Utilities is misspelled.

9. Page E-3, Table E-4: Installed capacity at Vernon is 26 MW not 260 MW.

10. Page E-4, first paragraph: J. Ginnetti's phone conversation with B. Blumeris indicated that this plan would not produce any additional hydropower, whereas the capture of spring runoff water would result in additional hydropower.

11. Page E-4, Table E-5: The hydropower installations at Collins Dam and Chicopee Falls Dam are rated at 1.25 MW and 2.17 MW, respectively.

Comments submitted by:
James A. Ginnetti
Manager-NEPEX Operations
June 23, 1992

CORSRPTCOM.JAG:dlh
WP9

FRANKLIN
COUNTY
COMMISSION

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413/774-4015

Regional Services:
413/774-3167

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Greenfield, MA 01301-3330

June 22, 1992

Joseph L. Ignazio
Director of Planning
Planning Directorate
Basin Management Division
Department of the Army
New England Division, Corps of Engineers
424 Trapelo Road
Waltham, MA 02254-9149

Dear Mr. Ignazio,

Thank you for the opportunity to comment on the Draft Massachusetts Water Resources Authority, Connecticut River Flow Augmentation Study, June 1992. The information generated and research compiled was very interesting and useful. The conclusion to abandon future efforts in light of the environmental and economic costs projected by the study seems well advised. We look forward to future efforts to enhance the Connecticut River and Quabbin basins, and appreciate the sensitivity on environmental issues evinced by this report.

Sincerely,

Lynn Rubinstein
Resource Planner

JOINT RIVER COMMISSIONS

Vermont
Connecticut River
Watershed
Advisory Commission

New Hampshire
Connecticut River
Valley
Resource Commission

June 16, 1992

Department of the Army
New England Division, Corps of Engineers
424 Trapelo Road
Waltham, MA 02254

Attn: Joseph L. Ignazio
Director of Planning

Dear Mr. Ignazio,

Thank you for the copy of the draft report regarding the Connecticut River Augmentation Study which we received on June 4, 1992. You may be interested to note that the New Hampshire General Court has, in May of this year, passed into law the protection of the Connecticut River for its entire length to the Massachusetts border.

Among the many provisions of this Rivers Management and Protection Program are three measures that will be pertinent in any future future studies regarding river flow. They are cited in section RSA 483:9-a paragraphs III, IV and V in the attached copy of the law.

We were pleased to note that significant consideration was given in your report to the potential impact on recreational facilities. The Joint Connecticut River Commissions have a mandate from their respective legislatures to encourage and promote tourism and recreation facilities in the river valley and we appreciate the Corps sensitivity to this situation.

Associated with these efforts is a concern regarding streambank erosion and we have underway a pilot program that addresses nonpoint pollution in Grafton County, New Hampshire. This study, conducted by the Soil Conservation Service in Grafton county, includes some intensive "from the river" observations of soils, slopes, vegetation and the like. In the past, the Joint Commissions have enjoyed similar presentations by Larry Gatto of CRREL. We mention this because of significant concerns by landowners regarding the loss of river banks and farmlands. We are also aware of studies done by the Corps on this subject and would appreciate any pertinent information you may have.

Sincerely,

George W. Moulton

George W. Moulton
Chairman, NH Commission

P.O. Box 1182 • Charlestown, NH 03603 • (603) 826-4800

Upper Valley Lake Sunapee Regional Planning Commission
RR #1 Box 123 Lebanon, NH 03766-9748 (603)448-1680

MEMO

To: Joseph L. Ignazio, Director of Planning, Army Corps, Waltham

From: Bruce D. Bender, AICP, Executive Director

Date: June 9, 1992

Re: Section 22, MWRA Connecticut River Flow Augmentation Study

---

Thank you for the opportunity to comment on this report. The North Hartland dam on the Ottauquechee River and the Union Village dam on the Ompompanoosuc River are both within our Region.

I am pleased that the MWRA has decided not to pursue the matter further.

For the record, I would like to make the following comments, just in case this idea should surface again at some point in the future.

1. I concur with the comments offered by the State of Vermont Agency of Natural Resources and the Connecticut River Valley Flood Control Commission found on pages G-11 through G-19 of the report. The potential impacts to the areas upstream of the tributary flood control dams are significant to the local communities.

2. Other potential impacts to local communities include significant change to the overall landscape and land use in certain areas. For example, the Ompompanoosuc valley upstream of the Union Village dam looks pretty much the same as if the dam weren't there. Occasional flooding has not changed the basic landscape, which consists of pasture surrounded by woodlands. This is in great contrast to a variable-level reservior scenario, which typically is characterized by drowned trees within the water body and a shoreline de-vegetated to the extent of the annual rise and fall of the water level.

3. The basic, overriding issue is a trans-regional one. Although I understand that MWRA needs to investigate alternatives to provide more water to their clientele, I fail completely to understand why this should be done at the expense of small rural Vermont communities.