

Prepared in cooperation with the
MASSACHUSETTS EXECUTIVE OFFICE OF ENVIRONMENTAL AFFAIRS and the
MASSACHUSETTS DEPARTMENT OF ENVIRONMENTAL PROTECTION

A Logistic Regression Equation for Estimating the Probability of a Stream Flowing Perennially in Massachusetts

Water-Resources Investigations Report 02-4043



Cover photographs are Shinglemill Brook, Hanover, Mass. (station HR-61) (left) and Unnamed Tributary to Bluefish River, Duxbury, Mass. (station DY-53) (right).

U.S. Department of the Interior
U.S. Geological Survey

A Logistic Regression Equation for Estimating the Probability of a Stream Flowing Perennially in Massachusetts

By GARDNER C. BENT and STACEY A. ARCHFIELD

Water-Resources Investigations Report 02-4043

Prepared in cooperation with the
MASSACHUSETTS EXECUTIVE OFFICE OF ENVIRONMENTAL AFFAIRS, and the
MASSACHUSETTS DEPARTMENT OF ENVIRONMENTAL PROTECTION

Northborough, Massachusetts
2002

U.S. DEPARTMENT OF THE INTERIOR
GALE A. NORTON, Secretary

U.S. GEOLOGICAL SURVEY
Charles G. Groat, Director

The use of trade or product names in this report is for identification purposes only and does not constitute endorsement by the U.S. Government.

For additional information write to:
Chief, Massachusetts-Rhode Island District
U.S. Geological Survey
Water Resources Discipline
10 Bearfoot Road
Northborough, MA 01532

or visit our Web site at

<http://ma.water.usgs.gov>

Copies of this report can be purchased from:
U.S. Geological Survey
Information Services
Box 25286
Denver, CO 80225-0286

CONTENTS

Abstract	1
Introduction	2
Purpose and Scope	2
Acknowledgments	3
Description of Study Area	3
Characteristics of Massachusetts	3
Characteristics of South Coastal Basin	3
Database Development	8
Factors that Affect the Perennial/Intermittent Status of Streams	8
Site Selection	9
Selection and Measurement of Basin Characteristics	14
Logistic Regression Equation	14
Development	15
Application	18
Limitations of the Logistic Regression Equation and Areas for Further Study	20
Summary and Conclusions	21
References Cited	23
Appendix A. Summary statistics for selected logistic regression analyses tested for use in development of an equation for estimating the probability of a stream flowing perennially in Massachusetts	45

FIGURES

1–3. Maps showing:

1. Location of discontinued and continuous streamflow-gaging stations and partial-record stations designated as perennial or intermittent stream sites used in development of the logistic regression equation for estimating the probability of a stream flowing perennially in Massachusetts	4
2. Location of field visited stream sites in the South Coastal Basin, southeastern Massachusetts, designated as perennial or intermittent stream sites used in development of the logistic regression equation for estimating the probability of a stream flowing perennially in Massachusetts	7
3. Location of precipitation stations analyzed to determine if the eastern region or western region of Massachusetts met the 310 Code of Massachusetts Regulations (CMR) 10.58(2)(a) definition of extended drought	10
4. Boxplots showing distribution of (A) drainage area, (B) drainage density, (C) areal percentage of stratified-drift deposits, and (D) mean basin slope for intermittent- and perennial- stream sites in the eastern region (ER), western region (WR), and South Coastal Basin (SCB) of Massachusetts used in development of the logistic regression equation for estimating the probability of a stream flowing perennially in Massachusetts	12
5, 6. Graphs showing:	
5. Observed frequency of perennial-stream sites by drainage-area range in the (A) eastern region, (B) western region, and (C) South Coastal Basin of Massachusetts	16
6. Total monthly precipitation from January through September 1999, as a percentage of the average long-term monthly precipitation for 1960–99 at the Brockton, Falmouth, Middleborough, and New Bedford precipitation stations near the South Coastal Basin, southeastern Massachusetts	21

TABLES

- 1. Months that the eastern or western regions of Massachusetts met the 310 Code of Massachusetts Regulations (CMR) 10.58(2)(a) definition of extended drought from January 1960 through August 1999 9
- 2. Analysis of maximum likelihood estimates for the logistic regression equation for estimating the probability of a stream flowing perennially in Massachusetts 18
- 3. Classification table for the logistic regression equation for estimating the probability of a stream flowing perennially in Massachusetts 19
- 4. Description, basin characteristics, and perennial- or intermittent-status determination for stream sites at discontinued and continuous streamflow-gaging stations and partial-record stations by region and major river basin in Massachusetts used in development of the logistic regression equation for estimating the probability of a stream flowing perennially in Massachusetts 27
- 5. Description, basin characteristics, and perennial- or intermittent-status determination for field-visited stream sites by town in the South Coastal Basin, southeastern Massachusetts used in development of the logistic regression equation for estimating the probability of a stream flowing perennially in Massachusetts 35

CONVERSION FACTORS AND VERTICAL DATUM

CONVERSION FACTORS

Multiply	By	To obtain
foot	0.3048	meter
inch (in)	25.4	millimeter
mile (mi)	1.609	kilometer
square mile (mi ²)	12.590	square kilometers
Temperature in degrees Celsius (°C) can be converted to degrees Fahrenheit (°F) as follows: $^{\circ}\text{F}=1.8^{\circ}\text{C}+32$		

VERTICAL DATUM

Sea Level: In this report “sea level” refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)—a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

A Logistic Regression Equation for Estimating the Probability of a Stream Flowing Perennially in Massachusetts

By GARDNER C. BENT and STACEY A. ARCHFIELD

Abstract

A logistic regression equation was developed for estimating the probability of a stream flowing perennially at a specific site in Massachusetts. The equation provides city and town conservation commissions and the Massachusetts Department of Environmental Protection with an additional method for assessing whether streams are perennial or intermittent at a specific site in Massachusetts. This information is needed to assist these environmental agencies, who administer the Commonwealth of Massachusetts Rivers Protection Act of 1996, which establishes a 200-foot-wide protected river-front area extending along the length of each side of the stream from the mean annual high-water line along each side of perennial streams, with exceptions in some urban areas. The equation was developed by relating the verified perennial or intermittent status of a stream site to selected basin characteristics of naturally flowing streams (no regulation by dams, surface-water withdrawals, ground-water withdrawals, diversion, waste-water discharge, and so forth) in Massachusetts. Stream sites used in the analysis were identified as perennial or intermittent on the basis of review of measured streamflow at sites throughout Massachusetts and on visual observation at sites in the South Coastal Basin, southeastern Massachusetts. Measured or observed zero flow(s) during months of extended drought as defined by the 310 Code of Massachusetts Regulations

(CMR) 10.58(2)(a) were not considered when designating the perennial or intermittent status of a stream site. The database used to develop the equation included a total of 305 stream sites (84 intermittent- and 89 perennial-stream sites in the State, and 50 intermittent- and 82 perennial-stream sites in the South Coastal Basin). Stream sites included in the database had drainage areas that ranged from 0.14 to 8.94 square miles in the State and from 0.02 to 7.00 square miles in the South Coastal Basin.

Results of the logistic regression analysis indicate that the probability of a stream flowing perennially at a specific site in Massachusetts can be estimated as a function of (1) drainage area (cube root), (2) drainage density, (3) areal percentage of stratified-drift deposits (square root), (4) mean basin slope, and (5) location in the South Coastal Basin or the remainder of the State. Although the equation developed provides an objective means for estimating the probability of a stream flowing perennially at a specific site, the reliability of the equation is constrained by the data used to develop the equation. The equation may not be reliable for (1) drainage areas less than 0.14 square mile in the State or less than 0.02 square mile in the South Coastal Basin, (2) streams with losing reaches, or (3) streams draining the southern part of the South Coastal Basin and the eastern part of the Buzzards Bay Basin and the entire area of Cape Cod and the Islands Basins.

INTRODUCTION

The Commonwealth of Massachusetts Rivers Protection Act (Chapter 258 of the Acts of 1996; The Commonwealth of Massachusetts, 1996) specifies that riverfront areas be protected on all rivers that flow on a year round basis. The Massachusetts Department of Environmental Protection (MADEP) adopted regulations to enforce the law, which defines rivers that flow on a year round basis as perennial streams. The riverfront area is defined in 310 Code of Massachusetts Regulations (CMR) 10.58(2)(a) (hereafter referred to as the Regulations) as the 200-ft wide area extending along the length of each side of the stream from the mean annual high-water line on each side of perennial streams, with exceptions in some urban areas (Massachusetts Department of Environmental Protection, 2000, p. 393-402). The Regulations define the mean annual high-water line as the line that is apparent from visible markings or changes in the character of soils or vegetation due to prolonged presence of water and that also distinguishes predominantly aquatic from predominately terrestrial land. Streams that do not flow on a year round basis, intermittent streams, have no jurisdictional riverfront area along the stream. City or town conservation commissions are charged with administering the Regulations by determining the perennial or intermittent status of a stream site and by regulating work in the riverfront areas. The MADEP addresses appeals of decisions made about the perennial or intermittent status of stream sites by city or town conservation commissions. The logistic regression equation provides these agencies with an additional method for assessing the status of stream sites.

A river is defined in the Regulations as any natural flowing body of water that discharges into an ocean, lake, pond, or another river, and which flows throughout the year (Massachusetts Department of Environmental Protection, 2000, p. 394). Perennial streams are rivers, but intermittent streams are not rivers. The Regulations specify that perennial streams be represented as such on the most current U.S. Geological Survey (USGS) topographic map or on a more recent map developed by the MADEP (if available), unless a competent source can provide adequate evidence to the contrary. A stream site shown as intermittent on USGS or MADEP maps or a site not shown

on either of these two maps can be considered perennial if (1) evidence can be established of the presence of aquatic invertebrates that require perennial flows, or (2) evidence of a stream order of two or greater, or (3) there is a USGS streamflow-gaging station upstream from the stream site, or (4) the drainage area upstream from the stream site is greater than 3 mi², except in the Buzzards Bay Basin, Cape Cod Basin, Islands Basin, South Coastal Basin, and Taunton River Basin, or (5) other credible evidence is available. To the contrary, a stream site shown as perennial on USGS or MADEP maps can be considered intermittent if (1) the river at the site is observed not flowing, provided the observation is not during an extended drought, or (2) no stream channel or banks are present, or (3) soils information shows that the ground-water elevation is not at or near the streambed, or (4) other credible evidence is available. A problem, however, is that USGS topographic maps are not made to the level of detail and accuracy presumed by the Regulations; therefore, they may not accurately represent whether a stream site is perennial or intermittent. The USGS, therefore, in cooperation with the Massachusetts Executive Office of Environmental Affairs (MAEOEA) and the MADEP, began a study in 1999 to develop a statistical method to more accurately determine whether a stream at a specific site is perennial or intermittent in Massachusetts.

Purpose and Scope

This report describes the development and application of a logistic regression equation for estimating the probability of a stream flowing perennially at a specific site in Massachusetts. The equation is based on historical streamflow data in Massachusetts from water years¹ 1960 through 1998 and on field data collected as a pilot project in the South Coastal Basin during the summer of 1999. Basin characteristics used in the analysis were obtained from digital data layers. Limitations of the logistic regression are discussed and areas for further study are presented.

¹A water year is the 12-month period beginning October 1 and ending September 30. It is designated by the calendar year in which it ends.

Acknowledgments

The authors thank the MADEP's Perennial/Intermittent Advisory Committee; the MADEP, Bureau of Resource Protection, Wetlands and Waterways Program; MAEOEA, Massachusetts Watershed Initiative; and George Zoto of the MAEOEA for providing input on the State's and South Coastal Basin's perspective related to perennial/intermittent issues. The authors also thank Gregory F. Koltun, USGS, for providing statistical assistance for the study.

DESCRIPTION OF STUDY AREA

The geography, climate, and surficial geology of a basin upstream of a selected stream site are factors that can affect whether the stream at that location will be perennial or intermittent. In Massachusetts and the South Coastal Basin these factors, and particularly the extent and type of surficial deposits, affect streamflow characteristics.

Characteristics of Massachusetts

Massachusetts encompasses 8,093 mi² in the northeastern United States (fig. 1). Altitudes range from 1 to 2 ft above sea level in coastal areas to more than 3,900 ft above sea level in the northwest. The climate in Massachusetts is humid. Average annual precipitation ranges from about 40 to 45 in. in eastern Massachusetts and from about 40 to 50 in. in western Massachusetts where higher altitudes may cause orographic effects. Average annual temperature is about 50°F in eastern Massachusetts and about 45°F in western Massachusetts.

Surficial deposits that overlie bedrock in most of Massachusetts were deposited mainly during the last glacial period, but can include areas of recent floodplain alluvium deposits. In this report, these surficial deposits are classified as either till (which includes till or bedrock, sandy till over sand, and end moraine deposits) or stratified-drift deposits (which includes sand and gravel, large sand, fine-grained, and floodplain alluvium deposits). This classification maintains consistency with characterizations of surficial deposits reported in four reports that discuss low-flow characteristics in Massachusetts (Ries, 1994a; 1994b;

and 1997; Ries and Friesz, 2000). Till, an unsorted, unstratified mixture of clay, silt, sand, gravel, cobbles, and boulders, was deposited by glaciers directly on bedrock throughout much of the State. Till primarily is found in the upland areas. Stratified drift is a common term for sorted, layered glaciofluvial and glaciolacustrine deposits. Glaciofluvial deposits are material of all grain sizes (clay, silt, sand, gravel, and cobbles) deposited by glacial meltwater streams in outwash plains and valleys. Glaciolacustrine deposits generally consist of clay, silt, and fine sand deposited in temporary lakes that were present after the retreat of the glacial ice sheet. Stratified-drift deposits are more wide spread in eastern Massachusetts than in western Massachusetts (Ries, 1994a, p. 6). In eastern Massachusetts, stratified-drift deposits overlie till deposits, particularly in the southeast. In other areas of the State, stratified-drift deposits are more likely to be in river valleys.

The extent and types of surficial deposits are important factors that help explain flow characteristics of Massachusetts streams (Ries, 1994a; 1994b; and 1997; Ries and Friesz, 2000). Till and fine-grained stratified-drift deposits generally have a lower infiltration capacity than medium- to coarse-grained stratified-drift deposits. The lower infiltration capacity of these materials results in greater direct runoff of precipitation; therefore, less precipitation is available to infiltrate the soil and recharge the aquifer than from medium- to coarse-grained stratified-drift deposits. During dry periods, the primary source of streamflow is ground-water discharge from the aquifer to the stream. Thus, basins underlain predominantly by till and fine-grained stratified-drift deposits generally have a lower streamflow per unit area during dry periods than basins underlain predominantly by medium- to coarse-grained stratified-drift deposits.

Characteristics of South Coastal Basin

The South Coastal Basin is one of 27 river basins in the State, and encompasses 240 mi² in southeastern Massachusetts (fig. 2). The basin includes all or part of 18 towns. Altitudes range from 1 to 2 ft above sea level to about 400 ft above sea level. The basin mainly has low relief and is characterized by low-gradient streams.

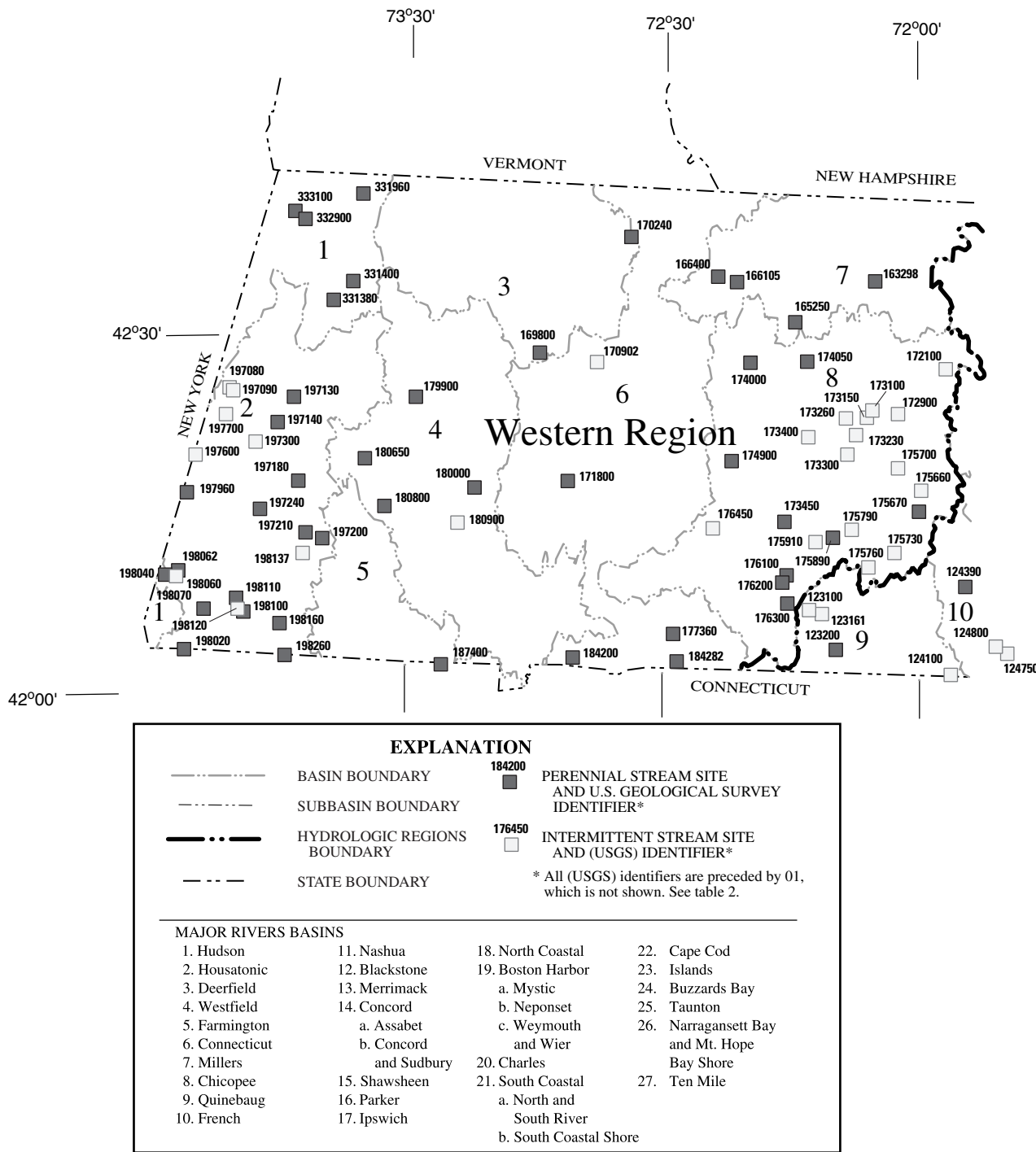


Figure 1. Location of discontinued and continuous streamflow-gaging stations and partial-record stations designated as perennial or intermittent stream sites used in development of the logistic regression equation for estimating the probability of a stream flowing perennially in Massachusetts.

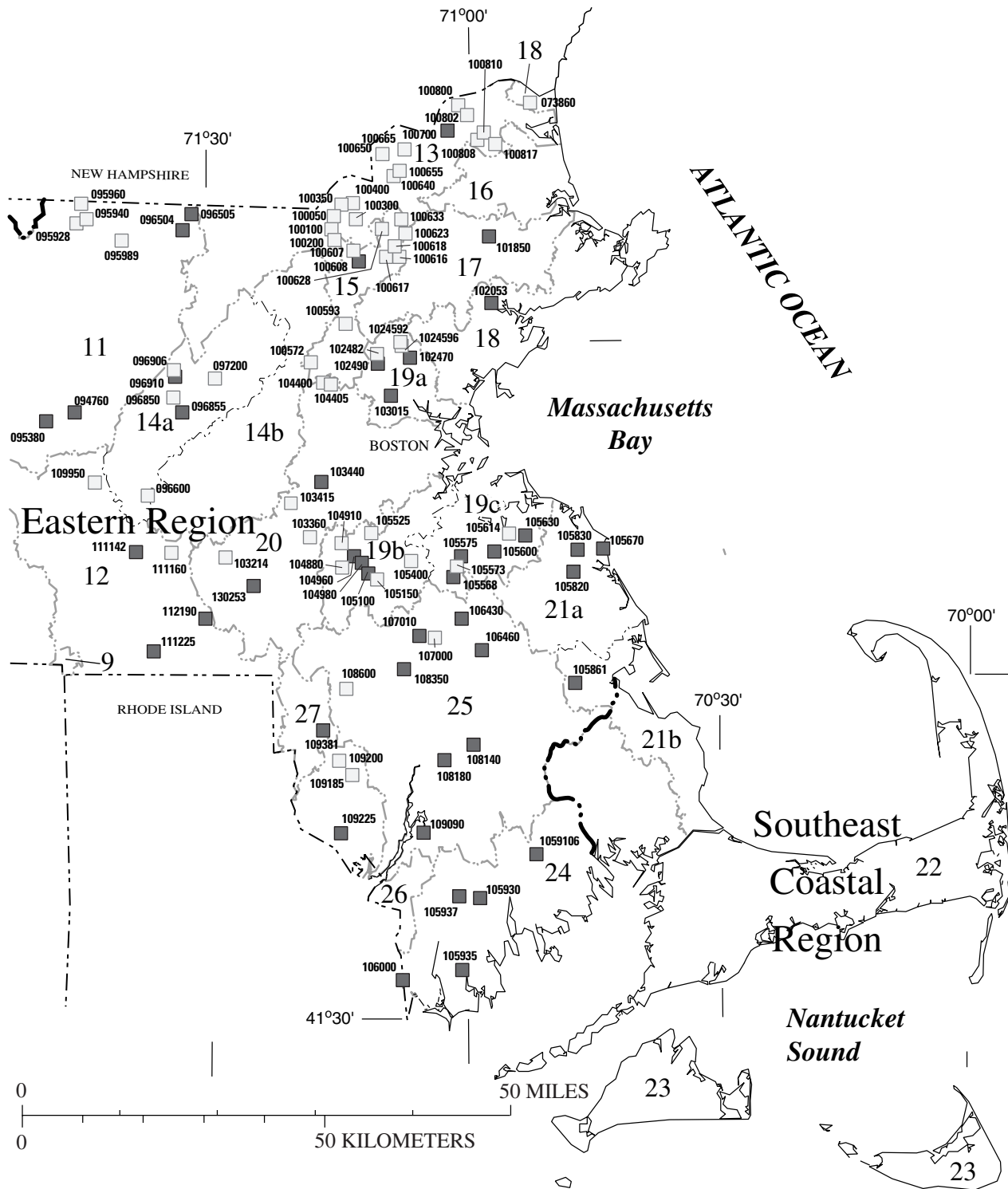
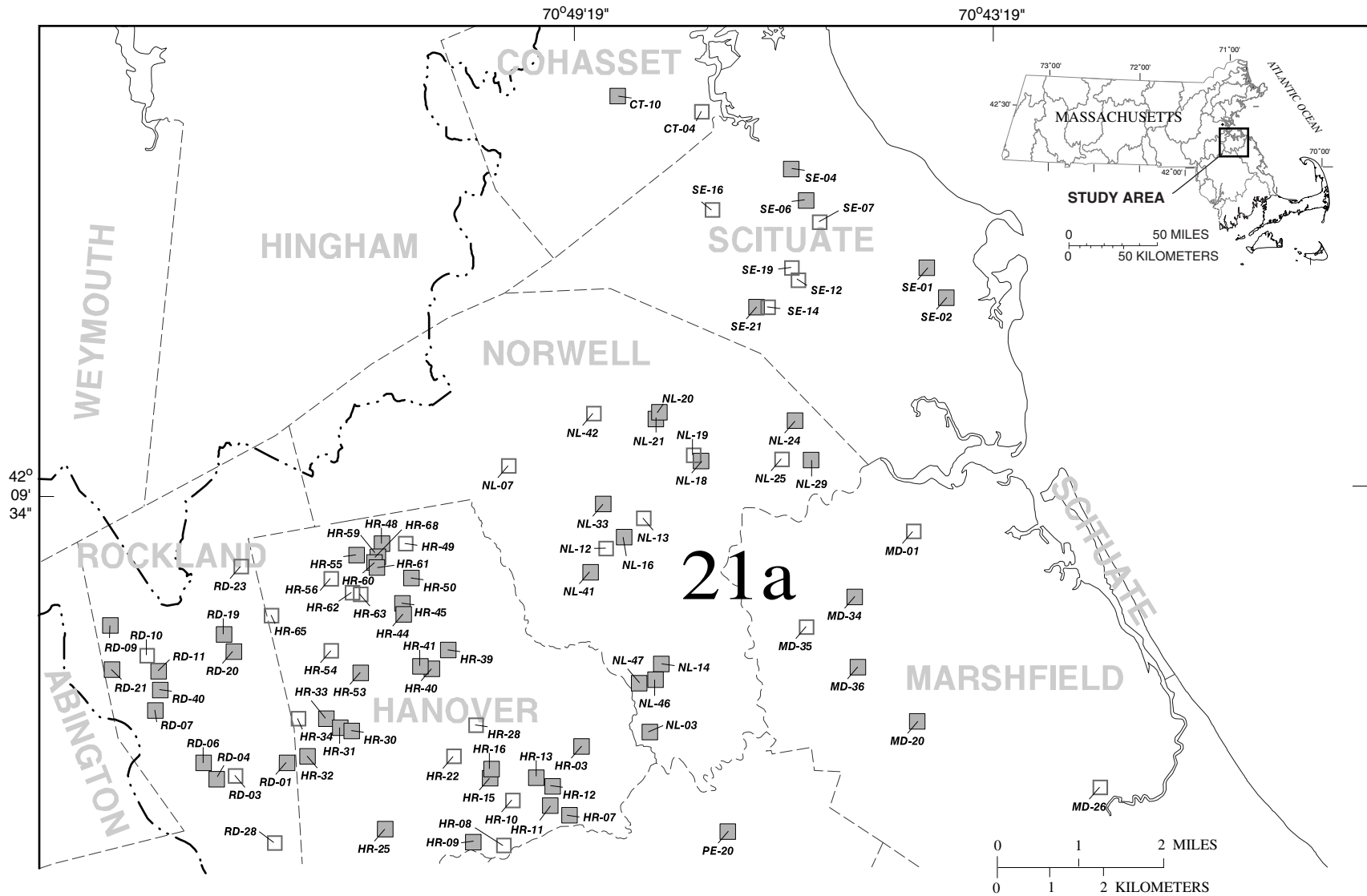


Figure 1. Location of discontinued and continuous streamflow-gaging stations and partial-record stations designated as perennial or intermittent stream sites used in development of the logistic regression equation for estimating the probability of a stream flowing perennially in Massachusetts—*Continued*.



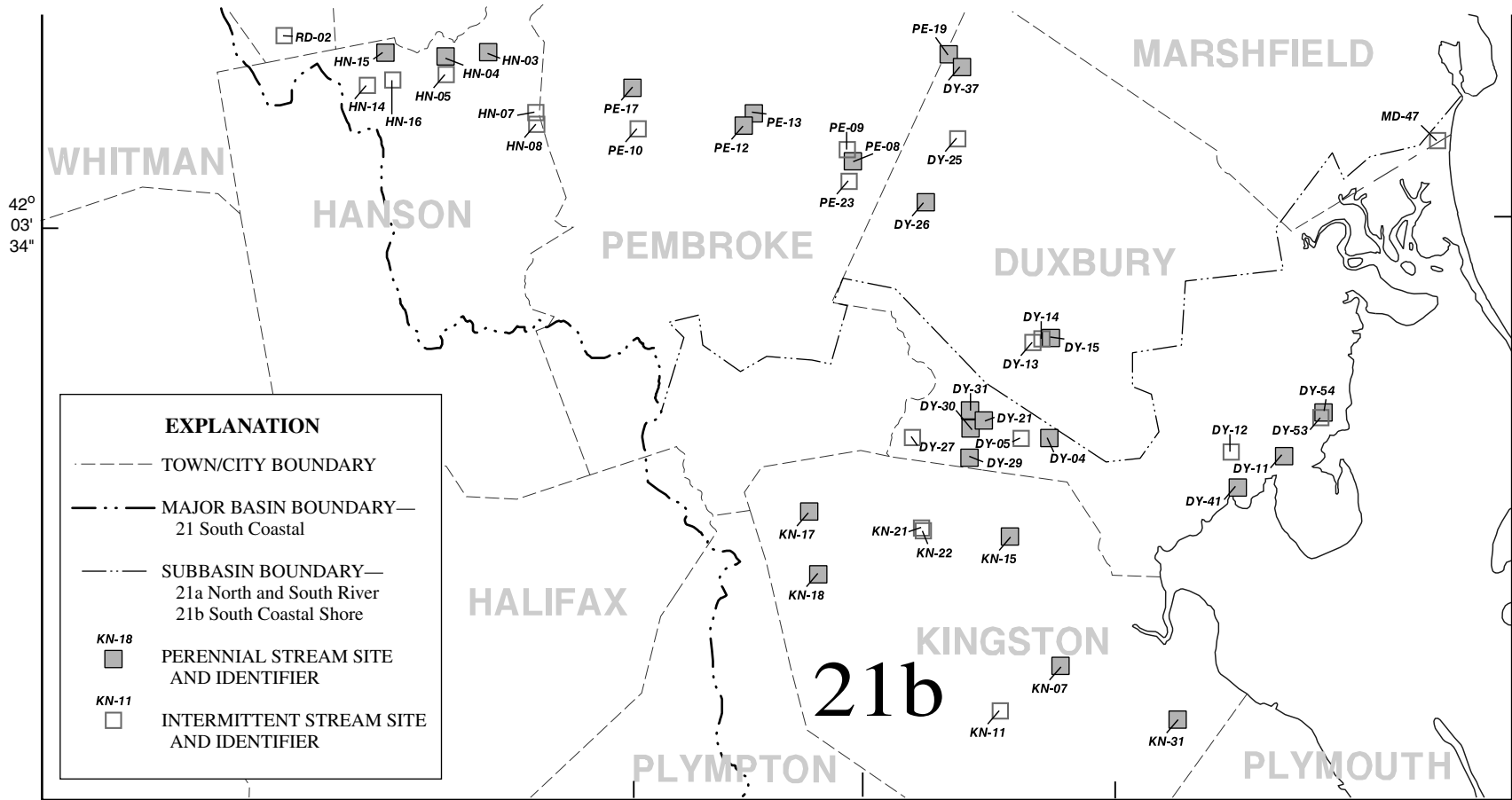


Figure 2. Location of field visited stream sites in the South Coastal Basin, southeastern Massachusetts, designated as perennial or intermittent stream sites used in development of the logistic regression equation for estimating the probability of a stream flowing perennially in Massachusetts.

Surficial geology is mainly stratified-drift deposits, as 65 percent of the 240-mi² basin is underlain by these deposits and the remaining area (35 percent) is underlain by till and bedrock. However, surficial geology in the basin is distinctly different from the northern 105 mi² (North and South River Subbasins), where about 33 percent of the area is underlain by stratified-drift deposits, and from the southern 135 mi² (South Coastal Shore Subbasin), where about 90 percent of the area is underlain by stratified-drift deposits (Ries, 1994b).

DATABASE DEVELOPMENT

To develop an equation for estimating the probability of a Massachusetts stream flowing perennially at a specific site, a database was developed that contains basin characteristic information on both perennial- and intermittent-stream sites in the State. Development of this database involved screening data to avoid entries for stream sites affected by regulation, drought conditions, or other factors that may alter the perennial or intermittent status of streams. The stream sites were selected from the USGS database of measured streamflow in the State from water years 1960 through 1998 and from sites visited in the South Coastal Basin in the summer of 1999.

Factors That Affect the Perennial/Intermittent Status of Streams

For this study, determination of the perennial or intermittent status of a stream site in Massachusetts was completed only for naturally flowing streams (no regulation). Regulated streams are those affected by dams, surface-water withdrawals, ground-water withdrawals (pumping wells), diversions, wastewater discharges, and so forth. The perennial or intermittent status of a stream at a specific site cannot be estimated accurately if the flows above or near the site are regulated, because regulations vary from site to site, and the majority of regulations are not quantified or easily quantifiable. Observations of no flow at stream sites

during abnormally dry periods and observations of flow at stream sites during abnormally wet periods were not included in the study database, to avoid observations that are unrepresentative of normal climatic conditions.

If zero flows were measured in the eastern or western region of the State during a month that occurred within an extended drought, as defined in the Regulations, those flows were not included in the database. The months that met the definition of an extended drought for both the eastern and western regions are listed in table 1.

The Regulations define an extended drought as a period of below normal precipitation for that month and the three previous months, with at least 3 of the months having 75 percent or less of the normal precipitation and 2 months having 50 percent or less of normal precipitation (Massachusetts Department of Environmental Protection, 2000, p. 395). This definition was used to analyze precipitation records from January 1960 through August 1999 (the period of measured streamflow used for development of the database) at 19 index-precipitation stations in the State (fig. 3), which included 10 index-precipitation stations from the eastern region and 9 index-precipitation stations from the western region. Although the NWS (National Weather Service) precipitation station in Ashburnham is about 1 mi within the eastern region boundary (fig. 3), it was used for the western region, because there were no other index stations in the eastern part of the western region. The Massachusetts Department of Environmental Management (MADEM) maintains the database of precipitation measured at these index-precipitation stations.

To determine when the eastern or western regions met the Regulation's extended drought definition, the following steps were used (1) the average long-term monthly precipitation for June 1960 through August 1999 was determined for each of the 19 index stations, (2) the average long-term monthly precipitation for the eastern region was determined by calculating the average long-term monthly precipitation (determined in step 1) of the 10 index stations and was determined for the western region by calculating the average long-term monthly precipitation (determined in step 1) of the 9 index stations, (3) the average monthly precipitation for each individual month and

Table 1. Months that the eastern or western regions of Massachusetts met the 310 Code of Massachusetts Regulations (CMR) 10.58(2)(a) definition of extended drought from January 1960 through August 1999

[Monthly precipitation average based on Massachusetts Department of Environmental Management precipitation data. The eastern region is based on precipitation stations at Brockton, Buffumville Lake, Concord, Falmouth, Lawrence, Lowell, Middleborough, New Bedford, Northbridge, and Waltham. The western region is based on precipitation stations at Amherst, Ashburnham, Chesterfield, Dalton, Greenfield, Otis, Plainfield, Stockbridge, and Worthington. Precipitation station locations shown in figure 3]

Month	Year
Eastern region	
June.....	1964
August	1964
May.....	1965
June.....	1965
July	1965
August	1965
January.....	1966
June.....	1966
September	1968
October	1968
February.....	1980
March.....	1980
March.....	1981
November	1984
April.....	1985
September	1988
August	1993
September	1997
Western region	
November	1964
December.....	1964
January.....	1965
May.....	1965
June.....	1965
February.....	1968
April.....	1978
May.....	1978
February.....	1980
March.....	1980
March.....	1981
December.....	1988
January.....	1989

year for the eastern region was determined by calculating the average monthly precipitation for the 10 index stations and was determined for the western region by calculating the average monthly precipitation for the 9 index stations, and (4) the regional average monthly precipitation for each individual month and year (determined in step 3) was then tested against the regional average long-term monthly precipitation (determined in step 2) to determine if each month in each region from January 1960 through August 1999 met the extended drought definition. This definition eliminated 3.8 percent of the months in the eastern region and 2.7 percent of the months in the western region during January 1960 through August 1999 (table 1).

Because the Regulations have no operational definition of an abnormally wet month, only those perennial-stream sites measured at least three times were included in the database. By measuring a perennial-stream site at least three times, it would be likely that at least one measurement was made during relatively normal climatic conditions.

Site Selection

Selecting stream sites for inclusion in the database of perennial- and intermittent-stream sites in Massachusetts involved (1) reviewing available USGS measured streamflow data from sites in the State (table 4, at back of report), and (2) visiting sites in the South Coastal Basin (table 5, at back of report). A list of perennial-stream sites in the State was available from Ries (1997), in which equations were developed to estimate the August median streamflow at ungaged sites in Massachusetts. Locations of intermittent-stream sites were determined through review of streamflow-measurement data collected from sites in the State. Stream sites in the South Coastal Basin (fig. 2) were evaluated visually in the field during the summer of 1999, to determine their perennial or intermittent status. As part of the stream-site-selection process, stream sites were accessed with the World Wide Web application STREAMSTATS, <http://ma.water.usgs.gov/streamstats/> (Ries and others, 2000), to determine if there were public community surface-water or ground-water withdrawals upstream of or nearby the sites.

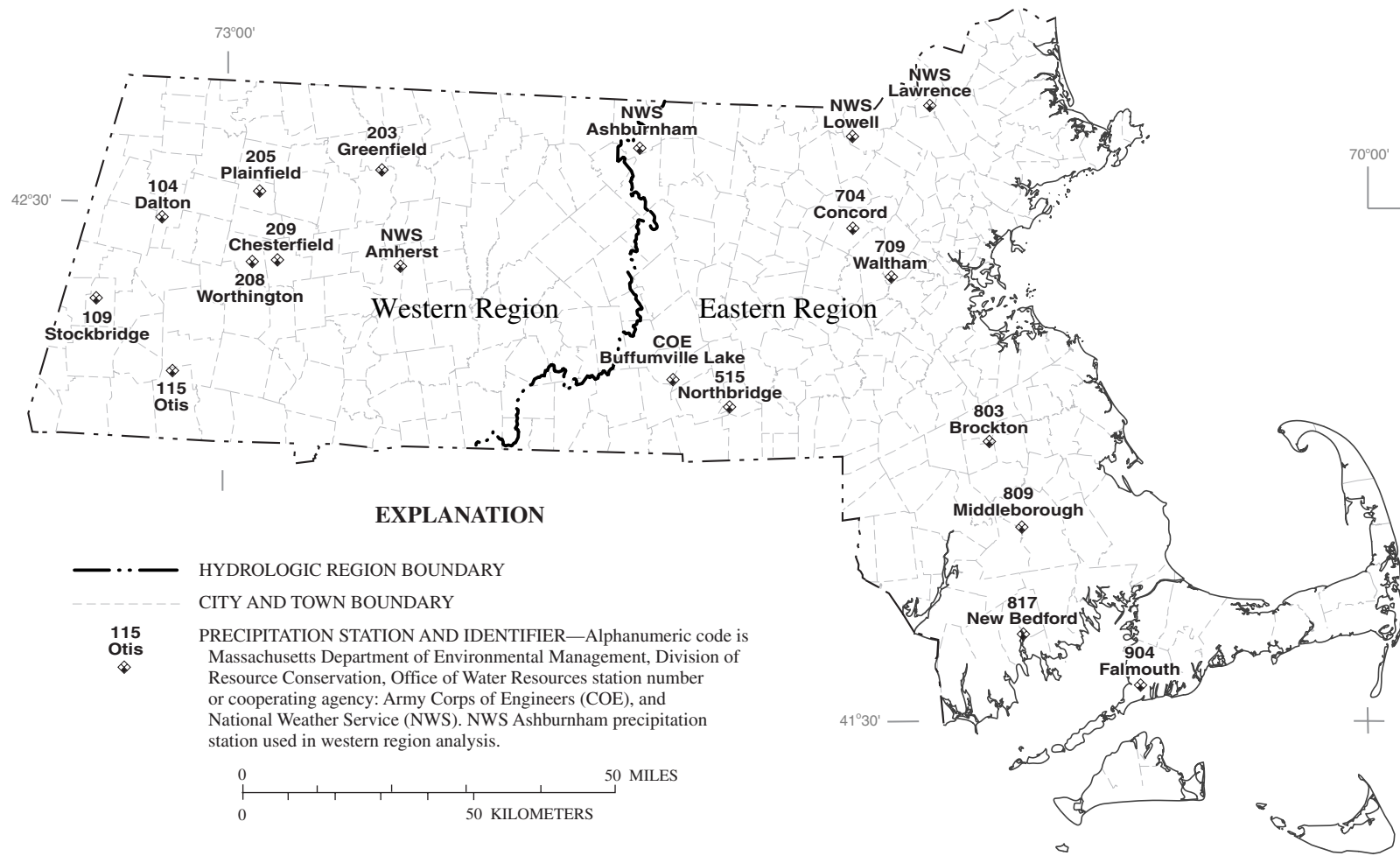


Figure 3. Location of precipitation stations analyzed to determine if the eastern region or western region of Massachusetts met the 310 Code of Massachusetts Regulations (CMR) 10.58(2)(a) definition of extended drought.

Approximately 1,300 stream sites (partial-record, discontinued streamflow-gaging, or continuous streamflow-gaging stations) in the USGS National Water Information System (NWIS) database were evaluated for measured zero flow(s) for water years 1960 through 1998 to determine intermittent sites in Massachusetts. Of these 1,300 stream sites, zero flow(s) had been measured at 174 sites. Of these 174 stream sites, 90 sites were omitted from the database because of one or more of the following conditions: (1) regulation of streamflow by dams, ground-water or surface-water withdrawals upstream or nearby, diversions, wastewater discharges, and so forth, (2) zero flow(s) measured only during an extended drought period, (3) the stream site was outside of Massachusetts, (4) questionable streamflow measurements, (5) the stream site was in the Buzzards Bay, North Coastal, or Taunton River Basins (where no digitized stream-network-data layers were available for these three basins in STREAMSTATS as of March 1, 2001), and (7) the site was in the Cape Cod Basin, Islands Basin, southern part of the South Coastal Basin, or eastern part of the Buzzards Bay Basin (labeled as Southeast Coastal Region in fig. 1) where the areas contributing ground water and surface water to a specific stream site may be appreciably different. Only 84 zero-flow sites from the USGS NWIS database of approximately 1,300 stream sites met these criteria and were used as part of the intermittent-stream sites in Massachusetts. These stream sites had a maximum drainage area of 8.04 mi² (station 01175790), a minimum drainage area of 0.14 mi² (stations 01100572, 01100618, and 01100623), a mean drainage area of 2.63 mi², and a median drainage area of 2.02 mi² (table 4).

An initial list of perennial-stream sites in Massachusetts was created from the 205 sites used by Ries (1997). Of the 205 stream sites, 116 sites were

omitted from the database because of one or more of the following conditions: (1) regulation of streamflows by dams, ground-water or surface-water withdrawals upstream or nearby, diversions, wastewater discharges, and so forth, (2) the stream site previously was identified as an intermittent (zero flow) site, and (3) the drainage area of the stream site was greater than 9.00 mi² (the intermittent-stream sites had a maximum drainage area of 8.04 mi²) and would not aid in development of the logistic regression equation. The remaining 89 perennial-stream sites included in the database had a maximum drainage area of 8.94 mi² (station 01106460), a minimum drainage area of 0.78 mi² (station 01197210), a mean drainage area of 5.16 mi², and a median drainage area of 5.27 mi² (table 4).

In the South Coastal Basin, 397 stream sites were visited from June through August 1999. These stream sites were at road crossings where access permitted a visual inspection to determine if there were flow in the stream. These stream sites were evaluated during periods of little to no precipitation that occurred at least 3 to 5 days following a precipitation event totaling 0.10 in. or greater. Observations recorded during the visual inspection at each stream site included whether the streambed was dry, had disconnected pools of water in the streambed, had water but no velocity (no flowing water), or had flowing water. The stream sites were inspected on both the upstream and downstream sides of each road crossing and documented with digital photographs of the upstream and downstream stream-channel conditions at each site. Those stream sites with a dry streambed or disconnected pools of water were classified as intermittent on the basis of on the definition that perennial streams are rivers that flow throughout the year.

Of the 397 stream sites visited in the South Coastal Basin, 261 sites were omitted because of one or more of the following conditions: (1) regulation of streamflows by dams, ground-water or surface-water withdrawals upstream or nearby, diversions, waste-

water discharges, and so forth, (2) no visible streambed observed in the field, although the site was shown as a stream on a USGS topographic map, (3) water but no velocity observed at the stream site (a velocity was not verified with a flow meter; therefore, the perennial or

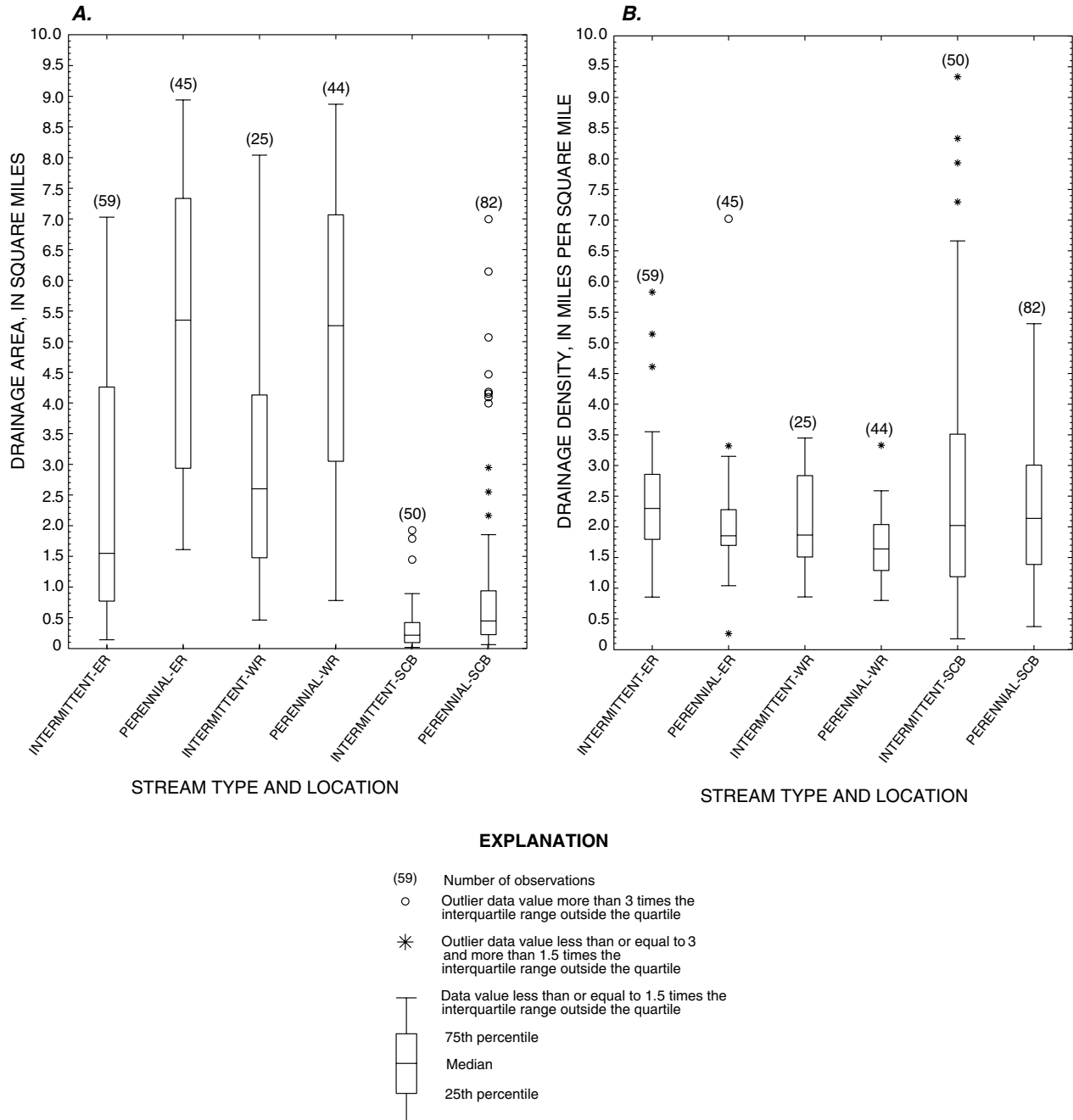
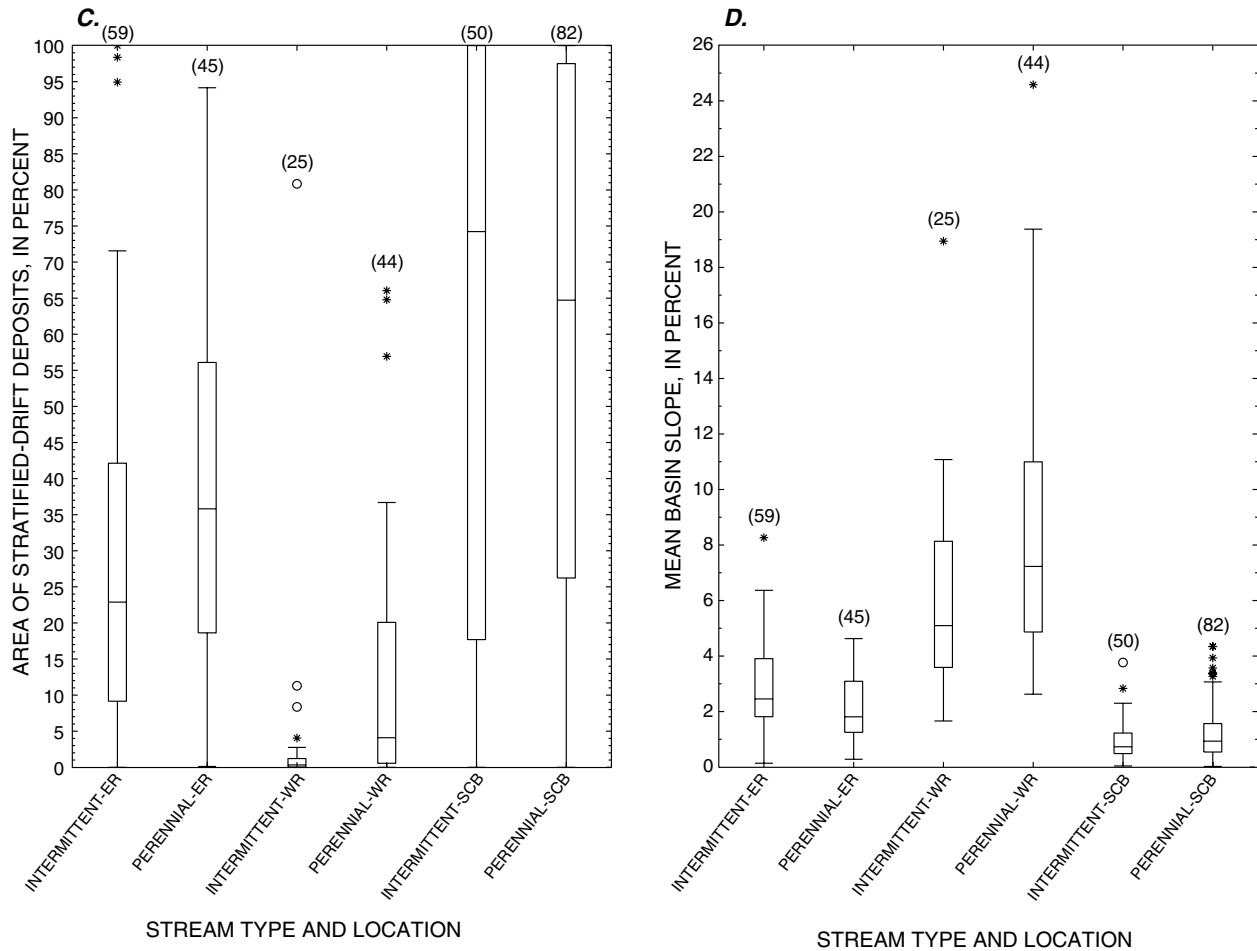


Figure 4. Distribution of (A) drainage area, (B) drainage density, (C) areal percentage of stratified-drift deposits, and (D) mean basin slope for intermittent- and perennial-stream sites in the eastern region (ER), western region (WR), and South Coastal Basin (SCB) of Massachusetts used in development of the logistic regression equation for estimating the probability of a stream flowing perennially in Massachusetts.

intermittent status could not be determined), (4) the stream site was just outside the South Coastal Basin, (5) no digitized stream-network data were available for the stream site in STREAMSTATS (because the stream is not shown on a USGS topographic map),

(6) the shape of the drainage-basin boundary drawn by STREAMSTATS did not match that determined from USGS topographic maps [because small drainage areas in low slope areas, such as the South Coastal Basin (fig. 4D), determined from STREAMSTATS



EXPLANATION

- (44) Number of observations
- Outlier data value more than 3 times the interquartile range outside the quartile
- * Outlier data value less than or equal to 3 and more than 1.5 times the interquartile range outside the quartile
- Data value less than or equal to 1.5 times the interquartile range outside the quartile
- 75th percentile
- Median
- 25th percentile

Figure 4. Distribution of (A) drainage area, (B) drainage density, (C) areal percentage of stratified-drift deposits, and (D) mean basin slope for intermittent- and perennial-stream sites in the eastern region (ER), western region (WR), and South Coastal Basin (SCB) of Massachusetts used in development of the logistic regression equation for estimating the probability of a stream flowing perennially in Massachusetts—*Continued.*

sometimes may not compare well to drainage areas for stream sites determined from topographic maps (P.A. Steeves, U.S. Geological Survey, oral commun., 2000)], and (7) the drainage area was greater than 9.00 mi². These criteria resulted in 50 intermittent- and 82 perennial-stream sites in the South Coastal Basin being included in the database. The intermittent-stream sites had a maximum drainage area of 1.92 mi² (station NL-19), a minimum drainage area of 0.02 mi² (station NL-42), a mean drainage area of 0.34 mi², and a median drainage area of 0.21 mi² (table 5). The perennial-stream sites had a maximum drainage area of 7.00 mi² (station HR-30), a minimum drainage area of 0.06 mi² (station HR-03), a mean drainage area of 1.00 mi², and a median drainage area of 0.45 mi² (table 5). The final database used in the analysis contained 305 stream sites, of which 134 sites were identified as intermittent, and 171 sites were identified as perennial.

SELECTION AND MEASUREMENT OF BASIN CHARACTERISTICS

Basin characteristics for most stream sites were determined with STREAMSTATS (Ries and others, 2000), unless the characteristics for a site had been determined for the Statewide August median stream-flow study by Ries (1997). STREAMSTATS was not used to verify basin characteristics determined in Ries (1997), because digital data layers were the same and STREAMSTATS is an automated procedure of the technique used in the earlier study. The basin-characteristics values determined for possible use in developing a logistic regression equation are drainage area, length of streams, area of stratified drift, and mean basin slope. Ries and Friesz (2000) found these characteristics to be the most significant explanatory variables for using regression equations to estimate low-flow characteristics at ungaged sites in Massachu-

setts. These characteristics, therefore, also may be important in predicting the probability of a stream flowing perennially at a specific site in Massachusetts.

These four basin characteristics currently (November 1, 2001) are determined by STREAMSTATS. Drainage areas were determined from 1:25,000 scale digital elevation models (DEMs). Length of streams were determined with centerline data of streams from a 1:25,000 scale hydrography digital data layer. The areas of stratified-drift deposits were determined from a 1:250,000 scale surficial geology digital data layer. Mean basin slopes were determined from 1:250,000 scale DEMs.

Drainage density (length of streams divided by drainage area) and the percentage of the drainage area of each basin underlain by stratified drift (area of stratified-drift deposits divided by drainage area) also were determined for each stream site for use in developing a logistic regression equation. Drainage density represents the magnitude per area of a network of streams within a basin for drainage of runoff. The areal percentage of stratified-drift deposits within a basin indicates whether a large or small proportion of the basin contains stratified-drift deposits.

LOGISTIC REGRESSION EQUATION

Logistic regression is a statistical technique that can be applied in water resources. In this technique, the probability of a result being in one of two response groups (binary response) is modeled as a function of the magnitudes of one or more explanatory variables (Helsel and Hirsch, 1992, p. 393–402). For instance, the probability whether or not a stream site is intermittent or perennial may be modeled as a function of the magnitudes of one or more basin characteristics. For this study, the response variable is “1” when the stream is perennial and “0” when the stream is intermittent.

Other studies have used logistic regression to determine the intermittent or perennial status of streams or to investigate other water-resource issues. In a study by Kliever (1996), logistic regression was used to determine the probability that streamflow would be zero for a particular low-flow statistic at a partial-record station given the same low-flow statistic at nearby index stations in northern Rhode Island. Other applications of logistic regression analyses in water resources have been completed by Eckhardt and others (1989), Eckhardt and Stackelberg (1995), Koltun and Sherwood (1998), and Squillace and others (1999).

Development

Logistic regression methods were used for estimating the probability of a stream being perennial at a specific site as a function of basin characteristics for the 84 intermittent- and 89 perennial-stream sites in the State and for the 50 intermittent- and 82 perennial-stream sites in the South Coastal Basin. Basin characteristics tested in the regression methods were drainage area, drainage density, areal percentage of stratified-drift deposits, and mean basin slope (tables 4 and 5). Drainage density and areal percentage of stratified-drift deposits represent a more relative measure of how these basin characteristics may affect the probability of a stream flowing perennially. These characteristics, therefore, were chosen over more absolute measures such as length of streams and area of stratified-drift deposits. Also, drainage density and areal percentage of stratified-drift deposits provide a more equal comparison of basins over a wide range of drainage-area sizes, as is the case in this study. Additionally, the four basin characteristics were transformed (square, cube, square root, and cube root), and then tested as possible explanatory variables. Transforming data is a common procedure that makes the data more symmetric, linear, and constant in variance (homoscedasticity) (Helsel and Hirsch, 1992, p. 12–14).

Two additional explanatory variables were tested that indicate whether the stream site was located in the western or eastern region of the State (fig. 1) and whether the site was located in the South Coastal Basin (fig. 2) or in the remainder of the State. The South Coastal Basin stream sites were those visited in the summer of 1999. Four stream sites in the South Coastal Basin, selected from review of the 205 perennial-stream sites in Massachusetts used by Ries (1997) (table 4), were not included with those sites visited in the summer of 1999. Massachusetts was split into western and eastern regions on the basis of observed differences in relations between the perennial or intermittent status of streams and their areal percentage of stratified-drift deposits and mean basin slope (figs. 4C and D).

Median drainage area and drainage density for perennial-stream sites in the eastern region were slightly greater than in the western region (figs. 4A and B). The median areal percentage of stratified-drift deposits for perennial-stream sites in the eastern region was about eight and a half times greater than in the western region (fig. 4C). The median mean basin slope for perennial-stream sites in the eastern region was about three and a half times lower than in the western region (fig. 4D). For drainage areas from 0.01 to 0.99 mi², the observed frequency of perennial-stream sites was greater in the western region than in the eastern region (figs. 5A and B). Additionally, Ries (1997) found in a Statewide August median streamflow study that the western region of the State had a higher August median streamflow per unit area than the eastern region. As a result of these tests, the regions were divided along the eastern border of the Connecticut River Basin or the eastern border of the Millers and Chicopee River Basins, which are a part of the Connecticut River Basin (fig. 1). Ries (1997) divided the State along these same borders.

The South Coastal Basin, which is part of the eastern region, was assigned its own location identifier because the data for this area of the State indicates a

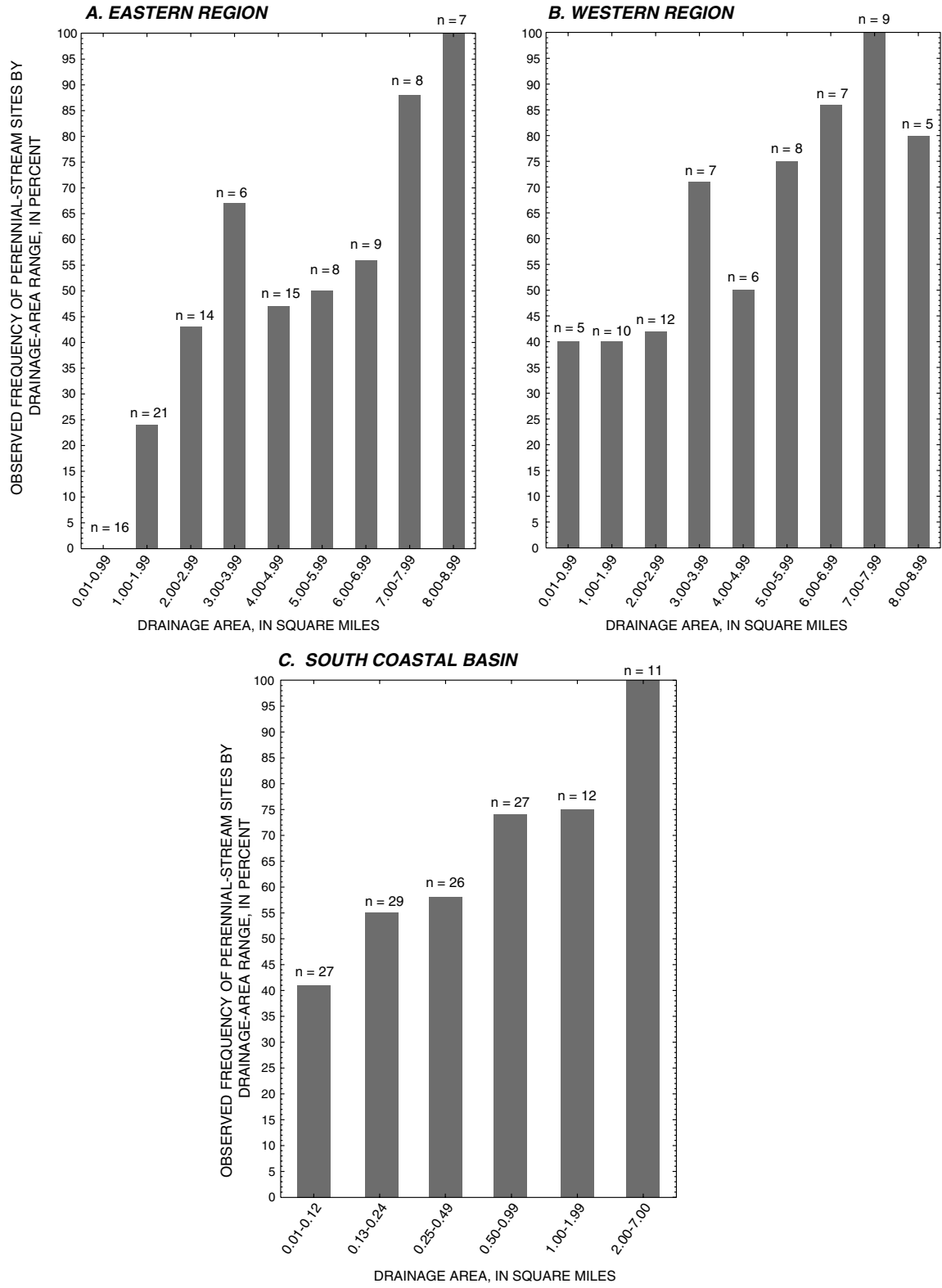


Figure 5. Observed frequency of perennial-stream sites by drainage-area range in the (A) eastern region, (B) western region, and (C) South Coastal Basin of Massachusetts (n, number of observations).

different relation between the perennial or intermittent status of stream sites and their drainage area, areal percentage of stratified-drift deposits, and mean basin slope that is different than the relation in the eastern and western regions of the State (figs. 4A, C, and D). For example, drainage area and mean basin slope were lower for stream sites in the South Coastal Basin than in the eastern and western regions, and areal percentage of stratified-drift deposits was greater in the South Coastal Basin than in the eastern and western regions (figs. 4A, C, and D). In the South Coastal Basin, the observed frequency of perennial-stream sites for drainage areas from 0.01 to 0.12 mi² is similar to the observed frequency of perennial-stream sites in the eastern region for drainage areas from 1.00 to 1.99 mi² and in the western region for drainage areas from 0.01 to 0.99, 1.00 to 1.99, and 2.00 to 2.99 mi² (figs. 5A–C). This greater observed frequency of a perennial-stream site for small drainage areas in the South Coastal Basin, as compared to the remainder of the State, likely results because of the greater areal percentage of stratified-drift deposit (fig. 4C). If the South Coastal Basin drainage area classes (fig. 5C) 0.01 to 0.12, 0.13 to 0.24, 0.25 to 0.49, and 0.50 to 0.99 mi² were combined, the observed frequency of perennial-stream sites would be 55 percent (62 perennial-stream sites of the 113 sites in those classes). This observed frequency of perennial-stream sites in the South Coastal Basin (55 percent) is not reached in the eastern region until the drainage area is from 2.00 to 2.99 mi² (fig. 5A), and is not reached in the western region until the drainage area is from 3.00 to 3.99 mi² (fig. 5B).

After stream sites were evaluated with basin characteristics for any regionalization, logistic regression analyses were done with the SAS statistical software package (SAS Institute, Inc., 1989; 1995). The general form of a logistic regression equation is

$$P = \frac{\exp(b_0 + b_1x_1 + \dots + b_ix_i)}{1 + \exp(b_0 + b_1x_1 + \dots + b_ix_i)},$$

where P is the probability of the condition being true, \exp is the exponential function and is written as $\exp(x)$ or $e^{(x)}$ (where “ e ” is the base of the natural logarithm and is approximately equal to 2.7183), b_0 is the intercept, $b_{1\dots i}$ is the coefficient for explanatory variable i , and $x_{1\dots i}$ is the value of explanatory

variable i . More detailed information on logistic regression can be found in Collett (1991) and Hosmer and Lemeshow (1989).

All potential explanatory variables (basin characteristics; square, cube, square root, and cube root transformations of the basin characteristics; and location identifiers) were evaluated by using the procedures of forward selection, backward elimination, stepwise selection, and best subset selection to help determine the best possible logistic regression equations (SAS Institute, Inc., 1995, p. 51–65). A statistical significance level of 0.05 for p -values of explanatory variables was used for entry or retention in the equations. These equations developed during the variable-evaluation process were used for estimating the probabilities that each of the stream sites was perennial.

The results of the equations were summarized in classification tables (SAS Institute, Inc., 1995, p. 45–50). These tables provide information about the predictive accuracy of an equation by summarizing the frequency with which observations are correctly and incorrectly classified as events or nonevents for different probability cutpoints. Because the same data are used to develop the equation and to test its predictive accuracy, a method that approximates the unbiased jackknifing procedure was used to create the classification tables (SAS Institute Inc., 1995, p. 45). Jackknifing minimizes bias caused when an independent set of observations is not available to test the predictive accuracy of the equation.

Goodness-of-fit of the potential logistic regression equations were evaluated with the Hosmer and Lemeshow (1989) goodness-of-fit test, which compares the observed to the predicted distribution of outcomes (SAS Institute, Inc., 1995, p. 67–72). Regression diagnostics of the equations also were evaluated to determine how each observation affects the fit of the logistic regression equation (SAS Institute, Inc., 1995, p. 73–79). Finally, receiver-operating-characteristic (ROC) curves were evaluated to assess the predictive accuracy of the logistic regression equation (SAS Institute Inc., 1995, p. 87–92).

The best logistic regression equation determined from data in this study is:

$$P = \frac{\exp(-5.6325 + 3.2619(x_1)^{1/3} - 0.2566(x_2) + 0.1248(x_3)^{1/2} + 0.1929(x_4) + 3.3236(x_5))}{1 + \exp(-5.6325 + 3.2619(x_1)^{1/3} - 0.2566(x_2) + 0.1248(x_3)^{1/2} + 0.1929(x_4) + 3.3236(x_5))},$$

where P is the probability of a stream flowing perennially at a specific site, \exp is approximately 2.7183, x_1 is the cube root of the drainage area of the basin (mi^2), x_2 is the drainage density in the basin (mi/mi^2), x_3 is the square root of the areal percentage of stratified-drift deposits in the basin (percentage), x_4 is the mean basin slope of the basin (percentage), and x_5 is an integer variable for the location of the stream site in the South Coastal Basin identifier (1 = in the South Coastal Basin, and 0 = in the remainder of State). Results of the analysis of the maximum estimates of this equation are presented in table 2 (SAS Institute Inc., 1995, p. 20–22). The p-values of each explanatory variable (parameters) are less than 0.05, the value used as the statistical significance level for entry or retention in the equation. Summary statistics of the logistic regression analyses for this equation with five explanatory variables (parameters) and other selected equations, which were determined to be the best equations of the equations tested with one to four variables, are presented in appendix A.

Application

An example application of the equation is provided for station NL—29 (table 5 and fig. 2) in the South Coastal Basin. Flow was observed at this stream site on August 20, 1999, and the site is represented as perennial on the USGS topographic map (Cohasset, Mass.). The values of the explanatory variables for input to the logistic regression equation were the cube root of a drainage area of 0.79 mi^2 (x_1), a drainage density of 2.26 mi/mi^2 (x_2), the square root of areal percentage of stratified-drift deposits of 45.61 percent (x_3), and a mean basin slope of 1.47 percent (x_4). The location-integer variable determined from a map was 1 (x_5), because the stream site is located in the South Coastal Basin. The equation for this stream site, therefore, is:

$$P = \frac{\exp(-5.6325 + 3.2619(0.79)^{1/3} - 0.2566(2.26) + 0.1248(45.61)^{1/2} + 0.1929(1.47) + 3.3236(1))}{1 + \exp(-5.6325 + 3.2619(0.79)^{1/3} - 0.2566(2.26) + 0.1248(45.61)^{1/2} + 0.1929(1.47) + 3.3236(1))}.$$

Table 2. Analysis of maximum likelihood estimates for the logistic regression equation for estimating the probability of a stream flowing perennially in Massachusetts

[SAS Institute, Inc., 1995; ^{1/3}, cube root; ^{1/2}, square root; <, actual value less than value shown]

Explanatory variable	Degrees of freedom	Estimate	Standard error	Chi-square	p-value
Intercept.....	1	-5.6325	0.9406	35.8614	<0.0001
Drainage area ^{1/3}	1	3.2619	.4829	45.6267	<.0001
Location (SCB or remainder of State).....	1	3.3236	.5381	38.1495	<.0001
Mean basin slope.....	1	.1929	.0636	9.1909	.0024
Areal percentage of stratified-drift deposits ^{1/2}	1	.1248	.0496	6.3344	.0118
Drainage density.....	1	-.2566	.1134	5.1242	.0236

The resulting probability, P , that this stream site is perennial, as determined with the logistic regression equation, is 0.76 (or 76 percent). Probabilities calculated with the logistic regression equation are given for the 173 stream sites in Massachusetts (table 4) and for the 132 sites in the South Coastal Basin (table 5).

The logistic regression equation developed during this study could be used for estimating the probability of a stream flowing perennial at a specific site at a probability cutpoint of 0.50, where a stream site would have an equal likelihood of being classified as perennial. The 0.50 cutpoint for this equation would

result in about 70 percent of the events (perennial streams) and nonevents (intermittent streams) in the database being correctly classified (table 3). Probability cutpoints other than 0.50 could be used, but the larger the cutpoint used, the greater the likelihood that a stream site will be classified as intermittent (table 3, False Negative column; events or perennial streams are incorrectly classified as nonevents or intermittent streams) and the smaller the cutpoint used, the greater the likelihood that a stream site will be classified as perennial (table 3, False Positive column; nonevents or intermittent streams are incorrectly classified as events or perennial streams).

Table 3. Classification table for the logistic regression equation for estimating the probability of a stream flowing perennially in Massachusetts

[Correct columns provide the frequency with which observations are correctly classified. Incorrect columns provide the frequency with which observations are incorrectly classified. Event is a perennial observation. Nonevent is an intermittent observation. Percent columns—Correct is the probability that the equation correctly classifies the sample data for each probability cutpoint. Sensitivity is the ratio of correctly classified events over the total number of events. For instance, at a cutpoint of 0.50 the sensitivity is 79.5 percent, because 136 of the 171 events are correctly classified. Specificity is the ratio of correctly classified nonevents over the total number of nonevents. For instance, at a cutpoint of 0.50 the specificity is 56.7 percent, because 76 of 134 nonevents are correctly classified. False positive is the ratio of the number of nonevents incorrectly classified as events over the sum of all observations classified as events. For instance, at a cutpoint of 0.50 the 58 nonevents incorrectly classified as events over the sum of 194 events. False negative is the ratio of the number of events incorrectly classified as nonevents over the sum of all observations classified as nonevents. For instance, at a cutpoint of 0.50 the 35 events incorrectly classified as nonevents over the sum of 111 nonevents. SAS Institute, Inc., 1995, p. 45–50]

Probability level	Correct		Incorrect		Percent				
	Event	Nonevent	Event	Nonevent	Correct	Sensitivity	Specificity	False positive	False negative
0.00	171	0	134	0	56.1	100.0	0.0	43.9	0.0
.05	171	8	126	0	58.7	100.0	6.0	42.4	.0
.10	171	15	119	0	61.0	100.0	11.2	41.0	.0
.15	168	29	105	3	64.6	98.2	21.6	38.5	9.4
.20	167	36	98	4	66.6	97.7	26.9	37.0	10.0
.25	164	41	93	7	67.2	95.9	30.6	36.2	14.6
.30	162	45	89	9	67.9	94.7	33.6	35.5	16.7
.35	159	58	76	12	71.1	93.0	43.3	32.3	17.1
.40	151	65	69	20	70.8	88.3	48.5	31.4	23.5
.45	141	73	61	30	70.2	82.5	54.5	30.2	29.1
.50	136	76	58	35	69.5	79.5	56.7	29.9	31.5
.55	127	86	48	44	69.8	74.3	64.2	27.4	33.8
.60	112	97	37	59	68.5	65.5	72.4	24.8	37.8
.65	100	100	34	71	65.6	58.5	74.6	25.4	41.5
.70	86	108	26	85	63.6	50.3	80.6	23.2	44.0
.75	68	121	13	103	62.0	39.8	90.3	16.0	46.0
.80	57	128	6	114	60.7	33.3	95.5	9.5	47.1
.85	33	130	4	138	53.4	19.3	97.0	10.8	51.5
.90	23	133	1	148	51.1	13.5	99.3	4.2	52.7
.95	11	133	1	160	47.2	6.4	99.3	8.3	54.6
1.00	0	134	0	171	43.9	.0	100.0	.0	56.1

LIMITATIONS OF THE LOGISTIC REGRESSION EQUATION AND AREAS FOR FURTHER STUDY

The logistic regression equation developed is applicable for stream sites with drainage areas between 0.02 and 7.00 mi² in the South Coastal Basin and between 0.14 and 8.94 mi² in the remainder of Massachusetts, because these were the smallest and largest drainage areas used in equation development for their respective areas. The equation may not be reliable for drainage areas less than 0.14 mi² in the State and less than 0.02 mi² in the South Coastal Basin. For drainage areas greater than 8.94 mi² in the State and greater than 7.00 mi² in the South Coastal Basin the equation could be used. It may not be necessary, however, because all stream sites greater than 8.04 mi² in the State and 1.92 mi² in the South Coastal Basin were perennial. The equation may not be reliable for losing reaches of streams, such as for streams that flow off an area underlain by till or bedrock onto an area underlain by stratified-drift deposits (these areas are likely more prevalent where hillsides meet river valleys in central and western Massachusetts). At this juncture of the different underlying surficial deposit types, the stream can lose streamflow through its streambed. Generally, a losing stream reach occurs where the water table does not intersect the streambed in the channel (water table is below the streambed) during low-flow periods. In these reaches, the equation would tend to overestimate the probability of a stream flowing perennially at a site.

The logistic regression equation may not be reliable in areas of Massachusetts where ground-water and surface-water drainage areas for a stream site differ. This condition may be present in southeastern Massachusetts, particularly for streams draining the southern part of the South Coastal Basin, the eastern part of the Buzzards Bay Basin, and the entire area of the Cape Cod and Islands Basins (labeled as the Southeast Coastal Region in fig. 1). In these areas, ground water can flow from one basin into another; therefore, in basins that have a larger ground-water contributing area than the surface-water drainage area the equation may underestimate the probability that a stream is perennial. Conversely, in areas where the

ground-water contributing area is less than the surface-water-drainage area, the equation may overestimate the probability that a stream is perennial.

The accuracy of the logistic regression equation is a function of the quality of the data used in its development. This data includes the measured perennial or intermittent status of a stream site, the occurrence of unknown regulation above a site, and the measured basin characteristics. The measured perennial or intermittent status of stream sites in Massachusetts is based on information in the USGS NWIS database. Streamflow measured as less than 0.005 ft³/s is rounded down to zero, so it is possible that several streamflow measurements reported as zero may have had flows less than 0.005 ft³/s in the stream. This measurement would cause stream sites to be classified as intermittent when they actually are perennial. Additionally, of the stream sites selected from the NWIS database, 61 of 62 intermittent-stream sites and 89 of 89 perennial-stream sites were represented as perennial streams on USGS topographic maps; therefore, the Statewide database (sample) used in development of the equation may not be random, because stream sites often selected for streamflow measurements are represented as perennial streams on USGS topographic maps. Also, the drainage area of stream sites selected for streamflow measurements generally is greater than about 1.0 mi², which may result in the sample not being random.

The observed perennial or intermittent status of stream sites in the South Coastal Basin database may also be biased, because the sites were measured during the summer of 1999. The summer of 1999 did not meet the definition of an extended drought; but monthly precipitation near the South Coastal Basin was less than 50 percent of average in April, less than 25 percent of average in June, about 75 percent of average in July (excluding one station), and about 50 percent of average in August (excluding one station) (fig. 6). Additionally, Socolow and others (2000) reported streamflows and ground-water levels well below normal throughout most of Massachusetts during the summer of 1999. Consequently, stream sites classified as intermittent would have been omitted from the database had this period been classified as an extended drought. This climatic condition during the summer of

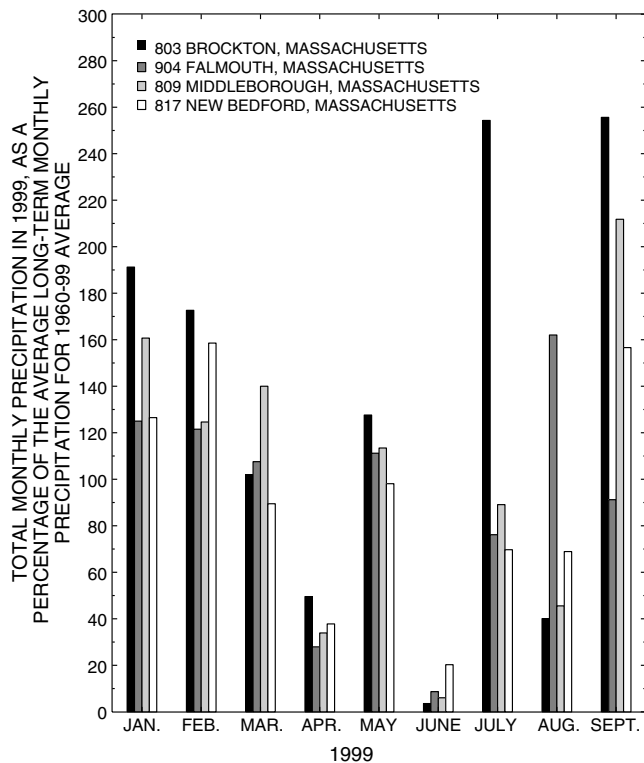


Figure 6. Total monthly precipitation from January through September 1999, as a percentage of the average long-term monthly precipitation for 1960–99 at the Brockton, Falmouth, Middleborough, and New Bedford precipitation stations near the South Coastal Basin, southeastern Massachusetts.

1999 could bias the logistic regression equation toward a lower probability of a stream site being considered perennial in the South Coastal Basin.

Basin characteristics of the stream sites used in the logistic equation development are limited by the accuracy of the digital data layers used. In the future, digital data layers (such as hydrography, surficial geology, soils, DEMs, and land use) will be at lower scales, such as 1:5,000 or 1:25,000. This would improve the accuracy of the measured basin characteristics used as explanatory variables to predict the probability of a stream flowing perennially. For this study, the area of stratified-drift deposits and consequently the areal percentage of stratified-drift deposits included areas with sand and gravel, large sand, fine-grained, and floodplain alluvium deposits. Future studies would allow more specificity in testing the areal percentage of surficial deposits as explanatory variables. For example, the

areal percentage of sand and gravel deposits may be an important explanatory variable for estimating the probability that a stream site is perennial.

The accuracy of the logistic regression equation also may be improved with the testing of additional basin characteristics as explanatory variables. These explanatory variables could include areal percentage of wetlands (forested and non-forested), areal percentage of water bodies, areal percentage of forested land, areal percentage of urban land, or mean, minimum, and maximum basin elevation. Soils data from county soil surveys completed by the Natural Resources Conservation Service (formerly the Soil Conservation Service) eventually will be available for all counties of Massachusetts as a digital data layer referred to as SSURGO (U.S. Department of Agriculture, Natural Resources Conservation Service, Soil Survey Division, 2000). This data layer would allow testing of soil characteristics (such as the four different hydrologic soil groups A, B, C, and D, which relate to the infiltration rate of particular soil types) as potential explanatory variables. Physically measured characteristics of the stream at the stream sites also may be reflective of its perennial or intermittent status, such as the width of the stream channel at the mean annual high-water line (bankfull), the stream channel area at bankfull, and general streambed material.

The logistic regression equation for this study or future studies could be incorporated into the STREAMSTATS, so that the probability of a stream flowing perennially at a specific site could be calculated interactively by users on the World Wide Web. The equation also could be used to develop maps depicting intermittent and perennial streams in Massachusetts, if a particular threshold of acceptable probability for classifying a stream as perennial at a site were determined.

SUMMARY AND CONCLUSIONS

City and town conservation commissions and the Massachusetts Department of Environmental Protection (MADEP) are charged with protecting the riverfront areas of all rivers that flow on a year round basis within Massachusetts, as specified in the Commonwealth of Massachusetts Rivers Protection

Act of 1996. The 310 Code of Massachusetts Regulations (CMR) 10.58(2)(a) defines the riverfront areas as the 200-ft wide area extending along the length of each side of the stream from the mean annual high-water line on each side of perennial streams, with exceptions in some urban areas. Initial designation of a stream being perennial or intermittent at a site is determined by the representation on the most current USGS topographic map, which may or may not accurately represent a perennial or intermittent status, or on a more recent map developed by the MADEP (if available). The Regulations, however, do allow the reversal of the perennial or intermittent status at a stream site if a competent source can provide specific evidence to the contrary.

To assist city and town conservation commissions and the MADEP in determining whether a stream is perennial or intermittent at a site, a logistic regression equation was developed by the U.S. Geological Survey, in cooperation with the Massachusetts Executive Office of Environmental Affairs (MAEOEA) and the MADEP, for estimating the probability of a stream flowing perennially at a specific site as a function of upstream basin characteristics. Approximately 1,300 stream sites in Massachusetts in the USGS National Water Information System (NWIS) database and 397 stream sites visually inspected in the South Coastal Basin were reviewed for possible inclusion in the database used for equation development. Stream sites had to meet four main requirements to be included in the database. The main requirements for stream sites to be included in the database were that (1) the stream site had to be a natural flowing stream (no regulation by dams, surface-water withdrawals, ground-water withdrawals, diversion, wastewater discharge, and so forth), (2) measured or observed zero flow(s) could not occur during a month of an extended drought, as defined by the Regulations, (3) the perennial-stream sites had to have at least three streamflow measurements to insure that it was likely that at least one measurement was made during normal climatic conditions (only for sites in the NWIS database), and (4) the stream site could not be in the Cape Cod Basin, Islands

Basin, southern part of the South Coastal Basin, or eastern part of the Buzzards Bay Basin (where ground-water and surface-water-source areas differ). The database used to develop the logistic regression equation included 305 stream sites (84 intermittent and 89 perennial sites in the State, and 50 intermittent and 82 perennial sites in the South Coastal Basin). Stream sites used in the database had drainage areas that ranged from 0.14 to 8.94 mi² in the State and from 0.02 to 7.00 mi² in the South Coastal Basin.

The basin characteristics determined for the 305 stream sites were drainage area, drainage density, areal percentage of stratified-drift deposits, and mean basin slope. These basin characteristics, transformations (square, cube, square root, and cube root) of the basin characteristics, a variable that identified whether the stream site was in the western or eastern region of the State, and a variable that identified whether the site was in the South Coastal Basin or in the remainder of the State, then were tested as explanatory variables in the logistic regression analyses. Results of the logistic regression analyses indicate that the probability of a stream flowing perennially at a specific site in Massachusetts can be estimated as a function of (1) drainage area (cube root), (2) drainage density, (3) areal percentage of stratified-drift deposits (square root), (4) mean basin slope, and (5) location of the stream site in the South Coastal Basin or the remainder of the State.

The logistic regression equation developed provides an objective means for estimating the probability of a stream being flowing perennially at a specific site; however, the reliability of the equation is constrained by the data used to develop the equation. The equation may not be reliable for (1) drainage areas less than 0.14 mi² in the State and less than 0.02 mi² in the South Coastal Basin, (2) streams with losing reaches, or (3) streams draining the southern part of the South Coastal Basin and the eastern part of the Buzzards Bay Basin and the entire area of the Cape Cod and Islands Basins.

REFERENCES CITED

- Collett, D., 1991, Modelling binary data: New York, Chapman and Hall, 369 p.
- Eckhardt, D.A.V., Flipse, W.J., and Oaksford, E.T., 1989, Relation between land use and ground-water quality in the upper glacial aquifer in Nassau and Suffolk Counties, Long Island, New York: U.S. Geological Survey Water-Resources Investigations Report 86-4142, 35 p.
- Eckhardt, D.A.V., and Stackelberg, P.E., 1995, Relation of ground-water quality to land use on Long Island, New York: *Ground Water*, v. 33, no. 6, p. 1019–1033.
- Helsel, D.R., and Hirsch, R.M., 1992, Statistical methods in water resources: New York, Elsevier Science Publishing Company, Inc., *Studies in Environmental Science* 49, 522 p.
- Hosmer, D.W., and Lemeshow, Stanley, 1989, Applied logistic regression: New York, John Wiley and Sons, 307 p.
- Kliever, J.D., 1996, Low-flow characteristics of selected streams in northern Rhode Island: U.S. Geological Survey Water-Resources Investigations Report 95-4299, 11 p.
- Koltun, G.F., and Sherwood, J.M., 1998, Factors related to the joint probability of flooding on paired streams: U.S. Geological Survey Water-Resources Investigations Report 98-4238, 32 p.
- Massachusetts Department of Environmental Protection, 2000, Wetlands protection act regulations, 310 CMR 10.00, accessed November 5, 2001, at URL <http://www.state.ma.us/dep/brp/ww/files/310cmr10.pdf>.
- Ries, K.G., 1994a, Estimation of low-flow duration discharges in Massachusetts: U.S. Geological Survey Water-Supply Paper 2418, 50 p.
- _____, 1994b, Development and application of generalized-least-squares regression models to estimate low-flow duration discharges in Massachusetts: U.S. Geological Survey Water-Resources Investigations Report 94-4155, 33 p.
- _____, 1997, August median streamflows in Massachusetts: U.S. Geological Survey Water-Resources Investigations Report 97-4190, 27 p.
- Ries, K.G., and Friesz, P.J., 2000, Methods for estimating low-flow statistics for Massachusetts streams: U.S. Geological Survey Water-Resources Investigations Report 00-4135, 81 p.
- Ries, K.G., Steeves, P.A., Freeman, Aleda, and Singh, Raj, 2000, Obtaining streamflow statistics for Massachusetts streams on the World Wide Web: U.S. Geological Survey Fact Sheet 104-00, 4 p.
- SAS Institute, Inc., 1989, SAS/STAT User's guide, version 6, fourth edition, volume 2: Cary, N.C., 846 p.
- _____, 1995, Logistic regression examples using the SAS system, version 6 (1st ed.): Cary, N.C., 163 p.
- Socolow, R.S., Zanca, J.L., Murino, Domenic, Jr., and Ramsbey, L.R., 2000, Water resources data Massachusetts and Rhode Island, water year 1999: U.S. Geological Survey Water Data Report MA-RI-99-1, 401 p. Available online at http://ma.water.usgs.gov/current_cond/adr/adr99/default.htm.
- Squillace, P.J., Moran, M.J., Lapham, W.W., Price, C.V., Clawges, R.M., and Zogorski, J.S., 1999, Volatile organic compounds in untreated ambient groundwater of the United States, 1985–1995: *Environmental Science and Technology*, v. 33, no. 23, p. 4176–4187.
- The Commonwealth of Massachusetts, 1996, An act providing protection for the rivers of the Commonwealth, accessed November 5, 2001, at URL <http://www.state.ma.us/dep/brp/ww/files/riveract.htm>.
- U.S. Department of Agriculture, Natural Resources Conservation Service, Soil Survey Division, 2000, National SSURGO database—data, accessed December 23, 2000, at URL http://www.ftw.nrcs.usda.gov/ssur_data.html.

Tables 4 and 5

Table 4. Description, basin characteristics, and perennial- or intermittent-status determination for stream sites at discontinued and continuous streamflow-gaging stations and partial-record stations by region and major river basin in Massachusetts used in development of the logistic regression equation for estimating the probability of a stream flowing perennially in Massachusetts

[USGS Station No.: Location shown in figure 1. **Latitude and longitude:** Given in degrees, minutes, seconds. I, Intermittent; P, Perennial; USGS, U.S. Geological Survey; mi/mi²; miles per square mile; mi², square mile; %, percent]

USGS station No.	Station name	Latitude ° ' "	Longitude ° ' "	Drainage area (mi ²)	Drainage density (mi/mi ²)	Area of stratified-drift deposits (%)	Mean basin slope (%)	Measured or recorded status of stream site	USGS topographic map designation of status of stream site	Probability of stream flowing perennially at stream site (%)
EASTERN REGION										
North Coastal Basin										
01073860	Small Pox Brook at Salisbury	42 51 00	70 51 59	1.83	2.30	98.36	0.84	I	P	30
01102053	Crane Brook at Danvers	42 33 34	70 56 55	2.72	1.79	63.24	1.99	P	P	46
Nashua River Basin										
01094760	Wausacum Brook near West Boylston	42 23 49	71 46 48	7.41	1.72	21.86	3.81	P	P	83
01095380	Trout Brook near Holden	42 23 00	71 50 12	6.79	1.71	28.72	3.99	P	P	82
01095928	Trapfall Brook near Ashby	42 40 24	71 46 39	5.89	2.25	11.21	4.93	I	P	74
01095940	Locke Brook at West Townsend	42 40 42	71 45 31	4.26	2.19	12.57	5.96	I	P	66
01095960	Walker Brook near West Townsend	42 42 07	71 46 06	7.03	1.67	2.23	6.37	I	P	83
01095989	Bixby Brook near Townsend	42 38 53	71 41 18	2.76	1.77	57.21	3.61	I	P	53
01096504	Reedy Meadow Brook at East Pepperell	42 40 03	71 33 55	1.92	1.70	79.17	1.93	P	P	37
01096505	Unkety Brook near Pepperell	42 41 23	71 32 54	6.84	1.86	67.54	2.28	P	P	82
Concord River Basin										
01096600	Assabet River at Westborough	42 16 16	71 37 59	6.73	2.36	23.72	3.63	I	P	77
01096850	Mill Brook near Hudson	42 24 59	71 35 09	4.61	2.75	29.51	3.47	I	P	61
01096855	Danforth Brook at Hudson	42 23 57	71 34 00	6.62	2.80	26.59	3.71	P	P	76
01096906	Boulder Brook near East Bolton	42 27 10	71 34 52	1.36	2.08	2.25	3.91	I	P	17
01096910	Boulder Brook at East Bolton	42 27 04	71 34 39	1.61	1.86	11.18	3.66	P	P	24
01097200	Heath Hen Meadow Brook at Stow	42 26 44	71 30 02	3.91	2.86	22.98	1.97	I	P	44
Merrimack River Basin										
01100050	Trout Brook near Dracut	42 41 08	71 16 10	.69	4.61	2.90	2.45	I	P	4
01100100	Richardson Brook near Lowell	42 39 48	71 16 02	4.23	2.99	25.42	1.96	I	P	47
01100200	Trull Brook near Lowell	42 38 58	71 15 38	4.33	1.94	71.56	1.36	I	P	62
01100300	Fish Brook near Andover	42 40 47	71 13 08	5.87	2.22	48.44	2.37	I	P	73
01100350	Bartlett Brook near Dracut	42 42 08	71 15 16	1.72	2.67	16.86	2.14	I	P	18

Table 4. Description, basin characteristics, and perennial- or intermittent-status determination for stream sites at discontinued and continuous streamflow-gaging stations and partial-record stations by region and major river basin in Massachusetts used in development of the logistic regression equation for estimating the probability of a stream flowing perennially in Massachusetts — *Continued*

USGS station No.	Station name	Latitude ° ' "	Longitude ° ' "	Drainage area (mi ²)	Drainage density (mi/mi ²)	Area of stratified-drift deposits (%)	Mean basin slope (%)	Measured or recorded status of stream site	USGS topographic map designation of status of stream site	Probability of stream flowing perennially at stream site (%)
EASTERN REGION—Continued										
Merrimack River Basin—Continued										
01100400	Bartlett Brook near Methuen	42 42 15	71 13 27	6.68	2.89	11.67	2.17	I	P	65
01100640	Bare Meadow Brook near Methuen	42 44 38	71 08 59	.80	1.90	32.50	1.94	I	P	12
01100650	Hawkes Brook at North Street near Methuen	42 46 35	71 10 19	1.40	1.28	9.15	2.34	I	P	19
01100655	Hawkes Brook near Methuen	42 45 06	71 08 17	4.35	1.99	17.72	2.57	I	P	53
01100665	West Meadow Brook near Haverhill	42 47 00	71 07 41	1.42	1.30	.00	2.69	I	P	14
01100700	East Meadow River near Haverhill	42 48 41	71 01 59	5.54	1.82	31.05	2.78	P	P	71
01100800	Cobbler Brook near Merrimac	42 50 55	71 01 10	.77	2.87	.00	4.27	I	P	7
01100802	Cobbler Brook at East Main Street at Merrimac	42 50 03	71 00 05	2.48	2.41	12.50	4.28	I	P	36
01100808	Sawmill Brook at West Newbury	42 47 53	70 58 45	.51	1.75	13.73	2.85	I	P	8
01100810	Indian River near West Newbury	42 48 25	70 58 04	1.41	1.80	11.27	3.37	I	P	20
01100817	Upper Artichoke Reservoir Tributary near West Newbury	42 47 33	70 56 45	1.34	1.62	30.60	2.61	I	P	22
Shawsheen River Basin										
01100572	Elm Brook Tributary near Concord	42 28 06	71 19 05	.14	2.14	100.00	.14	I	P	4
01100593	McKee Brook near Billerica	42 31 29	71 14 47	.29	1.86	13.79	.70	I	P	3
01100607	Meadow Brook at Kendall Street near Tewksbury	42 37 56	71 13 15	1.46	3.10	18.69	2.00	I	P	14
01100608	Meadow Brook near Tewksbury	42 37 14	71 12 44	4.09	2.50	53.06	1.37	P	P	53
01100616	Shawsheen River Tributary #3 at Ballardvale	42 37 32	71 08 27	.76	2.57	31.58	3.15	I	I	12
01100617	Shawsheen River Tributary #5 near Andover	42 37 31	71 09 58	.38	1.50	44.74	2.11	I	P	8
01100618	Shawsheen River Tributary #6 near Andover	42 38 25	71 08 45	.14	5.14	7.14	3.18	I	I	1
01100623	Rogers Brook Tributary at Andover	42 39 30	71 07 35	.14	1.40	.00	2.09	I	I	2
01100628	Hussey Brook near Andover	42 40 01	71 10 23	.38	3.11	28.95	1.75	I	P	4
01100633	Shawsheen River Tributary #8 near North Andover	42 40 49	71 08 02	.27	.96	.00	4.13	I	I	5
Ipswich River Basin										
01101850	Pye Brook near Topsfield	42 39 17	70 57 12	6.66	2.34	77.03	1.12	P	P	77

Table 4. Description, basin characteristics, and perennial- or intermittent-status determination for stream sites at discontinued and continuous streamflow-gaging stations and partial-record stations by region and major river basin in Massachusetts used in development of the logistic regression equation for estimating the probability of a stream flowing perennially in Massachusetts — *Continued*

USGS station No.	Station name	Latitude ° ' "	Longitude ° ' "	Drainage area (mi ²)	Drainage density (mi/mi ²)	Area of stratified-drift deposits (%)	Mean basin slope (%)	Measured or recorded status of stream site	USGS topographic map designation of status of stream site	Probability of stream flowing perennially at stream site (%)
EASTERN REGION—Continued										
Boston Harbor Basin										
011024592	Aberjona River Tributary #1 near Woburn	42 29 48	71 07 50	5.76	1.73	26.41	1.52	I	P	67
011024596	Aberjona River Tributary #3 near Woburn	42 29 36	71 07 44	6.17	1.83	65.56	1.57	I	P	77
01102470	Sweetwater Brook at Stoneham	42 28 45	71 06 44	2.08	.26	15.38	2.41	P	P	36
01102482	Little Brook near Woburn	42 28 48	71 11 01	1.04	2.59	2.88	2.63	I	P	9
01102490	Shaker Glen Brook near Woburn	42 28 16	71 10 34	3.05	1.66	11.15	3.21	P	P	43
01103015	Mill Brook at Arlington	42 25 20	71 08 59	5.35	1.96	42.24	3.21	P	P	73
01104880	Neponset River Tributary near Walpole	42 09 55	71 14 54	1.53	2.93	20.45	1.66	I	P	15
01104910	Bubbling Brook North Street near Westwood	42 12 04	71 15 01	.19	.85	.00	3.90	I	P	4
01104960	Germany Brook near Norwood	42 11 04	71 13 29	2.37	1.76	28.27	1.65	P	P	32
01104980	Hawes Brook at Norwood	42 10 26	71 12 31	8.64	1.79	25.46	2.27	P	P	84
01105100	Traphole Brook near Norwood	42 09 36	71 11 47	3.40	1.72	57.65	3.03	P	P	59
01105150	Neponset River Tributary #2 near Sharon	42 08 52	71 10 48	.39	3.02	54.96	4.38	I	P	10
01105400	Pequid Brook near Canton	42 10 29	71 06 45	4.52	1.74	39.08	.92	I	P	57
01105525	Purgatory Brook at Islington	42 12 54	71 11 24	1.28	2.66	5.09	1.96	I	P	11
01105568	Cochato River at Holbrook	42 09 19	71 01 37	4.31	1.52	47.33	1.30	P	P	60
01105573	Tumbling Brook at Holbrook	42 09 59	71 01 13	1.00	1.85	19.65	1.38	I	P	12
01105575	Cranberry Brook at Braintree Highlands	42 11 02	71 00 42	1.72	1.04	.58	2.13	P	P	18
01105600	Old Swamp River near South Weymouth	42 11 25	70 56 43	4.47	1.80	33.56	1.27	P	P	56
01105614	Whitmans Pond Outlet Tributary #2 at East Weymouth	42 12 52	70 55 08	.33	.91	94.93	1.82	I	I	12
01105630	Crooked Meadow River near Hingham Center	42 12 53	70 53 06	4.91	2.22	74.13	1.63	P	P	68
Charles River Basin										
01103214	Beaver Brook near Holliston	42 10 48	71 28 46	2.24	2.93	27.03	2.46	I	P	27
01103253	Chicken Brook near West Medway	42 08 27	71 25 26	7.23	2.55	15.08	2.29	P	P	72
01103360	Mill Brook near Medfield	42 12 38	71 18 48	2.14	2.48	31.41	3.01	I	P	31
01103415	Indian Brook near Sherborn	42 15 34	71 21 25	1.30	1.97	52.31	1.90	I	P	21
01103440	Fuller Brook at Wellesley	42 17 45	71 17 18	3.91	1.80	60.10	1.58	P	P	58
01104400	Hobbs Brook near Lincoln	42 26 17	71 16 51	1.30	2.52	45.44	2.56	I	P	20
01104405	Hobbs Brook at Mill Street near Lincoln	42 26 11	71 16 12	2.04	2.50	42.13	2.34	I	P	29

Table 4. Description, basin characteristics, and perennial- or intermittent-status determination for stream sites at discontinued and continuous streamflow-gaging stations and partial-record stations by region and major river basin in Massachusetts used in development of the logistic regression equation for estimating the probability of a stream flowing perennially in Massachusetts — *Continued*

USGS station No.	Station name	Latitude ° ' "	Longitude ° ' "	Drainage area (mi ²)	Drainage density (mi/mi ²)	Area of stratified-drift deposits (%)	Mean basin slope (%)	Measured or recorded status of stream site	USGS topographic map designation of status of stream site	Probability of stream flowing perennially at stream site (%)
EASTERN REGION—Continued										
South Coastal Basin										
01105670	Satuit River at Scituate	42 11 35	70 43 44	1.61	1.53	9.32	0.81	P	P	16
01105820	Second Herring Brook at Norwell	42 09 36	70 47 20	3.17	1.92	24.29	1.14	P	P	38
01105830	First Herring Brook near Scituate Center	42 11 30	70 46 49	1.72	1.85	4.65	.61	P	P	14
01105861	Jones River Brook near Kingston	41 59 47	70 47 18	4.74	1.67	89.03	1.06	P	P	69
Buzzards Bay Basin										
011059106	Masstapoissett River Tributary #1 near Rochester	41 44 35	70 52 04	2.58	1.34	63.57	.61	P	P	40
01105930	Paskamanset River at Turner Pond near New Bedford	41 40 43	70 58 39	8.09	2.15	44.87	1.24	P	P	81
01105935	Destruction Brook near South Dartmouth	41 34 20	71 00 47	2.64	2.18	54.55	1.82	P	P	40
01105937	Shingle Island River near North Dartmouth	41 40 55	71 01 05	8.59	1.78	38.07	1.52	P	P	84
01106000	Adamsville Brook at Adamsville, R.I.	41 33 30	71 07 47	7.99	2.21	2.25	1.51	P	P	69
Taunton River Basin										
01106430	Trout Brook at Brockton	42 05 26	71 00 45	5.88	1.70	40.48	1.62	P	P	72
01106460	Beaver Brook near East Bridgewater	42 02 43	70 58 17	8.94	1.93	36.91	1.50	P	P	84
01107000	Dorchester Brook near Brockton	42 03 41	71 03 59	4.71	2.04	18.68	1.10	I	P	52
01107010	Queset Brook at North Easton	42 03 57	71 05 43	7.47	2.50	27.84	1.94	P	P	76
01108140	Poquoy Brook near North Middleboro	41 54 20	70 59 19	8.20	1.95	85.12	1.09	P	P	86
01108180	Cotley River at East Taunton	41 52 57	71 02 54	7.48	1.54	49.33	.96	P	P	80
01108350	Mulberry Meadow Brook near Easton Center	42 01 07	71 07 35	8.35	3.15	41.92	1.26	P	P	77
01108600	Hodges Brook at West Mansfield	41 59 11	71 14 27	3.83	2.97	65.01	.96	I	P	48
01109090	Rattlesnake Brook near Assonet	41 46 36	71 05 23	4.22	1.47	35.78	1.81	P	P	59
Narragansett Bay and Mt. Hope Bay Shore Basin										
01109185	East Branch Palmer River near Rehoboth	41 51 36	71 13 47	5.86	1.48	45.90	.95	I	P	71
01109200	West Branch Palmer River near Rehoboth	41 52 46	71 15 18	4.33	2.14	64.20	.32	I	P	55
01109225	Rocky Run near Rehoboth	41 46 32	71 15 03	7.21	1.61	39.53	1.11	P	P	78
Tenmile River Basin										
01109381	Speedway Brook at Attleboro	41 55 37	71 17 08	2.82	7.02	94.15	.28	P	P	17

Table 4. Description, basin characteristics, and perennial- or intermittent-status determination for stream sites at discontinued and continuous streamflow-gaging stations and partial-record stations by region and major river basin in Massachusetts used in development of the logistic regression equation for estimating the probability of a stream flowing perennially in Massachusetts — *Continued*

USGS station No.	Station name	Latitude ° ' "	Longitude ° ' "	Drainage area (mi ²)	Drainage density (mi/mi ²)	Area of stratified-drift deposits (%)	Mean basin slope (%)	Measured or recorded status of stream site	USGS topographic map designation of status of stream site	Probability of stream flowing perennially at stream site (%)
EASTERN REGION—Continued										
Blackstone River Basin										
01109950	West Brook near Shrewsbury	42 17 29	71 44 23	2.23	2.66	23.33	4.96	I	P	38
01111142	Miscoe Brook near Grafton	42 11 25	71 39 23	5.67	2.06	22.93	3.98	P	P	73
01111160	Center Brook at Upton	42 11 13	71 35 46	2.10	2.66	22.89	4.90	I	P	34
01111225	Emerson Brook near Uxbridge	42 02 40	71 37 21	7.26	2.37	35.81	3.15	P	P	81
01112190	Muddy Brook at South Milford	42 05 35	71 31 11	6.17	2.63	15.40	3.38	P	P	69
Quinebaug River Basin										
01123100	Mountain Brook near Brimfield	42 07 10	72 13 08	1.35	3.04	14.35	8.26	I	P	32
01123161	Wales Brook at Brimfield	42 06 52	72 11 36	6.57	2.33	28.61	5.96	I	P	84
01123200	Stevens Brook at Holland	42 03 41	72 09 45	4.39	2.95	4.10	4.63	P	P	52
01124100	Tufts Branch near Dudley	42 01 42	71 56 19	2.40	3.55	4.98	4.83	I	P	28
French River Basin										
01124390	Little River at Richardson Road Corners	42 09 16	71 54 47	8.58	3.32	.12	3.82	P	P	73
01124750	Browns Brook near Webster	42 0 324	71 49 51	.52	2.52	.00	4.77	I	P	6
01124800	Sucker Brook near Webster	42 04 01	71 51 16	1.55	5.83	2.05	6.21	I	P	12
WESTERN REGION										
Millers River Basin										
01163298	Trout Brook near Baldwinville	42 35 49	72 05 28	7.22	1.51	35.87	3.09	P	P	84
01165250	Riceville Brook near South Athol	42 32 17	72 14 51	7.08	1.59	20.48	4.34	P	P	84
01166105	Whetstone Brook at Depot Road at Wendell Depot	42 35 39	72 21 41	5.24	2.02	23.66	7.39	P	P	82
01166400	Keyup Brook at Erving	42 36 08	72 24 00	7.03	1.08	4.13	11.38	P	P	94
Deerfield River Basin										
01169800	Poland Brook near Conway	42 29 16	72 44 47	4.02	2.04	1.17	7.01	P	P	63
01170240	Mill Brook near Bernardston	42 39 33	72 34 18	2.79	1.64	.00	11.40	P	P	68

Table 4. Description, basin characteristics, and perennial- or intermittent-status determination for stream sites at discontinued and continuous streamflow-gaging stations and partial-record stations by region and major river basin in Massachusetts used in development of the logistic regression equation for estimating the probability of a stream flowing perennially in Massachusetts — *Continued*

USGS station No.	Station name	Latitude ° ' "	Longitude ° ' "	Drainage area (mi ²)	Drainage density (mi/mi ²)	Area of stratified-drift deposits (%)	Mean basin slope (%)	Measured or recorded status of stream site	USGS topographic map designation of status of stream site	Probability of stream flowing perennially at stream site (%)
WESTERN REGION—Continued										
Connecticut River Basin										
01170902	Bloody Brook near South Deerfield	42 28 30	72 38 03	5.48	2.06	80.84	2.98	I	P	78
01171800	Bassett Brook near Northampton	42 18 09	72 41 16	5.56	1.65	36.69	5.20	P	P	81
01177360	South Branch Mill River at Porter Road near East Longmeadow	42 05 06	72 28 50	6.92	1.80	66.04	3.20	P	P	85
01184200	Still Brook near West Agawam	42 02 31	72 41 00	5.27	2.59	56.93	2.79	P	P	70
01184282	Watchaug Brook near East Longmeadow	42 02 44	72 28 25	2.80	2.34	64.78	2.63	P	P	47
Chicopee River Basin										
01172100	West Wachusett Brook near Princeton	42 28 47	71 55 28	1.83	1.53	.00	6.98	I	P	33
01172900	Potash Brook near Barre	42 24 16	72 02 41	.54	2.51	1.07	4.42	I	P	7
01173100	Galloway Brook near Barre	42 24 29	72 05 56	1.77	1.60	.20	3.55	I	P	20
01173150	Smith Brook near South Barre	42 23 52	72 06 17	.77	1.31	.46	3.92	I	P	11
01173230	Pine Hill Brook at Barre Plains	42 22 16	72 07 39	2.46	1.87	.33	5.12	I	P	34
01173260	Moose Brook near Barre	42 23 52	72 08 51	4.62	.87	.00	1.66	I	P	47
01173300	Winimusset Brook at Wheelwright	42 20 33	72 08 44	5.54	3.37	.06	5.10	I	P	57
01173400	Muddy Brook near Hardwick	42 22 06	72 13 16	4.20	1.57	.16	3.63	I	P	49
01173450	Flat Brook near Ware	42 14 56	72 15 53	6.60	1.64	15.15	4.27	P	P	80
01174000	Hop Brook near New Salem	42 28 42	72 20 05	3.39	2.35	2.06	6.53	P	P	53
01174050	East Branch Fever Brook near Petersham	42 28 49	72 13 27	5.03	1.25	14.31	4.60	P	P	73
01174900	Cadwell Creek near Belchertown	42 20 08	72 22 12	2.89	2.07	.69	5.96	P	P	43
01175660	Sevenmile River at State Highway 31 near Spencer	42 17 30	72 00 04	6.13	2.93	1.36	4.67	I	P	65
01175670	Sevenmile River near Spencer	42 15 54	72 00 19	8.69	1.93	12.77	5.46	P	P	89
01175700	Maynard Brook near Oakham	42 19 27	72 02 44	1.65	2.55	.23	2.86	I	P	14
01175730	Great Brook near East Brookfield	42 12 09	72 03 04	4.06	3.23	.10	2.97	I	P	34
01175760	Trout Brook near Brookfield	42 10 51	72 06 09	2.60	2.86	4.05	4.09	I	P	30
01175790	Coys Brook at West Brookfield	42 14 01	72 08 05	8.04	3.40	.41	3.42	I	P	68
01175890	Naultaug Brook near Warren	42 13 31	72 10 12	3.55	2.16	18.87	5.64	P	P	60
01175910	Cheney Brook at Warren	42 12 56	72 12 24	1.30	3.45	.14	6.93	I	P	17

Table 4. Description, basin characteristics, and perennial- or intermittent-status determination for stream sites at discontinued and continuous streamflow-gaging stations and partial-record stations by region and major river basin in Massachusetts used in development of the logistic regression equation for estimating the probability of a stream flowing perennially in Massachusetts — *Continued*

USGS station No.	Station name	Latitude ° ' "	Longitude ° ' "	Drainage area (mi ²)	Drainage density (mi/mi ²)	Area of stratified-drift deposits (%)	Mean basin slope (%)	Measured or recorded status of stream site	USGS topographic map designation of status of stream site	Probability of stream flowing perennially at stream site (%)
WESTERN REGION—Continued										
Chicopee River Basin—Continued										
01176100	Blodgett Mill Brook at West Brimfield	42 10 13	72 15 41	7.71	3.33	1.07	4.36	P	P	72
01176200	Kings Brook at West Brimfield	42 09 41	72 16 08	3.96	1.24	27.27	7.07	P	P	77
01176300	Foskett Mill Stream near Fentonville	42 07 43	72 15 31	6.57	1.33	21.46	8.54	P	P	91
01176450	Roaring Brook near Belchertown	42 14 07	72 24 18	2.77	2.17	.62	3.76	I	P	31
Westfield River Basin										
01179900	Trout Brook at West Worthington	42 25 21	72 59 19	6.46	1.05	2.94	5.34	P	P	80
01180000	Sykes Brook at Knightville	42 17 27	72 52 15	1.74	1.46	.00	9.72	P	P	45
01180650	Shaker Mill Brook at Becket	42 19 56	73 05 09	6.35	2.08	.00	4.74	P	P	69
01180800	Walker Brook near Becket Center	42 15 49	73 02 48	2.95	2.37	4.07	4.76	P	P	40
01180900	Roaring Brook at Fisk Avenue near Huntington	42 14 22	72 54 12	3.64	1.75	.43	5.76	I	P	53
Farmington River Basin										
01187400	Valley Brook near West Hartland, Conn.	42 02 03	72 55 49	7.37	1.66	9.50	11.04	P	P	94
Housatonic River Basin										
01197080	North Branch Mount Lebanon Brook at Shaker Village	42 25 38	73 21 02	.46	2.81	.00	10.52	I	P	14
01197090	Mount Lebanon Brook near Shaker Village	42 25 23	73 20 40	1.26	2.49	.00	10.61	I	P	33
01197130	Sykes Brook at Pittsfield	42 25 07	73 13 35	.81	1.90	.00	10.82	P	P	27
01197140	Yokun Brook near Lenox	42 22 51	73 15 26	5.95	1.26	.50	8.59	P	P	85
01197180	Greenwater Brook at East Lee	42 17 59	73 12 53	7.62	1.17	10.24	12.36	P	P	96
01197200	Hop Brook near Tyringham	42 12 49	73 09 55	4.07	1.50	7.37	7.88	P	P	74
01197210	Unnamed Tributary, Monterey Road, near Tyringham	42 13 21	73 11 53	.78	1.28	.00	10.86	P	P	30
01197240	West Brook near South Lee	42 15 22	73 17 11	4.16	1.57	.00	6.46	P	P	61
01197300	Marsh Brook at Lenox	42 20 59	73 17 56	2.18	.86	.46	9.29	I	P	56
01197600	Baldwin Brook near State Line	42 19 48	73 24 58	2.34	1.54	8.37	11.08	I	P	69

Table 4. Description, basin characteristics, and perennial- or intermittent-status determination for stream sites at discontinued and continuous streamflow-gaging stations and partial-record stations by region and major river basin in Massachusetts used in development of the logistic regression equation for estimating the probability of a stream flowing perennially in Massachusetts — *Continued*

USGS station No.	Station name	Latitude ° ' "	Longitude ° ' "	Drainage area (mi ²)	Drainage density (mi/mi ²)	Area of stratified-drift deposits (%)	Mean basin slope (%)	Measured or recorded status of stream site	USGS topographic map designation of status of stream site	Probability of stream flowing perennially at stream site (%)
WESTERN REGION—Continued										
Housatonic River Basin--Continued										
01197700	Cone Brook at Sleepy Hollow Road near Richmond	42 23 17	73 21 35	3.49	1.49	.00	6.20	I	P	53
01197960	Scribner Brook near Alford	42 16 42	73 25 46	1.95	2.17	1.03	13.86	P	P	66
01198020	Sages Ravine Brook near Taconic, Conn.	42 02 58	73 25 49	3.35	.80	26.87	13.90	P	P	91
01198040	Karner Brook near Mount Washington Road near South Egremont	42 09 37	73 28 09	1.91	1.75	.00	15.45	P	P	72
01198060	Fenton Brook near South Egremont	42 09 17	73 26 51	2.91	1.10	2.75	18.95	I	P	93
01198062	Unnamed Tributary, Rt.23, near South Egremont	42 09 55	73 26 40	1.71	1.33	.00	5.28	P	P	26
01198070	Willard Brook near Sheffield	42 06 41	73 23 38	3.70	1.74	28.11	13.77	P	P	91
01198100	Ironworks Brook near Sheffield	42 06 32	73 18 59	8.29	1.12	1.21	7.89	P	P	91
01198110	Soda Creek at Fink Road near Sheffield	42 07 35	73 19 49	1.59	1.37	.28	13.04	P	P	60
01198120	Soda Creek at County Road near Sheffield	42 06 25	73 19 38	2.87	1.25	11.29	10.15	I	P	74
01198137	Unnamed Tributary, Hupi Road, at Monterey	42 11 26	73 12 15	1.05	1.72	.00	5.46	I	P	15
01198160	Umpachene River at Southfield	42 05 26	73 14 40	8.46	2.23	3.19	6.22	P	P	87
01198260	Whiting River, Campbell Falls Road, near Canaan Valley, Conn.	42 02 46	73 14 00	8.87	1.35	9.70	4.27	P	P	88
Hudson River Basin										
01331380	South Brook at Cheshire	42 33 40	73 09 06	7.03	1.82	.28	10.47	P	P	90
01331400	Dry Brook near Adams	42 35 20	73 06 48	7.68	1.25	2.73	8.19	P	P	91
01331960	Hudson Brook at Middle Road at Clarksburg	42 42 59	73 05 48	7.36	1.31	8.19	8.87	P	P	92
01332900	Hopper Brook, Hopper Road, near South Williamstown	42 40 38	73 12 39	6.70	1.23	3.28	24.58	P	P	99
01333100	Hemlock Brook near Williamstown	42 41 16	73 13 50	5.25	1.93	8.38	19.38	P	P	97

Table 5. Description, basin characteristics, and perennial- or intermittent-status determination for field-visited stream sites by town in the South Coastal Basin, southeastern Massachusetts used in development of the logistic regression equation for estimating the probability of a stream flowing perennially in Massachusetts

[**Station No.:** Locations shown in figure 2. **Latitude and longitude:** Given in degrees, minutes, seconds. CT, Cohasset; DY, Duxbury; HR, Hanover; HN, Hanson; I, Intermittent; KN, Kingston; MD, Marshfield; NL, Norwell; P, Perennial; PE, Pembroke; RD, Rockland; SE, Scituate; USGS, U.S. Geological Survey; mi/mi², miles per square mile; mi², square mile; %, percent]

Station No.	Stream-site name and location	Latitude o ' "	Longitude o ' "	Drainage area (mi ²)	Drainage density (mi/mi ²)	Area of stratified-drift deposits (%)	Mean basin slope (%)	Date status of stream site was observed	Observed status of stream site	USGS topographic map designation of status of stream site	Probability of stream flowing perennially at stream site; (%)
Cohasset											
CT-04	Unnamed Tributary to The Gulf, Main Street	42 13 36	70 47 33	0.41	1.65	0.00	0.68	7-15-99	I	P	53
CT-10	Unnamed Tributary to Lily Pond, State Route 3A	42 13 46	70 48 44	.27	2.05	.00	.55	7-15-99	P	P	45
Duxbury											
DY-04	Bassett Brook, State Route 53	42 01 29	70 44 11	0.09	1.25	99.52	1.61	8-05-99	P	I	60
DY-05	Unnamed Tributary to Bassett Brook, Winter Street	42 01 29	70 44 32	.14	.59	40.58	.96	8-05-99	I	I	55
DY-11	Unnamed Tributary to Kingston Bay, Bay Road	42 01 18	70 41 10	.09	3.39	100.00	.97	8-05-99	P	I	43
DY-12	Unnamed Tributary to Kingston Bay, Old Railroad Grade	42 01 20	70 41 50	.08	1.13	100.00	.96	8-05-99	I	I	56
DY-13	Unnamed Tributary to South River, Chandler Street	42 02 24	70 44 22	.22	.47	100.00	.82	8-05-99	I	P	72
DY-14	Unnamed Tributary to South River, Bianca Road	42 02 26	70 44 15	.30	.76	100.00	.80	8-05-99	I	P	75
DY-15	Unnamed Tributary to South River, Bolas Road	42 02 27	70 4 08	.31	1.07	100.00	.80	8-05-99	P	P	73
DY-21	Halls Brook, Autumn Avenue	42 01 39	70 44 59	.18	1.13	81.48	.43	8-05-99	P	P	62
DY-25	Keene Brook, Union Street	42 04 22	70 45 19	.83	1.69	35.32	.88	8-06-99	I	P	78
DY-26	Keene Brook, Congress Street	42 03 45	70 45 45	.24	.37	84.48	.39	8-06-99	P	I	70
DY-27	Unnamed Tributary to Pine Brook, Pine Street	42 01 30	70 45 56	.12	5.22	100.00	.71	8-05-99	I	P	34
DY-29	Halls Brook, Hitty Tom Road	42 01 19	70 45 11	.77	2.01	94.42	.54	8-05-99	P	P	81
DY-30	Halls Brook, Clearwater Drive	42 01 34	70 45 09	.62	1.41	94.07	.49	8-05-99	P	P	81
DY-31	Unnamed Tributary to Halls Brook, Clearwater Drive	42 01 45	70 45 10	.22	1.27	100.00	.47	8-05-99	P	P	66
DY-37	Unnamed Tributary to Pudding Brook, Keene Street	42 05 03	70 45 16	.09	.98	55.35	2.33	8-06-99	P	P	57

Table 5. Description, basin characteristics, and perennial- or intermittent-status determination for field-visited stream sites by town in the South Coastal Basin, southeastern Massachusetts used in development of the logistic regression equation for estimating the probability of a stream flowing perennially in Massachusetts — *Continued*

Station No.	Stream-site name and location	Latitude ° ' "	Longitude ° ' "	Drainage area (mi ²)	Drainage density (mi/mi ²)	Area of stratified-drift deposits (%)	Mean basin slope (%)	Date status of stream site was observed	Observed status of stream site	USGS topographic map designation of status of stream site	Probability of stream flowing perennially at stream site; (%)
Duxbury—Continued											
DY-41	Unnamed Tributary to Kingston Bay, Bay Road	42 01 00	70 41 46	0.22	2.21	100.00	1.28	8-05-88	P	I	64
DY-53	Unnamed Tributary to Bluefish River, Partridge Road	42 01 39	70 40 40	.27	.43	100.00	1.15	9-03-99	I	P	76
DY-54	Unnamed Tributary to Bluefish River, Surplus Street	42 01 43	70 40 37	.54	.64	100.00	.96	9-03-99	P	P	83
Hanover											
HR-03	Iron Mine Brook, Rockland Street	42 06 52	70 49 20	0.06	1.53	100.00	1.91	8-12-99	P	P	55
HR-07	Unnamed Tributary to Indian Head River, Water Street	42 06 08	70 49 33	.27	3.15	100.00	.90	8-13-99	P	P	60
HR-08	Unnamed Tributary to Indian Head River, Water Street	42 05 49	70 50 28	.11	2.42	100.00	.57	8-13-99	I	I	50
HR-09	Unnamed Tributary to Indian Head River, Broadway Street	42 05 52	70 50 53	.56	3.03	100.00	.69	8-13-99	P	P	73
HR-10	Unnamed Tributary to Indian Head River, Broadway Street	42 06 18	70 50 20	.07	4.58	100.00	.49	8-13-99	I	I	31
HR-11	Unnamed Tributary to Indian Head River, Karen Road	42 06 14	70 49 47	.21	2.98	100.00	1.14	8-13-99	P	P	58
HR-12	Unnamed Tributary to Indian Head River, Broadway Street	42 06 27	70 49 47	.13	2.95	100.00	.71	8-13-99	P	P	49
HR-13	Unnamed Tributary to Indian Head River, Laurie Lane	42 06 33	70 49 59	.11	1.56	100.00	.37	8-13-99	P	P	54
HR-15	Unnamed Tributary to Indian Head River, Pine Tree Drive	42 06 32	70 50 39	.21	3.98	100.00	.13	8-13-99	P	P	47
HR-16	Unnamed Tributary to Indian Head River, Reed Drive	42 06 38	70 50 39	.17	4.22	100.00	.02	8-13-99	P	P	42

Table 5. Description, basin characteristics, and perennial- or intermittent-status determination for field-visited stream sites by town in the South Coastal Basin, southeastern Massachusetts used in development of the logistic regression equation for estimating the probability of a stream flowing perennially in Massachusetts — *Continued*

Station No.	Stream-site name and location	Latitude ° ' "	Longitude ° ' "	Drainage area (mi ²)	Drainage density (mi/mi ²)	Area of stratified-drift deposits (%)	Mean basin slope (%)	Date status of stream site was observed	Observed status of stream site	USGS topographic map designation of status of stream site	Probability of stream flowing perennially at stream site; (%)
<i>Hanover—Continued</i>											
HR-22	Mollys Brook, Grove Street	42 06 46	70 51 10	0.07	3.26	100.00	0.10	8-12-99	I	P	36
HR-25	Torrey Brook, Winter Street	42 06 00	70 52 09	.64	1.30	100.00	1.02	8-13-99	P	P	83
HR-28	Mollys Brook, Main Street	42 07 06	70 50 51	.37	2.02	99.88	.26	8-12-99	I	P	69
HR-30	Drinkwater Brook, Hanover Street	42 07 03	70 52 37	7.00	3.05	62.09	.71	8-12-99	P	P	99
HR-31	Cushing Brook, Hanover Street	42 07 05	70 52 47	4.15	2.49	77.14	.55	8-12-99	P	P	97
HR-32	Unnamed Tributary to French Stream, Summer Street	42 06 47	70 53 15	.23	4.34	99.17	.54	8-13-99	P	P	48
HR-33	Cushing Brook, Pleasant Street	42 07 11	70 52 59	4.09	2.47	76.81	.54	8-12-99	P	P	97
HR-34	Unnamed Tributary to French Stream, Hanover Street	42 07 11	70 53 23	.04	1.59	100.00	.49	8-12-99	I	P	43
HR-39	Unnamed Tributary to Drinkwater River, Union Street	42 07 54	70 51 14	.71	.75	52.47	1.28	8-12-99	P	P	83
HR-40	Unnamed Tributary to Drinkwater River, Main Street	42 07 42	70 51 28	1.03	.87	59.85	1.28	8-12-99	P	P	88
HR-41	Unnamed Tributary to Drinkwater River, Cedar Street	42 07 44	70 51 38	1.09	1.00	62.37	1.22	8-10-99	P	P	88
HR-44	Unnamed Tributary to Drinkwater River, Main Street	42 08 17	70 51 52	.31	1.88	30.49	1.17	8-10-99	P	I	58
HR-45	Unnamed Tributary to Drinkwater River, Main Street	42 08 24	70 51 53	.24	1.82	27.94	1.24	8-10-99	P	I	54
HR-48	Unnamed Tributary to Shinglemill Brook, Main Street	42 09 02	70 52 10	.17	3.28	73.87	.46	8-10-99	P	I	45
HR-49	Unnamed Tributary to Hackett Pond, Walnut Street	42 09 02	70 51 50	.46	1.21	27.12	.46	8-10-99	I	P	66

Table 5. Description, basin characteristics, and perennial- or intermittent-status determination for field-visited stream sites by town in the South Coastal Basin, southeastern Massachusetts used in development of the logistic regression equation for estimating the probability of a stream flowing perennially in Massachusetts — *Continued*

Station No.	Stream-site name and location	Latitude ° ' "	Longitude ° ' "	Drainage area (mi ²)	Drainage density (mi/mi ²)	Area of stratified-drift deposits (%)	Mean basin slope (%)	Date status of stream site was observed	Observed status of stream site	USGS topographic map designation of status of stream site	Probability of stream flowing perennially at stream site; (%)
Hanover—Continued											
HR-50	Unnamed Tributary to Drinkwater River, Dillingham Street	42 08 40	70 51 45	0.10	0.98	0.00	1.82	8-10-99	P	I	33
HR-53	Unnamed Tributary to Drinkwater River, West Street	42 07 40	70 52 29	3.99	3.97	52.70	.58	8-10-99	P	P	95
HR-54	Unnamed Tributary to Drinkwater River, Cedar Street	42 07 54	70 52 54	.89	9.34	57.00	.23	8-10-99	I	P	36
HR-55	Longwater Brook, Cedarwood Road	42 08 55	70 52 32	.67	2.40	72.52	.46	8-10-99	P	P	75
HR-56	Shinglemill Brook, Webster Street	42 08 40	70 52 54	.45	1.59	59.76	.60	8-10-99	I	P	70
HR-59	Unnamed Tributary to Shinglemill Brook, Cedarwood Road	42 08 55	70 52 16	.36	2.03	79.24	.63	8-10-99	P	P	67
HR-60	Unnamed Tributary to Shinglemill Brook, Brookwood Road	42 08 50	70 52 16	.39	2.14	73.79	.73	8-10-99	P	P	67
HR-61	Shinglemill Brook, Webster Street	42 08 46	70 52 15	1.14	2.52	67.70	.59	8-10-99	P	P	83
HR-62	Shinglemill Brook, Hacketts Pond Drive	42 08 31	70 52 36	.54	2.09	49.43	.71	8-10-99	I	P	70
HR-63	Shinglemill Brook, Country Road	42 08 30	70 52 29	.60	2.07	44.43	.69	8-10-99	I	P	71
HR-65	Unnamed Tributary to Mann Brook, Webster Street	42 08 17	70 53 45	.15	3.14	100.00	.61	8-10-99	I	P	50
HR-68	Unnamed Tributary to Shinglemill Brook, Cedarwood Road	42 08 54	70 52 14	.36	2.08	78.99	.70	8-10-99	P	P	67
Hanson											
HN-03	Unnamed Tributary to Indian Head Brook, Puritan Street	42 05 13	70 51 21	0.11	3.89	66.28	1.96	7-19-99	P	I	42
HN-04	Unnamed Tributary to Indian Head Brook, Old Pine Drive	42 05 10	70 51 12	.06	4.71	45.72	2.69	7-19-99	P	I	30
HN-05	Unnamed Tributary to Indian Head Brook, Winter Street	42 05 01	70 51 54	.02	8.33	100.00	.74	7-19-99	I	I	11
HN-07	Unnamed Tributary to Oldham Pond, State Street	42 04 39	70 50 45	.21	.36	100.00	.91	7-19-99	I	P	72
HN-08	Unnamed Tributary to Oldham Pond, Brook Street	42 04 32	70 50 44	.23	.85	100.00	.83	7-19-99	I	P	71

Table 5. Description, basin characteristics, and perennial- or intermittent-status determination for field-visited stream sites by town in the South Coastal Basin, southeastern Massachusetts used in development of the logistic regression equation for estimating the probability of a stream flowing perennially in Massachusetts — *Continued*

Station No.	Stream-site name and location	Latitude ° ' "	Longitude ° ' "	Drainage area (mi ²)	Drainage density (mi/mi ²)	Area of stratified-drift deposits (%)	Mean basin slope (%)	Date status of stream site was observed	Observed status of stream site	USGS topographic map designation of status of stream site	Probability of stream flowing perennially at stream site; (%)
Hanson—Continued											
HN-14	Unnamed Tributary to Factory Pond, Whitman Street	42 04 55	70 52 55	0.09	3.26	23.56	0.09	7-19-99	I	I	26
HN-15	Unnamed Tributary to Factory Pond, King Street	42 05 14	70 52 42	.68	2.36	57.12	.71	7-19-99	P	P	74
HN-16	Unnamed Tributary to Factory Pond, Whitman Street	42 04 58	70 52 35	.06	1.26	100.00	1.72	7-19-99	I	I	56
Kingston											
KN-07	Unnamed Tributary to Jones River, Brook Street	41 59 17	70 44 02	0.22	2.11	86.56	3.36	9-03-99	P	I	72
KN-11	Unnamed Tributary to Soules Pond, Sylvia Place Road	41 58 52	70 44 50	1.45	5.50	100.00	1.21	8-31-99	I	P	81
KN-15	Bassett Brook, Winthrop Street	42 00 32	70 44 40	.86	4.78	80.05	1.21	8-31-99	P	P	71
KN-17	Jones River, Lake Street	42 00 47	70 47 16	4.18	3.60	100.00	.93	8-31-99	P	P	97
KN-18	Jones River, Grove Street	42 00 12	70 47 09	4.47	3.70	100.00	.87	8-31-99	P	P	97
KN-21	Unnamed Tributary to Jones River, Pembroke Street	42 00 38	70 45 49	.09	.50	86.41	.24	8-31-99	I	P	56
KN-22	Unnamed Tributary to Jones River, Reed Street	42 00 36	70 45 48	.10	.87	86.85	.15	8-31-99	I	P	54
KN-31	Smelt Brook, Main Street	41 58 46	70 42 32	1.85	1.97	96.95	2.76	9-03-99	P	P	95
Marshfield											
MD-01	Hannah Eames Brook, State Route 3A	42 09 07	70 44 35	0.68	1.83	0.00	2.83	8-23-99	I	P	65
MD-20	Furnace Brook, School Street	42 07 06	70 44 32	.88	1.29	2.55	3.93	8-23-99	P	P	81
MD-26	Unnamed Tributary to South River, South River Road	42 06 23	70 41 57	.02	7.93	100.00	.61	8-30-99	I	P	12
MD-34	Unnamed Tributary to Cove Brook, Oak Street	42 08 26	70 45 25	.22	.97	.00	4.34	8-23-99	P	I	56
MD-35	Unnamed Tributary to Cove Brook, Union Street	42 08 07	70 46 07	.03	.41	4.08	3.77	8-23-99	I	I	39
MD-36	Unnamed Tributary to Oakham Pond, Stonewood Drive	42 07 41	70 45 23	.23	1.46	.00	4.35	8-23-99	P	I	54
MD-47	Cut River, Canal Street	42 04 18	70 39 08	.24	7.30	97.70	.59	9-03-99	I	P	31

Table 5. Description, basin characteristics, and perennial- or intermittent-status determination for field-visited stream sites by town in the South Coastal Basin, southeastern Massachusetts used in development of the logistic regression equation for estimating the probability of a stream flowing perennially in Massachusetts — *Continued*

Station No.	Stream-site name and location	Latitude ° ' "	Longitude ° ' "	Drainage area (mi ²)	Drainage density (mi/mi ²)	Area of stratified-drift deposits (%)	Mean basin slope (%)	Date status of stream site was observed	Observed status of stream site	USGS topographic map designation of status of stream site	Probability of stream flowing perennially at stream site; (%)
Norwell											
NL-03	Copeland Tannery Brook, Meadow Brook Road	42 07 01	70 48 23	0.49	1.78	18.37	1.41	8-23-99	P	P	65
NL-07	Unnamed Tributary to Burnt Plain Swamp, Prospect Street	42 09 51	70 50 21	.13	4.40	81.09	.25	8-20-99	I	P	35
NL-12	Wildcat Brook, Pleasant Street	42 08 58	70 48 58	.22	3.98	75.31	1.57	8-13-99	I	P	51
NL-13	Unnamed Tributary to Wildcat Brook, Forest Street	42 09 17	70 48 26	.54	2.37	6.36	2.30	8-13-99	I	I	62
NL-14	Unnamed Tributary to Third Herring Brook, Pine Street	42 07 44	70 48 11	.24	1.08	1.57	3.57	8-23-99	P	I	57
NL-16	Unnamed Tributary to Wildcat Brook, Circuit Street	42 09 05	70 4 8 43	.89	2.41	14.99	1.88	8-13-99	P	P	74
NL-18	Unnamed Tributary to Second Herring Brook, Mill Lane	42 09 53	70 47 35	2.16	2.69	12.91	1.52	8-20-99	P	P	88
NL-19	Unnamed Tributary to Second Herring Brook, Central Street	42 09 57	70 47 43	1.92	1.56	10.41	1.57	8-20-99	I	P	89
NL-20	Unnamed Tributary to Second Herring Brook, Central Street	42 10 24	70 48 13	.26	.50	6.04	3.40	8-20-99	P	I	65
NL-21	Unnamed Tributary to Second Herring Brook, Trout Brook Lane	42 10 21	70 48 14	.27	.71	5.89	3.26	8-20-99	P	I	63
NL-24	Stony Brook, Cross Street	42 10 18	70 46 15	.09	3.00	63.16	.32	8-20-99	P	P	36
NL-25	Unnamed Tributary to Stony Brook, Parker Street	42 09 54	70 46 27	.33	2.31	19.37	1.45	8-20-99	I	P	55
NL-29	Stony Brook, Main Street	42 09 53	70 46 01	.79	2.56	45.61	1.47	8-20-99	P	P	76
NL-33	Wildcat Brook, Main Street	42 09 26	70 49 00	.10	2.48	86.13	2.26	8-13-99	P	I	54
NL-41	Wildcat Brook, Wildcat Lane	42 08 43	70 49 12	1.46	2.60	26.84	1.55	8-13-99	P	P	84
NL-42	Unnamed Tributary to Wildcat Creek, Norwell Avenue	42 10 24	70 49 08	.02	6.66	100.00	1.28	8-20-99	I	P	15
NL-46	Unnamed Tributary to Third Herring Brook, Leonard Lane	42 07 34	70 48 17	.27	1.76	5.35	3.36	8-23-99	P	I	57
NL-47	Unnamed Tributary to Third Herring Brook, Tiffany Street	42 07 32	70 48 30	.36	1.84	6.17	3.07	8-23-99	P	I	61

Table 5. Description, basin characteristics, and perennial- or intermittent-status determination for field-visited stream sites by town in the South Coastal Basin, southeastern Massachusetts used in development of the logistic regression equation for estimating the probability of a stream flowing perennially in Massachusetts — *Continued*

Station No.	Stream-site name and location	Latitude ° ' "	Longitude ° ' "	Drainage area (mi ²)	Drainage density (mi/mi ²)	Area of stratified-drift deposits (%)	Mean basin slope (%)	Date status of stream site was observed	Observed status of stream site	USGS topo-graphic map designation of status of stream site	Probability of stream flowing perennially at stream site; (%)
Pembroke											
PE-08	McFarland Brook, Washington Street	42 04 09	70 46 39	0.22	5.31	100.00	0.94	7-29-99	P	P	43
PE-09	Unnamed Tributary to McFarland Brook, Washington Street	42 04 16	70 46 44	.08	1.37	33.20	.98	7-29-99	I	P	41
PE-10	Unnamed Tributary to Swamp Brook, Elm Street	42 04 29	70 49 26	.19	1.98	95.16	2.08	7-29-99	I	I	66
PE-12	Herring Brook, Barker Street	42 04 30	70 48 04	6.14	4.15	96.64	.99	7-29-99	P	P	98
PE-13	Little Pudding Brook, Barker Street	42 04 38	70 47 57	.91	1.77	34.26	.52	7-29-99	P	P	77
PE-17	Unnamed Tributary to Swamp Brook, Lowell Road	42 04 53	70 49 29	.12	.93	33.53	.66	7-29-99	P	I	48
PE-19	Pudding Brook, Spring Street	42 05 10	70 45 25	1.39	2.26	61.42	1.50	7-29-99	P	P	88
PE-20	Robinson Creek, Water Street	42 05 57	70 47 15	1.12	1.25	56.87	1.02	7-29-99	P	P	87
PE-23	McFarland Brook, Congress Street	42 03 58	70 46 43	.19	4.84	100.00	.72	7-29-99	I	P	43
Rockland											
RD-01	Unnamed Tributary to French Stream, Summer Street	42 06 43	70 53 33	0.52	2.33	100.00	0.54	8-04-99	P	P	75
RD-02	Unnamed Tributary to French Stream, Beech Street	42 05 24	70 53 59	.17	1.42	2.68	1.44	8-04-99	I	P	40
RD-03	Unnamed Tributary to French Stream, Summer Street	42 06 35	70 54 17	.18	3.34	56.45	.47	8-04-99	I	I	42
RD-04	French Stream, Summer Street	42 06 33	70 54 33	5.07	2.42	48.79	.52	8-04-99	P	P	97
RD-06	Unnamed Tributary to French Stream, Spring Street	42 06 43	70 54 44	.40	2.14	68.11	.09	8-04-99	P	I	65
RD-07	French Stream, West Water Street	42 07 17	70 55 25	2.95	2.43	47.65	.56	8-04-99	P	P	94
RD-09	French Stream, Spruce Street	42 08 11	70 56 03	.39	2.80	4.96	.07	8-03-99	P	P	41
RD-10	Unnamed Tributary to Studleys Pond, North Avenue	42 07 52	70 55 32	.07	4.65	.00	9.95	8-31-99	I	I	12
RD-11	Unnamed Tributary to Studleys Pond, Reed Street	42 07 42	70 55 22	.57	3.79	.36	.48	8-04-99	P	P	40
RD-19	Cushing Brook, Webster Street	42 08 05	70 54 26	.50	3.43	88.67	.20	8-03-99	P	P	65

Table 5. Description, basin characteristics, and perennial- or intermittent-status determination for field-visited stream sites by town in the South Coastal Basin, southeastern Massachusetts used in development of the logistic regression equation for estimating the probability of a stream flowing perennially in Massachusetts — *Continued*

Station No.	Stream-site name and location	Latitude ° ' "	Longitude ° ' "	Drainage area (mi ²)	Drainage density (mi/mi ²)	Area of stratified-drift deposits (%)	Mean basin slope (%)	Date status of stream site was observed	Observed status of stream site	USGS topographic map designation of status of stream site	Probability of stream flowing perennially at stream site; (%)
Rockland—Continued											
RD-20	Cushing Brook, Liberty Street	42 07 54	70 54 18	0.57	3.48	85.34	0.41	8-03-99	P	P	68
RD-21	French Stream, North Avenue	42 07 43	70 56 02	2.55	2.42	41.28	.49	8-04-99	P	P	92
RD-23	Unnamed Tributary to Mann Brook, Hingham Street	42 08 48	70 54 11	.33	.17	73.13	.04	8-03-99	I	P	73
RD-28	Unnamed Tributary to French Stream, Millbrook Street	42 05 52	70 53 44	.55	2.25	23.40	1.21	8-04-99	I	P	65
RD-40	Unnamed Tributary to Studleys Pond, Plain Street	42 07 30	70 55 21	.71	3.37	10.65	.60	8-04-99	P	I	57
Scituate											
SE-01	Satuit Brook, Beaver Dam Road	42 11 55	70 44 20	0.80	1.92	12.85	1.03	7-16-99	P	P	71
SE-02	Satuit Brook, Tilden Road	42 11 36	70 44 04	1.26	1.72	8.22	.88	7-16-99	P	P	79
SE-04	Unnamed Tributary to Musquashcut Brook, Hollett Street	42 12 59	70 46 16	.86	1.33	26.56	1.16	7-16-99	P	P	79
SE-06	Unnamed Tributary to Musquashcut Brook, Captain Pierce Road	42 12 39	70 46 05	.32	1.56	25.23	2.13	7-16-99	P	P	63
SE-07	Unnamed Tributary to Musquashcut Brook, Branch Way	42 12 25	70 45 53	.19	.81	12.66	2.17	7-16-99	I	I	55
SE-12	Unnamed Tributary to First Herring Brook, First Parish Road	42 11 48	70 46 12	.34	3.35	1.27	.27	7-16-99	I	P	33
SE-14	First Herring Brook, Maple Street	42 11 31	70 46 38	1.79	1.44	4.46	.60	7-16-99	I	P	84
SE-16	Unnamed Tributary to Bound Brook, Booth Hill Road	42 12 33	70 47 25	.25	2.02	.00	.60	7-16-99	I	I	34
SE-19	Unnamed Tributary to First Herring Brook, State Route 3A	42 11 56	70 46 17	.33	2.92	.09	.30	7-16-99	I	I	33
SE-21	First Herring Brook, Grove Street	42 11 31	70 46 47	1.75	1.43	4.56	.61	7-16-99	P	P	84

Appendix A

Appendix A. Summary statistics for selected logistic regression analyses tested for use in development of an equation for estimating the probability of a stream flowing perennially in Massachusetts

[Hosmer and Lemeshow, 1989; Collett, 1991; Helsel and Hirsch, 1992, p. 393–402; Eckhardt and Stackelberg, 1995; SAS Institute Inc., 1995; Squillace and others, 1999. **AIC:** Akaike Information Criterion. **C:** rank correlation coefficient of predicted probabilities and observed responses. SCB, South Coastal Basin; ^{1/3}, cube root; ^{1/2}, square root; <, actual value is less than value shown]

Equation No. and explanatory variables	Analyses											
	AIC	C	-2 Log likelihood	Likelihood ratio			Score			Hosmer and Lemeshow goodness-of-fit		
				Chi- square	Degrees of freedom	p-value	Chi- square	Degrees of freedom	p-value	Chi- square	Degrees of freedom	p-value
#1 Intercept Drainage area ^{1/3} Location (SCB or remainder of State) Mean basin slope Areal percentage of stratified-drift deposits ^{1/2} Drainage density	338.604	0.790	326.604	91.7166	5	<0.0001	77.7929	5	<0.0001	4.8962	8	0.7686
#2 Intercept Drainage area ^{1/3} Location (SCB or remainder of State) Mean basin slope Areal percentage of stratified-drift deposits ^{1/2}	342.121	.786	332.121	86.1994	4	<.0001	72.0429	4	<.0001	8.2218	8	.4121
#3 Intercept Drainage area ^{1/3} Location (SCB or remainder of State) Mean basin slope	345.513	.774	337.513	80.8074	3	<.0001	68.7859	3	<.0001	12.0893	8	.1473
#4 Intercept Drainage area ^{1/3} Location (SCB or remainder of State)	351.900	.759	345.900	72.4206	2	<.0001	62.9280	2	<.0001	6.6225	8	.5778
#5 Intercept Drainage area	399.379	.641	395.379	22.9409	1	<.0001	21.7610	1	<.0001	7.2108	8	.5141