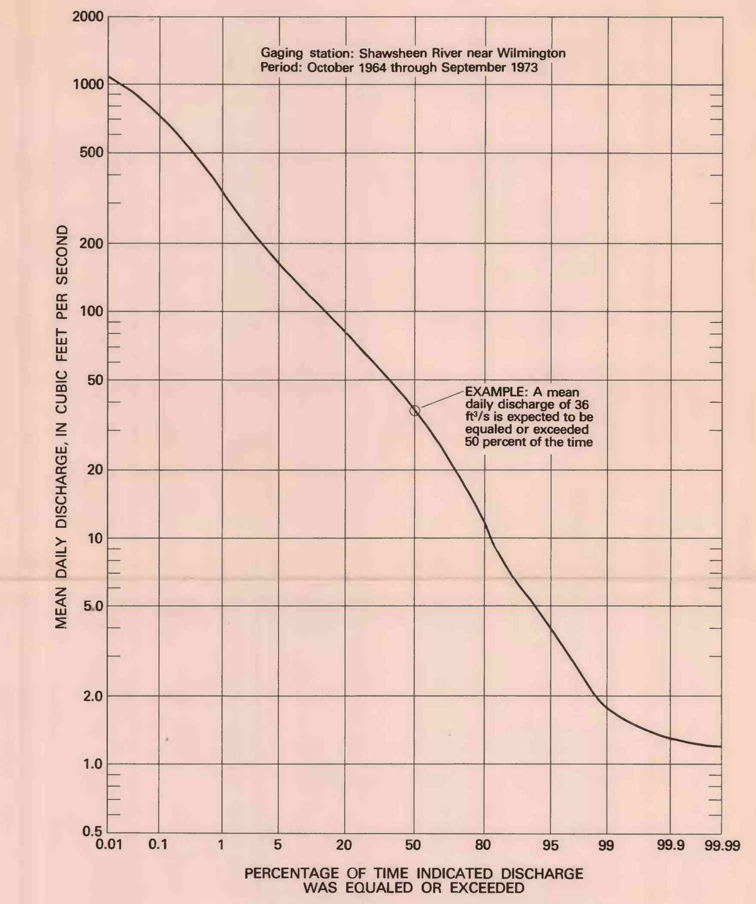
# SURFACE WATER

## AVAILABILITY

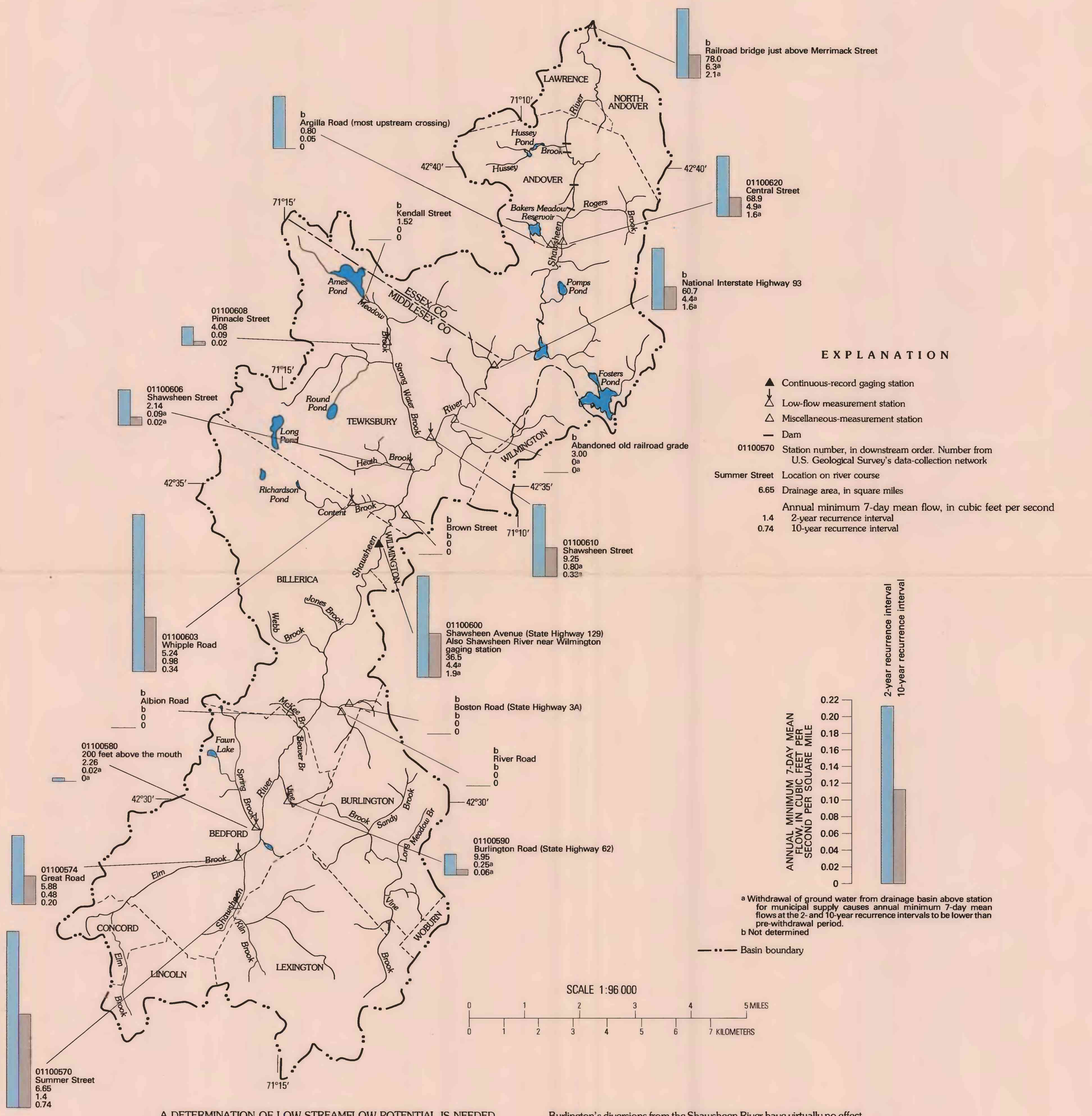
### LOW STREAMFLOW

### FLOW DURATION




THE PERCENTAGE OF TIME FUTURE FLOWS WILL BE EQUALED OR EXCEEDED AT WILMINGTON CAN BE ESTIMATED IF CONDITIONS THAT GOVERN RUNOFF DO NOT CHANGE.—The moderately sloping straight line at the high end of the flow-duration curve for the Shawsheen River indicates that natural storage in the upstream part of the basin absorbs peak flows and helps sustain high flows. Most of the natural storage occurs in swamps, as there are only a few small unregulated ponds or lakes above the Wilmington gaging station. The largest, Fawn Lake, has a surface area of about 122 acres. The flat slope at the low end of the flow-duration curve indicates that the stream is sustained by ground-water discharge during periods of high evapotranspiration and little or no overland runoff. Ground-water discharge is largely from storage in glacial sand and gravel deposits along the watercourses.

Except for a period from January through June 1973, this flow-duration curve represents runoff from the basin before diversions by the Town of Burlington, which began in January 1973 from a point on the Shawsheen River 2.0 river miles above the Wilmington gaging station. The Commonwealth of Massachusetts, Department of Public Health, permits Burlington to divert water from January through June and limits Burlington to various diversion rates beginning at 3.1 $ft^3/s$ when streamflow equals or exceeds 12 $ft^3/s$ and ending at 12.5 $ft^3/s$ when streamflow equals or exceeds 25 $ft^3/s$. If the same set of conditions that produced this flow-duration curve continues in the future, the effect of this diversion will be to shift the curve to the left at discharges greater than about 9 $ft^3/s$.




A DETERMINATION OF LOW-STREAMFLOW POTENTIAL IS NEEDED FOR THE EVALUATION OF RIVER-BASIN RESOURCES FOR WATER SUPPLY, WASTE DISPOSAL, AND RECREATION.—The annual minimum 7-day mean flow at the 10-year recurrence interval is used as a standard index of low-streamflow potential by designers of wastewater treatment facilities to insure adequate dilution of waste discharges. Estimates of the annual minimum 7-day mean flow at the 2- and 10-year recurrence intervals were obtained from curves correlating base-flow measurements made at low-flow and miscellaneous stations shown with concurrent streamflows gaged on the Shawsheen River, Charles River at Charles River Village, Parker River, and Squannacook River long-term gaging stations and averaging the results. Values for the annual minimum 7-day mean flow at the 2- and 10-year recurrence intervals for the four long-term gaging stations were developed from data that included the 1960's drought.

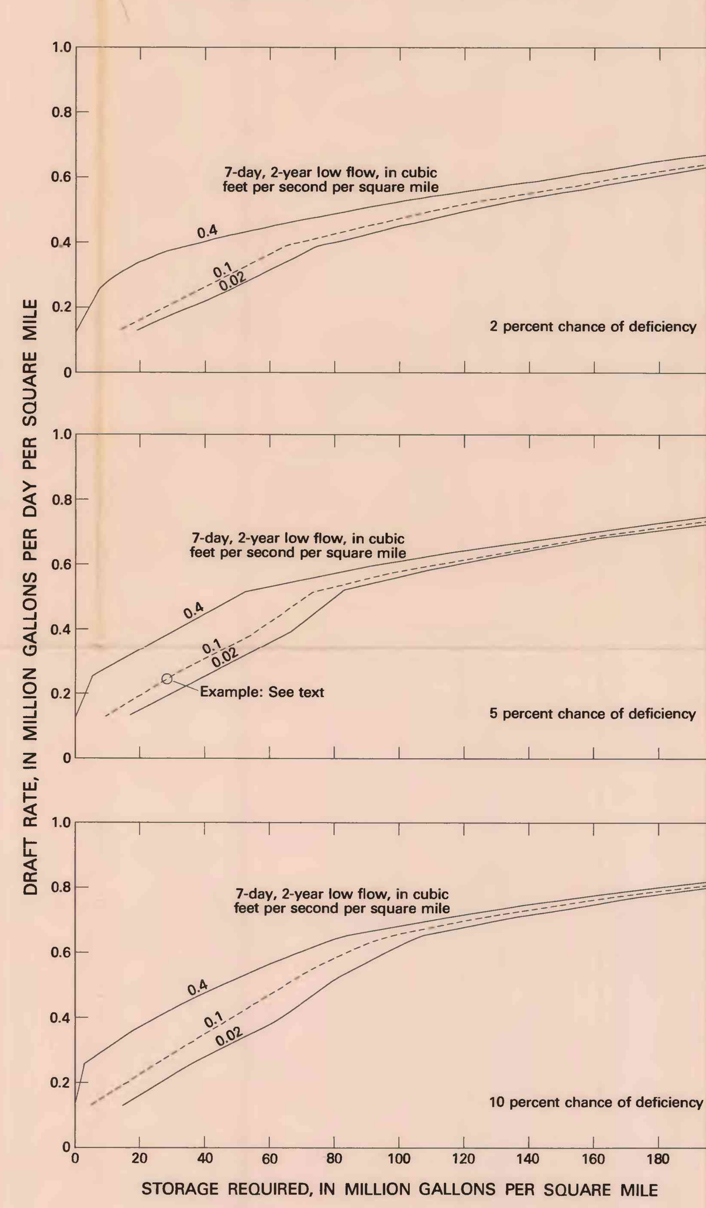
Streamflow per unit drainage area varies from stream to stream during low-flow periods as the result of either natural or man-made causes. Natural causes include nonuniformity of water storage, geology, evaporation, transpiration, water-table slope, and precipitation. Some man-made causes include diversion of water from streams, managed releases from reservoir storage to streams, ground-water pumping, waste-water discharge into streams, and changes in land use.

Burlington's diversions from the Shawsheen River have virtually no effect on its low flow because they are limited to January through June, a period when ground-water levels and streamflow are normally high. (See discussion in "Generalized hydrologic budget" section on sheet 1.)

Along the Shawsheen River, the annual minimum 7-day mean streamflow per unit drainage area at the 2- and 10-year recurrence intervals decreases with increased drainage area, because part of the water pumped from municipal supply wells in the basin is diverted, used, and discharged as waste water outside the basin. (See discussion in "Municipal water use" section on sheet 1 for streams.) The hydrologic impact of ground-water withdrawal and subsequent diversion out of the basin will reduce streamflow during low-flow periods when streamflow is derived almost entirely from ground-water discharge.

A visual reconnaissance of streamflow was made during July 31–August 1, 1974. All streams draining less than 1 $mi^2$ were flowing less than 0.10 $ft^3/s$ or had no flow at all. For the previous 7 consecutive days (July 25–31), streamflow at the gaging station on the Shawsheen River at Wilmington averaged 8.2 $ft^3/s$, with a corresponding recurrence interval of less than 2 years. Because the annual minimum 7-day mean flow at the 10-year recurrence interval is approximately one-quarter of that (1.9 $ft^3/s$), it is assumed the annual minimum 7-day mean flow at the 10-year recurrence interval will be essentially zero for all streams draining less than 1 $mi^2$.

### REGIONAL STORAGE ANALYSIS



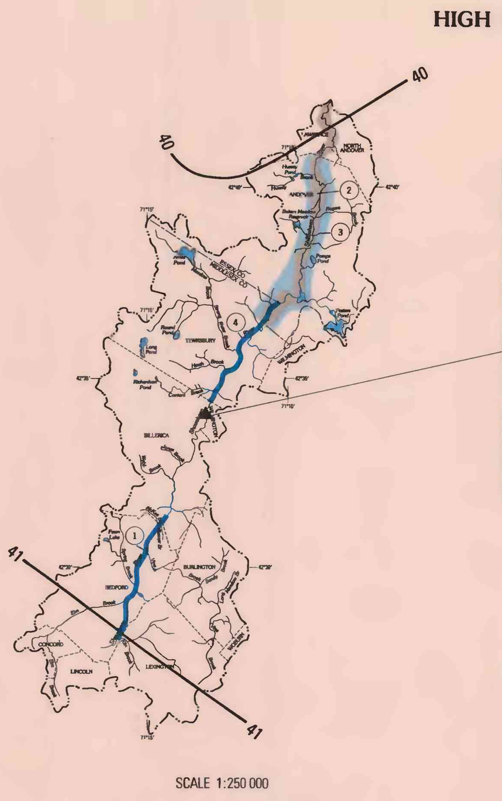

REGIONAL DRAFT-STORAGE-FREQUENCY ANALYSIS USED IN CONJUNCTION WITH ANNUAL MINIMUM 7-DAY MEAN FLOWS AT THE 2-YEAR RECURRENCE INTERVAL DETERMINED FROM THE LOW-STREAMFLOW MAP CAN PROVIDE INFORMATION USEFUL TO WATER MANAGERS AND PLANNERS IN COMPARATIVE STUDIES OR IN PRELIMINARY DESIGNS FOR RESERVOIR SITES.—These regional draft-storage-analysis curves were prepared by Tasker (1977). They are based on a regional analysis of streamflow records for 12 gaging stations in eastern Massachusetts and Rhode Island, using the methods recommended by Riggs and Hardison (1973) to account for seasonal as well as year-to-year variations in streamflow.

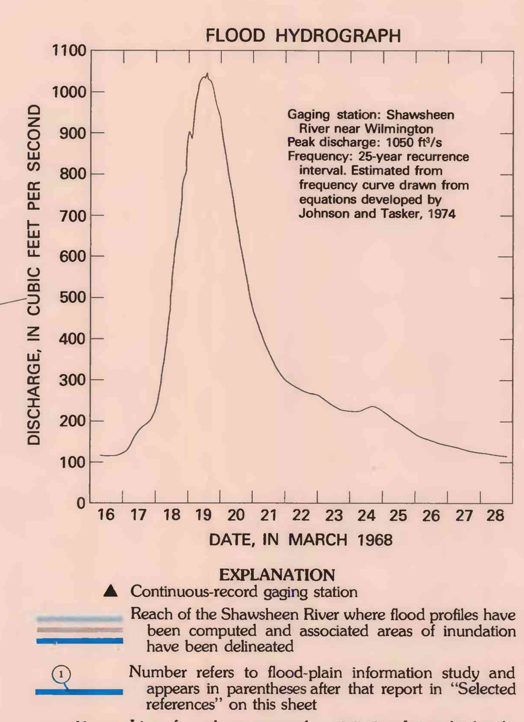
Draft rate is gross reservoir outflow occurring at a uniform rate and is uncorrected for increased water losses resulting from enlarging the water-surface area in the basin. Storage required is the usable volume of a reservoir required to maintain the indicated draft rate. When applying these curves to the evaluation of a specific reservoir site, the user should adjust the draft rates to account for expected evaporation and seepage losses, nonuniform draft rates, and low-flow augmentation requirements. Storage requirements should be adjusted for expected losses in reservoir capacity because of sedimentation.

The Committee on Rainfall and Yield of Drainage Areas of the New England Water Works Association (1969, p. 168–169) considers it economically unsound to develop storage capabilities much beyond 200 $Mgal/mi^2$ in New England watersheds. The rationale for this decision can be seen from inspection of the draft-storage curves. Increases of draft rates require disproportionately large increases of storage for rates exceeding about 0.5 $(Mgal/d)/mi^2$

Example: A stream has a 10.0 $mi^2$ drainage area and a annual minimum 7-day mean flow at the 2-year recurrence interval of 1.0 $ft^3/s$ or 0.1 $(ft^3/s)/mi^2$ at a given site. To maintain a draft rate of 2.5 Mgal/d or 0.25 $(Mgal/d)/mi^2$, a storage capacity of 28 $Mgal/mi^2$ or 280 Mgal would be enough, for an average of 95 out of 100 years (5 percent chance of deficiency), exclusive of losses.

### HIGH STREAMFLOW




EXPLANATION

- ▲ Continuous-record gaging station
- Reach of the Shawsheen River where flood profiles have been computed and associated areas of inundation have been delineated
- (1) Number refers to flood-plain information study and appears in parentheses after that report in "Selected references" on this sheet
- —41— Line of equal mean annual precipitation. Interval is 1 inch. Data from Knox and Nordenson (1955), 41-inch line is interpolated
- —··—··— Basin boundary

KNOWLEDGE OF THE EXTENT OF PAST FLOODING AND A MEANS OF ESTIMATING FLOOD POTENTIAL ARE VITAL TO THE MANAGEMENT OF STREAMSIDE DEVELOPMENT IN THE BASIN.—Major floods in the Shawsheen River basin occurred in March 1936, October 1962, and March 1968, with the March 1936 flood being the greatest. The Shawsheen River gaging station near Wilmington, which began operation in November 1963, recorded the March 1968 flood. (See flood hydrograph above.) High-water marks and flood profiles for the entire Shawsheen River have been published for the March 1936 flood (Massachusetts Department of Public Works, Geodetic Survey, 1936). Detailed flood-information studies have been conducted along various stretches of the river as shown in the illustration. These studies have determined flood profiles and associated areas of inundation for floods of various recurrence intervals such as 10, 50, 100, and 500 years. Recurrence interval is the average length of time between the exceedance of a flood of given magnitude.

Historically, floods on the Shawsheen River at its mouth have peaked well before those of its receiving stream, the Merrimack River. Although the possibility exists, it is considered highly unlikely that peak flows at the mouth of the Shawsheen River will coincide with peak flows in the Merrimack River at Lawrence.

During the March 1936 flood, streamflow in the Merrimack River at Lawrence peaked 8 days after the Shawsheen River. This peak backed water up into the Shawsheen River as far as the Redman Card Clothing Company's Dam (see map in "Time of travel" section for this and other locations) 5.57 river miles upstream from the Merrimack River. This backwater flooding attained an elevation of about 45 feet above mean sea level and was considerably higher than flooding caused by the Shawsheen River itself 8 days earlier. For instance, at Haverhill Street, 3.89 river miles upstream from the Merrimack River, this backwater flooding was about 15 feet higher than that 8 days earlier. Since 1936, the U.S. Army Corps of Engineers has constructed five flood-control dams in the upper reaches of the Merrimack River basin. These dams are designed to reduce flood discharge and stage in the Merrimack River at Lawrence and will reduce the backup of flood waters into the Shawsheen River.

At present, very little encroachment on the flood plain of the Shawsheen River has occurred above Stevens Mill Dam, 5.11 river miles upstream from the mouth. However, downstream from this dam there has been significant industrial and residential development on the flood plain, which is still subject to backwater flooding from the Merrimack River.

Instantaneous peak discharges at ungaged sites in the Shawsheen River basin can be estimated from instantaneous peak discharge equations developed from long-term streamflow data collected in Massachusetts (Johnson and Tasker, 1974).

In the equations listed below, instantaneous peak discharges at selected frequencies are related to drainage area, mean annual precipitation, and main-channel slope. These equations are valid if the drainage area is between 0.25 $mi^2$ and 500 $mi^2$, not affected by backwater flooding, largely rural, and not significantly affected by regulation.

A part of the study area is urbanized, and care should be exercised when applying instantaneous peak-discharge values determined from these formulas. Flow estimates based on these formulas are likely to be too low if a large part of the stream's drainage area is urbanized.

Regional flood-frequency formulas (Johnson and Tasker, 1974)

$$P_2=0.0645A^{0.816}S^{0.091}p^{4.59}$$
$$P_5=0.0795A^{0.831}S^{0.116}p^{4.67}$$
$$P_{10}=0.102A^{0.852}S^{0.132}p^{4.60}$$
$$P_{25}=0.144A^{0.885}S^{0.155}p^{4.43}$$
$$P_{50}=0.193A^{0.911}S^{0.171}p^{4.27}$$
$$P_{100}=0.260A^{0.940}S^{0.187}p^{4.08}$$

in which,

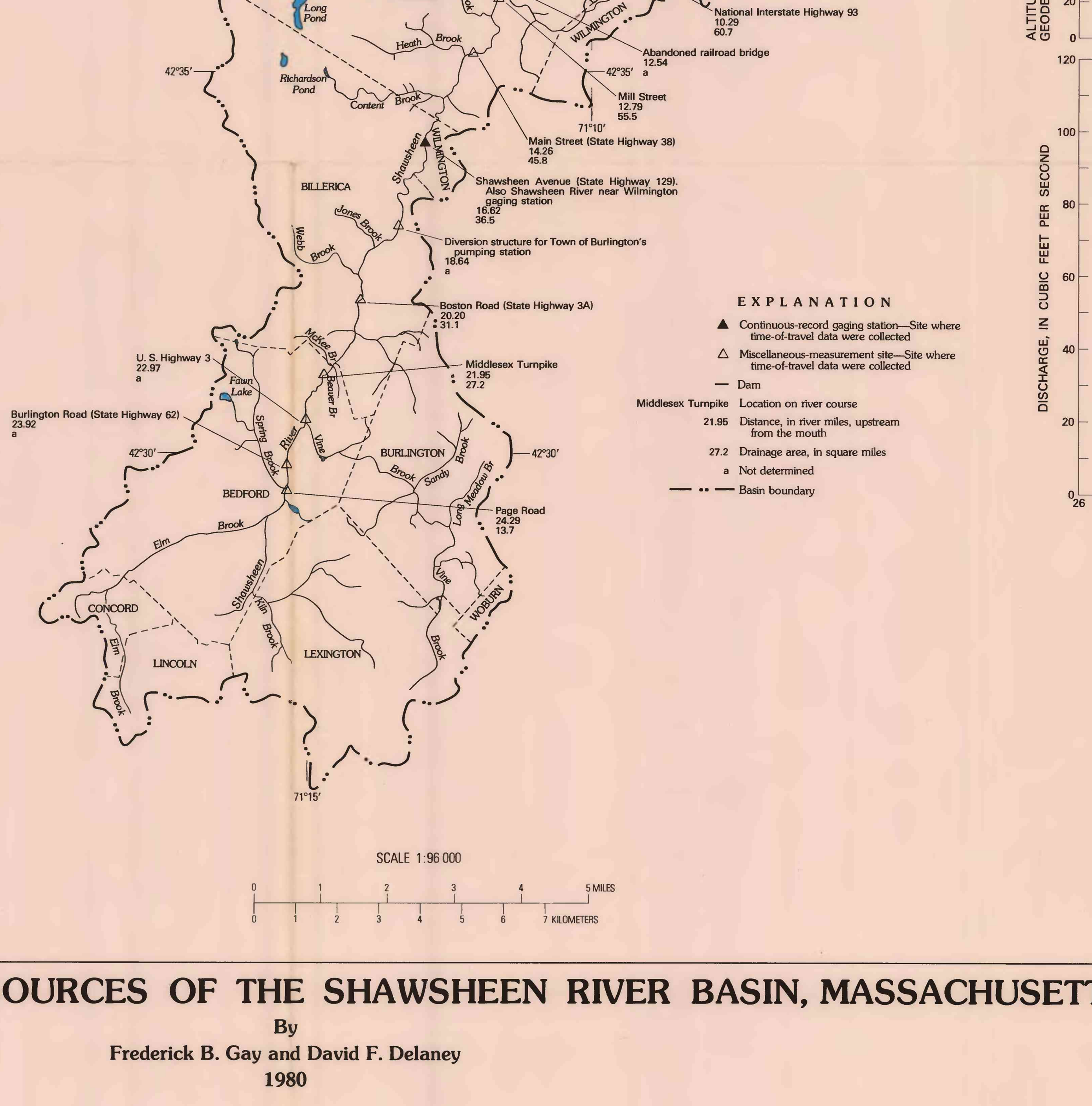
$P_2$, $P_5$, $P_{10}$, $P_{25}$, $P_{50}$, $P_{100}$=peak discharge for the 2-, 5-, 10-, 25-, 50-, and 100-year-recurrence intervals

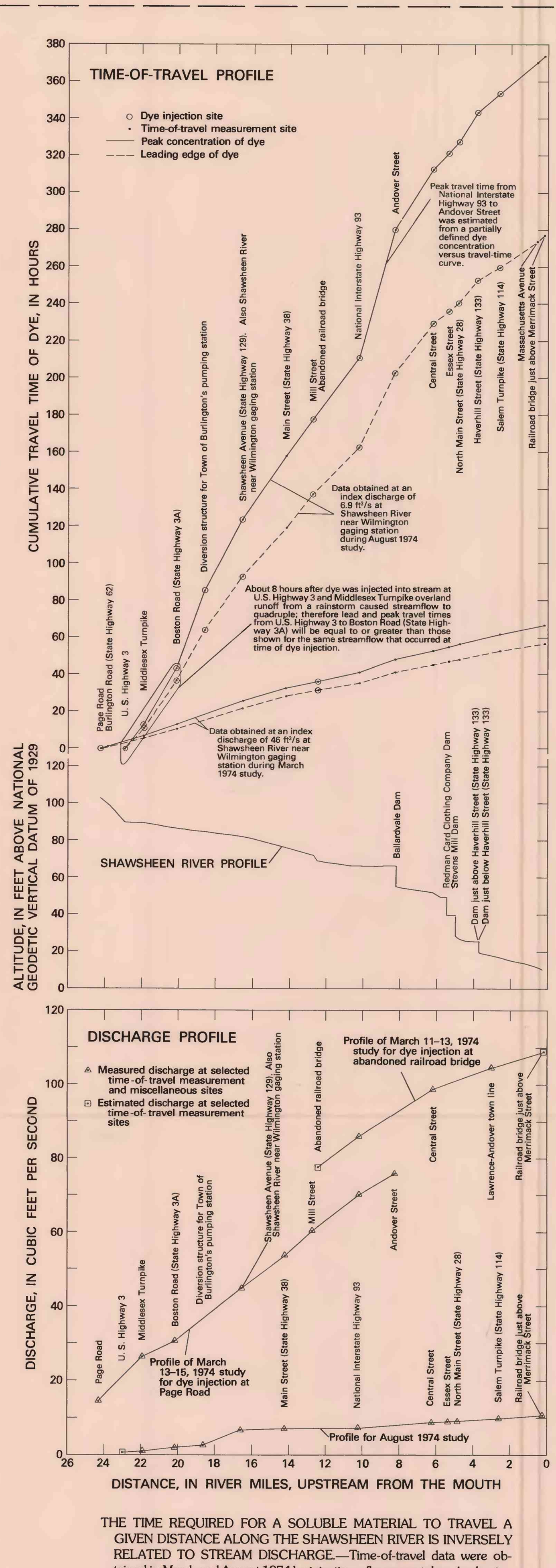
A=drainage area, in square miles

S=main-channel slope, in feet per mile. To determine main-channel slope, choose upstream from each stream junction point on a topographic quadrangle map the stream that drains the most area. At the last junction point, continue the main channel to the surface-water drainage divide by drawing an imaginary stream channel, as indicated by the contour lines. Measure the total length of the stream channel upstream from the site of interest to the drainage divide, and then locate points on the stream channel that are 85 and 10 percent upstream from the site. Determine the altitude at these points and divide the difference in altitude, in feet, by the stream length between the two points, in miles.

p=mean annual precipitation, in feet. Determine precipitation, in inches, from map and convert to feet.

### TIME OF TRAVEL




THE TIME REQUIRED FOR A SOLUBLE MATERIAL TO TRAVEL A GIVEN DISTANCE ALONG THE SHAWSHEEN RIVER IS INVERSELY RELATED TO STREAM DISCHARGE.—Time-of-travel data were obtained in March and August 1974 by injecting a fluorescent dye, rhodamine WT-20 percent, into the stream at selected sites and monitoring concentration of the dye at selected sites downstream. Streamflow at the Wilmington gaging station during the March study was in the medium-flow range, which is equaled or exceeded about 40 percent of the time; whereas, during the August study it was in the low-flow range, which is equaled or exceeded about 88 percent of the time. During both studies, there were no backwater effects from the Merrimack River and no diversions from the river by the Town of Burlington.

These data can be used to determine the time required for the leading edge and maximum concentration of a soluble material (for example, a pollutant) to travel from one point to another along the stream. They can also be used to determine stream velocity.

Streamflow velocities for the peak traveltime during the medium-flow study averaged 0.51 ft/s from Page Road to National Interstate Highway 93 (I-93) and 0.57 ft/s from I-93 to the mouth. However, during the low-flow study, the velocities averaged 0.09 ft/s for both reaches. Below I-93, ponded areas behind each of five dams retard streamflow velocities. At the Ballardvale Dam, the ponded area extends about 1 river mile upstream and causes the marked increase in traveltime between I-93 and Andover Street during the low-streamflow period.

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# HYDROLOGY AND WATER RESOURCES OF THE SHAWSHEEN RIVER BASIN, MASSACHUSETTS

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1980