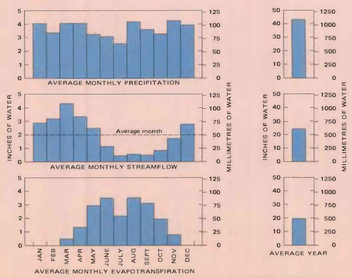
DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

PREPARED IN COOPERATION WITH THE
COMMONWEALTH OF MASSACHUSETTS WATER RESOURCES COMMISSION
BOSTON, MASSACHUSETTS

HYDROLOGIC INVESTIGATIONS
ATLAS HA-560 (SHEET 2 OF 2)

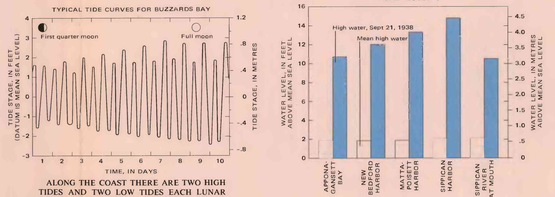
SURFACE WATER

AVERAGE PRECIPITATION STREAM–FLOW AND EVAPOTRANSPIRATION



MONTHLY PRECIPITATION THAT PRODUCES ABOVE-AVERAGE STREAMFLOW DURING THE NONGROWING SEASON (FALL TO SPRING) WILL PRODUCE BELOW-AVERAGE STREAMFLOW DURING THE GROWING SEASON (SPRING TO FALL), WHEN EVAPOTRANSPIRATION IS HIGH.—*Average streamflow and precipitation figures were determined from records of long-term stream-gaging stations near the study area and records of long-term precipitation stations in and near the study area.*

TIDAL CHARACTERISTICS



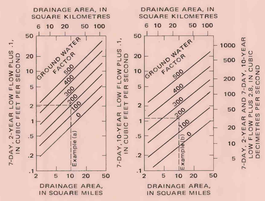
ALONG THE COAST THERE ARE TWO HIGH TIDES AND TWO LOW TIDES EACH LUNAR DAY (24 HOURS AND 50 MINUTES).—*The difference between high and low tides is greater than average at times of new and full moons and less than average at times of first and third quarter moons. (U.S. Coast and Geodetic Survey, Tide Tables).*

UNPROTECTED, LOW-LYING COASTAL AREAS ARE SUBJECT TO TIDAL FLOODING FROM HURRICANE SURGES.—*Tidal levels associated with the hurricane of September 1938 were the highest since August 1638 (U.S. Army Corps of Engineers, 1965; and Paulsen and others, 1940).*

STREAMFLOW CHARACTERISTICS

Planners and designers often are called upon to estimate streamflow characteristics at sites where little or no streamflow data are available. The curves below are an aid for estimating streamflow characteristics where data are lacking but should be considered only first-order approximations of the true values.

LOW FLOW CHARACTERISTICS



LIMITATIONS

This analysis is limited to unregulated streams in the study area.

DEFINITION

Ground-water factor,

$$G = 500XA_{300} + 300XA_{300-300} + 100XA_{300} + OXA_{b}$$
$$A_{300} + A_{300-300} + A_{300} + A_{b}$$

where,

G is the ground-water factor,

A_{300} is the area within the basin where properly designed and constructed wells generally will yield more than 300 gal/min (19 l/s),

$A_{300-300}$ is the area within the basin where properly designed and constructed wells generally will yield between 100 and 300 gal/min (6.3 and 19 l/s),

A_{300} is the area within the basin where properly designed and constructed wells generally will yield less than 100 gal/min (6.3 l/s), and

A_b is the area of till and bedrock; no water available from stratified drift.

EQUATIONS OF GRAPHS

$\log(Q_{7,2} + 0.1) = -1.101 + \log A + 0.0022(G)$

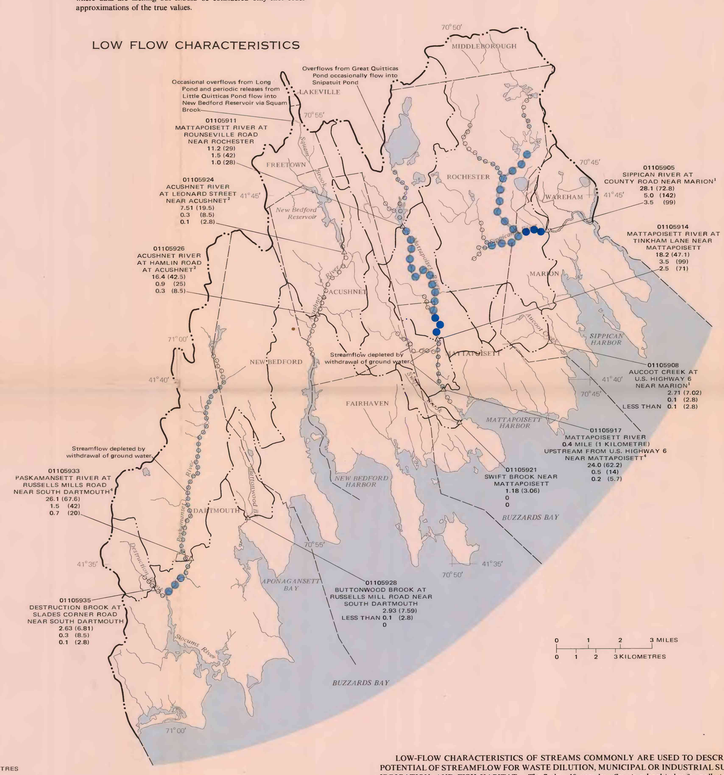
$\log(Q_{7,10} + 0.1) = -1.340 + 0.83 \log A + 0.0028(G)$

in which, $Q_{7,2}$ and $Q_{7,10}$ are the 7-day, 2-year and 10-year low flows, respectively, in cubic feet per second, A is the drainage area, in square miles, and G is the *ground-water factor*.

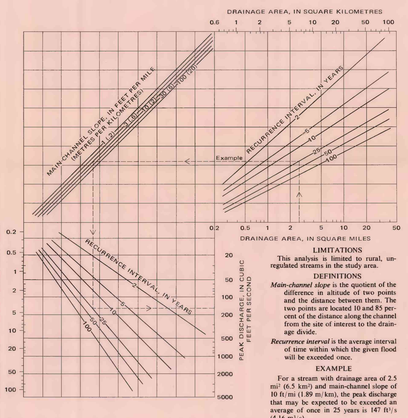
EXAMPLE

The 7-day, 2-year and 10-year low flows for an unregulated stream draining 10 mi² (25.9 km²) and having a *ground-water factor* of 200 is estimated as example (a), 2.1 ft³/s (0.059 m³/s), and example (b), 1.0 ft³/s (0.028 m³/s).

THE 7-DAY, 2-YEAR LOW FLOW AND 7-DAY, 10 YEAR LOW FLOW CAN BE ESTIMATED FROM THE SIZE OF THE DRAINAGE BASIN AND MAPS OF THE AVAILABILITY OF GROUND WATER (Tasker, 1972).



FLOOD FREQUENCY



LIMITATIONS

This analysis is limited to rural, unregulated streams in the study area.

DEFINITIONS

Main-channel slope is the quotient of the difference in altitude of two points and the distance between them. The two points are located 10 and 85 percent of the distance along the channel from the site of interest to the drainage divide.

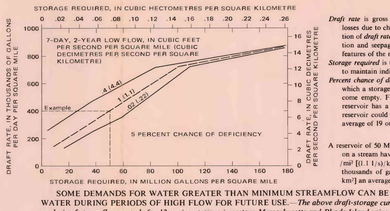
Recurrence interval is the average interval of time within which the given flood will be exceeded once.

EXAMPLE

For a stream with drainage area of 2.5 mi² (6.5 km²) and main-channel slope of 10 ft/mi (1.89 m/km), the peak discharge that may be expected to be exceeded an average of once in 25 years is 147 ft³/s (4.16 m³/s).

ESTIMATES OF THE MAGNITUDE AND FREQUENCY OF PEAK DISCHARGES ON RURAL UNREGULATED STREAMS IN MASSACHUSETTS CAN BE MADE IF THE DRAINAGE AREA, MAIN CHANNEL SLOPE, AND MEAN ANNUAL PRECIPITATION OF THE BASIN ARE KNOWN (Johnson and Tasker, 1974).—*Assuming mean annual precipitation over the study area is 44 inches (1,120 mm), peak discharges may be estimated from the relations shown above.*

STORAGE REQUIREMENTS



DEFINITIONS

Draft rate is gross reservoir outflow uncorrected for water losses due to changing land area to water area. That portion of *draft rate* assigned to water losses, such as evaporation and seepage, must be evaluated considering specific features of the reservoir site.

Storage required is the usable volume of a reservoir required to maintain indicated draft rate.

Percent chance of deficiency is the percentage of years within which a storage reservoir of indicated capacity would become empty. For example, if for a certain *draft rate* a reservoir has a *5 percent chance of deficiency*, then the reservoir could be expected to supply that *draft rate* an average of 19 out of 20 years.

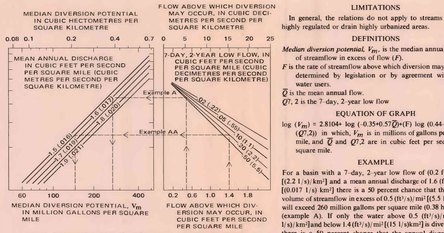
EXAMPLE

A reservoir of 50 Mgal/mi² of drainage area (0.073 hm³/km²) on a stream having a 7-day, 2-year low flow of 0.1 (ft³/s)/mi² [(0.1 l/s)/km²] should provide a draft rate of 400 thousands of gallons per day per square mile [(6.8 l/s)/km²] an average of 19 out of 20 years.

SOME DEMANDS FOR WATER GREATER THAN MINIMUM STREAMFLOW CAN BE MET BY IMPOUNDING WATER DURING PERIODS OF HIGH FLOW FOR FUTURE USE.—*The above draft-storage curves 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). The draft-storage relationship for any stream site in the area can be estimated from the above curves provided the 7-day, 2-year low flow can be estimated at the site.*

The curves are useful to water-resources planners and designers for comparative studies and preliminary designs. The analysis is general in that neither the reservoir site nor demands on the reservoir are specified. Consequently, when estimating storage requirements for a specific site and set of demands, adjustments for the effect of reservoir evaporation and seepage, for the reduction in reservoir capacity because of sedimentation, for the possible modification of capacity for flood control and recreation, and for the effect of nonuniform draft rates should be considered.

DIVERSION POTENTIAL



LIMITATIONS

In general, the relations do not apply to streams that are highly regulated or drain highly urbanized areas.

DEFINITIONS

Median diversion potential, Y_{50}, is the median annual volume of streamflow in excess of flow (F).

F is the rate of streamflow above which diversion may occur—determined by legislation or by agreement with other water users.

$\bar{Q}$ is the mean annual flow.

$Q7,2$ is the 7-day, 2-year low flow

EQUATION OF GRAPH

$$\log(Y_{50}) = 2.8104 \log(-0.35+0.57\bar{Q}/Q7) \log(0.44-0.11 \log(Q7,2))$$

in which, Y_{50} is in millions of gallons per square mile, and $\bar{Q}$ and $Q7,2$ are in cubic feet per second per square mile.

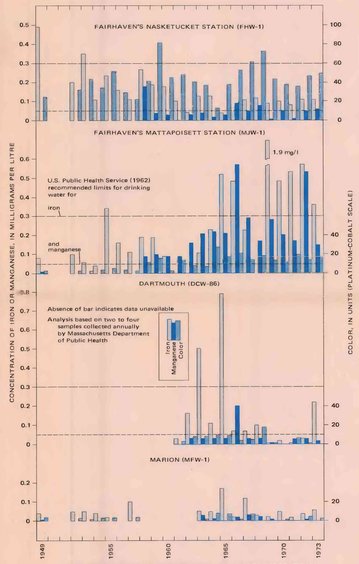
EXAMPLE

For a basin with a 7-day, 2-year low flow of (0.2 ft³/s)/mi² [(2.2 l/s)/km²] and a mean annual discharge of 1.6 (ft³/s)/mi² [(0.017 l/s) km²] there is a 50 percent chance that the annual volume of streamflow in excess of 0.5 (ft³/s)/mi² [(5.5 l/s)/km²] will exceed 260 million gallons per square mile (0.38 hm³/km²) (example A). If only the water above 0.5 (ft³/s)/mi² [(5.5 l/s)/km²] and below 1.4 (ft³/s)/mi² [(15 l/s)/km²] is diverted, then there is a 50 percent chance that the annual diversion will be 260–140=120 million gallons per square mile (0.18 hm³/km²) (example AA).

SOME DEMANDS FOR WATER MAY BE MET BY DIVERTING STREAMFLOW.—*Generally, only the water in excess of a certain legislated flow (F) is allowed to be diverted. The above graphs allow designers and planners to estimate the diversion potential of a stream if the 7-day, 2-year low flow and the mean annual discharge of the stream can be estimated (Tasker, 1973).*

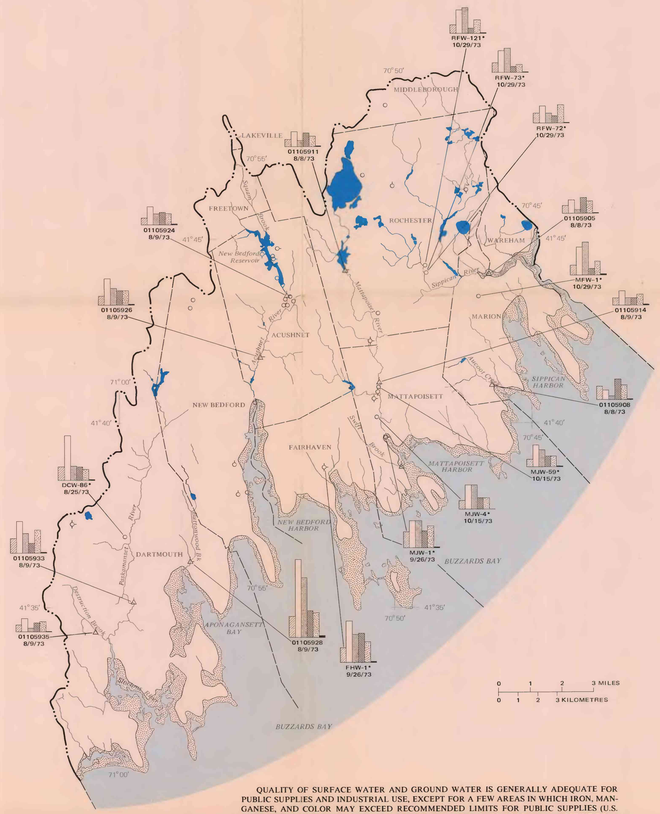
QUALITY OF WATER

TRENDS IN GROUND WATER QUALITY



LONG-TERM RECORDS OF CHEMICAL ANALYSES INDICATE NO DEFINITIVE TRENDS IN WATER QUALITY.—*Troublesome levels of iron, manganese, and color occur regularly in some wells, intermittently in some, and seldom in others. After many years of pumping, several wells, like Fairhaven's Mattapoisett station (MJW-1), have experienced a sudden increase of iron and manganese which may be associated with induced infiltration of surface water (Johnston and Dickerman, 1974).*

GENERAL CHARACTER AND PROBLEMS



QUALITY OF SURFACE WATER AND GROUND WATER IS GENERALLY ADEQUATE FOR PUBLIC SUPPLIES AND INDUSTRIAL USE, EXCEPT FOR A FEW AREAS IN WHICH IRON, MANGANESE, AND COLOR MAY EXCEED RECOMMENDED LIMITS FOR PUBLIC SUPPLIES (U.S. PUBLIC HEALTH SERVICE, 1962), AND SOME STREAM REACHES WHICH MAY RECEIVE DOMESTIC OR INDUSTRIAL WASTES.—*The water is generally soft (less than 60 mg/l hardness), acidic (average pH 6.6), and corrosive to metal. A narrow zone of salt-water intrusion under heavy pumping conditions or from storm flooding exists along the coast. Wells within this zone include Fairhaven's Mattapoisett River station (well number MJW-1), several shallow driven or dug wells, and a few bedrock wells. Stream water samples were taken during a period of low streamflow.*

EXPLANATION

Values of iron, manganese, and color shown under the first set of symbols are the limits recommended by the U.S. Public Health Service (1962) for drinking water. Combination of two or more ticks on symbols indicate that the water fails within two or more categories, described below.

WELLS

○ Concentration of iron 0.3 mg/l or less, manganese 0.05 mg/l or less, and color 15 units or less.

△ Concentration of iron more than 0.3 mg/l

◇ Concentration of manganese more than 0.05 mg/l

♀ Color exceeds 15 units

STREAMS

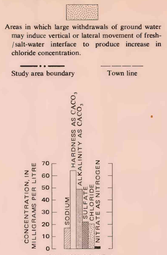
Sea water and mixed fresh and salt water of tidal reaches of streams that has concentration of dissolved solids greater than 500 mg/l at high tide when streamflow is low

Concentration of dissolved solids in streams and ponds equal to or less than 500 mg/l.

Areas in which large withdrawals of ground water may induce vertical or lateral movement of fresh-/salt-water interface to produce increase in chloride concentration.

Study area boundary

Town line



ANALYSES BY U.S. GEOLOGICAL SURVEY AND, WHERE INDICATED BY ASTERISK, BY MASSACHUSETTS DEPARTMENT OF PUBLIC HEALTH

Station number is that used to identify gaging stations and low-flow partial-record stations in national network of hydrologic data collection sites of the U.S. Geological Survey (1973-75).

EXPLANATION

01105905.....Station number¹
Sippican River at.....Station name and
County Road near.....location
Marion, Mass.²
28.1 (72.8).....Drainage area, in square miles (and square kilometres)
5.0 (142).....7-day, 2-year low flow and
3.5 (99).....7-day, 10-year low flow, in cubic feet per second (and cubic metres per second).

Low-flow partial-record station

Boundary of study area

Sub-basin boundary

Town line

Class intervals for 7-day, 10-year low flow for non-tide-affected stream reaches

in ft³/s	Symbol	in m³/s
0 to 0.1	none	0 to 0.0028
0.1 to 0.5	○	0.0028 to 0.014
0.5 to 1	◔	0.014 to 0.028
1 to 2	◑	0.028 to 0.057
2 to 4	●	0.057 to 0.113

Definitions: The 7-day, 2-year and 7-day, 10-year low flows are the annual minimum 7-day mean flows at the 2- and 10-year recurrence intervals, respectively. The probabilities of a lower mean flow for 7 consecutive days occurring in any 1 year are 0.50 and 0.10, respectively.

Recurrence interval is the average number of years between annual occurrences of 7-day mean flows less than the given values.

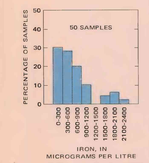
¹Station number is that used to identify gaging stations and low-flow partial-record stations in national network of data-collection sites of U.S. Geological Survey. ²Diversion from New Bedford Reservoir for industrial water supply above station. ³Some regulation by ponds and operation of cranberry bogs above station. ⁴Streamflow depleted by withdrawal of ground water upstream.

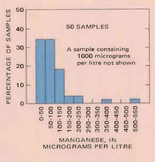
CONVERSION FACTORS

The following factors may be used to convert the English units published herein to the International System of Units (SI).

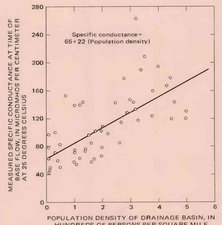
Multiply English units	By	To obtain SI units
LENGTH		
inches (in)	25.4	millimetres (mm)
feet (ft)	.3048	metres (m)
miles (mi)	1.609	kilometres (km)
AREA		
square miles (mi²)	2.590	square kilometres (km²)
VOLUME		
cubic feet (ft³)	.02832	cubic metres (m³)
million gallons (Mgal)	3785	cubic metres (m³)
	3.785×10^{-3}	cubic hectometres (hm³)
million gallons per square mile (Mgal/mi²)	1.461×10^{-3}	cubic hectometres per square kilometre (hm³/km²)
FLOW		
cubic feet per second (ft³/s)	.02832	cubic metres per second (m³/s)
cubic feet per second per square mile [(ft³/s)/mi²]	.01093	cubic metres per second per square kilometre [(m³/s)/km²]
gallons per minute (gal/min)	.06309	litres per second (l/s)
million gallons per day (Mgal/d)	.04381	cubic metres per second (m³/s)
thousands of gallons per day per square mile	.01692	litres per second per square kilometre [(l/s)/km²]
SLOPE		
feet per mile (ft/mi)	.1894	metres per kilometre (m/km)
ELECTRICAL CONDUCTIVITY		
micromhos	1.000	microsiemens (μS)
HYDRAULIC CONDUCTIVITY		
feet per day (ft/d)	.3048	metres per day (m/d)
TRANSMISSIVITY		
square feet per day (ft²/d)	.09290	square metres per day (m²/d)

The graphs below are based on data collected in the Taunton River basin (Williams, and others, 1973), and the coastal basins of southeastern Massachusetts (Williams and Tasker, 1974a, 1974b) in addition to data collected for this study.

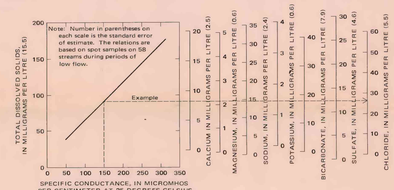




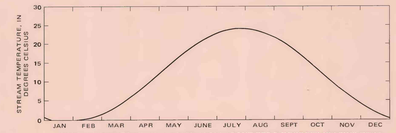
IRON AND MANGANESE IN STREAM WATER COMMONLY EXCEED THE LIMITS FOR DRINKING WATER RECOMMENDED BY THE U.S. PUBLIC HEALTH SERVICE (1962).—*The bar graphs are based on samples taken during periods of low flow from 50 streams in southeastern Massachusetts.*



THE CHEMICAL QUALITY OF STREAMFLOW IS RELATED TO THE POPULATION DENSITY OF THE DRAINAGE BASIN.



AN ESTIMATE OF THE CONCENTRATION OF SOME CONSTITUENTS IN STREAM WATER CAN BE MADE BY MEASURING THE SPECIFIC CONDUCTANCE.—*For example, a specific conductance of 150 micromhos (microsiemens) indicates a concentration of chloride of about 27 mg/l.*



STREAM TEMPERATURE VARIES FROM ABOUT ZERO DEGREES CELSIUS (32°F) IN JANUARY AND FEBRUARY TO ABOUT 25 DEGREES CELSIUS (77°F) IN LATE JULY DURING A TYPICAL YEAR.—*In central New England, stream temperature for a normal year may be approximated by a simple harmonic function whose period and amplitude depend on latitude and elevation (Tasker and Burns, 1974).*

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Interior–Geological Survey, Reston, Va.—1978—W76149

WATER RESOURCES OF THE COASTAL DRAINAGE BASINS OF SOUTHEASTERN MASSACHUSETTS, NORTHWEST SHORE OF BUZZARDS BAY

By
John R. Williams and Gary D. Tasker
1978