407-'56

NEW ENGLAND RIVER BASINS COMMISSION

CONNECTICUT RIVER BASIN PROGRAM

SUPPLEMENTAL FLOOD MANAGEMENT STUDY

PHASE 1 ASSESSMENT OF THE FLOOD DAMAGE REDUCTION PERFORMANCE OF THE EXISTING FLOOD CONTROL SYSTEM IN THE CONNECTICUT RIVER BASIN

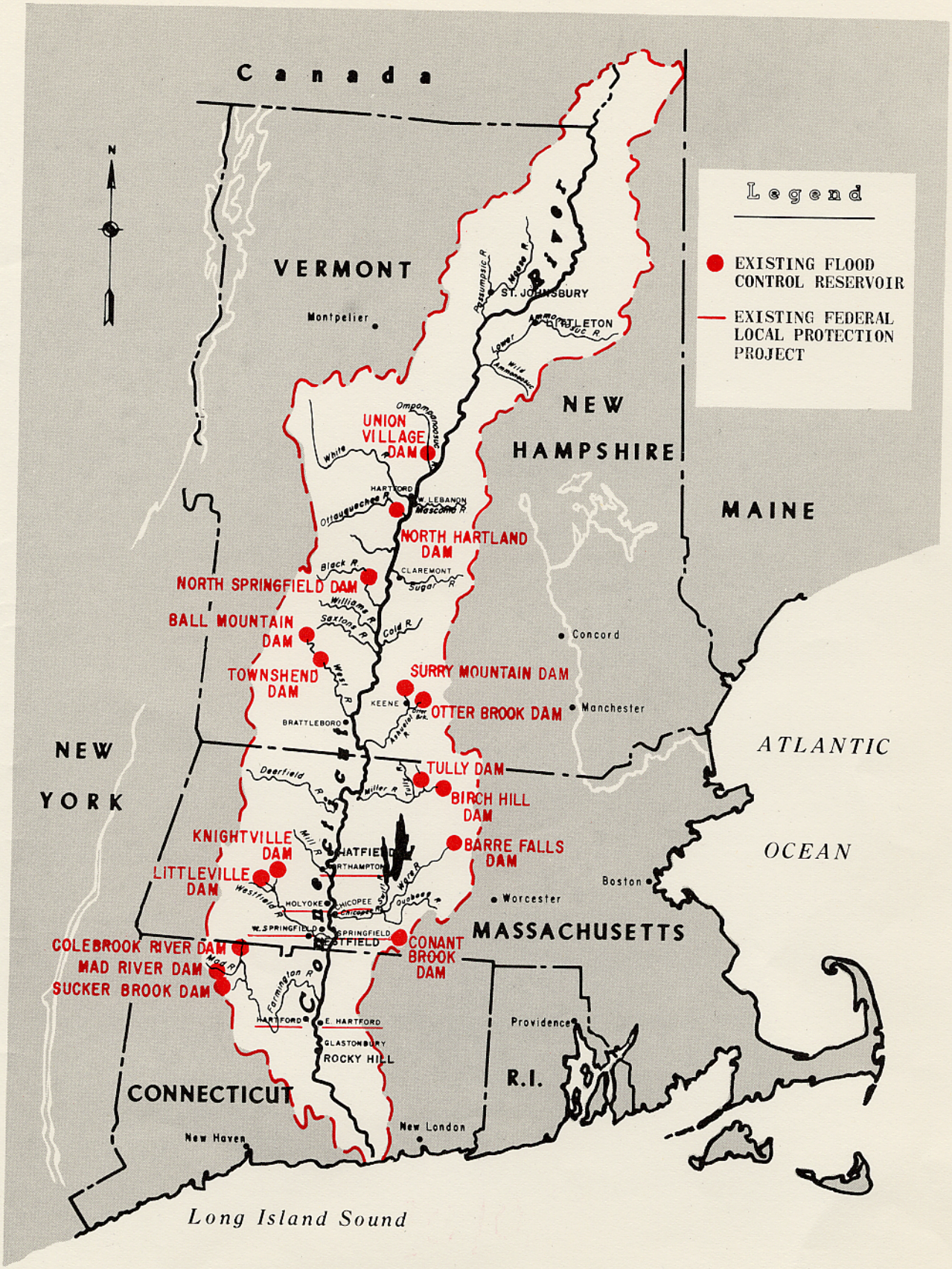
Prepared by the New England Division
U. S. Army Corps of Engineers
Supplemental Study Phase 1

1 July 1974

PREFACE

This report was prepared by the New England Division, U. S. Army Corps of Engineers, under the general supervision of the Study Management Team of the New England River Basins Commission Connecticut River Basin Program supplemental flood management study. The July 1973 Plan of Study Tasks specifically addressed by this report are COE 1.1 D, 1.2 D, 1.3 D, 1.3 E, and 1.4 D.

This report is one of a series of task group reports which deal with separate phases of the study. The main report will present a summary of the task group reports plus the findings and recommendations of the Study Management Team and CRBP Coordinating Group. Task group reports and the main report are subject to review by the Governors of the affected States, by the interested federal agencies at the departmental level and by the Water Resources Council prior to transmittal to the President for his review and ultimate transmittal to the Congress.



Connecticut River Supplemental Study

CONNECTICUT RIVER SUPPLEMENTAL STUDY

PHASE 1 REPORT

CORPS OF ENGINEERS

1. PURPOSE

This report has been prepared as the Corps of Engineers input to Phase 1 of the Connecticut River Supplemental Study. As described in the NERBC Plan of Study, 1 July 1973, Phase 1 is to consist of "Problem Definition -- assess flood-damage reduction performance of existing flood-management system. Select structural and non-structural flood management alternatives, criteria for evaluation, methods of evaluation, and alternatives to be evaluated." Specific tasks assigned to the Corps of Engineers for inclusion in the Phase 1 portion of the study include a description of the full range of floods that could affect the basin, an assessment of the impact of structural and non-structural flood damage reduction measures presently being implemented, and identification of the major flood damage centers in the Connecticut River Basin.

2. GENERAL

The record of flooding in the Connecticut River Basin is very similar to that of other major basins in the Northeastern United States. Great floods in the past have resulted from excessive rainfall, run-off from snowmelt, or from a combination of both. Although more common during the Spring snowmelt season, large floods can occur in any month.

As with other basins of a similar size, there have been historically significant floods of both a general, basin-wide nature, and also very localized floods. An example of the latter case would be the November 1927 flood, which approached Standard Project Flood levels on some streams and devastated large portions of the State of Vermont, but did little damage in the lower Connecticut River Basin. In like manner, the storm of August 1955 was centered over the States of Massachusetts and Connecticut and caused severe damages in these areas, but had little affect on the upper basin.

The floods of March 1936 and September 1938 were caused by intense storms which were relatively uniform across the entire basin. The 1936 event was the basin flood of record, with record high river stages throughout most of the watershed. This flood resulted from a combination of exceptionally heavy snow cover, warm weather, and heavy rainfall. As the basin flood of record, the 1936 flood provides one standard by which to assess the effectiveness of the structural and non-structural flood damage reduction measures that have been implemented in the Connecticut River Basin.

3. FLOOD LOSSES

Table 1 presents the losses, in millions of dollars, that could be expected to occur along the mainstem of the Connecticut River with a recurrence of the 1936 flood under natural conditions, without any of the structural flood control measures that have since been constructed. These losses are based upon present day development and 1974 price levels. The principal towns that would sustain flood losses in each of the mainstem damage zones are listed in Table 3.

Table 2 presents the losses that would occur today from an identical flood, but takes into account the protection provided by the system of structural flood control measures constructed by the Corps of Engineers since the 1936 flood. These include 16 upstream reservoirs and 7 Connecticut River mainstem local protection projects. As can be seen by comparing these two tables, the existing system of flood control measures would bring about a reduction in losses of over 90 percent for a recurrence of the 1936 flood.

While this loss reduction is quite substantial, it must be noted that it does not apply for all floods, but only those of the magnitude of the 1936 flood. Since much of the protection is provided by dikes, flood stages substantially higher than those of 1936, but still below the Standard Project Flood, could overtop many of the dikes and cause a huge incremental increase in flood damages. The Standard Project Flood would overtop six of the seven Federally-constructed local protection works along the mainstem of the Connecticut River and cause catastrophic damages much in excess of those of the 1936 flood of record.

TABLE 1

CONNECTICUT RIVER (MAINSTEM)

RECURRING 1936 FLOOD LOSS (IN $ MILLIONS)

NATURAL*

1974 PRICE LEVEL

Damage Zone**	Urban	Rural	Highway	Railroad	Industrial	Utilities	Total
C-1					.5		.5
C-2					.1		.1
C-3	.1			.1	.1		.3
C-4		.1			1.0		1.1
C-5				.2	.3		.5
C-6	.3	.5	1.2	.8		.1	2.9
C-7	1.0			.6	.2	.1	1.9
C-8	.4	.1	.1	.1	3.2		3.9
C-9	.1	.2	.4	.3		.5	1.5
C-10	.1	.7	1.1	2.8	3.0	.1	7.8
C-11		.8	1.2	1.2			3.2
C-12	.5	.4	.3		1.2	.1	2.5
C-13	4.4	1.4	1.7	.3	2.7		10.5
C-14	51.6	.4	2.4	1.2	76.3		131.9
C-15	1.9	.8	.2	.1	5.9	1.0	9.9
C-16	53.0	.1	2.9	1.0	70.5		127.5
C-17	4.5	.8	.5	.2	7.2	.1	13.3
Totals	117.9	6.3	12.0	8.9	172.2	2.0	319.3

* Without the existing system of structural flood control measures in operation.

** See Table 3 for description of damage zones.

TABLE 2

CONNECTICUT RIVER (MAINSTEM)

RECURRING 1936 FLOOD LOSS (IN $ MILLIONS)

MODIFIED*

1974 PRICE LEVEL

Damage Zone	Total Losses	Damage Zone	Total Losses
C-1	.5	C-10	1.5
C-2	.2	C-11	.5
C-3	.5	C-12	.6
C-4	1.2	C-13	2.6
C-5	.5	C-14	2.6
C-6	2.9	C-15	6.9
C-7	1.8	C-16	.9
C-8	2.1	C-17	5.1
C-9	.3		
		TOTAL	30.7

* Recurring Losses reflect the flood stage reduction of the system of 16 existing reservoirs and 7 mainstem Connecticut River local protection projects.

** See Table 3 for description of damage zones.

TABLE 3

CONNECTICUT RIVER BASIN

MAINSTEM DAMAGE ZONES AND AFFECTED COMMUNITIES

C-1	Pittsburg, Stewartstown, Colebrook, Columbia, NH
C-2	North Stratford, NH; Brunswick Springs, Bloomfield, VT
C-3	Stratford, Groveton, Northumberland, NH; Maidstone, VT
C-4	Lancaster, Dalton, NH; Guildhall, Lunenburg, VT
C-5	East Barnet, Barnet, McIndoe Falls, East Ryegate, VT; Monroe, NH
C-6	Newbury, Wells River, Bradford, Thetford, Ely, Pompanoosuc, Lewiston, VT; Woodsville, North Haverhill, Hanover, NH
C-7	West Lebanon, NH; Wilder, White River Junction, VT
C-8	North Hartland, Hartland, Windsor, Ascutney, VT
C-9	Weathersfield, Bow, Goulds Mill, Bellows Falls, VT; Charlestown, NH
C-10	Walpole, Westmoreland, NH; Westminster, Brattleboro, Vernon, VT
C-11	South Vernon, VT; Northfield, Gill, Turners Falls, MA
C-12	Greenfield, Deerfield, Montague, Sunderland, Whately, MA
C-13	North Hadley, Hatfield, Northampton, Hockanum, South Hadley, Hadley, MA
C-14	Holyoke, West Springfield, Chicopee, Springfield, Agawam, Longmeadow, MA
C-15	Enfield, Windsor Locks, Windsor, CT
C-16	Hartford, East Hartford, Wethersfield, CT
C-17	Glastonbury, Rocky Hill, Middletown, Portland, Essex, Lyme, Saybrook, Chester, East Haddam, Haddam, East Hampton, CT

4. STAGE REDUCTIONS

The reduction in stage brought about by the existing system of 16 upstream flood control reservoirs is shown in Table 4. These stage reductions are shown for the 18 damage centers selected for study, and apply directly only to the flood of record at the particular community. Floods of a different magnitude than the flood of record may have slightly different stage reductions. Those damage center communities located on tributaries with no upstream flood control reservoirs would, of course, experience no change in flood stages.

5. FLOOD DAMAGE CENTER REPORTS

The reports contained in Appendix I deal with the present status of flood damage reduction efforts in 18 different damage centers in the Connecticut River Basin. The information contained in these reports consists of a compilation and review of existing information from federal, state and local agencies describing the existing flood damage potentials, and the measures, both structural and non-structural, which have been undertaken to reduce flood losses.

The 18 flood damage centers selected for this analysis are:

Connecticut	Massachusetts	Vermont	New Hampshire
Glastonbury	Hatfield	Brattleboro	Littleton
Hartford	Northampton	St. Johnsbury	Lebanon
East Hartford	Springfield	Hartford	Claremont
Rocky Hill	Chicopee		Keene
	Holyoke		
	West Springfield		
	Westfield		

These 18 communities were selected for three basic reasons:

1. They provide a wide spectrum of community types, community size, and flood loss potential.

2. They are geographically diverse.

3. They would be affected by implementation of the Coordinating Committee's 1980 Flood Control Plan.

TABLE 4

STAGE REDUCTION

By Corps of Engineers System of Reservoirs
for the Flood of Record

Damage Center Community	Damage Zone	Number of Upstream Reservoirs	Flood of Record	Stage Reduction (feet)
St. Johnsbury, VT	Passumpsic R.	--	1927	--
Brattleboro, VT	C-10	5	1936	4.5*
Hartford, VT	C-7	1	1927	0.8**
Keene, NH	Ashuelot R.	2	1936	--
Claremont, NH	Sugar R.	--	1936	--
Littleton, NH	Ammonoosuc R.	--	1927	--
Lebanon, NH	C-7	1	1927	0.8**
Springfield, MA	C-14	13	1936	3.5
W. Springfield, MA	C-14	13	1936	3.5
Holyoke, MA	C-14	9	1936	3.6*
Chicopee, MA	C-14	11	1936	3.6*
Northampton, MA	C-13	9	1936	3.7
Westfield, MA	Westfield R.	2	1955	--
Hatfield, MA	C-13	9	1936	4.3*
E. Hartford, CT	C-16	16	1936	3.9*
Hartford, CT	C-16	16	1936	3.9*
Rocky Hill, CT	C-17	16	1936	4.1*
Glastonbury, CT	C-17	16	1936	4.1*

* Stage reductions interpolated from computed reductions at index stations.

** Stage reduction shown is for the 1936 flood, not the 1927 flood of record.

6. HYDROLOGY REPORT

The report contained in Appendix II presents the hydrologic data needed to define the range of floods which will affect flood damage reduction measures in the Connecticut River Basin. Included in this report are:

a. Discharge frequency curves and stage-discharge rating curves. These curves show discharge, frequency, and stage relationships under natural conditions unmodified by the existing flood control reservoirs. These relationships are given for index stations 7 through 17 along the mainstem of the Connecticut River.

b. Test Floods. For the purposes of determining the basin's flood producing characteristics, both historic and synthetic floods were examined. For all tributary areas, the relative timing and contributions to peak flows on the Connecticut River are presented for four major historic floods. A hypothetical flood, the Typical Tributary Contribution Flood (TTCF), was also developed in order to provide an average hydrologic basis for economic analyses of alternative flood control measures.

c. Flood reductions by the existing reservoir system. This section includes stage-frequency curves under natural conditions and as modified by the 16 existing upstream flood control reservoirs, all based upon the TTCF. Stage and discharge reductions for a recurrence of the 1936 and 1938 floods are also listed.

d. An assessment of the effects of non-flood control reservoirs and natural valley storage. It was determined that neither the main stem dams nor the many small headwaters reservoirs have a significant effect upon Connecticut River flood stages, although the small headwater storages can be locally effective. Natural valley storage areas in the Connecticut River Basin were found to be quite limited. Notable areas were identified and their effects analyzed.

7. SUMMARY

This section presents a summary of the present flood damage potential in the 18 communities analyzed in the Flood Damage Center Reports of Appendix I. It was expected that these communities would provide a wide spectrum of flood loss potential, and the detailed reports bear this out. These damage centers can be divided into two major categories: Those with existing main stem Connecticut River local protection projects, and those without.

There are seven communities in the former group, all of them in the more highly developed lower portion of the Connecticut River Basin. These communities are: Hartford and East Hartford, Connecticut; and Springfield, West Springfield, Holyoke, Chicopee, and Northampton, Massachusetts. A very substantial amount of development has taken place behind these local protection works in all of these communities. However, because the complete Connecticut River Basin flood control system, as initially designed, was not completed, all of these local protection works, with the exception of those at Hartford, would be overtopped by a flood approaching the magnitude of the Standard Project Flood. Thus, while all of these communities are safe from moderately large floods, an extreme event like the SPF would cause catastrophic damage to six of the communities. Only Hartford, Connecticut, of all the damage centers examined, appears safe from floods as large as the SPF.

The eleven communities studied which do not have Federal local protection projects cover a broad range of flood damage potentials. At one end of the scale, Westfield, Massachusetts would suffer considerable damage from even a 100-year flood, and very severe losses from an SPF. On the other hand, there is very little development in the flood plain in Rocky Hill, Connecticut, and damages would not be great even in a SPF. For the remaining communities, damages would vary depending upon the severity of the flood and the intensity of development in the flood plain. Because of the great differences in the scale of development in the communities surveyed, catastrophic damages to the smaller, upper-basin communities would, on an absolute economic scale, be relatively minor compared to the high flood damage potentials in the more developed lower basin.

NEW ENGLAND RIVER BASINS COMMISSION

CONNECTICUT RIVER BASIN PROGRAM

SUPPLEMENTAL FLOOD MANAGEMENT STUDY

APPENDIX I

FLOOD DAMAGE CENTER REPORTS

Department of the Army
New England Division
Corps of Engineers

17 May 1974

APPENDIX I

FLOOD DAMAGE CENTER REPORTS

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ACKNOWLEDGEMENTS

The Corps of Engineers hereby acknowledges the assistance of the contractors listed below who have prepared the following damage center reports:

Keene, Claremont, Lebanon, New Hampshire:

Anderson-Nichols Corporation
150 Causeway Street
Boston, Massachusetts 02114

Rocky Hill, Hartford, East Hartford, Connecticut, West Springfield, Westfield, Holyoke, Massachusetts:

The Center for the Environment & Man, Inc.
275 Windsor Street
Hartford, Connecticut 06120
Mr. Lynn E. Johnson

The writer gratefully acknowledges the assistance of officials of the city governments in Holyoke, West Springfield and Westfield, Massachusetts. Particular mention is due the following individuals;

Mr. James Wininger - Holyoke Planning Board
Mr. William Dempsey - West Springfield Planning Board
Mr. Donald Weinle - Westfield City Engineer

Springfield, Chicopee, Northampton, Massachusetts

Curran Associates, Inc.
182 Main Street
Northampton, Massachusetts 01060

The writer gratefully acknowledges the assistance of officials of the city governments in Northampton, Springfield and Chicopee, Massachusetts. Particular mention is due members of each city's engineering, building and planning departments, and also to those representatives of private industry who supplied information regarding individual flood proofing efforts.

Littleton, New Hampshire, Hartford, St. Johnsbury, Vermont:

Dufresne-Henry Engineering Corporation
Precision Park
North Springfield, Vermont 05150

Damage center reports for Glastonbury, Connecticut, Hatfield, Massachusetts, and Brattleboro, Vermont were prepared by the New England Division, U. S. Army Corps of Engineers.

PRESENT STATUS OF ELEMENTS FOR FLOOD DAMAGE REDUCTION

ROCKY HILL, CONNECTICUT

ROCKY HILL, CONNECTICUT

1.0 GENERAL

Rocky Hill, Connecticut, is located in Hartford County, on the Connecticut River about 40 miles above the mouth and south of the City of Hartford. (See map, Figure 1.) It is bordered on the east by the Connecticut River and the across-river town of Glastonbury, on the south by Cromwell, on the west by Newington and Berlin, on the north by Wethersfield.

The town's total area of 13.9 square miles is located in the Central Lowland of Connecticut. About 1.7 square miles is Connecticut River flood plain, while the remaining land area presents a rolling topography at elevations of 100 to 250 feet. The Connecticut River, which forms the town's eastern border, together with its minor tributaries, Goff and Dividend Brooks, provides the principal surface drainage system.

The area now occupied by the Town of Rocky Hill was originally settled in 1650 as part of Wethersfield, one of the oldest towns in the state. In 1722 it was called Stepney Parish but Wethersfield people usually referred to it as "going down by the rocky hill." Hence, when the town was incorporated on June 10, 1843, the more descriptive name Rocky Hill was chosen. (1)

Rocky Hill was the head of navigation on the Connecticut River until about 1825. Cargoes of onion, cattle, swine, bricks, shingles, grain, pipe staves and manufactured articles were shipped out of Rocky Hill. The first ferry started running between Rocky Hill and South Glastonbury in 1700. and is presently the oldest active ferry in the United States.

Specialization in agriculture gradually evolved, with dairy farming predominating. With the increase of population, former agricultural land is being utilized more intensively for residential and commercial purposes. Industrial activity has also accelerated so that Rocky Hill presently produces such vital goods as metal laundry products, steel, glass and plastic balls, chemical coatings, machine shop equipment, electronic components and small tools.

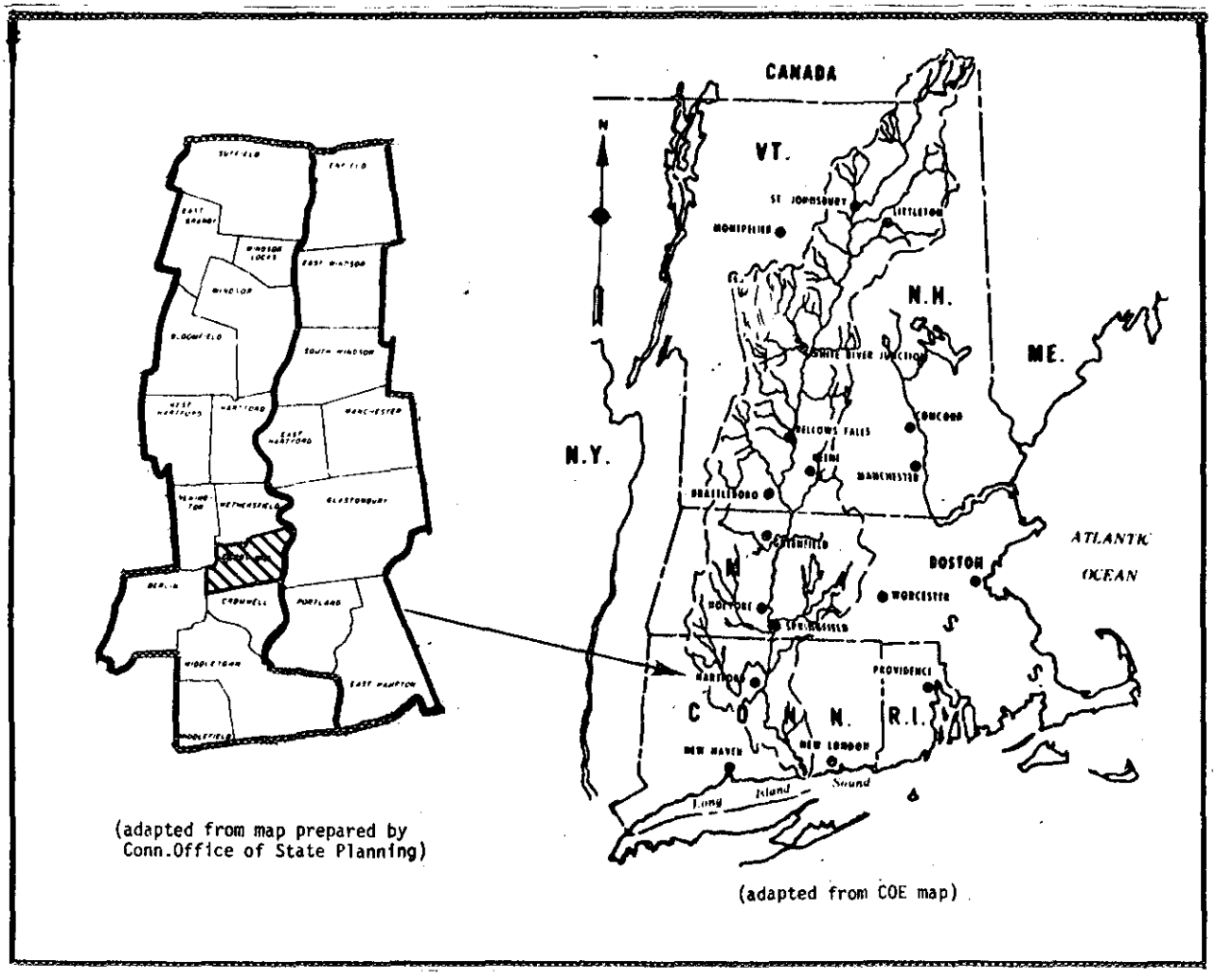

Figure 1. Location map, Rocky Hill, Connecticut.

The population of Rocky Hill has increased to a 1970 level of 11,102 as compared to 7,404 in 1970. (2) In the past, development centered along Silas Deane Highway and Main Street. Completion of Interstate Highway 91 to the west of the town center has provided the impetus for residential and commercial development in the western portion of the town.

2.0 FLOOD HISTORY

The Town of Rocky Hill has an area of 13.9 square miles of which approximately 12 percent, or 1.7 square miles, is low land forming the Connecticut River flood plain. The western portion of town is located on higher ground at elevations above 50 feet. (See map, Figure 2.) Almost all of the development in the town has taken place on the higher ground. The 1936 flood, which reached a maximum stage of approximately 34.5 feet at Rocky Hill (River Mile 40) (3) and is the maximum flood of record, (3, 4), inundated all of the flood plain portion of Rocky Hill but caused little damage to the main portion of town. Average ground elevation of the flood plain is approximately 10 to 20 feet.

Flood stages during the 1938, 1927, and 1955 flood events, the other most severe events for this section of the Connecticut River mainstem, also resulted in inundation of the flood plain but caused little damage to the developed sections of town. (5) Extensive portions of the flood plain were inundated in the recent flooding of July 1973, resulting in damage to crops but no structural damage. (6)

The flooding problems presently experienced in the developed portions of town are minor and are due primarily to storm water runoff and the inability of storm sewers to carry excess runoff away. The experience in other urbanizing areas across the country indicates that this type of problem increases as larger portions of the drainage area are paved and sewered.

3.0 THE FLOOD PLAIN

The Connecticut River flood plain in Rocky Hill has been legally defined by the establishment of flood plain encroachment lines, based on 1936 flood levels, by the Connecticut Water Resources Commission. The encroachment line elevation has been set at approximately the 32-foot elevation (M.S.L.). (7) The central, developed portion of the

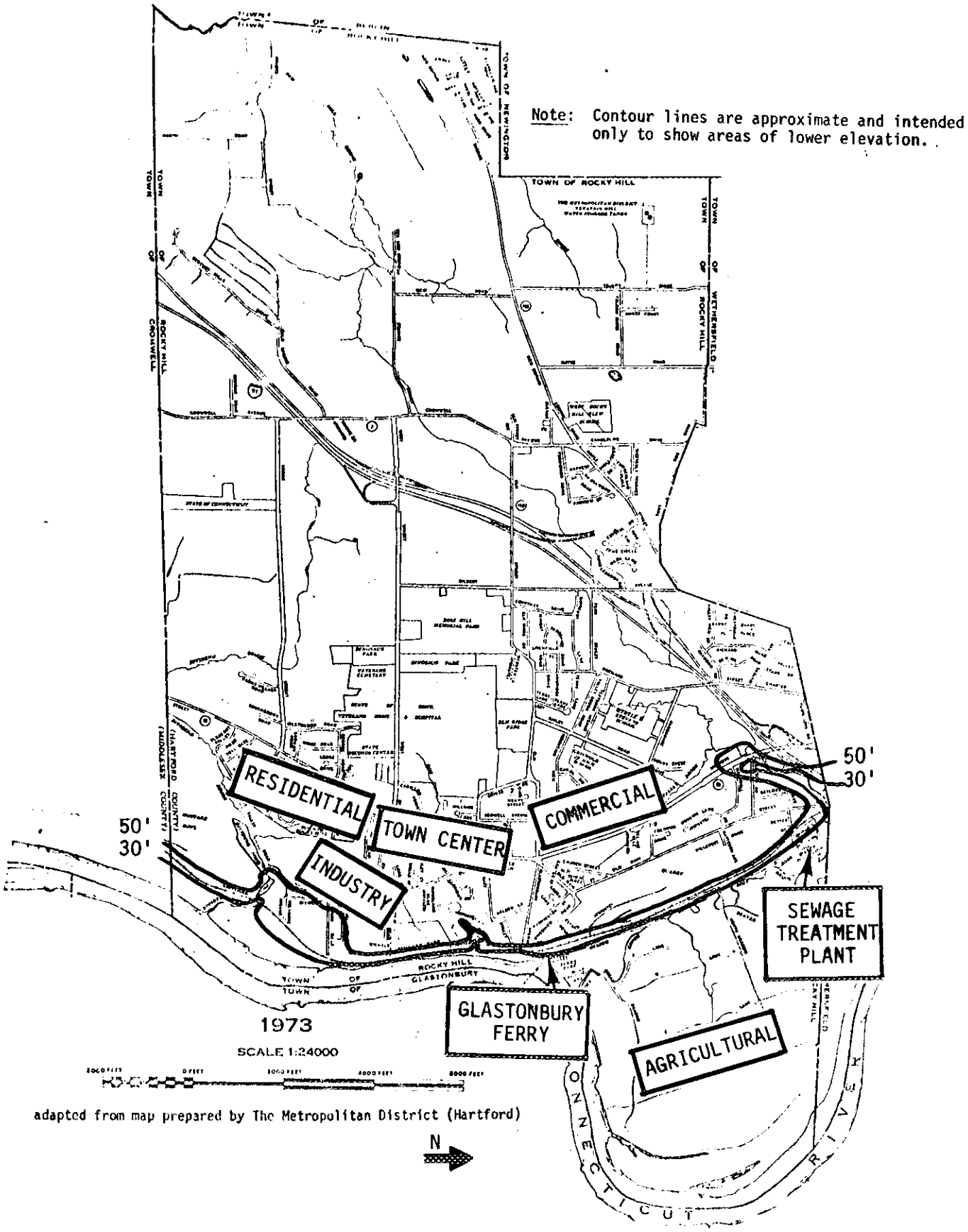

Fig. 2. Rocky Hill flood plain development.

town is located above and away from the flood plain. Approximate areas of low elevation are indicated on the map, shown in Figure 2, along with a general description of land use. Figure 3, a more detailed map of Rocky Hill, is presented to allow for more precise location of facilities relative to streets, etc.

The major area in the flood plain is composed of approximately 1,000 acres of predominantly agricultural land, referred to as the "Meadows," bounded by the Connecticut River on the east and south, Meadow Road on the west, and the Rocky Hill/Wethersfield town line on the north. There are no major structures in this area. The Meadow Street Ferry Park and boat launching ramp, located in the southwestern corner of the "Meadows" is periodically closed due to flooding but sustains little or no structural damage. The Rocky Hill sewage treatment plant, currently under construction, is located in the northwestern corner of the "Meadows" and is being diked to an elevation of 32 feet to avoid frequent flooding.

South of the "Meadows" the river banks rise relatively steeply from the river. Some older industrial development at the end of Pratt Street is located partially within the encroachment line and may be subject to inundation during extreme flood events. Other structures located within the flood encroachment lines consist of two older houses on the river bank near Buckley Park. A corner of a warehouse of the Pratt and Whitney industrial complex in the southeast portion of town near Dividend Brook is located within the channel encroachment line. Damages sustained by these structures in the past have not been frequent or severe enough to warrant protective action or the purchase of flood insurance. Determining the extent of potential damage to these buildings would require running survey levels along the river course.

4.0 CLEARANCE

Historically, there has been little or no development in the flood-plain areas of Rocky Hill. This obviates the necessity for clearance of structures to reduce flood damages. (5)

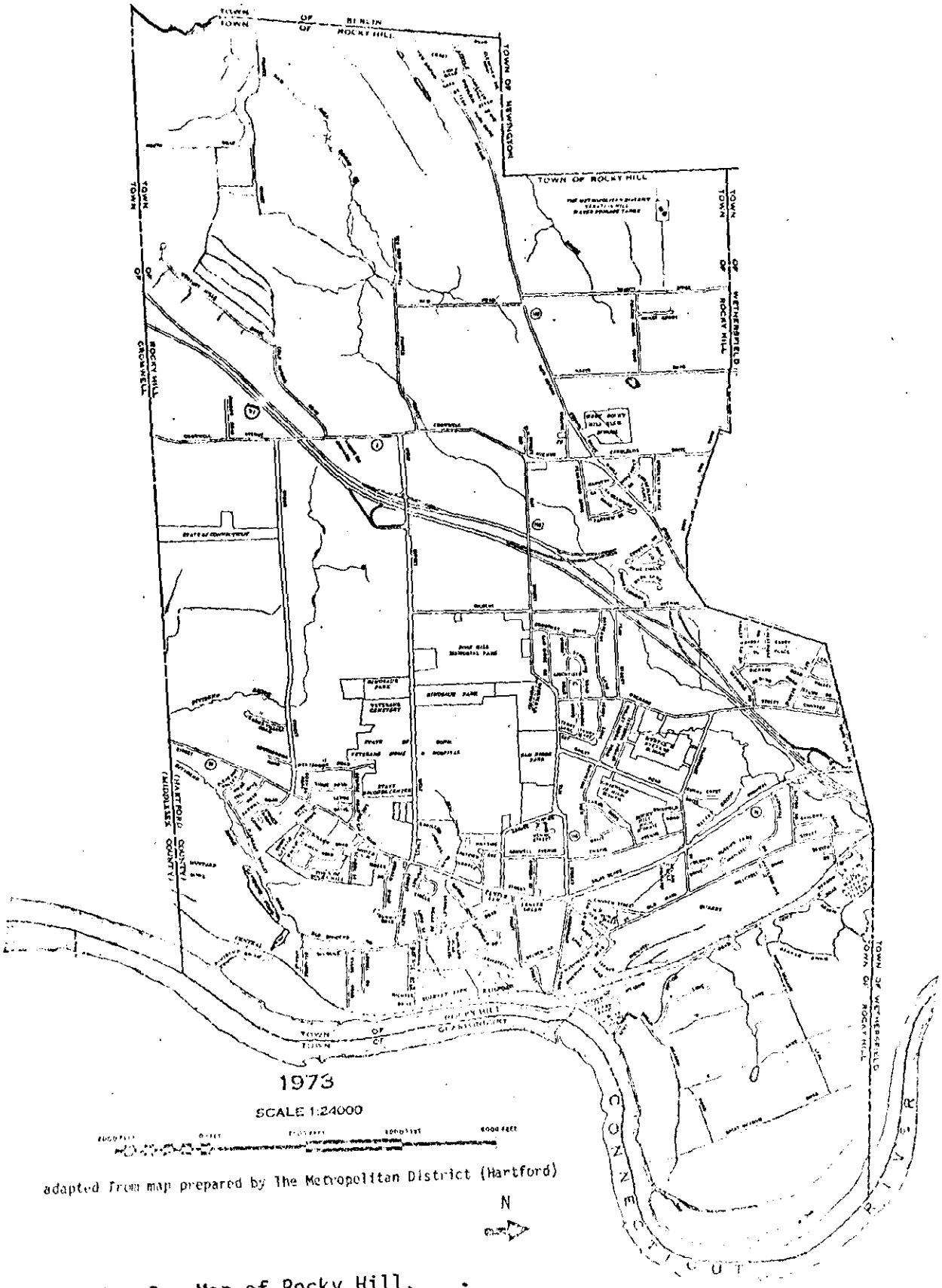

Fig. 3. Map of Rocky Hill.

5.0 FLOOD PROOFING

Rocky Hill's flood plain zoning ordinance allows only agricultural use of the flood plain. (5) The Rocky Hill sewage treatment plant, currently under construction, will be protected by dikes and piping will be provided with check valves to prevent backup into the structure area. Top elevation of the dike is 32 feet M.S.L. (7)

6.0 URBAN DRAINAGE

As the Town of Rocky Hill develops, the urban drainage network is being extended to prevent storm water runoff problems. The small drainage systems of Goff Brook, Dividend Brook, Bog Brook, and Saw Mill Brook (which drains to the Mattabesset River to the west) are the major avenues for drainage of storm water. Current town development plans call for preservation of these drainage ways in their natural state as corridors of open space, (5) and town administrators are planning to retain a consultant to set encroachment lines on these areas. (5) The recently enacted Inland Wetland Act (Conn. Stat. 155) which restricts development on land classified as wetland will also serve to restrict development in local flood-prone areas.

7.0 FLOOD PLAIN INFORMATION REPORTS

There is no flood plain information report for the Town of Rocky Hill.

8.0 PUBLIC INFORMATION

The programs of assistance to delineate flood hazard areas in the Town of Rocky Hill have been discussed above. These have resulted in the establishment of flood encroachment lines along the Connecticut River flood plain which provides the basis for delineation of the town's flood plain zone. Restrictions on development in this zone have been enforced and there are currently few, if any, structures which would sustain damage if a recurrence of the 1936 flood were to take place.

Similarly, the prospect of damage due to flooding has not been considered significant enough to warrant the purchase of flood insurance by any property owner in Rocky Hill. Of the four or five properties identified above, none has purchased flood insurance.

The National Weather Service, River Forecast Center, Hartford, issues flood warnings for the Connecticut River. These warnings are received by the Town of Rocky Hill. The Civil Defense unit, police and fire departments are notified, in turn. In addition, the town retains an independent meteorological forecasting service in order to provide more detailed information on anticipated weather conditions in the Rocky Hill area. (5)

The Town of Rocky Hill maintains an Emergency Operation Center (EOC) facility, including emergency communication equipment, in a central location in the Town Hall. There is, however, no clearly defined special organizational plan for natural disaster situations which would allow for centralized decision-making by town officials. Although the possibility of massive flood damage to developed portions of the Town of Rocky Hill is remote (given the location of the town center relative to the flood plain) it is prudent to have such emergency plans prepared and periodically tested.

9.0 FLOOD CONTROL IMPOUNDMENTS

There are presently 16 major flood control reservoirs in the Connecticut River above Rocky Hill. These facilities would reduce the flood stage of a Standard Project Flood by approximately 4 feet from approximately 39 feet M. S. L. to 35 feet M. S. L. Damages at these stages, as discussed above, would be limited to only a few buildings located directly adjacent to the river channel.

10.0 LOCAL PROTECTION PROJECTS

The only local protection project in Rocky Hill is the dike being constructed around the sewage treatment plant located on the western edge of the flood plain. This dike, with a top elevation of 32 feet M. S. L. is intended to prevent frequent flooding of the treatment facilities.

11.0 CONCLUSIONS

Rocky Hill does not have a flooding problem in terms of the damage potential of properties located in the flood plain. Development in the Connecticut River flood plain, the "Meadows," has been restricted in the past, and indications, in the form of state and local ordinances and policies, are that it will be in the future. Current and future development is being directed to areas away from the flood plain to higher ground near or adjacent to I-91. Agricultural usage of the flood plain will probably continue with crop damages incurred periodically. Employment in the town will not be affected by a flood except for farming.

The town would be well-advised to pursue present plans for open-space zoning of local drainage ways. Increased development and urbanization of the area will undoubtedly result in higher peak flows on the small streams which could result in downstream damages. Encroachment on and filling of these waterways would only decrease the channel capacity and accentuate the problem. Adoption of the Inland Wetland Act (Conn. Stat. 155) and the setting of encroachment lines on the small watercourses and marshes will preserve the flood water storage capacity of the drainage areas as well as preserving much of the aesthetic character of the area.

Also, it is recommended that the town rehearse its emergency plans for reaction to major disasters such as floods. Even though the major part of the town is not susceptible to flooding, it is better to be prepared for such an eventuality, however remote.

REFERENCES

(1) Connecticut Register and Manual, 1971.

(2) Source: U.S. Bureau of the Census. Census Publication PC(VI)-8.

(3) Connecticut River Basin Coordinating Committee, Connecticut River Basin Comprehensive Water and Related Land Resources Investigation, June 1970.

(4) U.S. Department of Interior, Geological Survey, Water Resources Data for Connecticut, Part 1, Surface Water Records, 1971.

(5) Personal communication, Mr. Leo La Farge, Town Planner, Town of Rocky Hill, October 25, 1973.

(6) Hartford Courant, July 3, 1973

(7) Personal communication, Mr. Manu Patel, Town Engineer, Town of Rocky Hill, October 29, 1973.

(8) Zoning Regulations, Town of Rocky Hill.

PRESENT STATUS OF ELEMENTS FOR FLOOD DAMAGE REDUCTION

GLASTONBURY, CONNECTICUT

GLASTONBURY, CONNECTICUT

GENERAL

Glastonbury is located in central Connecticut on the east bank of the Connecticut River, the center line of the river constituting the western boundary of the town. A map of the town is shown in Figure 4.

The town's 53.5 square miles consists of a rolling topography in the northwestern third of its area with numerous extensive level areas and elevations generally below 200 feet mean sea level. The southern two-thirds of the town presents a more rugged topography. Highest elevations are to be found in the eastern area. Roaring Brook, Hubbard Brook, and Salmon Brook, draining directly into the Connecticut River, are the principal surface drainage features in the town. The surface geology consists primarily of till, drift, sand, and clay of glacial origin. Flood Plain deposits of considerable thickness occur adjacent to the Connecticut River.

Glastonbury is the eleventh largest town in Connecticut, with its population centered in six major areas: Glastonbury Center, South Glastonbury, East Glastonbury (Eastbury), Addison, Hopewell, and Buckingham. Based on the April 1, 1970 census, the population was 20,651. As of June 30, 1972, the population was estimated at 22,000 with a density of 411 per square mile.

The principal areas of business and commercial development are concentrated on Main Street, which runs parallel to the Connecticut River, and on the New London Turnpike in the northwest section of town. The latter is above the flood plain of the Connecticut River. The river is bordered primarily by a residential zone except for two industrial zones, one mentioned above, at the northwest corner of the town and the other in the extreme southwest corner. There exists some agricultural activity including poultry, dairy, fruit, and tobacco farming with light manufacturing industry. A condominium complex is being constructed adjacent to the confluence of Hubbard and Holland Brooks, within 500 feet of the Connecticut River. Care should be exercised to assure that additions to this complex are not placed in the flood hazard area.

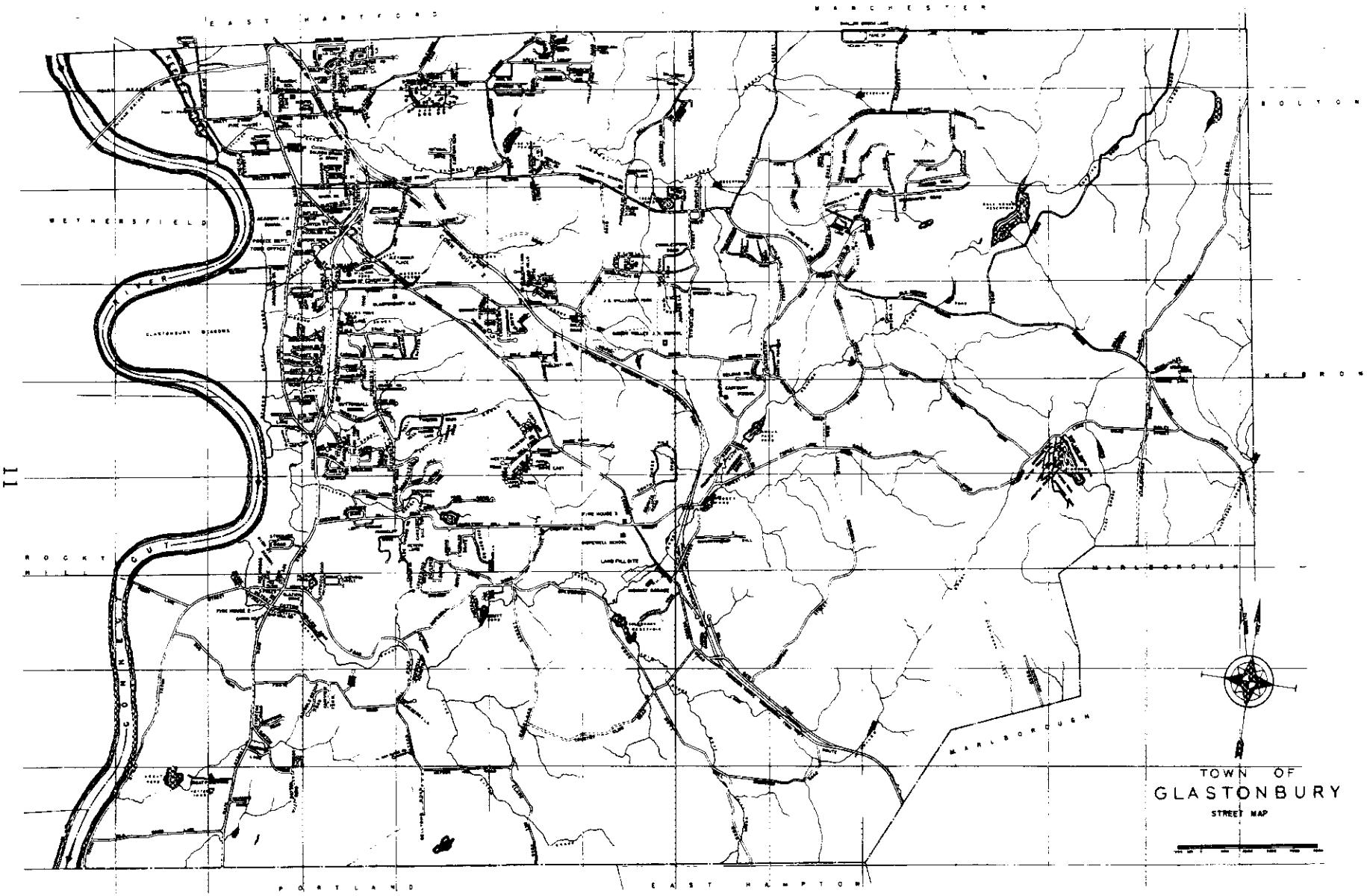
EAST HARTFORD
MANCHESTER
BOLTON
HEBRON
MARLBOROUGH
EAST HAMPTON
PORTLAND
ROCKY HILL
WETHERSFIELD
RIVER
CONNECTICUT
TOWN OF
GLASTONBURY
STREET MAP

Figure 4

FLOOD HISTORY

Glastonbury, like all other towns on the Connecticut River, was subject to the great floods of 1927, 1936, 1938, and 1955. The 1936 flood, the flood of record, reached a crest of approximately elevation 35 feet mean sea level. Since the construction of the 16 Corps of Engineers flood control reservoirs upstream in the Connecticut River watershed, there has been only minor spring flooding in the lowlands, including Hubbard, Smith, Salmon and Wickham Brooks; except in 1955, when Salmon Brook overflowed, inundating the Main Street area to elevation 31.

Point Road, an access to Point Meadows across Keeney Cove, is covered every spring with approximately five feet of water. During flooding, the Department of Public Works barricades this road.

Since 1961, the flood stage has not exceeded the 16 foot elevation. There are no flood control structures within the town limits and none anticipated by the town.

THE FLOOD PLAIN

Three low lying areas separate the developed portions of the town from the Connecticut River. The northernmost of these areas is known as the Keeney Cove Meadows area. It extends from the Glastonbury - East Hartford town line south to a point west of the center of town. The second area, Glastonbury Meadows, extends from this point, west of the center of town, in a southerly direction. This second area is bordered on the east and south by Hubbard Brook. The third low-lying area extends from Roaring Brook south almost to the Glastonbury-Portland town line.

These three low-lying areas, which have a total area of about 1,600 acres, are very similar. They are, for the most part, situated between elevation 10 and elevation 20 mean sea level. This land is intensely farmed, corn being the predominant crop. Very few structures are to be found in these areas, except for some tobacco drying sheds. All this land is now zoned as Rural and Country Residence (1 to 2 acres). However, the Glastonbury Plan of Development, January 1, 1970, lists these areas as Natural Preserve. A Marina at Keeney Cove is mentioned as a possibility for future development.

These low-lying areas along the Connecticut River are, of course, subject to frequent flooding. In fact, some of the lower areas are covered with water almost every spring. Activity in the meadows has adjusted itself to this almost annual flooding. The tobacco sheds, scattered throughout the area, can withstand some flooding, and crops are not planted until after the high stages caused by spring run-off have subsided.

Floods, such as occurred in August 1955 and early July 1973, are a different story. These floods inundated the meadow areas after planting had taken place and caused considerable crop damage. The same floods in the spring would have caused little or no damage in this area. Corps of Engineers flood control reservoir operational procedures attempt to maintain lower mainstem river levels during the agricultural season than during flooding other times of the year. The July 1973 flood peak was reduced an estimated 2 feet at Hartford, Connecticut, by the upstream flood control reservoirs. Stages at Glastonbury were reduced by about the same 2 feet.

An oil storage tank complex lies close to the river at elevation 20 $\pm$ feet mean sea level, in the Keeney Cove area. It seems quite possible that a flood of the magnitude of the Standard Project Flood, which would put almost 20 feet of water in this location, might cause some or all of the tanks to fail and spill their contents into the river. This whole meadow area falls under the provisions of the town's flood plain zoning ordinance. The ordinance places very stringent controls on all land below elevation 30 feet mean sea level. It is noted that the 100-year flood under today's conditions in the basin would cause river stages in town ranging from elevation 29 at the Glastonbury - East Hartford town line to elevation 26 at the Glastonbury - Portland town line. The zoning ordinance as written should do an excellent job of curtailing future losses from any flood of a magnitude of slightly higher than a 100-year event.

The 7.5 miles of Connecticut River bank between the Glastonbury - East Hartford town line and the Glastonbury - Portland town line is also restricted for development by the Connecticut Channel Line Encroachment Program. Development or filling within the flood plain requires a permit from the State of Connecticut.

The only major construction in the meadows area, in recent years, was the municipal wastewater treatment plant. This structure, completed in 1973, is located in the north end of the Glastonbury Meadows areas. The ground elevation here is about 10 feet mean sea level, but the whole complex is protected by a dike with a top

elevation of 28 feet mean sea level. The dike is designed so that spill-in would occur with river stages 3 feet below the top of the dike. An Intermediate Regional Flood with a stage of 29 feet mean sea level would, therefore, overtop these protective works.

A low bank, 10 to 20 feet high, separates the meadows areas from the developed portion of town. The area above the bank, but still within flood limits, is heavily developed, mostly with single-family residences. There are also several commercial developments and a few public buildings in this area. A major flood would cause very heavy damage in this area. A Standard Project Flood with stages of about elevation 39 feet mean sea level would cause some damage to an estimated 600 structures. This area is, for the most part, zoned for high density residential development (2 to 3 families per acre). Due to its suitability for construction, we will probably see many new housing starts in this area in the future.

CLEARANCE

Very little of the development which has taken place within the town is located below elevation 20 feet mean sea level. About 100 residences are located between elevation 20 and elevation 30. Another 500 structures, mostly homes, are located between elevation 30 and the calculated Standard Project Flood flow line at elevation 39. Residential flooding in Glastonbury is infrequent. The last flood which reached elevation 16 was in 1961. However, the 1955 flood reached elevation 31, the 1936 flood reached elevation 35, and the 1938 flood reached elevation 33.

Clearing structures from the flood plain is not a reasonable solution to the infrequent flooding which the community can expect. Cost of moving these structures, together with the associated resettlement of residents and the relocation of roads and utilities would be prohibitively expensive compared with the benefits which would be derived from preventing the rather infrequent flooding. The one possible exception to this is about half a dozen residences on Glastonbury Ferry Road, Route 160, which appear to be located below elevation 20. The economics of moving these structures to higher ground should be investigated.

FLOOD PROOFING

As mentioned before, the town's municipal sewage treatment plant is flood proofed to elevation 25 feet mean sea level. The oil storage tanks in Keeney Cove area are diked to contain oil spills; these dikes might prevent lesser floods from reaching the tanks. No other structures in the flood plain are flood proofed.

Glastonbury's zoning regulations do not specifically mention flood proofing. Building below elevation 30 is restricted by the ordinance; however, it might be reasonable to expect a variance would be granted for a structure that was flood proofed to elevation 30.

URBAN DRAINAGE

Most of the drainage within the town passes under Main Street. From north to south, Salmon, Hubbard, Smith, Holland, and Roaring Brooks carry their run-off under Main Street through culverts which appear to be adequate. Under extreme high water conditions on the Connecticut River, all of these culverts will be affected by backwater from the Connecticut River. In 1955, the Salmon Brook culvert area at Main Street was flooded to elevation 31. This, however, was undoubtedly caused by Connecticut River backwater.

The town does have certain drainage problems which seem to be caused by inadequate culverts. Glastonbury has had more than its share of growth with accompanying drainage problems. Culverts which were adequate when designed have been overtaxed by increasing peak run-offs caused by new development. Situations have arisen where the State has designed new culverts under existing conditions which drain into older facilities with less capacity downstream, aggravating problems at the downstream facility. This has caused problems, but one must remember that each facility is designed using parameters which are appropriate at the time of design.

The town is presently considering a town-wide drainage study. One of the reasons for this study is that information is simply not available to assess plans for drainage facilities which accompany applications for building permits. Further, such a study would make drainage information available on a uniform basis throughout the town for anyone desiring to develop a tract of land.

FLOOD PLAIN INFORMATION REPORT

No Federal Flood Plain Information Report has been prepared for the town of Glastonbury. The town has established a Flood Plain Zoning ordinance in 1963 which restricts building below the 30 foot elevation based on mean sea level datum. Only those existing legal uses may be expanded, continued, altered or enlarged, provided that expansion of an existing residential use shall not permit accommodations of more families, or more boarders or roomers than now occupy the premises. A single-family dwelling may be erected on any lot of record on a public street existing at the time of adoption of this regulation. Any agricultural, forestry, or farming enterprise is permitted in this zone.

A proposed amendment to the above regulation has been drafted which contains more stringent measures concerning encroachment, filling, grading, and excavating of any kind. It is anticipated that this amendment will be adopted.

The town is now enrolled in the U. S. Department of Housing and Urban Development (HUD) emergency flood insurance program. Enrollment on the emergency program is temporary, pending the establishment of actuarial rates. HUD will eventually establish various premium rate zones; and in so doing, they will delineate the hazard area (below the 100-year flood line).

PUBLIC INFORMATION

As soon as HUD determines the flood hazard area, this information should be made public so that people subject to flooding will be made aware of this fact. Further, the public will be made aware of the extent of the flood threat to their property and the premiums they would have to pay to carry flood insurance.

Most of the town's problems in a major flood would come from the Connecticut River. Flood warnings are issued from the National Weather Service - River Forecast Center, Hartford. These warnings should be heeded in a major flood event to remove as much property as possible out of the way of an impending flood. River stages on the mainstem of the Connecticut River do not rise fast enough to endanger life if reasonable precautions are taken. There is no area in town where flooding is particularly hazardous in terms of human life.

FLOOD CONTROL IMPOUNDMENTS

There are no flood control reservoirs designed to protect the town of Glastonbury exclusively. The existing network of Corps of Engineers flood control reservoirs does, however, afford the town considerable flood relief. All sixteen reservoirs in the basin are located upstream of Glastonbury. The system of reservoirs would reduce a recurring 1936 flood by about 4.5 feet; a Standard Project Flood would be reduced by about 4.2 feet. Translating stage reduction to land area protected shows that the system of reservoirs would remove 215 acres of land in Glastonbury from flooding at the Standard Project Flood level. All of this land is above the bank which separates the low-lying meadows areas from the developed portions of town. All of the 215 acres is high density residentially zoned and is either developed or can expect development in the near future. None of these 215 acres are included in the area which the town has zoned as flood plain. Aside from this area removed from the flooded area in an SPF, it must be kept in mind that all the land which would still be flooded by the modified SPF would be flooded to a depth of 4.2 feet less than would have occurred under natural conditions. This stage reduction, while probably not very beneficial to a deeply flooded area such as the meadows areas, would greatly benefit the developed fringe areas of flooding.

The Soil Conservation Service has identified Roaring Brook as a possible upstream watershed project to meet 1980 needs. The three impoundments identified on Roaring Brook would be designed to reduce flood damages on that tributary. The impoundments would probably reduce damages in Glastonbury in a flash flood situation. However, in a basin-wide flood, Glastonbury can expect the Connecticut River to cause most of the town's problems.

LOCAL PROTECTION PROJECTS

The town has no local protection projects in operation with the exception of the dike around the new wastewater treatment plants. As mentioned previously, this dike would protect the plant from floods up to elevation 25 feet mean sea level.

CONCLUSIONS

Glastonbury, Connecticut, population 22,000, is located on the east bank of the Connecticut River. The town consists of two distinct areas which are subject to flooding. Immediately along the bank of the river, some 1,600 acres of low-lying meadow land are flooded almost every year to some extent, usually in the spring. The use of this land has accommodated itself to this frequent flooding. The meadowland is used almost exclusively for farming, crops being planted after the threat of snowmelt flooding has passed. This area is, however, subject to damage when summer storms cause flooding after crops are planted. This was the case during the August 1955 and the July 1973 floods.

The second area subject to flooding is the area east of the meadowlands that lies between elevation 20 and 39 feet mean sea level. This area is heavily developed above elevation 30. Only rare floods would reach the residential development which predominates this area. An Intermediate Regional Flood would cause stages of 29 feet mean sea level, a Standard Project Flood would cause stages of 39 feet mean sea level.

The 16 existing flood control reservoirs in the basin, all above Glastonbury, would reduce Standard Project Flood levels at Glastonbury by an estimated 4.2 feet. This stage reduction means that some 215 acres of developed or developable land have already been freed from the threat of flooding.

The IRF would inundate 2,540 acres of predominantly agricultural land to an elevation of about 28 feet mean sea level.

The town has taken a very progressive stance in its efforts to eliminate future increases in its flood loss potential. The enacted flood plain zoning ordinance restricts development below a flood level that can be expected once in 100 years. Further, HUD flood insurance under the emergency program has been secured.

Every effort should be made to advertise the availability of flood insurance within the flood hazard area; but beyond this, people located at an elevation between the 100-year flow line and the Standard Project Flood should be encouraged to secure flood insurance. It should be kept in mind that any property below the Standard Project Flood level is subject to flooding, although the probability of flooding in the range between the Intermediate Regional Flood and the Standard

Project Flood is low. Eventually, flood insurance premiums will be established which will reflect the probability of flooding. In other words, people in the upper limits of the flood plain will pay less for insurance than people in the lower areas.

PRESENT STATUS OF ELEMENTS FOR FLOOD DAMAGE REDUCTION

HARTFORD, CONNECTICUT

HARTFORD, CONNECTICUT

1.0 GENERAL

Hartford, the capital city of Connecticut, is located in central Connecticut midway between New York City and Boston. It is bordered on the east by the Connecticut River, about 52 miles above the mouth of the river, and the across-river town of East Hartford, on the south by Wethersfield and Newington, on the west by West Hartford, on the northwest by Bloomfield, and on the north by Windsor. (See map, Figure 5.)

Hartford, having an area of 18.4 square miles, is located entirely within the Central Lowland of Connecticut and presents a gently rolling topography with numerous extensive level areas and elevations generally below 100 feet. The Connecticut River and its tributary, the Park River (drainage area, 78.7 sq. mi.), which meanders through many sections of the city, make up the principal surface drainage system.

Although a Dutch trading post was located at the confluence of the Connecticut and Park Rivers as early as 1623, the actual settlement of Hartford was accomplished in 1635 by a company from the Massachusetts Bay Colony led by Thomas Hooker. The new colony was named after Hartford, in Hertfordshire, England.

At the time of the first U.S. Census of Population in 1774, Hartford boasted a sizable population of 5,031. The city experienced rapid growth during the 19th Century as its budding industries and commerce thrived, enhanced by a strategic location with respect to Connecticut River navigation, railroad and highways. Interstate highways I-91 and I-84 intersect in downtown Hartford.

The employment opportunities attracted workers and their families by the thousands, and by 1950, the population had increased to 177,397 (1).

Rapid expansion of the population has been checked largely by the current trend of suburbanization in outlying areas. This is indicated by the decrease of population to 155,900 in 1970 (2). The city still remains the business and cultural center of the region.

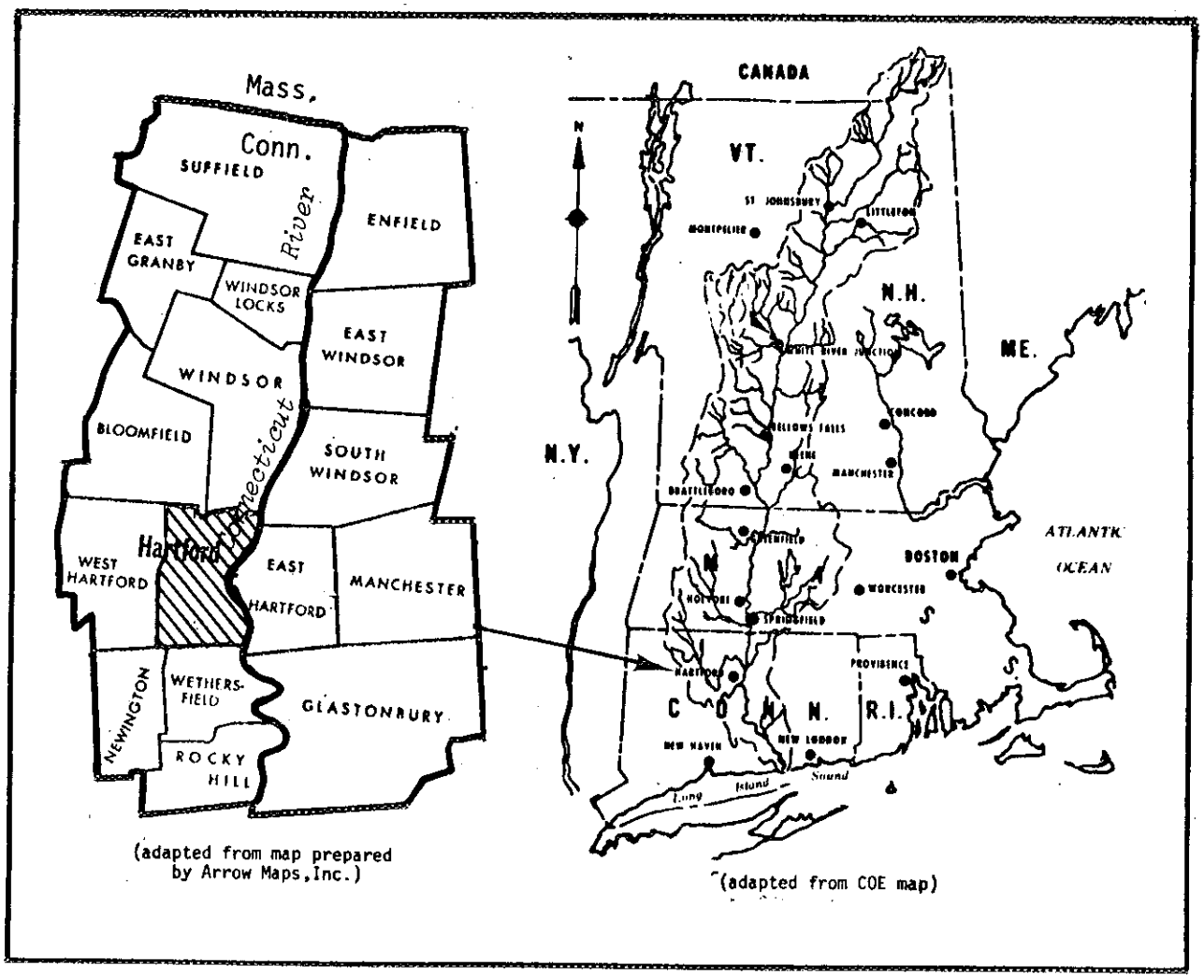

Figure 5. Location map, Hartford, Connecticut.

2.0 FLOOD HISTORY

Over the past forty years, the Greater Hartford area has experienced four major floods: March 1936, September 1938, August 1955 and October 1955 (3). The flood of record on the Connecticut River at Hartford, Connecticut, is the March 1936 event. Both the 1936 and 1938 events caused extensive damage to the east side of Hartford and resulted in a concerted effort to obtain protection along the Connecticut River.

The greatest flood of record in the Park River Basin occurred on August 19, 1955, and was followed two months later by the second greatest flood of record. Various accounts of earlier floods are sketchy and incomplete, but records available from 1911 indicate that the Park River Basin has experienced flood damage at least forty-eight times since then (4). Figure 6 indicates the areas flooded during the 1955 flood.

The first flood commission was appointed for the City of Hartford after the record-breaking flood of 1936. Prior to this date, flood protection had been undertaken on an individual and municipal committee basis. Following the floods of 1955, the Connecticut State Legislature established the Park River Flood Control Commission later renamed The Greater Hartford Flood Commission for the purpose of controlling floods in the Park River Basin (4).

If these historical floods were to recur today, stages on the Connecticut River would be considerably lower than actually experienced, due to the operation of the system of flood storage reservoirs in the Basin. The situation on the Park River, in spite of the construction of a variety of flood control projects, is not so clear. The changing land use patterns of the Basin have led to increased runoff characteristics and encroachment upon the natural channel storage, thereby resulting, in inadequate capacity of the system to control major floods. Present plans call for an extension of the Park River conduit up into the North and South Branch Park Rivers, stream channelization and an auxiliary conduit to the Connecticut River running under Park Street. Figure 6 indicates the recommended plan for the Park River and the approximate area flooded during the 1955 flood. The design of these facilities has been based upon a hydrologic study which accounts for the anticipated urbanization of upstream areas (5).

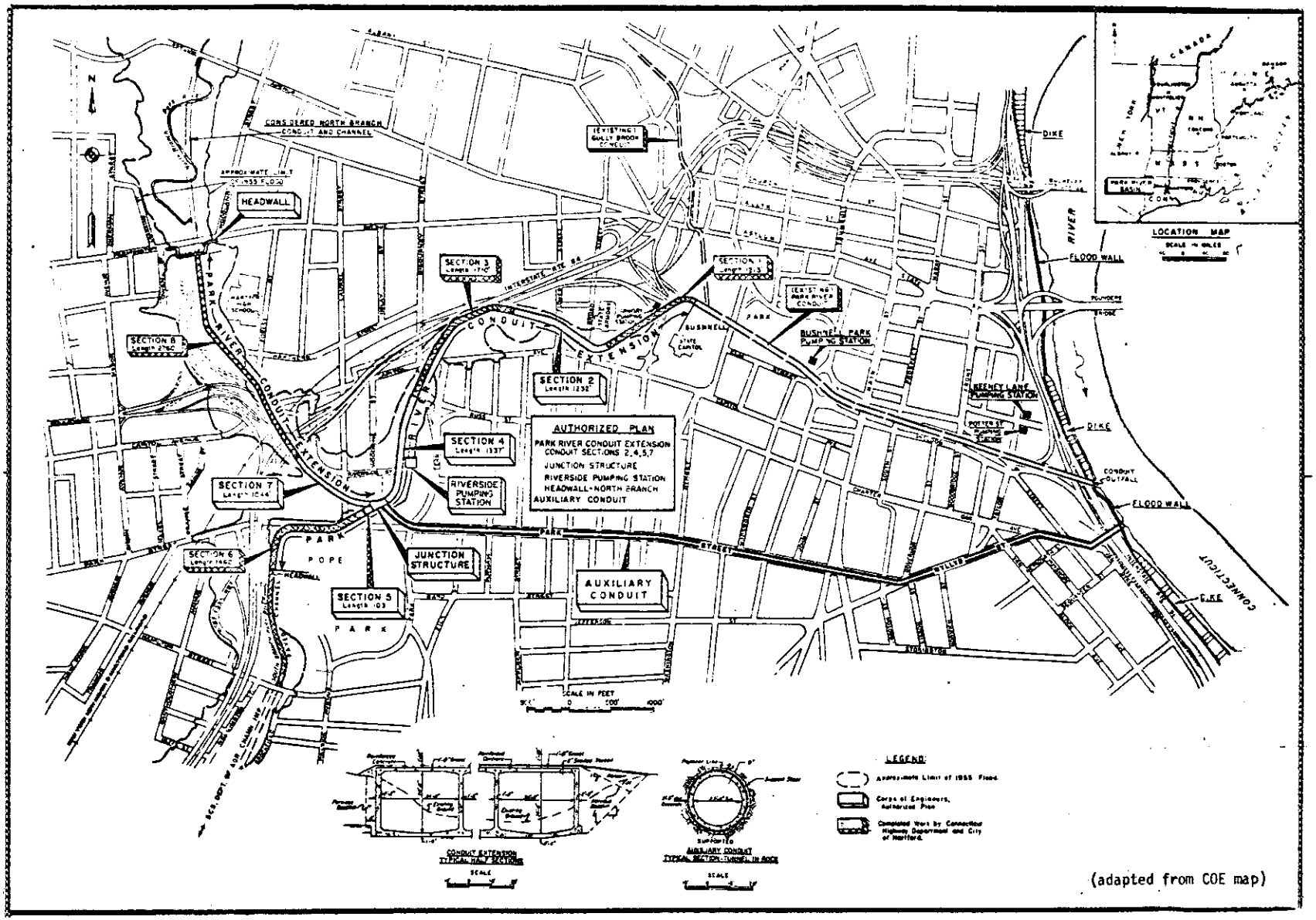

Fig. 6 General plan, local flood protection, Park River, Hartford.

3.0 THE FLOOD PLAN

CONNECTICUT RIVER - The Connecticut River flood plain in Hartford is defined as extending from the river edge to the top of approximately 35,000 feet of earth dikes and 4,400 feet of concrete floodwells. (See map, Figure 7.) These structures extend from high ground on Windsor Avenue near the Hartford-Windsor town line, south to high ground near the Hartford-Wethersfield town line. Land use outside the dike system is restricted to open space and park use. The only structures presently in existence are a bathhouse and pool at Riverside Park, which also has a boat-launching pad.

Areas of lower elevation both outside and inside the dikes are indicated on Figure 7 along with a general description of the land use. Figure 8, a more detailed map of Hartford, is presented to allow for more precise location of facilities relative to streets, etc.

The dike, with a top elevation varying between 42.5 and 47.5 feet M.S.L., protects about 2,800 acres* of heavily built-up industrial and commercial property from a recurrence of the 1936 flood event. Included in the protected area, shown on the map of Figure 7, is a heavily industrialized section along Windsor Avenue consisting of approximately two dozen industrial establishments and the major railroad yard of the region. Also, service facility developments, consisting of several gas stations, motor hotels and trucking warehouses, have developed along Interstate I-91. The downtown are of Hartford, the major cultural and business center of the region, is located immediately behind the dikes. Included in this area are several major hotels, numerous department stores, office buildings, commercial establishments, Constitution Plaza, and the city governmental buildings. Just south of the city center is the Colt Industrial Park, the Connecticut Regional Market, and Brainard Airport. Scores of industrial and commercial establishments are located here as well as numerous service-type businesses, such as restaurants, motor courts, and gas stations, which have developed as a result of access to Interstate 91 and the airport. The Hartford Sewage Treatment Plant is located the southern margin of the dike.

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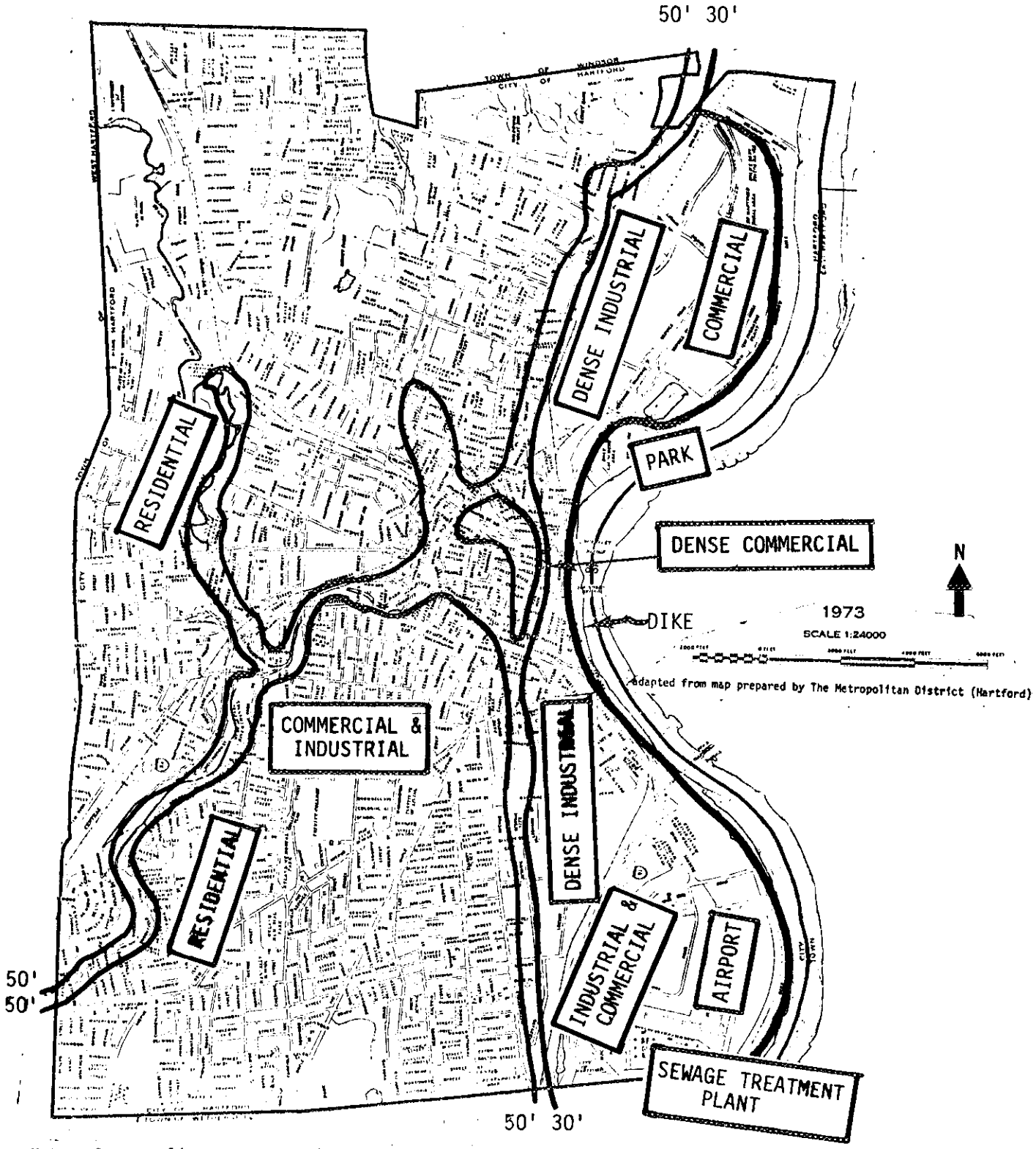
* This protected region of 4.4 sq. mi. is about 25 percent of Hartford's total land area of 17.2 miles.



Note: Contour lines are approximate and intended only to show areas of lower elevation.

Fig. 7. Hartford flood plain development.

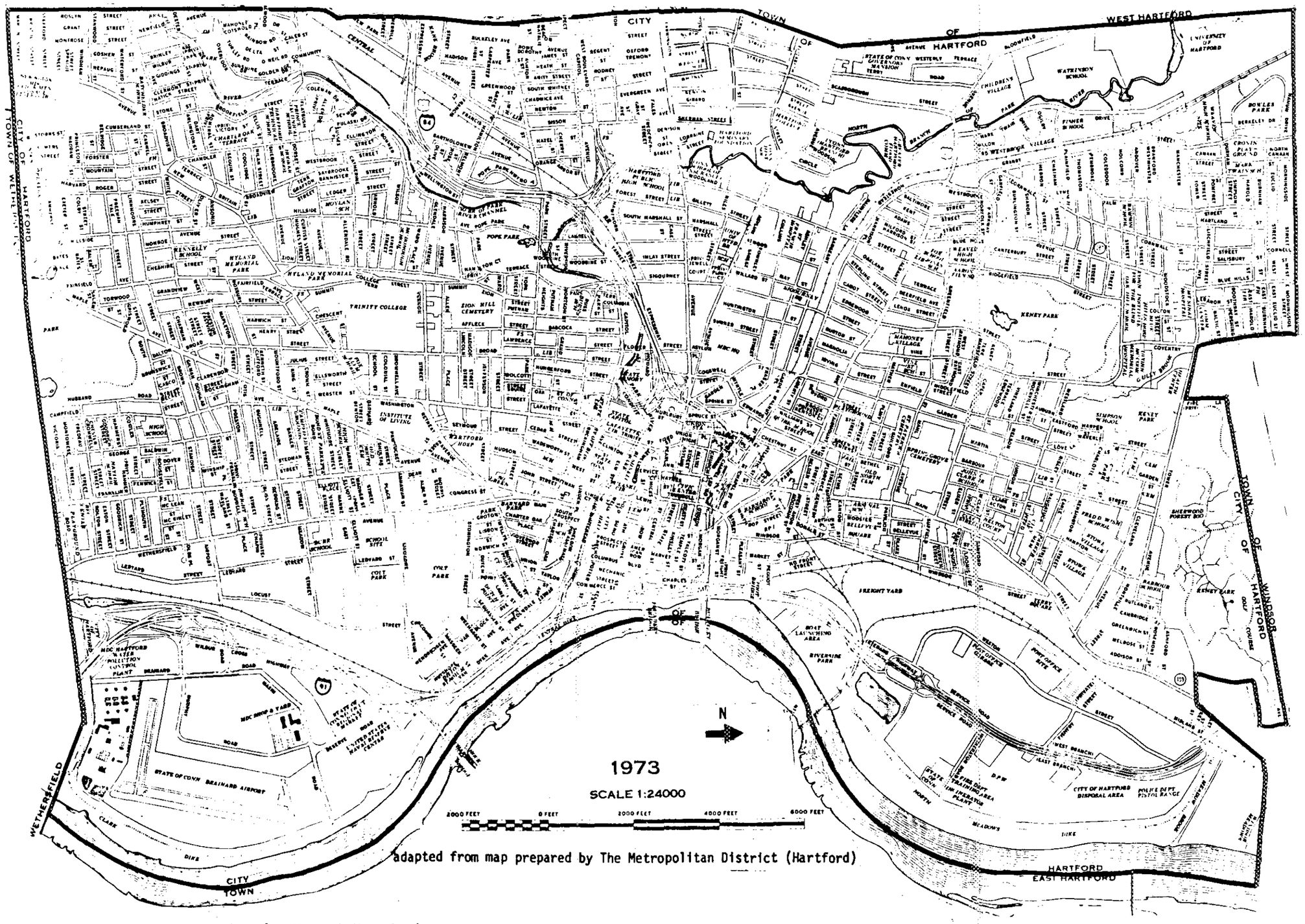


Fig. 8 Map of Hartford.

PARK RIVER - The Park River flood plain in Hartford was defined by the Greater Hartford Flood Commission at elevation 54.0' Metropolitan District Commission Datum. This includes areas on both the North and South of West Hartford and Bloomfield. The Park River is formed by the junction of the North and South Branches in the vicinity of Laurel Street. At the rear of the State Capitol, in the heart of the city, the Park River is directed into a pressure conduit approximately 5,600 feet long which leads to the Connecticut River. The Hartford portion of the drainage system is heavily populated and a great portion of the area is devoted to commercial and industrial uses. The mixed commercial and industrial area located near the confluence of the North and South Branch Park Rivers is particularly susceptible to damage; also, residential areas near Albany Avenue on the North Branch Park River and near Flatbush Avenue on the South Branch River. The August 1955 flood resulted in extensive damages in these areas and losses were reported to 1659 residential, 237 commercial, 64 industrial, 19 public and 19 other buildings and facilities (4). Figure 6 indicates the areas which were flooded during the 1955 flood. Increased runoff resulting from more intensive urban and suburban development in formerly rural upstream areas threatens the mixed industrial and commercial area upstream of the completed Park River conduit. A large flood on the Park River would flood much of the area of downtown Hartford on the land side of the dikes. North-south traffic on Interstate I-91 could be disrupted and access routes to the bridges across the Connecticut River would be closed.

Since the 1955 floods some of these buildings have been removed. Extensive channel work has been conducted in order to increase the efficiency of the drainage system to carry flood-waters. Much of this channel work was accomplished during construction of the major highway works through the area. Eight flood storage reservoirs control approximately 18 percent of the drainage area of the North and South Branch Park Rivers. In addition, a flood plain zoning ordinance has been instituted and administered since 1968.

There is some doubt, however, as to whether there would be adequate protection afforded by these measures in the event of an extreme flood. This is because urbanization of the Basin is increasing the runoff rate of the Basin due to stream channelization, storm sewering and an increase in the impervious area of the upstream portions of the drainage basin. Planned improvements to existing facilities are expected to be adequate to control the Standard Project Flood (SPF).

4.0 CLEARANCE

Hartford has no recorded experience of public initiative for clearance of flood hazard areas as a means of reducing the potential for flood damages. The construction of Interstate Highway 84 through the center of the city did result in the removal of a number of buildings in the Capitol Avenue area which were in the flood plain of the Park River. In addition, extensive damages caused by the 1955 floods resulted in the demolition of several buildings in the flood plain. This has not been the rule, however, as most property owners have rehabilitated their buildings and taken precautionery measures, such as constructing walls, in recognition of the flood threat.

5.0 FLOOD PROOFING

The City of Hartford adopted the Hartford Zoning Ordinance, including provisions for the Flood-Plain District, in 1968 (6). The Flood-Plain District section of this ordinance, the major thrust of which is directed toward the Park River drainage system, was to be a superimposed district on top of, or in addition to, the basic zoning classification of the city map. It adjusts the use of a basic zone by dealing with the flood threat as a physical hazard. As such, it allows the city and the owner to make use of the property for any purpose allowed under the basic zone but requires that the owner satisfy the requirements and regulations allowing for equal water storage volume in the flood plain (7).

The general criteria used to determine the compatibility of proposed construction with the objective of reducing flood damages are as follows:

1. That no building will impede the flow of the channel.
2. That the loss in valley storage due to filling is not a significant amount, nor is it such that there would be a significant loss if adjacent owners were to develop to the same degree.
3. That the structure, if it is on piers and occupies the area over the flood plain, is designed to withstand velocities or hydrostatic pressures and is flood proofed as to utilities to the elevation above the maximum flood of record or, in the case of Hartford, to 54'.
4. That there is safe access or relatively safe access to high ground at all times.

Hartford Flood-Plain District also takes advantage of some of the following flood profiling concepts. First, with proper site layout, the owner keeps the buildings on high ground and places the accessory uses, such as parking facilities, on the flood plain. Second, raising the building on piers so that the required flood storage is assured, the building will satisfy the structural requirement details of the City's building code, and there is no human occupation within the area that could be flooded (7).

Structures built prior to the Ordinance are exceptions to the Ordinance, but requirements are applied by the Building Inspection Department as to how and what has to be done to flood-proof the structures when and if an owner wishes to refurbish his building or to improve his building.

This flood proofing can be done in many ways:

1. Permanent closure of opening with masonry, if possible without risk of failure due to buoyancy.
2. Thoroseal coating to reduce seepage.
3. Valve on sewer line.
4. Underpinning.
5. Instrument panel raised above expected flood level.
6. Machinery protected with polyethylene covering.
7. Strips of polyethylene between layers of cartons.
8. Underground storage tank properly anchored.
9. Cracks sealed with hydraulic cement.
10. Rescheduling to empty the loading dock.
11. Steel bulkheads for doorways.
12. Sump pump and drain to eject seepage.

These flood-proofing measures are not explicitly listed in the Hartford Building Codes but serve as policy guidelines for the Building Inspection Department when reviewing building permits.

In addition, if a new building is to be built using the air rights over the flood plain, it has been required that the owners protect their utilities to elevation 54'. In some cases, this has meant placing the heating plant on the roof, waterproofing the electric outlets and placing the electrical board above the 54' elevation, and protecting the remainder of the utilities (7).

6.0 URBAN DRAINAGE

CONNECTICUT RIVER - Interior drainage from areas behind the Hartford dikes is handled by five pumping stations located along the dike. Two of these stations were constructed by the City of Hartford and four of the five are maintained by the City. One, the Potter Street Station, which has been maintained by the Metropolitan District, will soon be demolished. Two new pumping stations are planned in conjunction with the completion of the Park River Conduit.

PARK RIVER - The greatest amount of urban area in Hartford is drained by the Park River and its tributaries. There are presently three pressure conduits: the completed section of the Park River Conduit, 5,600 feet long, passing beneath the central part of the City into the Connecticut River; the 3,100-foot Gully Brook Conduit which ties into the Park River Conduit; and the 2,200-foot Folly Brook Conduit which ties into an existing conduit at the lower end of Folly Brook near the Wethersfield town line. An additional 1,451 feet of channel was paved upstream of the Park River Conduit intake on the South Branch of the Park River (3).

The changing land use patterns along with the accompanying increased runoff characteristics and natural storage encroachment has resulted in the present conduit becoming inadequate to pass flows from major floods. The conduit is the one weak link in the Hartford local protection system which would otherwise contain a flood to the magnitude of the Standard Project Flood (SPC) (3).

Current plans, illustrated in Figure 6, are to construct four additional conduit sections extending up the North and South Branches of the Park River, an auxiliary conduit running from the junction of the North and South Branch Park Rivers to the Connecticut River under Park Street, and stream channelization of sections of the South Branch Park River. It is interesting to note that the design flow for the Park

River conduit and the planned auxiliary conduit has been increased from 18,000 cubic feet per second (cfs), computed in 1940, to 30,000 cfs, computed in 1962 (5). Part of this increase is due to an increase in the design rainfall storm but a significant part is due to the influence of urbanization in the upper basin.

The Greater Hartford Flood Commission maintains jurisdiction over building and encroachments in the Park River flood plain at or below the 54.0-foot elevation. This elevation is based upon computations of the channel storage and hydraulic head required for the channel and conduit system to handle the design SPF.

7.0 FLOOD PLAIN INFORMATION REPORTS

There is no Corps of Engineers' Flood Plain Information Report for Hartford. Since planned flood control improvements will provide protection from the SPF, it is not envisioned that such a report will be required in the future.

8.0 PUBLIC INFORMATION

Hartford's recently enacted flood plain zoning ordinance (1968), the publishing of the Federal Insurance Administration flood hazard boundary maps and continuing publicity of the Park River flood control works have all served to inform citizens and property owners of the relative flood hazard associated with their property.

The river prediction service presently in effect in the Connecticut River Basin is operated from the National Weather Service River Forecase Center (RFC) at Hartford. This office provides early warning of flood stages for the main stem Connecticut River, including Hartford. A telemetry gage presently installed on the North Branch Park River can provide an early warning of high water stages in the lower portion of the Basin (3). An additional gage with similar capabilities is planned for the South Branch Park River as well.

The City of Hartford has developed a detailed Civil Preparedness plan (8) for natural disasters such as hurricanes, floods, tornadoes, accidents, and major failures of public utilities. This plan, reputed to be one of the best in the country, provides policy direction, and explicitly defines the responsibilities of city departments. In addition to early communication with the River Forecast Center which provides

early warning of flood threats on the Connecticut and Park Rivers, the city maintains an Emergency Operation Center (EOC) which would coordinate the activities of the city, state and federal agencies and the media during a disaster. Although most towns have such facilities and capabilities on paper, they are seldom supported by permanent staffing and continuous coordination and testing as exhibited in Hartford.

9.0 FLOOD CONTROL IMPOUNDMENTS

There are presently 16 flood control reservoirs in the Connecticut River Basin above Hartford, Connecticut. These facilities are considered adequate to prevent the Hartford dikes from being overtopped during the Standard Project Flood (SPF).

There are eight flood storage sites in the headwaters of the Park River, with a total flood storage capacity of 6880 acre-feet, which control approximately eighteen percent of the drainage area of the Basin (3). These facilities, authorized under Public Law 566, in addition to planned channel work, mentioned above, are considered adequate to contain an SPF in the Basin.

10.0 LOCAL PROTECTION PROJECTS

Hartford is protected from flooding on the Connecticut River by approximately 40,000 feet of earthen and concrete dikes and walls. With a top elevation varying between 42.5 and 47.5 feet M. S. L., these structures, in combination with upstream reservoirs, are considered adequate for protection against the Standard Project Flood (3). Hartford's dikes, completed in 1943, are approximately 5.5 feet higher than those at East Hartford, directly across the river. This was done by a combination of local businessmen and engineers in Hartford because they wanted protection at that time, and because they knew it would take two decades for the upstream control to be completed.

Hartford has a long history of local protection works. In the decade between 1850 and 1860, Mr. Samuel Colt constructed the first dike on the Hartford riverfront of the Connecticut River, in order to protect a manufacturing plant and housing for his labor force. This dike had a top elevation of approximately 36 feet M. S. L., and was overtopped during the 1936 flood (7).

Local protection works on the Park River are currently in the final stages of planning and implementation. As discussed above, this project consists of extending the Park River Conduit and channelization of the North and South Branch Park Rivers. Completion of this work, in conjunction with upstream storage already available, is expected to protect the center of downtown Hartford from what is now considered the Standard Project Flood that could occur on the Park River Basin.

11.0 CONCLUSIONS

Hartford, which has historically suffered from damages due to floods, has applied a wide spectrum of flood damage reduction measures in an effort to alleviate the problem. The city is secure from all but catastrophic flood events on the Connecticut River because of the extensive diking system along the river. Local initiative resulted in the construction of dikes which are 5.5 feet higher than East Hartford's dikes, located directly across the river. Other structural solutions used include the Park River pressure conduit, channel improvements, floodways, and storage reservoirs. Current plans call for additional control works on the Park River. These have been required because of the increased runoff resulting from urbanization in up-basin areas.

Nonstructural measures applied include the establishment of stream channel encroachment lines (Connecticut Public Act #435, 1963), the formation of the Greater Hartford Flood Commission after the 1955 Park River flood, and the development of a flood plain zoning ordinance (adopted in 1968). The city was one of the early qualifiers for participation in the HUD flood insurance program. The city maintains a readiness to react to flooding events through coordination with the River Forecast Center and by the development and maintenance of an emergency preparedness plan.

With the completion of the currently planned flood control improvements on the Park River, combined with the structural and nonstructural flood control measures already in operation, it appears that the city of Hartford will be protected from major damages from all floods up to and including the Standard Project Flood.

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(4) Greater Hartford Flood Commission, 1955 FLOOD DAMAGES, PARK RIVER BASIN, 1958.

(5) Metcalf and Eddy, Consulting Engineers, Control of Floods in Park River Basin, 1958.

(6) Hartford Zoning Ordinance, Section 38.5.254, Flood Plain Zoning.

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PRESENT STATUS OF ELEMENTS FOR FLOOD DAMAGE REDUCTION EAST HARTFORD, CONNECTICUT

1.0 GENERAL

East Hartford, located across the Connecticut River from Hartford, has an area of 18.1 square miles, almost all of which is flat or gently rolling land. It is bordered on the north by South Windsor, on the east by Manchester and on the south by Glastonbury (see map, Figure 9).

The Connecticut River, which has historically been a major avenue for trade in the region, and the Hockanum River which drains from the east through the center of town and which has supplied power for early manufacturing enterprises comprise the principal drainage system.

East Hartford's early history and subsequent growth is closely allied with the City of Hartford. The area was settled in 1635 and incorporated as a separate town in 1783. The population has grown from 2,000 people in 1774 to 57,583 in 1970. The population increased by approximately 14,000 people in the decade from 1960 to 1970 but present projections indicate a leveling off to 63,000 in 1980. (1)

The older, central part of town is located behind the dike. Since the completion of the dikes in 1943, development has taken place in the area south of the Hockanum River and consists of commercial and industrial facilities along South Main Street and Route 2. Included in this area is the Pratt and Whitney Aircraft facility, one of the major employers of the region.

The principal industries of the town are the manufacture of precision parts and aircraft engines, steel fabrication, tobacco growing and processing and bulk oil storage and distribution. The town is also a major transportation center because of the major interstate highways, I-84 (east-west), I-86, and I-91 (north-south) which intersect at East Hartford/Hartford (see map, Figure 10).

2.0 FLOOD HISTORY

East Hartford has sustained severe flood damages over the years as have other communities located along the Connecticut River. Almost half of the town has a ground elevation of 50 feet or lower and the major industrial and commercial development has taken place in this area. The flood of 1936, the flood of record, and the 1938 flood provided the motivation for the construction of the dike and floodwall system completed in 1942, which presently protects the downtown portion of the city. Before its erection, more than a third of the central downtown portion of East

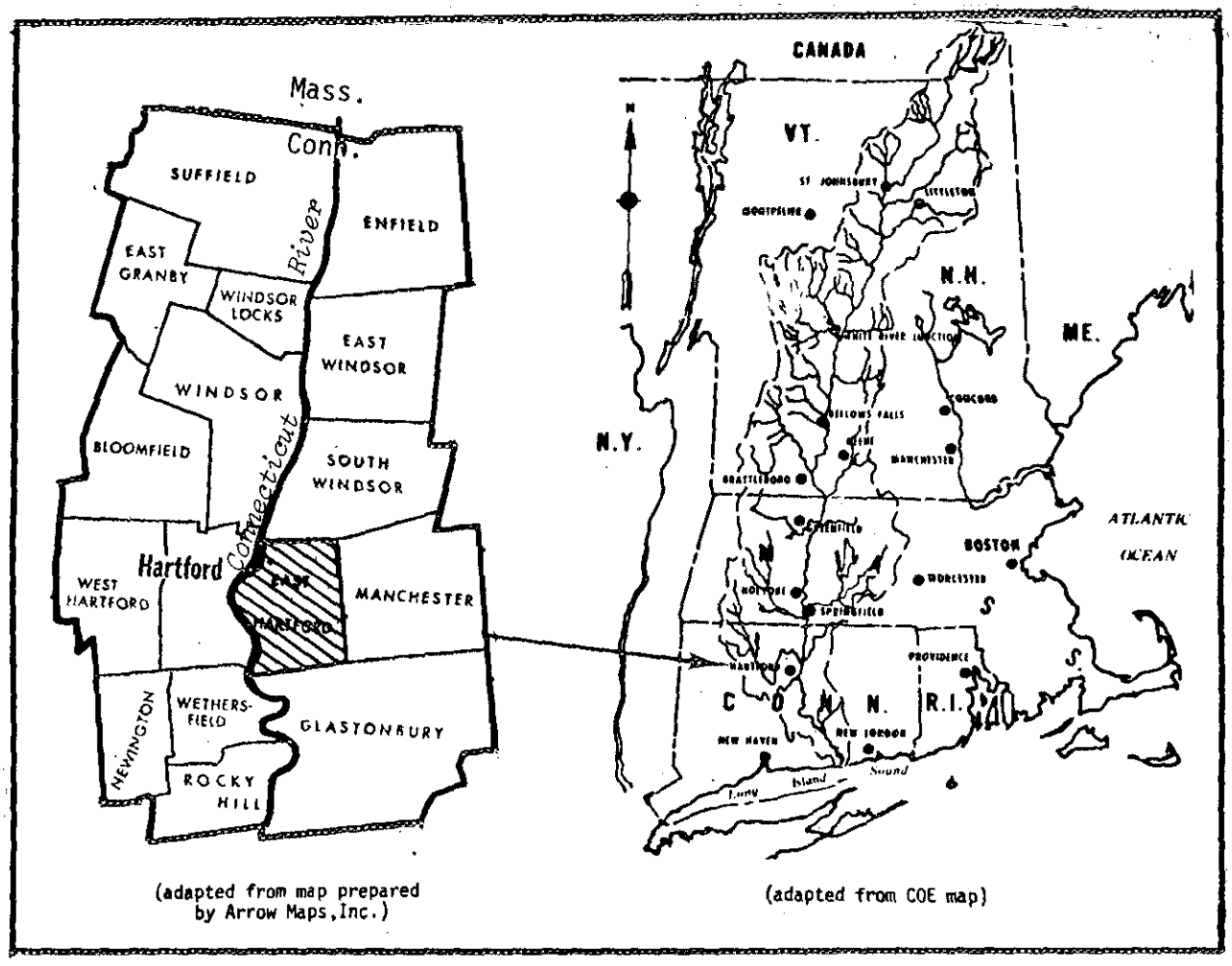


Fig. 9: Location map, East Hartford, Connecticut

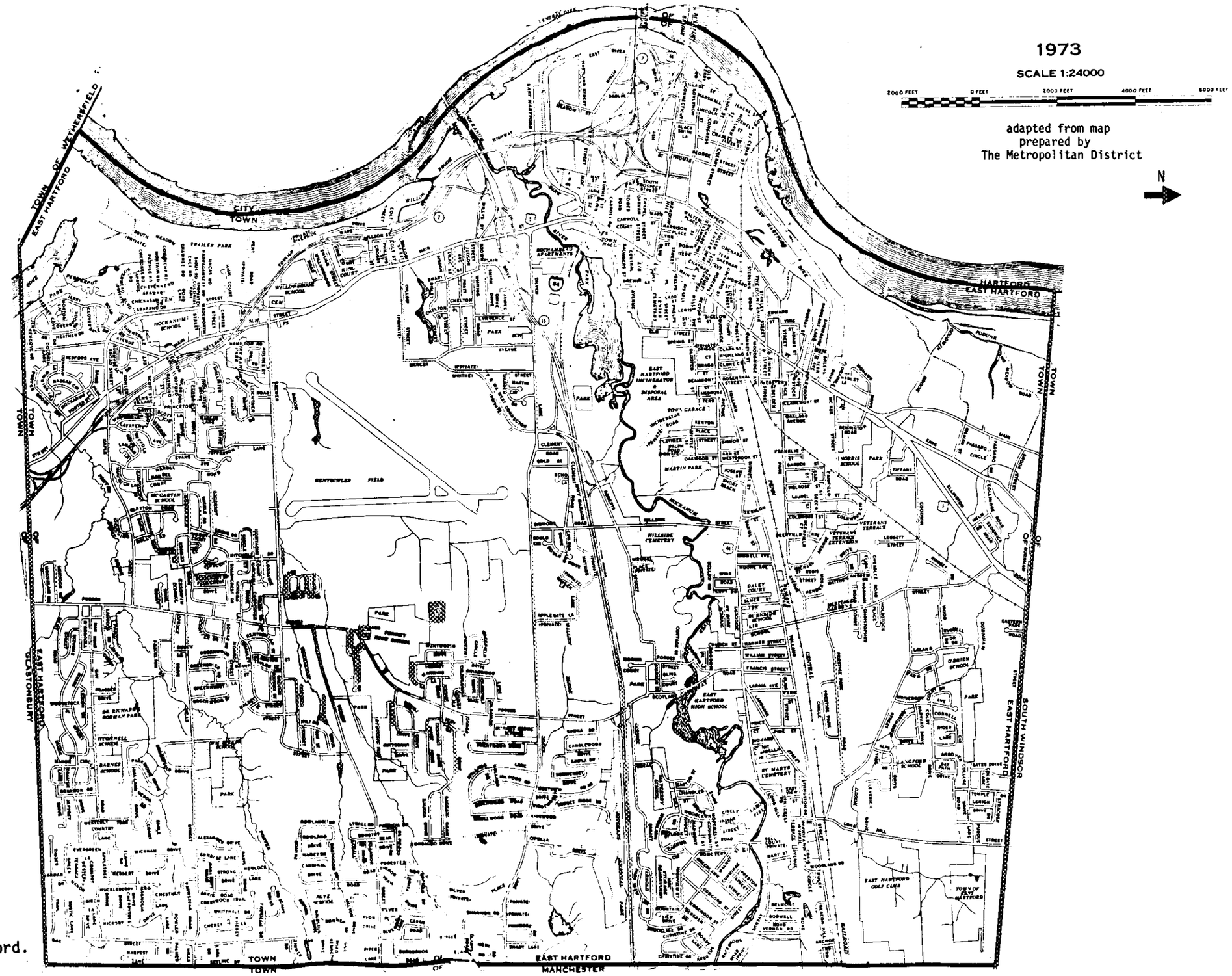


Fig. 10 Map of East Hartford.

Hartford along the river was flooded every year. The March 1936 flood, with a flood stage of 37.6 feet (M. S. L.), caused water damage to about 1,050 of the 3,300 local dwellings in the town. (2) One account noted that oil storage tanks located on the river banks were torn away and floated downstream. (3) The recent high water of July 1973 resulted in damage to crops cultivated in the flood plain, primarily in the north and south "Meadows" areas. (4)

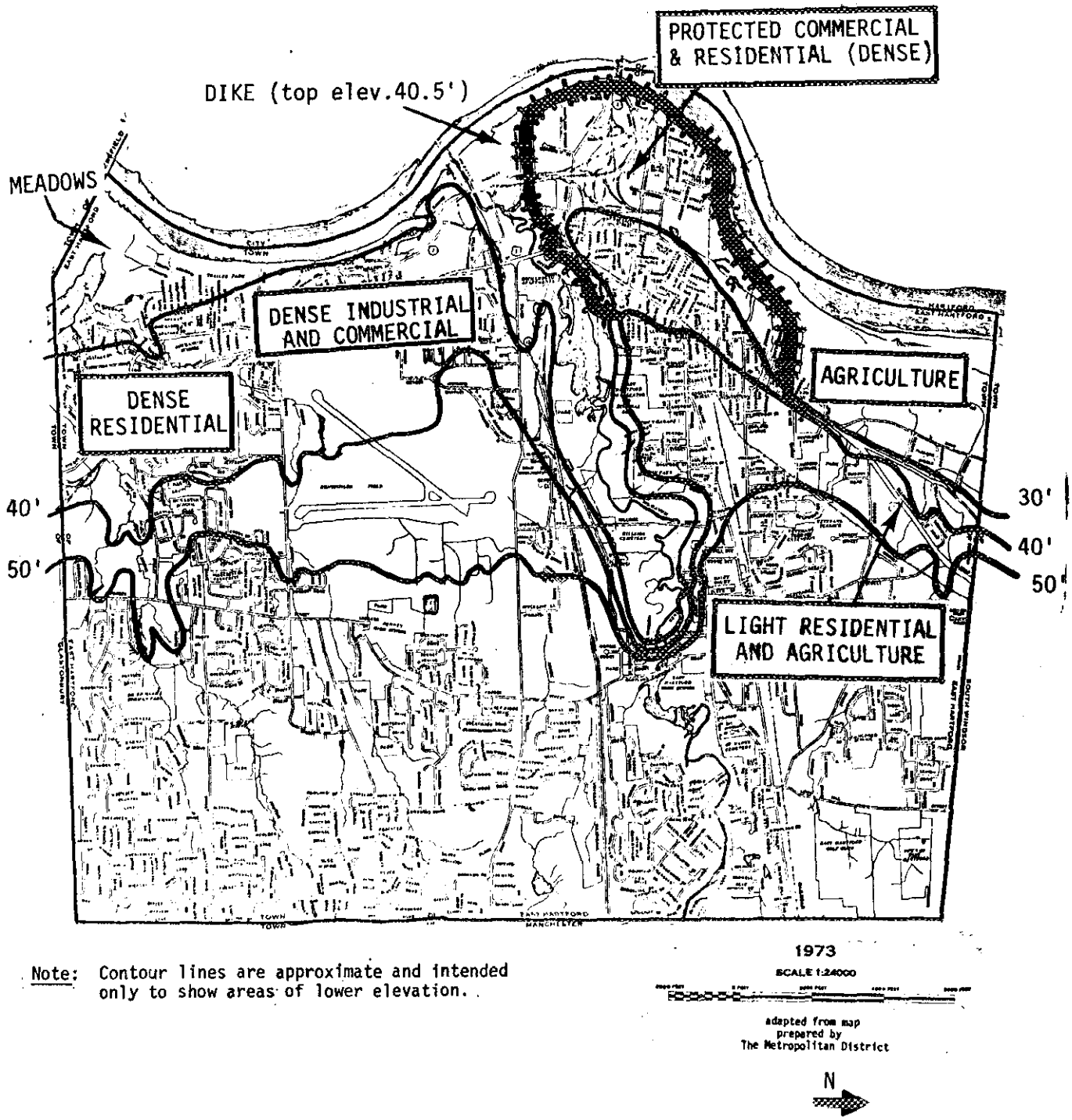
The Hockanum River, which flows directly through the town from the east has also caused extensive damage over the years. The flood of record is the September 1938 event with severe damages also being incurred during the floods of August and October of 1955. (5) Most of the damages were attributed to bridges and highways along the river course.

3.0 THE FLOOD PLAIN

CONNECTICUT RIVER - Approximately 760 acres of heavily urbanized land of downtown East Hartford is protected by about 19,000 feet of earth dikes and 750 feet of concrete floodwalls along the Connecticut and Hockanum Rivers. Top elevation of the dikes is 40.5 feet (M. S. L.). (7) This area comprises the major commercial center of the town and includes the Town Hall and library, approximately 1,000 dwellings, several hundred commercial establishments and office buildings, trucking warehouses and several motor hotels. The major interstate and state highways, I-86, I-84 Route 2, Route 4, and Route 5 intersect behind the dikes in a convoluting system locally referred to as the "mixmaster". Approximate areas of low elevation, both protected and outside the dikes, are indicated on the map, shown in Figure 10, along with a general description of land use. Figure 1, a more detailed map of East Hartford, is presented to allow for more precise location of facilities relative to streets, etc.

Properties located outside the diked area and officially in the flood plain, at 30 feet M. S. L. or lower, are primarily in the southwest portion of the town. There are seven or eight homes located along North Main Street which are located in the flood plain. In the southwest portion of the town there are approximately 230 family homes, 125 mobile homes, 3 apartment houses, 10 small businesses, and three industrial or large commercial establishments located in the flood plain. Most of the mobile homes are located in the Keeney Cove area near High Street and Naubic Avenue. The town has recently received a donation of 53 acres of open space in the meadow near Keeney Cove. Town plans indicate that this type of land use for this area is to be promoted in the future.

It is evident that substantial flood damages would be incurred if an



Note: Contour lines are approximate and intended only to show areas of lower elevation.

Fig. 11 East Hartford flood plain development.

Intermediate Regional Flood (IRF) on the Connecticut River were to occur (i. e., flood stages of 30 feet M. S. L.). Detailed level surveys would be required in order to establish the stage-damage relationship for properties subject to flooding. Flood stages in excess of this would cause progressively greater damages as the stage increased. The Standard Project Flood (SPF), with a flood stage of approximately 42 feet M. S. L., would be disastrous. The East Hartford dikes, with a top elevation of 40. 5 feet (M. S. L.) would be overtopped. Flood waters would move beyond Route 2 into the heavily industrialized area along South Main Street. The Pratt and Whitney Aircraft complex, a major employer of the region, would be impacted. The large housing development in the Keeney Cove area would be severely damaged. In short, the major commercial, industrial, and transportation corridors in East Hartford would be severely damaged.

HOCKANUM RIVER- The Hockanum River flood plain is defined by the channel encroachment lines set by the Connecticut Water Resources Commission (now the Department of Environmental Protection) in December of 1970. The flood plain zone, as defined in East Hartford's zoning regulations, is set at 30 feet M. S. L. downstream of the first dam at Forbes Street. (8) This area is subject to backwater from the Connecticut at flood stages. The predominant land use is open space and park land. Much of the land is marsh and would be restricted for development by several state and local ordinances. There is a large apartment complex located below the 30 foot line at Hillside Avenue, which has been flood - proofed to elevation 32 feet.

Upstream of the first dam to the Case Brothers dam, flood encroachment lines have been set by the Connecticut Department of Environmental Protection and are based on a hydraulic study of the channel. There are few, if any, buildings in this area. Current plans are for the creation of a linear park along the Hockanum River within the channel encroachment lines.

4.0 CLEARANCE

There are no recorded instances of public efforts in East Hartford to clear structures off flood-prone properties in order to diminish damages due to flooding.

5.0 FLOOD PROOFING

The flood proofing of homes and businesses susceptible to flooding in East Hartford has only recently been required. A flood plain zoning ordinance was enacted in November 1972 which required that structures and

building improvements be designed to withstand structural damage and erosion up to an elevation of not less than two (2) feet above the elevation of the flood plain limit. (8) The flood plain limit is regarded as being at 30 feet M. S. L. along the Connecticut River. The newer housing developments in the Keeney Cove area near Naubic Avenue and High Streets, consisting of upwards of a hundred homes, were built with the first floor of the living quarters at or above the 32 foot elevation. In addition, all heating, electrical and sanitary equipment is to be protected from flood drainage to prevent interruption of service, although this equipment is not necessarily required to be above the 32 foot elevation.

Buildings located behind the dikes are not required to be flood proofed.

6.0 URBAN DRAINAGE

Heretofore, urban drainage of flood waters in East Hartford has not resulted in extensive or frequent damages. Some localized flooding of a temporary nature is experienced during periods of intense rainfall due to storm sewer backup. The Hockanum River, which drains the upstream towns of Vernon and Manchester before entering East Hartford, does not normally cause flooding problems except during periods of extremely high runoff. Rapid urbanization of the upstream communities, Vernon and Manchester, with attendant storm sewering, stream channelization and increases in the percent of impervious area in the drainage basin, could change this situation in the future.

Localized urban drainage, which collects in the protected area behind the dikes, is handled by three pumping stations located at Meadow Hill, Cherry Street and Pitkin Street.

7.0 FLOOD PLAIN INFORMATION STUDIES

There is no Corps of Engineers flood plain information study available for the Town of East Hartford. It is anticipated that a flood plain study will be conducted under the auspices of the Department of Housing and Urban Development (HUD) in order to determine the actuarial rates for the Federally-subsidized flood plain insurance which East Hartford has qualified for. This study would involve the detailed delineation of areas subject to flooding hazard. The town has qualified for the flood plain insurance program and 482 personal and 26 commercial policies have been written. (10)

8.0 PUBLIC INFORMATION

East Hartford's recently enacted flood plain zoning ordinance (November 1972), the establishment of channel encroachment lines on the Hockanum River (December 1970), and the approval in 1972 of the Federally-subsidized flood insurance program have all served to inform owners of property in or near the flood plain of the relative flood hazard associated with their property.

In addition, current town plans for open space uses of the flood plain, such as the linear park along the Hockanum River and the potential for open space preservation in the Keeney Cove area, have been noted by area media and town officials as compativle uses of the flood plain which are to be pursued.

East Hartford's organizational plans for dealing with natural disasters, such as a major flood event, are based upon the existing organizational structure of the town government. The National Weather Service River Forecast Center, in Hartford, issues flood warnings for the Connecticut River, These warnings are received by the Town of East Hartford. The police and fire department units are in turn notified. Although the town has a Civil Preparedness Director, who serves in a part-time capacity, it does not have documented flood contingency plans, such as exist in Hartford, which would provide policy direction and detailed definition of departmental responsibility. (11) Given the nature of the properties in and near the flood-plain, particularly in the Keeney Cove area, it would be prudent for the town to develop and exercise an emergency action plan.

9.0 FLOOD CONTROL IMPOUNDMENTS

There are presently 16 existing flood control reservoirs in the Connecticut River Basin above East Hartford. The stage reduction is not considered to be adequate to prevent the overtopping of the East Hartford dikes during the design S. P. F. (7)

There are no flood control reservoirs on the Hockanum River. Some flood flow regulation has been attributed to Shenipsit Lake, basically a water supply reservoir, during periods when the lake has been drawn down such as occurred in the August and October flood events of 1955. (12)

10.0 LOCAL PROTECTION WORKS

Approximately 760 acres of heavily urbanized and commercial down-town area of East Hartford is protected from flooding on the Connecticut River by approximately 19,000 feet of earth dike and concrete floodwalls. The dike, which extends from high ground near Green Terrace in the north to

high ground at Brewer Lane and Central Avenue in the south, has a top elevation of 40.5 feet M.S.L. (7) East Hartford's dikes, designed for protection against a recurrence of the 1936 flood-of-record, are 5.5 feet lower than the Hartford dikes directly across the river and would be overtopped by a design Standard Project Flood, expected to crest at approximately 42 feet.

11.0 CONCLUSIONS

Of the two major rivers in the Town of East Hartford- theConnecticut and the Hockanum- the Connecticut River poses the greatest immediate flood threat. A serious flood with stages over 30 feet M.S.L. would cause damages to residential development in the flood plain. The bulk of these damages would be incurred in the Keeney Cove area, in the southwest portion of the town. Additionally, the flood stage of 42.0 feet associated with the Standard Project Flood (SPF) would overtop the East Hartford dikes and result in damage to substantial portions of the commercial and industrial development of the town, including the devlopment south of the Hockanum River along South Main Street.

Unfortunately, there does not apper to be a clear-cut solution to this problem. The construction of the seven (7) flood control reservoirs recommended by the Coordinating Committee would reduce the SPF flood stage by about 4 feet and would prevent over topping of the dikes. Substantial damages would still be incurred, particularly in the Keeney Cove area and possibly along South Main Street.

Response to the Federal Flood Insurance Program begun in December 1972 has been quick, with about 500 policies written in six months. This program would help substantially in reducing the individual burden which property owners would have to bear in the event of flodding.

The town of East Hartford has somewhat belatedly recognized the flood threat as evidenced by the recent passage of a flood plain zoning ordinance. Also, town officials are promoting the use of flood plain land as open apace. This effort has been helped with the donation to the town of 53 acres of land in flood plain near Keeney Cove.

The Town of East Hartford would be well advised to develop and periodically test an emergency action plan for flood emergencies. Detailed plans for coordintion of departmental activities and state and regional authorities through an Emergency Operation Center (EOC) can go a long way towards mitigating the severe impacts of major disasters.

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(3) The Great Flood of 1936.

(4) Hartford Courant, July 3, 1955.

(5) U. S. Department of Interior, Geological Survey, Water Resources Data for Connecticut, Part 1, Surface Water Records, 1971.

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(9) Encroachment Line Study, Hockanum River, East Hartford, Connecticut, The Water Resources Commission, Cohn Engineers, Inc., Consulting Engineers, December 1970.

(10) Personal communication, Mr. Crown, Flood Plain Insurance Area Coordinator, Aetna Insurance Company, Hartford, Connecticut.

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PRESENT STATUS OF ELEMENTS

FOR FLOOD DAMAGE REDUCTION

SPRINGFIELD, MASSACHUSETTS

SPRINGFIELD, MASSACHUSETTS

General

The city of Springfield, Massachusetts, located in the central portion of Hampden County, is the largest metropolis in western Massachussetts and the third most populated city in the Commonwealth, following Boston and Worcester. It is bordered in the north by portions of Chicopee and the Chicopee River, on the west by the Connecticut River, on the south by Longmeadow and East Longmeadow, and on the east by Wilbraham. In general, the topography is fairly level in the major developed areas. However, elevations vary from approximately 50 feet at the Chicopee River to 330 feet near the East Longmeadow border. The land along the south and southwest borders is the only hilly district in the city. A map of the city is provided in Figure 12.

Since its founding in 1636, Springfield has dominated the economic growth in the Lower Pioneer Valley. Initially, agriculture attracted most of the town's residents, but early in the 18th century, the power of the Connecticut River began to be tapped and many mills were erected. Saw and grist mills were the first to appear and the large clay deposits in the area were used to manufacture bricks. In 1794, the government established an armory in Springfield, thus creating a rise in the metal goods industry. Many large industries such as Monsanto Chemical Company, United States Envelope Company and the Van Norman Company, have operated in the city since the early 1900's. Today, Springfield continues to be an industrial city with a healthy diversity of manufacturing concerns. In 1971, an average of 18,220 persons were employed by 231 firms with an annual payroll of $151,756,928. Still, the city actively engaged in promoting the movement of new industry into Springfield through organizations such as the Industrial Development Finance Commission. Indications are that Springfield will experience continued growth in the industrial sector, primarily along Interstate routes 291 and 91, with the bulk of industrial land in the northeastern outlying areas of the city.

The industrial growth of recent years has not been matched by comparable growth of the resident population. As with many cities of its size, Springfield has lost much of its population to suburban towns. This outmigration began about 1960 and amounted to approximately 6.05 percent between 1960 and 1970. A recent state solid waste report by Raytheon gives a population projection to the year 2000 showing a

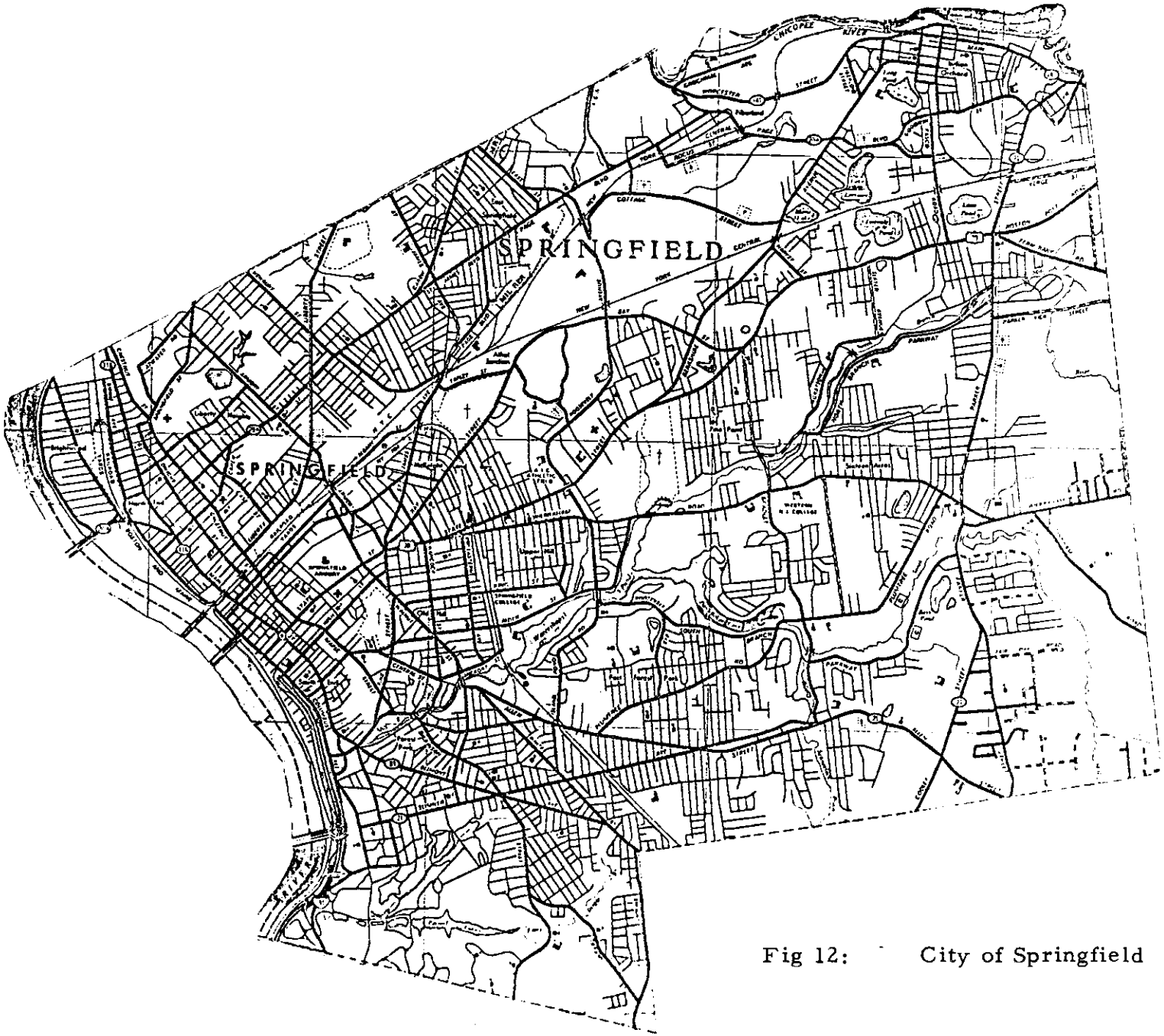

Fig 12: City of Springfield

slow but steady population increase totaling 4.02 percent above the 1970 figure of 163,905.

Flood History

Although there are a number of interior streams which have caused localized flooding problems over the years in Springfield, the major flood threat to the city is from two rivers: the Connecticut River in the west and its largest tributary, the Chicopee River on the north. Flood heights have been recorded on the Connecticut River at Springfield since 1801 and on the Chicopee River in Indian Orchard section of Springfield since 1928. Records for the Connecticut River at Springfield show that the 20-foot flood level is reached or exceeded at an average interval of 11 years. The most disasterous floods of recent record to hit the Springfield area have all occurred in the 20th Century, in 1927, 1936, 1938, and 1955.

The flood of record on the Connecticut was the March 1936 event. It is estimated that this flood resulted in direct losses to the city of Springfield in excess of 4 million dollars (1936 prices). As a result of this flood, the U.S. Army Corps of Engineers undertook the construction of a dike and flood wall to run virtually the length of the Connecticut River in Springfield. Since the completion of these works in 1948, all flood flows on the Connecticut River have been contained.

On the Chicopee River, four floods of major proportions have been experienced since 1936. These occurred in March 1936 (2 floods), September 1938 and August 1955. The September 1938 storm produced the greatest flow of record on the Chicopee River and caused extensive damage to Chicopee, Chicopee Falls and the Indian Orchard section of Springfield. Historical records indicate a substantial flood in the Chicopee River Basin in May 1854 and October 1869, but specific data regarding the magnitude of these two floods is lacking.

If these historical climatological events were to recur today, stages on both the Connecticut and Chicopee would be somewhat lower than actually experienced due to the operation of the system of flood storage reservoirs in the basin. Still, the potential for major flooding exists on both streams as evidenced by the 1955 event.

The Flood Plain

Chicopee River. The Corps of Engineers Flood Plain Information Report for the Chicopee River has been completed and defines flood-prone areas bordering the Chicopee River from Three Rivers Village in Palmer

westerly to the confluence with the Connecticut in Chicopee. This includes the 3-1/2 miles of river channel through Springfield, in the Indian Orchard section of the city.

In the event of an Intermediate Regional Flood (IRF)[1] on the Chicopee River, approximately 91.6 acres in the Bircham Bend and Indian Orchard sections of Springfield would be inundated. An additional 92.2 acres would be covered by a Standard Project Flood (SPF).[2] Although the major portion of this land is open, damage would be extensive in the vicinity of the Monsanto complex, where roughly half of the company's facilities would be flooded. There is also a large mobile home park in this area.

Connecticut River. The flood plain of the Connecticut River in the vicinity of Springfield has been greatly reduced by local protection works. During the flood of 1936, the entire downtown portion of Springfield was under water. Today, as a result of the dike and floodwall system, an IRF would flood only about 26 acres, mostly in the vicinity of the South End bridge. The only significant structure in this area is a railroad yard. In the event of an SPF, the dike would be topped and most of the downtown section, including Bay State West and City Hall, would be inundated. Also, the new Springfield wastewater treatment plan now under construction on Bondi Island in Agawam, with a dike elevation of 63 feet, msl, would be flooded by the SPF.

Clearance

After the 1936 flood, a large number of private dwellings were cleared from the flood plain. However, since the completion of the dike and flood wall, the area behind the dikes has been extensively developed. This development is almost continuous except for the narrow band associated with the Route 91 corridor. The thin band of river bank and flood plain west of the dike remains essentially in open space, and is owned by the city.

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1 In Intermediate Regional Flood (IRF) is a hypothetical flood situation with a 1 in 100 chance of occurrence in any one year.

2 The Standard Project Flood (SPF) is defined as the flood that may be expected from the most severe combination of meteorological and hydrological conditions that are considered reasonably characteristic of the geographical area in which the drainage basin is located, excluding extremely rare combinations, and including the reductive effects of existing dams.

Springfield's Conservation Commission has had great success in acquiring land along interior streams and brooks. Most of the land paralleling the North and South Branches above Watershops Pond are already devoted to open space. Also, large areas around Abbey Brook and Porter Lake have been acquired, thus reducing potential damages in these areas.

Flood Proofing

The city of Springfield limits its own flood proofing efforts to operational procedures required for the sewer lines and sewage treatment plant. A large portion of Springfield's sewerage system is combined, especially in the older sections of town. Thus storm water runoff greatly increases flows to the existing sewage treatment facility. In order that the existing treatment plant not be flooded, all flows in excess of 40 million gallons per day (mgd) are bypassed directly to the Connecticut River. All water surface elevations at the new plant will be designed so that the effluent will be discharged above the maximum flood level estimated by the U. S. Army Corps of Engineers for the Connecticut River at the Memorial Bridge in Springfield.

Private flood proofing efforts along the Connecticut have been virtually nonexistent, presumably due to the sense of security provided by the floodwall. On the Chicopee River, Monsanto Chemical Company has taken some limited actions to flood proof several plant buildings. These include installation of gate valves on sewer lines and storage of sand bags.

Urban Drainage

Most of Springfield's more recent flood problems have been associated with its interior streams. As mentioned before, the city's Conservation Commission has acquired many of the flood-prone areas, but still some localized problems exist.

1. Van Horn Reservoir. An early source of water supply for the city of Springfield, this pond overflowed in 1955 necessitating the evacuation of the ground floors of the city hospital. As a result, a new gate house and conduit were installed.

2. Watershops Pond. A series of gates were installed by the Army Corps of Engineers after the 1955 flood to protect the Springfield Armory. The city now operates the facility.

3. Abbey Brook. Urban flooding in this area continues to be a problem. The city engineering department and State Waterways Division are currently formulating a plan to alleviate flooding problems on the brook.

Flood Plain Information Reports

The city of Springfield has not had a flood plain information study done specifically for its portion of the Connecticut River. On the other hand, a report has been completed for the Chicopee River and it includes information regarding the Springfield portion of that river. Also, the U. S. Geological Survey has prepared a series of maps for the entire Connecticut River Basin, which delineates those areas which are considered "flood-prone." Finally, in 1970, the U. S. Department of Agriculture, Soil Conservation Service (SCS) completed a special study for the city of Springfield, which detailed wetlands and flood prone areas within the city and recommended selected acquisition. Wetland information is also contained in the city's 1967 Comprehensive Plan.

Public Information

As far as development policy is concerned, the city is quite limited inasmuch as most of its river front area has already been developed. There is still some open space, primarily to the west of the dikes and in the area of Forest Park, and indications are that these areas will remain open.

A local flood plan has been developed through the cooperation of the city government, local civil defense officials and the Army Corps of Engineers. The plan outlines steps to be taken at various stages of the river's rise.

Flood Control Impoundments

There are presently 13 flood control dams in the Connecticut River Basin above Springfield. All are operated by the Army Corps of Engineers. While the impoundments reduce the river's stage to some extent, there are four which have a very direct effect on Springfield and its surrounding towns. Two of these are in the Westfield River Basin and the remaining two are in the Chicopee River Basin.

1. Westfield River Basin. The Knightville Dam, completed in 1941, is located on the Westfield River about four miles north of the

town of Huntington. Littleville, the smaller and more recent of the two dams, is located on the Middle Branch of the Westfield River, one mile upstream of its confluence with the main river. Through the operation of these dams, flood stages are controlled along the Westfield River. Protection is also provided but to a lesser extent at damage centers along the Connecticut River below the mouth of the Westfield in Agawam.

2. Chicopee River Basin. Barre Falls Dam is located on the Ware River, about 0.3 miles below the junction of the East and West Branches of the Ware River in the town of Barre. Conant Brook Dam is located on the Conant Brook tributary of Chicopee Brook, about two miles southeast of the center of the town of Monson. Operation of these dams allows for reduced stages for the Chicopee River, and to a lesser extent for the Connecticut River below the mouth of the Chicopee. It is estimated that the combined effect of the Westfield and Chicopee River dams has been to reduce the potential flood stage at Springfield by about two feet.

In addition to the Corps of Engineers' dams, there are a number of small SCS dams which have been completed in the immediate watershed, but whose operation would have a very limited effect downstream at Springfield, These include Upper Quaboag River (8 sites), Broad Brook (2 sites) and Powdermill Brook (2 sites).

Local Protection Projects

The Springfield flood protective works are located along about five miles of the east bank of the Connecticut River. The project was constructed in various segments, beginning in 1937 and ending in 1948. The improvement protects two large, low areas totaling 820 acres located in the northern and southern sections of the city. In the northern area, earth dikes and concrete floodwalls extend from localized high ground north of the Chicopee-Springfield city line downstream to high ground near the Penn Central Railroad bridge. In the southern section, concrete walls extend across low areas from high ground below the Memorial Bridge to high ground at the South End bridge. A pressure conduit extends from the Connecticut River up the Mill River, to provide protection from Connecticut River backwater and to carry the flow of the Mill River. Additionally, the project provided wingwalls along the Mill River above two dams and a highway bridge, stoplog structures, one pumping station, and miscellaneous drainage structures to supplement the city systems for disposal of interior drainage. For its part, the city of Springfield constructed intercepting sewers, surface drains and six pumping stations which have been

incorporated in the protective system. Since the completion of the project in 1948, there has been no serious flooding of the downtown area.

As far as the Chicopee River is concerned, there are local protection works in Chicopee and Chicopee Falls, but no protection works are provided along the Springfield section of the river.

Conclusions

There are two major streams affecting the city of Springfield -- the Connecticut and Chicopee Rivers. No protective works, either public or private have been constructed along the portion of the Chicopee River which flows through the Indian Orchard-Bircham Bend section of Springfield. In the event of serious flooding, damage in this area, particularly to the Monsanto facility, would be extensive. In light of this prospect, it is recommended that Monsanto investigate alternatives, including flood proofing and other structural means, to reduce the flood threat.

The Connecticut River on the other hand, presents an entirely different threat to the city of Springfield. The entire stretch of the Connecticut River in Springfield has been lined with dikes and floodwalls. Spurred by the apparent security offered by these protective works, development in the downtown section has been extensive. It has been estimated by the Corps that the occurrence of the SPF, as presently modified by the existing Corps' reservoirs, would top the Springfield dike by more than a foot. Should this actually be the case, the consequences to Springfield would be disasterous. It is thus clear that Springfield should develop a flood plan of structural and/or nonstructural measures to insure against flooding of its downtown area.

PRESENT STATUS OF ELEMENTS

FOR FLOOD DAMAGE REDUCTION

WEST SPRINGFIELD, MASSACHUSETTS

GENERAL

West Springfield, Massachusetts, is located in the southwestern part of the state in Hampden County. It is bordered on the east by the cities of Springfield and Chicopee and the Connecticut River, on the north by the town of Holyoke, on the west by the town of Westfield, and on the south by Agawam and the Westfield River. It is about 90 miles from Boston, 26 miles from Hartford, Connecticut, and 135 miles from New York City (see figure 13).

West Springfield, having an area of 16.75 square miles, has a hilly terrain along the west and north, with elevations rising about 200 to 600 feet above mean sea level (M. S. L.). The land is relatively level along the east and central sections at an elevation of approximately 200 feet M. S. L. The Connecticut River and a major tributary, the Westfield River, which border the town on the east and south, make up the principal surface drainage system (see map, Figure 14).

The original settlement of West Springfield in 1655 was on "Chicopee Plains" now the town's north end. With the building of a dam at Mittineague Falls on the Westfield River in 1840, industry flourished. At present, West Springfield can be described as an attractive suburb with diversified manufacturing industry that has shown considerable expansion over the past decade (1). Machinery and parts, paper and allied products are principal products made in the town.

Population growth in the town has been steady, increasing from 20,438 persons in 1950 to 28,461 persons in 1970. Population projections indicate an increase to 32,350 persons by 1980 and to 36,200 persons by the year 2000 (2).

FLOOD HISTORY

The major flood threat to the town of West Springfield is from the Connecticut River on the east and its tributary, the Westfield River, on the south. Flood heights have been recorded on the Connecticut River at Springfield since 1801 and on the Westfield River since 1914. Records for the Connecticut River at Springfield show that the 20-foot level, relative to the gaging station datum, is reached or exceeded at an average interval of once every 11 years. Flooding of lowland areas begins to occur at the 20-foot level. The most serious flood damage in West Springfield has been caused by the Connecticut River. Table 1 summarizes information on peak stages of the Connecticut River in the West Springfield area during three of the most serious floods.

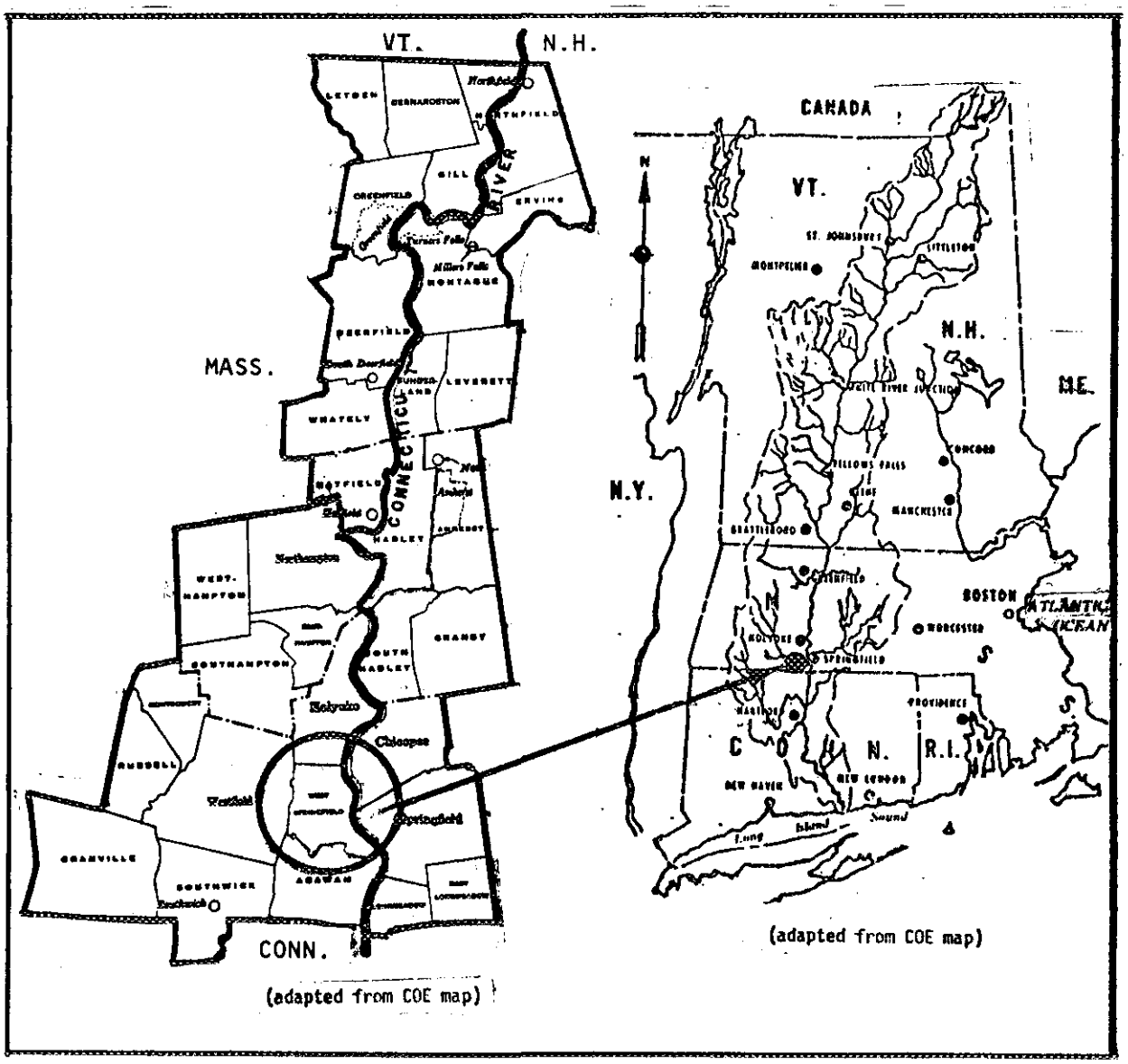


Fig 13: Location map, West Springfield, Massachusetts

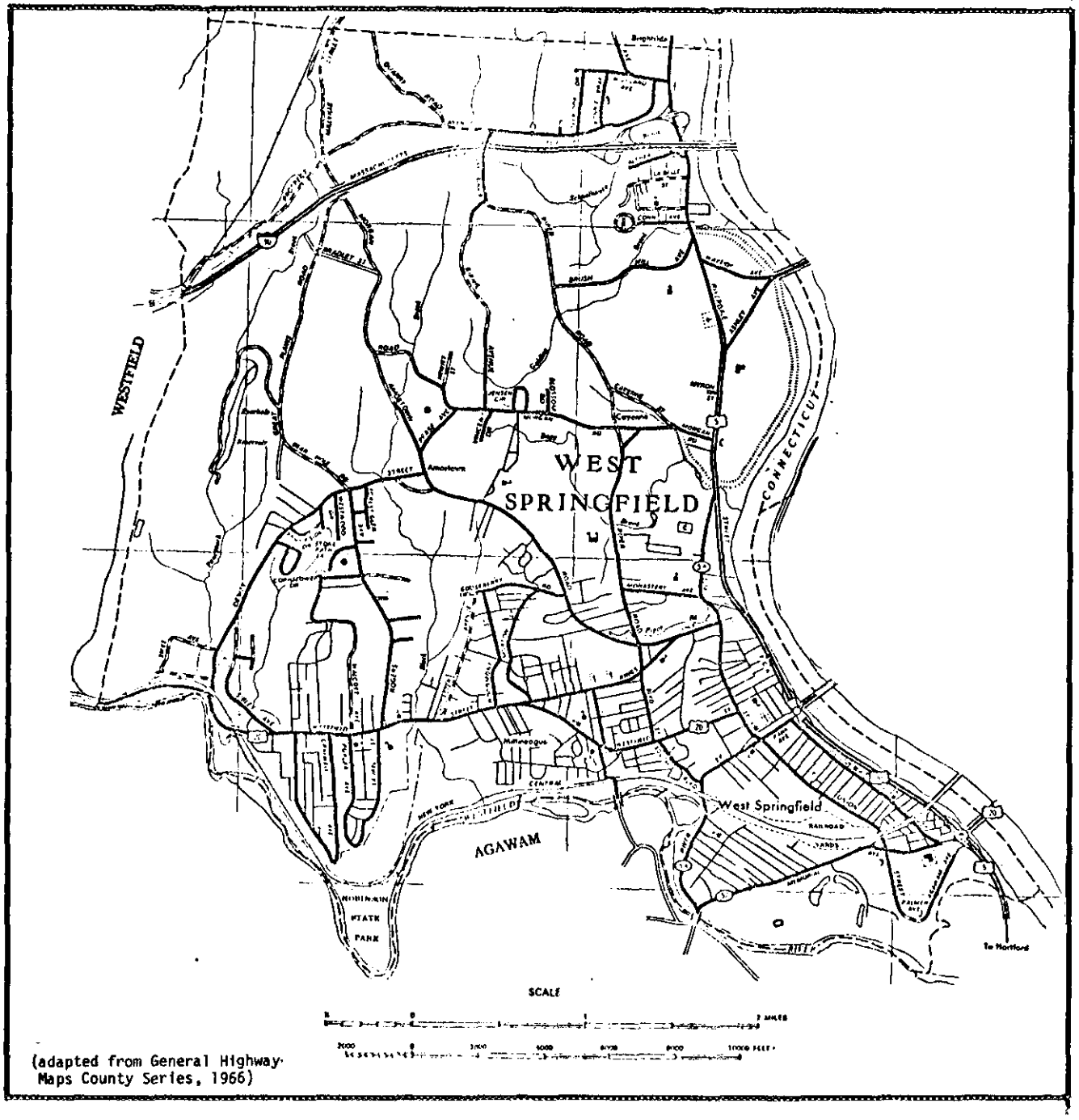


Fig. 14: Map of West Springfield.

TABLE 1

HISTORICAL PEAK STAGES, CONNECTICUT RIVER IN WEST SPRINGFIELD (4)

Date	Stage (ft.)	M. S. L. Elevation at Penn Central RR Bridge (ft.)
1927, November 5	22.0	60
1936, March 19-20	28.4	66.4
1938, September 22	25.75	63.2

The effects of the most serious flood, the March 1936 event, are described below in an excerpt from West Springfield, Massachusetts:

A Town History (5):

"Local residents recall that 1936 was one of the few years when the Agawam (Westfield) River didn't reach flood peak and subside before the Connecticut started to reach the high water mark. The result was what the newspaper called 'the biggest flood (the area) ever had.' Both rivers rose rapidly during Wednesday the 18th of March. Every effort was made to hold back the water at the Agaway Bridge and protect the lower end of town, in the area of Memorial Avenue, where the danger was first apparent. Over 1,000 feet of sandbags were put in levee form along River Street. However, the water rose so quickly all efforts failed.

"By late afternoon on March 18th the Connecticut had overflowed. Soon afterwards the Agawam (Westfield) was over its banks.... Before dark, water had inundated the Riverdale-Elm Streets area. ... Before the waters started to recede, several days later, the Connecticut had reached a peak of 28.4 feet--nearly 7 feet higher than during the flood of 1927.

"The population of the town at the time of the 1936 flood was 17,000. Out of that number, nearly 8,000 people were forced to leave their homes. Almost 2,000 of the town's 3,200 dwellings were involved, as were most businesses. Nearly 1,200 people found refuge in one of the seven emergency centers. Some of them stayed nearly three weeks and others found relatives or friends with whom they could stay after a few days."

Prompted by this flood, the U. S. Army Corps of Engineers undertook the design and construction of a dike and flood wall to run along two miles of the west bank of the Connecticut River (the Riverdale section) and three miles of the north bank of the Westfield River (the West Springfield section). These local protection works protect about 1,500 acres of highly developed industrial, commercial, public and residential property. In addition, if the historical floods were to recur today, stages on both the Connecticut and Westfield Rivers would be considerably lower than actually experienced due to the operation of the system of flood control reservoirs in the Basin. The reservoirs which have the most direct effect on reducing flood stages at West Springfield are the Barre Falls Reservoir (Chicopee River) and the Knightville and Littleville Reservoirs (Westfield River).

THE FLOOD PLAIN

The flood plain in West Springfield has been legally defined for zoning purposes by the limits of the Intermediate Regional Flood (IRF)* as determined by the U. S. Army Corps of Engineers on the Connecticut and Westfield Rivers. As depicted on Figure 15, this area is primarily restricted to that riverward of the dike and flood wall system which protects the town and includes an estimated thirteen business firms and fourteen dwellings(6).

Occurrence of a Standard Project Flood (SPF)** would result in overtopping of the West Springfield local protection works and result in inundation of approximately 1500 acres of protected area. The Riverdale dike would be overtopped by approximately one foot and the West Springfield dike by approximately four feet (4). The approximate area inundated is also indicated on Figure 15. Referral to the Generalized Land Use map of Figure 16 indicates that these areas contain the bulk of the city's commercial and industrial development. Historically, the area in the southern portion of the city, protected by the West Springfield dike, has developed as a consequence of the availability of water power and rail service. Major industries and commercial enterprises located in this area include the Eastern State Exposition Grounds, the Breck Co., Western Massachusetts Electric, and Sears Roebuck, Inc. Strathmore Paper Co., a large paper manufacturer located further to the west on the Westfield River, would also be affected. The area further to the north along Route

*The IRF is defined as a flood having an average frequency of occurrence in the order of once in 100 years or a flood with a 1% chance of occurring each year.

**The SPF is defined as the largest flood that can be expected from the most severe combination of meteorological and hydrological conditions that are considered reasonably characteristic of the geographic region involved.

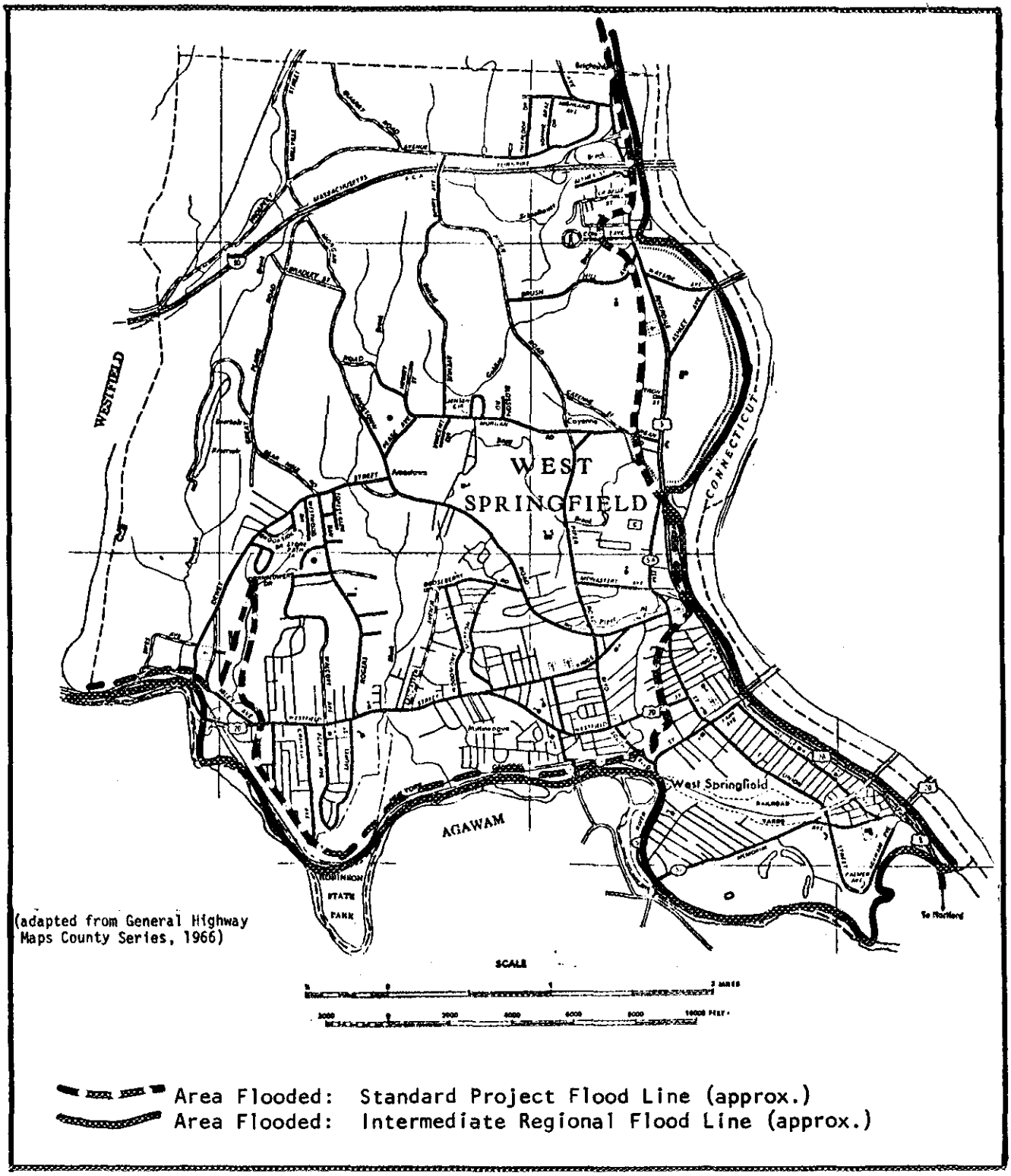
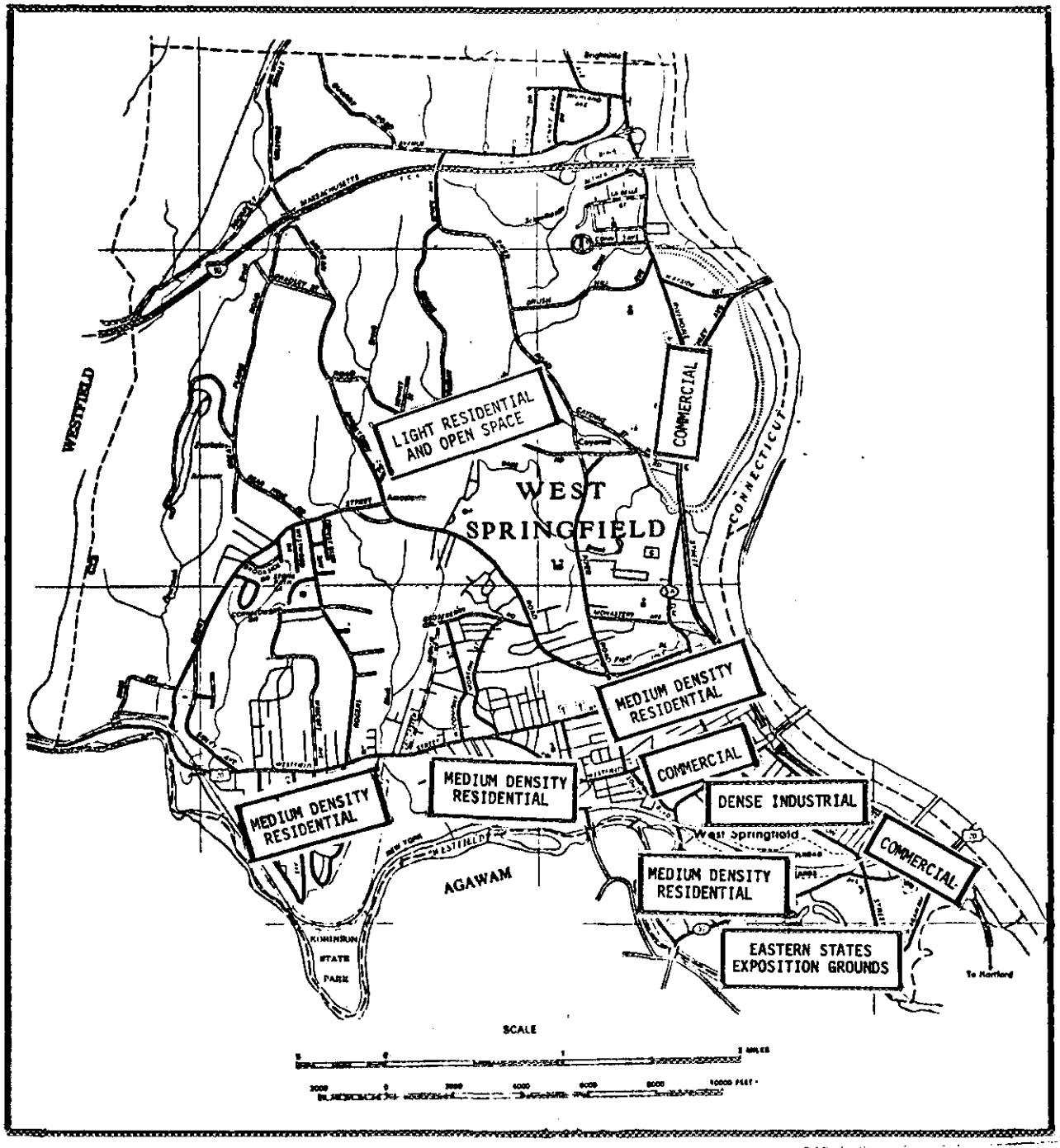


Fig. 15: Approximate areas flooded, West Springfield.



(adapted from General Highway Maps County Series, 1966)

Fig 16: Generalized land use map, West Springfield.

5 and near I-91, protected by the Riverdale dike, is continuing to develop as a result of access to these major transportation corridors. There are several motels and numerous other highway related commercial establishments located in this area. Further development in this area is probable. Obviously, the impact of a flood event of such magnitude, albeit a remote possibility, would be catastrophic to the economy of the city and region.

CLEARANCE

There are no recorded instances of public efforts to clear structures off the flood-prone properties in order to reduce the potential for flood damages. After the 1936 and 1938 floods and the subsequent construction of the local protection works, it is believed that the majority of property owners rehabilitated or rebuilt damaged structures with little regard to flooding (7).

The town is also pursuing plans to acquire open space for recreational purposes along Block Brook, a small watershed tributary to the Westfield River (8). These areas do not normally flood during high water periods on the Westfield, but the rapid urbanization of the watershed and the potential for increased urban runoff speak well for the open space plan.

FLOOD PROOFING

Private flood proofing efforts in West Springfield have been almost nonexistent, presumably due to the sense of security provided by the local protection works. Local building codes require only that building foundations be waterproofed (7). As noted above, there are only a few structures which would be affected by an IRF and these apparently are prepared to "bear-the-loss" with assistance from the National Flood Insurance Program. Public flood proofing efforts include the maintenance and operation of the stop log structures in the dike and flood wall system and the operational procedures required for the sewer lines and sewage treatment plant.

URBAN DRAINAGE

Urban drainage of flood waters in West Springfield is not considered to be a significant problem (8). Some localized flooding of a temporary nature is experienced during periods of intense rainfall. The town is presently pursuing plans to maintain open space along Broad Brook, a minor tributary watershed to the Westfield River which is undergoing urbanization.

Localized urban drainage which collects behind the dikes is handled by a pumping system consisting of five pumping stations, a relief well, and drainage system.

FLOOD PLAIN INFORMATION STUDIES

To date no Flood Plain Information Study has been completed by the U. S. Army Corps of Engineers for the Connecticut and Westfield Rivers in West Springfield. Information outlining the town's flood history and damage potential has been drawn from local sources and other publications, including the map of Plate M-11 of the Connecticut River Basin Comprehensive Study (9).

West Springfield, presently participating in the emergency flood insurance program, is anticipating making application for the regular program of the National Flood Insurance Program and is considering the need for more detailed flood damage potential data (8).

PUBLIC INFORMATION

The National Weather Service, River Forecast Center, Hartford, Connecticut, issues flood warnings for the Connecticut River. These warnings are received by West Springfield town officials, radio and television stations and the local press media for further dissemination to residents of the area. Additionally, the Corps of Engineers operates an Automatic Hydrologic Radio Reporting Network, which provides information essential for the regulation of flood control dams in the region.

FLOOD CONTROL IMPOUNDMENTS

There are presently 13 major flood control projects in the Connecticut River Basin above West Springfield operated by the Corps of Engineers. The impoundments which have the most direct effect on flood stages at West Springfield are the Knightville and Littleville projects in the Westfield River Basin and the Barre Falls project in the Chicopee River Basin. These projects have a total flood storage capacity of 96,000 acre-feet (9). Should there be a recurrence of a flood of the magnitude of the 1936 flood of record, these impoundments would reduce Connecticut River flood stages by approximately 3.5 feet.

LOCAL PROTECTION PROJECTS

Two major flood protection works have been constructed in the West Springfield area. The southern section, known as the West Springfield Local Protection Project, is located along two miles of the west bank of the Connecticut River and three miles of the north bank of the Westfield River. This federally-constructed dike protects about 1500 acres of highly developed industrial, commercial, public, and residential property. This area was heavily damaged in the March 1936 flood when locally built dikes were overtopped, undermined, and eroded. This southern section is about 24,500 feet long. It starts at high ground in the vicinity of Harrison Place and extends downstream along the Connecticut River and up the north bank of the Westfield River to high ground at the Penn Central Railroad.

The northern section of the protective works, referred to as the Riverdale Dike, starts near the intersection of U.S. Route 5 and Brush Hill Avenue, and extends 12,700 feet in an egg-shaped curve downstream along the west bank of Bagg Brook to high ground near Morgan Road (9). The outline of the dike system can be seen as nearly coincident with the IRF line of Figure 15.

CONCLUSIONS

West Springfield has little flood plain area outside of the protective works which line the Connecticut and Westfield Rivers and only a few properties would be subjected to an Intermediate Regional Flood (IRF). A Standard Project Flood (SPF), however, would overtop the dikes and result in inundation of the major portion of the industrial and commercial base of the town.

The locational advantages for development in the areas of the town protected by the dikes are evident and further development in the lower density portions of these areas such as that area behind the Riverdale Dike will undoubtedly continue.

Although the local protection works provide a substantial degree of protection, there is little awareness within the town that they could be overtopped. It would be to the town's advantage to consider additional flood damage reduction measures, such as the flood proofing of new buildings and the development and maintenance of an emergency action plan.

REFERENCES

(1) City and Town Monograph, Town of West Springfield, Massachusetts Department of Commerce and Development, 1972.

(2) Personal communication, Mr. George Boyle, Lower Pioneer Valley Regional Planning Commission, January 17, 1974.

(3) M. T. Thomson, et al., Historical Floods in New England, U. S. Department of the Interior, 1964, p. 65.

(4) Estimated from Plate No. M-11, Connecticut River Basin Coordinating Committee, Connecticut River Basin Comprehensive Water and Related Resources Investigation, June 1970.

(5) Swift, E. M., West Springfield: A Town History, 1968, pp. 106-109.

(6) Application for Eligibility under the Provisions of the National Flood Insurance Act of 1968, Town of West Springfield, Massachusetts, November 29, 1971, courtesy of Mr. William Dempsey, Town Planner.

(7) Personal communication, Mr. Ray DeStephano, Building Inspector, City of West Springfield, January 1974.

(8) Personal communication, Mr. William Dempsey, City Planner, West Springfield, January 1974.

(9) Water Resources Development in Massachusetts, U.S. Army Corps of Engineers, 1971.

PRESENT STATUS OF ELEMENTS

FOR FLOOD DAMAGE REDUCTION

WESTFIELD, MASSACHUSETTS

GENERAL

Westfield, Massachusetts, is located in the southwestern part of the state about 11 miles west of the city of Springfield in Hampden County. It is approximately 100 miles from Boston and 85 miles from Albany, New York. It is bordered on the east by the towns of Agawam, West Springfield and Holyoke, on the north by Southampton, on the west by Montgomery and on the south by Granville and Southwick (see Figire 17).

The city of Westfield, with a total area of 46.85 square miles, is generally hilly, with elevations ranging from 120 feet in the Westfield River valley to 800 feet in the surrounding hills. The city of Westfield is located in the level portion of the valley at the confluence of the Westfield River (drainage area at USGS gage, 497 square miles) and the Little River (drainage area at mouth, 84 square miles). Other smaller tributaries of significance in the central developed area of the city include Powdermill Brook and Great Brook (see map, Figure 18).

Originally settled in 1660, Westfield was incorporated as a town in 1669 and as a city in 1920. Due to its alluvial meadow lands, the inhabitants of this area were entirely devoted to agricultural pursuits for about 150 years. Tobacco was a major cash crop. Early land grants refer to the town as "Woronoco", meaning "the winding land." Population of the city, presently approximately 31,500 persons, is projected to increase to 35,190 in 1980 and 39,500 in the year 1990 (1).

The town has a substantial industrial employment base as a result of early utilization of water power on both the Westfield and Little Rivers. More recently, development has been aided by access to major rail and highway transportation routes which are located in or near the Westfield River valley.

FLOOD HISTORY

Flooding of the Westfield and Little Rivers in Westfield has been a common occurrence since the city was first settled. During most of these floods, damage has occurred to roads, residences, agricultural, commercial and industrial developments (2).

Floods on streams in this area can be expected at any time of the year and are caused by heavy rainfall alone or heavy rain augmented by melting snow. The floods of August 1955 and September 1938 were produced by heavy rain accompanying a tropical hurricane. The flood of

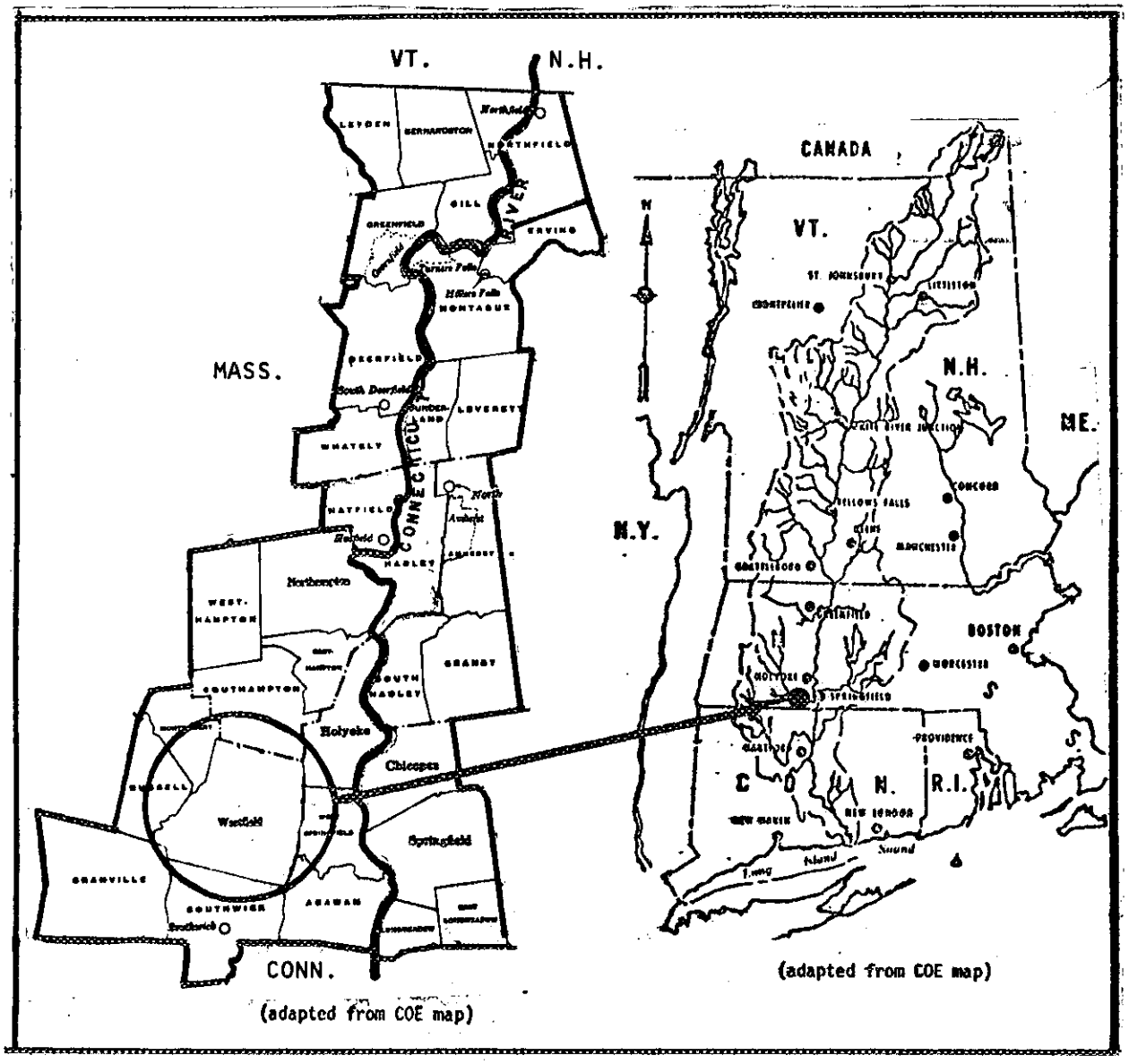
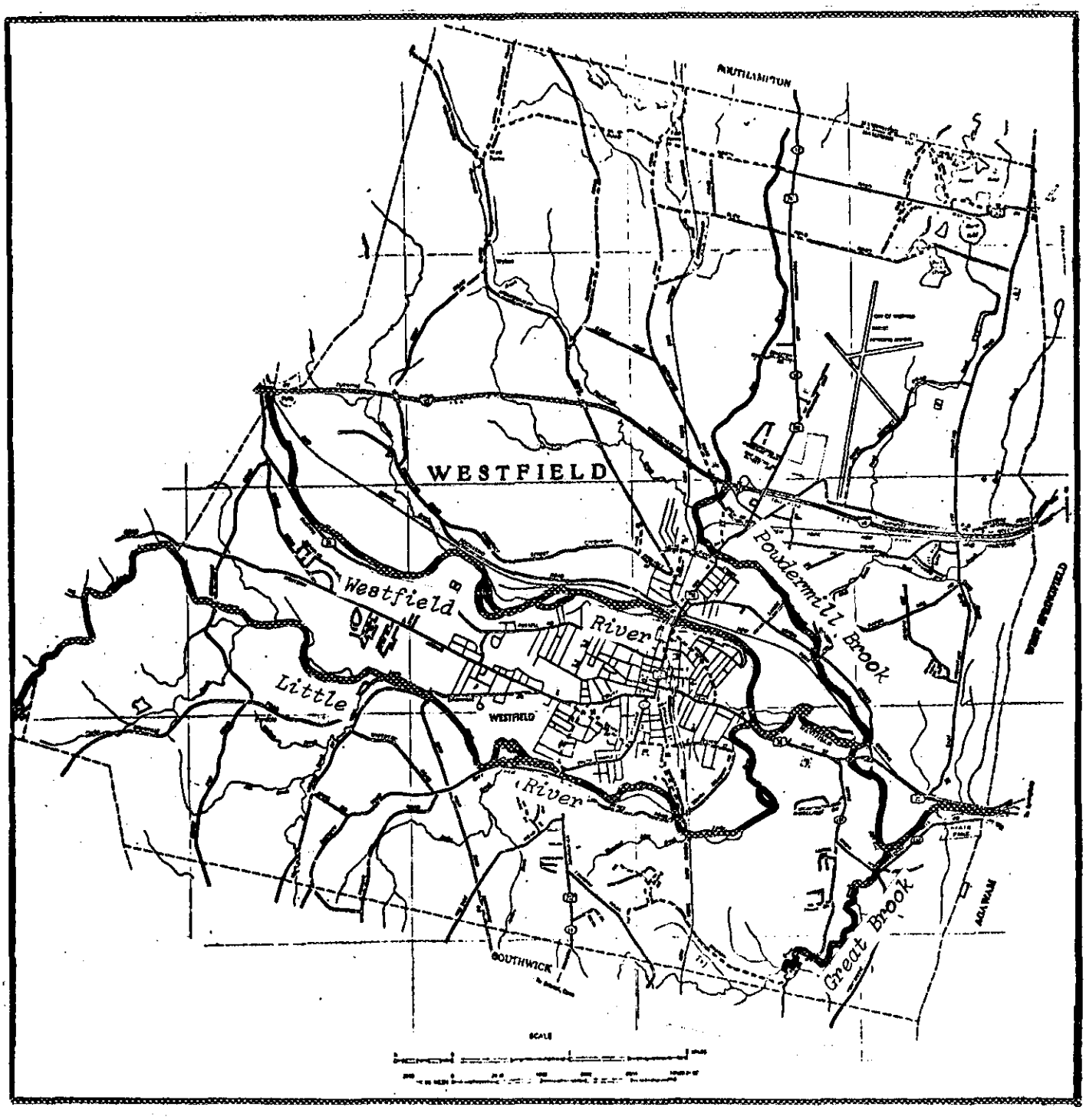


Fig. 17: Location map, Westfield, Massachusetts



(adapted from Commonwealth of Mass.
General Highway Map, Hampden Co.)

Fig. 18:. Map of Westfield.

March 1936 was caused by a combination of heavy rainfall and melting snow (2).

The highest known flood on the Westfield River in the vicinity of Westfield was that of August 1955 when the flood peak reached an elevation of 132. 4 feet (M. S. L.) at the USGS gage (located downstream near the West Springfield boundary). The September 1938 flood was about three to five feet lower in the vicinity where most damage occurred. The third largest flood occurred in March 1936. This flood was about four to seven feet lower than the flood of 1955. The highest known flood on the Little River occurred in August 1955. All other major floods which have occurred on the Little River have been modified by the Cobble Mountain Reservoir which controls more than half of the Little River drainage area (2). Pertinent information on peak discharges of the Westfield River near Westfield are summarized in Table 1 (3).

Floods higher than those of the past can occur. A study by the U. S. Army Corps of Engineers of floods and storms occurring in the area surrounding the city of Westfield indicates that future floods can be significantly higher than the record flood of August 1955(3).

The magnitude and potential impact of future flooding can be based on the determination of the Intermediate Regional Flood (IRF)* and the Standard Project Flood (SPF)**. These floods are determined from an analysis of floods on these streams and other streams in the same general area.

The analysis indicates that the Intermediate Regional Flood for the Westfield River is about equal to the flood experienced in September 1938 and about three feet lower than the August 1955 flood. On the Little River, the Intermediate Regional Flood is about one to two feet below the August 1955 flood (2).

The Standard Project Flood represents reasonable upper limits of expected flooding. Such floods on the Westfield and Little Rivers, based upon storms and floods which have already occurred over these watersheds and in the region, would be significantly higher than previous floods. Determinations indicate that the SPF flood level on the Westfield River below Elm Street Bridge would be three to five feet higher than that observed in August 1955. The Standard Project Flood determinations for the Little River indicate that water levels would be two to three feet higher than those in the August 1955 flood (2).

* The IRF is defined as a flood having an average frequency of occurrence in the order of once in 100 years or a flood with a 1% chance of occurring each year.

** The SPF is defined as the largest flood that can be expected from the most severe combination of meteorological and hydrological conditions that are considered reasonably characteristic of the geographic region involved.

TABLE 1

HIGHEST SIX KNOWN FLOODS IN ORDER OF MAGNITUDE
WESTFIELD RIVER, NEAR WESTFIELD, MASSACHUSETTS

Order No.	Date of Crest	Gage Height		Estimated Peak Discharge (cfs)
		Stage (Ft.)	Elevation (Ft.,msl)	
1	August 19, 1955/1	34.2	132.4	70,300/3
2	September 21,22, 1938	29.4	127.6	55,500
3	March 18, 1936	27.2	125.4	48,200
4	November 4, 1927	25.4	123.7	42,500
5	December 31, 1948/1	22.0	120.2	32,200/2
6	October 16, 1955/1	21.8	120.0	31,000/4

Notes:
1. Modified by Knightville.
2. Unmodified peak would have been 52,500 cfs.
3. Unmodified peak would have been 81,000 cfs.
4. Unmodified peak would have been 44,500 cfs.

TABLE 2

RELATIVE FLOOD HEIGHTS

Flood	Elm Street Bridge	Above or Below August 1955 Flood	
		Confluence of Little and Westfield Rivers in feet	Westfield USGS Gage
August 1955/1	0	0	0
September 1938	1.8	- 3.3	- 4.8
Intermediate Regional/2	0.9	- 3.0	- 5.7
Standard Project/2	4.8	3.0	5.0

Notes:
1. Modified by Knightville Flood Control Dam.
2. Modified by Knightville and Littleville Flood Control Dams.

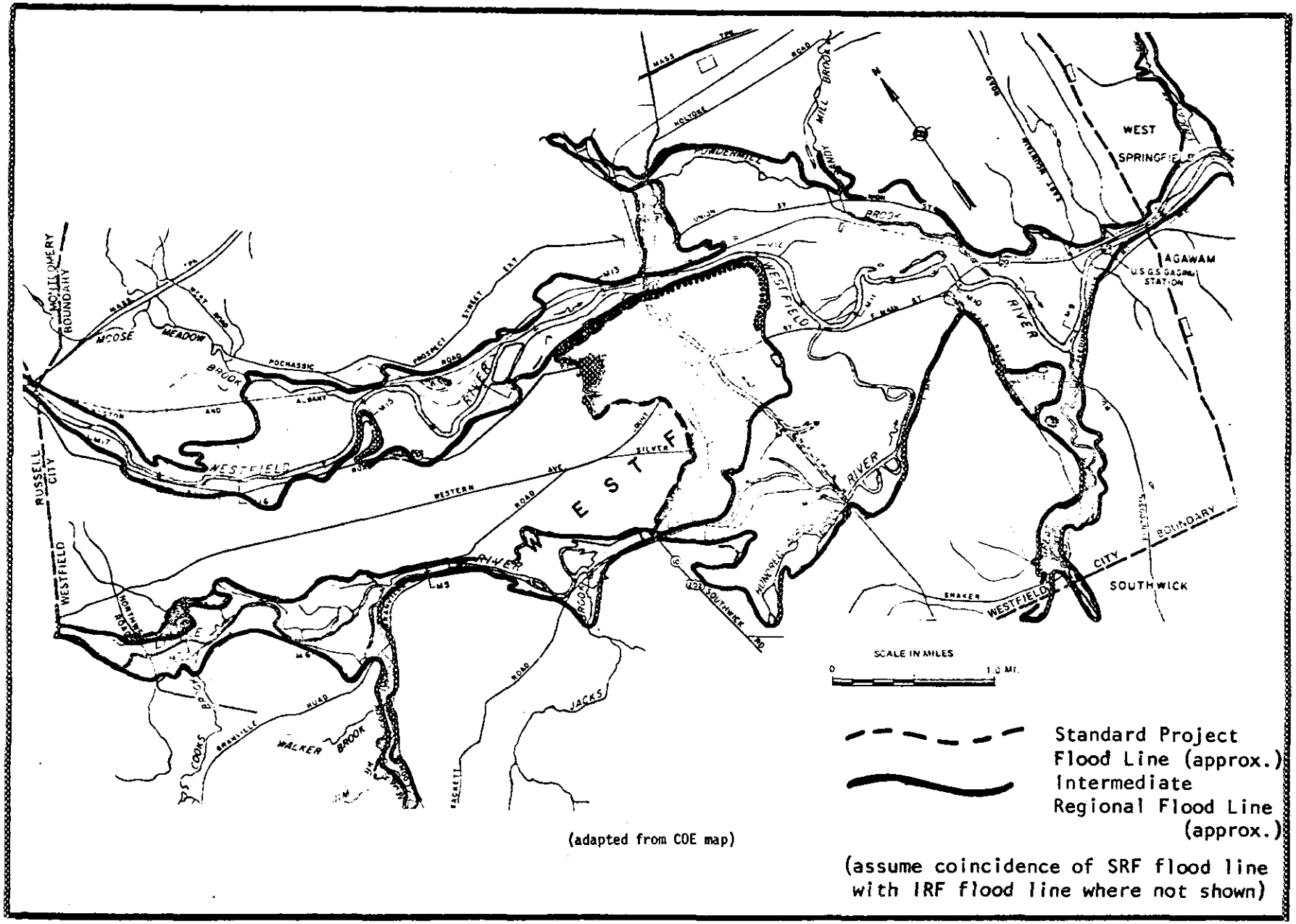
Table 2 summarizes the comparison of the flood heights along the Westfield River. The areas of Westfield which would be flooded by the Intermediate Regional Flood and the Standard Project Flood are outlined in Figure 19 (2).

THE FLOOD PLAIN

Over 3,100 acres in the city of Westfield are subject to flooding by the Standard Project Flood modified by the Knightville and Littleville Reservoirs. Figure 20 presents a generalized map of land use in the flood plain. More than 1,900 residential properties, 260 commercial establishments, and 30 public buildings, comprising a major portion of the main business district and valued in excess of $20,000,000 are vulnerable to flooding in the Westfield area (3). Most of these urban properties are located in the highly developed lowland between the Westfield and Little Rivers. This area is vulnerable to flooding by the Little River and by the Westfield River through breaching or overtopping of an inadequate dike on the right bank of the mainstream (3).

The flood of record, the August 1955 event, inundated approximately 2,000 acres, caused damage to about 633 dwellings (of which 423 had water to at least the first floor and some up to 12 feet higher), 55 commercial establishments, 11 industrial enterprises, and 16 farms (3). The greatest industrial losses were incurred by Stevens Paper Company (which lost two dams) and the Sterling Radiator Company (which lost three buildings), both of which are located on the Little River.

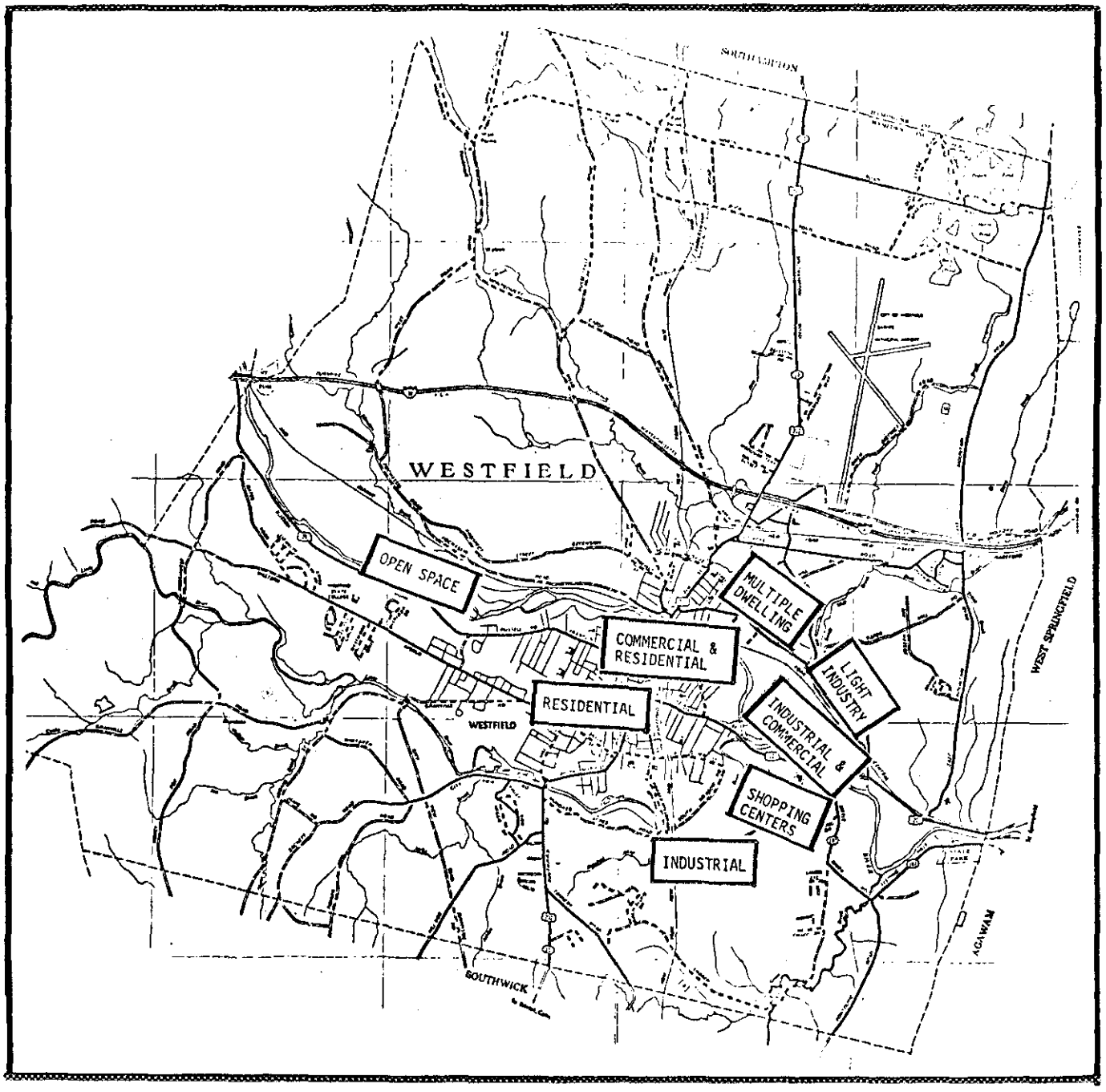
Since the 1955 flood and the subsequent completion of Littleville Reservoir on the Middle Branch Westfield River, extensive development has taken place on the flood plain to the east of the city center along Route 20 (4). The development in this area, highlighted on the map of Figure 20, consists of the multimillion dollar shopping plazas, Westgate Shopping Center and Westfield Shopping Center, a branch savings bank, an Agway warehouse and a trailer park all located to the south of Route 20 just east of the confluence of the Little and Westfield Rivers. Industrial and commercial development has occurred to the north of Route 20 in this same area and consists of several automobile dealerships, gas stations, a propane gas storage yard and the New England Concrete Pipe, Inc. Much of this development has probably occurred as a consequence of access to the railroad which traverses the flood plain. Approximately 500 units of multiple dwelling housing units have been built just to the south of Powdermill Brook and north of Union Street within the encroachment line of the Intermediate Regional Flood.



(adapted from COE map)

(assume coincidence of SRF flood line with IRF flood line where not shown)

Fig. 19: Flood plains, Westfield.



(adapted from Commonwealth of Mass.
General Highway Map, Hampden Co.)

Fig. 20: Generalized land use map, Westfield.

It is obvious that the occurrence of a flood of the order of magnitude of the Intermediate Regional Flood (frequency of occurrence approximately 1 in 100 years) would be disastrous to the economic and social well-being of the city of Westfield and the region. This is in spite of the presence of the Knightville and Littleville flood-control reservoirs upstream in the Westfield River basin.

CLEARANCE

There are no recorded instances of public efforts in Westfield to clear structures off flood-prone properties in order to diminish the potential for flood damages due to flooding. A number of houses and industrial buildings damaged during the 1955 flood were condemned and not renovated because of the extent of damage. However, this was a consequence of a decision made on the basis of the costs of renovation by the individual property owners involved, and not a part of a coordinated community effort.

FLOOD PROOFING

Flood proofing of buildings and structures susceptible to flooding is not required by ordinance in Westfield (4). Damages sustained by the water supply system during the 1955 flood have prompted flood-proofing efforts during construction, e. g., the electrical equipment at the new water supply wells has been flood-proofed. The recently constructed sewage treatment plant, located just downstream from the confluence of the Little and Westfield Rivers, has been designed so that critical electrical gear can be removed.

A flood plain zoning ordinance, in draft form for some time and not yet enacted, would require that buildings used as dwellings be constructed with the main floor at least three feet above the Intermediate Regional Flood level, and that all new construction be conducted according to flood proofing guidelines published by the Corps of Engineers (5). Recent development in the flood plain, described above, has not been conducted in accordance with any of the standard flood-proofing criteria (4).

URBAN DAMAGE

Heretofore, urban drainage of flood waters in Westfield has not resulted in extensive or frequent damages, with the possible exception of the Powdermill Brook area. A recently completed Soil Conservation Service Project (P. L. 566) on the Powdermill Brook provides flood control benefits for a portion of the northern part of Westfield. Approximately 40 percent of the Powdermill drainage area (5,076 of 12,800 acres) is controlled by the project (5).

FLOOD PLAIN INFORMATION STUDIES

A flood plain information study for the Westfield and Little Rivers in Westfield has been completed by the Corps of Engineers (3). The report summarizes the flood history of the city and delineates the extent of inundation for the Intermediate Regional and Standard Project Flood events (see Figure 19). This information is a necessary prerequisite for rational determination of the flood plain which would be subject to regulation by local ordinance in the event such an ordinance is enacted. Local regulatory control of development in the flood plain is required before a municipality can qualify for the National Flood Insurance (NFI) Program. Westfield has qualified for participation in the emergency phase of the NFI Program but it does not appear that any restrictions have been placed on development which has taken place since the 1955 flood.

PUBLIC INFORMATION

As evidenced by the extensive development which has occurred in the Westfield flood plain there is little or no formal information program to altert developers of the potential threat. It may be that the threat is well-recognized but that development occurs because of other more compelling locational decision criteria.

The Westfield and Little Rivers rose at an average rate of 2.7 feet per hour over a seven-hour period during the 1955 flood. This indicates the need for an effective early warning communications system to alert residents and property owners of impending flood threat. The city's local radio, television and press media receive flood warnings from the National Weather Service, River Forecast Center in Hartford, Connecticut. Subsequent action is carried out by the civil defense agency working in conjunction with the police and other responsible agencies. Some confusion was experienced during the 1955 flood because flood warnings were issued for the Connecticut River and not for the Westfield River.

FLOOD CONTROL RESERVOIRS

There are presently two major flood control reservoirs in the Westfield River basin which provide a measure of protection to the city of Westfield. The Knightville Dam, completed in 1941, is located on the Westfield River about four miles north of Huntington, Massachusetts. The reservoir has a flood control storage capacity of 49,000 acre-feet,

equivalent to 5.7 inches of runoff from the drainage area of 162 square miles (7). Littleville Dam, completed in 1965, is located on the Middle Branch of the Westfield River, one mile upstream of its confluence with the main river. The project provides a multiple purpose flood control and water supply reservoir with a total storage capacity of 32,400 acre-feet, of which 23,000 acre-feet, or 8.2 inches of runoff from the tributary drainage area of 52.3 square miles, is reserved for flood control (7).

Cobble Mountain Reservoir, on the Little River, provides some degree of incidental flood storage but its primary purpose is for water supply.

The Powdermill Brook flood prevention project, recently completed by the Soil Conservation Service, provides flood protection to properties adjacent to the small tributary in the northern part of Westfield. The project, which consists of two earthen dams, provides a total flood storage capacity of approximately 1,100 acre-feet and controls 5,076 acres of the total 12,800 acre drainage area of the tributary (5).

LOCAL PROTECTION

At Westfield, the dike on the right bank of the Westfield River upstream of the Elm Street Bridge was constructed prior to 1869. This dike has been overtopped and washed out several times. After the 1938 flood, it was rebuilt and extended downstream by the Commonwealth of Massachusetts. In 1955, the state-constructed dike failed, either by overtopping or by breaching. The dike, which has since been repaired, gives only limited protection to the main industrial, commercial, and residential areas in Westfield (3).

A local protection project for Westfield has been recommended for authorization by the Corps of Engineers. The project consists of dikes along both the Little and Westfield Rivers for protection of the center of the city and along the north bank of the Westfield River to protect the industrialized areas. A 1973 estimate indicates a total cost including channel realignments of approximately $16.8 million (8).

CONCLUSIONS

The city of Westfield has been subjected to recurring large floods which have caused extensive damages and human suffering. In the face of this, the city has taken little or no action to reduce the potential for future damages of a similar nature. In fact, new development has continued apace on land which has been inundated frequently.

As discussed above, the occurrence of a large flood, such as the Intermediate Regional Flood, would result in extensive damages to the city, in spite of the presence of two large flood control reservoirs upstream.

The question remains, however, as to what actions can be taken to reduce the potential for these or larger losses in the future.

The city has drafted a flood plain zoning ordinance, some form of which could be adopted. The restrictions placed on future development by such an ordinance would help reduce the potential for extreme flood damages through provisions on minimum first floor elevations and flood proofing.

The city would do well to study the possibility of preventing development on existing open space located within the flood plain. Acquisition of property and use for parks or recreational areas could be considered. The Westfield River flood plain upstream of the city center could provide an opportunity for such actions.

Additional study on the feasibility of providing local protection for existing development is another alternative which should be considered. Also, because the Westfield River has a tendency to rise rapidly during flood conditions, a detailed action plan for early warning and emergency evacuation should be maintained in readiness. Given enough warning, the potential danger of, for example, a liquid propane tank being floated downstream could be averted.

The city of Westfield has the opportunity to institute a range of measures for reducing the flood damage potential on its flood plains. The need for action is unquestionable.

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(5) U.S. Department of Agriculture, Soil Conservation Service, Powdermill Brook-Watershed Protection and Flood Prevention Project.

(6) Personal communication, Mr. Robert Gardner, Civil Defense Coordinator, Westfield, Massachusetts, January 1974.

(7) U.S. Army Corps of Engineers, New England Division, Water Resources Development by the USCOE in Massachusetts.

(8) Letter to Planning Department, Westfield, Massachusetts, from Mr. John Leslie, U.S. Army Corps of Engineers, Waltham, Massachusetts, July 1973.

PRESENT STATUS OF ELEMENTS

FOR FLOOD DAMAGE REDUCTION

CHICOPEE, MASSACHUSETTS

CHICOPEE, MASSACHUSETTS

GENERAL

The city of Chicopee, Massachusetts, is located in the north central portion of Hampden County at the confluence of the Connecticut and Chicopee Rivers. It is bordered on the north by South Hadley and Granby, on the west by the Connecticut River, on the south by Springfield, and on the east by Ludlow. The terrain is gently rolling, and is dominated by the two valley systems bordering the Connecticut and Chicopee Rivers. It is therefore not surprising that most of the city's development has been along these two river systems. The map of the city (Figure 21) indicates that there are essentially three areas of intense development: the Willimansett area east of the Connecticut River, Chicopee center at the mouth of the Chicopee River and Chicopee Falls north of Springfield on the Chicopee River. In addition, scattered development has taken place in the vicinity of Westover Air Force Base, which will soon shut down.

Chicopee is one of the oldest towns in western Massachusetts. It was first settled in 1641 and originally was the northern portion of Springfield. The broad meadows along the two rivers attracted the first settlers, and the area remained a quiet farming community until the early 19th Century when the Chicopee River's water power began to be tapped for industry. Today industrial manufacturing continues to form the basis of the city's economy. Important products include electrical machinery, rubber and sporting goods. In 1971, fully 64.6 percent of the employed population was engaged by 98 manufacturing firms.

Chicopee's resident population has increased steadily over the past 20 years. In 1970, the figure stood at 66,676 people including those attached to Westover Air Force Base. Despite the base closing, it is anticipated that the population of Chicopee will continue to grow. The projected population for the year 1995 is 73,386 people. [1]

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[1] Population figures extracted from "Water Pollution Control Report, City of Chicopee, Massachusetts," prepared by Tighe & Pond, Inc., 1972.

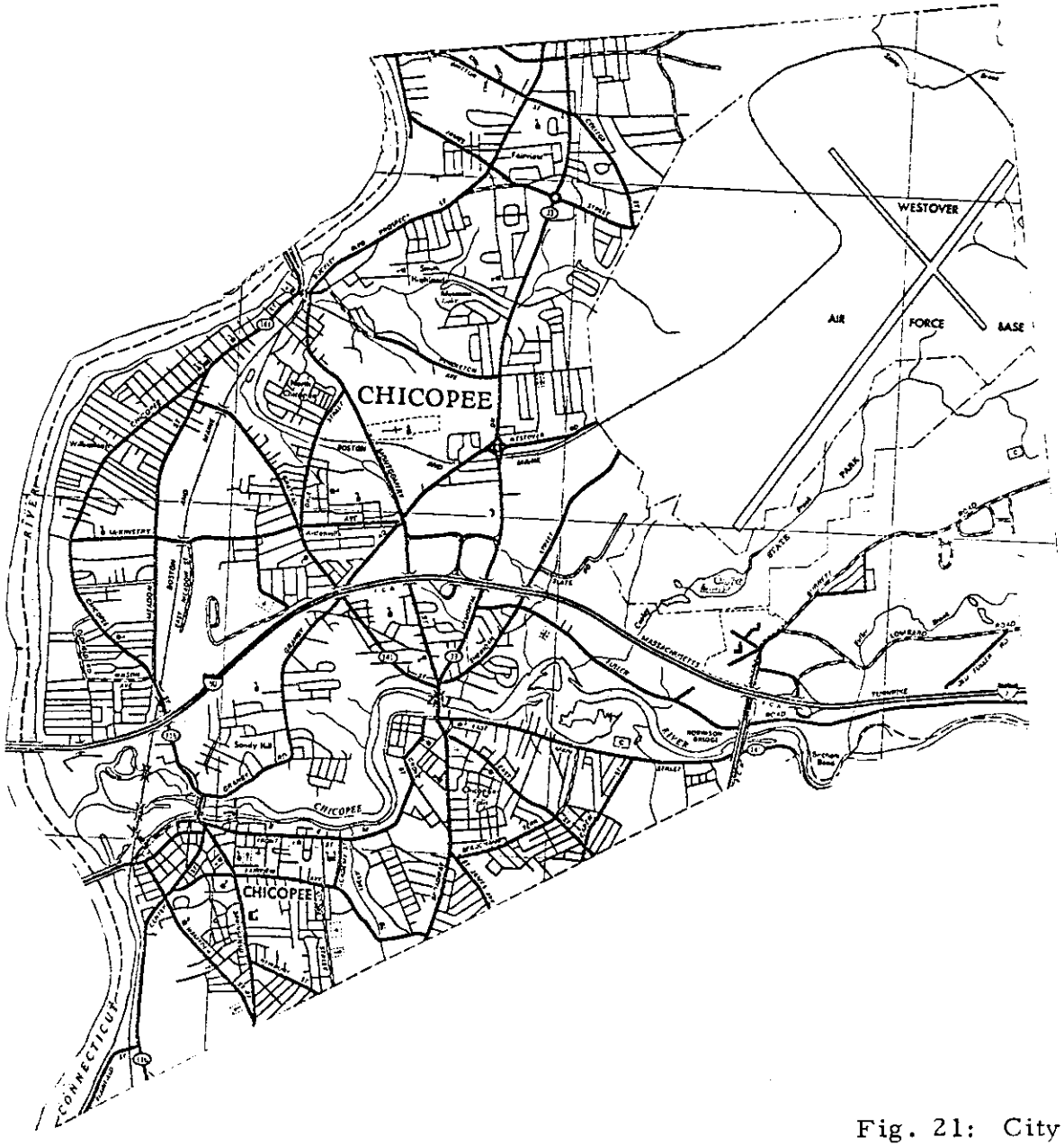

Fig. 21: City of Chicopee

Flood History

It is apparent that both the Chicopee and Connecticut Rivers have played an important role in both the physical and economic development of the city. Unfortunately, flooding on both of these streams has also been a part of Chicopee's history. Major historical floods on the Connecticut River have been recorded as early as 1639. Since that time, floods such as the "Jefferson Flood" in 1801, the "Nebraska Flood" in 1854, and the "Pumpkin Freshet" in 1869 have all caused varying degrees of damage to Chicopee and its environs. By far, the most destructive floods have occurred in the present century, due in part to increased river stages and also to the accelerated development of flood prone lands. The flood of record on the Connecticut River near Chicopee is the March 1936 event. Two years later in 1938, intense rains caused by a hurricane produced a record flood on the Chicopee River. Both of these events caused extensive damage to sections of Willimansett, Chicopee Falls and Chicopee center. In August 1955, hurricane Diane swept through the area causing heavy rains and a flood on the Chicopee River which almost matched that of 1938. Again, damage to Chicopee was extensive.

As a result of these historical floods, a series of local protection works have been erected in Chicopee, both along the Connecticut and the Chicopee Rivers. Also completed were a number of upstream flood control impoundments which will help lower future flood stages. Still, larger floods have been experienced in the past on streams with similar geographical and physiographical characteristics as the Connecticut and the Chicopee. Therefore, the potential for future flooding in Chicopee must certainly be considered a possibility.

The Flood Plain

Chicopee River. The Chicopee River is the largest stream tributary to the Connecticut River. Its flood plain is generally narrow, but in certain areas extends from 1,000 to 2,000 feet or more on either side of the channel. However, the existing local protection works in Chicopee center and Chicopee Falls have greatly reduced the natural flood plain in those areas. The Flood Plain Information Report for the Chicopee River has been completed and defines those areas of Chicopee subject to flooding. The Intermediate Regional Flood (IRF) would inundate about 480 acres, which is defined as the flood hazard area. Of this land, approximately 60 percent or about 290 acres is

in the vicinity of the Oxford Country Club and Bircham Bend. This area is primarily open space with but a few private residences along Fuller Road; thus damages in this section would be limited. Of the remaining 190 acres, the vast portion of this hazard area lies at the mouth of the Chicopee and is flood plain common to both the Chicopee and Connecticut Rivers. This area is virtually free of development except for an abandoned power facility. In the event of a Standard Project Flood (SPF), an additional 210 acres would be flooded, most in Chicopee center including portions of the city's industrial and residential core and many of the plants on Canal Street.

The flood potential on the Chicopee River is further complicated by the presence of a number of obstructions, dams and bridges, which could cause serious backwater effects in the event of high river stage. There are four bridges across the Chicopee River in Chicopee. The under-clearance elevation of two of these bridges is but a few feet higher than the projected stage of the IRF, and thus collecting debris and high water could seriously limit their carrying capacity.

Connecticut River. The flood plain of the Connecticut River in the vicinity of Chicopee has been greatly reduced by the erection of local protection works. The flood of record, in March 1936, inundated vast portions of Willimansett and Chicopee center. As a result, the Army Corps of Engineers, in 1941, completed a system of dikes and floodwalls to protect these areas. Still, a small portion of Chicopee's riverfront, north of the Holyoke-Willimansett Bridge remains unprotected. Originally, it was planned to construct two short lengths of dike in this area, but these plans were subsequently dropped. In the event of an IRF, a railroad spur, an industrial plant and road connections in this low area would be flooded. If the Standard Project Flood were to occur today, it is estimated that the Chicopee dike would be topped by almost two feet and that roughly 1200 acres of Chicopee's residential and industrial center would be under water.

Clearance

Despite the number of damaging floods the city of Chicopee has experienced, there has never been any formal clearance program proposed for its flood-prone areas. Most of the firms damaged by floods have remained at pre-flood locations, and some have increased their plant capacities since the 1955 event. Plant space has been added in some areas and at least one firm has shifted its location within the flood-prone area.

Flood Proofing

There are no existing city or county zoning ordinances, building codes, or other regulatory measures specifically for the reduction of flood damages. A quick sampling of local commercial and industrial concerns indicated that most private flood proofing was limited to sump pumps and evacuation of valuable materials. Also much of the industrial materials, including lumber, containers and storage tanks, is unrestrained, and, if carried away by flood waters, these objects could cause serious damage to downstream structures and could clog bridge openings creating serious backwater problems.

Urban Drainage

All the major residential and industrial portions of Chicopee drain toward either the Connecticut or Chicopee Rivers. Since the early nineteenth century, the city has had a sewerage system. For the most part, this system is combined and many miles of the old brick and segmental tile sewers are still in service. In general, these sewers are adequately sized to carry most storm water runoff in addition to the sewage load. Yet some drainage problems do exist primarily in the industrial areas of Chicopee and Chicopee Falls. A report completed in 1958 estimated that the sewer system could pass a storm water flow 1500 gallons per day per acre, which is roughly the equivalent of .18 inches of rainfall per day. Storm water runoff in excess of this figure is allowed to overflow, through a system of sewage regulators, to the rivers to prevent complete inundation of the wastewater treatment plant. In some cases, localized urban flooding results from this practice.

Flood Plain Information Reports

As mentioned previously, the Flood Plain Information report has been completed for the entire Chicopee River. Also, the U.S. Geological Survey has prepared a series of maps for the Connecticut River Basin, which delineate those areas that are considered "flood-prone." Both of these sources should be a great help to the city of Chicopee in its present effort to obtain eligibility for the National Flood Insurance Program.

Public Information

The U.S. Department of Commerce, National Weather Service, is responsible for monitoring high water on the nation's rivers and for issuing flood warnings for the protection of life and property. The Connecticut River Basin comes under the jurisdiction of the Department's National

Weather Service River Forecast Center at Hartford, Connecticut, which issues warnings to city officials, radio and television stations and the local press media for further dissemination to residents of the area. Subsequent action in Chicopee is carried out by the civil defense agency working in conjunction with the police and the Chicopee Sewage Division. Additionally, the Corps of Engineers operates an Automatic Hydrologic Radio Reporting Network, which provides information essential for the regulation of flood control dams in the region.

Flood Control Impoundments

While flood stages at Chicopee are affected by all of the upstream Corps of Engineers flood control dams, of particular significance to the city are the dams at Barre Falls and Conant Brook, both on major tributaries of the Chicopee River. The larger of these two dams, Barre Falls, is located on the Ware River in the town of Barre, and has a capacity of 24,000 acre-feet. Conant Brook Dam and Reservoir was completed in 1966 and provides 3,740 acre-feet of flood storage on Conant Brook in the Quaboag River Basin. It is estimated that the combined operation of these two dams will effect reductions of flood stages downstream on the Chicopee River to levels for which the completed local protection works are built. Reductions effected by dams on the Connecticut have been less significant and would not prevent topping the dike system in the event of the SPF.

Local Protection Works

Local protection structures have been erected in two separate areas of Chicopee: Chicopee Falls and along the Connecticut River near the mouth of the Chicopee. In Chicopee Falls, the project is located primarily along the east bank of the Chicopee River. It provides flood protection for the heavily industrialized area by means of dikes and floodwalls extending from Chicopee Dam downstream for approximately 5,000 feet to high ground. The improvement also includes about 3,300 feet of channel modifications along the west bank near the lower end of the project. Surface drainage immediately upstream of the protected area and interior drainage are intercepted and subsequently controlled by two pumping stations.

Protective works along the Connecticut River may be divided into two sections, above and below the mouth of the Chicopee River. In the upper reach, an earth dike extends along the east bank of the Connecticut River for about 3.8 miles from high ground at Leslie Street, downstream along the Connecticut River and up the north bank of the Chicopee River to high ground at Bertha Avenue. This section also includes four pumping stations.

The lower section of the works runs along the southern bank of the Chicopee River, starting just above the Davitt Memorial Bridge (Route 116), and extends downstream along the Chicopee and Connecticut Rivers to high ground near Depot Street. In all, the lower dike and wall extends 4,700 feet and includes four sets of tailrace gates at water-using industries, and the Dwight Street Pumping Station.

A section of Chicopee just above the Springfield city line is protected by the Springfield protective works. However, the city of Chicopee operates and maintains all the works within the city limits.

Conclusions

There are two major streams within the city of Chicopee-the Connecticut and Chicopee Rivers. It is evident that the major flood prevention and protection measures taken thus far in the city of Chicopee have been federally sponsored. The Army Corps of Engineers has completed local protection works along both the Connecticut and Chicopee Rivers and has constructed flood control reservoirs on two upstream tributaries of the Chicopee. As a result of these efforts, the flood threat to populated sections along the Chicopee River have been greatly reduced. Still, the potential for flooding exists in certain sections of the city, notably the region around the Oxford Country Club, Bircham Bend and the northern portion of Willimansett. Local efforts to mitigate flood damage, both public and private have been quite limited.

As a first effort, the city should press its current effort to secure HUD flood insurance eligibility. Also, the city should examine the results of studies completed to date, and develop flood plain zoning and a flood plan of both structural and nonstructural flood control.

PRESENT STATUS OF ELEMENTS

FOR FLOOD DAMAGE REDUCTION

HOLYOKE, MASSACHUSETTS

GENERAL

Holyoke, Massachusetts, is located in Hampden County in the southwestern part of the state. It is bordered on the east by South Hadley and Chicopee, on the south by West Springfield, on the west by Westfield and Southampton, and on the northwest by Easthampton (see Figure 22). It is 97 miles from Boston, 142 miles from New York and 34 miles from Hartford, Connecticut.

Holyoke, having an area of 21.2 square miles, has a generally hilly terrain which rises sharply from the Connecticut River, which forms the eastern boundary, to elevations of three to four hundred feet (M. S. L.) in the major developed portions of the city. The Connecticut River and the Holyoke dam and canal system constitute the principal drainage and hydraulic features of the city (see map, Figre 23).

Once known as "The Paper Capital of the World," Holyoke today is a manufacturing center with a diversified economy. Organized as a town in 1850, it was named for Captain Elizur Holyoke. Water power has been the impetus for industry, with a great dam spanning the Connecticut River between Holyoke and South Hadley Falls, feeding three levels of power canals along which mills and factories are located. The area is also known for the Atlantic shad runs, some of which pass the dam by means of a fishway on their upstream migration, and the Triassic dinosaur tracks which were uncovered during construction of I-91 (1).

Population growth in the city has been decreasing, reflecting an exodus to outlying suburban development. From a 1960 level of 52,689, the population decreased to its present level of approximately 50,112 persons. Projections indicate a 1990 population of approximately 48,000 persons (2).

FLOOD HISTORY

The waters of the Connecticut River have sustained Holyoke's industry for more than a century, but there have been a few occasions when the same river rose to a level where its force was destructive. The 1936 flood was the highest of the three major floods on the Connecticut River in the past 50 years; the other two occurred in 1927 and 1938.

Flood stage at the Holyoke Water Power (HWP) dam is 9.0 feet (i.e., a 9.0 foot depth of water flows over the dam) above which flooding of lowlands occurs. Records of the HWP Company showing the occurrence of flood levels are listed in Table 1 (3). Industries in Holyoke have for many

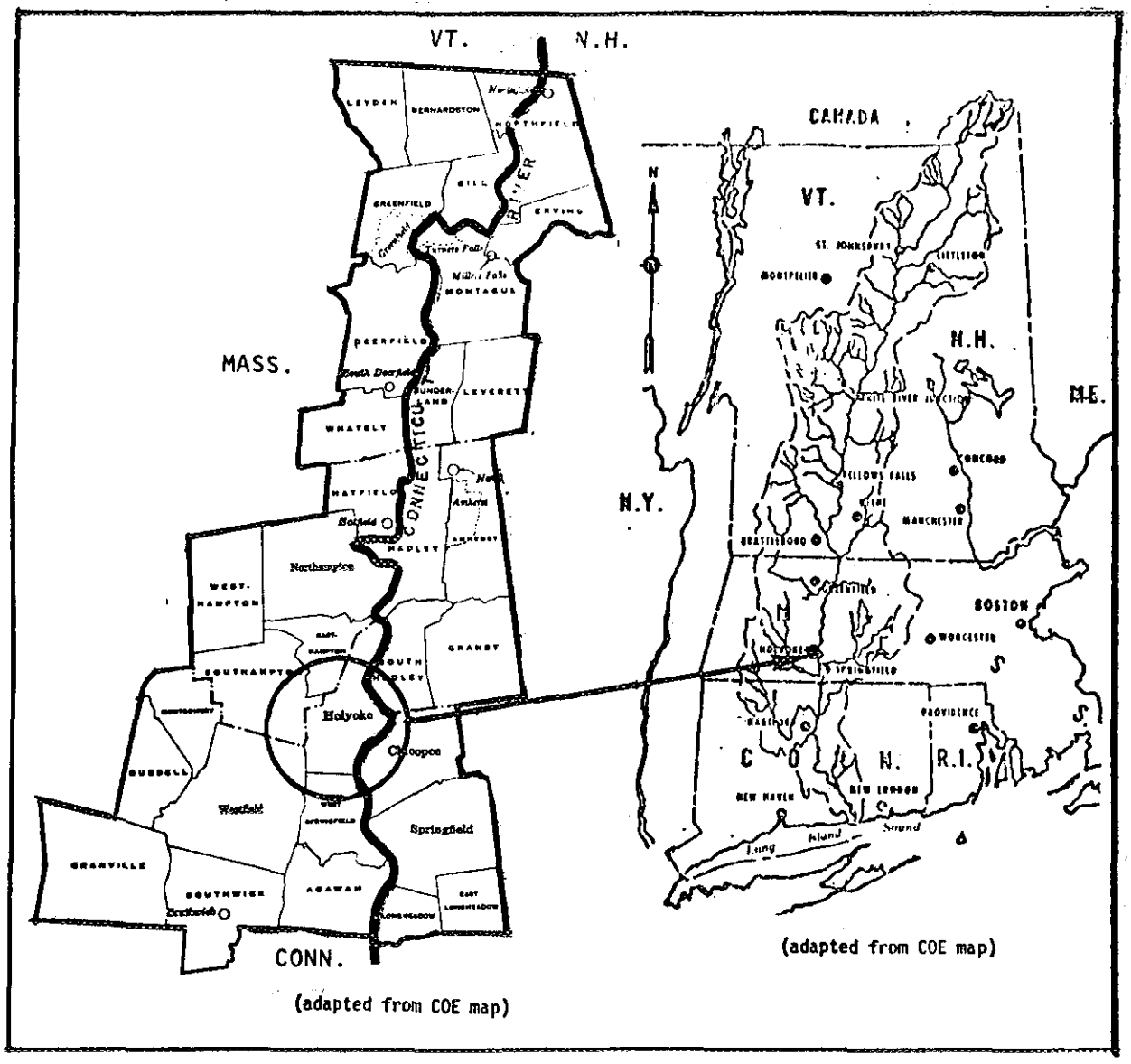

Fig. 22: Location map, Holyoke, Massachusetts

years called upon HWP river stage recordings as a supplement to that available from the U. S. Weather Bureau.

TABLE 1
HISTORICAL FLOOD STAGES AT HOLYOKE DAM

Year	Flood Stage at Dam (feet)
1960	12.0
1901	12.1
1862	12.5
1869	12.7
1913	12.7
1933	13.2
1927	14.75
1938	14.9
1936	16.8

A huge ice jam preceded the 1936 flood. It began to form on March 13 about six and one-half miles above the dam at Mt. Tom Junction and diverted the river flow through Hockanum Meadows to the east. The jam moved out on the 15th, passing over the dam at a river stage of 9.5 feet. The river then started to level off, but heavy rains up river and warm weather in the entire watershed started it rising again.

A HWP hydraulic engineer's report discusses the protective actions taken by the company during the 1936 flood (4). Three vulnerable spots were listed where the company had to take emergency measures to hold off the river. Those locations were the gatehouse and railroad cut on the Holyoke side, the South Hadley abutment and gatehouses, and the hydro and steam electric station on the river bank at the foot of Mosher Street. Sandbagging operations were completely successful at either end of the dam but at the electric generating station water broke through a sandbagged window and flooded the entire generating station. Damages were severe in other portions of the city as well.

Since the 1938 flood event the U. S. Army Corps of Engineers has designed and constructed flood protection works along the west bank of the Connecticut River in Holyoke. The protection works, built to a height of 3.0 feet above the maximum level of the 1936 flood, provide flood protection for about 230 acres of highly developed urban complex, including industrial, commercial, residential and public properties.

If these historical flood events were to recur today, stages on the Connecticut River would be somewhat lower than previously experienced due to the operation of the system of flood storage reservoirs in the basin.

THE FLOOD PLAIN

The flood plain in Holyoke is defined as being those areas which would be inundated by an Intermediate Regional Flood (IRF)* as modified by the existing upstream reservoir system. Referring to the map, Figure 24, these areas include the land adjacent to the Connecticut River in the northern portion of the city including the Mt. Tom electrical generating station; an area at Smiths Ferry referred to as the "duck" which is inundated by backwater from the Connecticut River through a drainage culvert under the railroad; the lowland adjacent to the river just upstream of the Holyoke Dam; and a narrow strip of land south of Ingleside to the Holyoke-West Springfield city boundary.

Occurrence of a Standard Project Flood (SPF)** would result in overtopping of portions of the Holyoke local protection works and result in inundation of approximately 230 acres of protected area. The top elevation of the Springdale section of the Holyoke dikes is 72.5 feet (M. S. L.) which is below the SPF level of approximately 75 feet (M. S. L.) (5). Detailed delineation of the areas and properties which would be affected is a complicated hydraulic computation because of the Holyoke canal system, but would include properties in the 3rd level canal area and downstream near Springdale Park. Figure 23 outlines the approximate areas impacted by the SPF.

Figure 24 presents the generalized land use of the city of Holyoke. An estimate of the impact of the IRF includes the following data (6):

Population in flood prone area	-74
Number of 1-4 unit(s) buildings	-11
Number of 4+ units buildings	- 1 (16 unit)
Number of small businesses	- 3
Membership Clubs	- 2
Steam generation plant	- 1

* The IRF is defined by the U.S. Army Corps of Engineers as a flood having an average frequency of occurrence in the order of once in 100 years or a flood with a 1% chance of occurring each year.

** The SPF is defined as the largest flood that can be expected from the most severe combination of meteorological and hydrological conditions that are considered reasonably characteristic of the geographic region involved.

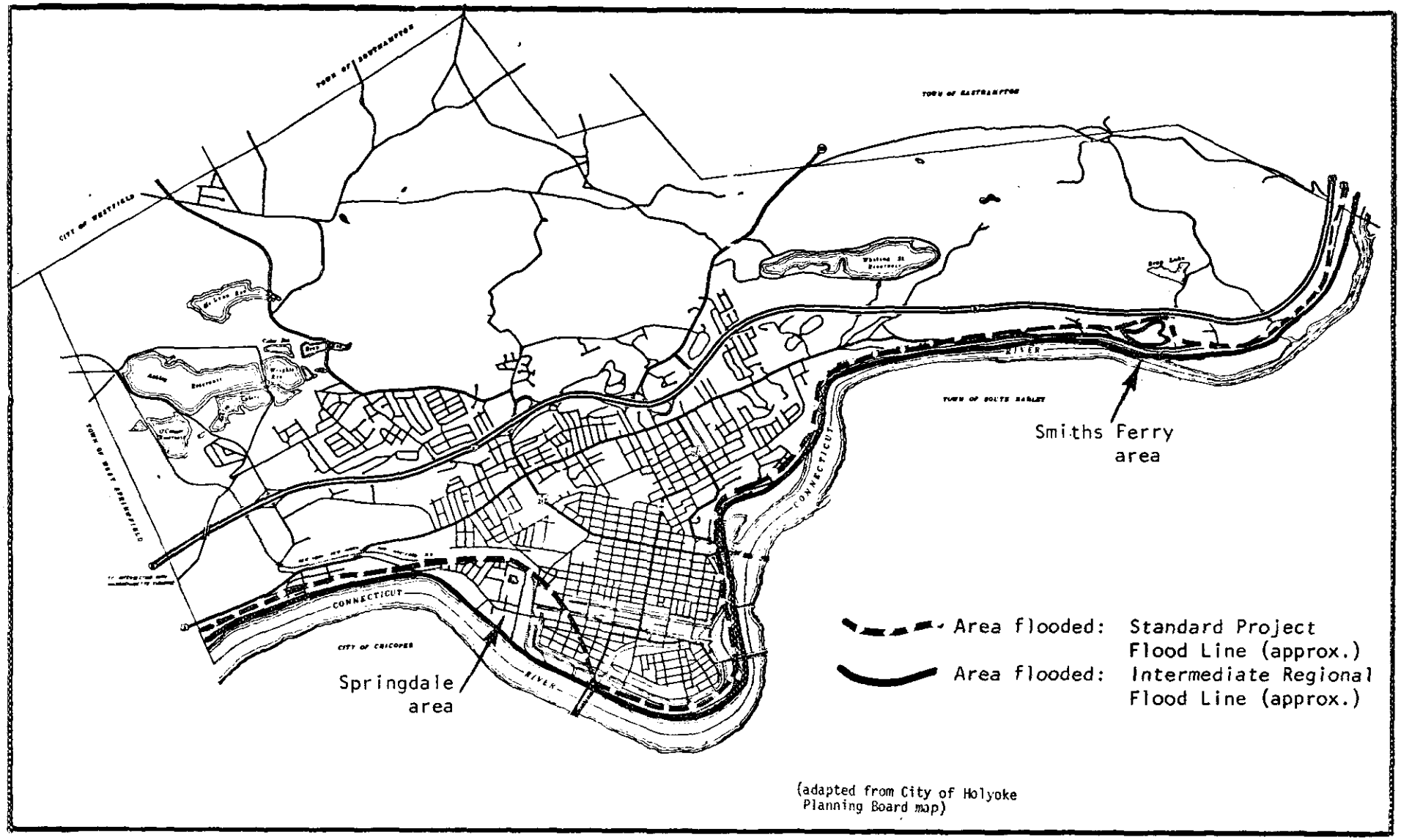

Fig. 23:Flood plain, City of Holyoke.

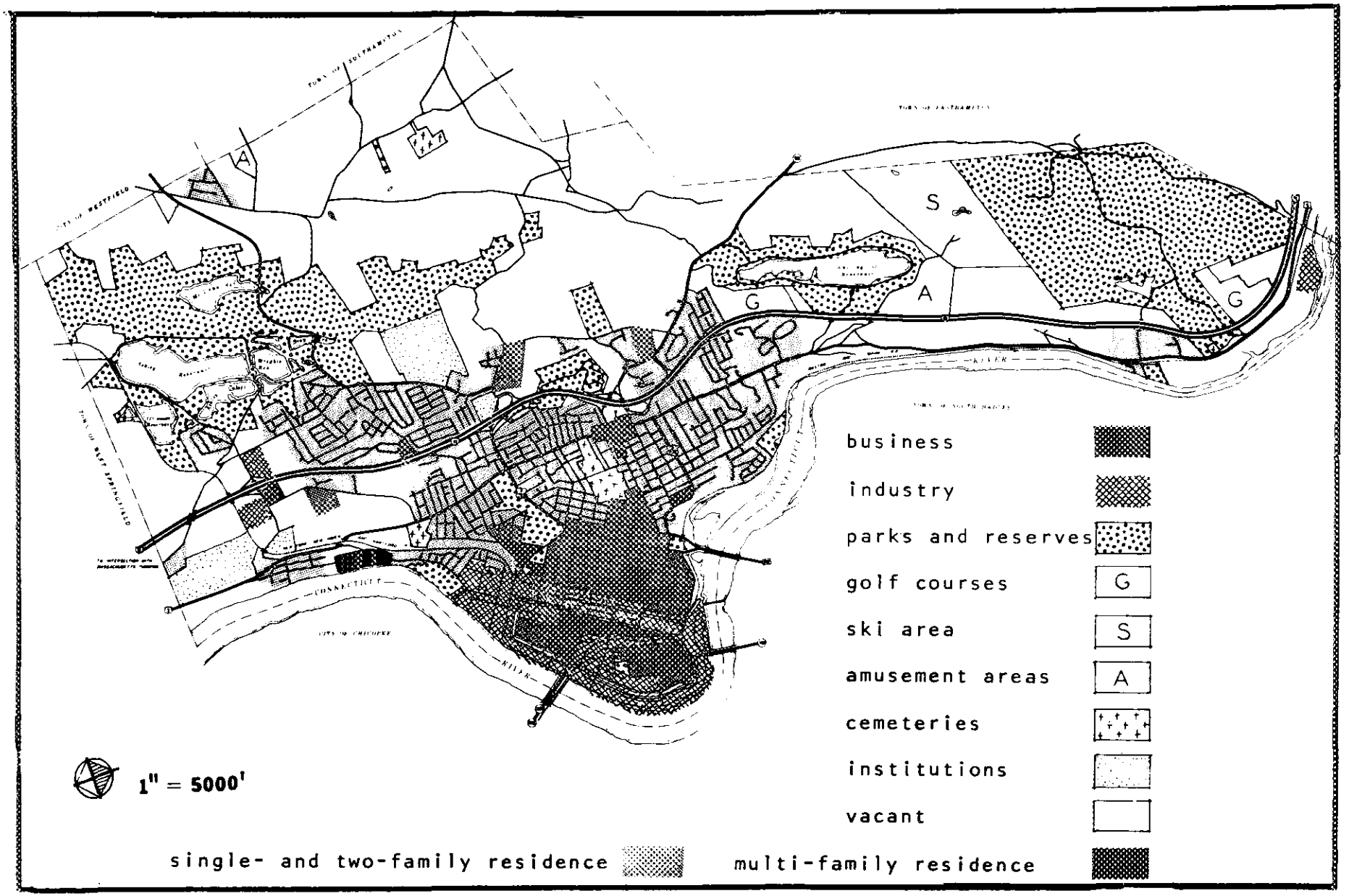

Fig. 24: Generalized land use, City of Holyoke. (map by City of Holyoke Planning Board)

The area most affected by the IRF is the "duck" area at Smiths Ferry north of the city center. Flood waters from the Connecticut River back up a drainage conduit which runs underneath the railroad tracks and results in ponding and flooding of approximately eight buildings, mostly residences, and a portion of an apartment building. The flood plain riverward of the railroad tracks in the Smiths Ferry area includes approximately seven buildings, the majority of which are residences. The Mt. Tom power station and appurtenances further to the north are located in the IRF flood plain in the narrow river reach between Mt. Tom and the Holyoke range. The flood plain south of the city center includes only three buildings, one of which is associated with recreational access to the river and two of which are dwellings.

An SPF event, which would overtop the Holyoke dikes in the Springdale area just south of the city center, would result in a substantial impact on the city's economy. Properties included in this area include Sunoco Paper, Acme Chair, and Holyoke Wire Cloth. The number of persons employed by these firms constitutes a major portion of the total employment for the city. Also, the Holyoke sewage treatment plant would be flooded by an SPF.

CLEARANCE

The City of Holyoke has never had a formal clearance program aimed at relocation or resettlement outside of the flood plain. Most of the industrial-commercial land flooded during the March 1936 event is now protected by the diking system. The substantial industrial development located near the river has historically been dependent upon the hydropower gained from the river through the canal system. None of the urban renewal projects currently being undertaken in the city of Holyoke are located on flood-prone land.

FLOOD PROOFING

The city of Holyoke limits its flood proofing efforts to operational procedures required for the sewerage system. Several of the factory buildings along the canals damaged during the 1936 flood were rebuilt to withstand a recurrence of a similar event. Other properties, such as those in the Smiths Ferry area, were apparently rebuilt with little or no provision for flood proofing. Maintenance and operation of the system of stop gates to prevent high water from the Connecticut River backing into the mills is the major flood-proofing activity.

URBAN DRAINAGE

Heretofore, urban drainage of flood waters in Holyoke has not resulted in extensive or frequent damages. Some localized flooding of a temporary nature is experienced during periods of intense rainfall due to storm sewer backup.

Localized urban drainage, which collects in the protected area behind the dikes, is handled by seven pumping stations.

FLOOD PLAIN INFORMATION STUDIES

There has been no official Corps of Engineers flood plain information study conducted for the city of Holyoke. The city has used the IRF flood elevation data designated on Plate No. M-12 of the Connecticut River Basin study as the basis for delineating the Flood Plain District (7). It is anticipated that a more detailed flood plain study will be conducted under the auspices of the Department of Housing and Urban Development (HUD) in order to determine the actuarial rates for the Federal flood insurance program. The city has not qualified for the emergency flood plain insurance program but is currently making application in response to recent Federal legislation (8).

PUBLIC INFORMATION

The National Weather Service, River Forecast Center, in Hartford, Connecticut, issues flood warnings for the Connecticut River in order that potential flood damage centers in the path of flood waters can prepare for the high water. Holyoke's organizational plans for dealing with major flood events are based on the existing structure of the city's government.

In addition, industries in Holyoke have for many years called upon the Holyoke Water Power Company (HWP) for more detailed flood height information to supplement that available from the U. S. Weather Service. The HWP maintains remote communication links to five upstream gaging stations (four on the Connecticut River and one on the Deerfield River) as well as continuously recording the river stage at the Holyoke Dam. The HWP also has an outlet from the U. S. Weather Service teletype system and maintains close contact during periods of high water.

Holyoke's flood plain district is presently an exclusionary zone in which only agricultural, recreational and utility corridor uses are permitted. Manufacturing is allowed by permit only. A proposed amendment to the zoning code would change the flood plain zone to an

overlying district allowing for no new development but making provision for rebuilding of existing structures by special permit in case of flooding or other damage (8).

FLOOD CONTROL IMPOUNDMENTS

There are presently nine Army Corps of Engineers flood control dams in the Connecticut River Basin above Holyoke. The reservoirs which have the most direct effect on the Holyoke area are the Birch Hill and Tully Dams, both in the Millers River Basin. Should a flood of the magnitude of the 1936 flood of record recur, these reservoirs would reduce flood stages in the Holyoke area by approximately 3.5 feet.

LOCAL PROTECTION WORKS

The Holyoke and Springdale local protection works, located along the west bank of the Connecticut River in the city of Holuoke, consist of three sections and are among the most complex in the Connecticut Valley. The first section, extending from the Holyoke Dam, includes about 400 feet of earth dikes and 5,600 feet of concrete flood walls. The second section, extending from high ground near Appleton Street southerly to the Springdale Dike, consists of about 10,500 feet of concrete flood walls along the Connecticut River and both banks of the third-level power canal. The third section is the Springdale Dike which extends about 4,200 feet along the river and ties into high ground south of Riverside Park (9).

Eighteen stop-log structures are provided at openings in the concrete flood walls. There are 36 gates at the 22 gate structures for inlet and outlet works of existing power developments to prevent high water from the Connecticut River backing into the mills. The city of Holyoke operates and maintains the system (9).

These protective works provide flood protection for about 230 acres of highly developed industrial, commercial, residential and public properties.

CONCLUSIONS

Historically, the City of Holyoke owes much of its industrial development to the availability of hydropower, water supply, and wastewater disposal resources of the Connecticut River. Holyoke was deliberately laid out as a mill town by Boston industrialists to take advantage of the water resources for product processing. Three levels of canals bring

water from the Connecticut River through the industrial area to provide power and water for processing.

The incidence of floods on these developments has been severe but has been endured because of the locational advantages on the river. It is not likely that the industries presently located within reach of Connecticut River flood waters will relocate because of this threat.

The local protection works provide a substantial degree of protection for potentially flood-prone areas. However, these protective works would be overtopped during a Standard Project Flood. The economic and social impacts of such an event, albeit a remote possibility, would be severe. The city and potentially affected industries and property owners would do well to maintain awareness of this threat and, where possible, to make use of flood proofing and emergency evacuation measures.

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PRESENT STATUS OF ELEMENTS

FOR FLOOD DAMAGE REDUCTION

NORTHAMPTON, MASSACHUSETTS

NORTHAMPTON, MASSACHUSETTS

GENERAL

The city of Northampton, Massachusetts, is located in the south-central portion of Hampshire County and despite its relatively small population of 30,000 people, it is the largest municipality within the county boundaries. It is bordered on the east by the Connecticut River, on the north by Williamsburg and Hatfield, on the west by Westhampton and on the south by Easthampton. The terrain is generally hilly, with elevations ranging from 200 feet in the central section to 800 feet along the western edge of the city. The area along the Connecticut River in the east is fairly level, due to the wide flood plain. Although the Connecticut River is the largest stream within the city, most of Northampton's development has been along the Mill River which flows in a southeasterly direction through the center of the city to its confluence with the Connecticut at the Oxbow. A glance at the map (Figure 25) indicates that growth along the Mill River has taken place primarily on its eastern bank and rather than being continuous, it has centered around three distinct commercial centers: Leeds in the north, Florence in the central portion and Northampton's central business district in the southeast.

Historically, agriculture formed the base of the economy and many farms proliferated along the fertile banks of the Connecticut and Mill Rivers. In the middle 1800's, industry, including silk, wood products, brushes and paper production began to develop, primarily along the Mill River. Today, Northampton is an integral part of the educational community involving principally the University of Massachusetts, Amherst College and Hampshire College in Amherst, Smith College in Northampton and Mt. Holyoke College in South Hadley. Manufacturing has been and continues to be the major employer in Northampton. Of the 31 manufacturers in town, one has over 1,000 employees and seven have over 100 employees. Products are generally diverse and range from tooth brushes to caskets.

The Northampton resident population has changed very slightly over the past forty years. In 1930, 24,381 people made their home in Northampton, and in 1950 there were 29,063. In 1970, the figure stood at 29,664, down from a high of 30,457 in 1965. The city's most recent master plan [1] suggests that growth of the local college community and increased highway connection will soon reverse much

1 Comprehensive Plan for Northampton, Massachusetts, prepared by Metcalf & Eddy, Inc., 1972

STREET INDEX

The letters and figures after names (as C3) denote the square on the map in which the street is located, as indicated by the corresponding figures in the border.

Acrebrook Drive C, D-3
Adare Place C-6
Alvarado Avenue D-6
Alamo Court C-3
Aldrich Street C-6
Aller Place C-7
Allison Street B-6
Arch Street B-3
Arlington Street C-6
Armory Street D-7
Arnold Avenue D-6
Atwood Drive D-7
Audubon Road A-1, 2
Baker Hill Road C-5
Bancroft Road C-6
Bardwell Street B-4
Barrett Place C-6
Barrett Street B-6
Bates Street B, C-7
Beacon Street C-4, 5
Beattie Drive D-3
Bedford Terrace C-6
Beech Street B-4
Belmont Avenue D-6
Bemis Road B-5
Berkshire Terrace B, C-5
Bernache Street A-3
Birch Hill Road C-3
Blackberry Lane B-6
Bliss Street C-4
Blueberry Ridge C-3
Bottom Road C-4, 5
Bradford Street C-7
Braman Court B-4
Brewster Avenue D-7
Bridge Road B-4, 6
Brierwood Drive C-3
Bright Street C-6, 7
Brookside Circle D-3
Burnoth Road B-4
Butts Pit Road D-2, 5
Butter Place C-7
Button Street C-6, 7
Camillane Terrace D-3
Calvin Terrace C-6
Carolyn Street B-4
Cedar Street D-6
Center Court C-7
Center Street C-6, 7
Chapel Street D-5, 6
Charles Street D-6
Cherry Street C-7
Chesterfield Road B-1, 3
Chestnut Avenue A-3
Chestnut Street B-4, 5
Church Street C-6
Clair Avenue B-5
Clapp Street E-5, 6
Clark Avenue D-6, 7
Clark Lane E-2
Clark Street C-3, 4
Clear Spring Court D-3
Clement Street C, D-5
Cloverdale Street B-4
Cole Meadow Road A-6
College Lane C, D-6
Columbus Avenue D-6, 7
Conz Street D-7
Cooke Avenue B-6
Coolidge Avenue C-7
Corticelli Street B, C-4
Cosmian Avenue B-4
Country Way A-4
Court Street C-7
Crafts Avenue C-7
Crescent Street C-6
Crosby Street C-7
Cross Street C-4
Curtis Hook Road D-6
Damon Road B-6, 7
Dana Street B, C-5
Danks Road D, E-6
Day Avenue C-7
Deerfield Drive D-3
Denise Court B-6
Dennision Place C-5
Depot Avenue B-4
Dewey Court D-7
Dickinson Street C-5
Dike Road D-7
Dimock Street B-2
Drewson Drive D-3
Drury Lane E-1
Dryads Green C-6
Earle Street D-6
East Center Street A-3
Eastern Avenue C-7
Edgewood Terrace D-6
Edwards Road D-7
Elizabeth Street C-7
Elm Street C-5
Evergreen Road A-3
Fairfield Avenue B-5
Fair Street C-7
Fairview Avenue C-6
Federal Street C-5
Fern Street B-4
Ferry Avenue E-7
Fifth Avenue C-6
Finn Street C-6
First Square Road D-8
Florence Street A-2, 3
Florence Street C, E-4
Florida Avenue C, D-7
Forbes Avenue C-6
Forest Glen Drive C-3
Fort Hill Road E-6
Fort Hill Terrace D-6
Fort Madison Avenue D-6, 7
Fourth Avenue C-6
Fox Farms Road B-4
Francis Street B-6
Franklin Court C-6
Franklin Street C-6
Front Street A-3
Fruit Street D-7
Garfield Avenue B-5
Gilfrain Terrace C-3
Gleason Road B-6
Glendale Road E-2
Glenwood Avenue C-7
Golden Drive C-3
Gothic Street C-6, 7
Grandview Street B-6
Grant Avenue C-7
Graves Avenue C-7
Greeley Avenue B-4
Green Street C, D-6
Grove Avenue A-2
Grove Street D-5, 6
Hampden Street D-6
Hampton Avenue D-7
Hampton Terrace D-7
Hancock Street C-7
Harlow Avenue D-6
Harold Street B-4
Harrison Avenue C-6
Hastings Heights B-4
Hatfield Road A-6
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Hawley Street C-7
Haydenville Road A-2, 3
Hayes Avenue C-6
Hayward Road B-4
Hebert Avenue D-6
Hellerman Street A, B-3
Henry Street D-7
Henshaw Avenue C-6
Hickory Drive C-3
Highland Avenue C-7
High Street B-4, 5
Hillcrest Drive B-4
Hillside Road C-6
Hinckley Street C-5
Hockanum Road D-7, 8
Holly Court C-3
Holyoke Street C, D-7
Hooker Avenue C-6
Hospital Road C-5
Hubbard Avenue C-7
Hunts Road D-7, 8
Howes Street B-4
Irwin Place C-6
Isabella Street C-7
Island Road E-7
Jackson Street B, C-6
James Avenue C-5, 6
Jewett Street C-6
Jumper Street B-4
Kary Street D-7
Kennedy Road A-2, B-3
Kensington Avenue C-6
Keyes Street B-4
Kimball Street B-4
King Avenue B-4
Kings Highway D-8
Kingsley Place D-7
King Street B, C-6
Ladd Avenue C-5
Lake Street B-4
Lampron Avenue D-2
Landy Avenue C-4
Langworthy Road C-6
Lasell Avenue D-6
Laurel Lane A-6
Laurel Street D-5, 6
Lawn Avenue C-6
Lenox Terrace B-4
Leonard Street A-3
Lexington Avenue C-4, 5
Liberty Street C-5
Lilly Street B-4
Lincoln Avenue C-7
Linden Street C-7
Locust Street B, C-5
Longview Drive D-3
Longdale Avenue C-5
Loudville Road E-1
Lovelield Street E-5
Lyman Road D-6, 7
Mandelle Road C-6
Manhan Road D-7
Manhan Street D-6, 7
Mann Terrace C-4
Maple Avenue D-7
Maple Street B, C-4
Maplewood Terrace C-5
Marc Circle B-5
Marian Street A-6
Market Street C-7
Marshall Street B, C-7
Maryjane Lane B-5
Massasoit Avenue C-6
Massasoit Street C-6
Maynard Road C-6
Meadow Street B-4
Michelman Avenue D-7
Middle Meadow Road D-7, 8
Middle Street B-4
Middle Street B-9
Mill Yard Road C-7
Milton Street C-5
Montague Road B-1
Moosview Avenue D-7
Mountain Street B-4
Mt. Tom Road D-7
Murphy Terrace C-6
Mulberry Street A-2
Munroe Street D-6, 7
Myrtle Street C-6
New South Street D-6, 7
New Street C-5
Nonotuck Street C-4
Nook Road D-7, 8
Norfolk Avenue C-5, 6
Northampton-Easthampton Road D-6, E-5
Northampton-Westhampton Road D-4, E-1
North Elm Street B-5, C-6
Northern Avenue C-7
North Farms Road A, B-4
North King Street A, B-6
North Main Street B-3, 4
North Maple Street B-4
North Street C-7
Norwood Avenue C-5
Nutting Avenue C-5
Oak Street B-4
Old Bed Road D-7
Old Ferry Road C-7, 8
Old Rainbow Road C-9
Old Shepherd Road A, B-2
Old South Street C-7
Old Springfield Road D, E-6
Oliver Street E-2
Olive Street D-6
O'Neill Street E-5
Orchard Street C-7
Ormond Drive C-5
Overlook Drive D-3
Oxbow Road D-6, 7
Pauquette Avenue D-6
Paradise Road C-6
Park Avenue C-6, 7
Park Hill Road E-2, 4
Park Street B, C-4
Park Terrace D-6
Parsons Street C-7
Parsons Swamp Road D-7, 8
Pearl Street B-7
Perkins Avenue C-6
Phillips Place C-7
Pidgeon Drive C-5
Pine Street B, C-4
Pioneer Knolls C-3
Pleasant Street D-7
Plymouth Avenue B-4
Potash Road D-7
Pound Lane D-7
Powell Street B-4
Prince Street D-5, 6
Prospect Avenue B-6, C-5
Prospect Court C-6
Prospect Heights C-6
Prospect Street C-6
Pynchon Meadow Road D, E-6
Railroad Avenue C-7
Rainbow Road C-8
Randolph Place D-7
Redfield Drive D-3
Reed Street D-6
Reservoir Road A, B-2
Revell Avenue D-6
Rick Drive B-4, 5
Ridgewood Terrace B-6
Riverbank Road C-8
River Road A-2
Riverside Drive C-4, 5
River Street E-6, 7
Rockland Heights Road A-6
Rocky Hill Road D-4, 5
Roe Avenue C-5, 6
Round Hill Road C-6
Rural Lane D-3
Rust Avenue D-3
Ryan Road C-4, D-2
Sanderson Avenue C-6
Scanlon Avenue C-4
School Street D-6
Service Center Road D-7
Sheffield Lane B-4
Shepherds Farm Road C-8
Sherman Avenue C-7
Smith Street D-7
South Main Street B-5
South Street C, D-7
South Park Terrace D-6
Spring Grove Avenue B-4
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Spruce Hill Avenue C-3
State Street C-6
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Sterling Road B-4
Stilson Avenue B-4
Stoddard Street C-6
Stonewall Drive A-6
Stowell Street A, B-3
Straw Avenue B-5
Strawberry Hill B-4
Strong Avenue C-7
Strongs Road C-8
Summer Street C-6
Sumner Avenue B-5
Sun Hill Drive B, C-5
Sylvester Road B-1, C-2
Swan Street C-7
Taylor Street C-6
Terrace Lane B-5
Texas Road D-6
Trinity Row B-5
Trumbull Road C-6, 7
Turkey Hill Road D-1, 2
Tyler Court C-6
Union Street C-7
Upland Road A-3
Valley Street D-7
Venturesfield Road C-7
Verona Street B-4, 5
Vernon Street C-5
View Avenue C-7
Walnut Street C-7
Walnut Trees Path C, D-8
Ward Avenue C-5
Warfield Place C-6
Warners Row A, B-3
Warner Street C-5
Warren Street B-4
Washington Avenue C-6
Washington Place C-3, 6
Water Street A-2
Webbs Hollow Road C, D-8
West Center Street B, C-4
Western Avenue C-6
West Farms Road D-2
Westhampton-Easthampton Road E-1
West Street B-9
West Street D-6
Westwood Terrace D-2
White Pine Drive D-3
Wilder Place B-4
Williams Street C, D-7
Willow Drive A-3
Willow Street C-4
Wilson Avenue D-7
Wilson Road D-5, E-4
Winchester Terrace D-3
Winslow Avenue C-5
Winter Street C-6
Winthrop Street D-6
Wood Avenue C-5
Woodbine Avenue C-7
Woodlawn Avenue C-6
Wright Avenue D-7
Young Rainbow Road C-8, 9

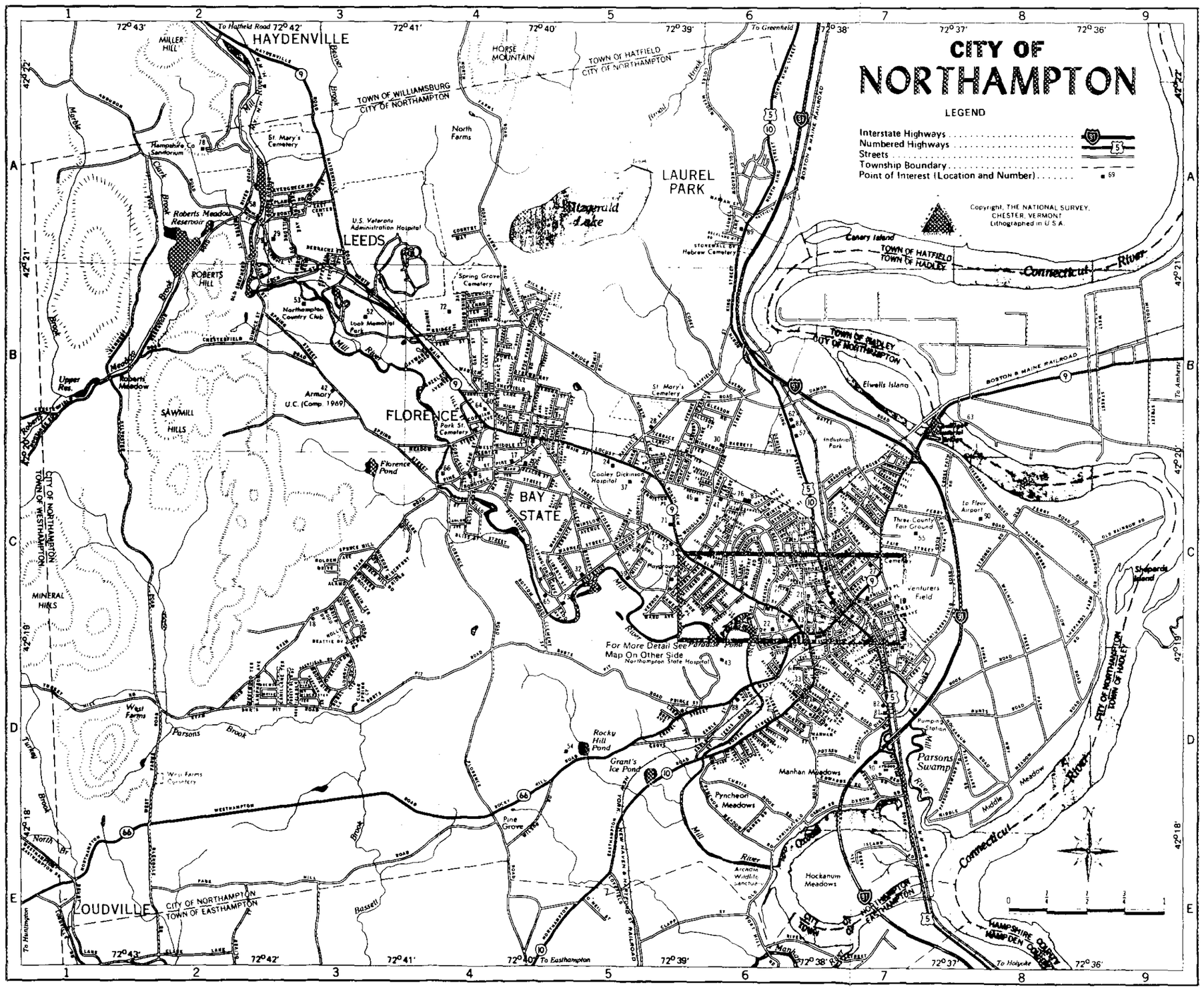

Fig. 25: City of Northampton

of the present migration pattern. Based on this assumption, they have predicted a resident population of 36,890 for the year 1990. Another projection, developed by the Lower Pioneer Valley Regional Planning Commission [2], forecasts essentially no change in the resident population over the next 50 years. As can be seen, there is a good deal of disagreement regarding Northampton's growth potential.

FLOOD HISTORY

The Northampton area has long been cognizant of the flood threat posed by both the Connecticut and Mill Rivers. As early as 1692 there is mention of flood damage due to high stages on the Connecticut River. In a paper written in 1928[3], Eugene E. Davis describes what were then the ten greatest Connecticut floods on record at Northampton. These included the "Jefferson Flood" on March 20, 1801, a flood on February 5, 1840, which cut the present river channel east of the Oxbow in Northampton, the "Lincoln Flood" on April 20, 1862, the "Pumpkin Flood" of October 6, 1869, so-called "because of the large number of pumpkins, as well as other farm produce, which floated down the river," and lastly, the highest flood to that date on November 5, 1927. There is also discussion of a flood on the Mill River in 1874, when, following the failure of a small industrial water storage reservoir near Williamsburg, 143 lives were lost and more than $1,000,000 in damages was caused. It is clear that floods were part of life throughout Northampton's developing years.

Records of river height are continuous on the Connecticut River at Montague City, Massachusetts, since 1904, and on the Mill River at Northampton since 1938. The flood of record on the Connecticut River at Northampton is the March 1936 event, while the hurricane-spawned 1938 flood is the flood of record on the Mill River. Both these events caused extensive damage to the center of Northampton, and as a result, in 1941 the Army Corps of Engineers completed a series of local protection works including dikes, a pumping station and a diversion of the Mill River away from the center of town. If these historical floods were to recur today, stages on the Connecticut River would be considerably lower than actually experienced due to the operation of a system of flood storage reservoirs in the basin. This is not the case with the Mill River, however, as there are no flood impoundments on that stream.

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[2] Water Supply and Sewerage, Thirteen Communities, Hampden and Hampshire Counties, Massachusetts, prepared by Curran Associates, Inc., for the Lower Pioneer Valley Regional Planning Commission, 1971.

[3] "Ten Great Floods on the Connecticut River," Eugene E. Davis, 1928.

Since 1938, there has been additional flooding on both streams, notably 1948 and 1955, which has caused limited damage. The most recent event is the storm of June 1973, which caused flooding and subsequent economic losses to agricultural lands in the meadows portion of the city.

A flood plain zoning ordinance resulting from a master plan[4] was proposed for the city in 1963, but was never adopted by the city council. Another proposal is currently being prepared and should be acted upon early in 1974.

THE FLOOD PLAIN

Mill River. The flood plan of the Mill River has not been accurately defined, since Northampton has not had a flood plain information study done. Interpretation of flood hazard areas were made with the aid of maps of flood-prone areas prepared by the U.S. Geological Survey. The resulting indication is that an Intermediate Regional Flood (IRF)[5] would cause inundation in three separate parts of the city. Approximately 280 acres in the Leeds-Florence area around the Northampton Country Club and Look Memorial Park would be covered to about elevation 250. This area is thus far sparsely populated and little damage would be incurred. Residential developments are proposed, however, for the area. Another 105 acres in the vicinity of Paradise Pond on the Smith College campus would be flooded, including the Northampton High School field and some homes along Riverside Drive in the Bay State section of the city. Finally, there are about 1,000 acres of flood plain south of Northampton center common to the Connecticut and Mill Rivers which will be discussed in the following sections.

Connecticut River. The reach of the Connecticut River in the vicinity of Northampton is characterized by a sweeping flood plain stretching from Elwells Island in the north to the Oxbow in the southeast section of the city. The area includes roughly 3300 acres of open ground, primarily farm land. Still there exists a number of commercial-industrial establishments which would sustain extensive damage in the event of a severe flood. These include an asphalt plant and portions of a garden apartment development off Damon Road near Elwells Island. Also, the three-county fairgrounds and LaFleur Airport in the vicinity of Routes 9 and I-91 would be inundated. The major damage to the city would be felt

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[4] The Master Plan, City of Northampton, prepared by Technical Planning Associates, Inc., 1963.

[5] An Intermediate Regional Flood (IRF) is a hypothetical flood situation with a 1 in 100 chance of occurrence in any one year.

along Route 5 in the Oxbow area. This region includes the Colonial Hilton Inn at the junction of Route I-91 and Route 5, and the Tri-City Container Plant located off Route 5 at the Oxbow. Both are located outside of the protection works. The present diking system would protect the central portion of the city, but some private residences would experience damage mainly in the area of the fairgrounds and also along Island Road at the Oxbow. Most of these facilities have been constructed within the past 10 years.

CLEARANCE

The city of Northampton has never had a formal clearance program aimed at relocation or resettlement outside of the flood plain. Most of the commercial-residential land flooded during the March 1936 event is now protected by the diking system and Mill River diversion. Some limited clearance did take place soon after the 1936 flood in the Fulton Avenue area, but most of these damaged residences were removed to make way for a new section of Route 5. The remaining land outside the dike is primarily agricultural, except for those exceptions noted in the previous Flood Plain Section. Of these, only the three-county fairgrounds existed at the time of the 1936 flood when it sustained extensive damage.

FLOOD PROOFING

The city of Northampton limits its own flood proofing efforts to operational procedures required for the sewerage system. Gate valves have been installed on all lines entering the treatment plant from beyond the dike. Should flood waters reach a prescribed gauge height, these valves are systematically closed to prevent flooding at the plant. Private flood proofing efforts have been quite limited. Examples are as follows:

1. Colonial Hilton Inn. The motel, completed in 1968, is connected to Northampton's sewerage system and all its sewage is pumped off the premises. Also the building is situated on fill material which was excavated from the property perimeter. The excavated portion has subsequently been lined with dumped rock. Nonetheless, in the event of an IRF, the entire area would be flooded.

2. Tri-City Container Plants. Located on the Oxbow Island, the older plant buildings are at elevation 119 but all new facilities will be slightly higher at 122. All plant production material can be evacuated in 24 hours.

3. Pro-Brush Division of Vistron Corp. Located on the Mill River in Florence, Pro-Brush suffered limited damage as a result of the 1938 flood. Since that time, the company has installed their own floodwall, placed gate valves on all storm drains and placed sump pumps in the lower floor of the plant. Also all material on the lower floor has been coded for ease of removal in time of a flood and immovable objects have been coated with a plastic covering.

URBAN DRAINAGE

The three residential centers of Leeds, Florence and Northampton center are all well drained and have experienced little problem with urban flooding. A storm water drainage system extends throughout the populated sections of town. In the older central area the system is combined and all flows are channeled to the existing sewage treatment facility. A program to separate the older sewers is presently under way.

FLOOD PLAIN INFORMATION REPORTS

As mentioned previously, Northampton has not had a flood plain information report done. Still there has been some effort, both locally and on a federal level to define the limits of the flood plain. The U. S. Geological Survey has prepared a series of maps for the entire Connecticut river basin, which delineate those areas which are considered "flood prone." Also, in both the 1963 and 1972 comprehensive plans, the Planning Board of Northampton has designated flood plain and flood-prone lands bordering both the Connecticut and Mill Rivers, and recommended compatible uses for this land. In this regard, an amendment to the city's ordinance has again been proposed which would limit the use of all lands below elevation 125 msl and establishes local watershed protection districts. Finally, the Soil Conservation Service of the U. S. Department of Agriculture, under authority of the Flood Prevention and Watershed Protection Act, Public Law 566, has completed a preliminary investigation of the Mill River Watershed and recommended a series of three small flood control dams two in Williamsburg and one in Northampton.[6] The Plan is presently under review by concerned agencies.

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[6] Report of Preliminary Investigation of the Mill River Watershed by the U. S. Department of Agriculture, Soil Conservation Service, 1971.

PUBLIC INFORMATION

There is presently no formal program to discourage flood plain development or to alert developers of the potential threat. Fortunately, the flood plain is still primarily agricultural land.

A local flood emergency plan has been developed through the cooperation of the city government, local civil defense officials and the Army Corps of Engineers. The plan outlines steps to be taken (road closings, evacuations) at various stages of the river's rise.

FLOOD CONTROL IMPOUNDMENTS

There are presently nine Army Corps of Engineers flood control dams in the Connecticut River Basin above Northampton. Most of these are in Vermont. The reservoirs which have the most direct efforts on the Northampton area are the Birch Hill and Tully Dams, both in the Millers River Basin. It is estimated that the combined effect of these upstream dams is to have lowered potential flood stages between two and four feet at Northampton.

There are presently no flood control impoundments on the Mill River. As mentioned, the Soil Conservation Service has recommended three dams for the watershed, but thus far this proposal has encountered a great deal of local opposition, primarily from environmental groups. There are still a number of old mill dams on the Mill River, most of which are in disrepair or heavily silted. It has been recommended that these dams either be removed or repaired to relieve the hazard of a sudden break.

LOCAL PROTECTION PROJECTS

The local protective works at Northampton close off the valley of the Mill River, within the city limits, and divert the river through a canal to the Connecticut River via the Oxbow south of the city.

A dike with a maximum height of 23 feet and about 5,000 feet long in the eastern portion of town extends along the Connecticut River from high ground at Pomeroy Terrace across the bed of the Mill River to high ground west of U.S. Route 5. There is a pumping station located at the dike to remove storm water from behind the dike when the river is at high stages. Where the line of the dike crosses U.S. Route 5 and the Boston and Maine Railroad, there are stoplog structures. These eastern section works protect against flood stages on the Connecticut River.

In the western section, two lengths of dike with a maximum height of 25 feet, totaling about 1,900 feet in length and a flood wall about 450 feet long extend along the east bank of the Mill River from high ground near Paradise Pond, across the Mill River and then into high ground at Hebert Avenue. This section of dike serves as a dam and diverts the Mill River into a 10,500-foot long diversion channel, which carries the river to discharge at the Oxbow. This section also includes a drop structure and bridge, stoplog structures and street relocations.

Construction of these local protection works was started in 1939 and completed in June 1941. Since that time, it is estimated that these works in conjunction with the upstream reservoirs have prevented damages of $1,728,000 [7] in Northampton.

CONCLUSIONS

There are two major streams in the city of Northampton -- the Connecticut and Mill Rivers. The occurrence of a Standard Project Flood, as currently modified by the existing Corps flood control dams, would come within a foot of topping the existing dike system at U.S. Route 5. Inasmuch as a design criteria for these dikes requires three feet of freeboard, it cannot be guaranteed that the dike would withstand a flood of such magnitude. As for the flood plain, the city should make every effort to prevent further flood plain development. Passage of the proposed flood plain zoning ordinance would go a long way toward achieving this end.

The potential flood threat posed by the Mill River is more difficult to evaluate, due to the flashy nature of this stream. Existing local protection works will adequately protect the central portion of the city. Yet, the potential for flooding and subsequent damage still exists in the area of Paradise Pond and also the Look Park area of Florence.

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7 Water Resources Development in Massachusetts, U.S. Army Corp of Engineers, 1971.

PRESENT STATUS OF ELEMENTS

FOR FLOOD DAMAGE REDUCTION

HATFIELD, MASSACHUSETTS

HATFIELD, MASSACHUSETTS

GENERAL

Hatfield, Massachusetts can best be described as a small agricultural - residential community lying on the west bank of the Connecticut River, some 23 miles north of Springfield. The town is roughly bisected in a north - south direction by Interstate Route I-91, U. S. Route 5, the Boston and Maine Railroad and the Mill River, all of which roughly parallel one another in a 2,000 foot wide corridor. The town is thus divided into its hilly western terrain and the Connecticut River plateau to the east. Figure 26 is a map of the Town of Hatfield.

The western portion of town is mostly undeveloped. Development has taken place along route U. S. 5 and to a greater extent to the east in the center of town. The development along Route 5 consists of some residential, light commercial and light industrial. The center of town takes on a picturesque quality with huge old trees and antique houses along Main Street. The houses are dated with plaques indicating they were built from the mid-1700's to the mid-1800's. The houses have mostly been restored and are in excellent condition as are the grounds. The public buildings and Smith Academy appear to be of the same vintage as the older houses. There are also newer houses in several locations along Main Street, a modern church and a small apartment complex. These newer structures blend well with the old, as does a small business block.

Away from Main Street both to the west and easterly to the Connecticut River are fields interspersed with tobacco drying sheds. Tobacco, however, is not the predominant crop that it once was. More acreage is now devoted to potatoes than anything else. Onions, corn, tobacco, cucumbers and strawberries are grown to a lesser extent.

The town sports an active airport on the Hatfield - Watley town line. About half a dozen light planes and gliders are housed off Main Street near Pilgrim Airport's single turf runway.

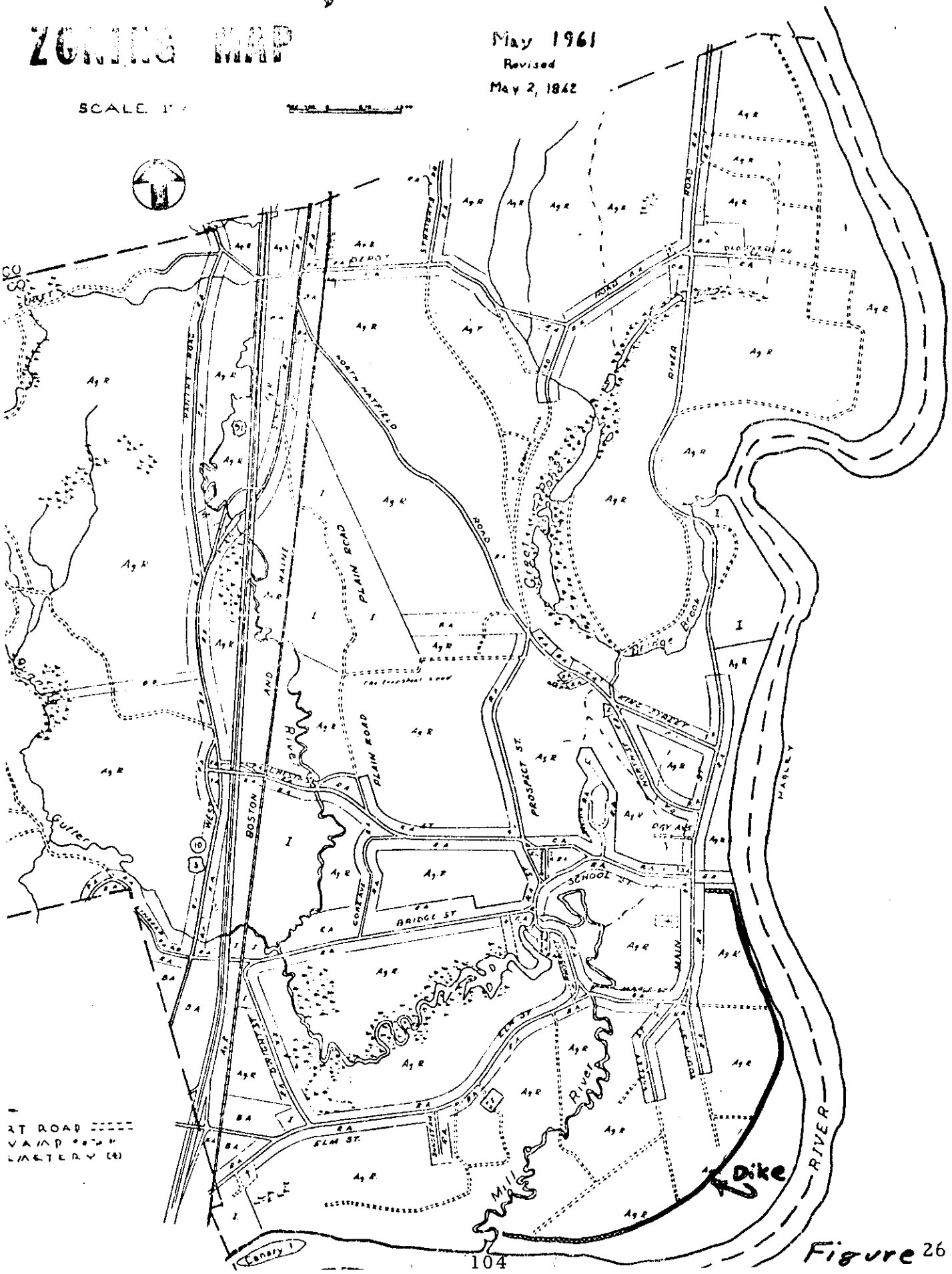
ZONING MAP
May 1961
Revised
May 2, 1962
SCALE 1"
NORTH HATFIELD ROAD
PLAIN ROAD
BOSTON AND MAINE
WEST
PROSPECT ST.
BRIDGE ST
SCHOOL ST
MAIN
ELM ST.
Mill River
Dike
RIVER
HAGLEY
Canary I
Gutter
Bridge Brook
Ag R
I
BA

Figure 26

FLOOD HISTORY

The town of Hatfield has an area of 16.7 square miles (s.m.) or 16.0 s.m., not including that part of the town covered by the Connecticut River at low water. The hilly western portion of the town covers 5.0 s.m. and the Connecticut River plateau makes up the remaining 11.0 s.m. Almost all of the development in the town has taken place on the 11.0 s.m. river plateau. The 1936 flood covered about 5.0 s.m. or 45 percent of this usable land. The 1936 event was accompanied by river stages of 130.9 feet msl. The ground elevation in the center of Hatfield is 129 and most, if not all, of the buildings on Main Street were inundated. Two and one-half years later, the storm of 1938 with stages of only 2 to 3 feet less than the 1936 flood again put most of the town under water.

After the 1936 flood, a plan of flood control for the entire Connecticut River watershed was developed. Twenty-six impoundments were authorized by Congress as part of this plan. Although this plan has not yet been fully implemented, there are 16 reservoirs in the basin (9 upstream of Hatfield). Were a recurrence of the 1936 or 1938 events to take place today, river stages would be substantially less than those experienced in 1936 and 1938.

THE FLOOD PLAIN

The flood plain has not been accurately defined. Hatfield has not had a flood plain information study done, so that what follows here is the result of tracing the Intermediate Regional Flood (IRF) [1] on a United States Geological Survey (USGS) Quadrangle Sheet, scale 1" = 2,000' and a 10-foot contour interval. To identify individual buildings in the flood plain would require running survey levels through much of the community, especially on Main Street. An IRF would cause stages of about elevation 127 in the village of Hatfield. Approximately 4.2 s.m. or 38 percent of the land in the river plateau would be inundated. [2]

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[1] An Intermediate Regional Flood (IRF) is a hypothetical flood situation with a 1 in 100 chance of occurrence in any one year.

[2] It is noted that the IRF would inundate less land area than was inundated in 1936. However, the 5.0 square miles inundated in 1936 flood occurred before the system of upstream reservoirs was constructed. The IRF is calculated under today's conditions; that is after construction of the existing system of 16 reservoirs in the basin. Further, the 1936 flood and the IRF are the results of different storm patterns and tributary runoff regimens. The effects of these two floods on river stages in the town of Hatfield are not comparable.

The area in the flood plain is roughly as follows:

* Main Street from Memorial Town Hall south.
* Elm Street from the Mill River east.
* Main Street from Bridge Brook north to the Village of Bradstreet.

These areas include about half the town's antique houses, many other residences, a church, a school, and a library. Almost all of the remaining land area inundated is actively farmed.

Damages in Hatfield would begin when river stages reached about elevation 120. A system of dikes is effective to stage of about elevation 124. Below elevation 124, about the only thing to get inundated is agricultural land and dollar losses would be slight. Above elevation 124, the damages would increase uniformly. The dikes would fail from the backwater of the Mill River and failure would be gradual.

Some of the town is now sewered and the wastewater is treated in a community septic tank. Planned is a treatment plant adjacent to the Connecticut River near the Hatfield - Northampton town line. Care should be taken so that this facility will be secure from high frequency inundation.

CLEARANCE

No plans have been developed for clearance of the flood plain in the town of Hatfield. While very few structures are subject to frequent flooding, a large number of the town's buildings would be inundated by a less-frequent flood of major proportions, making it necessary to relocate a substantial portion of the town in order to gain full benefit of flood plain clearance. Furthermore, because of the distance from the swifter main channel flood flows, structural damage from a major flood would not be significant. For these reasons, and because of the social disruption it would cause, clearance of the flood plain does not appear to be socially or economically feasible as a flood damage reduction measure.

FLOOD PROOFING

None of the structures in town have been flood proofed. Considering the infrequency of flooding and the type of buildings in the flood plain, it does not appear economically feasible to undertake flood proofing.

URBAN DRAINAGE

No significant urban drainage problems have been reported in the town of Hatfield.

FLOOD PLAIN INFORMATION REPORTS

No government funded Flood Plain Information Study has been conducted in Hatfield and none has been requested by the town. The community has not yet established its eligibility for Federal flood insurance.

It is impossible to say with certainty which areas of town would have to be restricted for future development so the town could qualify for flood insurance. A Flood Plain Information Study would identify these areas. However, it appears that the 4.2 square miles, including much of Main Street, which is below the IRF flow line would have to be zoned as a flood hazard area.

In 1969, the town enacted a flood plain zoning by-law. The by-law delineates specific tracts of land along the Connecticut River which are flood prone and restricts development upon them. It appears that all tracts flood plain zoned were previously agricultural - residence zoned. Except for a few tobacco drying sheds, there are no existing structures on the lands which have been specified in the by-laws. The by-law prohibits the placing of any new structure on land flood plain zoned. Land sub-divided into residence A, prior to the enactment of the by-law, may be exempt from the by-law. However, it appears that few, if any, parcels fall under this provision.

The flood plain zoned land is in two separate areas. The first is in a strip of land outside the dike in the southern part of the town. The strip of land zoned here runs along the Connecticut River from the Hatfield - Northampton town line to the Elm Street extension. The second area of flood plain zoned land is in the northern portion of the town and runs in a 1,000 foot strip along the Connecticut River from the Hatfield - Wately town line to Bridge Brook.

The total area of the 2 tracts flood plain zoned is 1.2 square miles or 29 percent of the 4.2 square miles of land area which would be inundated by the IRF. It seems that the land which is flood plain zoned would be the least likely to receive development pressure in the community because it is for the most part the lowest land in the

community, farthest from the center of town and is not serviced by roads or utilities. It is unlikely that an individual would want to locate a house outside an existing dike in any case. The flood plain zoning by-law is good as far as it goes, but falls far short of providing adequate protection for future construction in the community.

PUBLIC INFORMATION

Other than the flood warnings issued by the National Weather Service, there is no formal system for alerting the public about potential flood dangers, nor is there a program for informing developers about flood-prone areas in the town.

FLOOD CONTROL IMPOUNDMENTS

There are presently nine Army Corps of Engineers flood control dams in the Connecticut River Basin above Hatfield. In a recurrence of a flood of the magnitude of the 1936 flood of record, it is estimated that these dams would reduce Connecticut River flood stages in the vicinity of Hatfield by approximately 3.7 feet.

At the present time, there are no flood control impoundments on the Mill River.

LOCAL PROTECTION PROJECTS

Several dikes, shown on Figure 26 have been constructed through the years in Hatfield. The main dike runs from the Mill River along the west bank of the Connecticut River upstream for a length of about 11,300 feet to the upper end of the village of Hatfield. Sections of this dike were constructed from 1903 to 1936 by the State and Town to elevation 129 msl. In the Bradstreet Meadows area, 2-1/2 miles north of the village, three small dikes of 800 feet total length were constructed to elevation 134 msl across erosion gullies. The three dikes were built in 1937 by the Corps of Engineers, under the Emergency Relief Appropriation Act of 1936. Under the same appropriation, 3,000 feet of the main dike damaged by the 1936 flood were also restored.

The March 1936 flood exceeded the top elevation of the main dike by some two feet, inundating it along its entire length. Hatfield's Main Street was entirely flooded by waters of the Connecticut River backing

up the Mill River and by Connecticut River waters passing over a low bank section north of the main dike. This low bank section, together with backwater up the Mill River, means that the dike has an effective level of protection of about 124 ± msl. The three small dikes constructed after the 1936 flood closed small swales in the Bradstreet Meadows area. There are no pumping facilities behind any of the dikes to dispose of interior drainage water.

The flood of 1938, although 2 to 3 feet lower than the 1936 flood again flooded Hatfield. The town used WPA funds to do repair work on the dikes after this flood.

The potential flood situation at Hatfield was studied in draft, Review Report for the Local Protection Works of the Connecticut River Basin, Corps of Engineers, 1947. The study found that providing a complete system of local protection at Hatfield was not economically feasible, even before considering upstream impoundments to reduce Connecticut River stages. The comprehensive plan for the Connecticut River at that time included storage reservoirs in the Connecticut River watershed which would have reduced stages of a recurring 1936 flood by 8.6 feet at Hatfield. Many, but not all, of these impoundments have been constructed since 1936. The existing system of flood control reservoirs would reduce stages at the Montague City flow gage, 14 miles upstream of Hatfield, by an estimated 5.6 feet.

An inspection by the Corps of Engineers in 1947 revealed that the dikes were in fairly good condition. Several minor deficiencies were noted, the most serious being the presence of woodchuck and mole holes. It was concluded that these holes could lead to dike failures; however, repair work was carried out at that time. It is safe to assume, though, that the woodchucks and moles resumed their work after the repairs were carried out. No regular inspection and maintenance program is carried out on these dikes, so that their integrity at the present time is unknown.

CONCLUSIONS

Hatfield is secure from all but major floods, having had no significant problem since the 1938 flood. However, if a major flood event were to take place, say an IRF, a major portion of the town land area and structures would be inundated. An IRF would inundate about half the development on Main Street; and SPF would completely inundate Main Street. However, the town's buildings are far removed from the

river, and it is expected that structural damage would be slight because the water would probably not have the velocity or depth to move buildings from their foundations. Crops inundated would, of course, be lost; however, because of the high banks along the Connecticut River, erosion or sedimentation on farm land would probably not be a serious problem. Employment in town would not be affected by a flood except for farming.

The town would be well advised to take advantage of the free Federal Flood Plain Information Study service. Based on the flood hazard areas identified in such a study, additional appropriate flood plain zoning by-laws could be enacted. Hatfield should also apply for eligibility to the Federal Flood Insurance Program. If accepted, this would make all inhabitants of the town eligible to subscribe to Federal flood insurance.

As stated previously, it does not appear economically feasible to either flood proof any buildings or remove them from the flood plain. The benefits derived from low frequency floodings would be extremely low when reduced to an annual figure and obviously would not warrant the expenditures that would be necessary to flood proof or move structures.

This leaves two measures to reduce the potential flood loss to residents. Both solutions are recommended in the 1980 Connecticut River Basin Plan. The construction of 7 flood control reservoirs, all above Hatfield would substantially reduce flood stages. The adoption of adequate flood plain zoning by-laws and subscription of flood insurance by residents would minimize dollar losses. These two flood damage reduction measures would complement one another in an exemplary manner in the case of Hatfield. The reservoirs would reduce stages to a point where an IRF would inundate very little except farm land. Zoning measures would then prohibit the construction of flood prone structures on this land. If flood plain zoning were adopted alone, then much of the developed area of town and much of the land most suitable for development would have to be zoned as flood hazard areas. On the other hand, if the structural measures (reservoirs) of the 1980 Plan were adopted without the flood plain zoning, flood stages would still be reduced, but future development in the hazard areas could again create a problem.

PRESENT STATUS OF ELEMENTS

FOR FLOOD DAMAGE REDUCTION

BRATTLEBORO, VERMONT

BRATTLEBORO, VERMONT

GENERAL

The town of Brattleboro, Vermont, shown in Figure 27, is located in the southeastern portion of the State in Windham County. The town, with a total land area of over 33 square miles, is in a mountainous area bordered on the east by the Connecticut River. The principal area of business and residential development borders the Connecticut River and is mostly situated high above the river level. There are three major streams in the town of Brattleboro. The West River flows in a southeasterly direction and meets the Connecticut River just north of the downtown area. Whetstone Brook flows in an easterly direction roughly bisecting the downtown area. Development through the years has taken place along State Route 30 paralleling the West River and along State Route 9 paralleling Whetstone Brook. West Brattleboro is located on Route 9 about 2-1/2 miles from downtown Brattleboro.

The town was chartered in 1753 and had a population of 9,816 in 1930. The present population is over 12,000, and the population projected to the year 1990 is 14,090.[1] Growth, as can be seen, has been slow but steady and is expected to continue that way.

For its size, Brattleboro would have to be considered as moderately industrialized. Of the 36 manufacturers in town, one has over 500 employees, another six have over 100, and another seven have over 20 employees. Twelve of these 36 manufacturers produce wood or wood related products and eight others are in the printing business.

FLOOD HISTORY

Some 24 damaging floods have occurred in the vicinity of Brattleboro on the Connecticut River Basin since records were kept from about 1770. The earliest records, of course, are sketchy and we are unable to compare the earlier floods with later events. A major flood occurred in October 1869; and since that time, records are somewhat better, although really useful records began with the installation of

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[1] Population figures extracted from A Projection of the Vermont Population -- Central Planning Office, State of Vermont, September 21, 1964.

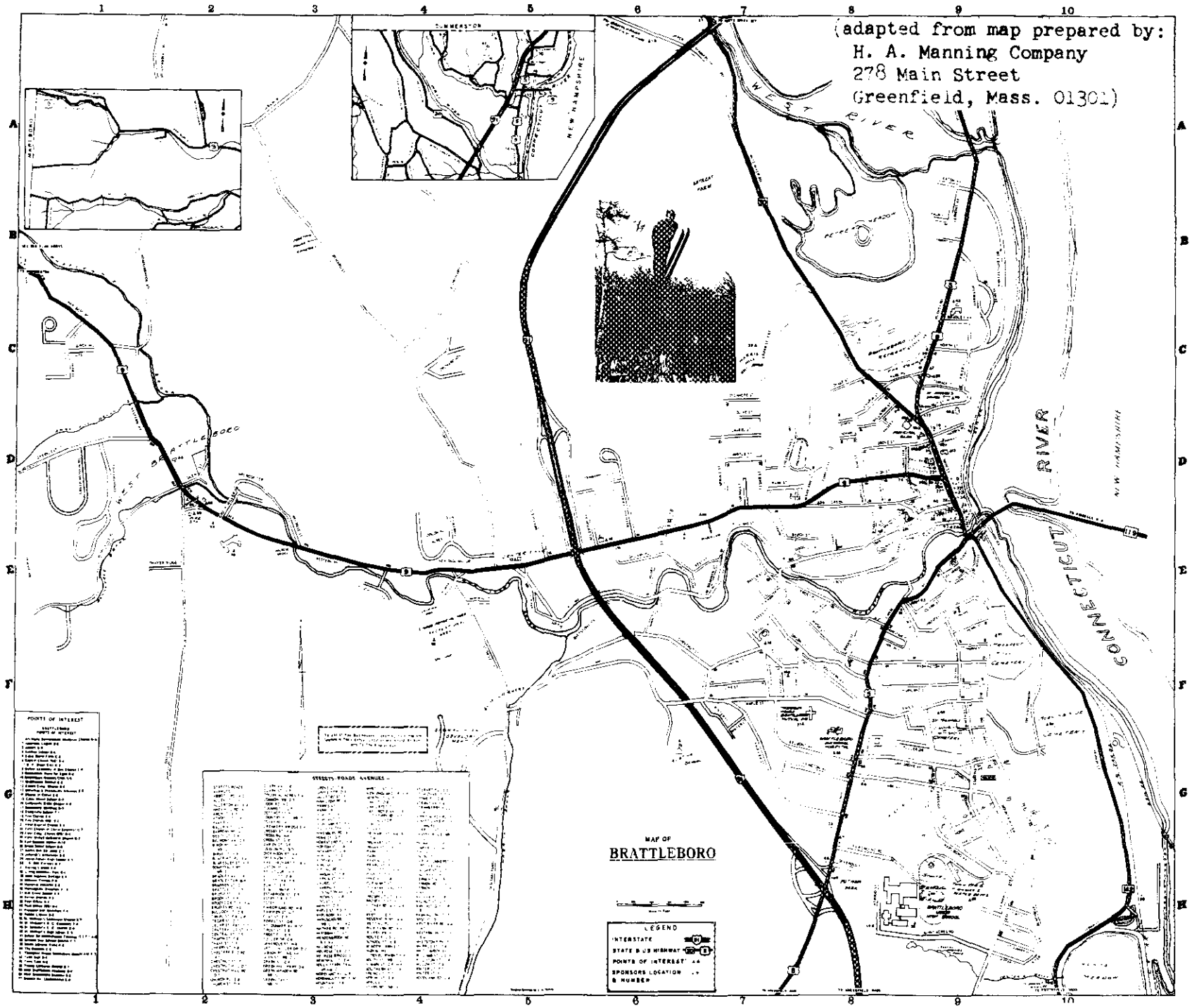

(adapted from map prepared by:
H. A. Manning Company
278 Main Street
Greenfield, Mass. 01301)
MAP OF
BRATTLEBORO
LEGEND
INTERSTATE
STATE & US HIGHWAY
POINTS OF INTEREST
SPONSORS LOCATION & NUMBER
POINTS OF INTEREST
STREETS, ROADS, AVENUES
WEST RIVER
CONNECTICUT RIVER
NEW HAMPSHIRE
WEST BRATTLEBORO

Figure 27

flow recording devices on the rivers. Records are continuous on the West River at Newfane, Vermont from 1928; on the Connecticut River at Vernon, Vermont from 1944; and on the Connecticut River at Montague City, Massachusetts since 1904.

The flood of record on the Connecticut River at Brattleboro is the March 1936 event. The 1938 flood is the flood of record on the West River, with the November 1927 and December 1948 floods also exceeding the 1936 flood on this tributary. It is impossible to say with certainty which was the highest flood during this period for Whetstone Brook, but probably it was the 1938 flood. The 1927 flood was the most damaging event that the State of Vermont has experienced, but fortunately for Brattleboro, the storm's isohyet centered itself further north in the State.

If these historical floods were to recur today, stages on the West and Connecticut Rivers would be considerably lower than actually experienced due to the operation of the system of flood storage reservoirs in the Basin. This is not the case with Whetstone Brook, however, as there are no flood impoundments on that stream.

The most recent event is the storm of June 1973. This storm centered itself north of Brattleboro. No damage was suffered in Brattleboro on the West and Connecticut Rivers. Damage on Whetstone Brook was slight and will be discussed later on.

THE FLOOD PLAIN

Whetstone Brook - There is a substantial tributary flood plain in the lower reaches of Whetstone Brook. The Flood Plain Information Report defined this flood plain from a tributary of Whetstone Brook, Halladay Brook, 5-1/2 miles downstream to the Connecticut River. The Intermediate Regional Flood (IRF) would inundate about 210 acres, which is defined as the flood hazard area. The Standard Project Flood, about 5 feet higher than the IRF, would inundate 250 acres of land area.

The downstream reach of Whetstone Brook is the most heavily developed. The area between Flat Street, Frost Street and Whetstone Brook is all flood hazard area. The area contains a large department store, a lumber company with kiln drying facilities, numerous other businesses and over twenty residences. Proceeding up the Brook, one finds scattered residences and light commercial facilities in the flood plain.

In West Brattleboro, Melrose Terrace, a public housing complex for the elderly sits in the flood plain on the bank of Whetstone Brook. The 80 one-story housing units have not suffered any substantial damage since their construction in 1968; however, water has entered the grounds on several occasions. The June 1973 flood breached a sandbag barrier set up around the buildings and water came within a foot of the floor level of the lower structures. Poor judgement was exercised in locating this complex in the flood plain. The access bridge to the housing would obstruct flows in a major flood. The bridge's supporting steelwork is about 6 inches below the calculated Intermediate Regional Flood (IRF) level. An IRF would inundate all the units in this facility, and it is likely that debris would plug the access bridge waterway, worsening the situation.

Upstream of West Brattleboro, a large flood plain extends to a point just upstream of Halladay Brook. Again there are scattered permanent homes and light commercial establishments. Several large trailer courts are located here with an estimated 300 mobile homes located in the flood plain. The June 1973 flood caused damage to some of the mobile homes and several families were evacuated. Many of these mobile homes are located immediately on the banks of Whetstone Brook and would undoubtedly be destroyed in a major flood.

West River - The Brattleboro Flood Plain Information Report has defined the tributary flood plain on the West River from its confluence with the Connecticut River upstream about 3 miles to the Brattleboro - Dummerston town line. An Intermediate Regional Flood would inundate a land area of 150 acres, and a Standard Project Flood would inundate a land area of 220 acres. Very few structures are located on this flood-prone land.

Two Corps of Engineers flood control impoundments, Ball Mountain and Townshend, effectively control 278 square miles of the West River's 423 square mile watershed. These two projects were constructed in the late 1950's and since that time have all but eliminated flood damage on the West River downstream of Jamaica, Vermont.

As mentioned previously, Route 30 runs parallel to the West River. Most of this road is above calculated Intermediate Regional Flood levels. The exception is a quarter-mile stretch of Route 30 in the Retreat Meadows area near the mouth of the West River. It is possible that Route 30 would suffer some washouts in a major flood, and an emergency water supply well field in the Retreat Meadows area would be inundated; however, dollar damages from major flooding on the West River would not be severe. A town road paralleling Route 30 would carry traffic should portions of Route 30 wash out.

Connecticut River - The Flood Plain Information Report defines the entire mainstem flood plain of the Connecticut River in Brattleboro from the Brattleboro - Vernon town line upstream to the Brattleboro - Dummerston town line. Steep banks characterize this reach of river. Several large industrial enterprises are located in the flood plain south of the confluence of the Connecticut River and Whetstone Brook. The June 1973 flood did not cause damage here, but a larger flood would inundate substantial lumber storage areas and kiln drying sheds. Inundation and water velocity should not be sufficient to cause structural damage or carry off stacked lumber. Two other industrial plants in this area would suffer some damage in a major Connecticut River flood.

FLOOD PLAIN CLEARANCE

As mentioned previously, an estimated 300 mobile homes are located in the flood plain of Whetstone Brook. These homes represent a sizeable loss potential, both in terms of dollars and lives, should a major flood occur. The extreme flashy nature of Whetstone Brook, together with the fact that very few people live along the Brook upstream of West Brattleboro means that a flash flood could occur in West Brattleboro with little or no forewarning. Such a situation would put many lives in jeopardy. Experience has shown that when lives are lost, it usually happens in the early hours of a flood situation and usually on tributary streams. Probably the reason this happens is that people who live along streams cannot imagine how vicious the stream can become in a flood situation and how fast the stream can rise as it approaches its crest.

Mobile homes, by their very nature, can be moved to other locations. It is recognized that many of these homes have foundations and all are serviced by utilities. However, moving these units to a safer location seems to be a simple and relatively inexpensive way to alleviate a flood hazard.

There might be some problem in finding suitable land which these units can be relocated upon. Brattleboro is not a community which is endowed with an abundance of prime land for development. There does, however, appear to be scattered areas throughout the Town that are flood safe and could be prepared to accept mobile homes. It seems with a little effort the Town could investigate the ownership and zoning ordinances of various potential sites for these trailers and encourage their relocation.

FLOOD PROOFING

Very little has been done to flood proof structures in Brattleboro. A cluster of small oil storage tanks on the Connecticut River is protected by a traprock dike. The dike was probably built to contain oil spills, but it would prevent Connecticut River water from reaching the tanks. It is not known if a major flood would overtop the dikes or if the dikes were overtopped, an oil spill would occur.

FLOOD PROOFING

Two lumber companies have requested building permits from the Town for the construction of kiln drying facilities in the flood plain. One of these companies is located on the lower reach of Whetstone Brook, the other is located on the Connecticut River about a mile upstream of the Brattleboro - Vernon town line. Electric wiring is to be constructed into the ceilings of these plants and electric motors will be above floor level. Some diking is also planned. In other words, an effort is being made to keep water out of these plants; however, it is felt that a major flood would inundate these plants, but they will be constructed to withstand inundation with only minor damage. The Town now makes it an unofficial policy that new construction in the defined flood plain will be constructed so that flooding will cause only a minimum of damage.

URBAN DRAINAGE

No significant urban drainage problems have been reported in the Town of Brattleboro.

FLOOD PLAIN INFORMATION REPORT

A Flood Plain Information Report was prepared by the Corps of Engineers in January 1972. To date, however, Brattleboro has not accomplished any flood plain zoning. The Town is reluctant to establish a flood plain zoning by-law because of the possible adverse effect on land values. Development in Brattleboro has been subject to the floodway criteria established under Act 250, the Vermont State land use legislation. The Town has been referring to the Flood Plain Information Report when it receives requests for building permits. If construction takes place in an area identified as flood prone, then that construction is required to be reasonably safe from flooding. Thus, Brattleboro, although it does not have a flood plain zoning ordinance, attempts to act as if it did have one. New construction in the flood plain is regulated to prevent the compounding of damage potential in the future.

The Town is presently eligible for Department of Housing and Urban Development (HUD) flood insurance. Much of the groundwork for the flood insurance program has already been accomplished through the Corps of Engineers Flood Plain Information Report, which identified the hazard areas in the Town. Since almost any structural plan adopted will not be effective for every structure in the flood plain, it seems only equitable that an effort be made to permit the unprotected individuals to secure flood insurance.

PUBLIC INFORMATION

The United States Weather Service, Hartford, River Forecast Center, issues flood warnings for the Connecticut River and many of its tributaries, including the West River. These warnings are received by the Town of Brattleboro. The Civil Defense unit, police and fire departments are, in turn, notified.

A warning of high stages was issued during the June 1973 flood. The warning, however, was only for flooding on the Connecticut River. Stages were predicted for Bellows Falls about 24 miles upstream of Brattleboro. These warnings were misinterpreted by the Town of Brattleboro, and they expected much higher stages than were experienced. The Town had no official warning of tributary flooding.

Several residents of Whetstone Brook called a town official and reported they were experiencing unusually high precipitation and brook stages. The Civil Defense unit notified the police and fire departments. The Flood Plain Information Report was then consulted to identify danger areas, and units were dispatched to inform residents. Several residents in mobile homes along the banks of Whetstone Brook were evacuated. Civil Defense volunteers stayed on duty throughout the flood in anticipation of worsening conditions which would have required extensive evacuation of mobile homes, permanent homes, and the housing for the aged complex in West Brattleboro.

This procedure seemed to work out all right in the June 1973 flood; however, the reliance on receiving a warning from an upstream resident and the transmittal of the warning to the appropriate people for action seems fraught with danger. A stream as flashy as Whetstone Brook can peak in a matter of hours; in fact, it has been estimated that Whetstone Brook could reach its peak stage within three hours after the start of an intense rainfall. It, therefore, becomes obvious that there is a strong probability that, for one reason or another, a warning would not come from upstream or that the storm would be worse than expected.

It would seem reasonable that the Weather Service could expand its flood warning service to include small tributaries. Perhaps, warnings could be issued based on storm patterns and precipitation reports in the case of streams which do not have flow gages. If flood warnings were issued directly to police or fire departments, it would be certain that a responsible person was on duty at all times to receive the warning. The Town should have hazard areas identified and know exactly who should be notified in a flood situation.

Brattleboro has established an Emergency Evacuation Plan designed to provide for the rapid evacuation of residents in the southeastern corner of Brattleboro should an emergency occur at the Vermont Yankee Power Plant in Vernon. A simulated emergency situation was used in 1972 to test the effectiveness of the plan's alert notification system and the responsiveness of emergency staff personnel. This plan, which is coordinated with State Civil Defense officials, could be expanded to provide an excellent vehicle for notifying residents of flood hazard areas of impending disaster. A dry run of a flood situation would serve to iron out any kinks in the plan. Such a dry run would also impress residents in the flood plain of their peril should a flood occur.

FLOOD CONTROL IMPOUNDMENTS

There are presently three Army Corps of Engineers flood control dams in the upper Connecticut River Basin that affect flood stages on the Connecticut River through Brattleboro. These are the North Springfield, North Hartland, and Union Village Dams, all in Vermont. It is estimated that these impoundments would lower potential flood stages by approximately four feet for a flood of the magnitude of the 1936 flood, which is the flood of record.

Two Army Corps of Engineers dams, Townsend and Ball Mountain Dams, are located on the West River above Brattleboro. These two dams effectively control over 65 percent of the West River drainage area and, since their construction in the late 1950's, have essentially precluded flood damage on the West River.

There are at the present time no flood control impoundments on Whetstone Brook, the third major stream posing a flood threat to the Town of Brattleboro. However, at the request of the Brattleboro Board of Selectmen, the Soil Conservation Service (SCS) has prepared a report entitled "Whetstone Brook Watershed, A Watershed Investigation Report, October 2, 1972." The study concludes the following:

"Based on the studies to date, some conclusions can be reached.

1) There is a serious flood danger in the Whetstone.

2) A project to prevent flood damages appears economically feasible.

3) Many alternative solutions are possible.

Any solution to the problem will require strong local initiative and participation."

According to the report, floods have occurred in 1869, 1927, 1936, 1938, 1955, and 1969. One would suppose that 1973 would now be added to that list. The report mentions the over 300 mobile home units and the housing development for the elderly along with other problem areas in West Brattleboro and the Brattleboro business district itself.

The Report states a major flood (the result of a 100-year storm) in the watershed would be disasterous resulting in $3.25 million damages and threatening the safety of those residing in the flood plain. Average annual damages have been estimated at $206,200.

Alternative solutions to the problems of flooding are discussed in general terms. A sample alternative is presented for the Whetstone. Seven impoundments and three sections of diking would cost an estimated $3.8 million.

The Whetstone watershed was one of nine upstream watershed projects identified in the Connecticut River Basin Report to meet 1980 needs in the Connecticut River Basin. It appears that if the towns of Brattleboro and Marlboro are interested in pursuing this project, the next step is for these communities to formally request that a Public Law 566, Upstream Watershed Project, be instituted for Whetstone Brook.

LOCAL PROTECTION PROJECTS

The Town has no major local protection projects and none are authorized by the Federal Government. The Town manager requested by letter in 1969 that the Corps of Engineers look into the matter of providing flood protection for the Melrose Terrace housing for the elderly project.

The Corps carried out a preliminary investigation under the authority of Section 205 of the 1948 Flood Control Act. A letter report to the Town manager dated 29 December 1969 presented the findings of the study. A plan of protection was developed which would prevent overbank flooding to the buildings of the Housing for the Elderly. The project would consist of a small earth dike and a sheet steel piling floodwall on the west side of the property along the left bank of Whetstone Brook. The improvement was estimated to cost $75,000 in 1969.

Since the Soil Conservation Service had made a study of potential Public Law 566 project sites upstream of the housing project area, the Corps of Engineers report suggested that the Town of Brattleboro contact the Soil Conservation Service for such information from SCS as related to their program. The Corps deferred studies under the 205 Program at that time, pending the results of discussions between the Town and the SCS.

CONCLUSIONS

There are three major streams in the Town of Brattleboro -- the Connecticut and West Rivers and Whetstone Brook. Whetstone Brook, by far, holds the greatest flood threat to the Town of Brattleboro. A serious flood would cause damage to the downtown area, chiefly to commercial and industrial establishments. In West Brattleboro, damage would be mostly residential, either mobile homes, public housing, and private residences. Brattleboro is fortunate in one respect. There appear to be solutions to the flood threat problem in the community.

Several studies have come up with possible solutions to the flood threat. The Soil Conservation Service plan of upstream impoundments and downstream diking is one solution. The Corps of Engineers has developed a plan of diking around the Melrose Terrace housing for the aged. The Town is to be commended in its effort to restrict development in the flood plain and its development of a warning system in the event of an impending flood; however, there are some obvious avenues which the Town should pursue to alleviate the flood threat as follows:

1) Efforts should be made so that all flood warning sources are fully utilized. This includes, but is not limited to, warnings from upstream residents on Whetstone Brook. The Town should prepare itself so that it is able to properly interpret the Hartford River Forecast Center Warnings.

2) A fail-safe system should be set up so that these warnings can be received and interpreted at any time and that all residents of the flood plain be notified of an impending flood and that evacuation of residents be implemented when necessary. The system should be tested in a dry run.

3) Suitable flood plain zoning by-laws should be enacted.

4) Coverage by HUD flood insurance should be encouraged.

5) An effort should be made by the Town to see that mobile homes in the flood plain are relocated to safe sites. This should begin with the most vulnerable units.

6) The Town should examine the results of the Federal Studies carried on to date , develop a flood plan of structural and/or non-structural measures and pursue the plan to its implementation.

PRESENT STATUS OF ELEMENTS

FOR FLOOD DAMAGE REDUCTION

KEENE, NEW HAMPSHIRE

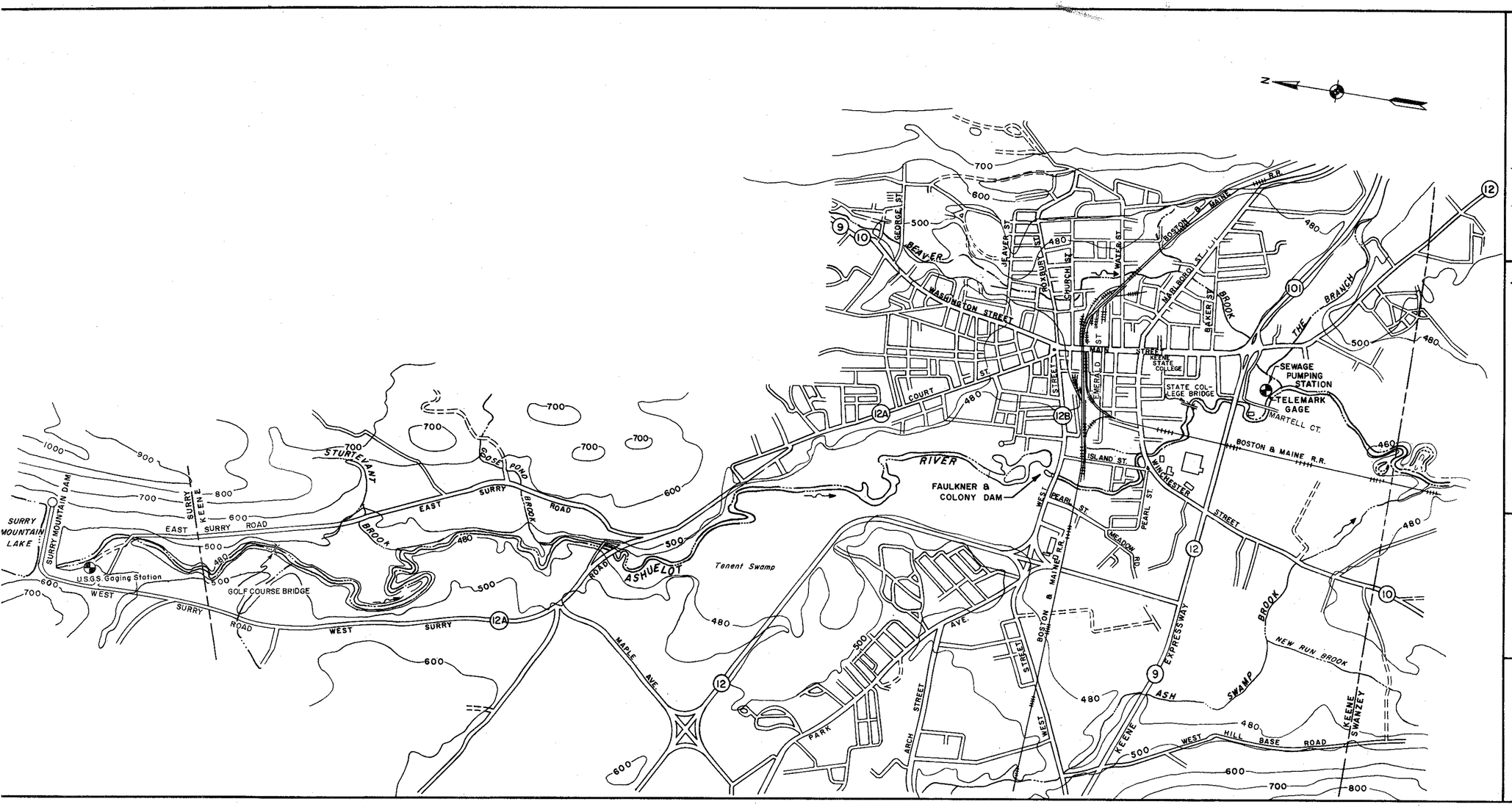
KEENE, NEW HAMPSHIRE

GENERAL

The City of Keene is located in southwestern New Hampshire, bordered on the west by Chesterfield and Westmoreland, to the north by Surry and Gilsum, to the east by Sullivan, Roxbury, and Marlboro, and to the south by Swanzey. It is the County Seat of Cheshire County and is the fifth largest municipality in the State. The year 1736 saw the first settlement of the town, then called Upper Ashuelot, with the first permanent settlement coming in 1750. In 1753, the town was renamed Keene, and chartered as a city in the year 1873. Farming was initially the principal livelihood, but the town soon became the area focal point for industry and marketing. Industrial development was concentrated along the banks of the streams. The city's tradition has been upheld, and Keene remains the regional economic center, with an economy which can be described as fairly stable and industrialized. Retail establishments number 368, while professional fields are well represented in 200 offices throughout Keene. South of Central Square, approximately 35 separate firms are engaged in manufacturing and industrial endeavors. The population rose 16.5 percent in the decade of 1960 to 1970 from 17,562 to 20,467. Continued population growth is anticipated, with the recently adopted Land Use Plan estimating a population of 31,000 (an approximate 15 percent growth projection) for the year 2000. Land area in the city is approximately 37 square miles. (See Figure 28).

The principal area of development in the city is along the new Route 12 bypass. Land on both sides of the new bypass forms a rapidly expanding area of commercial and retail development spurred by the bypass construction. Areas outside the urbanized and developing areas are mainly steeply-sloped, heavily-wooded hills, with about 850 acres of the city in agricultural use.

Topographically, Keene is bisected by a large, flat plain dividing the city into eastern and western segments. Through this plain flows the Ashuelot River and several tributaries joining it in this reach. The Ashuelot is a major tributary of the Connecticut River, rising in Sullivan County and joining the Connecticut River at river mile 139.8 in Hinsdale, New Hampshire, after meandering its way through the City of Keene. The second tributary is Beaver Brook, which flows north to south through heavily built-up areas of the city, joining The Branch just above its confluence with the Ashuelot River. The third major tributary flowing from the mountainous terrain to the east of the plain is Otter Brook, which becomes The Branch upon its confluence with the Minnewawa Brook. The Branch joins the Ashuelot River 1.6 miles below the Faulkner & Colony Dam, and 0.4 miles above the Keene-Swanzey boundary.



LEGEND

500 — GROUND ELEVATION IN FEET (U.S. C. & G.S.) SEA LEVEL DATUM

KEENE CITY LIMITS

CHANNEL

NOTES:

1. MAP BASED ON U.S.G.S. 15 MIN. KEENE QUADRANGLE SHEET, 1958. MINOR ADDITIONS AND ADJUSTMENTS MADE BY CORPS OF ENGINEERS.
2. MINIMUM CONTOUR INTERVAL IS 20 FT.

SCALE IN MILES

0.2 0.0 0.2 0.4

KEENE, NEW HAMPSHIRE
ASHUELOT RIVER

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

FIGURE 28

Flowing from the hills to the west is the Black Brook-Ash Swamp Brook system, joining the Ashuelot just south of the Swanzey boundary. On three sides of this flat, bisecting plain in Keene are steeply-sloped wooded hills forming a bowl-like structure with Keene in the bottom. It is on these steep slopes that the tributaries to the Ashuelot originate.

FLOOD HISTORY

There are a number of gaging stations in the basin providing stream flow data. U. S. G. S. gaging stations have been maintained on Otter Brook near Keene, and subsequently below the Otter Brook Lake after the dam was constructed, since October 1923. Other gages have been in use, including those on the south branch of the Ashuelot River at Webb, New Hampshire since October 1920; on the Ashuelot River near Gilsum, New Hampshire since August 1922; on the Ashuelot River below Surry Mountain Lake since September 1945; and, on the Ashuelot River near Hinsdale, New Hampshire since March 1907. In addition, the Corps of Engineers has a telemark gage on the Ashuelot River just above its confluence with The Branch. There are several other staff gages located at various points throughout Keene which are maintained by the City Department of Public Works.

As is the case throughout the Connecticut River Basin, the main flood season in Keene is in the spring, when floods usually result from rain falling on melting snow. However, floods can occur during any month, and two of the greatest floods (1927 and 1938) did, in fact, occur during the fall.

As is the case throughout the Connecticut River Basin, the main flood season in Keene is in the spring, when floods usually result from rain falling on melting snow. However, floods can occur during any month, and two of the greatest floods (1927 and 1938) did, in fact, occur during the fall.

The volume flood of record for the City of Keene on the Ashuelot River is the March 1936 event, when the telemark gage reached an elevation of 473. 4 feet above mean sea level(msl). The peaking flood of record, representing the peak stage of flood waters in the city, occurred during the September 1938 event, when a hurricane passed over the Basin. During this storm, the telemark gage reached an elevation of 475. 3 feet msl. Other large recorded floods, in descending order of magnitude of stage, occurred in 1927, 1920, 1923, 1960, 1934 and 1933 (based on the U. S. G. S. gage on the Ashuelot River at Hinsdale, New Hampshire). Fourteen floods causing significant damage have been reported to have occurred between 1738 and 1900. Little data on these floods are available, but it is estimated that the flood of October 1869 probably caused the most damage of any of these early floods.

THE FLOOD PLAIN

Because of the bowl-like topography discussed earlier, there is essentially one large flood plain in Keene, identified as the Keene Flood Plain in the Flood Plain Information report prepared by the Corps of Engineers for the city. This flood plain receives waters from the Ashuelot and its tributaries. The flood plain has as its upstream limits the Faulkner & Colony Dam above West Street in Keene, and its downstream limits at Dickinson Dam in West Swanzey. That part of the flood plain from the Faulkner & Colony Dam to the mouth of The Branch, a distance of 1.6 miles, is the most critical flood damage area. Here, the river meanders, and has a low discharge capacity because of its small cross-sectional area and flat gradient (the Ashuelot River is essentially flat through the urbanized area of Keene). The result is that considerable ponding occurs, and areas remain inundated for several days during flood events. The extent of flooding, together with water-surface profiles of the Standard Project Flood (SPF) and the Intermediate Regional Flood (IRF), have been prepared by the Corps of Engineers for the Ashuelot River from Surry Mountain Dam to just downstream of the city boundary. These are presented in the Flood Plain Information report prepared for the city. The SPF is approximately 1 to 1-1/2 feet higher than the IRF. Therefore, the extents of flooding are the same as they cannot be differentiated at the scale of available mapping. Under present-day conditions with Surry Mountain and Otter Brook Dams in operation, the SPF levels would be reduced to approximately 2.6 feet below the stage experienced at the telemark gage during the September 1938 flood. The area inundated along the Ashuelot River by both the IRF and the SPF is approximately 3,120 acres. An additional 370 acres are indicated as being inundated along Beaver Brook from George Street to its confluence with The Branch and the Ashuelot. The total flood prone area represents about 14.7 percent of the city.

Immediately below the Surry Mountain Dam is a golf course which would be partially inundated in times of flooding. Also found in this stretch of the flood plain is a mobile home park on the south bank of the Ashuelot at the West Surry Road Bridge (Route 12A crossing). A part of the mobile home park appears to be susceptible to flooding. Immediately upstream of the Faulkner & Colony Dam is a low income housing project for the elderly, presently under construction, which is indicated as being in the flood plain, as defined by the Flood Plain Information report. A significant amount of inundation does occur between these two dams. Only a small amount of flood damage can be anticipated because it is a relatively undeveloped area, particularly nearer the Surry Mountain Dam.

As mentioned above, the major damage areas are downstream of the Faulkner & Colony Dam. Since the new Keene bypass bisects this area, it is also an area of intense development. The square area between West Street and Route 12, the expressway bypass and Keene State College, is of special interest. It is an intense area of development. The Winchester Street area in particular has two big shopping centers, grocery stores, retail stores, and gas stations. West of this area is the location of Cheshire Homes, a condominium/apartment high density housing development.

South of Route 12 at the Winchester Street and Route 12 intersection, a motel is under construction and many other retail and commercial developments appear to be in the offing. This is the area where growth is now being encouraged in the city.

On Emerald Street, an electrical substation and gas company yard are subject to inundation from high flood waters. On the other side of the Boston and Maine railroad tracks is the site of the Keene State College expansion into the flood plain on the left bank of the river. Downstream of the bypass is the city's sewage pumping station, off Martell Court. Much of this development is being placed on fill. For example, the area where the low-income housing for the elderly was built was placed on some fill, some of the shopping centers received a little fill, and portions of the Beaver Brook flood plain also received some fill.

The areas discussed above are predominantly subject to inundation by major floods. The seasonal (annual) flood plain is associated mainly with Beaver Brook and the inundated areas shown on the FPIR are essentially accurate according to discussions with the City Planning Director and others. Considerable industrial development occurs along the railroad tracks in that area, but other streets - Roxbury and Church Streets - are residential areas and they do suffer significant basement flooding because of Beaver Brook apparently contributes to these problems, and the city plans to improve the bridge, which they believe would improve their flood flows.

CLEARANCE

Flood plain clearance has never been used as a management tool in the City of Keene. The city seems to favor channel improvements and local protection as their principal management techniques. There are considerations, however, as indicated in the recently published and adopted Land Use Plan, for the purchase of the more sensitive flood-prone areas as a means of controlling development. Long-range plans call for the purchase of real estate subject to seasonal flooding, in particular areas

along Beaver Brook. This type of purchase will encourage relocation and effectuate a clearance of the area, converting it to a more suitable and compatible flood plain use.

Although Keene has no resettlement/relocation, or clearance plans, mobile home developments are relocatable. However, this does not appear to be an acceptable solution to the city, because of its topography. The most developable land is in the flood plain along the bypass, and the city plans to continue development in this area.

FLOOD-PROOFING

While most structures in the rather extensive Keen flood plain are not flood-proofed, there are several newer buildings in the area that do have provisions to minimize flood damage. In particular, new dormitories at Keene State College, constructed in the flood plain were designed utilizing removable heating units and roll-up carpeting. In times of flooding, the area can be easily evacuated, cleaned up, and all equipment removed before the floodwater can pass through the building. This will result in minimal damage to furnishings within the building. Other buildings in the city apparently incorporate similar design provisions to minimize flood damage.

The building code of the city, however, does not directly address flooding, and the Building Inspector is aware of no buildings utilizing extensive flood-proofing measures. Flood-proofing that does occur is on an individual, voluntary basis by the developer. The Building Inspector maintains a library of literature on flood-proofing in his office, and both he and the Planning Department give advice concerning construction in the flood plain. At this time, all help and constraints are advisory. Techniques currently being recommended include interior pumping and the placement of parking structures underneath residential structures. These ideas for housing in the flood plain include flood-proofing specifications and recommendations to minimize flood damage that would otherwise occur to such developments in the flood plain. Also, fill is regarded as a method of flood-proofing, and there are a number of places mentioned above where fill have been put in place before building.

URBAN DRAINAGE

Approximately 75 percent of the City of Keene is covered by catch basins and a storm-drain system to control urban runoff. It is a very old, separated system, and suffers from heavy infiltration, a problem that is intensified during flooding. The sewage treatment plant is also affected; the problem is due largely to infiltration, which in time of flooding makes it necessary to pass up to 4 million gallons of raw sewage into the

river. Thus, one could say that Keene has urban drainage problems from an old, undersized system, subject to heavy infiltration of ground water, that overloads under flooding conditions.

Generally speaking, the urban flood problems can be divided up into the occasional inundation of ponding and flash flooding. During heavy rainstorms, some flash flooding does occur in various portions of the city, because of undersized drains and some basements have been known to experience flooding. The big problem in Keene, however, is ponding - the flood water remains for a number of days, unable to drain because of the flat drainage gradient through the city. In addition to ponding along the Ashuelot, Beaver Brook is another area subject to storm drainage problems in the lowland along the brook where the gradients are such that stormwater will back up into basements during times of high water. A pumping station has been suggested to improve drainage in this area; however, this is still in the planning stages. Ponding is also a problem here, as annual flooding occurs when the basin fills with water.

FLOOD PLAIN INFORMATION REPORT

The Corps of Engineers has prepared a Flood Plain Information report for the City of Keene, entitled: "Flood Plain Information, Ashuelot River, City of Keene, New Hampshire." This report contains a discussion of past flooding in Keene and predictions of expected future conditions. Included in the report are profiles, and the delineation of the extent of flooding caused by the Ashuelot River and the lower portions of Beaver Brook.

In addition to this Flood Plain Information report, the Corps of Engineers has prepared several studies investigating proposed flood control structures and multi-purpose reservoirs, to be constructed on tributaries to the Ashuelot, upstream of Keene. Additional information has been received through the services of the Soil Conservation Service (SCS). In December 1972, the SCS submitted a report entitled: "Ash Swamp Brook Watershed, Preliminary Feasibility Report." This report reviews past flood control measures taken in connection with the Ash Swamp Brook Watershed, investigates the possibilities of three potential structurally improved sites to control flood waters, and reaches the conclusion that the potential benefits from such structures would be small in comparison to the costs involved. Recommended instead was the development of a flood plain zoning program to restrict the use of flood-prone areas of Keene. The report also recommended that such measures as flood-proofing and flood insurance be investigated for the provision of physical and economic relief from flood damages to existing developments. The major reason for rejecting structural measures can be directly attributed to the fact that the main portion of the Keene flood plain is

associated with land influenced by the Ashuelot River. Additionally, large portions of the Ashuelot Watershed and flood plain are coincident with Ash Swamp Brook flood plains; flooding along the Ash Swamp Brook is significant as a direct result of conditions on the Ashuelot. An additional report is that undertaken by a college student for a Bachelor of Engineering project. It essentially reiterates material that the Corps of Engineers has already done regarding Beaver Brook Dam and the other structures in the area, and its recommendations were essentially those of the Corps concerning major structural control measures.

PUBLIC INFORMATION

Publicity - Public information concerning flooding appears to be largely the responsibility of the Planning Department in Keene. Copies of the Flood Plain Information report and brochures are available in the offices of the Building Inspector, City Manager, and the Planning Department. The Planning Department also maintains its own information concerning flooding in the city, including reports by the SCS and others. Information is available to people approaching either the Building Inspector or the Planning Department concerning construction in flood sensitive areas. Information concerning flooding is disseminated to actual or potential users of the flood plain, in their required dealings with the Planning Department. As an additional source of publicity, the recently adopted land use plan is being discussed in groups throughout the town and these discussions have resulted in publicity regarding flooding and the flood plain in the area.

Flood Warning - At the present time, the City of Keene is in the process of putting together a plan for emergency situations such as flooding. Currently, all emergency measures are relatively informal, and under the supervision of the Fire Chief, who is the recipient of National Weather Service flood warnings. While the new plan has not been fully developed at this time, it can be expected to include established locations for relief stations, lists of people to notify, and an exact description of procedures to be followed in the event of emergency. In conjunction with this future emergency program is the development of a communication system, involving central radio dispatching for coordination of all emergency resources, including fire and police. Presently, there is no contact with the operators of either Surry Mountain or Otter Brook Dams regarding discharges from those structures and their possible effects upon flooding in the city itself.

FLOOD CONTROL IMPOUNDMENTS

There are two Corps of Engineers flood control dams within the Ashuelot River Watershed. The first of these is Surry Mountain Dam and Reservoir, located on the Ashuelot River five miles north of Keene in Surry. The reservoir is operated for flood control purposes and has a storage capacity of 32,500 acre-feet, equivalent to 6.1 inches of runoff from the drainage area of 100 square miles. The second structure is Otter Brook Dam and Reservoir located on Otter Brook, approximately 4.9 miles above the confluence of The Branch with the Ashuelot River. It too is operated for flood control purposes and has a flood storage capacity of 17,600 acre-feet which is equivalent to 7.0 inches of runoff from its drainage area of 47 square miles. The operation of these structures would have reduced the peak of the March 1936 and 1938 flood stages by 2.7 and 3.6 feet respectively, at the Corps of Engineers telemark gage. The Corps of Engineers has plans for another development, which is authorized as a multi-purpose structure. This is the Beaver Brook Dam and Reservoir. It would impound 2,750 acre-feet for flood control, as well as serving to provide recreational opportunities. Unconstructed but authorized structures are discussed in Appendix M of the "Connecticut River Basin Comprehensive Water and Related Land Resources Investigation," Connecticut River Basin Coordinating Committee, June 1970.

LOCAL PROTECTION PROJECTS

Several completed local protection projects involve the City of Keene. One is under the auspices of the Corps of Engineers and one under the SCS.

The Corps of Engineers flood-control local protection project was completed in 1954, and encompasses a total of 1800 feet of channel improvements to improve drainage conditions (two channel improvements, one 1400 feet, the other 400 feet). The second local protection project is a rather extensive drainage system developed by the SCS. Originally designed as an entirely non-structural system, it was intended as a drainage system for agricultural use. The area actually involved in the SCS project is portions of the lower Ash Swamp Brook watershed, terminating near the intersection of Winchester Street and the Keene bypass. In addition to being in the Ash Swamp Brook flood plain, this area is also in the Ashuelot flood plain. The area is so flat that it has virtually no gradient, and the stream channels are so small that the discharge is very low. This rather extensive drainage system was, therefore, developed to improve discharge. Elements of

these projects, specifically the drainage ditches, pass very close to the extensive new development of shopping centers and retail outlets along the Keene bypass, in the Ash Swamp Brook - Ashuelot River flood plain. Additionally, there is a small channelization project on the Black Brook, upstream of Wilson Pond and Route 12.

The cost of maintaining all of these local protection projects is underwritten by the City of Keene as required by P. L. 89-205, and the city conducts an annual inspection in conjunction with the local SCS office to insure adequate maintenance.

CONCLUSIONS

Flooding in the Keene area is due to floods on the Ashuelot River and its tributaries occurring primarily in the spring months from excessive rainfall and snowmelt, although flooding can occur in other months from tropical storms. Keene, at the bottom of a topographic hollow ball, suffers mainly from the ponding of water in the flood plain; the water often remaining for many days because of the flat gradient. Some flash flooding on the smaller tributaries of the Ashuelot occur as a result of excessive rainfall runoff in their watersheds. Urban drainage is a problem, particularly below the Faulkner & Colony Dam. The separated storm sewer system is undersized and old, suffers from excessive ground water infiltration, and stoppages. As a result of infiltration during flooding, the sewage treatment plant discharges up to 4 mgd of raw or incompletely treated sewage into the Ashuelot River.

Two Corps of Engineer upstream impoundments, Surry Mountain Dam and Reservoir and Otter Brook Dam and Reservoir, provide as much as 50,000 acre-feet of flood water storage and would reduce damages if a flood equal in magnitude to the flood of record of March 1936 re-occurred in Keene. No formal flood-proofing is required by the building code, but several apparently effective methods are used by developers who are building in some of the flood-prone areas. Keene has a plan, and apparently some funds, to buy up housing located in the most flood vulnerable areas as a means of clearing parts of the flood plains. The city, apparently by intent, has encouraged flood plain development, where the flood hazard is considered less severe. Use of fill in flood-prone areas is fairly extensive, which is a flood-proofing device, but also represents additional encroachment of the flood plain. Some designs of recent buildings utilize the lowest level for parking, or utilize easily evacuable furnishing on the lowest floor. The City Building Inspector provides guidance in flood-proofing, but the help and constraints are advisory not mandatory at this time. Both the Corps of Engineers and the Soil Conservation Service have prepared flood plain information reports, the former for the entire City of Keene, the latter for Ash Swamp Brook Watershed, a tributary of the Ashuelot River. Publicity

of the flood situation appears to have made the Keene inhabitants aware of flood potentials. At present, the city is developing an emergency plan for floods and other disasters. Both the Corps of Engineers and the SCS have constructed local protection projects in Keene. The Corps' project consists of 1,800 feet of channel improvements in two channels of 400 and 1,400 feet respectively. The SCS project involves 10.3 miles of drainage ditches in Lower Ash Swamp Brook Watershed. Keene maintains these projects and accompanies Federal personnel on an annual inspection of them.

PRESENT STATUS OF ELEMENTS

FOR FLOOD DAMAGE REDUCTION

CLAREMONT, NEW HAMPSHIRE

CLAREMONT, NEW HAMPSHIRE

General

The City of Claremont, New Hampshire is located in the southwestern portion of the State in Sullivan County, known as the Middle Connecticut Valley Area. It is approximately 23 miles south of Lebanon and 120 miles northwest of Boston. It is bordered on the west by the Connecticut River and Weathersfield, Vermont; on the north by Cornish; on the east by Newport; and on the south by Unity and Charlestown, New Hampshire. Founded in 1764, Claremont has grown to be the largest city in the county. Its 1970 census population was 14,221, increasing from 13,563 in 1960, or 4.9 percent. Population growth is expected to continue to increase at a moderate rate to a projected population of from 15,900 to 16,400 by the year 2000. Land area of the city is 42.4 square miles. (See Figure 29).

Known as a " shopper's city," Claremont is a regional retail and commercial center as well as a major manufacturing center for the area. Manufacturers include older firms, some of which utilize water of the Sugar River, including 2 paper mills, a woolens plant, and a drill and mining machinery manufacturer, as well as newer industries manufacturing health products, tool bits, lumber, plastic products, precision tools, and steel joists and trusses. Current development is now occurring along Washington Street (Routes 11 and 103) as well as in the southwestern portions of the city along or near Route 12A. The development along Washington Street (Routes 11 and 103) east of the center of the city is primarily strip development including retail and commercial businesses. Outside of the central business district, which is essentially retail and commercial except for the industries along the Sugar River, the city is primarily rural residential with some farms interspersed.

The form of government in Claremont is the City Council- City Manager, with an appointed Planning Board and a full time City Planner.

The topography of Claremont is generally hilly to mountainous, most of which is in forest cover. Some areas are used for agricultural purposes, particularly along the Connecticut River. Principal surface waters include the Connecticut River which flows north and south along the western edge of the city, forming its boundary, and the Sugar River which flows in a twisting manner generally east to west through the city, entering the Connecticut at river mile 195.2 just downstream of the Route 103 bridge. The river bisects the city passing through the central business

district. Routes 11 and 103 roughly paralell the river as it passes through the city.

The entire city drains into the Sugar or Connecticut Rivers, except for a small area in the southwest portion of the city around Routes 11 and 12, which drains into)x Brook, a further downstream tributary of the Connecticut River.

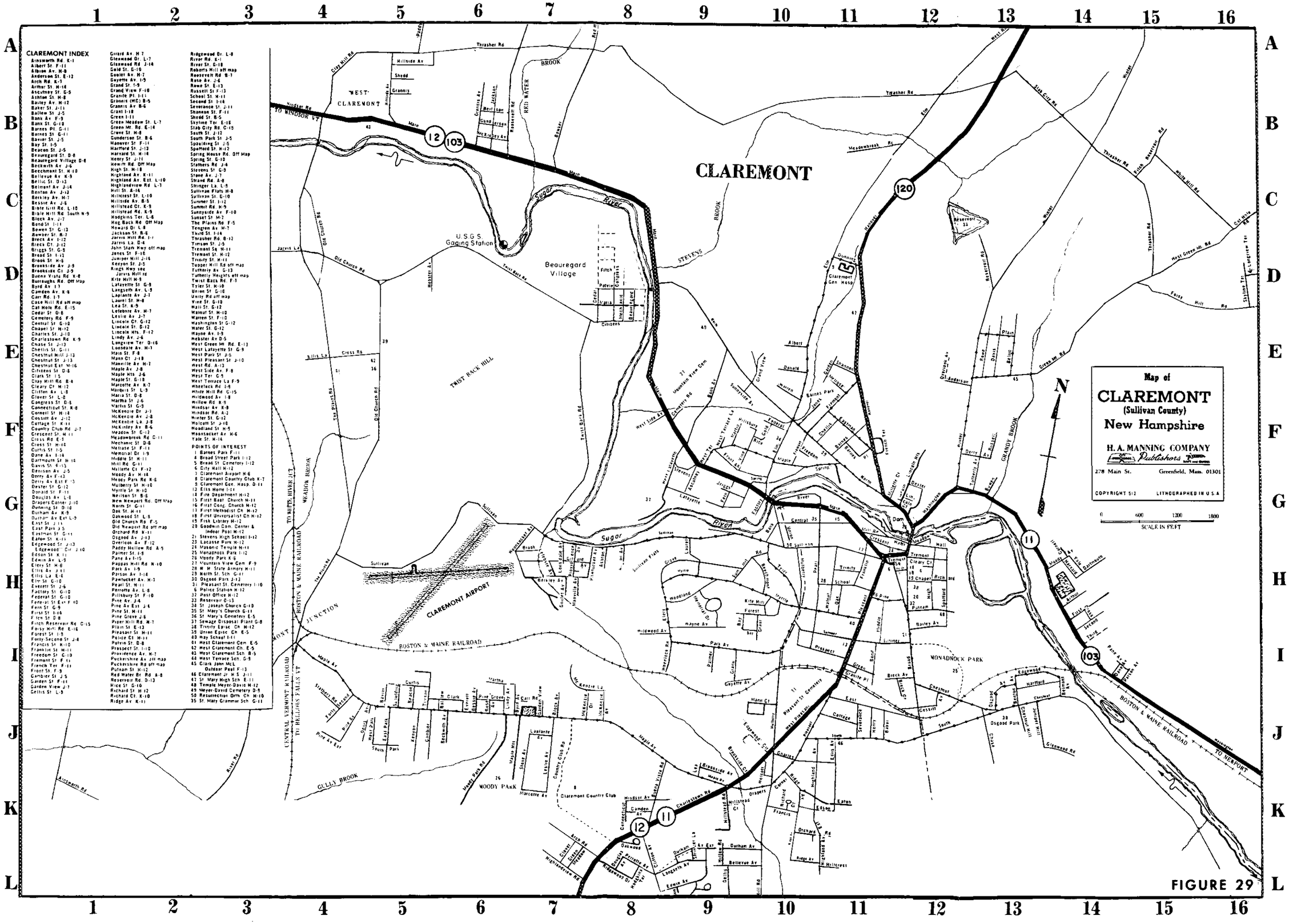
The central section of the city has sanitary sewers, and water supply is obtained from impoundments and wells in scattered locations throughout the city.

Flood History

Stream flow records have been maintained on the Connecticut River at a U. S. G. S. gaging station at West Claremont since May 1928. As is common to the entire Connecticut River Basin, the main flooding season is the spring, when the combination of rain and snow melts contributes to a high rate of runoff.

Connecticut River- The two major floods of record on the Connecticut River in the vicinity of Claremont occurred in March 1936 and November 1927. The stages for these two floods were approximately the same, and are roughly equal to the Standard Project Flood modified by existing reservoirs as defined by the Corps of Engineers. Other large floods occurred, in descending order of magnitude of stage, in 1936, 1913, 1922, 1938, 1973, 1953, 1933, 1959, 1912, 1914, and 1925. It is fairly certain that recent floods have been the most severe since the settlement of the area. Connecticut River floods do not cause great damage in Claremont, except for some agricultural land, because of the high steep banks along the river in Claremont.

Sugar River- The flood of record along the Sugar River is the March 1936 event, when a discharge of 14,000 cfs occurred with a recorded gage height of 10,92 feet. This flood caused major damages to industrial, commercial, and residential property. It caused a great deal of railroad and highway damage, with lesser amounts of agricultural damage. Other major floods of the Sugar River occurred in 1927, 1938, 1934, 1953, 1960, 1951, 1940, 1937, 1939, and 1973. The most recent flooding occurred in early July 1973, with a gage height of 6.96 feet and an associated discharge of 6,110 cfs recorded at the West Claremont Gaging Station (from provisional U. S. G. S. data). The flooding was not major and the damage was restricted mostly to erosion, scour, and sedimentation.


Map of
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SCALE IN FEET
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N
CLAREMONT
WEST CLAREMONT
TO WINDSOR VT
U.S.G.S. Gaging Station
Beauregard Village
TWIST BACK HILL
CLAREMONT AIRPORT
BOSTON & MAINE RAILROAD
CENTRAL VERMONT RAILROAD
TO BELLOWS FALLS VT
MONT JUNCTION
MEADOW BROOK
GULLY BROOK
MOODY PARK
MONADNOCK PARK
Claremont Country Club
Claremont Gen. Hosp.
Mountain View Cem.
Sugar River
RED WATER BROOK
STEVENS BROOK
GRANDY BROOK
TO NEWPORT
CLAREMONT INDEX
POINTS OF INTEREST

FIGURE 29

The only developed area threatened with inundation was the Beauregard Village portion of West Claremont.

The Flood Plain

Connecticut River- The Connecticut River flood plain in the Claremont area has been defined by the Corps of Engineers in Appendix M of the "Connecticut River Basin, Comprehensive Water and Related Land Resources Investigation," published by the Connecticut River Basin Coordinating Committee, June 1970, using the Intermediate Regional Flood (IRF) and the Standard Project Flood (SPF). The SPF is between 3.5 and 4.5 feet above the IRF and is approximately equal in stage to the 1927 and 1936 floods in this area. Because of the high steep banks along the Connecticut River, there is very little flood plain in the area. No development has taken place in the flood plain except for two small agricultural areas, one in the vicinity of Jarvis Island, just before the river makes a sharp turn to the south, and the other at the mouth of the Sugar River which receives flood waters from the Connecticut. Development along the high banks north of the mouth of the Sugar River is also limited to residences and agricultural uses; however, this area is sufficiently elevated above the river to prevent flooding.

Sugar River- The Soil Conservation Service (SCS) in its "Work Plan for Watershed Protection, Flood Prevention and Recreation," defined the flood plain as a 100-year flood along the Sugar River from the industrial area along Route 103 west to the U.S.G.S. gaging station in West Claremont. Also included in this report is the delineation of this flood after installation of the proposed flood control structures recommended in this Work Plan. The SCS has delineated the 100-year flood plain for the entire length of the river in Claremont on aerial photographs at a scale of 1 inch = 400 feet. These delineations also include water surface profiles. The principal areas of inundation and damage caused by flooding of the Sugar River occur in the same length of river shown in the Work Plan that defines the 100-year flood. Approximately 460 acres would be inundated by the 100-year event. The flat plain between the Broad Street bridge and the eastern city boundary is a ponding area for flood waters that would suffer extensive flooding during a 100-year event. This area along New Hampshire Route 103 is an area of strip development. Flooding would involve one of the largest dairy operations in the State, a junk yard, a drive-in theatre, a machine shop, a radio station, 30 residences, 5 to 10 commercial establishments, oil storage tanks, one railroad bridge, several hundred feet of railroad and highway, athletic fields, and hundreds of acres of agricultural land.

The Broad Street Dam was recently lowered a few feet to obtain a

drainage gradient for the Monadnock Park development. It is not believed that this will affect flood stages in this ponding area. From Broad Street through the urbanized area of the city, the river falls steeply, remaining in its channel for the most part. However, a paper processing mill and woolen mill are subject to high velocity inundation during severe flooding. West of the urban area the river once again experiences out-of-bank flow, first passing the existing primary sewage treatment plant, which is protected by an old diking system. The plant would not be inundated, but would be surrounded by water. The most critical and sensitive flood-prone area which is flooded or threatened with flooding nearly every spring is the Beauregard Village area of West Claremont. This area contains three commercial establishments, roads, and various residences including a hotel and about 30 mobile homes. During large floods the area will be surrounded by water, estimated to be 5 to 6 feet deep. About 30 to 50 residences (mostly mobile homes) would be damaged by moderate velocity flow. The July 1973 high water required sand-bagging and other precautionary measures to protect the area. Downstream of Beauregard Village, out-of-bank flooding continues, but because the area is not highly developed, the damage is minor. However, portions of roads and a paper company just beyond the next downstream bridge will be threatened.

Other- The SCS has some preliminary soils maps which indicate flood plains on some of the small tributaries that are subject periodically to flash flooding caused by heavy rainfall in Claremont. Such streams include Red Water Brook where flooding would involve a few farmsteads and residences along its length. Other minor flooding occurs in the area of Puckershire apparently caused by flash flooding from Quabbinnight and Spring Farm Brooks.

Clearance

Resettlement, relocation, or clearance is not presently used as a flood plain management technique in Claremont. The only area susceptible to one of these approaches would be Beauregard Village. The large number of mobile homes would suggest relocation to higher ground out of the danger of flood waters. Such a program is not now anticipated in the city.

Flood-Proofing

No buildings in Claremont are known to be flood-proofed. The city's building code does not address itself to the problems of flooding. In lieu of specific regulations, either building code or zoning, the building inspector (in whose office the aforementioned SCS water surface profiles and delineations are filed) encourages or advises those contemplating

building in the flood plains concerning adequate protection for structures. For example, a new manufacturing building is being constructed near the flood plain along Washington Street (Route 103) on the site of a former lumber yard. The original location of the building was moved to a higher point, with construction methods and materials selected with consideration for flood potentials, Such procedures have not been applied to the residential Beauregard Village area where development has taken the form of incoming mobile homes.

Urban Drainage

Significant portions of the City of Claremont are serviced by storm drain catch basins. The system is a separated system with discharge at various points along the Sugar River. No significant flooding problems are associated with urban runoff, either becuase of the lack of storm drains or inadequately sized storm drains. Local flooding only occurs under circumstances where storm drains are plugged by leaves or debris. Located near the mouth of the Sugar River, flooding experienced by Claremont is due almost entirely to upstream runoff and to the flat gradient that causes ponding upstream of the Broad Street bridge.

Flood Plain Information Report

No flood plain information report has been prepared by the Corps of Engineers for the City of Claremont; however, in connection with the proposed Claremont Dam, the Corps of Engineers has performed studies on flooding in the Sugar River Basin.

The main source of flood plain information for the city has been through work performed by the SCS. The Work Plan mentioned earlier, published in 1969, revised in 1971, and updated this summer (1973) at the request of HUD, contains discussions of past flooding, damages, the flood plain, and presents a proposed plan for structural measures to reduce flood stages and provide recreation sites. The water surface profiles and delineation are included in the Work Plan for the 100-year flooding event. The delineations (on aerial photos) show both the extent of flooding for existing conditions and for conditions after construction of the flood-water retarding system. These profiles and delineations are on file in the Building Inspector/Planning Office. As mentioned above, preliminary soils maps have been prepared indicating areas along tributaries which may be subject to flash floodings.

At the request of Claremont, the SCS is planning to perform a Flood Hazard Analysis study during the spring of 1974, in anticipation of the city's adoption of flood plain zoning.

Public Information

Publicity- In terms of the publicity of flood protection measures, significant publicity has occurred as a result of the proposed Claremont Dam, the structure proposed by the Corps of Engineers, which would have a significant effect on downstream flooding. The structure has received considerable publicity in the town, and several referendums have been taken in the city, all of which have been against the development of the dam site. As a result of the referendum and the Governor's subsequent action in 1967, the dam project was reclassified as inactive by the Corps of Engineers. An additional publicity matter is indicated in the Work Plan written by the SCS. In this report there is a statement that the City of Claremont agrees to publicize annually the 100-year flood plain. Other than these measures, there is no existing active plan for publicity of flood problems in the city. The city anticipates adopting a flood-plain zoning ordinance in the spring, and it is expected that that will arouse considerable interest in the problems associated with flooding.

Currently, information on the status of flood projects and flood control measures and the extent of flooding is available through the SCS offices in Claremont, and the Office of the Planner/Building Inspector. Delineations and profiles are kept on file in the Building Inspector's office, and are consulted whenever an application for a building permit is received.

Flood Warning- Emergency procedures, including those for flood hazards, are the responsibility of the police in Claremont. Flood warnings are received from the National Weather Service at the Police Station; in addition, the police are dependent on local residents for information on small tributary flooding. In the event of an emergency, a list of officials has been prepared to be notified. Emergency cots are available in several public buildings if evacuation is required. There is no list or designation, however, of homes in flood-prone areas. Police and Civil Devense personnel rely on past experience concerning threatened areas, and go from house to house for evacuation as necessary. The police are cognizant of the places to check first for flood hazards because of the nature of flooding in Claremont, and the fact that there are specific areas that are known to be flood-prone. The most recent test of the emergency program occurred when a crack was reported in the

White Water Dam, one of the city's water supply reservoirs flowing into Red Water Brook. As a result of this report, all residents along Red Water Brook were evacuated on a house to house basis by the police. The operation was reported to be smooth and well-functioning.

Flood Control Impoundments

Connecticut River- Two flood control reservoirs affect flood flow in the Connecticut in the reach in which Claremont is located. Both were built and are operated by the Corps of Engineers. The first of these is the Union Village Dam, a single-purpose flood-control structure located on the Ompompanoosuc River four miles above its junction with the Connecticut. The structure was completed in June 1950. Available storage at the spillway crest is 38,000 acre-feet, equivalent to 5.7 inches of runoff, from a drainage area of 126 square miles. The second structure affecting flood flows is the dam impounding North Hartland Lake. This is a multipurpose reservoir designed for flood control, recreation, and fishery enhancement. It is located on the Ottauquechee River and was completed in June 1961. At the spillway crest, it has an available flood control storage of 71,400 acre-feet which is equivalent to 6.1 inches of runoff from the 220 square miles of drainage area that it controls.

Sugar River- The Soil Conservation Service Work Plan, mentioned earlier for the Sugar River Watershed, includes ten proposed flood water retarding structures. Six of these had recreational sites associated with them. The planned period of completion for these structures is seven years from the date of publication (May 1971). One of these proposed structures has been built, Site C2, Eastman Pond, located on Eastman Brook. This structure provides 1,972 acre-feet of retarding storage equivalent to 4.74 inches of runoff from its drainage area of 7.80 square miles. The only other structure providing flood storage on the Sugar River is Lake Sunapee, under the operational control of the New Hampshire Water Resources Board. While not designated as a flood control structure, having no flood control storage per se, the water level in the lake is lowered during the fall in anticipation of spring floods. Private development around the lake shore, however, prohibits maximum use of the lake as a flood control device. Numerous other small ponds in the headwaters of the Sugar River affect flood flows, but are not controllable as flood protection devices.

As was mentioned earlier, the Corps of Engineers proposed a flood control structure to be located in the City of Claremont in that area, discussed earlier, where ponding now occurs. This proposal was turned

down by Claremont in a referendum in 1967, and the project is now considered inactive. If the structure were to be built, flood damages downstream could be expected to be reduced significantly.

Local Protection Projects

There are no local protection projects in the City of Claremont. Some bank stabilization has been performed by individual owners at random locations. Clean up from the July 1973 flooding is presently underway, concentrating essentially on the deposited sediments and erosion that occurred during the flooding.

Conclusions

Flooding in the Claremont area is due primarily to high rate of runoff in the Sugar River Watershed, resulting principally from spring freshets following rains and snow melt in the headlands, and to a much lesser extent from large volume flows in the Connecticut River. Two small agricultural areas are flooded by the Connecticut. The steep gradient of the Sugar River causes high velocity flood flows in some portions of the city that are especially damaging to property. Major damage has occurred to industrial, commercial, and residential property in Claremont. Certain flat gradient areas along the Sugar River suffer ponding problems from flood waters, especially upstream of the Broad Street bridge. An old diking system protects the sewage treatment plant west of the main urbanized area. However, Beauregard Village is a particularly sensitive flood-prone area in West Claremont. Flash flooding occurs on some of the small streams from high intensity rainfall.

Claremont has its major flood plains identified. The Corps of Engineers has delineated the SPF and IRF along the Connecticut, reflecting a small flood plain in the vicinity of Claremont. The SCS in its Work Plan has delineated the 100-year event for the Sugar River, comparable to the IRF. The SCS has made some tentative delineation of small stream flash flooded areas based on preliminary soils maps. In addition, the SCS is planning to perform a Flood Hazard Analysis for Claremont in early 1974.

Beauregard Village would benefit from a clearance program, especially if the mobile homes in the area could be relocated to higher ground. Flood-proofing of buildings in Claremont is unknown; however, the building inspector provides guidance concerning adequate protection for structures to prospective builders in the flood plain. Only minor problems from drains plugged by leaves and debris occur; thus urban drainage is not a problem. The Corps of Engineers has no Flood Plain Information report for Claremont, but has made studies of the Sugar River in conjunction with an authorized project, the Claremont Dam.

Local and State opposition in 1967, however, caused this project to be reclassified as inactive. The SCS, under P. L. 566, has developed a Work Plan, and Eastman Pond, one of six planned small multi-purpose flood water retarding structures in the Sugar River Watershed has been constructed. The Work Plan includes ten structures in all. Lake Sunapee, under control of the New Hampshire Water Resources Board, is operated in such a manner that it provides some spring runoff storage, but private development pressure around the lake prohibits maximum effectiveness as a flood control device. No local protection projects have been authorized or constructed.

PRESENT STATUS OF ELEMENTS

FOR FLOOD DAMAGE REDUCTION

LEBANON, NEW HAMPSHIRE

LEBANON, NEW HAMPSHIRE

GENERAL

Lebanon, New Hampshire is located along the western edge of the State in Grafton County, approximately 45 miles northwest of Concord. It is bordered to the west by the Connecticut River and Hartford, Vermont, to the north by Hanover, to the east by Enfield, and to the south by Plainfield, New Hampshire. (See Figure 30).

Chartered as a town in 1761, Lebanon became a city in 1957. Because of its location on the falls of the Mascoma River, water and water power were important aspects of the city's development. Originally, water power was put to use by grist and sawmills. Later development included textile production and other manufacturing such as leather goods. While water power manufacturing has declined in recent years, the city has become the retail, commercial, and industrial center of what is known as the Upper Valley Area. Recent growth in Lebanon can be attributed to its location near the intersection of two major interstate highways, I-89 and I-91, which intersect nearby across the Connecticut River. In addition, Lebanon is located near the educational and medical centers associated with Dartmouth College. Population is growing at a declining rate, however, increasing only 4.6 percent from 9,299 in 1960 to 9,725 in 1970, as compared to an increase of about 9.4 percent in the preceding decade. The total land area of the city is 40.6 square miles.

There are two centers of development in Lebanon today. West Lebanon, located along state Routes 10 and 12A along the Connecticut River, has witnessed shopping, retail, and commercial growth both along Route 10 and along Route 12A near the mouth of the Mascoma River, where Route I-89 intersects Route 12A and crosses the Connecticut River. The second area of growth and development is the central business district of Lebanon where an urban renewal project has recently revamped the area into a shopping mall. Additional growth also is occurring along Route 120.

The topography of Lebanon is largely composed of wooded hills with plains along the Connecticut River from West Lebanon south, and along the Mascoma River. There are two major watersheds in the city. As stated above, the Connecticut River forms the western

HARTFORD-WHITE RIVER JCT.

LEBANON-WEST LEBANON

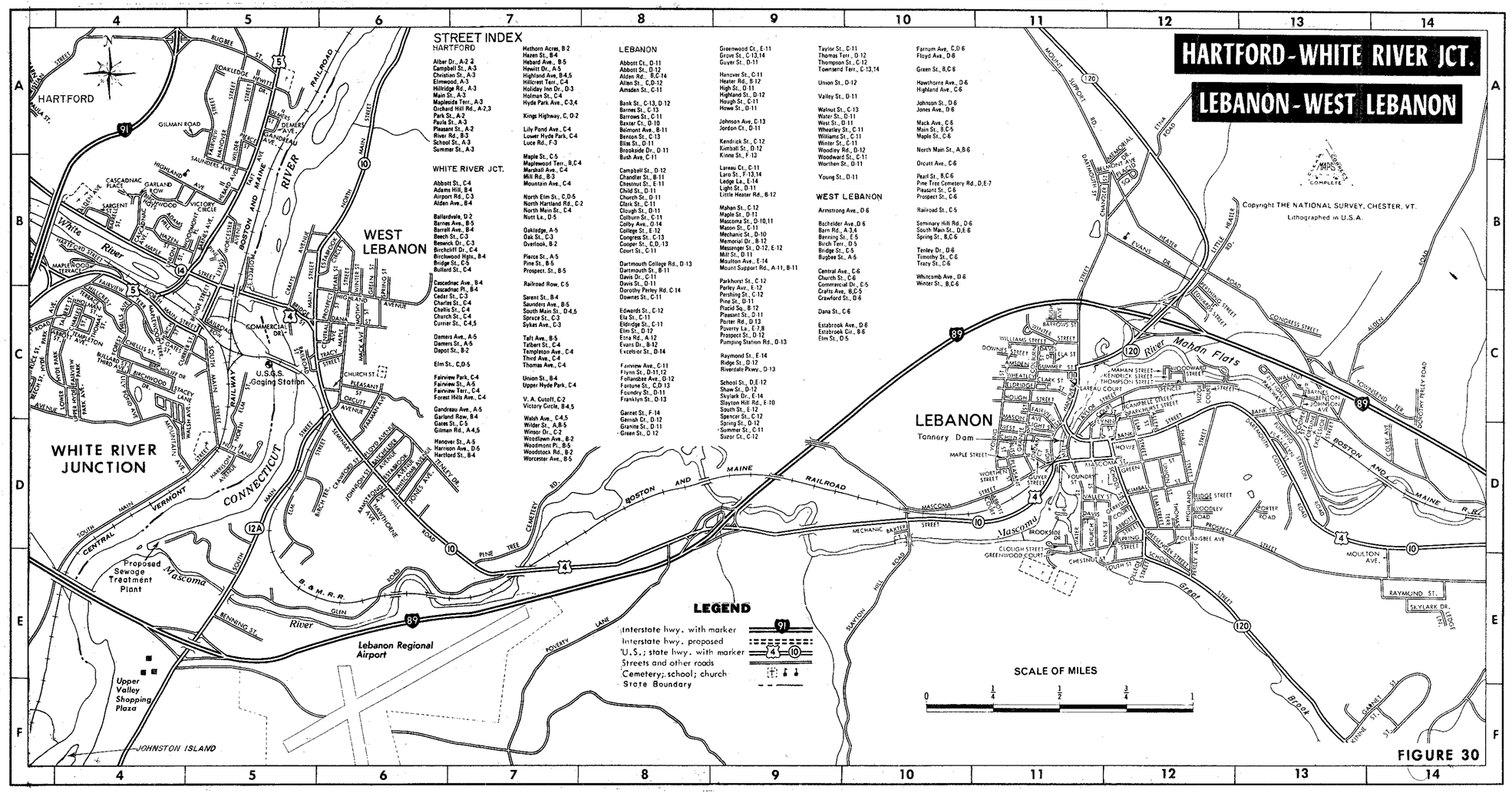

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FIGURE 30

boundary of the city. The Mascoma River flows from east to west through the center of the city and joins the Connecticut at river mile 213.9, about 1.2 miles downstream from the junction of the Connecticut and White Rivers. Except for the two centers of development in West Lebanon and Lebanon, most of the city is undeveloped woodland with some agricultural lands along the Connecticut River, south of the Mascoma River.

FLOOD HISTORY

Systematic compilation of stream flow records from major New England rivers began around 1904. In the vicinity of Lebanon, United States Geological Survey (U. S. G. S.) stream flow records have been maintained on the Connecticut River at White River Junction since October 1911, and on the Mascoma River at Mascoma, New Hampshire, since August 1923.

Since the installation of the gaging station at White River Junction in 1911, there have been at least 24 floods on the Connecticut River. Flooding has occurred on the average once every two years in this reach.

The flood of record for the Connecticut River near Lebanon occurred in November 1927, when a stage of 35.0 feet was reached at the White River Junction gage, with an associated discharge of 136,000 cubic feet per second (cfs). Other large floods (in descending order of magnitude of stage) occurred in 1936, 1913, 1922, 1938, 1973, 1953, 1933, 1959, 1912, 1914 and 1925. Large floods are known to have occurred prior to the installation of the White River Junction gage. While earlier floods such as the September 1828 and October 1869 floods were known to be damaging, it is fairly certain that recent floods have been the most severe since the first settlement of the area.

The most recent flooding occurred in late June and early July of 1973, when the Connecticut River crested at a stage of 25.30 feet with an associated discharge of 79,100 cfs (from provisional U. S. G. S. data).

In their Flood Plain Information report prepared for the Lebanon area, the U. S. Army Corps of Engineers, referring to the Mascoma River, stated,

> Records do not show any history of seriously damaging floods in this basin. The Mascoma basin has been relatively free from such occurrences and whenever extraordinarily high waters have occurred, the damages have been low in comparison with figures for other basins.

On the basis of a discharge frequency curve which they prepared, the Corps of Engineers estimates that nuisance flooding occurs once every two years in Lebanon, while significant flooding occurs once every five years along the Mascoma River. In March 1936, a stage of 7.5 feet, with an associated discharge of 5,840 cfs, was recorded as the flood of record at the Mascoma, New Hampshire gaging station. Other large floods, (in descending order of magnitude of stage) include the events of 1953, 1938, 1933, 1925, 1934, 1927, 1973, 1951, 1926, and 1932. As along the Connecticut River, the most recent flooding occurred in early July of 1973. On 1 July the Mascoma crested at a stage of 5.75 feet with an associated discharge of 3,700 cfs, based on provisional U.S.G.S. data. This was a significant flood for the City of Lebanon.

The main flood season on both the Connecticut and Mascoma Rivers occurs in the spring, when the combination of rain and melting snow and ice has historically contributed to large floods. However, not all Connecticut River flooding is associated with rain and snow melt; in fact, two very large floods, including the flood of record, have occurred in the fall. Lebanon has experienced flood conditions in nine months of the year.

THE FLOOD PLAIN

Connecticut River - Flooding along the Connecticut River occurs when the stage reaches 20.0 feet at the White River Junction gage. For the preparation of the Flood Plain Information report, the Corps of Engineers determined the water surface profile and extent of inundation for the Standard Project Flood (SPF) and the Intermediate Regional Flood (IRF) along the Connecticut River. While the SPF is actually about 8 feet higher than the IRF, since only large scale mapping is available, the area depicted as inundated is essentially the same for both events. These floods would inundate approximately 620 acres of Lebanon, which is 2.4 percent of the total area.

South of Johnson Island, few structures are affected by flood waters. This broad, flat area is mostly cropland, and damage would be restricted to agricultural holdings. Below the city's sanitary landfill, however, is a recently developed auto graveyard where junk vehicles are stacked

in the flood plain. There is also very little development north of the junction of the White River. Here the banks of the Connecticut are steep, resulting in a very narrow flood plain. Additionally, the water above the Wilder Dam is controlled by this structure. There are a few buildings near the water upstream of Wilder Dam, but this area is for the most part an undeveloped woodland. Wilder Dam is about 1.5 miles upstream of the Route 4 bridge crossing of the Connecticut River.

The West Lebanon business and residential area is located on a plateau, and is not susceptible to Connecticut River flooding. A ready-mix concrete plant, located at a low point in the flood plain near the Route 10 bridge, does nevertheless receive periodic inundation.

The prime area of flooding by the Connecticut River in Lebanon lies in the large plain at the mouth of the Mascoma River, where I-89 crosses the Connecticut River. This area is presently undergoing intense development. The intersection of I-89 and Route 12A spurred commercial growth at this location. Between the Connecticut River and Route 12A is a large shopping center, the Upper Valley Shopping Plaza, an addition to which is currently under construction, as well as a large home furnishing store. Across Route 12A from this shopping center are various retail and commercial buildings including furniture and carpet stores, a fast food outlet, a retail lumber supplier, and the headquarters of a local electrical contractor. All these buildings have been recently constructed. Another building is under construction and water lines recently have been extended to the area. The characteristic gasoline service stations are also located near this interstate highway intersection. The July 1973 flooding came up to the doorstep, just below the floor level of all the stores in the Upper Valley Shopping Plaza, indicating a very real flood threat in this area.

Between I-89 and the Mascoma River is the site of several new commercial establishments including cable TV offices and another fast food restaurant, as well as several older residences. On a spit of land forming the north bank of the Mascoma River is the site of the city's proposed new sewage treatment plant. A little further upstream, a low income housing project is under construction in what appears to be the outer limits of the Connecticut River flood plain.

Mascoma River - The second major flood plain in the City of Lebanon is that of the Mascoma River. Mahan Flats is Lebanon's most sensitive flood prone area. This is an area which lies in a reach of about a mile in length, between the Tannery Dam and the Bank Street Bridge. Flooding occurs here almost yearly, and is largely caused by the Tannery Dam in association with the flat gradient upstream. Flooding involves approximately 80 acres on both sides of the river, although

most development is on the south side. Here are found both residences and business establishments, including homes, a nursery, a tool manufacturer, and a building supply business. In addition to the structures on the south side of the river, the commercial establishments along the east side of Old Route 120 might suffer basement flooding under severe conditions.

In general, the banks of the Mascoma River in Lebanon are fairly steep, resulting in a narrow flood plain except for a few places such as Mahan Flats. Other areas along the Mascoma susceptible to flooding include some of the commercial establishments along Mechanic Street (Route 10) which include a dairy, used car lot, and hardware/lumber business. An event of the magnitude of the SPF would probably affect these establishments. The only significant flood plain, other than Mahan Flats, is at the junction of the Mascoma with the Connecticut River. The combined effects of these two rivers causes inundation of large areas. Two new light industries, located between I-89 and the Mascoma River, appear to be in the flood plain. If these buildings themselves would not suffer inundation, it is certain that their access road would be covered with water thus isolating both buildings.

The IRF of the Mascoma River would inundate approximately 560 acres upstream of the Route 12A crossing. The SPF can be expected to inundate about 990 acres.

Other - Other flooding in Lebanon occurs on Bloods Brook, though no residences or buildings suffer inundation as a direct result. In the past, however, the area has been subjected to culvert and road washouts due to high velocity runoff. Bloods Brook is located in the southwestern corner of the city about 1-3/4 miles south of Lebanon Regional Airport.

CLEARANCE

No program of flood plain clearance or relocation of occupants has ever been implemented in Lebanon, nor is such a program anticipated for the future. However, the particularly flood sensitive area of Mahan Flats has been zoned as an industrial district partially to eliminate further residential development in the flood plain. In this way, zoning is being used to encourage relocation and clearance of residences, but no direct action is being taken in this area.

FLOOD PROOFING

No known flood-proofed structures are in Lebanon. The city's building code does not address itself to flooding or flood-proofing, and no cases of voluntary flood-proofing have been reported. The new commercial development on the flood plain at the confluence of the Connecticut and Mascoma Rivers has not been flood-proofed, and, in fact, a portion of the flood plain was excavated for placement of the Upper Valley Shopping Plaza.

The Mascoma River is the source of water for Lebanon, and the water treatment plant is located near the flood plain. It is judged to be outside of the flood plain, and the building itself is not specifically flood-proofed. There is a diversion channel for the intake, and velocities and sediments are sometimes a problem. No structural damage to the building or the operation, however, has ever occurred.

URBAN DRAINAGE

Surface runoff in major urbanized areas of Lebanon is collected by an urban drainage system, covering West Lebanon north of I-89, and Lebanon south of I-89. This system is a combined sewerage system with a few short separate storm sewers. In general, West Lebanon sewers drain into the Connecticut River at various points below the Route 4 bridge, while storm drains in Lebanon discharge at various points along the Mascoma River. A new city sewerage system has been planned. It will consist of a combined sewerage system with interceptors running along the Mascoma River to a treatment plant situated at the confluence of the Mascoma and Connecticut Rivers.

Urban runoff and drainage have not been known to cause any significant flooding except for localized cases of drains plugged by leaves or other debris. Because of low elevations, the Mahan Flats and Riverdale sections of the city currently receive backup from existing storm drains on the Mascoma. It is expected that the planned additional interceptors will ease the situation somewhat by diverting discharge to the treatment plant below Tannery Dam. However, this will not alleviate flooding in these two low areas, as the situation stems from upstream discharge backed up by the Tannery Dam, rather than from the local urban runoff.

The Lebanon Master Plan suggests some channel straightening and other improvements to obtain better drainage for the Mahan Flats area. The existing storm drains discharge directly into the Mascoma River. The Plan suggests that the Mahan Flats storm drains should be

modified to empty into the Banks Street sewer, which discharges into the School Street sewer and in turn discharges downstream of the Tannery Dam. Of course, the new sewage plant, with the interceptor running along the river, would effectively accomplish this if the final discharge of the School Street sewer was diverted into the interceptor. However, as mentioned earlier, flooding in that area is primarily caused by the dam. While storm-sewer backup does occur, it apparently is coincident with overland flooding, and the nuisance caused exclusively by storm-sewer backup is probably minimal. Detailed analysis would be required to determine the amount of runoff actually involved in the storm drains in this very flat area.

FLOOD PLAIN INFORMATION REPORT

The report entitled "Flood Plain Information, Connecticut - White - Mascoma Rivers, Thetford, Norwich, Hartford, and Hartland, Vermont, Lime, Hanover, Lebanon and Plainfield, New Hampshire" was prepared by the Corps of Engineers and released in May 1972. This publication discusses past flooding of the Connecticut, White and Mascoma Rivers, as well as presenting profiles and delineations of the IRF and SPF along the three rivers. The report is the principal source of flood plain information for the City of Lebanon, and is the basis for flood plain insurance and preparation of flood plain zoning.

PUBLIC INFORMATION

Publicity - Information concerning flood hazards in Lebanon is available in several ways. The Flood Plain Information report brochures are displayed in the Office of the City Manager, and the report itself is available for use as a reference. The flood insurance program in the city has received a small amount of publicity; the Planning Board's consideration of flood plain zoning has additionally resulted in some newspaper publicity. In general, however, very little publicity and active passing of information has occurred. Flood plain information reports are available from the above agencies upon request. Thus, information is available on a passive basis, with little or no active dissemination.

Flood Warning - The city receives flood warnings from the National Weather Service (NWS) via a receiver which is located in the police station. Civil Defense responsibility has been jointly assiged to the Police Chief and the City Manager. The Police Chief has indicated that the NWS advisements have been received a little late for their purposes, and it would have been helpful if the notice had been received sooner.

At the present time, there is no organized plan to be followed in the event of flooding. Emergency service regarding evacuation is informal, based on the past experience of the Police Chief and the City Manager. For information concerning flooding on smaller tributaries of the Mascoma River, the police department is dependent upon the random receipt of information from residents at upstream points. In July of 1973, erroneous information was received by the police department indicating that a break in the Mascoma Lake Dam had occurred. This resulted in extensive emergency procedures that ultimately proved unnecessary. These emergency procedures were described as slipshod. In this case, the lack of preparation, coupled with action based on faulty information resulted in an editorial by the local newspaper. As a result of this experience, the police and City Manager are now in the process of preparing a program for an organized procedure, including designated personnel to report on upstream structures and stages.

FLOOD CONTROL IMPOUNDMENTS

Connecticut River - The Union Village Dam, built and operated by the Corps of Engineers, is the only upstream flood control impoundment affecting flood stages along the Connecticut River in the reach passing through West Lebanon. This dam is a single-purpose flood control structure located on the Ompompanoosuc River four miles above its junction with the Connecticut. The structure was completed in June 1950. Available storage at the spillway crest is 38,000 acre-feet, equivalent to 5.7 inches of runoff, from a drainage area of 126 square miles.

Mascoma River - The Mascoma River has no existing or authorized flood control impoundments. The gate operation schedule at the Mascoma Lake Dam, which is a power generating facility, does affect flood flows. Such effect, however, is small, and in its Flood Plain Information report, the Corps of Engineers reported that the effectiveness of its schedule of operation had not been proved by major flood events. This dam is operated by the New Hampshire Water Resources Board.

Several small dams along the Mascoma River in the Lebanon area are under the operational control of the New Hampshire Water Resources Board, but they are small structures and have little effect on flood flows, other than losing flashboards during flooding. In fact, one of the flashboards is now being replaced. It would have been desirable to take all of the flashboards out permanently and lower the water level in the area of the Slayton Hill Road Bridge. But lowering the water level of this dam that is just downstream of the bridge, however, uncovered several sewage discharge pipes. Therefore, it is necessary to replace the flashboard and raise the water level again so that the sewage discharges remain under water.

LOCAL PROTECTION PROJECTS

There are no local protection projects per se, either on the Mascoma River in Lebanon or upstream of it. Cleanup operations presently under way as a result of the July 1973 flood include channel cleaning as well as some bank improvement and stabilization, especially near the mouth of the Mascoma just upstream of the Route 12A bridge. These operations consist mostly of sediment removal and erosion repair.

The "Connecticut River Basin Comprehensive Water and Land Resources Investigation", published by the Connecticut River Basin Coordinating Committee, June 1970, mentions a 1957 local protection project. This project was a small study performed by the Corps of Engineers with a letter report to Lebanon. It concerned possible protection for a shopping center and a cement plant. However, nothing was recommended or built, and the project was immediately dropped.

CONCLUSIONS

Flooding in the Lebanon area can occur from either the Connecticut River, the Mascoma River, or both. The largest area subject to Connecticut River flooding lies at the mouth of the Mascoma River. Mahan Flats, a low-lying area in the northeastern part of urbanized Lebanon, is flooded by backwater from the Tannery Dam on the Mascoma River. Most of this flood water results from upstream discharges. The total land subject to flooding in Lebanon appears to be about 6 or 7 percent, representing perhaps as much as 1600 acres. However, a number of man-made structures presently occupy the flood prone areas, and this number is increasing with little effort to control or manage the flood plain. No flood-proofing of structures is known or reported. Urban drainage and associated problems do not appear to contribute significantly to flooding. The area most affected by blocked urban drainage is Mahan Flats, and planned local actions appear adequate to reduce this cause of flooding. Removal of the Tannery Dam, after correction of the storm drainage and planned installation of new interceptor sewers and a combined sewage treatment plant, would probably prevent all but the most severe flooding in the Mahan Flats area. Action has been taken to establish an effective flood warning system. No local protection projects have been authorized or constructed in Lebanon.

PRESENT STATUS OF ELEMENTS

FOR FLOOD DAMAGE REDUCTION

HARTFORD, VERMONT

HARTFORD, VERMONT

GENERAL

The Town of Hartford, Vermont, was chartered on July 4, 1761 and has a land area of about 39 square miles. Its 1890 population of 3,740 had increased to 6,477 as of the 1970 census. Within the Town there are several unincorporated communities which are located either in, or adjacent to, the flood plains formed by the three principal rivers flowing through the Town. The communities of Quechee, Quechee Lakes and Deweys Mills lie along the Ottauquechee River; Hartford, West Hartford and White River Junction are situated on the White River; and Wilder and White River Junction are on the Connecticut River. Most of the Town of Hartford is of the typical Northern New England hill and valley topography, with the rivers flowing in valleys with steep sides and only scattered overbank areas available for development.

White River Junction (1970 population 2,379) is appropriately named being at the intersection of several primary routes of travel including the junction of the Boston & Maine Railroad and the Central Vermont Railroad, the intersection of U.S. Highways 4 and5, and the interchange of Interstate Routes I-89 and I-91. As a result of easy access to transportation routes in all directions, White River Junction has several wholesale distributors in addition to a downtown area of retail stores, and is the most highly developed community in the Town of Hartford. Quechee Lakes is a newly planned residential and recreational community located on the Ottauquechee River upstream of Deweys Mills, in and around the Village of Quechee. The other communities of the Town of Hartford are primarily residential with agricultural businesses in the outlying areas and a number of small commercial establishments along Vermont Route 14 paralleling the White River on the north.

At a point just downstream of the mouth of the White River, the Connecticut River has a drainage area of 4,089 square miles. The upper reach of the river is fed by steep mountain streams falling from elevations as high as 6,288 feet mean sea level with the main stream falling 1,321 feet in a distance of 189 miles. Within the Town of Hartford the riverbanks are steep with little flood plain. A number of major power developments are situated upstream along the main river with sizable reservoirs. In addition, one reservoir for flood control purposes was completed in 1949 at Union Village, Vermont, on

the Ompompanoosuc River, with a usable capacity of 1,660,000,000 cubic feet. The combined usable capacity of all the impounding strucutres above White River Junction is 17.2 billion cubic feet.

The White River has a drainage area of 712 square miles consisting of steep slopes with very little channel storage. Over a total length of 58 miles, this river falls a total of 2,170 feet, with 1,600 feet of the drop coming in the uppermost 9-mile reach of the stream. There are no appreciable impoundments on the White River.

The Ottauquechee River flows generally easterly and has about the same topological attributes as the White River. This river is 40 miles long with an average slope of 27 feet per mile and a drainage area of 223 square miles at its mouth. The North Hartland reservoir, 1.5 miles upstream from the river's mouth, regulates floodflows from this river before they enter the Connecticut River. With the north Hartland reservoir full, there would be a total of 2.2 square miles of the Ottauquechee River watershed in ponds, lakes and reservoirs.

FLOOD HISTORY

White River Junction is the only community in the Town of Hartford which is susceptible to flooding by two of the three principal rivers within the Town. Floods have occurred frequently in White River Junction as a result of both ice jams and heavy rains. The ice jam of March 1964 on the White River was responsible for destroying part of a bridge in the downtown area, and the flood of June 1973 flooded the basement of the firehouse and caused the precautionary evacuation of residents from the low-lying area next to the Connecticut River. Records have been maintained since 1915 on the White River at West Hartford, Vermont, and since 1911 on the Connecticut River at White River Junction, Vermont. The flood of record for both the Connecticut and White Rivers for the immediate area occurred in November 1927 when the White River, by some accounts, flooded as many as 200 homes and had the highest discharge rate per square mile of record for a drainage area of comparable size in New England. Historical accounts combined with records maintained by the U.S. Geological Survey tell of at least 13 damaging floods occurring in White River Junction in the last 100 years due to either ice jams or heavy rains.

In recent years, ice jams have occurred with increasing frequency on the White River. Peak discharges may, or may not,

be concurrent with the highest stage occurring as a result of the ice jam. For example, in March 1964, the ice jam on the White River broke and caused its major damage when the discharge was approximately 16,000 cubic feet per second (cfs). The maximum discharge of 23,000 cfs occurred 12 hours after the jam had moved. TABLE 1 shows a partial list of recent ice jams which have been experienced on the White River in Hartford and the relative peak discharge.

TABLE I

ICE JAM FLOODS- WHITE RIVER

DATE	DISCHARGE cfs
March 1964	23,000
April 1959	11,300
January 1959 (Two floods)	(1)
March 1953	26,300
March 1946	27,800

(1) Peak discharges unknown.

Non-ice jam floods are caused by heavy rainfall alone or by a combination of heavy rain and melting snow. TABLE II is a list of known major floods with their corresponding peak discharges that have occurred on the White and Connecticut Rivers in the vicinity of White River Junction.

TABLE II

NON-ICE JAM FLOODS

DATE	WHITE RIVER cfs	CONNECTICUT RI\ cfs
November 1927	120,000	136,000
March 1936	45,400	120,000
March 1913	-	113,000
April 1922	35,500	89,000
September 1938	47,600	82,400
June 1973	42,300	79,100
March 1953	26,300 (1)	73,300
June 1947	31,100	63,400

(1) Ice Jam

According to U.S. Geological Survey records, the most recent flood on the White River resulted in a peak stage at the West Hartford, Vermont, gage of 19.13 feet gage datum or 393.66 feet MSL at 5:00 p.m. on June 30, 1973. The estimated discharge was 42,300 cubic feet per second. Based on the Flood Plain Information Report for the White River Junction area, the 1973 flood on the White River was 4.34 feet lower than the Intermediate Regional or 100-year Flood. On the basis of discharge, the 1973 flood was fourth largest of record (since 1915) (see TABLE I). On the basis of stage, it was third highest at West Hartford.

It is probable that the peak on the White River at White River Junction occurred at about the same time as the Connecticut River peak but, because the Connecticut River peak was over 6 feet below the 1936 flood peak, this tended to reduce the backwater offect on the White River and lower the White River stages throughout the Village.

U.S. Geological Survey records on the Connecticut River at White River Junction, below the mouth of the White River indicate a peak stage at 6:30 p.m. on June 30, 1973 of 25.30 feet gage datum (346.82 feet MSL) with a discharge of 79,100 cubic feet per second This stage was 6.48 feet below the Intermediate Regional Flood of 109,500 cfs. However, it was the sixth highest flood at that point since at least 1912.

Quechee has experienced flooding due to a gorge located downstream of Deweys Mills causing ice jams at times. Floods have occurred on the Ottauquechee River in the same years as floods on the Connecticut and White Rivers. Again, the Flood of November 1927 is the flood of record in that by some accounts it was 4 inches higher than the 1936 flood with the high water of 1936 resulting from an ice jam.

THE FLOOD PLAIN

White River: The flood plain along the White River is occupied primarily by the Fire House, Town Hall, and an abandoned woolen mill in White River Junction along with residences, a library, and some commercial buildings in the Village of West Hartford. Also, fuel storage tanks, a fuel distributor, and a sports sales enterprise located upstream of the Fire House are susceptible to flood damage from the Intermediate Regional Flood. A flood the size of the November

1927 event would damage additional stores along with several residences. Precise delineation is not available due to 20-foot contours on available maps.

Connecticut River: An area with roughly 17 residences and a building material distributor occupy the flood plain on the Vermont side downstream of the mouth of the White River. Some residents of this area (Nutt Lane and North Elm Street, see Figure 31) were evacuated as a precautionary measure during the June 1973 flood but their homes received only wet basements. The lumber yard had water in the extreme lower portions of its storage lot but sustained little loss. A flood of greater proportions would have been disastrous for the commercial operation and residents of this area.

Ottauquechee River: The flood plain for the Ottauquechee River is determined primarily by the reservoir formed behind the North Hartland dam. When filled to spillway elevation, the reservoir floods 1,173 acres. In 1967, a 220-acre seasonal conservation lake within the reservoir was dedicated by Mrs. Lyndon B. Johnson as "George Perkins Marsh Lake" which is held behind the dam from mid-May to mid-October. At flood stage, the lake inundates a local road, an old mill dam, and pasture/crop land. The area above Deweys Mills is being subjected to planned recreational-residential development which has, by and large, dedicated the flood plain to golf courses and recreational areas ; however, a Village Green restoration has been planned for the flood plain. This restoration is being constructed on fill which will put the buildings above the flood stage of the lake and at or above the flood stage experienced in 1927.

CLEARANCE

By comparison of the present community of White River Junction to pictures taken during the 1927 flood, it is apparent that a few houses have been cleared from the flood plain, either by construction of new roads or establishment of new businesses. The bridge at Woolen Mill Road has been reconstructed in a manner to make it less obstructive to floodflows. A new bridge carrying Route 5 across the White River is higher than the old Route 5 bridge, but the old bridge is still used. The Upper Valley Planning and Development Council has formulated no plans which call for the clearance of the flood plain in the Town of Hartford.

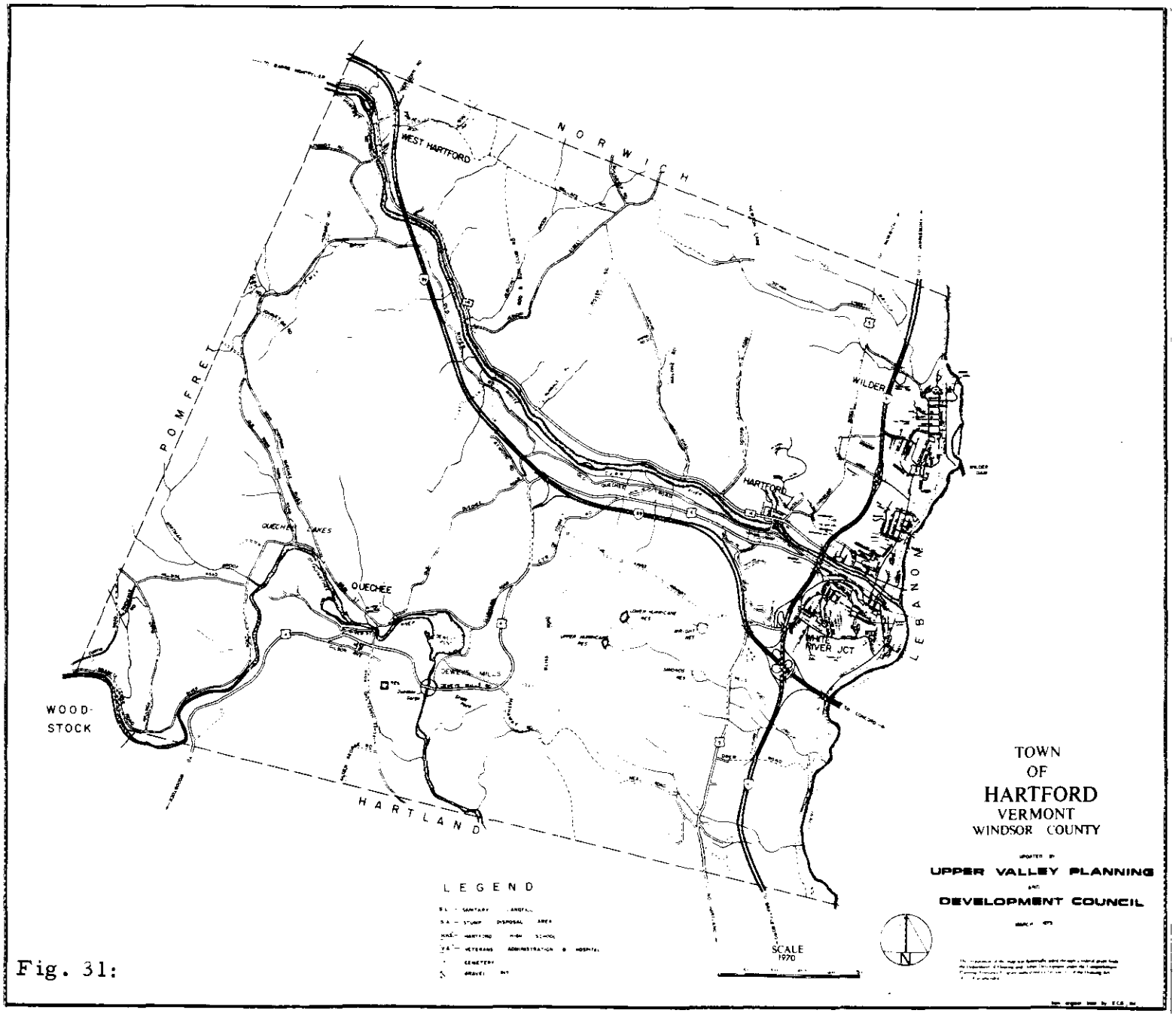

TOWN
OF
HARTFORD
VERMONT
WINDSOR COUNTY
UPPER VALLEY PLANNING
AND
DEVELOPMENT COUNCIL
NORWICH
POMFRET
HARTLAND
LEBANON
WOOD-
STOCK
WEST HARTFORD
HARTFORD
WILDER
QUECHEE
WHITE RIVER JCT
LEGEND
SCALE
1970
N

Fig. 31:

FLOODPROOFING

No business or municipal building in the Town of Hartford has been floodproofed even though there are a few structures located in an area which is subject to frequent flooding. The Town Hall is located on the flood plain at an elevation which is one half foot above the Intermediate Regional Flood (see Flood Plain Information Report). This building could be floodproofed easily by blocking out the basement windows and insuring that the utilities serving this vital building would not be damaged or destroyed during a flood of major proportions.

URBAN DRAINAGE

No significant problems of urban drainage have been reported in the Town of Hartford.

FLOOD PLAIN INFORMATION REPORT

Flood Plain Information for the Town of Hartford adjacent to the White and Connecticut Rivers was part of the report entitled "Flood Plain Information; Connecticut-White-Mascoma Rivers; Thetford, Norwich, Hartford and Hartland, Vermont; Lyme, Hanover, Lebanon and Plainfield, New Hampshire."

The Town of Hartford has made the Flood Plain Information Report available to real estate, engineering, and planning organizations, but has not adopted flood plain zoning measures even though the Town has been accepted in the emergency flood insurance program. An informal study has been completed by the Water Resources Department of the Vermont Agency for Environmental Conservation delineating the flood hazard of the Ottauquechee River with a copy furnished to the Ottauquechee Regional Planning and Development Commission.

PUBLIC INFORMATION

No public meetings have been conducted to inform residents of the flood hazard or how to floodproof their investments. Some residents of the Connecticut River Flood Plain were made aware of their hazard rather abruptly when they were evacuated from their homes by Civil Defense officials during the June 1973 flood. Measures should be taken to alert other residents of the Town to the flood hazard.

FLOOD CONTROL IMPOUNDMENTS

There are no existing impoundments on the White River and one proposed impoundment at Gaysville faces severe State and Local opposition. The Union Village Dam on the Ompompanoosuc River has the capability of reducing the flood stage on the Connecticut River at White River Junction by 1.1 feet for a flood similar to the November 1927 event.

LOCAL PROTECTION PROJECTS

A contract for channel improvements of the White River from Hartford to the Connecticut River was awarded in 1970 and the project has been completed. It is hoped that there will be no ice build-up now on the White River upstream of White River Junction; Attention is being focused on the ice jam problems on the Connecticut River at the mouth of the Mascoma River and the attendant backwater which at times may extend to White River Junction and for a distance up the White River.

CONCLUSIONS

In the Town of Hartford there are three major rivers: the Ottauquechee, White, andConnecticut Rivers. A major flood in the communities of this Town would inundate several homes, municipal buildings and commercial establishments. Damages wrought by severe flooding can be reduced or precluded by taking the following steps:

(1) Floodproof buildings to the 100-year floodlevel or a foot or two above for an added factor of safety.
(2) Clear the flood plain of unused buildings.
(3) Develop a flood plain zoning ordinance with rigid enforcement.
(4) Insure that public utilities are above predicted flood levels or are adequately protected.
(5) Consideration might be given to one or more ice retention structures on the ConnecticutRiver that would hold ice upstream of White River Junction and, thus, prevent jams from forming downstream of White River Junction.

PRESENT STATUS OF ELEMENTS

FOR FLOOD DAMAGE REDUCTION

LITTLETON, NEW HAMPSHIRE

LITTLETON, NEW HAMPSHIRE

GENERAL

The Town of Littleton, New Hampshire, is located in the foothills of the White Mountains and derives much of its income from the tourist industry. Some light industry and lumber operations, in addition to retail outlets, can be found in the Town, along with several motels. The Town was incorporated in 1784. Its 1940 population of 4,571 had grown to approximately 5,000 as of 1970. The bulk of the development in the Town has been within the Village limits.

Numerous State and Federal highways intersect within the Town boundaries, and the Boston & Maine Railroad follows the Ammonoosuc River through the Town as it changes its route from north-south to an easterly direction on its way to Maine. At present, Interstate I-93 has three interchanges in the Town of Littleton which provide easy access for the tourist trade to the popular Franconia Notch area. Future plans call for the extension of I-93 to St. Johnsbury, Vermont, where it will connect with Interstate I-91. U.S. Route 302 follows the Ammonoosuc River from Woodsville, New Hampshire, through Littleton, thence on its way to Crawford Notch, an area of a long-established tourist industry, and finally to its terminus in Maine. Also, New Hampshire Routes 10, 18, 116, and 135 are major highways serving the Town of Littleton.

The Ammonoosuc River, which has its headwaters at the Lake of the Clouds on Mt. Washington, falls 3,470 feet in its first 8.6 miles. At Littleton, the River has a drainage area of 131 square miles, a main stem length of approximately 30 miles, and has fallen a total of 4,170 feet from its source. The River upstream lies in a valley with steep sides with no sizeable areas for overbank flow until it passes through the Village of Littleton. Southwesterly of Exit 42 on Interstate I-93, the River has developed a fairly wide flood plain along U.S. Route 302, an area that is under pressure for future development. At present, however, much of the development in the Town is taking place on the hillsides away from the flood plain.

FLOOD HISTORY

Flooding along the Ammonoosuc River has occurred in every season of the year with ice jams causing floods as significant as

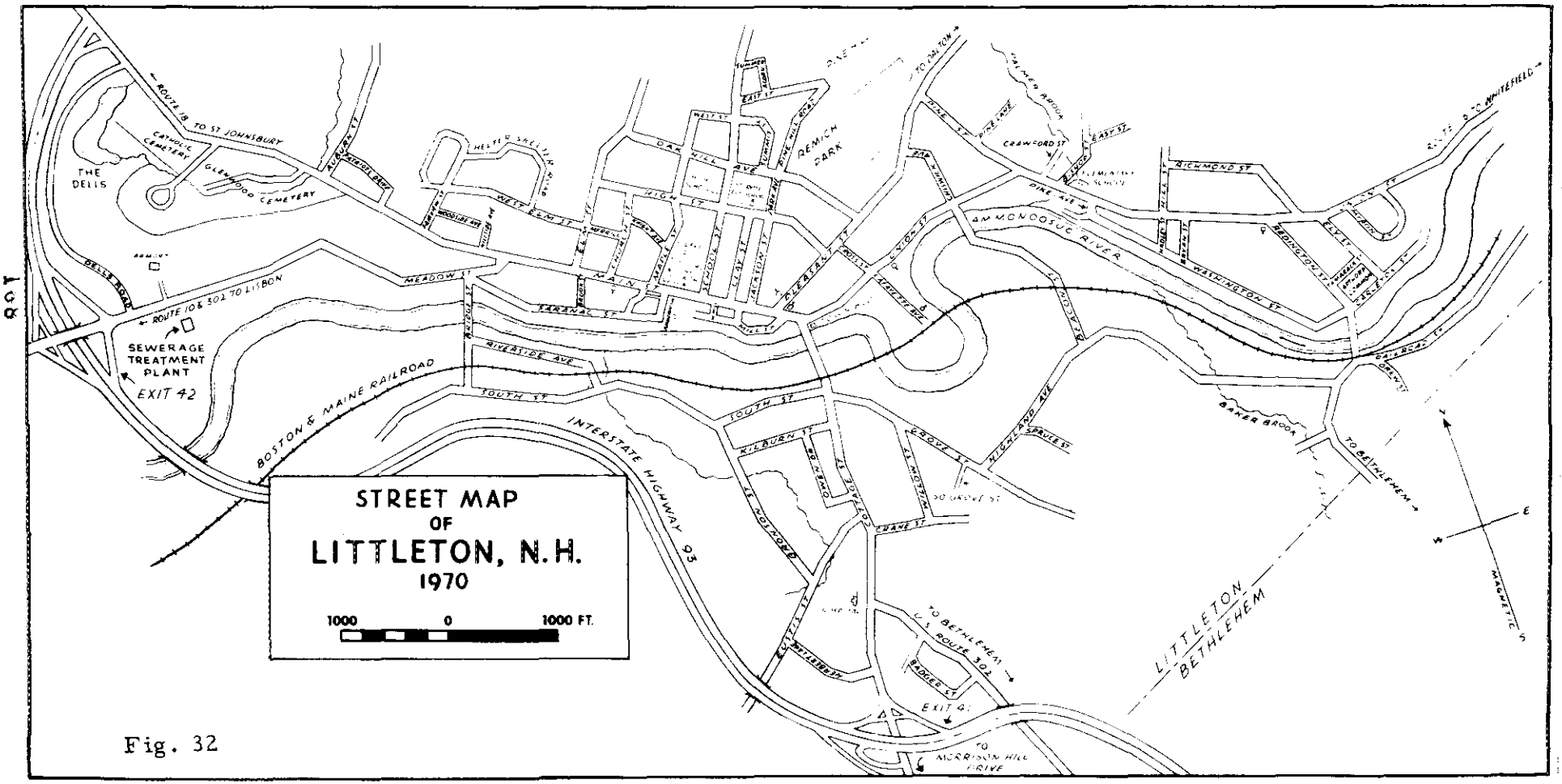

STREET MAP
OF
LITTLETON, N.H.
1970
1000
0
1000 FT.
THE DELLS
CATHOLIC CEMETERY
GLENWOOD CEMETERY
ROUTE 18 TO ST JOHNSBURY
ROUTE 10 & 302 TO LISBON
SEWERAGE TREATMENT PLANT
EXIT 42
BOSTON & MAINE RAILROAD
INTERSTATE HIGHWAY 93
REMICH PARK
AMMONOOSUC RIVER
BAKER BROOK
TO BETHLEHEM
LITTLETON
BETHLEHEM
TO BETHLEHEM U.S. ROUTE 302
EXIT 41
TO MORRISON HILL DRIVE
MAGNETIC

Fig. 32

those caused by snowmelt and/or torrential rains. The Flood of Record, by historical accounts, was the November 1927 Flood. This Flood washed out three highway bridges in Littleton and caused severe damage to the Saranac Glove factory which was built near the river for water power purposes.

Homes at the foot of Lafayette Street were flooded as was the basement of a livery stable on Union Street. Shallow flows over Apthorp Flat and along Saranac Street washed away light outbuildings. The road downstream toward Lisbon, in the meadow area south of Littleton, also was covered. Other floods of major proportions occurred in 1869, 1936, 1959, and 1973.

The major cause of anxiety during the floods of 1936 and 1938 were the flashboard s on the Apthorp Dam. At that time, they were held in place by 2-1/2-inch extra heavy pipe and remaind in place rather than failing during the flood. The Apthorp Dam is no longer in use and therefore the flashboards have been removed, providing considerable additional capacity over the dam to pass floods. The 1973 flood was of the same magnitude as the 1959 flood at the U. S. G. S. gage on the Ammonoosuc River at Bethlehem Junction, about 10 miles upstream from Littleton.

Since most of Littleton is built up on the hillsides of the flood plain, the major damage caused by the June 1973 flood was the erosion of stream banks and the failure of one trunk sewer which was laid in the stream bed. This break permitted large amounts of silt, sand, and gravel to wash into the treatment plant. Some homes, however, were inundated when a local dam failed on Palmer Brook, a small tributary to the Ammonoosuc River that flows southerly through Town and under Route 116, west of the elementary school.

THE FLOOD PLAIN

Beginning at the upstream end of the study area on the right bank at the Littleton-Bethlehem Town line is a saw mill in the flood plain of the Ammonoosuc River. Next is the area known as Apthorp which has several mobilehomes and permanent residences on the right bank downstream of the now unused Littleton Power Plant and dam. No floods have topped the dam abutments and levee since 1927 An oil distributor has bulk tanks on the left bank a little further

downstream and a flood of major proportions could put them in a dangerous situation. Adjacent to a factory on Chiswick Avenue on the left bank, there is a parking lot with about a 200-car capacity which might be overtopped by a major flood. On the right bank at the foot of Lafayette Street at the present electrical substation is a building that had water in its basement during the June 1973 Flood. Immediately downstream on the left bank is a small flood plain presently undeveloped that was inundated in 1973. Channel inprovements in this area have recently been carried out at Town expense.

Just upstream of Bridge Street is the old Saranac Tannery and Glove Factory on the right bank, and a refrigerated warehouse on the left bank. These structures may be vulnerable to flooding at greater frequencies than the development on the flood plain. Downstream of Bridge Street there are a saw mill and land fill on the left bank and a wastewater treatment plant on the right bank. The treatment plant is elevated so that it is above the 1927 Flood level. In the meadow downstream of the Interstate crossing on the right bank is the Town Garage. Federal monies have been spent to stabilize the stream bed at this point, so that no more of the equipment and parking lot will be lost. Sand and gravel have been removed and are being stockpiled for future highway construction. Downstream of the Town Garage is an automobile dealer with several vehicles on the flood plain. Much of the development identified as being on the flood plain may be subject to flooding on a 100-year basis.

By and large, this has been a description of those areas which are in the lowest places along the banks of the Ammonoosuc River in the Town of Littleton, but not necessarily within the 100-year flood zone which has not been defined as of now.

CLEARANCE

No plan exists for removing the old Apthorp Dam. If it were to be removed, dredging would be desirable to remove the accumulated silt in the power pool rather than permit it to rush downstream. Trash from the saw mills along the Ammonoosuc River should probably be removed to higher locations. There are no reports of other plans for the clearance of structures from the flood plain.

FLOODPROOFING

None is required or feasible due to the infrequent nature of the floods of the magnitude which would inundate applicable

structures.

URBAN DRAINAGE

No significant urban drainage problems have been reported in the Town of Littleton.

FLOOD PLAIN INFORMATION REPORT

No Flood Plain Information Report has been prepared for the Town of Littleton. A preliminary analysis of the flood plain, based on soil classifications, has been provided the local Planning Commission by the Soil Conservation Service. The major flood plain which exists is the meadow area downstream of the Village which presently is not developed to a high degree.

PUBLIC INFORMATION

The only public dissemination of the flood hazard in Littleton was the recently held forum by the Citizens Advisory Group of the New England River Basins Commission. The Civil Defense Agency, Police Department and Fire Department have contingency plans to implement in the event severe flooding should be anticipated or forecast by the National Weather Service River Forecast Center in Hartford, Conne cticut.

FLOOD CONTROL IMPOUNDMENTS

No flood control impoundments exist upstream of Littleton on the Ammonoosuc River or any of its tributaries. Littleton, by its location high on the banks of the Ammonoosuc River, would probably reap little benefit from the flood control aspect of the proposed Bethlehem Junction reservoir. However, a small watershed project on Palmer Brook might be warranted.

LOCAL PROTECTION PROJECTS

Town funds are set aside annually for channelization and erosion control measures along the Ammonoosuc River within the Town of Littleton. Federal disaster assistance monies have been used to restore eroded areas on the banks of the Ammonoosuc River after the June 1973 Flood. Locally constructed levees now protect the residences on Apthorp Flat and at the foot of Lafayette Avenue affording a high degree of protection from the flood threat.

CONCLUSIONS

1. Littleton, New Hampshire, as it is now developed, is susceptible to grave damages by only an infrequent, very large flood flow. Most areas in the flood plain which would be flooded by a flood of lesser proportions are either protected by levees, occupied by facilities that will suffer little damage, or remain as agricultural land.

2. Advantage should be taken of the Federal programs now available and flood plain zoning ordinances adopted to preclude further development on the flood plain, particularly downstream from the Village.

3. A small dam constructed on Palmer Brook under Public Law 566 might help to protect those residences which now suffer from local flooding.

4. Consideration should also be given to removing flotable debris from the flood plain so that it will not float downstream and form obstructions to the flood flows.

5. A situation which might lead to local flooding appears to be developing along Baker Brook south of the Norton Company plant where a swamp area is being filled gradually for a mobile home park. At present, seven units are situated on apparently built-up land, gradually reducing the flood-water detaining capacity of the marshy area. If this development is extended, peak rates of flow in Baker Brook at the rear of the Norton Plant may be increased and the capacity of the Highland Avenue bridge exceeded, causing overflow of the road and adjacent land. This situation may warrant investigation and evaluation by local authorities.

PRESENT STATUS OF ELEMENTS

FOR FLOOD DAMAGE REDUCTION

ST. JOHNSBURY, VERMONT

ST. JOHNSBURY, VERMONT

GENERAL

The Town of St. Johnsbury, Vermont, shown in Figure 33, is located in the northeastern part of the State in Caledonia County. The Town, with a total land area of 33 square miles, is in a mountainous area with most of its industry located on, or close to, the flood plains of the Sleepers, Moose, and Passumpsic Rivers. The Sleepers and Moose Rivers are major tributaries to the Passumpsic River. The Moose River flows southwesterly to where it joins the Passumpsic River just upstream of downtown St. Johnsbury. Sleepers River flows easterly and empties into the Passumpsic River just downstream of downtown St. Johnsbury. U. S. Highways 2 and 5 intersect in downtown St. Johnsbury. Future highway development calls for Interstate Route I-91 to be completed through St. Johnsbury with an interchange with U. S. Route 2 planned in the Sleepers River flood plain north of the present U. S. Route 2 crossing.

The town of St. Johnsbury was chartered in 1786 and the Village of St. Johnsbury chartered in 1852. In 1965, the Village merged with the Town. St. Johnsbury's population grew to 9,292 in 1950 from a population of 6,567 in 1890. Since 1950, the population has decreased to 8,409 in 1970; however, a population growth is expected upon completion of the Interstate Routes in St. Johnsbury.

The June 30, 1973 Flood was less than the predicted Intermediate Regional Flood (a flood that could be expected on the average of once in 100 years although it may occur in any year) in St. Johnsbury. Greater floods can reasonably be expected to occur in the future in the area. Local runoff caused severe damage to back roads, but high waters on the rivers also caused extreme hardship by flooding several homes, a grange hall, and a store in St. Johnsbury Center. For a period of time, the only road open out of Town was one lane of Vermont Route 18 to Waterford.

The gas distribution facilities at South Main Street were flooded as was the wastewater treatment plant across the railroad tracks from it. Also, water mains were broken at four river crossings. The depth of water over the dam at Stiles Pond was cause for concern in that loss of this dam would have left St. Johnsbury without a water supply. Homes

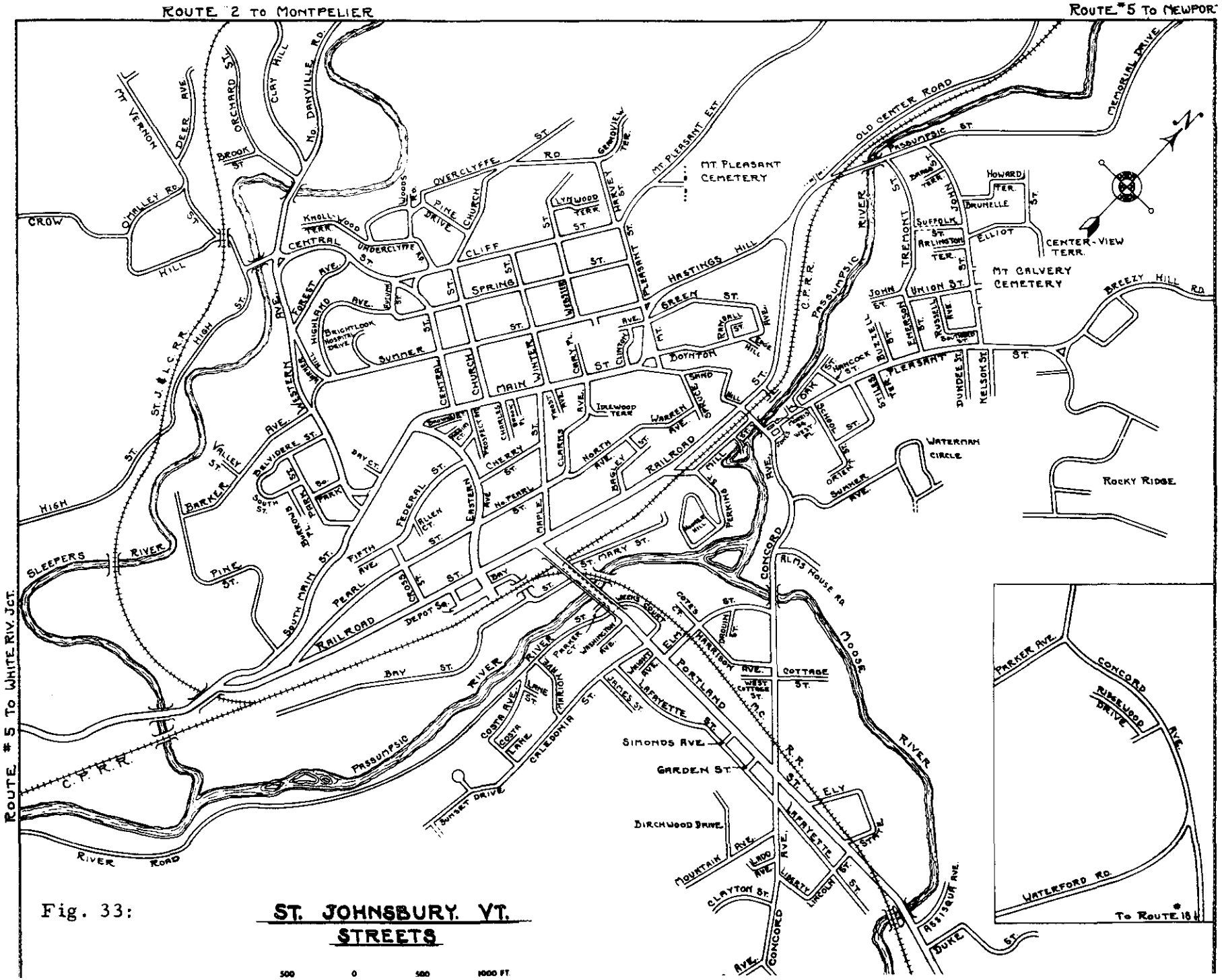


Fig. 33: ST. JOHNSBURY, VT. STREETS

on St. Mary Street had water at their doorsteps, while children frolicked in the swiftly-moving waters on Elm Street. Estimates of damage varied from an $80,000 loss reported by VEMCO, a modular home fabricator, to a $2,000 loss suffered by Millar's, a heating and plumbing supplier located in the "Loop Area." An initial estimate for damage to public facilities in St. Johnsbury was quoted as high as $1,750,000 in a local newspaper. Several streets were flooded along with low-lying businesses, such as auto dealers, drive-in snack bars, and gas stations. A similar event can happen in the future as there are no flood control impoundments existing or authorized upstream of St. Johnsbury and the current local protection measures are significantly inadequate.

THE FLOOD PLAIN

Moose River: There are three areas of substantial flood plains along the Moose River: (1) at the mouth of the River, (2) at river mile 4 in the vicinity of East St. Johnsbury, and (3) upstream of mile 5.0 where Knapp Brook flows into the Moose River.

Starting at the upstream limit of this study at the St. Johnsbury-Kirby Town Line, there is a furniture sales store on the right bank. In East St. Johnsbury, there is a gas station, and the school becomes an island in the floodwaters. In the vicinity of river mile 4, there is a gift shop built on fill which may put it above flood stage. A manufacturing plant is on the flood plain near Spaulding Brook, but it is protected from all floods except the most severe by the levee formed by the Maine Central Railroad bed. Upstream of the Portland Street bridge, the parking lot of a building material supplier and possibly the heating facilities are prone to flooding. Downstream of the Portland Street bridge there are salvage materials on the left bank. Finally, in the vicinity of Concord Street, there is a mobile home and five houses on the left bank with gas tanks at a higher elevation on the right bank. In past years, there has been a water main obstructing the flows under the Concord Avenue bridge at the mouth of the Moose River, but after it was broken during the Flood of 1973, it was reinstalled in a less obstructive manner.

Sleepers River: The Flood Plain Information Report for the Town of St. Johnsbury did not detail the Sleepers River flood plain except for the area close to the mouth.

Along Sleepers River on the North Danville Road on the right bank of the river is a new house with a beauty salon and a recently constructed

school building whose basements will probably be damaged by severe flooding Other problems in this upper section of Sleepers River are primarily bank erosion which destroys the local road and causes deposits of silt and gravel on agricultural land. The bridge crossing of U. S. Highway 2 has been topped by past floods so the abandoned mill on the left bank would be damaged by a major flood as would the three homes on the right bank.

Further downstream, the old Fairbanks Scale plant is being razed with two buildings being left on the flood plain as warehouses. The Flood of June 1973 reached at least the middle of the windows on the first floor of these buildings and the storage of material in the buildings appears to be an unwise decision. This land has been sold to a developer whose construction plans are presently not available. This land has not been zoned as flood plain because it was not included in the Flood Plain Information Report.

Also on the banks of the Sleepers River close to its mouth, there is the Town land fill area, a gas utility, several homes and the waste-water treatment plant. All of these structures felt the impact of the Flood of 1973.

Passumpsic River: The Flood Plain Information Report for St. Johnsbury defines the entire mainstem flood plain of the Passumpsic River in the Town from the St. Johnsbury-Waterford town line to the St. Johnsbury-Lyndon town line. Starting at the Lyndon town line downstream to approximately river mile 14, the flood plain is undeveloped with the exception of a Central Vermont Public Service dam at river mile 15. The pond above the dam has no appreciable flood water storage. At river mile 14, there is a modular fabricator on the right bank and further downstream at river mile 13 there is a motel with 11 units that would be flooded by the Intermediate Regional Flood. At river mile 12.5 on the right bank, there is a mobile home park with 13 mobile homes on the flood plain.

Continuing downstream, St. Johnsbury Center has much of its Main Street in the flood plain with more than 36 homes, the Post Office, Grange Hall, and a local store which are susceptible to flooding. Just upstream of river mile 11, there is an automobile dealer, a mobile home dealership, a trucking depot, two homes, a drive-in snack bar, a bottled gas distributor, and a proposed shopping center. Between river mile 11 on the Passumpsic River and the mouth of the Moose River, there are four additional automobile dealers, five service stations, six homes, a bait shop, building materials, and at least six commercial enterprises which are vulnerable to flooding.

On St. Mary Street there are eight homes and on Elm Street there are six homes in the flood plain. In the vicinity of Portland Street bridge is a bakery and two gas stations on the flood plain.

Downstream of the Portland Street bridge there is a building materials supplier, a wholesale food distributor, an office equipment supplier, and a grain distributor on the right bank, all of which would be damaged during a major flood. In the "loop area" there is a feed dealer, at least three bulk oil dealers, a plumbing and heating supplier, and the St. Johnsbury wastewater treatment plant. Downstream of the loop, there are agricultural activities in the flood plain and a dam and power plant of the Central Vermont Public Service.

CLEARANCE

No attempt has been made by local officials to relocate individuals or commercial establishments from flood-prone areas and people appear to move from the flood plain only after they have sustained flood damages quite frequently. Otherwise, many people are faced with the fact that they are living in homes or own businesses which are completely paid for and they cannot afford to relocate. The Town reportedly does not desire to subscribe to the Federal Flood Insurance Program because of the fear that it will lose the tax base due to the more stringent zoning regulations required by the Federal Insurance Administrator.

FLOOD PROOFING

No instruction appears to have been given people who have been flooded in measures that they may take to protect their property. In some cases, people wish to protect their property but cannot afford a loan at the interest rate which will be charged for a loan. Other establishments are seriously considering bricking up basement windows so that the more frequent floods will be kept from their basements.

URBAN DRAINAGE

The levee which was constructed around the Wastewater Treatment Plant has two major deficiencies: (1) it is not high enough, and (2) the pipe which is provided for local drainage has no flap valve to preclude high stage river water from flooding back through the pipe. Further, the chlorine contact chamber is lower than river flood stage and no provision is made for storing the effluent or pumping the effluent against the head due to high water. Therefore, the plant is operated until just before the effluent tops the walls on the final chamber, at which time the plant is bypassed. No other urban drainage problems have been reported in St. Johnsbury.

FLOOD PLAIN INFORMATION REPORT

A Flood Plain Information Report dated December 1972 was prepared for the Town of St. Johnsbury by the Department of the Army, New England Division, Corps of Engineers. After the June 1973 Flood, the Department of Water Resources for the Vermont State Agency of Environmental Conservation designated the flood plain as defined by the Flood Plain Information Report as an area subject to periodic flooding; hence, the Town of St. Johnsbury now has incorporated flood plain zoning into its zoning regulations which were effective March 27, 1973. The Flood Plain Information Report, however, did not include the flood plain along Sleepers River; therefore, this flood plain is not presently part of the flood plain zoning ordinance.

PUBLIC INFORMATION

Public instruction or media coverage has not been given as to the flood hazard to riverine businesses or homes in St. Johnsbury. Civil Defense personnel, along with police officials, were instrumental in warning residents about the rising waters of the June 1973 Flood and, consequently, several families were able to remove some of their valuables prior to the flood crest. However, ice jams on the Passumpsic River have occurred without warning in the past, causing more damage by catching residents unaware of their impending fate.

Stages associated with the Intermediate Regional Flood will be somewhat higher than the June 1973 Flood event, but the number of homes and businesses affected would be about the same, although damages would be greater due to increased depths of inundation and velocities of flow. The lack of communication between local officials and residents in the flood plain could, in part, be corrected by more extensive distribution of the Flood Plain Information Report to those residents and businesses in the flood-prone areas.

FLOOD CONTROL IMPOUNDMENTS

No flood control impoundments exist upstream of St. Johnsbury on any of the rivers flowing through Town. A proposed reservoir on the Moose River would benefit a few people in St. Johnsbury, but it is quite evident, due to the development in the flood plain of the Passumpsic River upstream of the mouth of the Moose River, that greater benefit would be realized by the Town of St. Johnsbury, and particularly those property owners in the Village of St. Johnsbury Center, if an impoundment were constructed on the Passumpsic River north of St. Johnsbury.

LOCAL PROTECTION PROJECTS

Levees have been constructed in two places in St. Johnsbury: one levee is around the Wastewater Treatment Plant and the second had been along the left bank of the Passumpsic River in the vicinity of Elm Street. The levee around the treatment plant is inadequate and the levee in the vicinity of Elm Street has been bulldozed away by the Town during snow removal operations. The Elm Street area has been a convenient dumping area for the snow removed from the areas in Town and the snow, in turn, has been bulldozed into the Passumpsic River.

An extensive levee in the "loop area" as proposed in the 1980 Plan had been considered by the selectmen of St. Johnsbury, but they felt that the cost to the Town was too high to warrant building such a structure. The Town would accept any protection that might be granted them by structural measures, but the local officials do not propose to provide any local funding for such measures.

At the same time that the Elm Street levee was constructed, the island still shown on the attached map (FIGURE 33) was removed from the area at the mouth of the Moose River, reducing the probability of ice jams. Other channelization projects may warrant consideration along the Passumpsic River, but bridges and other encroachments are going to remain on the river; consequently, the problem of ice jams, in all likelihood, will remain, and a system of river watching should be established when ice is moving during spring thaw.

CONCLUSIONS

There are three major streams in the Town of St. Johnsbury: the Passumpsic, Moose and Sleepers Rivers. All three rivers flood areas within the Town as a result of ice jams and also as a result of torrential rains and/or snowmelt. Ice jams frequently occur in the vicinity of the mouths of both the Moose and Sleepers Rivers with backwater effects usually being felt on all rivers. The toll of a major flood in St. Johnsbury would include more than 70 homes, two motels, at least five automobile dealers, a mobile home sales park, four building material suppliers, along with several other commercial enterprises. Several alternatives appear to warrant consideration as means for reducing or controlling flood damages in the Town of St. Johnsbury. They are as follows:

(1) Consider an impoundment upstream of Lyndonville on the Passumpsic River rather than in Victory on the Moose River.

(2) Enforce the current flood plain zoning ordinance and designate a flood plain along Sleepers River before it becomes more highly developed.

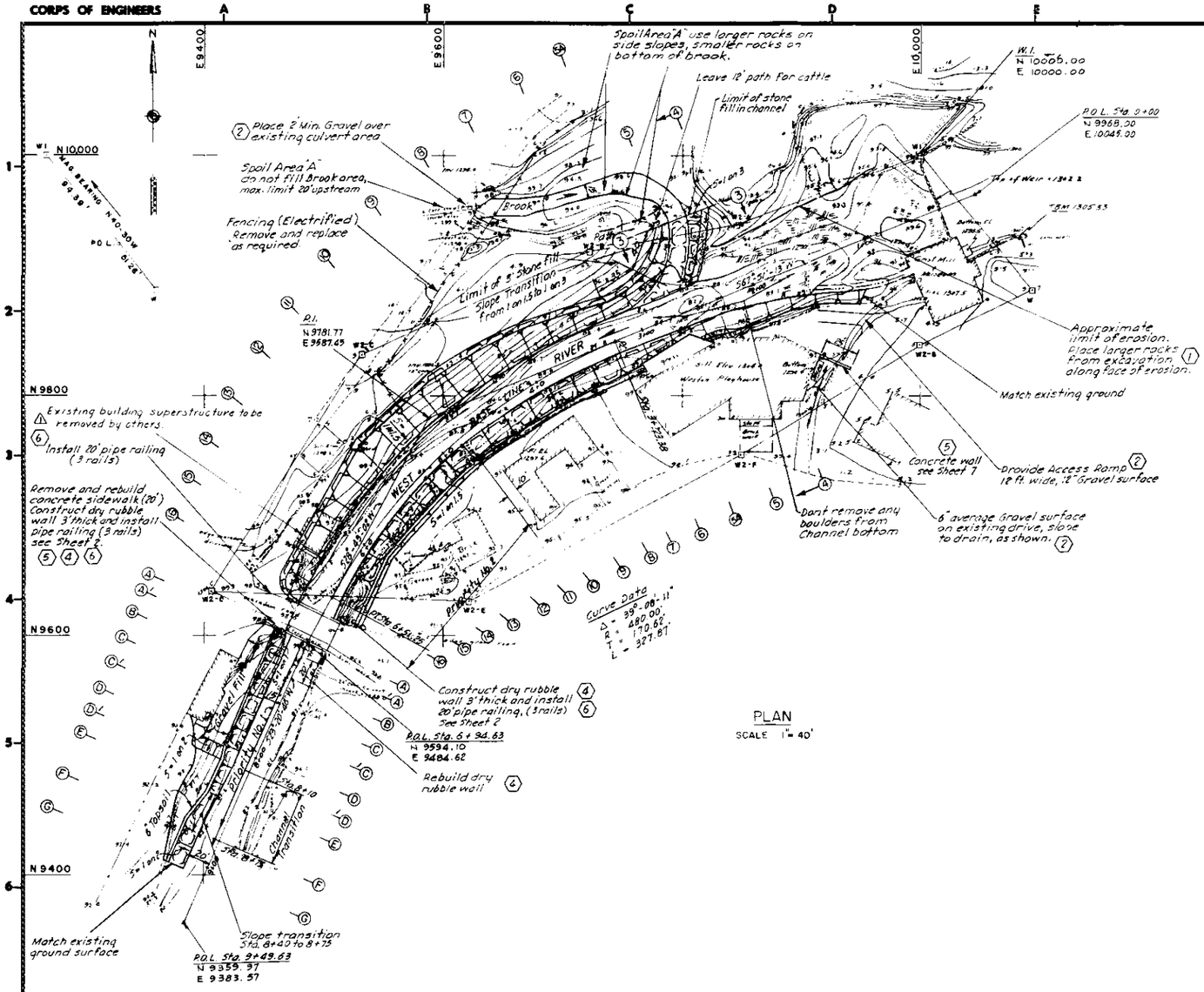
(3) Remove those obstructions which tend to precipitate ice jams and establish a river watch when ice flows are moving in the rivers as warning of impending ice jam flooding appears to be a key factor in reducing damages.

(4) Encourage those businesses on the flood plain to floodproof their structures, and those with floatable material to store it in another location or provide means of securing it.

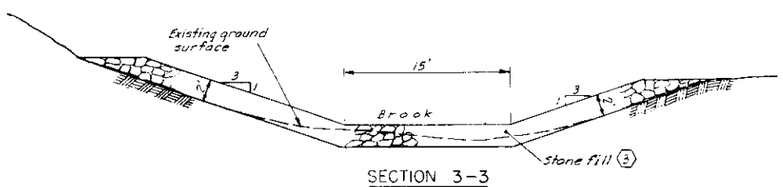
(5) Protect those utilities in the "loop area" with an adequate levee and include the necessary appurtenances to the included storm drains so that high water will not back through and drown them out.

(6) Make available loans at a reduced interest rate so that property owners who so desire can floodproof existing structures.

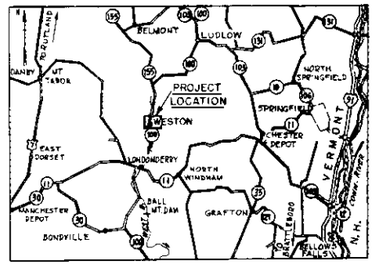
CORPS OF ENGINEERS — U. S. ARMY



PLAN
SCALE 1" = 40'



SECTION 3-3
SCALE 1" = 5'



LOCATION MAP
1 INCH = 5 MILES

	INDEX TO DRAWINGS
SHEET NO.	DESCRIPTION
1	GENERAL PLAN & INDEX
2	PLAN & SECTION
3 TO 9	SECTIONS

NOTES
1. Elevations refer to Mea Sea Level Datum.
2. Coordinates are based on local system.
3. All Sections are looking downstream.
4. Figures in hexagons indicate Item numbers under which payment will be made.
5. Do not remove any boulders in the river channel outside the limit of the required excavation.

GRAPHIC SCALES
1" = 5'
1" = 40'

As Built Drawing
33740-0075

REVISION	DATE	DESCRIPTION	BY
1	11-5-73	Note added (Am. #1)	

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

WATER RESOURCES DEVELOPMENT PROJECT
WESTON VERMONT
REHABILITATION OF CHANNEL
GENERAL PLAN & INDEX
WEST RIVER — VERMONT
DATE OCT. 1973
SCALE 1" = 40'
SPEC. NO. DACW35-76-B-R0004
WES - 1
SHEET 1

NEW ENGLAND RIVER BASINS COMMISSION
CONNECTICUT RIVER BASIN PROGRAM
SUPPLEMENTAL FLOOD MANAGEMENT STUDY

COMMENTS ON PHASE I DRAFT REPORT

Department of the Army
New England Division
Corps of Engineers

The Commonwealth of Massachusetts
University of Massachusetts
Amherst 01002

DRESS:
ent of Agricultural and Food Economics, Draper Hall
ty of Massachusetts, Amherst, Massachusetts 01002
aper Hall

Telephone: 413-545-2489

September 10, 1973

To: John Smith and Larry Dingman

Subject: Reports on Hatfield, Massachusetts and Brattleboro, Vermont

I have reviewed the draft report on Hatfield, Massachusetts and Brattleboro, Vermont, and both reports appear complete and accurate based upon my limited knowledge of these two areas. The only suggestion I have is that the Brattleboro report might include some reference to the supplemental flood management study and the recommendations of the Connecticut River Basin program. I am enclosing copies of some recent information that is available on the Town of Hatfield which you may find useful in preparation of the reports.

Sincerely,

N. Eugene Engel

N. Eugene Engel
Science Advisory Group

NEE/kag

Enclosure

UNIVERSITY OF NEW HAMPSHIRE
DURHAM, NEW HAMPSHIRE 03824

Water Resources Research Center

September 17, 1973

Mr. Lawrence Dingman
New England River Basins Commission
P. O. Box 651
9 South Main Street
Hanover, New Hampshire 03755

Dr. Mr. Dingman:

The following are my comments relative to the draft reports prepared by the Corps of Engineers on the Hatfield and Brattleboro areas.

First - I feel that the reports are very well prepared and provide an excellent summary and offer some suggestions. Therefore, my comments are limited and perhaps with more study on my part, I would find the answers to my questions.

I think that the use of the word'substantially' - pages 3 & 9 of the Hatfield report - is somewhat meaningless. I feel that a more indicative figure could be developed as a result of the dam construction. On page 4, mention is made that the sewer facilities should be placed above inundation - what elevation is this?

Brattleboro -

The suggestion is made that buildings on the flood plains should possibly be protected - why not removed? Are they going to develope an environmental impact statement of flood control vs. flood plain zoning? As the author pointed out, the reliance of people living in a flood zone upon the transmittal of a warning from an upstream resident is entirely unacceptable. However, should people be living in the flood zone in the first place? I realize that these are questions that must be answered and that these reports relate only to one agency's review and recommendations. I trust that recommendations from all sources will be integrated and the most logical approach adopted.

In summary, I would say that the Corps of Engineers is using a realistic approach, but should probably expand where possible to include actual figures to substantiate its' conclusions. For example, I would like to know within reason just how much protection the dams already constructed have provided over the damage anticipated if they had not been constructed. What impact will the providing of protection

on tributaries at various locations on the river have on the main stream itself? Are they going to develope, or have they already available, a flood routing chart for the main stem, i.e. the Connecticut River. Environmental impact statements for or against the construction of a dam on a triburary may be overshadowed when applied to the river as a whole. I am confident that the development of such a picture is planned for - but feel that there is no harm in my mentioning it at this time.

Trusting these few comments will be helpful.

Sincerely,

Gordon L. Byers
Chairman

GLB/lhw

UNIVERSITY OF MASSACHUSETTS
AMHERST

MEMORANDUM

ROM Frank C. Kaminsky DATE October 11, 1973

O John Smith

UBJECT Draft Reports for Hatfield, Massachusetts and Brattleboro, Vermont

In general I found the reports to be informative and helpful in providing basic data for the analysis of flood management problems in the two areas under study. The information on the flood plain of the Whetstone Brook was particularly interesting and could provide the basis for a flood management study which would eventually serve as a model for other areas of the basin.

As a result of our discussions at the meetings of the sub-committee on flood control it was my understanding that data was to be provided for dollar damages as a function of flow rate for each area under study. This information was not provided in the draft reports in sufficient detail. For example, the report indicates that Hatfield would experience damages which increase at a uniform rate when the river stage exceeded a particular level. A more precise functional relationship should be provided. Similarly, for the Whetstone Brook a dollar damage figure is not provided as a function of the flow rate or river stage.

I would suggest that the reports be revised to include the frequency-stage-flow rate-damage relationships in such a way that the model proposed by Larry Dingman in his recent report could be used for our analysis.

Frank Kaminsky

Frank C. Kaminsky

FCK/dh

State of Vermont

AGENCY OF ENVIRONMENTAL CONSERVAT

MARTIN L. JOHNSON, Secr

Montpelier, Vermont 0

DEPARTMENT OF WATER RESOUI

MANAGEMENT & ENGINEERING DIVIS

Department of Fish and Game
Department of Forests and Parks
Department of Water Resources
Environmental Board
Division of Environmental Protection
Division of Recreation
Division of Planning
Natural Resources Conservation Council

November 14, 1973

Mr. David Harrison
Connecticut River Basin Program
P.O. Box 651
9 South Main Street
Hanover, New Hampshire 03755

Dear Dave,

I have just had an opportunity to review the Corps draft of the Brattleboro, Vermont flood protection status report ahd have the following comments, the majority of which I have already made to John Smith verbally:

Page 6: Flood Plain Zoning. Reference should be made to the criteria for floodways and floodway fringes under Act 250 (copy enclosed). This constitutes a degree of state flood plain zoning. State also now has reference to flood plains in their trailer park regulations and the subdivision regulations.

Page 7: Flood Insurance. Brattleboro now is eligible for the flood insurance program. Also, John indicates, "to be eligible, the town should have to enact a satisfactory flood plain zoning ordinance." This is incorrec

Page 11: Flood Plain Clearance (end of first paragraph). In 1969, Whetstone Brook experienced substantial flooding.

Sincerely yours,

Robert J. Wernecke

Robert J. Wernecke
Chief, Hydrology Section

RJW/kmp

STATE OF CONNECTICUT
DEPARTMENT OF ENVIRONMENTAL PROTECTION
STATE OFFICE BUILDING HARTFORD, CONNECTICUT 06115

January 24, 1974

Mr. John Smith, Civil Engineer
U. S. Army Corps of Engineers
New England Division
424 Trapelo Road
Waltham, Massachusetts 02154

Re: NERBC Report Review: Present Status of Elements for Flood Damage Reduction, Glastonbury, Connecticut

Dear John:

I have just completed review of the subject report and offer the following comments:

1. Under Flood Control Impoundments, the report mentions the effect of the seven recommended reservoirs on flood heights in the Town (the reservoirs are mentioned in some of the Corps' other reports, also). I don't believe it is the intent of the Corps' task to assess these reservoirs when they are under criticism and have to be further evaluated as the study progresses. This report should direct itself to the present status of flood reduction techniques (see description in P.O.S. page 9 COE 1.3E).

2. Under Local Protection Projects, two possible diking schemes are mentioned. Again this is not, I believe, appropriate for this report. Even if it is, I don't feel that the diking of the entire flood plain, especially when you consider its value as a natural storage area, and the fact that Glastonbury's Master Plan proposes its use as a natural area, should even be considered. Also, what predicates "higher land uses in the meadows areas"? That's a value judgement and should not even be mentioned. Many of us feel that, left in its natural state, the meadows constitute the highest use for that particular land form.

These reports should assess the status of the present elements for flood damage reduction in particular towns. Future proposals are to be made later on in the study.

Very truly yours,

Stephen W. Tibbetts
Water Resources Engineer
Water and Related Resources

SWT:n

cc: Larry Dingman, NERBC

This paper was produced from recycled paper - both broke and pouted

The Center for the **ENVIRONMENT & MAN**, Inc. 275 Windsor Street • Hartford, Connecticut 06120 203 549-440

CEM

February 6, 1974
L-2081
1570

Mr. John T. Smith, P.E.
Department of the Army
Corps of Engineers
New England Division
424 Trapelo Road
Waltham, Massachusetts 02154

Dear John:

Attached are review comments for the draft report entitled, Community Flood Control Status, Hartford, Connecticut. The comments were submitted to me by Mr. T. Brindemaur of the Hartford Department of Public Works. It is unfortunate that they are being submitted so late but they are constructive and the changes indicated, particularly on page 8, will add to the report.

I had approached the officials with whom I met in East Hartford and Rocky Hill about review comments but none were forthcoming. In the current study on Holyoke, West Springfield and Westfield, Massachusetts review comments from town officials will be incorporated prior to submission of the reports.

Sincerely,

Lynn E. Johnson
Research Scientist

LEJ:ccm
enc.

Comments re report entitled:

COMMUNITY FLOOD CONTROL STATUS
HARTFORD, CONNECTICUT.

Draft dated October 30, 1973

ıge 1, line 4
Hartford is also bordered on the south by Newington, for about 2250 feet.

ıge 2, line 10
The colony was named after Hertford, in Hertfordshire, England. (See Connecticut Register and Manual, 1971, p. 604).

ıge 3, line 17 & 18
Following the floods of 1955, the Connecticut State Legislature established the Greater Hartford Flood Control Commission for.. .....Word Control not now in title. (Actually original name was Park River Flood Control Commission, and later changed to Greater Hartford Flood Commission, without 'Control').

.ge 5, line 15
The top elevation of the dike varies from 42.5 to 47.5 feet, M.S.L.

.ge 8, line 5
Elevation 54 does not extend into Bloomfield, (Also, G.H.F.C. has no jurisdiction in Newington, as it does in West Hartford).

ge 8, lines 23, 24 & 25
"North-south traffic on Interstate I-91 would be disrupted etc." How? (It would take more than a 1955 flood to cut off I-91 and the Connecticut River bridges. Downtown Hartford was not flooded in 1955.

ge 8, lines 30, 31
Eight flood storage reservoirs control approximately 18 percent, not 40 percent of drainage area.....(So. Branch 11% controlled, No. Br. 30% controlled, for total of 18% in both branches.

ge 11, line 12
Interior drainage behind dikes is handled by 5 pumping stations, not 6. Two were built by the City (South Meadows and Potter St.). Four are maintained by City (Potter St. by M.D.C.). Potter Street station will soon be demolished, leaving only 4 stations. Two more stations are planned in conjunction with the completion of the Park River Conduit.

ge 11, last line
I do not believe there is any stream channelization planned for the North Branch.

ge 13, line 10
Approximately eighteen percent of the drainage area....(See also note re Page 8, lines 30, 31).

ge 13, line 16
Top of dike elevation varies, 42.5 to 47.5 M.S.L. (See note re Page 5, line 15).

ge 14, line 15
Greater Hartford Flood Commission (word 'Control' not in title).

Connecticut River Basin Program

NEW ENGLAND RIVER BASINS COMMISSION
P.O. Box 651
9 South Main Street
RBC Hanover, New Hampshire 03755
(603) 643-5831

Home Office: 55 Court Street
Boston, Massachusetts 02108
(617) 223-6244

MEMORANDUM

To: John Smith
From: Larry Dingman LD
Date: March 4, 1974
Subject: Draft Damage-Center Reports; Draft Hydrology Report

Damage - Center Reports

I have reviewed the 18 damage - center reports, with particular reference to how they fulfill the requirements of COE 1.3D, 1.3E, and 1.4D. Since my detailed knowledge of the flood-related activities in the centers is limited, I have not commented on that aspect.

The above - mentioned items in the Plan of Study call for assessment of flood-damage reduction performance of 1) certain existing non-structural methods; 2) existing flood-control impoundments; and 3) existing local protection works. In addition, COE 1.4D asks for identification of feasible target areas for flood-plain management.

1. Assessment of flood-damage reductions performance of certain existing non-structural methods (clearance, flood-proofing, urban drainage, technical/planning information, and public information). These topics appear to be well covered in all the reports, with a couple of exceptions as discussed below. The discussion are necessarily qualitative, but appear to provide adequate data for assessing the present flood-damage reduction performance of these measures. I note, however, that urban drainage is not discussed in the reports on Brattleboro, Hatfield, Hartford, Vt., and Littleton; nor is the subject handled adequately in the St. Johnsbury report (i.e., the general value of urban drainage is not discussed). The Brattleboro and Hatfield reports should perhaps be reorganized to have the same sections as the others. Neither of those reports have discussions of clearance or eduation - these should be added. The discussion of clearance in the Littleton report could also be improved - the implication is that there is little reduction to be gained from this, but it is not directly stated.

2-3. Assessment of flood-damage reduction performance of flood-control

impoundments and local-protection works. I feel the most critical shortcoming of the reports lies in these areas. All the reports give some information on these topics, but it is all in terms of protection relative to the SPF and/or the IRF, rather than in terms of damage reductions. There seems to be an underlying assumption that all these places should have SPF protection. The CRSS is interested in the economics, however, and some attempt should be made to discuss this, as indicated in the Plan of Study. For those areas with SPF protection, it would seem safe to assume that average annual damages are reduced to negligible levels, because the SPF is so rare. For those with less-than-SPF protection, knowledge of the flood-damage reduction is essential to good planning. I'm not sure how this can be improved, since the Corps has indicated that it can't supply stage-frequency-damage relations for individual communities. I feel strongely, though, that the reports should contain some assessment of flood-damage reduction.

4. Identification of feasible target areas for flood-plain management - this is not specifically addressed in the Lebanon, Claremont, and Keene reports, and could be more completely discussed in the Hartford and Holyoke reports. Perhaps a section of each report could be devoted to a brief discussion of this.

Hydrology Report

Plan of Study items to be included in the Hydrology Report are listed below, along with comments as to how the report addresses these items.

1. Characterize full range of floods (COE 1.1D) - This is covered by flood-frequency rivers for C-7 downstream. Is there any reason why C-1 to C-6 can't be included?

2. Characterize full-range of streamflow variations (COE 1.1D) - This is not covered. I raised this question in my memo to Phil Manley (26 October 1973). Leslie replied (8 Nov. 73) that effects of flood-control operations on natural stream-flow variations are small. Some discussion of this should be included- though I agree with Leslie that this can be more specifically examined in Phase 2.

3. Satisfy data needs (COE 1.1D) - To the extent that the items listed are not covered in the report, I am assuming that the data will be presented as necessary for complete evaluation of alternatives in Phase 2.

4. Route selected floods (COE 1.3D) - This is covered adequately via the discussions in section 5, where the TTCF is presented. I assume the percent reductions in Table II are for peaks - this should perhaps be explicitly stated.

5. Assess flood-damage reductions of non-flood-control impoundments - and

lakes (COE 1.3D) - This is covered in section 6, quite adequately. The phrase "peak runoff to the storage" in the last sentence of the first paragraph is not clear. As a side light to the discussion here, I have found that the ratio lake volume/drainage area is an excellent measure of storage effect, and lake area/drainage area is a good measure of this effect (see Water Resources Research, V. 7, no. 5, p. 1208). I note also that Table 12 and page M-1-45 of the Coordinating Committee Report mentions some additional impoundments that affect flood flows - particularly mainstream power dams. This discrepancy should be clarified. Maps showing the extent of significant natural valley storage areas would be very helpful.

6. I note that the frequency-of-filling curve for flood-control reservoirs, as mentioned in Manley's memo of 16 October 1973, is not covered. I assume that this information will be provided in Phase 2 as required for evaluations of alternatives.

SLD/jd

Report and Evaluations by Institutional and Social Subcommittee of SAG on Phase I Reports, CRSS

by E. R. Kaynor, 29 March 1974

(The following comments have been extracted verbatim from a larger report reviewing draft work submitted to the New England River Basins Commission)

4. COE 4 "Damage Center" Reports

(a) Consensus Comments

- These reports are uneven in degree of completeness.
- Most of them do not specify the POS task to which they are addressed.
- Those reviewed lack sufficient data on effects of existing structural and nonstructural flood management devices.

(b) Individual Comments (not circulated)

- The Hartford - East Hartford - Rocky Hill report and the Lebanon - Claremont - Keene report are more complete than the St. Johnsbury - Hartford (VT) - Littleton report and the Northampton - Springfield - Chicopee report.
- All reports appear deficient especially in failure to specify effectiveness of existing measures (COE 1.3E and COE 1.3D), but also in adequacy of maps, and in simple description of nonstructural devices in force.
- The mapping for Chicopee and Springfield is especially poor.
- Unless effectiveness of nonstructural measures is assayed elsewhere in Phase I of the CRSS, these reports should be returned to the Corps with instructions to make such an assay.
- The Hartford report provides a sophisticated analysis of the status of flood damage reduction measures.
- The Northampton report overlaps with a much more detailed SCS Mill River Study.
- The Northampton report says nothing about the industrial park outside the Connecticut River dike.
- Criticisms of the Northampton report are possible because of personal familiarity, not so true of the other damage center reports.

11 Lakewood Circle
Greenwich, CT 06830
January 2, 1974

Dave Harrison
NERBC
Hanover, NH

Dear Dave:

Further to our conversation, you have my comments on the Meta Systems report in a previous letter and on page 2 of the CAG - SAG minutes.

With respect to the COE reports, they serve as a good summary of the present status. I am attaching a copy of page 3 of the minutes, amended with an additional note. These reports would be much more useful if good maps were included, such as the maps in the Agnes report. More graphic presentation and less words would be very useful in all reports. However, the COE reports are not on the verbose side.

The SCS report is very informative. Again, it lacks adequate maps -- a good opportunity for cooperation between SCS and COE -- there is no need for both doing the same job.

All reports lack consideration of the property owners responsibility in relation to flood water retention structures in areas of new residential or commercial development. Perhaps that is because there are no such requirements in the Connecticut River Watershed.

Sincerely,

1 incl

F. W. JOHNSON

NOTE: Also an outline of areas that would be effected by intermediate and standard project floods should be shown on the town maps in the reports.

that the present report does not fulfill all of the requirements in the Plan of Study.

Johnson felt that the COE damage center reports he had seen so far reflect an over emphasis on earlier approaches to flood management. There was a lack of consideration of upstream measures (such as could be required of subdividers through zoning and subdivision regulations).

Quinn (CAG) reported that Part I of the Cheney, Miller, and Ellis report on non-structural methods was very well done; she suggested that parts of it be abstracted for use by public officials. She felt that Part II was useful, but that: 1) more alternatives should be examined; and 2) the treatment of "opportunity costs," using only economic yardsticks, did not reflect many important considerations, especially environmental factors. Others added that permanent evaluation, especially after damage by floods, is a tool that should be given more consideration in the report.

Quinn was the only one present who had reviewed the SCS upstream watershed report; she found it too descriptive, with a seriously inadequate treatment of evaluation criterior.

D. Institutional/Social

Kaynor (SAG) briefly noted that SAG was still reviewing the Cheney, Miller, and Ellis report. Sargent (SAG) said that 90% of that report was very good, but contained errors on some aspects of flood-plain zoning laws in Vermont.

INCL 1

NEW ENGLAND RIVER BASINS COMMISSION
CONNECTICUT RIVER BASIN PROGRAM
SUPPLEMENTAL FLOOD MANAGEMENT STUDY

APPENDIX II
HYDROLOGY REPORT

Department of the Army
New England Division
Corps of Engineers

PHASE I

CONNECTICUT RIVER
SUPPLEMENTAL STUDY

HYDROLOGIC ENGINEERING INPUT

1. PURPOSE

This report presents hydrologic engineering information as input to the Phase I portion of the on-going Connecticut River supplemental study (Ref: Plan of Study dated 1 July 1973). Included are sections on flood frequencies, discharge rating curves, test floods, flood reductions by existing reservoir system and an assessment of the effects of non-flood control reservoirs and valley storage.

2. FLOOD DISCHARGE FREQUENCIES

Discharge frequency curves for index stations along the Connecticut River are shown on plates 1 through 3. These curves represent peak flow frequencies unmodified by flood control reservoirs and are a graphical presentation of the data tabulated in table C-10, Appendix C, of the June 1970 Connecticut River Comprehensive Report. Peak discharge frequencies were determined by a regional analysis using a Log Pearson Type III analysis as described in Water Resources Council Bulletin No. 15, entitled: "A Uniform Technique for Determining Floodflow Frequencies." Further discussion of the frequency analysis was presented in Appendix C of the 1970 Comprehensive Report.

3. RATING CURVES

Stage-discharge rating curves for index stations on the Connecticut River are presented on plate 4. These curves were developed using: (a) experienced stage-discharge data, (b) U.S. Geological Survey river rating data, and (c) conventional hydraulic formulae.

4. TEST FLOODS

The Corps of Engineers, in its hydrologic studies of floods on the Connecticut River, has determined the basin's flood producing characteristics using both historic and synthetic floods.

a. Historic floods. Notable historic floods that have been analyzed are the basinwide floods of March 1936 and April 1960 and the lower central basin floods of September 1938 and August 1955. For purposes of analysis, the basin was divided into 72 component areas as shown on plate 5. The contributing hydrographs from the component areas were combined and routed, thereby determining their relative timing and contribution to peak flows on the Connecticut River. The component contributions to peak flows on the Connecticut River are shown graphically on plates 6 through 9. The component contributions were tabulated in Appendix C, tables C-12 through C-14 of the Connecticut Comprehensive Report. Through the analysis of these historic floods and others the Corps determined the relative timing of component contributions and developed appropriate routing coefficients.

b. TTCF. For any magnitude of flood at a point on a river, there is an infinite number of different upstream storm and runoff conditions that could produce that discharge. Therefore, the representative effectiveness or average annual benefits of a reservoir system cannot realistically be determined by analysis of one or two historical flood events. One approach, to determine average system effectiveness, would be to analyze the system operation under an infinite number of storm orientations and runoff conditions. This, of course, would be an infinite task. Another approach is to develop a typical distribution or average flood over the basin and then, by studying multiples of this flood, determine the average or typical effectiveness of a flood control system for a wide range of flood frequencies. Using the latter approach, the New England Division, Corps of Engineers, developed the "Typical Tributary Contribution Flood" (TTCF). With this method of analysis, TTCF hydrographs are developed for all tributaries. The peaks of the hydrographs are made proportional to the area under the frequency curves and the volume of the hydrographs are proportional to average annual runoff of the streams. These tributary hydrographs are combined and routed to determine the typical contribution of the tributary flows to flood peaks at downstream damage centers. By developing natural and modified TTCF floods and using multiples of these floods the typical effectiveness of flood control systems is determined for the entire range of flood frequencies at the respective damage centers.

The TTCF is not used as a criteria for design. Its only function is to provide a hydrologic basis for economic analyses of flood control measures.

The TTCF flood developed for the Connecticut River is presented graphically on plate 10. The TTCF component contributions to peak flows on the Connecticut River are listed in table I.

5. FLOOD REDUCTIONS BY EXISTING SYSTEM

Flood reductions by the existing system of reservoirs are illustrated by the natural and modified stage-frequency curves shown on plate 11. The reductions shown are based on the TTCF analysis. It is cautioned that one should not infer that for every occurrence of a certain frequency flood the reduction will be as indicated by the modified frequency curve. Some reductions will be greater and some less, depending on the storm orientation with respect to the reservoirs. The modified frequency curve represents the expected average or typical reduction for a wide range of floods and is therefore used to determine average benefits. Percent reductions in the TTCF floods at index stations on the Connecticut River are listed in table II. Reductions in discharges and stages that would be provided by the system in the recurrence of the 1938 and 1936 historical floods have been computed and are listed in table III.

6. EFFECTIVENESS OF NON-FLOOD CONTROL RESERVOIRS

Unless a dam fails, practically all ponds and lakes have some modifying effect on floodflows. Even if full at the beginning of a flood, the rise in lake level to produce spillway discharge represents some temporary storage of flood runoff which normally results in some reduction of the flood peak. The flood control significance of any one lake or storage reservoir in a basin depends on the drainage area at the site, since useable storage can only affect the peak runoff to the storage, and the amount of useable storage relative to the size of the watershed.

The volume of runoff during major New England floods may vary from 2 to 3 inches for the flash-type flood or 6 to 10 inches for the longer duration events involving rainfall and snowmelt. Hence, the relative effectiveness of ponds or lakes for flood control may be judged by the amount of storage or rise in lake level represented by 6 inches of runoff from the contributing watershed. For example, an inch of runoff upstream of Sunapee Lake represents a volume of water one inch deep over a watershed of 45 square miles. Should this one inch of runoff flow into Lake Sunapee, which has a water area of 6.3 square miles (4,058 acres), the lake level would rise only 7 inches. This small rise

No.	TRIBUTARY NAME	Peak at Mouth (cfs)	D.A. at Mouth (sq.mi.)	CONNECTICUT RIVER BASIN T.T.C.F. FLOOD CONTRIBUTION TO PEAK AT									
				Dalton 1514 s.m.	Wells River 2644 s.m.	South Newbury 2825 s.m.	White River Junction 4092 s.m.	North Walpole 5493 s.m.	Vernon 6266 s.m.	Montague City 7865 s.m.	Holyoke 8309 s.m.	Thompson-ville 9661 s.m.	Bodkin Rock 10870 s.m.
1	Conn. R. @ No. Stratford	20,300	799	11,330	4,924	6,000	4,010	4,020	4,007	4,005	4,011	4,009	4,175
2	Upper Ammonoosuc R.	12,250	254	9,920	2,401	3,860	1,290	1,295	1,278	1,277	1,283	1,281	1,480
3	Israel R.	6,550	135	5,000	2,172	3,250	700	710	682	682	690	686	880
4	Local	4,760	97.4	3,340	2,023	2,520	830	825	783	780	790	786	945
5	Local	400	8.5	175	240	255	90	91	84	84	85	84	103
6	Bog Brook	1,260	26.2	890	532	665	210	212	201	200	203	202	245
7	Local	2,840	57.9	2,100	879	1,340	300	302	294	293	297	[illegible]	375
8	Local	2,560	52.5	1,960	566	1,000	260	264	261	260	263	262	315
9	Johns R.	3,660	75.5	3,420	587	1,160	380	382	381	380	382	381	435
10	Local	392	8.0	225	158	215	40	42	41	40	41	41	55
11	Local	3,730	89		1,930	2,090	470	460	449	450	453	452	565
12	Local	1,680	40		1,000	1,040	210	208	202	202	204	204	262
13	Passumpsic R.	21,300	507		15,182	16,600	1,860	1,860	1,490	1,460	1,560	1,522	2,920
14	Local	375	9		271	270	60	54	48	48	49	49	70
15	Stevens R.	1,800	43		1,480	1,300	340	270	234	230	240	237	355
16	Local	1,665	40		1,050	1,025	200	205	201	202	204	203	255
17	Ammonoosuc R.	31,400	402		30,850	19,200	2,320	2,690	2,215	2,190	2,340	2,291	4,240
18	Wells R.	4,200	100			1,860	2,100	1,400	900	700	770	870	1,155
19	Local	1,780	41			680	780	550	340	270	295	330	440
20	Oliverian Brook	1,690	40			870	610	475	320	250	275	310	440
21	Local	1,580	39				360	350	250	215	230	224	360
22	Waits R.	6,710	158				3,600	2,600	1,580	1,200	1,500	1,520	2,100
23	Eastman Brook	770	22				700	550	360	275	300	281	360
24	Local	2,820	64				2,160	1,550	1,000	760	830	950	990
25	Clay Brook	660	19				600	450	300	235	255	300	315
26	Local	2,390	55				2,190	1,450	990	740	800	900	925
27	Ompompanoosuc R.	5,900	136				5,400	3,520	2,168	1,970	2,130	2,005	2,430
28	Local	2,390	62				1,730	1,555	1,250	990	1,050	1,140	1,025
29	White R.	45,600	712				45,600	24,700	15,538	14,065	15,030	14,120	15,350
30	Mascoma R.	6,450	194					3,600	2,165	1,990	2,180	2,057	2,860
31	Local	1,390	39.5					1,140	757	690	730	690	730
32	Ottauquechee R.	19,900	222					11,180	7,175	6,460	6,850	6,412	6,120
33	Local	14,700	167					9,280	5,963	5,330	5,500	5,167	4,220
34	Sugar R.	15,700	275					10,880	6,271	5,620	6,020	5,633	5,940
35	Local	4,200	72.5					3,500	2,014	1,800	1,860	1,750	1,610
36	Black R.	17,900	204					14,380	6,828	5,815	6,220	5,701	5,400
37	Local	2,240	24					1,850	780	675	700	639	550
38	Williams R.	12,000	118					8,100	4,261	3,750	3,860	3,555	2,965
39	Local	585	7					95	254	252	230	234	152
40	Saxtons R.	6,400	78					1,990	3,390	3,285	3,230	3,110	2,060
41	Cold R.	9,050	100						4,261	4,150	3,990	3,905	2,440
42	Local	6,240	107.3						2,777	3,340	3,180	3,350	2,340
43	Local	8,500	71.5						1,700	2,590	2,450	2,729	1,710
44	West R.	48,800	423						31,900	34,600	27,600	27,056	13,600
45	Local	7,900	71.2						2,020	3,240	3,080	3,396	1,900
46	Ashuelot R.	14,100	421							13,600	13,400	13,169	10,260
47	Local	7,700	78.2							2,940	3,010	3,311	1,890
48	Millers R.	12,320	392							12,100	11,660	11,309	8,710
49	Fall R.	3,750	35.7							1,850	1,850	1,914	1,055
50	Local	452	8.1							230	230	242	183
51	Deerfield R.	57,600	664							45,300	40,600	40,245	22,500
52	Local	3,800	113								3,380	3,411	2,565
53	Mill R.	6,480	50								840	1,038	1,310
54	West Branch Mill R.	5,450	56								4,060	3,382	1,650
55	Local	7,390	225								4,400	4,583	4,245
56	Local	1,740	18.5									375	430
57	Chicopee R.	17,010	721									16,420	12,020
58	Westfield R.	54,800	517									8,077	12,000
59	Local	2,720	54									1,493	1,250
60	Local	3,880	41.5									610	810
61	Stony Brook	2,400	40.3										900
62	Local	1,325	25										545
63	Scantic R.	5,300	114										2,620
64	Farmington R.	36,600	609										18,380
65	Local	1,900	36.3										350
66	Park R.	8,200	78.3										2,290
67	Hockanum R.	3,800	82.2										1,995
68	Local	1,720	37										720
69	Roaring Brook	1,120	23.9										405
70	Local	4,300	40										405
71	Mattabesset R.	11,000	105										1,620
72	Local	1,900	18										120
	COMPUTED TOTALS			38,360	66,300	65,200	79,400	119,000	120,350	194,000	197,650	221,000	209,400

TABLE II

REDUCTIONS IN TTCF DISCHARGES
BY EXISTING CORPS RESERVOIRS

Index Station	Location	Percent Reduction in "Q"
C-6	USGS Gage at South Newbury	0
C-7	USGS Gage at White River Junction	3.0
C-8	Headwater Windsor Highway Bridge	16.1
C-9	Headwater Bellows Falls Dam	21.3
C-10	Headwater Vernon Dam	21.2
C-11	Schell Bridge Turners Falls	21.7 25.7
C-12	USGS Gage at Montague City	23.6
C-13	Calvin Coolidge Bridge	21.6
C-14	USGS Gage at Thompsonville	20.4
C-15	Windsor Locks Highway Bridge	21.1
C-16	Bulkeley Memorial Bridge	21.1
C-17	USGS Gage at Bodkin Rock	21.1

TABLE III

CONNECTICUT RIVER BASIN

MAJOR FLOODS - EFFECT OF RESERVOIR SYSTEMS

Damage Zone	Location	MARCH 1936 FLOOD				SEPTEMBER 1938 FLOOD			
		Observed		Modified by 16 Existing*		Observed		Modified by 16 Existing*	
		Discharge	El.	Discharge	El.	Discharge	El.	Discharge	El.
C-2	North Stratford Gage	28,400	894.8	28,400	894.8	12,800	889.9	12,800	889.9
C-6	Wells River	(E) 79,500	418.6	79,500	418.6	(E) 44,000	413.1	44,000	413.1
C-7	White River Junction	120,000	354.1	115,000	353.3	82,400	347.7	78,500	347.0
C-9	North Walpole Gage (at Rte. 123 Bridge)	166,500	258.8	134,700	252.8	118,500	249.4	92,600	243.8
C-10	Vernon Dam	176,000	231.3	142,400	227.2	132,500	226.3	98,200	223.0
C-11	Schell Bridge	(E) 192,600	218.2	145,600	209.2	(E) 145,500	209.1	106,800	202.1
C-12	Montague City Gage	236,000	149.1	185,200	143.4	195,000	144.7	151,800	139.2
C-13	Holyoke Dam (at Calvin Coolidge Bridge)	244,000	129.9	187,500	126.2	189,000	126.4	148,000	122.3
C-14	Thompsonville Gage	282,000	55.1	211,600	51.6	236,000	52.9	189,200	50.6
C-15,16,17	Bodkin Rock Gage	267,500	28.0	206,100	23.5	239,000	26.0	194,500	23.8

* Existing Reservoirs include Union Village, North Hartland, North Springfield, Ball Mountain, Townshend, Surry Mountain, Otter Brook, Birch Hill, Tully, Barre Falls, Conant Brook, Knightville, Littleville, Sucker Brook, Mad River, Colebrook.

All Elevations in Feet Above Mean Sea Level Datum.

(E) Estimated Flow

in lake level illustrates that Sunapee has a large amount of storage, hence is very effective in modifying flood runoff.

An example of an opposite condition from that at Sunapee Lake would be Ashuelot Pond. With a 25 square mile drainage area and 0.67 square mile lake area, one inch of runoff would raise the pond 37 inches or over 3 feet. To a hydrologist, this would indicate that Ashuelot Pond has very limited potential for natural flood control effectiveness.

Most of the main stem dams on the Connecticut River, namely, Holyoke, Turners Falls, Vernon, Bellows Falls and Wilder are mainly "run of river" type projects with insufficient storage capacity, in relation to watershed, to be either currently or potentially effective for flood control purposes. Similarly, most of the many small headwater storages, though effective in controlling runoff from their respective drainage areas, have little modifying effect on Connecticut River floods due to the small percentage of total drainage area they control. Further regulation of a large number of these small reservoirs is operationally not feasible because of their relatively small overall potential for flood control effectiveness.

There are several large lakes and reservoirs in the Connecticut River basin that do have an important role in the control of flood runoff. Some of the larger and more effective of these bodies of water, and organizations regulating them, are listed in table IV. All of these lakes and reservoirs have an appreciable effect on floods and, except those for water supply, are drawn down during the winter in anticipation of the spring runoff.

7. NATURAL VALLEY STORAGE

Before high rates of runoff can occur following intense rainfall and/or snowmelt over a watershed, a depth or volume of water is required to provide the hydraulic conveyance. For example, before a flow of 80,000 cfs can occur on the Connecticut River there must be sufficient volume of water in the river channel to provide the conveyance for 80,000 cfs. This principle applies whether the watershed is the Connecticut River basin or a paved parking lot. This hydraulic requirement for runoff to occur involves temporary storage which in turn results in lagging and attenuation of runoff from a watershed. Travel time of runoff over the watershed also lags the runoff hydrographs. On steep, flashy watersheds the hydraulics of runoff is

TABLE IV

PRINCIPAL CONNECTICUT RIVER BASIN RESERVOIRS

Reservoir	Drainage Area (sq.mi.)	Usable Storage (ac-ft)	Operator
New Hampshire			
Connecticut Lakes	82	88,000	New England Power Co. (NEPCO)
Lake Francis	170	99,300	N.H. Water Resources Board (NHWRB)
Moore Reservoir	1,600	114,000	NEPCO
Mascoma Lake	182	24,400	NHWRB
Lake Sunapee	45	19,800	NEPCO
Vermont			
Somerset Reservoir	30	57,400	NEPCO
Lake Whitingham	184	116,000	NEPCO
Massachusetts			
Quabbin Reservoir	186	1,235,000	Metropolitan District Commission
Cobble Mountain	46	77,900	City of Springfield
Otis Reservoir	17	17,900	Mass. Water Resources Commission
Connecticut			
Barkhamstead Reservoir	54	93,000	Hartford Metropolitan District
West Branch Reservoir	122	20,100	" " "
Nepaug Reservoir	32	28,500	" " "

sometimes analyzed using hydrodynamic principles of unsteady flow. For the flatter watersheds the hydraulics of runoff can be quite accurately approximated by treating the process as a series of storage routings. The methodologies and procedures for analyzing the hydraulics of runoff and river routings are quite well known.

Another principle having little effect on the hydraulics of flow but considerable effect on the lagging and attenuation of hydrographs is the effect of natural valley storage. Natural valley storage areas consist of swamps and flood plain areas, adjacent to, but lying outside, the hydraulically important floodway areas.

During flood periods when discharges and stages in streams are increasing, flows escape the principal floodway and enter these natural valley storage areas where they are temporarily stored until the recession period of the flood. The effect of this temporary storage is to lag and reduce the flood peak as it progresses downstream. When natural valley storage is lost, the flows that would normally enter the storage areas must either move into adjoining storage areas causing higher stages or move on through the reach causing increased flood discharges downstream.

Change of storage in a flood plain can only occur as a result of change in stage which in turn is a function of the change in flow in the river. The relative magnitude of the effect of flood plain storage on outflow is therefore dependent on the rate of rise of the flood crest, the amount of flood plain area, and the magnitude of the riverflow. During rising flood stages, the outflow from a reach is less than the inflow by a flow amount equivalent to the rate of rise in stage multiplied by the natural valley storage area. The amount the outflow peak is reduced below the inflow peak depends greatly on the type of flood. Natural valley storage has the greatest modifying effect on flash-type floods that peak and recede quickly. With this type flood, reduction in peak discharge can approach the reduction between inflow and outflow experienced during the rising portion of the floods. During long duration flooding such as snowmelt floods, where flood discharges remain high for a long period, the effect of natural valley storage becomes minimal, because once the valleys are filled to the stage required to sustain the peak flow, outflow equals inflow.

Natural valley storage areas in the Connecticut River basin are quite limited both on the main stem and its tributaries. There is practically no storage in the principal flood producing tributaries on the westerly side of the river in Massachusetts and Vermont.

Notable tributary storage areas are located on the Westfield River in the city of Westfield, on the Ashuelot River in the city of Keene, and on the Farmington River between River Glen and Tariffville. Table V lists the approximate size of these flood plain areas, a typical rate of rise of stage over the flood plain during flood occurrences and the equivalent rate of inflow this rate of rise represents.

Four notable valley storage areas along the main stem Connecticut River are listed in table VI. Included in the listing is the approximate size of the valley storage areas, typical rates of rise in stage over the areas during flood occurrences and the equivalent rate of inflow this rate of rise represents. The percent of 100-year frequency outflow, listed in the table, is an indicator of the maximum possible effect this natural valley storage has on reducing peak floodflows. As previously discussed, the actual reduction in peak flow would vary depending on the flashyness of the inflow hydrograph.

Because of both valley storage and time of travel, peak flows from the area generally north of Wells River have not been large contributors to peak flows on the lower Connecticut River but have generally contributed during the recession portion of the flood hydrographs.

TABLE V

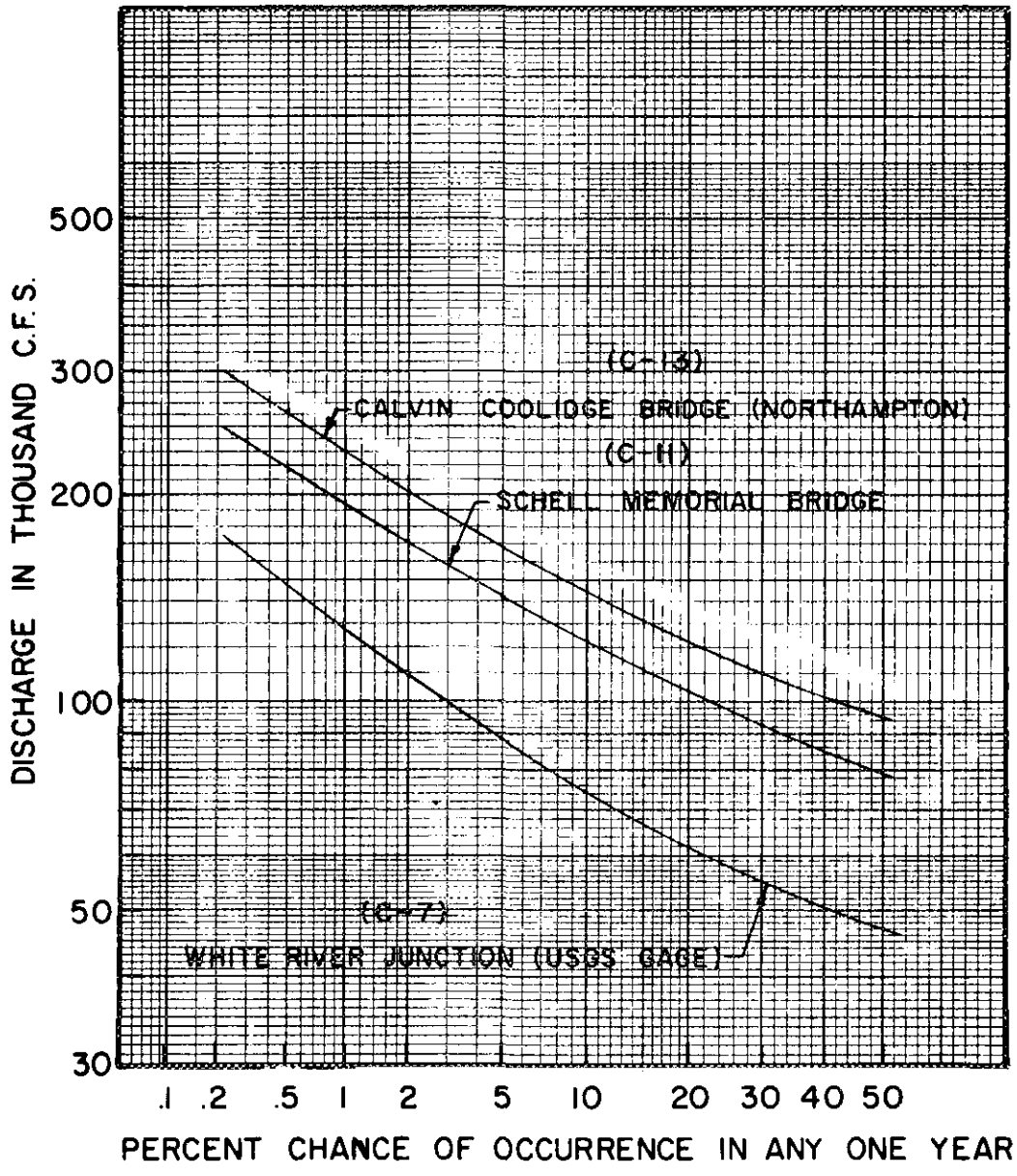
CONNECTICUT RIVER TRIBUTARY STORAGE AREAS

Location	Flood Plain Area (acres)	Rate of Rise in Stage (ft/hr)	Inflow to Storage (cfs)	Percent of 100-Year Outflow
Farmington River River Glen to Taraffville, Conn.	6,000±	0.25	18,000	40±
Westfield River Westfield, Mass.	800±	3	25,000	50±
Ashuelot River Keene, N.H.	2,500±	0.30	10,000	100±

TABLE VI

CONNECTICUT RIVER MAIN STEM STORAGE AREAS

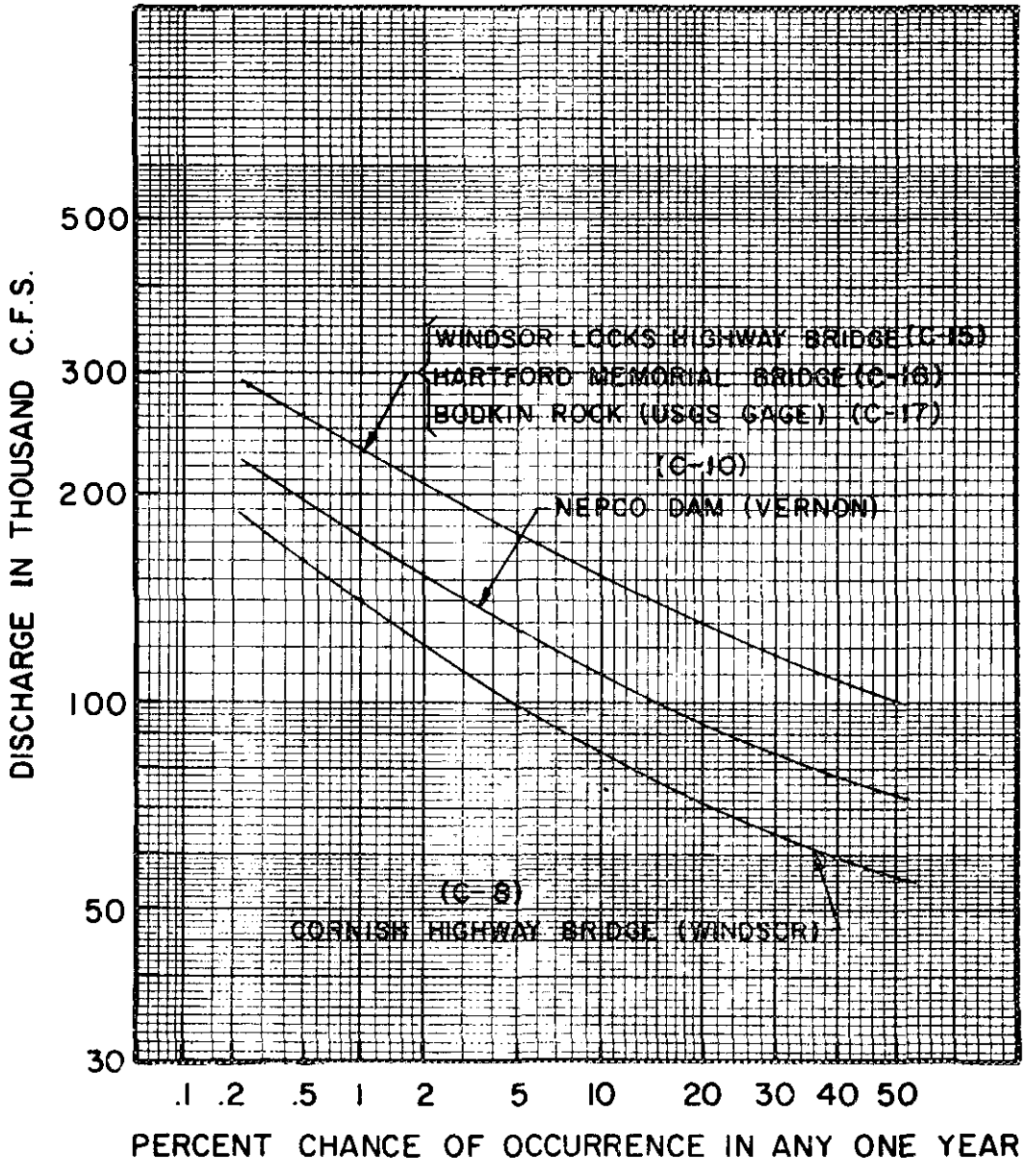
Location	Flood Plain Area (acres)	Rate of Rise in Stage (ft/hr)	Inflow to Storage (cfs)	Percent of 100-Year Outflow
West Stewartstown to Lancaster, N.H.	12,000±	0.1	15,000	50±
Woodsville to Bradford	4,000±	0.1	5,000	7±
Montague City to Holyoke	8,500±	0.5	50,000	30±
Middletown to Windsor Locks	20,000±	0.15	36,000	20±



CONNECTICUT RIVER

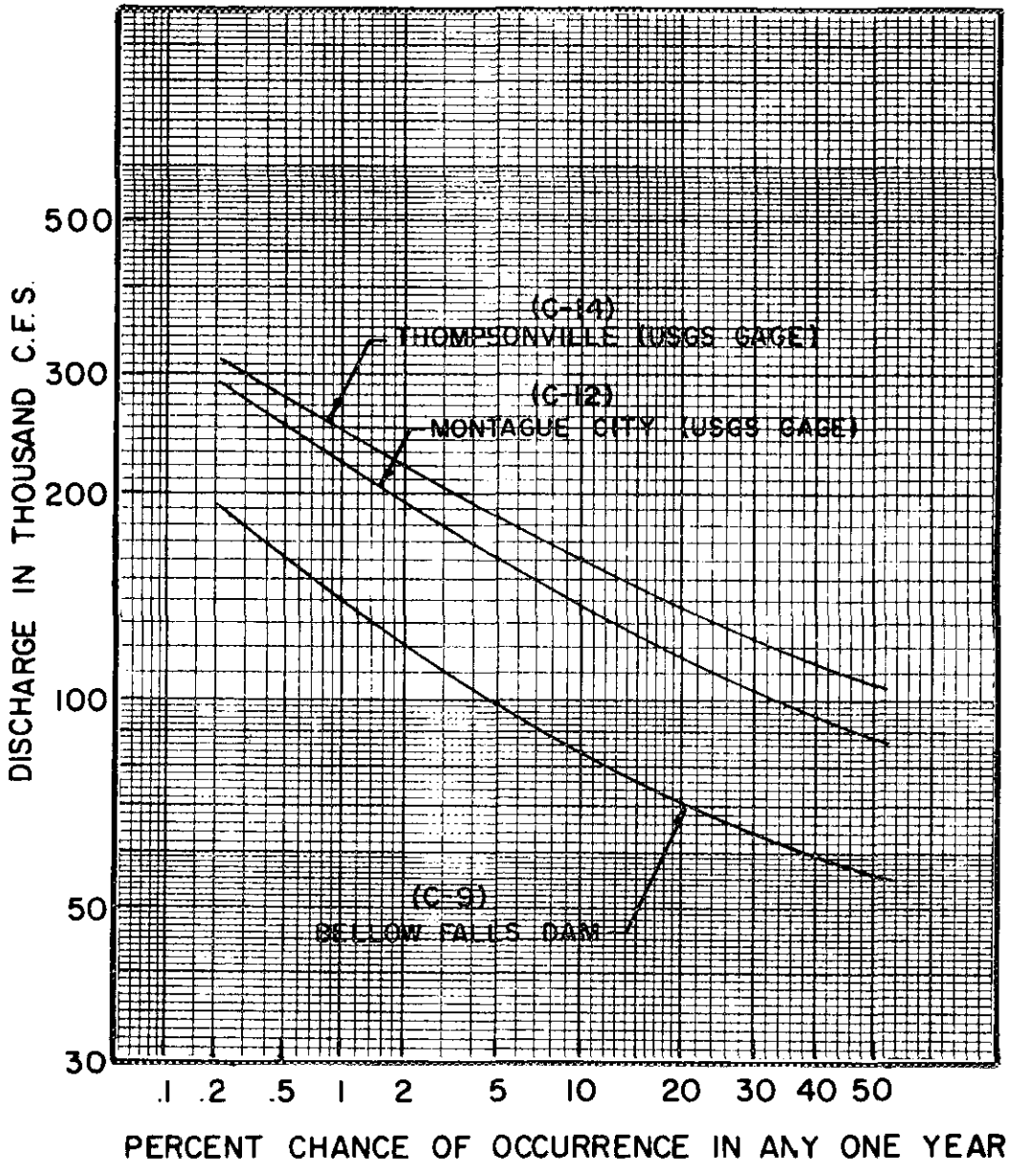
DISCHARGE FREQUENCY CURVES

PLATE I



CONNECTICUT RIVER

DISCHARGE FREQUENCY CURVES



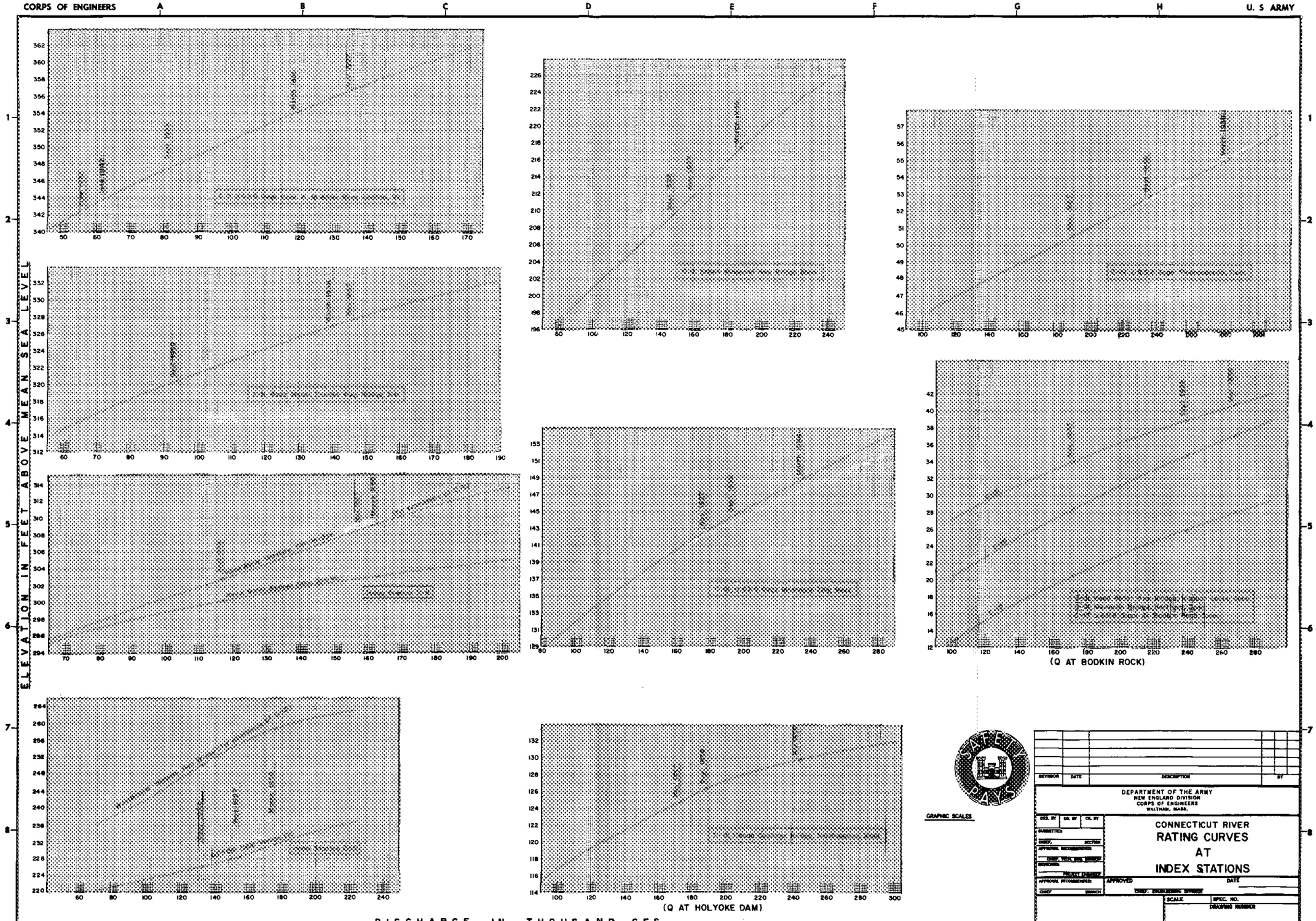
CONNECTICUT RIVER

DISCHARGE FREQUENCY CURVES

PLATE 3

CORPS OF ENGINEERS

U. S ARMY



GRAPHIC SCALES

REVISION	DATE	DESCRIPTION	BY

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

DES. BY | DR. BY | CK. BY

SUBMITTED:
CHIEF, SECTION
APPROVAL RECOMMENDED:
CHIEF, TECH. ENG. BRANCH
BRANCH:
PROJECT ENGINEER
APPROVAL RECOMMENDED:
CHIEF BRANCH

CONNECTICUT RIVER
RATING CURVES
AT
INDEX STATIONS

APPROVED
DATE
CHIEF, ENGINEERING DIVISION

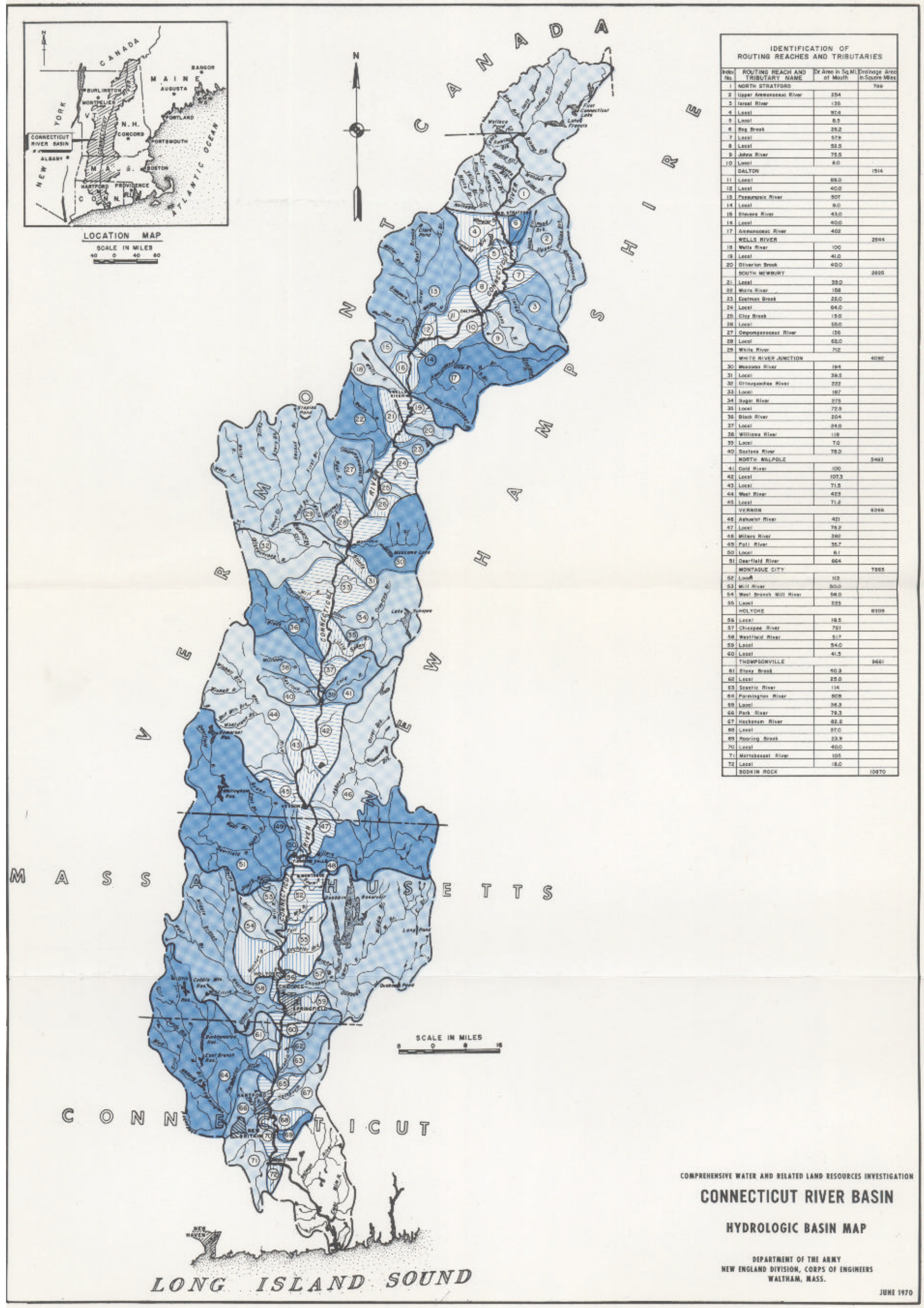
SCALE | SPEC. NO.
DRAWING NUMBER
SHEET

PLATE 4

LOCATION MAP

SCALE IN MILES

40 0 40 80



IDENTIFICATION OF ROUTING REACHES AND TRIBUTARIES

Index No.	ROUTING REACH AND TRIBUTARY NAME	Dr Area in Sq. Mi. of Mouth	Drainage Area in Square Miles
1	NORTH STRATFORD		798
2	Upper Ammonoosuc River	254	
3	Israel River	135	
4	Local	97.4	
5	Local	8.5	
6	Bog Brook	26.2	
7	Local	57.9	
8	Local	52.5	
9	Johns River	75.5	
10	Local	6.0	
	DALTON		1514
11	Local	89.0	
12	Local	40.0	
13	Passumpsic River	507	
14	Local	9.0	
15	Stevens River	43.0	
16	Local	40.0	
17	Ammonoosuc River	402	
	WELLS RIVER		2594
18	Wells River	100	
19	Local	41.0	
20	Olverian Brook	40.0	
	SOUTH NEWBURY		2895
21	Local	33.0	
22	Waits River	158	
23	Eastman Brook	22.0	
24	Local	64.0	
25	Clay Brook	19.0	
26	Local	36.0	
27	Ompompanoosuc River	136	
28	Local	62.0	
29	White River	712	
	WHITE RIVER JUNCTION		4092
30	Mascoma River	194	
31	Local	39.5	
32	Ottauquechee River	222	
33	Local	187	
34	Sugar River	275	
35	Local	72.8	
36	Black River	204	
37	Local	24.0	
38	Williams River	118	
39	Local	7.0	
40	Saxtons River	78.0	
	NORTH WALPOLE		5493
41	Cold River	100	
42	Local	107.3	
43	Local	71.5	
44	West River	423	
45	Local	71.2	
	VERNON		6266
46	Ashuelot River	421	
47	Local	78.2	
48	Millers River	392	
49	Fall River	35.7	
50	Local	8.1	
51	Deerfield River	664	
	MONTAGUE CITY		7865
52	Local	113	
53	Mill River	50.0	
54	West Branch Mill River	58.0	
55	Local	22.5	
	HOLYOKE		8309
56	Local	10.5	
57	Chicopee River	721	
58	Westfield River	517	
59	Local	54.0	
60	Local	41.5	
	THOMPSONVILLE		9661
61	Stony Brook	40.3	
62	Local	25.0	
63	Scantic River	114	
64	Farmington River	608	
65	Local	36.3	
66	Park River	78.3	
67	Hockanum River	82.8	
68	Local	87.0	
69	Mooring Brook	23.9	
70	Local	40.0	
71	Mattabesset River	105	
72	Local	18.0	
	BODKIN ROCK		10870

COMPREHENSIVE WATER AND RELATED LAND RESOURCES INVESTIGATION

CONNECTICUT RIVER BASIN

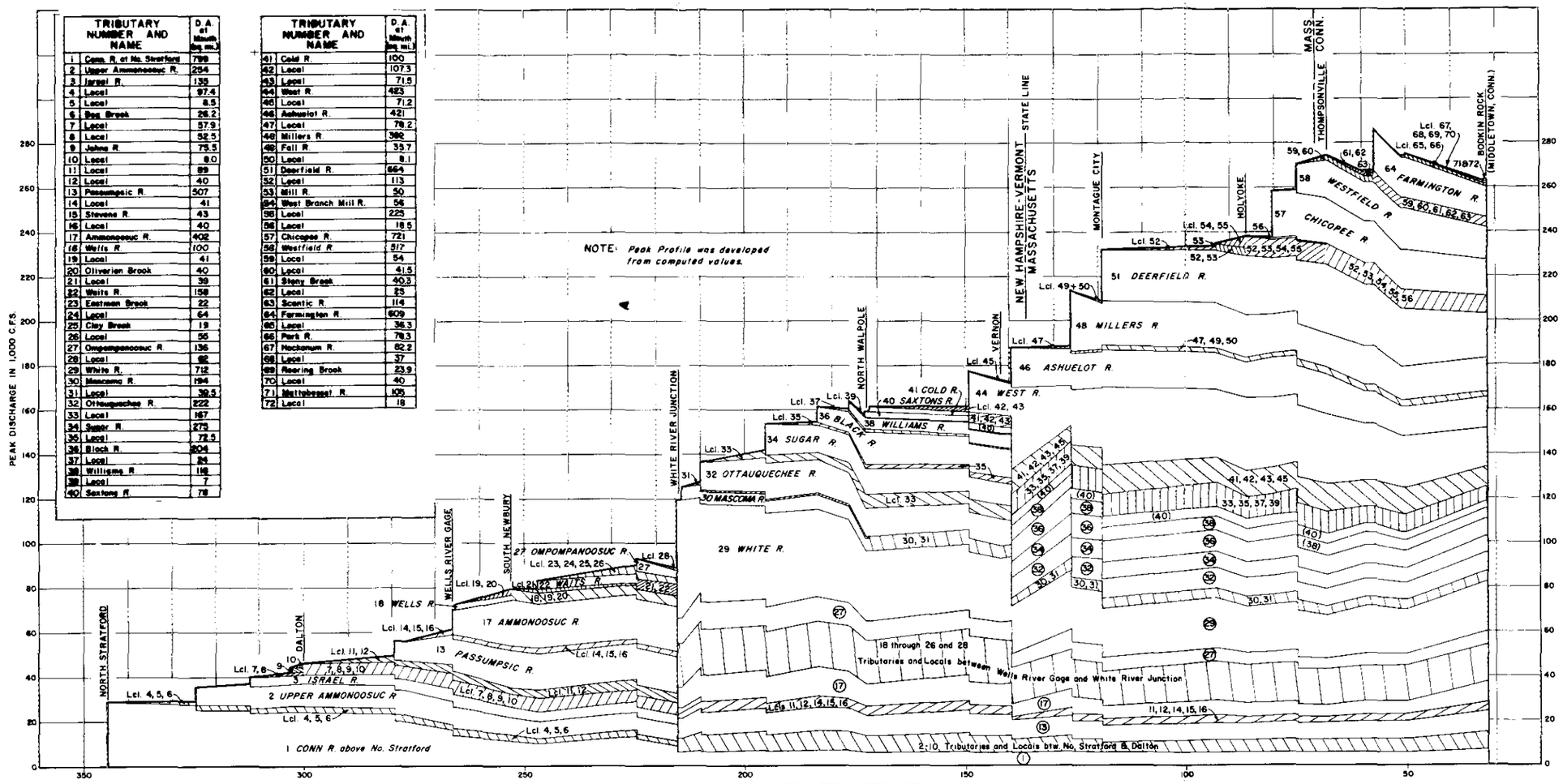
HYDROLOGIC BASIN MAP

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

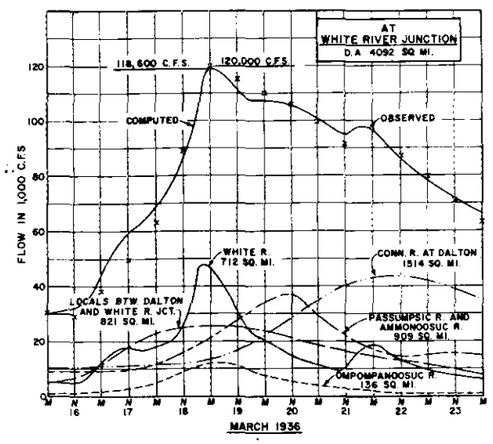
JUNE 1970

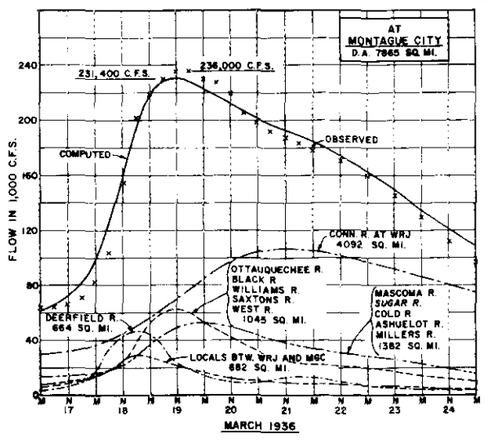
TRIBUTARY NUMBER AND NAME		D.A. at Mouth (sq. mi.)
1	Conn. R. at No. Stratford	799
2	Upper Ammonoosuc R.	254
3	Israel R.	135
4	Local	97.4
5	Local	8.5
6	Bog Brook	26.2
7	Local	57.9
8	Local	52.5
9	Johns R.	75.5
10	Local	8.0
11	Local	89
12	Local	40
13	Passumpsic R.	307
14	Local	41
15	Stevens R.	43
16	Local	40
17	Ammonoosuc R.	402
18	Wells R.	100
19	Local	41
20	Olivarian Brook	40
21	Local	39
22	Waits R.	158
23	Eastman Brook	22
24	Local	64
25	Clay Brook	19
26	Local	55
27	Ompompanoosuc R.	136
28	Local	62
29	White R.	712
30	Mascoma R.	194
31	Local	39.5
32	Ottauquechee R.	222
33	Local	167
34	Sugar R.	275
35	Local	72.5
36	Black R.	204
37	Local	24
38	Williams R.	118
39	Local	7
40	Saxtons R.	78

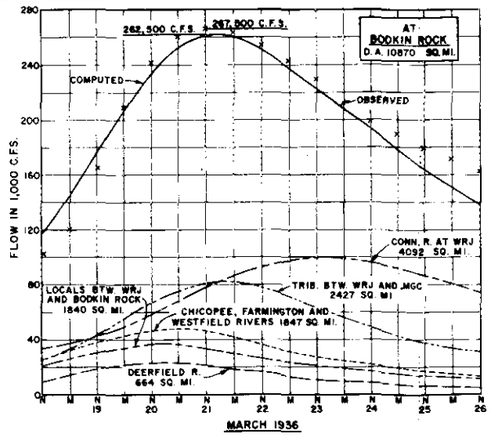
TRIBUTARY NUMBER AND NAME		D.A. at Mouth (sq. mi.)
41	Cold R.	100
42	Local	107.3
43	Local	71.5
44	West R.	423
45	Local	71.2
46	Ashuelot R.	421
47	Local	78.2
48	Millers R.	382
49	Fall R.	35.7
50	Local	8.1
51	Deerfield R.	664
52	Local	113
53	Mill R.	50
54	West Branch Mill R.	56
55	Local	225
56	Local	18.5
57	Chicopee R.	721
58	Westfield R.	517
59	Local	54
60	Local	41.5
61	Stony Brook	40.3
62	Local	25
63	Scantic R.	114
64	Farmington R.	609
65	Local	36.3
66	Park R.	78.3
67	Hockanum R.	62.2
68	Local	37
69	Roaring Brook	23.9
70	Local	40
71	Mattabesset R.	105
72	Local	18



MARCH 1936 FLOOD PEAK PROFILE







COMPREHENSIVE WATER AND RELATED LAND RESOURCES INVESTIGATION

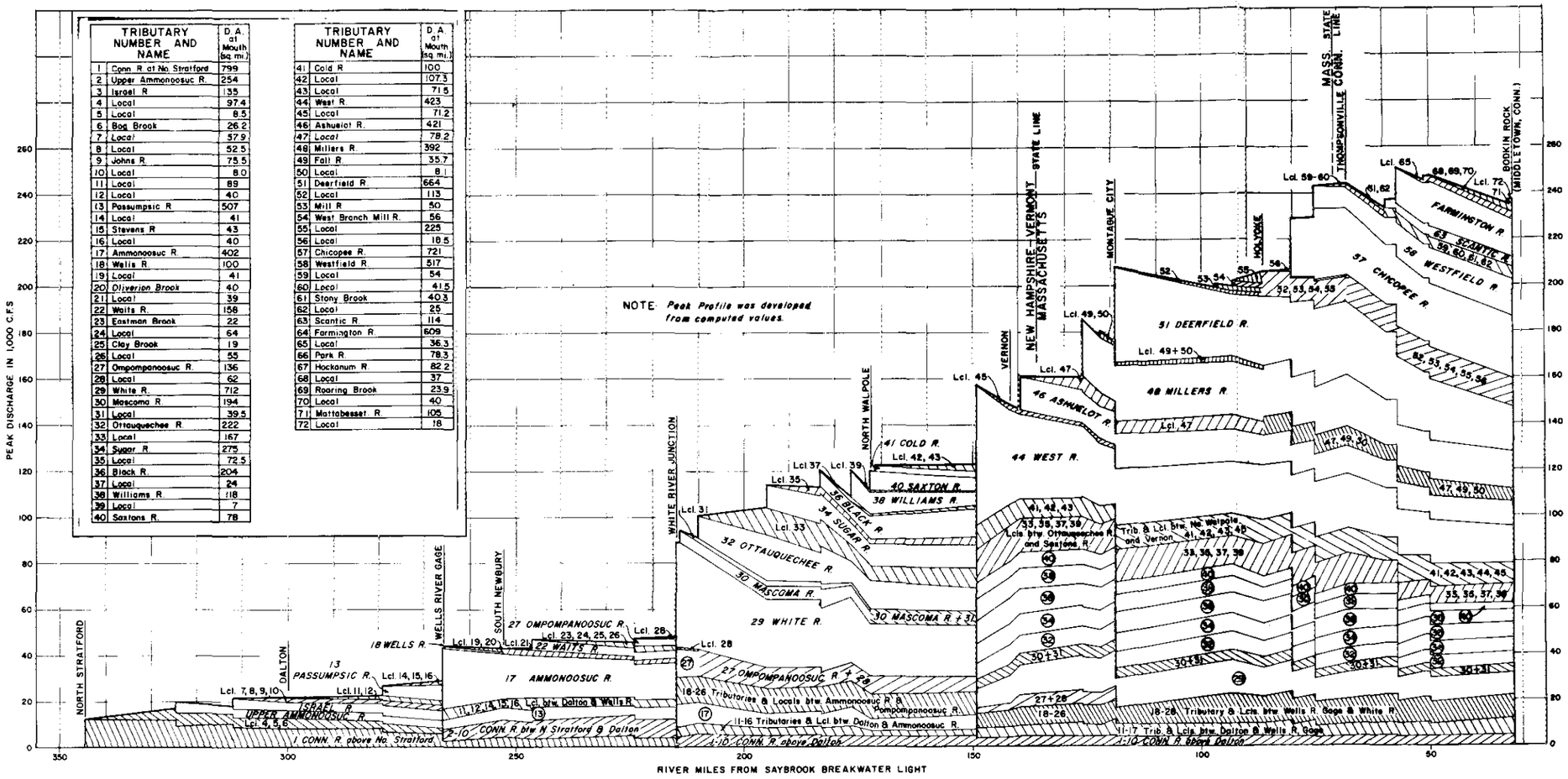
CONNECTICUT RIVER BASIN
PEAK DISCHARGE PROFILE
MARCH 1936 FLOOD

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

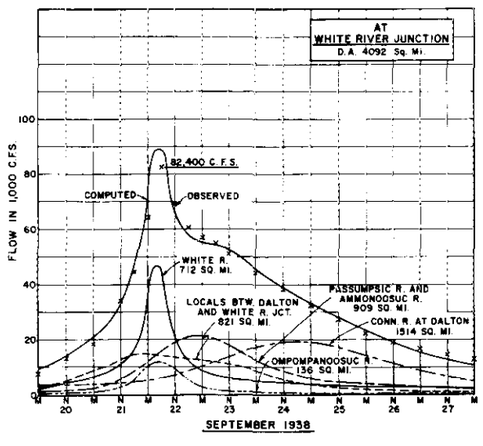
JUNE 1970

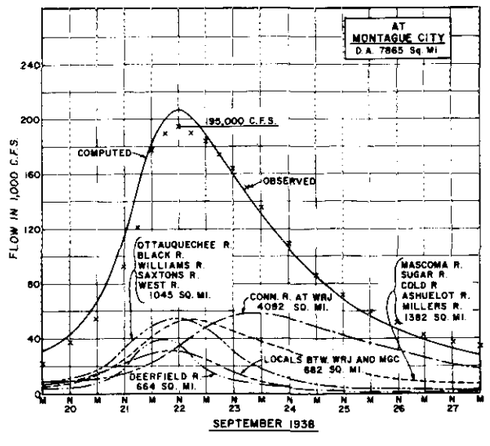
TRIBUTARY NUMBER AND NAME		D.A. at Mouth (sq. mi.)
1	Conn. R. at No. Stratford	799
2	Upper Ammonoosuc R.	254
3	Israel R.	135
4	Local	97.4
5	Local	8.5
6	Bog Brook	26.2
7	Local	57.9
8	Local	52.5
9	Johns R.	75.5
10	Local	8.0
11	Local	89
12	Local	40
13	Passumpsic R.	507
14	Local	41
15	Stevens R.	43
16	Local	40
17	Ammonoosuc R.	402
18	Wells R.	100
19	Local	41
20	Oliverian Brook	40
21	Local	39
22	Waits R.	158
23	Eastman Brook	22
24	Local	64
25	Clay Brook	19
26	Local	55
27	Ompompanoosuc R.	136
28	Local	62
29	White R.	712
30	Mascoma R.	194
31	Local	39.5
32	Ottauquechee R.	222
33	Local	167
34	Sugar R.	275
35	Local	72.5
36	Black R.	204
37	Local	24
38	Williams R.	118
39	Local	7
40	Saxtons R.	78

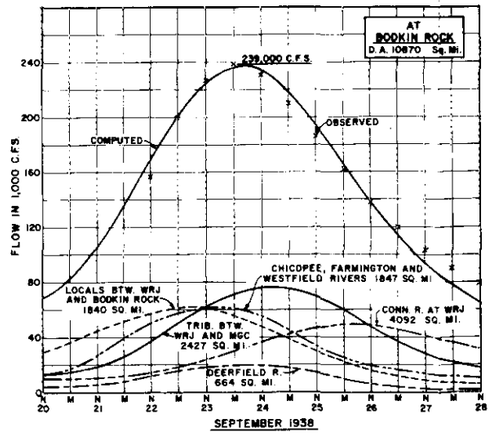
TRIBUTARY NUMBER AND NAME		D.A. at Mouth (sq. mi.)
41	Cold R.	100
42	Local	107.3
43	Local	71.5
44	West R.	423
45	Local	71.2
46	Ashuelot R.	421
47	Local	78.2
48	Millers R.	392
49	Fall R.	35.7
50	Local	8.1
51	Deerfield R.	664
52	Local	113
53	Mill R.	50
54	West Branch Mill R.	56
55	Local	225
56	Local	18.5
57	Chicopee R.	721
58	Westfield R.	517
59	Local	54
60	Local	41.5
61	Stony Brook	40.3
62	Local	25
63	Scantic R.	114
64	Farmington R.	609
65	Local	36.3
66	Park R.	78.3
67	Hockanum R.	82.2
68	Local	37
69	Roaring Brook	23.9
70	Local	40
71	Mattabesset R.	105
72	Local	18



SEPTEMBER 1938 FLOOD PEAK PROFILE







COMPREHENSIVE WATER AND RELATED LAND RESOURCES INVESTIGATION

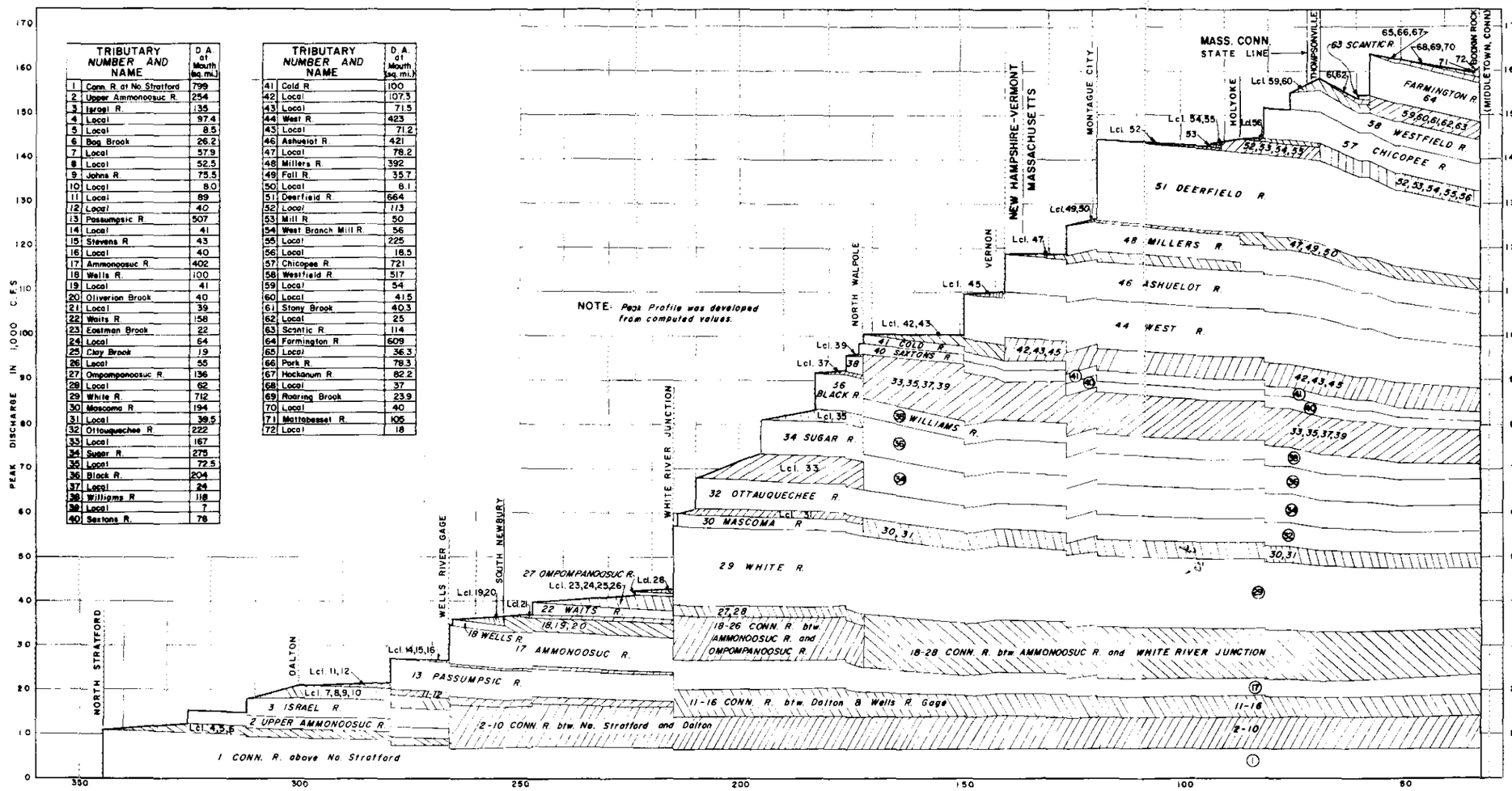
CONNECTICUT RIVER BASIN
PEAK DISCHARGE PROFILE
SEPTEMBER 1938 FLOOD

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

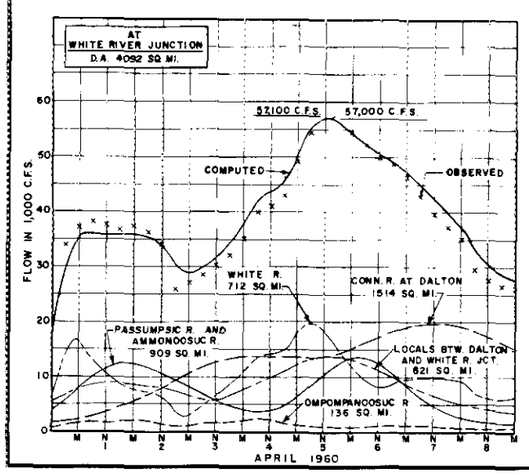
JUNE 1976

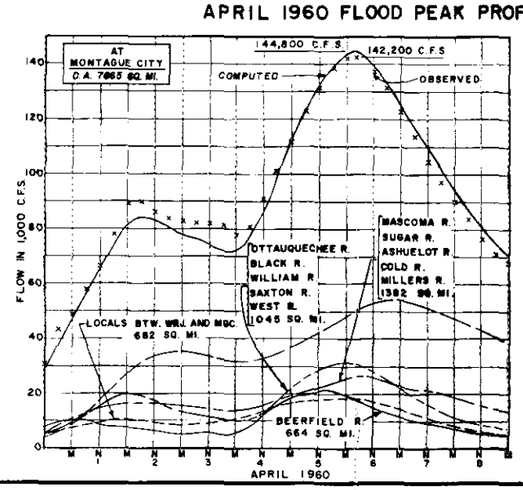
TRIBUTARY NUMBER AND NAME		D.A. at Mouth (sq. mi.)
1	Conn. R. at No. Stratford	799
2	Upper Ammonoosuc R.	254
3	Israel R.	135
4	Local	97.4
5	Local	8.5
6	Bog Brook	26.2
7	Local	57.9
8	Local	52.5
9	Johns R.	75.5
10	Local	8.0
11	Local	89
12	Local	40
13	Passumpsic R.	507
14	Local	41
15	Stevens R.	43
16	Local	40
17	Ammonoosuc R.	402
18	Wells R.	100
19	Local	41
20	Oliverian Brook	40
21	Local	39
22	Waits R.	158
23	Eastman Brook	22
24	Local	64
25	Clay Brook	19
26	Local	55
27	Ompompanoosuc R.	136
28	Local	62
29	White R.	712
30	Mascoma R.	194
31	Local	39.5
32	Ottauquechee R.	222
33	Local	167
34	Sugar R.	275
35	Local	72.5
36	Black R.	204
37	Local	24
38	Williams R.	118
39	Local	7
40	Sextons R.	78

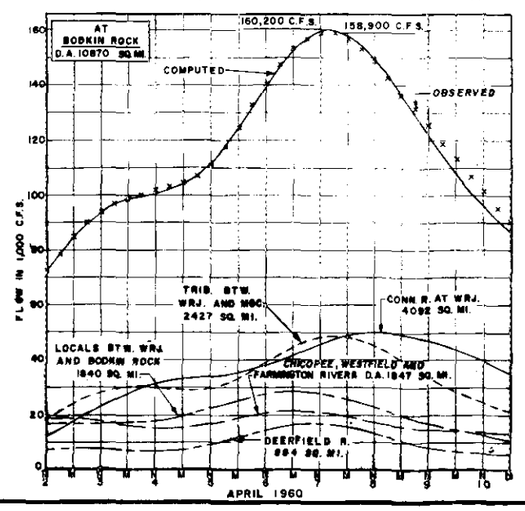
TRIBUTARY NUMBER AND NAME		D.A. at Mouth (sq. mi.)
41	Cold R.	100
42	Local	107.3
43	Local	71.5
44	West R.	423
45	Local	71.2
46	Ashuelot R.	421
47	Local	78.2
48	Millers R.	392
49	Fall R.	35.7
50	Local	8.1
51	Deerfield R.	664
52	Local	113
53	Mill R.	50
54	West Branch Mill R.	56
55	Local	225
56	Local	18.5
57	Chicopee R.	721
58	Westfield R.	517
59	Local	54
60	Local	415
61	Stony Brook	40.3
62	Local	25
63	Scantic R.	114
64	Farmington R.	609
65	Local	36.3
66	Park R.	78.3
67	Hockanum R.	82.2
68	Local	37
69	Roaring Brook	23.9
70	Local	40
71	Mattabesset R.	105
72	Local	18



APRIL 1960 FLOOD PEAK PROFILE





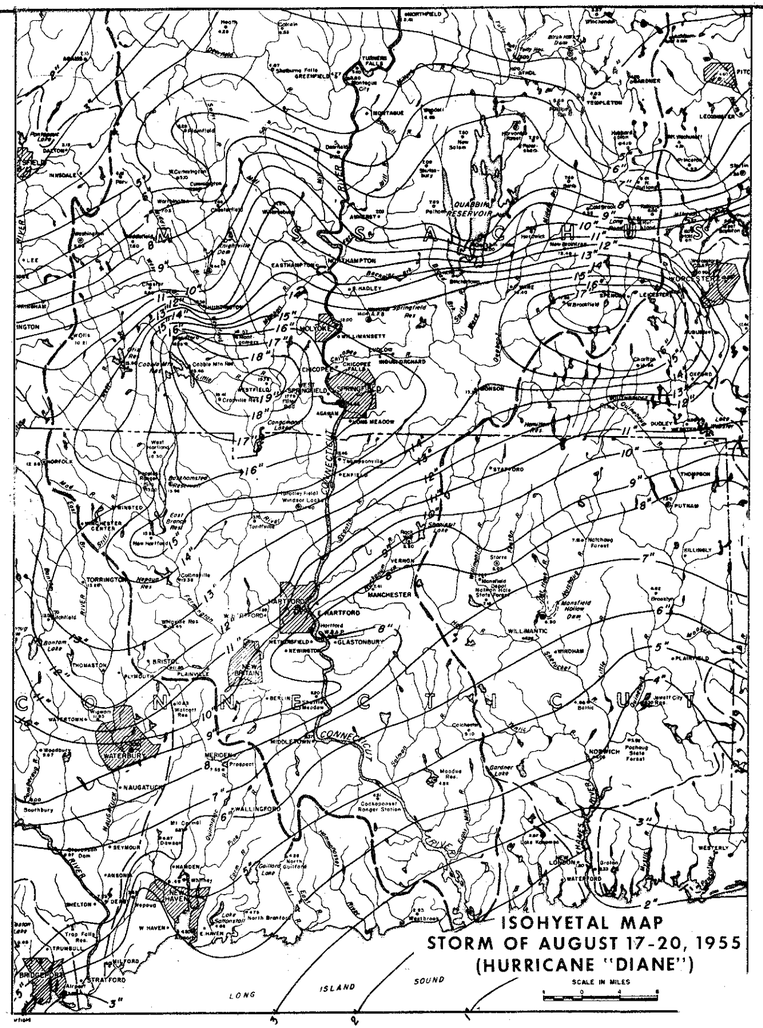


COMPREHENSIVE WATER AND RELATED LAND RESOURCES INVESTIGATION

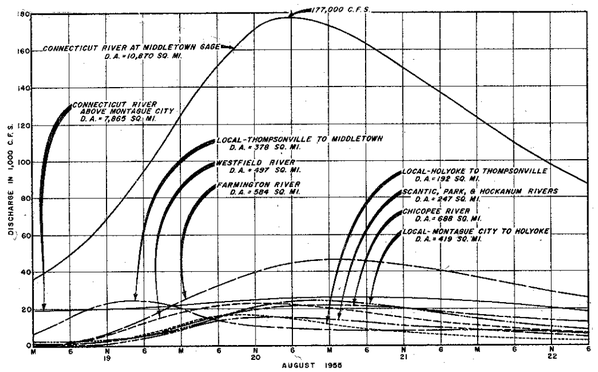
CONNECTICUT RIVER BASIN
PEAK DISCHARGE PROFILE
APRIL 1960 FLOOD

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

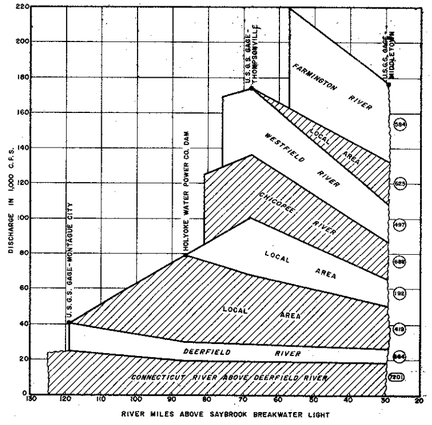
JUNE 1970



CONNECTICUT RIVER AT MIDDLETOWN



CONNECTICUT RIVER



COMPREHENSIVE, WATER AND RELATED LAND RESOURCES INVESTIGATION

CONNECTICUT RIVER BASIN

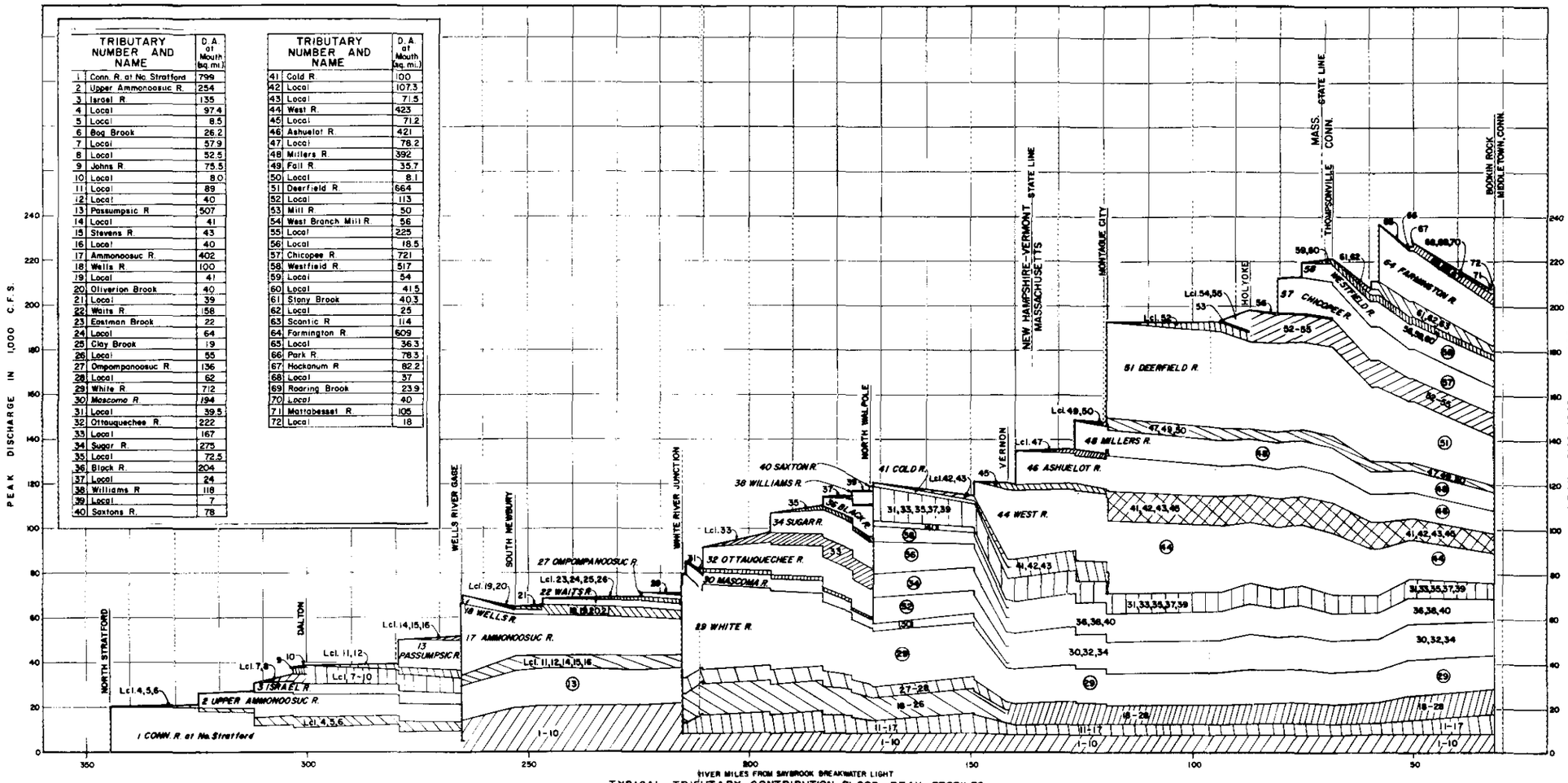
ISOHYETAL MAP AND PEAK DISCHARGE CONTRIBUTION AUGUST 1955 STORM

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

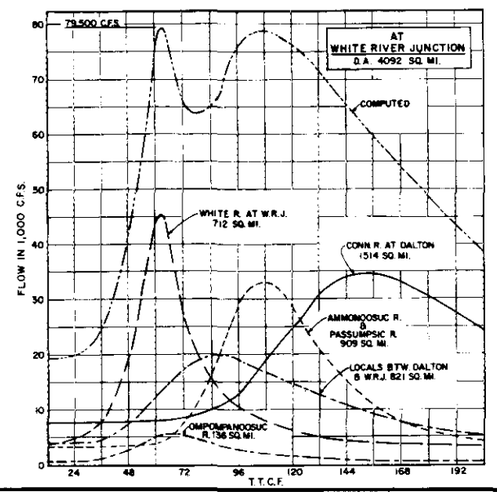
JUNE 1970

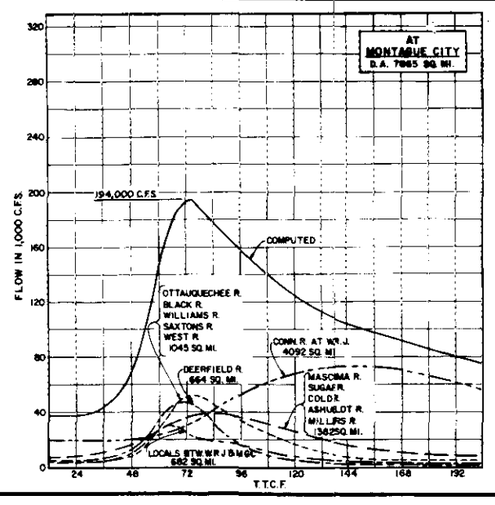
TRIBUTARY NUMBER AND NAME		D.A. at Mouth (sq. mi.)
1	Conn. R. at No. Stratford	7196
2	Upper Ammonoosuc R.	254
3	Israel R.	135
4	Local	97.4
5	Local	8.5
6	Bog Brook	26.2
7	Local	57.9
8	Local	52.5
9	Johns R.	75.5
10	Local	8.0
11	Local	89
12	Local	40
13	Passumpsic R.	507
14	Local	41
15	Stevens R.	43
16	Local	40
17	Ammonoosuc R.	402
18	Wells R.	100
19	Local	41
20	Oliverian Brook	40
21	Local	39
22	Waits R.	158
23	Eastman Brook	22
24	Local	64
25	Clay Brook	19
26	Local	55
27	Ompompanoosuc R.	136
28	Local	62
29	White R.	712
30	Mascoma R.	194
31	Local	39.5
32	Ottauquechee R.	222
33	Local	167
34	Sugar R.	275
35	Local	72.5
36	Black R.	204
37	Local	24
38	Williams R.	118
39	Local	7
40	Saxtons R.	78

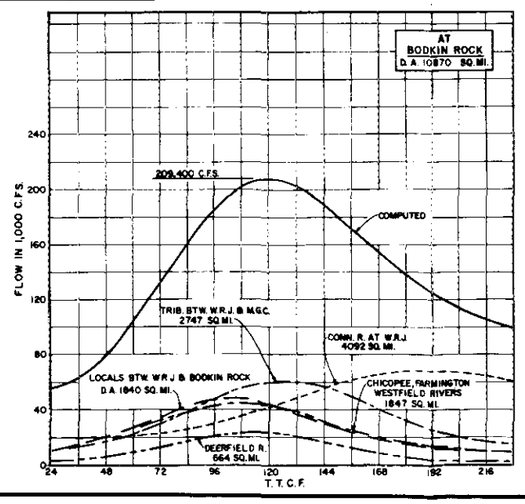
TRIBUTARY NUMBER AND NAME		D.A. at Mouth (sq. mi.)
41	Cold R.	100
42	Local	107.3
43	Local	71.5
44	West R.	423
45	Local	71.2
46	Ashuelot R.	421
47	Local	78.2
48	Millers R.	392
49	Fall R.	35.7
50	Local	8.1
51	Deerfield R.	664
52	Local	113
53	Mill R.	50
54	West Branch Mill R.	56
55	Local	225
56	Local	18.5
57	Chicopee R.	721
58	Westfield R.	517
59	Local	54
60	Local	41.5
61	Stony Brook	40.3
62	Local	25
63	Scantic R.	114
64	Farmington R.	609
65	Local	36.3
66	Park R.	78.3
67	Hockanum R.	82.2
68	Local	37
69	Roaring Brook	23.9
70	Local	40
71	Mattabesset R.	105
72	Local	18



TYPICAL TRIBUTARY CONTRIBUTION FLOOD-PEAK PROFILES







COMPREHENSIVE WATER AND RELATED LAND RESOURCES INVESTIGATION

CONNECTICUT RIVER BASIN

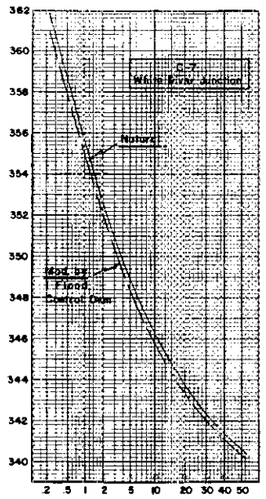
PEAK DISCHARGE PROFILE
TYPICAL TRIBUTARY CONTRIBUTION FLOOD

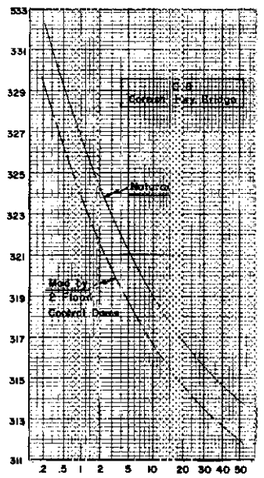
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

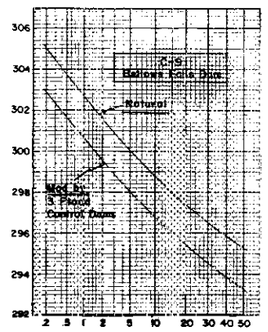
JUNE 1970

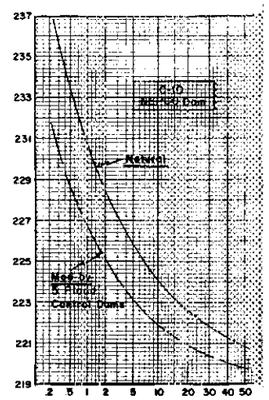
CORPS OF ENGINEERS

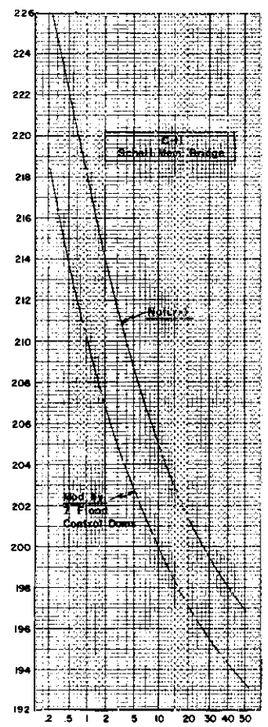
U. S ARMY

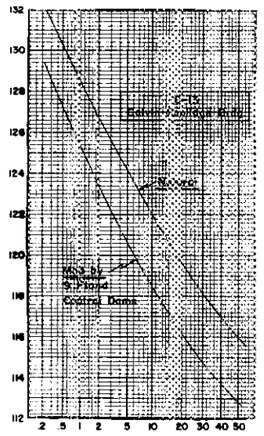


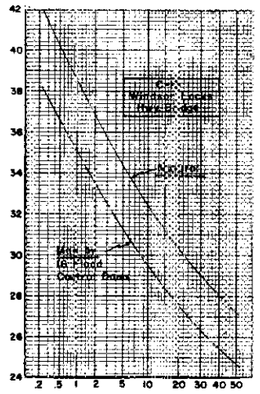


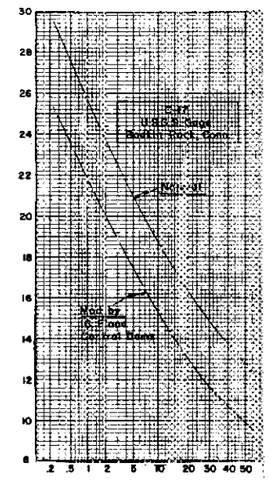


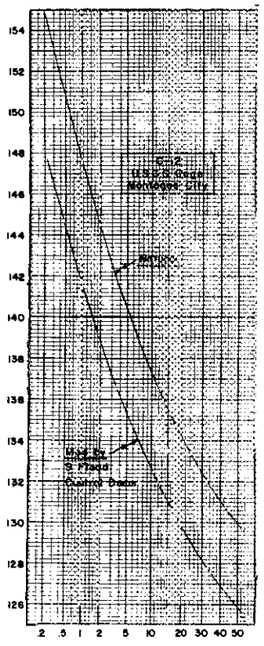


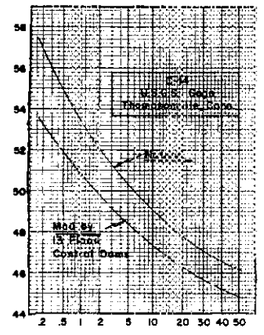


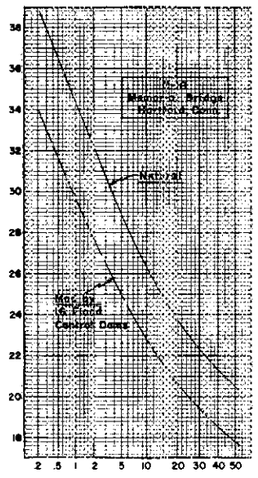












ELEVATION IN FEET ABOVE MEAN SEA LEVEL

PERCENT CHANCE OF OCCURRENCE IN ANY ONE YEAR

GRAPHIC SCALES

REVISION	DATE	DESCRIPTION	BY

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

DES. BY | DR. BY | CK. BY

SUBMITTED

CHIEF, SECTION

APPROVAL RECOMMENDED

CHIEF, TECH. ENG. BRANCH

REVIEWED

PROJECT ENGINEER

APPROVAL RECOMMENDED

CHIEF BRANCH

APPROVED

CHIEF, ENGINEERING DIVISION

DATE

CONNECTICUT RIVER
ELEVATION-FREQUENCY
CURVES
AT
INDEX STATIONS

SCALE

SPEC. NO.

DRAWING NUMBER

SHEET

PLATE II