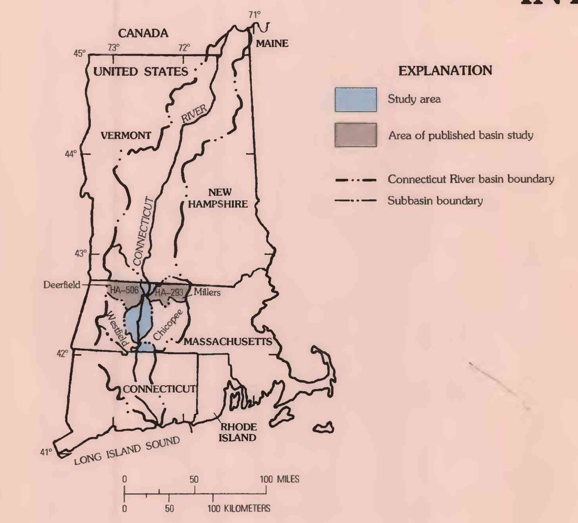
INTRODUCTION



THE STUDY AREA INCLUDES THE MINOR RIVER BASINS AND EXCLUDES THE MAJOR RIVER BASINS DRAINING INTO THE CONNECTICUT RIVER.—The water resources of the Millers, Deerfield, Westfield, and Chicopee River basins have been or will be studied as part of the current Statewide cooperative program.

SUMMARY

The Connecticut River, the largest river in New England, enters Massachusetts at the border with Vermont and New Hampshire and leaves at the border with Connecticut. This study includes the drainage areas of small streams in the Connecticut River lowlands in Massachusetts, but excludes the major tributaries—the Millers, Deerfield, Westfield, and Chicopee Rivers. In Massachusetts, the annual mean flow of the Connecticut River increases from 11,000 ft^3/s (310 m^3/s) to 16,200 ft^3/s (460 m^3/s), owing to contributions of 4080 ft^3/s (115 m^3/s) from the four major tributaries and 1,120 ft^3/s (32 m^3/s) from the small streams of the study area.

Annually, the flow of the Connecticut River and its tributaries varies from highest in early spring to lowest in early fall in response to release of water stored in the winter snowpack and seasonal changes in evapotranspiration rate. Major floods have been caused by intense rainfall associated with hurricanes, September 1938 and August 1955, or by intense rainfall combined with snowmelt, March 1936. The annual minimum 7-day mean flow at the 10-year recurrence interval ranges from zero for streams draining less than 2 mi^2 (5.2 km^2) to as much as 0.19 $(ft^3/s)/mi^2$ [2.1 $(dm^3/s)/km^2$]. Demands for water from reservoirs can be satisfied through storage of seasonal high flows when demands are less than 0.5 $(ft^3/s)/mi^2$ [5.5 $(dm^3/s)/km^2$].

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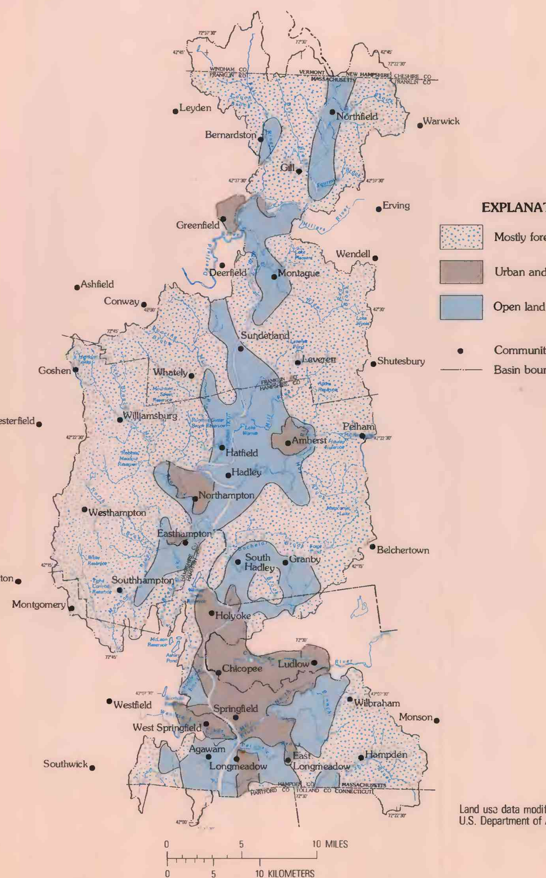
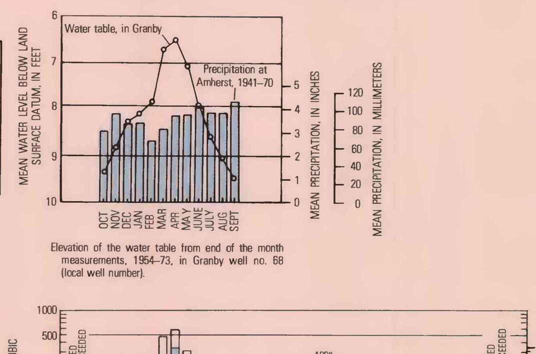
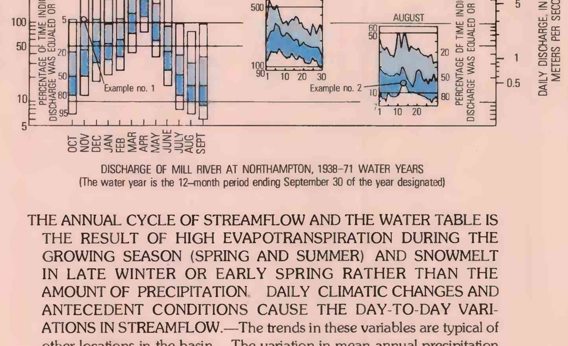
SURFACE WATER



THE 693-MI^2 (1795 KM^2) AREA DRAINED BY THE MINOR TRIBUTARIES TO THE CONNECTICUT RIVER INCLUDES ALL OR PARTS OF THE INDUSTRIAL CITIES OF SPRINGFIELD-HOLYOKE-CHICOPEE, THE EXPANDING URBAN AREA OF NORTHAMPTON-AMHERST, AND 40 OTHER COMMUNITIES.—Population has increased 13 percent between 1960 and 1970 (about 418,600), with the largest increase in Hampden and Hampshire Counties, where several water-supply systems rely on imported water. This report, based upon field investigations in 1971–73, summarizes the surface-water resources (sheet 1) and water quality (sheet 2) to aid in satisfying the current water needs from development and in planning for the future resources of the region. The information on ground-water availability in this area is presented in a companion atlas (Walker and Caswell, 1977).

HYDROLOGIC CYCLE





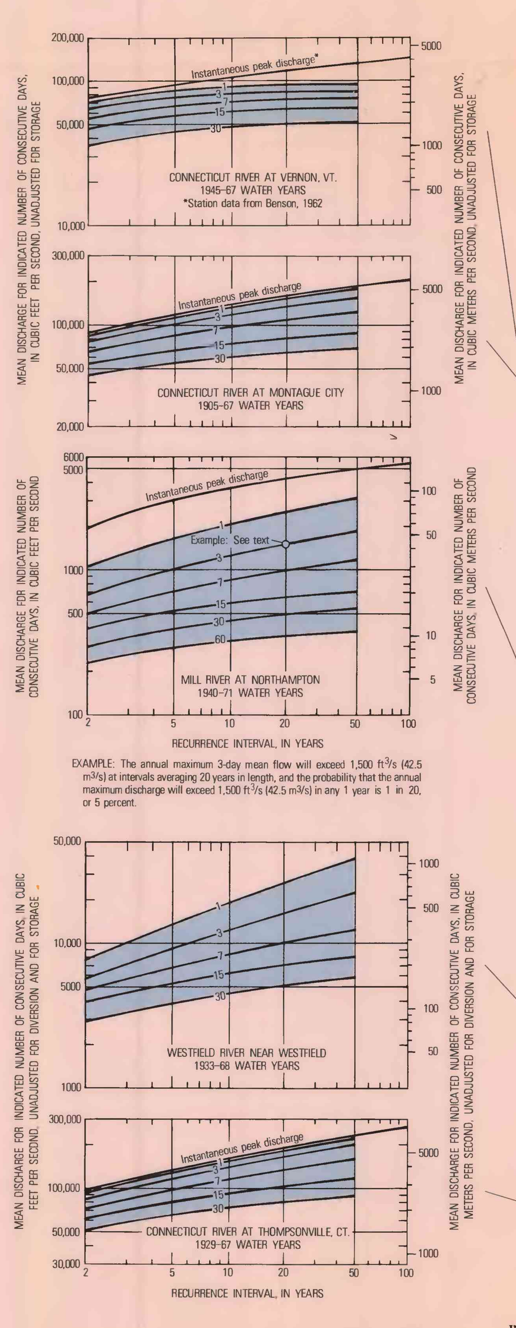
DISCHARGE OF MILL RIVER AT NORTHAMPTON, 1938–71 WATER YEARS
(The water year is the 12-month period ending September 30 of the year designated)

THE ANNUAL CYCLE OF STREAMFLOW AND THE WATER TABLE IS THE RESULT OF HIGH EVAPOTRANSPIRATION DURING THE GROWING SEASON (SPRING AND SUMMER) AND SNOWMELT IN LATE WINTER OR EARLY SPRING RATHER THAN THE AMOUNT OF PRECIPITATION. DAILY CLIMATIC CHANGES AND ANTECEDENT CONDITIONS CAUSE THE DAY-TO-DAY VARIATIONS IN STREAMFLOW.—The trends in these variables are typical of other locations in the basin. The variation in mean annual precipitation is shown on the flood-flow map.

EXAMPLE NO. 1: The daily discharge during November was equal to or greater than 105 ft^3/s (2.97 m^3/s) 20 percent of the time in the base period.

EXAMPLE NO. 2: On August 13th the daily discharge was equal to or greater than 13 ft^3/s (0.37 m^3/s) 80 percent of the time during the base period.

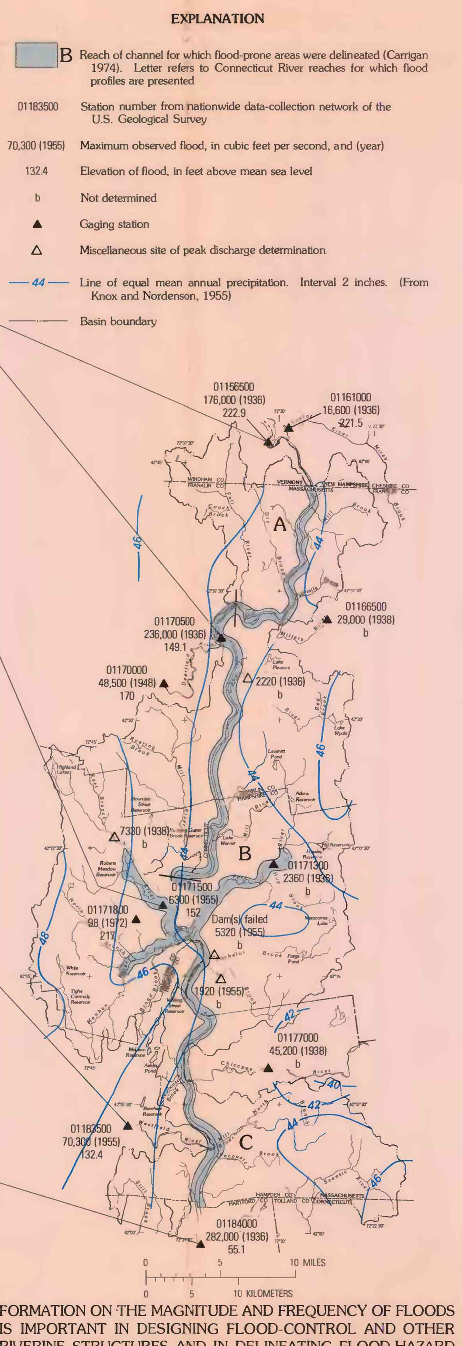
FLOOD FLOW



EXAMPLE: The annual maximum 3-day mean flow will exceed 1,500 ft^3/s (42.5 m^3/s) at intervals averaging 25 years in length, and the probability that the annual maximum discharge will exceed 1,500 ft^3/s (42.5 m^3/s) in any 1 year is 1 in 25, or 4 percent.

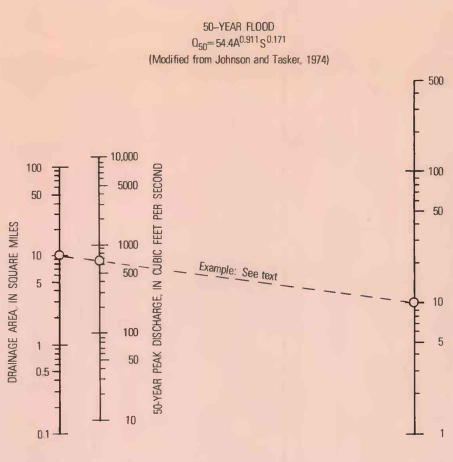
EXPLANATION

- B — Reach of channel for which flood-prone areas were delineated (Carrigan, 1974). Letter refers to Connecticut River reaches for which flood profiles are presented
- 01183500 — Station number from nationwide data-collection network of the U.S. Geological Survey
- 76,300 (1938) — Maximum observed flood, in cubic feet per second, and (year)
- 132.4 — Elevation of flood, in feet above mean sea level
- — Not determined
- Gaging station
- Miscellaneous site of peak discharge determination
- Line of equal mean annual precipitation. Interval 2 inches. (From Knox and Nordenson, 1955)
- Basin boundary



INFORMATION ON THE MAGNITUDE AND FREQUENCY OF FLOODS IS IMPORTANT IN DESIGNING FLOOD-CONTROL AND OTHER RIVERINE STRUCTURES AND IN DELINEATING FLOOD-HAZARD AREAS.—Flood and high-flow data are needed for the basinwide management of flood-control structures, for developing flood-control policies, and for interbasin water-resources-systems analyses.

50-YEAR FLOOD
$Q_{50}=54.4A^{0.911}S^{0.171}$
(Modified from Johnson and Tasker, 1974)



THE 50-YEAR PEAK DISCHARGE, FREQUENTLY THE DESIGN FLOOD FOR HYDRAULIC STRUCTURES, MAY BE ESTIMATED FOR RURAL, UNREGULATED STREAMS FROM DRAINAGE BASIN CHARACTERISTICS.—The nomograph applies to Massachusetts streams in areas where the mean annual precipitation is 45 in (1140 mm). The 50-year peak discharge in other precipitation regions may be estimated by use of the appropriate adjustment factor (table 1). The magnitude of other events (2-yr, 5-yr, 10-yr, 25-yr, and 100-yr floods) at ungaged sites can be computed from Johnson and Tasker (1974).

DEFINITIONS

MAIN-CHANNEL SLOPE: The difference in altitude at points 10 percent and 85 percent of the main channel distance from the site to the basin divide divided by the length between these two points.

50-YEAR PEAK DISCHARGE: The annual peak discharge that will be exceeded on the average of once in 50 years. This discharge has a 1 in 50 or a 2 percent chance of being exceeded in any 1 year.

EXAMPLE: In a region where the mean annual precipitation is 45 in (1140 mm) a stream with a drainage area of 10 mi^2 (25.9 km^2), a main-channel slope of 10 ft/mi (1.89 m/km); the estimated 50-year peak discharge is 660 ft^3/s (18.7 m^3/s). If this site was located in a region where the mean annual precipitation is 48 in (1220 mm), then the estimated 50-year peak discharge is 660 × 1.32 or 870 ft^3/s (24.6 m^3/s).

Table 1.—Adjustment factors to Q_{50} for mean annual precipitation

Mean annual precipitation, in inches	Adjustment factor to Q_{50} from nomograph Multiply by
42	0.74
43	.82
44	.91
45	1.00
46	1.10
47	1.20
48	1.32
49	1.44

Table 3.—Conversion factors for English and metric units

To convert from	To	Multiply by
Inches (in)	Millimeters (mm)	25.4
Feet (ft)	Meters (m)	.3048
Miles (mi)	Kilometers (km)	1.609
Feet per mile (ft/mi)	Meters per kilometers (m/km)	.1894
Cubic feet per second (ft^3/s)	Cubic meters per second (m^3/s)	.02832
Square miles (mi^2)	Square kilometers (km^2)	2.59
Gallons per minute (gal/min)	Liters per second (l/s)	.0631
Cubic feet per second-day (ft^3/s-day)	Cubic meters (m^3)	2447
Cubic feet per second per square mile [$(ft^3/s)/mi^2$]	Cubic decimeters per second per square kilometer [$(dm^3/s)/km^2$]	10.93
Million gallons per square mile ($Mgal/mi^2$)	Cubic meters per square kilometer (m^3/km^2)	1461

LOW FLOW

EXPLANATION

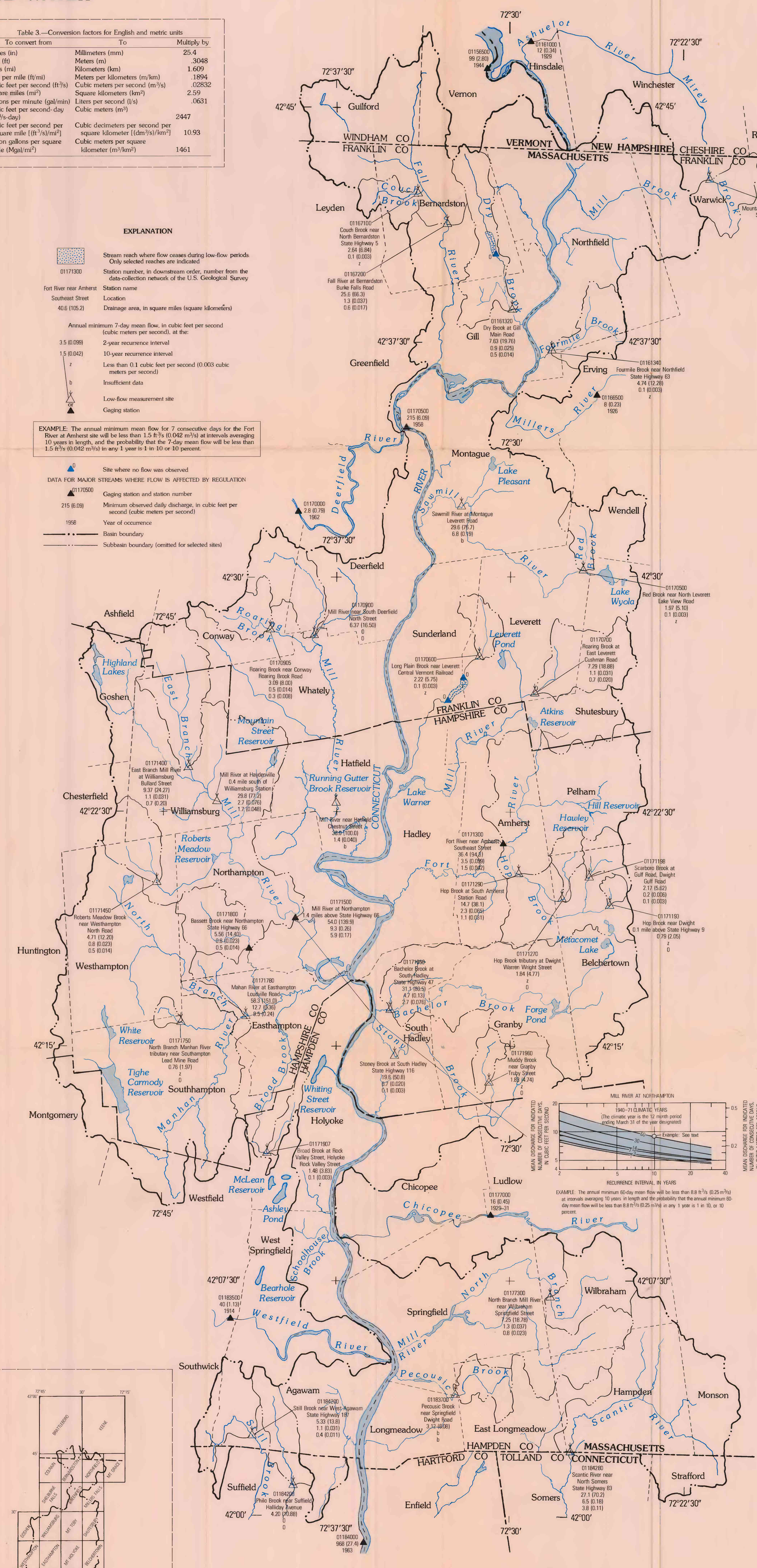
- Stream reach where flow ceases during low-flow periods. Only selected reaches are indicated
- 01171500 — Station number, in downstream order, number from the data-collection network of the U.S. Geological Survey
- Fort River near Amherst — Station name
- Southeast Street — Location
- 40.6 (105.2) — Drainage area, in square miles (square kilometers)
- Annual minimum 7-day mean flow, in cubic feet per second (cubic meters per second), at the:
  - 3.5 (0.099) — 2-year recurrence interval
  - 1.5 (0.042) — 10-year recurrence interval
  - z — Less than 0.1 cubic foot per second (0.003 cubic meters per second)
  - b — Insufficient data
- Low-flow measurement site
- Gaging station

EXAMPLE: The annual minimum mean flow for 7 consecutive days for the Fort River at Amherst site will be less than 1.5 ft^3/s (0.042 m^3/s) at intervals averaging 10 years in length, and the probability that the 7-day mean flow will be less than 1.5 ft^3/s (0.042 m^3/s) in any 1 year is 1 in 10 or 10 percent.

- Site where no flow was observed

DATA FOR MAJOR STREAMS WHERE FLOW IS AFFECTED BY REGULATION

- 01170500 — Gaging station and station number
- 215 (6.09) — Minimum observed daily discharge, in cubic feet per second (cubic meters per second)
- 1958 — Year of occurrence
- Basin boundary
- Subbasin boundary (omitted for selected sites)

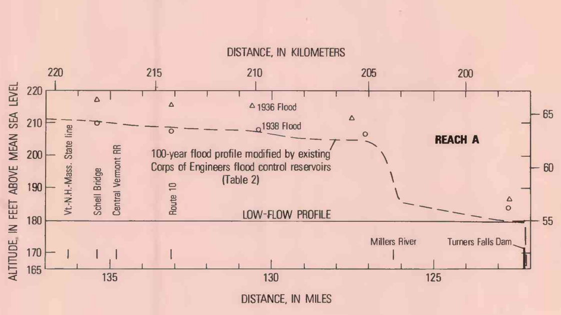


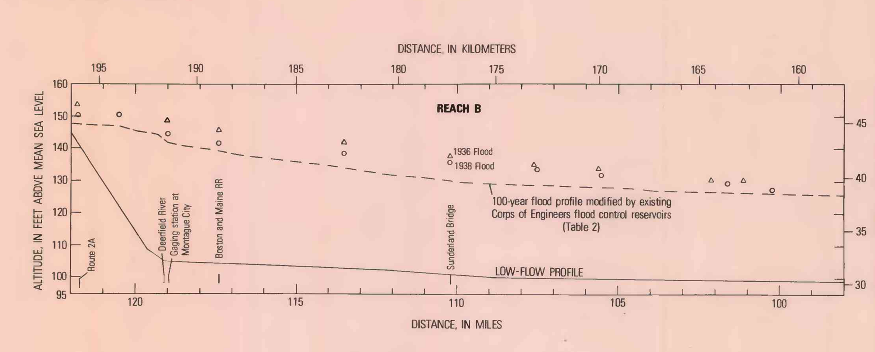
EXAMPLE: The annual minimum 60-day mean flow will be less than 8.8 ft^3/s (0.25 m^3/s) at intervals averaging 10 years in length and the probability that the annual minimum 60-day mean flow will be less than 8.8 ft^3/s (0.25 m^3/s) in any 1 year is 1 in 10, or 10 percent.

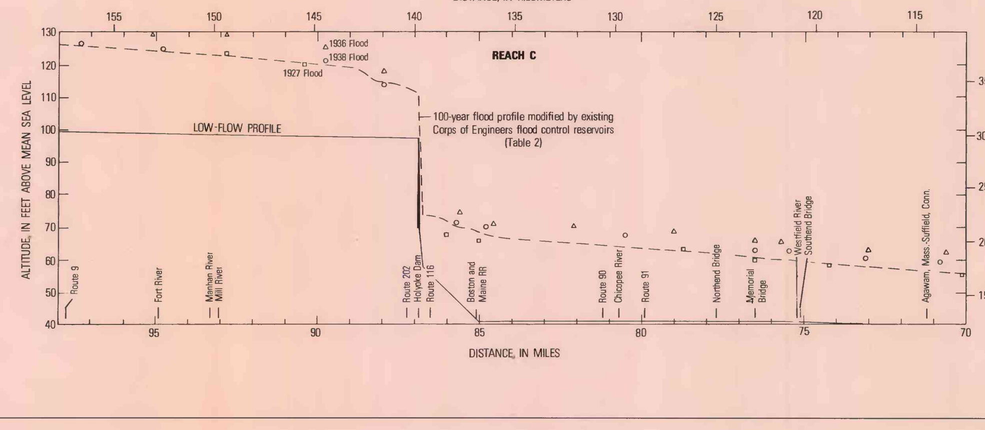
BASE FROM U.S. GEOLOGICAL SURVEY
1:24,000 AND 1:62,500 QUADRANGLES

LOW-FLOW CHARACTERISTICS ARE USEFUL IN ASSESSING THE POTENTIAL OF A RIVER FOR WATER SUPPLY, WASTE DISPOSAL, FLOW AUGMENTATION, RECREATION, OR FISH HABITAT.—Differences in low flows are caused by variations in geology, evapotranspiration, water-table slope, water use, and extent of urbanization. The low flow of Mountain Brook in Warwick is unusually high for the area due to the large amount of permeable sand and gravel deposits that sustain streamflow during dry periods. The 7-day low flow at the 10-year recurrence interval will be zero for streams draining less than 2 mi^2 (5.2 km^2); however, reaches of streams in the lowland area adjacent to the Connecticut River can cease flowing annually. The low-flow parameters were obtained by correlating base-flow measurements with data from long-term gaging stations. The low-flow statistics are representative of the hydrologic conditions existing during the data-collection period.

FLOOD PROFILES







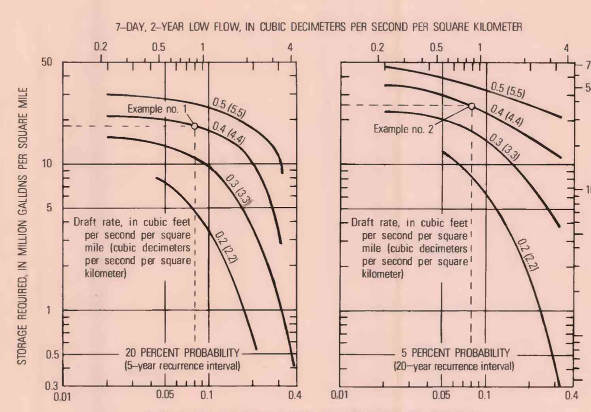
THE 100-YEAR FLOOD ELEVATION IS USED TO DELINEATE FLOOD PRONE AREAS AND TO DEVELOP FLOOD-HAZARD REGULATIONS.—Future land uses can consider the extent of flood-prone areas prior to locating structures. Reaches where flood profiles were computed (U.S. Army Corps of Engineers, 1970) and where flood-prone area maps were completed (Carrigan, 1974) are indicated on the flood flow map.

Table 2.—U.S. Army Corps of Engineers, reservoirs in Connecticut River basin

Union Village Reservoir, Vt.	Birch Hill Reservoir, Mass.
North Hartland Reservoir, Vt.	Tully Reservoir, Mass.
North Springfield Reservoir, Vt.	Barre Falls Reservoir, Mass.
Ball Mountain Reservoir, Vt.	Conant Brook Reservoir, Mass.
Townshend Reservoir, Vt.	Knightville Reservoir, Mass.
Surry Mountain Lake, N. H.	Littleville Lake, Mass.
Otter Brook Lake, N. H.	

REGIONAL STORAGE ANALYSIS

SEASONAL

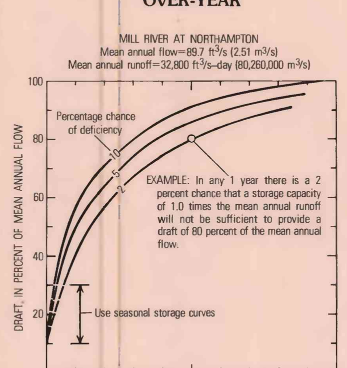


DEFINITION: The annual minimum 7-day mean flow at the 2-year-recurrence interval (7-day, 2-year low flow) is the annual minimum mean flow for 7 consecutive days that is expected to be less than the given value at intervals averaging 2 years in length. The probability that a lower 7-day mean flow will occur in any 1 year is 1 in 2 or 50 percent.

EXAMPLE NO. 1: For a potential reservoir site on a stream where the 7-day, 2-year low flow is 0.08 $(ft^3/s)/mi^2$ [0.87 $(dm^3/s)/km^2$], there is a 20-percent chance in any 1 year that a storage of 18 $Mgal/mi^2$ (26,300 m^3/km^2) will not maintain a draft rate of 0.4 $(ft^3/s)/mi^2$ [4.4 $(dm^3/s)/km^2$].

EXAMPLE NO. 2: For this same site there is a 5 percent chance in any 1 year that a storage of 25 $Mgal/mi^2$ (36,500 m^3/km^2) will not maintain a draft rate of 0.4 $(ft^3/s)/mi^2$ [4.4 $(dm^3/s)/km^2$].

OVER-YEAR



The draft-storage curves for Mill River at Northampton can be used for preliminary storage estimates for other locations in the basin. Mean flow and mean runoff of ungaged sites can be computed from Johnson's (1970) equation.

REGIONAL STORAGE RELATIONS ARE USEFUL TO THE WATER RESOURCES PLANNER IN ESTIMATING POTENTIAL DEVELOPMENT OF STREAMFLOW, IN COMPARING DEVELOPMENT POSSIBILITIES OF DIFFERENT STREAMS, AND IN COMPARING LOW-FLOW AUGMENTATION REQUIREMENTS. DEMANDS IN EXCESS OF NATURAL STREAMFLOW CAN BE MET BY IMPOUNDING WATER DURING PERIODS OF HIGH FLOW (SEASONAL STORAGE) OR DURING WETTER YEARS (OVER-YEAR STORAGE).—These curves provide a first approximation to the amount of storage required for given drafts. Losses from reservoir evaporation, sedimentation, and seepage are not included.

Seasonal or within-year storage is the impoundment of some of the high flow each year for release during a later low-flow period. This method of storage assumes that the reservoir will be refilled by April 1. The streamflow records for nine nearby gaging stations were used in the seasonal storage analysis.

When the demands for water exceed that stored from the high flow each year (draft rates in excess of 0.5 $(ft^3/s)/mi^2$ [5.5 $(dm^3/s)/km^2$] in this area), then extra water must be stored during periods of wetter years for later release during dry years. This type of storage is called over-year or carry-over storage. Over-year storage requires a larger storage reservoir and less frequent filling than seasonal storage. The over-year relations, with adjustments for seasonal variations, for the Mill River at Northampton were computed by characterizing the distribution of annual inflows after Riggs and Hardison (1973). This method assumes that the annual discharges are independent of one another. That is, a year of low flow is as likely to follow either a year of high flow or low flow. If a year of low flow is more likely to follow a low-flow year than a high-flow year, then the annual discharges are dependent, and more storage will be needed to maintain the same draft rate than if the flows were independent. This effect of serial correlation on the draft rate can be estimated, as indicated in Riggs and Hardison (1973).

Base from U.S. Geological Survey

STREAMFLOW AND WATER QUALITY IN THE CONNECTICUT RIVER LOWLANDS, MASSACHUSETTS

By
S. W. Wandle, Jr., and W. W. Caswell

1977

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