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Determination of the Primary and Secondary Source-Water Protection Areas for Selected Surface-Water Public-Supply Systems in South Carolina, 1999

U.S. Geological Survey
Water-Resources Investigations Report 00–4097

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

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Columbia, South Carolina
2000

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CONVERSION FACTORS, VERTICAL DATUM, AND ABBREVIATIONS

Multiply	By	To obtain
	Length	
meter (m)	3.281	foot
kilometer (km)	0.6214	mile
	Area	
square meter (m^2)	10.76	square foot
square kilometer (km^2)	0.3861	square mile
	Volume	
cubic meter (m^3)	35.31	cubic foot
	Flow rate	
cubic meter per second (m^3/s)	35.31	cubic foot per second
meter per square second (m/s^2)	3.281	foot per square second

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 both the United States and Canada, formerly called Sea Level Datum of 1929.

Abbreviations used in this report:

BLTM	Branched Lagrangian Transport Model
GDA	gage drainage area
GQ_{10}	gage flow for the 10-percent exceedance flow
GQ_{50}	gage flow for the 50-percent exceedance flow
GQ_{90}	gage flow for the 90-percent exceedance flow
hr	hour
HUC	hydrologic unit code
IDA	intake drainage area
MGQ	annual mean flow at gage
RK	river kilometer
SCDHEC	South Carolina Department of Health and Environmental Control
SWAP	source-water assessment and protection
TOT	time of travel
TOT_{10}	time of travel for the 10-percent exceedance flow
TOT_{50}	time of travel for the 50-percent exceedance flow
TOT_{90}	time of travel for the 90-percent exceedance flow
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
yrs	years

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ABSTRACT

In a 1998 pilot project, the U.S. Geological Survey developed methods to determine in-stream travel distance and the primary and secondary source-water protection areas for protecting surface-water public-supply intakes. Three intakes in South Carolina were used to develop and test the methods. To verify the statewide applicability, these methods were applied to the remaining 71 intakes in South Carolina.

The 24-hour travel distance from an intake computed for the 10-percent exceedance flow of the intake was the distance used to segment the primary and secondary source-water protection areas. The primary source-water protection area encompasses all 14-digit Hydrologic Unit Code basins that adjoin the streams, tributaries, and reservoirs between an intake and the computed 10-percent exceedance flow travel distance upstream from the intake. The remainder of the intake drainage basin upstream from the primary source-water protection area is designated as the secondary source-water protection area. The length of the primary travel-time segment was reduced substantially if the travel time through a reservoir was included in the 24-hour travel-time calculation. If the reservoir were to be removed from the flow system after determining the primary travel-time segment, the segment would have to be recalculated. For this study, the effects of all reservoirs with volumes less than that of Fishing Creek Reservoir are not included in determining the primary travel-time segment. However, for intakes with primary travel times that extended into larger reservoirs, the base of the larger reservoir's dam was considered to be the upstream limit of the primary protection area. If an intake is located on any part of a reservoir, the primary source-water protection area for the reservoir intake includes all 14-digit Hydrologic Unit Code basins adjoining the reservoir and the feeder streams within a 24-hour travel distance upstream from the headwaters of the reservoir. The 24-hour travel distance was determined on the main stream(s) and selected tributaries upstream from 45 intakes with drainage areas that have more than 24-hours of in-stream travel time between the intake and the 14-digit Hydrologic Unit Code basin(s) in the headwaters of the drainage basin.

A total of 29 intakes in South Carolina have drainage areas that are equal to or less than one 14-digit Hydrologic Unit Code basin, or are estimated to have less than 24-hours of in-stream travel time between the intake and the 14-digit Hydrologic Unit Code basin in the headwaters of the drainage basin. For these intakes, the 24-hour travel distance was not calculated, and the entire drainage basin upstream from the intake was designated as the primary source-water protection area.

The travel-distance method was not applicable for five intakes in coastal areas because

of tidal conditions. Therefore, one-dimensional dynamic flow and transport models were applied to these intakes to determine the primary and secondary source-water protection areas.

INTRODUCTION

Public drinking-water systems that rely on water withdrawals from streams or reservoirs are susceptible to potential contaminants from sources within drainage basins that supply water to these sources. Contaminants can enter a source-water system directly by spills to streams or reservoirs, or indirectly by overland runoff and ground water. The chemical and physical properties of a potential contaminant and the location of its source in a drainage basin determine the likely path and, hence, travel time for the contaminant to reach the surface-water intake. Therefore, travel time is one factor in determining the susceptibility of the surface-water intake, which hereafter will be referred to in this report as intake.

In implementing the 1996 amendments to the Federal Safe Drinking Water Act, the U.S. Environmental Protection Agency (USEPA) initiated the Source-Water Assessment and Protection (SWAP) Program. Two objectives of the SWAP Program are to focus attention on the susceptibility of public drinking-water supplies to contamination and to ensure a future supply of clean water to public-supply systems. The SWAP Program consists of three parts: (1) delineation of source-water protection areas for all public drinking-water systems, (2) inventory of potential contaminant sources within the source-water protection areas, and (3) determination of the susceptibility of intakes to potential contaminant sources.

The South Carolina Department of Health and Environmental Control (SCDHEC) developed a State SWAP plan in February 1999, which was approved by the USEPA in October 1999 (D. Baize, South Carolina Department of Health and Environmental Control, oral commun., 1999). The SCDHEC plans to implement the State SWAP plan for most of the public water supplies in South Carolina by May 2003 (R. Devlin, South Carolina Department of Health and Environmental Control, oral commun., 1999). In part one of the State SWAP plan, the primary and secondary source-water protection areas were determined for the drainage areas upstream from selected intakes; these areas will be used to prioritize the inventory of potential contaminant sources and to assess susceptibility to potential contamination (fig. 1).

As part of the development of the State SWAP plan in 1998, the U.S. Geological Survey (USGS) entered into a cooperative agreement with the SCDHEC to develop methods to determine in-stream travel distance and the primary and secondary source-water protection areas for protecting surface-water intakes (Lanier and Falls, 1999; South Carolina Department of Health and Environmental Control, 1999). Three representative intakes were chosen to develop and test the methods in the 1998 pilot project (fig. 2). These intakes include the Aiken intake on Shaw Creek (Coastal Plain stream example), the Belton-Honea Path intake on the Saluda River (Piedmont stream example), and the Greenwood intake on Lake Greenwood (reservoir example).

In June 1999, the USGS entered into a cooperative agreement with the SCDHEC to verify the statewide applicability of source-water protection methods previously developed by the USGS for the South Carolina SWAP plan (South Carolina Department of Health and Environmental Control, 1999). These methods include estimating in-stream travel distance and delineating the primary and secondary source-water protection areas for intakes in South Carolina. The methods were applied to 71 intakes in South Carolina (fig. 1; table 1). The travel distances and the primary and secondary source-water protection areas delineated in this study will be used by the SCDHEC to prioritize the inventory of potential contaminant sources and to implement a susceptibility assessment for each intake in South Carolina.

Purpose and Scope

The purpose of this report is to document the delineation of the primary and secondary source-water protection areas for 74 water-supply intakes in South Carolina. In addition, the in-stream 24-hour (hr) travel distance is documented for the 10-, 50-, and 90-percent exceedance flows for selected intakes in South Carolina.

The scope of this report includes verification and application of the source-water protection methods (South Carolina Department of Health and Environmental Control, 1999). These methods are used to determine the 24-hr in-stream travel distance for the 10-, 50-, and 90-percent exceedance flows, and the primary and secondary source-water protection areas

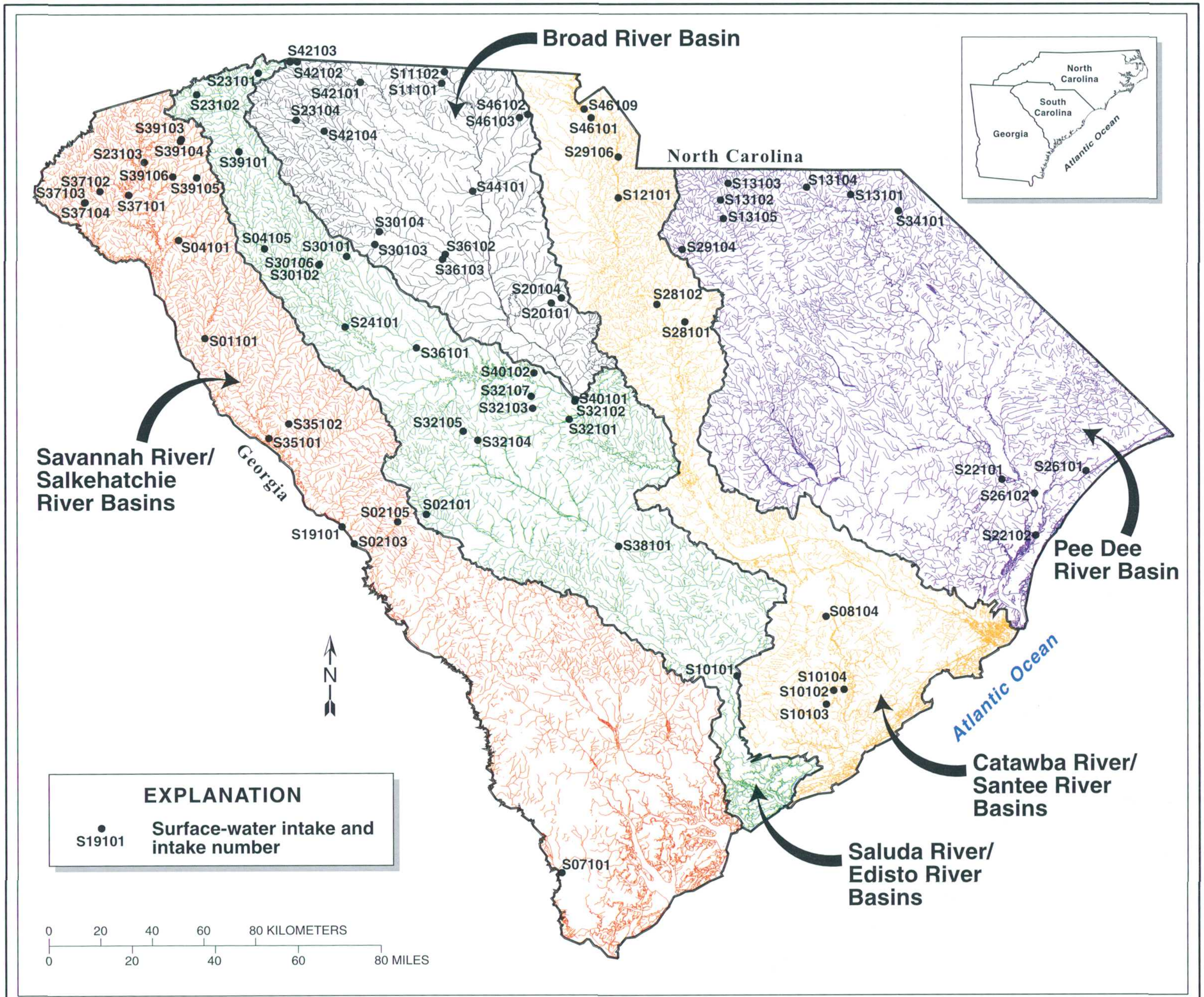


Figure 1. Locations of major basins and surface-water intakes in South Carolina, 1999.

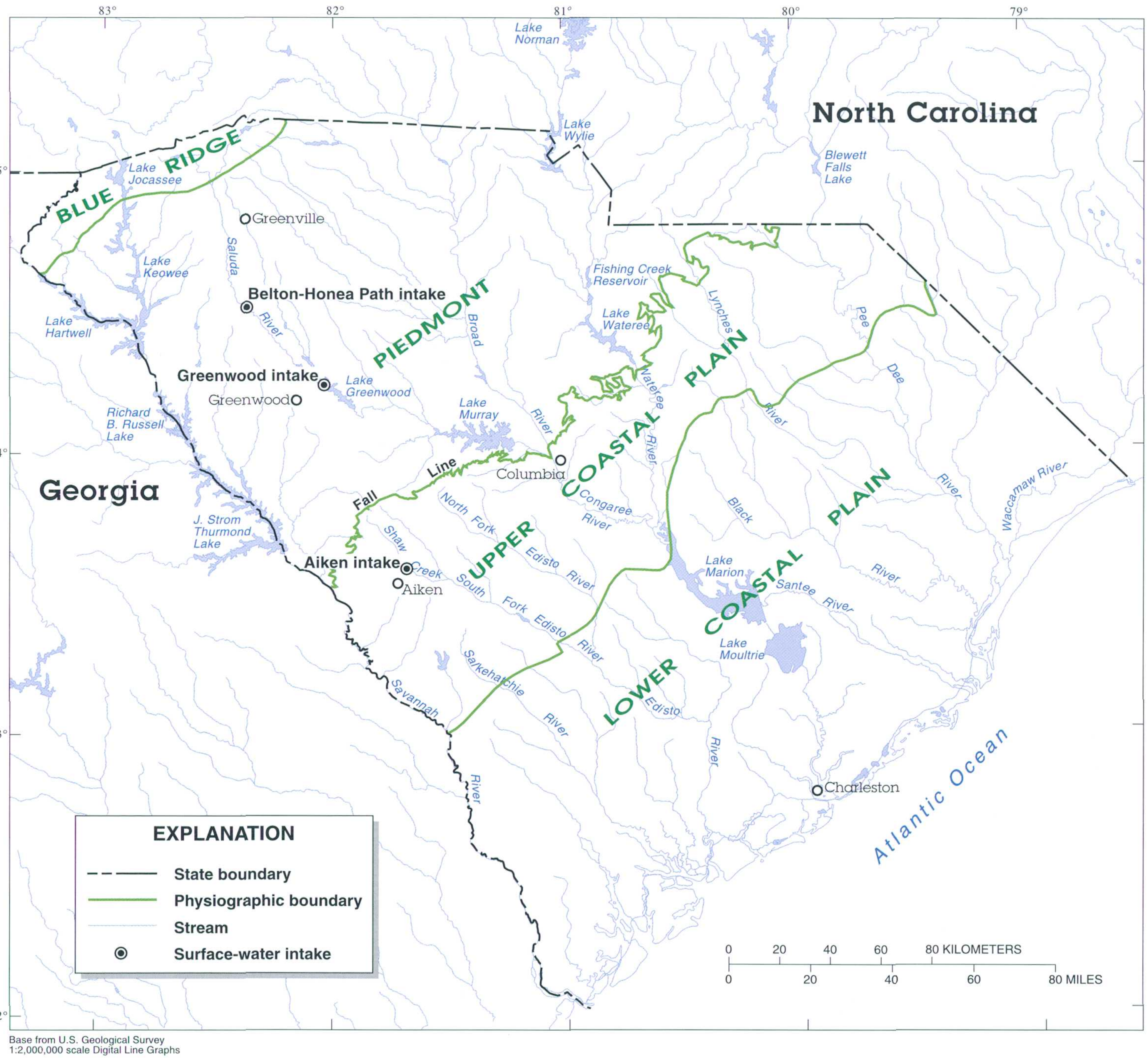


Figure 2. Physiographic provinces and locations of the Aiken, Belton-Honea Path, and Greenwood surface-water intakes, South Carolina.

Table 1. Locations and descriptions of intakes in South Carolina, 1999 (from R. Devlin, South Carolina Department of Health and Environmental Control, written commun., June 1999)

Intake no. (fig. 1)	Operator	Latitude	Longitude	Main stream or reservoir
		Saluda-Edisto Basin		
S02101	City of Aiken	33°36'19"	81°41'11"	Shaw Creek
S04105	Belton-Honea Path Water Authority	34°31'47"	82°22'37"	Saluda River
S10101	Charleston Commission of Public Works	33°01'59"	80°23'15"	Edisto River
S23101	Greenville Water System	35°08'28"	82°24'33"	North Saluda River
S23102	Greenville Water System	35°03'51"	82°40'20"	Table Rock Reservoir
S24101	Greenwood Commission of Public Works	34°15'30"	82°01'47"	Lake Greenwood
S30101	Laurens Commission of Public Works	34°30'15"	82°01'39"	Reedy Creek
S30102	Laurens Commission of Public Works	34°28'28"	82°08'38"	Rabon Creek
S30106	Laurens Commission of Public Works	34°28'36"	82°08'29"	Lake Rabon
S32101	City of Cayce	33°56'04"	81°04'56"	Congaree Creek
S32102	City of West Columbia	33°59'52"	81°03'27"	Saluda River
S32103	City of Lexington	33°58'25"	81°14'12"	Twelve Mile Creek
S32104	Town of Batesburg-Leesville	33°51'47"	81°28'08"	Lightwood Knot Creek
S32105	Town of Batesburg-Leesville	33°53'40"	81°31'49"	Duncan Creek
S32107	City of West Columbia	34°00'56"	81°14'33"	Lake Murray
S36101	City of Newberry	34°11'09"	81°43'41"	Saluda River
S38101	Orangeburg Department of Public Utilities	33°29'28"	80°52'41"	North Edisto River
S39101	Easley Combined Utility	34°52'00"	82°29'21"	Saluda Lake
S40101	City of Columbia	34°00'14"	81°03'19"	Broad River Canal
S40102	City of Columbia	34°05'51"	81°13'48"	Lake Murray
		Broad Basin		
S11101	Gaffney Board of Public Works	35°06'29"	81°37'16"	Lake Welchel
S11102	Gaffney Board of Public Works	35°08'51"	81°36'34"	Broad River
S20101	Town of Winnsboro	34°20'27"	81°09'18"	Sand Creek
S20104	Town of Winnsboro	34°21'31"	81°06'42"	192 Acre Lake
S23104	Greer Commission of Public Works	34°58'38"	82°14'43"	South Tyger River
S30103	City of Clinton	34°32'47"	81°54'25"	Duncan Creek
S30104	City of Clinton	34°35'27"	81°53'16"	Enoree River
S36102	Town of Whitmire	34°30'44"	81°36'26"	Enoree River
S36103	Town of Whitmire	34°29'41"	81°37'07"	Duncan Creek
S42101	Spartanburg Water System	35°06'37"	81°58'13"	South Pacolet River
S42102	City of Landrum	35°10'49"	82°14'29"	Vaughns Creek
S42103	City of Landrum	35°10'48"	82°16'23"	Hog Back Mountain
S42104	Stinlev, Jackson, Wellford, Duncan Water District	34°56'24"	82°07'29"	Middle Tyger River
S44101	City of Union	34°43'57"	81°29'22"	Broad River
S46102	City of York	34°59'57"	81°15'10"	Lake Carolyn
S46103	City of York	34°59'16"	81°17'18"	Lake Caldwell (Turkey Creek)
		Catawba-Santee Basin		
S08104	Santee Cooper Regional Water	33°14'10"	80°00'40"	Lake Moultrie
S10102	Charleston Commission of Public Works	32°58'38"	79°59'05"	Foster Creek
S10103	Charleston Commission of Public Works	32°55'44"	80°00'59"	Goose Creek Reservoir
S10104	Charleston Commission of Public Works	32°58'47"	79°56'29"	Bushy Park Reservoir
S12101	Chester Metro	34°42'29"	80°52'04"	Catawba River
S28101	City of Camden	34°16'19"	80°35'17"	Little Pine Tree Creek
S28102	Lugoff-Elgin Water Authority	34°20'03"	80°42'22"	Lake Wateree
S29106	Catawba River Water Treatment Plant	34°51'01"	80°51'58"	Catawba River
S46101	City of Rock Hill	35°00'59"	81°00'38"	Catawba River
S46109	City of Rock Hill	34°59'10"	80°58'52"	Lake Wylie
		Pee Dee Basin		
S13101	Town of Cheraw	34°42'26"	79°52'34"	Great Pee Dee River
S13102	City of Pageland	34°41'45"	80°25'52"	Lake Terry
S13103	City of Pageland	34°45'13"	80°23'52"	Old Town Pond
S13104	City of Chesterfield	34°44'08"	80°03'48"	Thompson Creek
S13105	Town of Jefferson	34°37'52"	80°25'12"	Lynches River

Table 1. Locations and descriptions of intakes in South Carolina, 1999 (from R. Devlin, South Carolina Department of Health and Environmental Control, written commun., June 1999)--Continued

Intake no. (fig. 1)	Operator	Latitude	Longitude	Main stream or reservoir
	Pee Dee Basin (Continued)			
S22101	City of Georgetown	33°42'07"	79°15'32"	Great Pee Dee River
S22102	Georgetown County Water and Sewer District/ Waccamaw Neck	33°30'14"	79°07'22"	Waccamaw River
S26101	City of Myrtle Beach	33°43'27"	78°54'13"	Atlantic Intracoastal Waterway
S26102	Grand Strand Water and Sewer Authority	33°38'60"	79°07'23"	Bull Creek
S29104	Town of Kershaw	34°31'30"	80°35'51"	Hanging Rock Creek
S34101	City of Bennettsville	34°38'52"	79°40'24"	Lake Paul Wallace
	Savannah-Salkehatchie Basin			
S01101	City of Abbeville	34°12'55"	82°37'32"	Rocky River/Lake Russell
S02103	City of North Augusta	33°30'05"	81°59'22"	Savannah River
S02105	Avondale Mills, Inc.	33°34'41"	81°48'25"	Flat Rock Pond
S04101	Duke Power Water	34°33'23"	82°44'36"	Lake Hartwell
S07101	Beaufort, Jasper Water and Sewer Authority	32°20'58"	81°07'31"	Savannah River
S19101	Edgefield County Water and Sewer Authority	33°33'37"	82°02'27"	Savannah River
S23103	Greenville Water System	34°49'37"	82°53'37"	Lake Keowee
S35101	McCormick Commission of Public Works	33°52'05"	82°21'06"	Strom Thurmond Reservoir
S35102	McCormick Commission of Public Works	33°55'09"	82°16'05"	Rocky Creek
S37101	City of Seneca	34°42'43"	82°57'31"	Lake Keowee
S37102	City of Walhalla	34°43'25"	83°04'53"	Coneross Creek
S37103	Westminster Commission of Public Works	34°41'03"	83°08'37"	Ramsey Creek
S37104	Westminster Commission of Public Works	34°40'59"	83°08'47"	Chauga River
S39103	City of Pickens	34°54'29"	82°44'09"	City Reservoir
S39104	City of Pickens	34°54'04"	82°44'24"	Twelve Mile Creek
S39105	City of Liberty	34°46'29"	82°40'07"	Eighteen Mile Creek
S39106	Easley Central Water District	34°46'38"	82°46'16"	Twelve Mile Creek

upstream from intakes in South Carolina and in applicable parts of North Carolina and Georgia.

Previous Investigations

In 1998, as part of a cooperative project with the SCDHEC, the USGS developed methods to determine in-stream travel distance and the primary and secondary source-water protection areas for protecting surface-water intakes (Lanier and Falls, 1999; South Carolina Department of Health and Environmental Control, 1999). These methods (described later in this report) were applied to three intakes in South Carolina. The primary source-water protection area for an intake includes all of the hydrologic units, identified by 14-digit Hydrologic Unit Codes (HUC's) (Bower and others, 1999), that adjoin the stream within a 24-hr (10-percent exceedance flow) travel distance upstream from the intake. These subwatersheds generally range in size from 12.1 square kilometers (km^2) to 162 km^2 and serve as a reference for drainage area information (Bower and others, 1999). The 24-hr travel time was selected because the SCDHEC estimated that an intake operator would be unable to react and make proper adjustments for contaminant spills in less than 24 hrs (D. Baize, South Carolina Department of Health and Environmental Control, oral commun., February 1998). If the drainage basin for an intake is larger than the primary source-water protection area, the remainder of the basin upstream from the primary source-water protection area is designated as the secondary source-water protection area.

The optimal method for estimating the travel time of a potential contaminant is to collect time-of-travel (TOT) data for high-, intermediate-, and low-flow conditions upstream from an intake. However, this method is data-intensive and is not a feasible method for most surface-water intake operators. Therefore, a simpler method is needed to estimate the travel time of a potential contaminant for streams where little or no travel-time data are available. In-stream travel-time methods described by Jobson (1996) provide guidance for predicting travel time and dispersion in streams and rivers by using readily attainable data. As described by Jobson (1996), TOT data from more than 980 subreaches for approximately 90 rivers in the United States were used to develop three regression equations that include up to four variables (drainage area, reach slope, annual mean flow, and the measured flow for the reach at the time of the TOT study) to compute the mean velocity between two points. For each of the three mean-velocity equations, a maximum probable velocity equation was developed, for which 99 percent of the observed velocities were smaller.

A hydrologic analysis of TOT studies for selected South Carolina streams was conducted by the USGS to verify use of Jobson's (1996) three mean-velocity equations for computing mean velocity for streams in South Carolina. In this analysis, mean flow velocities from 45 TOT studies (23 in the Piedmont and 22 in the Coastal Plain) on 19 streams were compared to the velocities computed by using Jobson's three mean-velocity equations. Results verify that equation 12 in Jobson (1996) (equation 1 below) reasonably estimated the velocities in South Carolina Piedmont streams (fig. 2) by using drainage area, reach slope, annual mean flow, and measured flow as explanatory variables. Equation 14 in Jobson (1996) (equation 2 below) reasonably estimated velocities in South Carolina Coastal Plain streams (fig. 2) by using drainage area, annual mean flow, and measured flow as explanatory variables. The equations are defined as follows:

South Carolina Piedmont streams:

$$V_p = 0.094 + 0.0143(D'_a)^{0.919}(Q'_a)^{-0.469}S^{0.159}Q/D_a \quad (1)$$

South Carolina Coastal Plain streams:

$$V_p = 0.020 + 0.051(D'_a)^{0.821}(Q'_a)^{-0.465}Q/D_a, \quad (2)$$

where

V_p = mean velocity of the peak concentration, in meters per second;

D'_a = dimensionless drainage area = $(g^{0.5} \times D_a^{1.25})/Q_a$,

where

g = acceleration of gravity, 9.81 meters per square second;

D_a = average drainage area for the segment of interest, in square meters; and

Q_a = annual mean flow of segment of interest, in cubic meters per second;

Q'_a = dimensionless relative flow = Q/Q_a;

S = reach slope, meter per meter; and

Q = average river flow at time of the measurement, in cubic meters per second.

Acknowledgments

The author is grateful to Mr. David Baize, South Carolina Department of Health and Environmental Control, for administrative and technical support and to Mr. Rob Devlin, South Carolina Department of Health and Environmental Control, for providing selected intake data.

METHODS FOR DELINEATION OF PRIMARY AND SECONDARY SOURCE-WATER PROTECTION AREAS

Measured streamflow velocities from TOT studies for South Carolina streams were compared to streamflow velocities calculated by using empirical flow-velocity equations (Jobson, 1996). Results of this comparison were used to determine the equations that best predict streamflow velocity for streams in the Piedmont and Coastal Plain of South Carolina (fig. 2). Streamflow velocities for gaged and ungaged streams in the Piedmont and Coastal Plain of South Carolina can be estimated by using equation 1 for Piedmont streams and equation 2 for Coastal Plain streams (South Carolina Department of Health and Environmental Control, 1999). By using these equations specific to the Piedmont and Coastal Plain physiographic provinces, streamflow velocity was calculated at a high in-stream flow (10-percent exceedance) and multiplied by 24 hrs to determine a 24-hr (10-percent exceedance) travel distance upstream from the intake. As previously stated, a 24-hr time period was chosen because the SCDHEC estimated an intake operator would be unable to react and make proper adjustments for contaminant spills in less than 24 hrs (D. Baize, South Carolina Department of Health and Environmental Control, oral commun., February 1998). A 24-hr travel distance was computed for high (10-percent exceedance), intermediate (50-percent exceedance), and low (90-percent exceedance) flows at the request of the SCDHEC. The stream segment between the intake and the 24-hr point computed at high flow is referred to in this report as the primary travel-time segment. As previously stated, the primary source-water protection area encompasses all 14-digit HUC basins between the intake and the 24-hr point computed at high flow. The remainder of the basin upstream from the primary source-water protection area is designated as the secondary source-water protection area. These procedures also were applied to tributaries of the main stream that have drainage areas of at least 20 km^2 and are contained in the primary travel-time segment. Tributaries that drain areas less than 20 km^2 are considered to be too small for evaluation; if a spill occurs within these small tributaries, the travel time from the confluence of the small tributary and the main stem to the intake is used as the response time.

Reservoirs are a common part of the surface-water flow systems in the Piedmont and the Coastal Plain of South Carolina. The length of the primary travel-time segment is reduced substantially if the travel time through a reservoir is included in the 24-hr travel-time calculation. If the reservoir were to be removed from the flow system after determining the primary travel-time segment, the segment would have to be recalculated. For this study, the effects of all reservoirs with volumes less than that of Fishing Creek Reservoir (fig. 2) are not included in determining the primary travel-time segment. The 7 steps for estimating the 24-hr travel distance for a generic site are given below.

1. *Determine drainage areas and stream distances:*

The intake drainage area (IDA) is delineated for the stream of interest. The stream channel is divided into 1- or 5-kilometer (km) intervals from the intake to a point approximately 55 km upstream. The distance of 55 km was chosen because the empirically derived in-stream flow velocity typically results in a 24-hr travel distance of less than 55 km. The 55-km stream segment is then used in computing the slopes and for referencing the computed 24-hr travel distances.

2. *Determine reach slope (Piedmont sites only):*

Contour elevations and intervening distances are tabulated for every topographic contour between the first contour downstream from the intake and the contour closest to the 55-km point upstream from the intake, or at the headwaters of the basin. The slope between each contour is calculated for the study reach. A weighted average reach slope is computed by multiplying the slope between each contour by the distance between the contours, summing the products, and dividing the sum by the total distance from the downstream-most to the upstream-most contour.

3. *Select an appropriate gaging station:*

The USGS annual data report for South Carolina (Cooney and others, 1998) can be used to determine if any USGS gaging stations (active or discontinued) are located on or near the stream of interest. The minimum length of record required for the station is 13 years (yrs). This number is based on the minimum requirement of 10 yrs set forth in Bulletin 17B (U.S. Water Resources Council, 1981) for computing flood-frequency curves, with an additional 3 yrs added to be conservative.

If two or more USGS gaging stations are located on the stream of interest, the gaging station with a drainage basin that is closer in size to the IDA is used. If no gaging stations are located on the stream of interest, data can be used from a gaging station in a nearby basin—preferably one in the same physiographic region. If additional gaging stations are located in nearby basins, a gaging station with a drainage area that has land use and soil type similar to the IDA of the stream of interest is selected.

The information needed for the gaging station includes gage drainage area (GDA), annual mean flow (MGQ), and the 10-, 50-, and 90-percent exceedance flows (GQ_{10}, GQ_{50}, and GQ_{90}). The GQ_{10} for a stream is a discharge that is exceeded 10 percent of the time for a designated period of time and represents a high flow. The empirical velocity equations do not apply to overbank flow conditions that would occur during flood flows. Flows at or below the GQ_{10} for a stream typically are contained within the stream channel. Therefore, the GQ_{10} for a gaging station is used to calculate the high-flow velocity of the stream rather than extreme flood-flow conditions. The 50- and 90-percent exceedance flows for a stream represent intermediate and low flows, respectively. The 10-, 50-, and 90-percent exceedance flows for the intake are estimated by multiplying the GQ_{10}, GQ_{50}, and GQ_{90} by the ratio of the drainage area for the intake to the drainage area for the gaging station.

4. *Determine the 24-hour range:*

Rather than delineating drainage areas throughout the basin upstream from the intake to determine the 24-hr travel distance, a 24-hr range can be determined by computing the minimum and maximum 24-hr travel distance upstream from the intake. Once the range has been defined, only that part of the basin between these distances needs to be further subdivided.

Examining the exponents of equations 1 and 2 (Previous Investigations section), it can be seen that the average velocity is proportional to the magnitude of D_a, Q, and Q_a. Of these three parameters, only D_a and Q can be varied. D_a is the average drainage area for the segment of interest, or $(D_{u/s}+D_{d/s})/2$, where $D_{u/s}$ is the upstream drainage area and $D_{d/s}$ is the downstream drainage area (both in square meters). If $D_{d/s}$ is equal to the IDA, then only $D_{u/s}$ can be varied. Therefore, to determine the maximum D_a, $D_{u/s}$ also is set equal to the IDA (D_a = IDA). For the minimum D_a, $D_{u/s}$ is set to zero or D_a = IDA/2.

For Q, the maximum is 10-percent exceedance flow and the minimum is 90-percent exceedance flow. An average velocity must be computed for both the maximum and minimum D_a and Q values. The 24-hr range then can be computed by using these maximum and minimum velocities.

If the minimum 24-hr travel distance is greater than the total length of the basin upstream from the intake, then the entire basin is contained within the 24-hr travel distances for all three flows, and the computation of the maximum 24-hr distance is not necessary. For Piedmont basins, if the maximum 24-hr distance is greater (or less) than the distance to the farthest-measured upstream contour, then the reach slope to the first contour upstream from the maximum 24-hr travel distance will need to be recomputed and a new weighted average reach slope calculated. The minimum and maximum 24-hr travel distance then can be recomputed by using the new reach slope.

5. *Delineate drainage areas within the 24-hour range:*

The drainage area is delineated for the area upstream from the minimum 24-hr travel distance. Moving upstream between the minimum and maximum 24-hr travel distance, the reach is proportionally subdivided into weighted drainage-area increments where each increment is no greater than 30 percent of the previous drainage area. By subdividing the 24-hr range into these increments, the change in the average velocity between increments will be kept to about 10 percent. The basin will need to be subdivided upstream and downstream from tributaries if they contribute at least 30 percent of the total area at the point of confluence. If the maximum 24-hr travel distance exceeds the distance to the basin headwaters, the basin does not need to be subdivided into drainage areas of less than 20 km^2. This will not greatly decrease the accuracy of the computation, but will notably decrease the drainage area computations, which can be time consuming.

6. *Determine average drainage areas and final velocities:*

The incremental drainage areas are tabulated from the intake to the maximum 24-hr travel point. The tabulation should include the drainage areas at the minimum and maximum travel-time points, drainage areas delineated between the minimum and maximum travel points, and the river kilometer (RK) where each drainage area is located. If the maximum 24-hr travel distance is greater than the length of the basin, then the total length of the basin is determined and the drainage area is assigned a value of zero at the headwaters. Then, starting at the intake and proceeding upstream, the average drainage area (D_a) is computed for each segment. For example, the first D_a would be computed as the average of the IDA and the delineated drainage area at the minimum 24-hr travel point. The D_a at the second segment would be the average of the delineated drainage area at the minimum 24-hr travel point and the next drainage area subdivision upstream. Once all D_a's are determined, the velocity for each segment is computed by using the 10-, 50-, and 90-percent exceedance flows in conjunction with either equation 1 or 2, as appropriate.

7. *Determine the 24-hour travel distance:*

For each segment between the subdivided drainage areas, the TOT is computed for the 10-, 50-, and 90-percent exceedance flow velocities. For each flow, the computation would begin with the TOT at the first segment, which would include the IDA, and proceed upstream adding the TOT's from each segment until 24 hrs is exceeded. Then 24 hrs is subtracted from the summed TOT. This difference is multiplied by the velocity of the segment where the TOT exceeded 24 hrs. This product is the distance where the 24-hr point was exceeded. The location of the final 24-hr TOT point is computed by subtracting this distance from the location of the upstream end of the segment in which 24 hrs was exceeded. The 24-hr travel distance computed for the 10-percent exceedance flow is the primary travel distance used to segment the source-water protection areas. An example of the final 24-hr TOT points for the 10-, 50-, and 90-percent exceedance flows is shown in figure 3.

Figure 3. Final 24-hour time-of-travel points for the 10-, 50-, and 90-percent exceedance flows for the Aiken intake on Shaw Creek, South Carolina.

As part of the 1998 USGS pilot project, these methods were applied to the Aiken intake on Shaw Creek, the Belton-Honea Path intake on the Saluda River, and the Greenwood intake on Lake Greenwood (fig. 2). As an example, the computation of the 24-hr travel distance for the 10-percent exceedance flow for the Shaw Creek intake is included as supplemental data at the end of the report (T.H. Lanier and W.F. Falls, U.S. Geological Survey, written commun., 1998).

INTAKES WITH ONLY PRIMARY SOURCE-WATER PROTECTION AREAS

An intake has only a primary source-water protection area if the upstream drainage area is equal to one or part of one HUC basin, or is conservatively estimated to have less than 24 hrs of in-stream (high-flow) travel time between the intake and the HUC basin in the headwaters of the drainage basin (T.H. Lanier and W.F. Falls, U.S. Geological Survey, written commun., 1998). For such an intake, the 24-hr travel distance does not have to be calculated to determine that the entire drainage area is designated as a primary source-water protection area. The 29 intakes with only primary source-water protection areas are listed in table 2 along with the 14-digit HUC basins, the corresponding drainage areas, and the intake drainage areas.

Table 2. Surface-water intakes and drainage areas in South Carolina with only primary source-water protection areas, 1999

[HUC, Hydrologic Unit Code; DA, drainage area; km^2, square kilometer]

Intake no. (fig. 1)	14-digit HUC basin[a]	HUC basin DA (km^2)	Intake DA (km^2)
S10103	03050201070010[b]	156	116[c]
S11101	03050105110010[b]	60.4	38.2[c]
S13102	03040202060010[b]	108	16.8[c]
S13103	03040201100010[b]	124	4.74[c]
S20101	03050106080010[b]	99.3	20.6[c]
S20104	03050106080020[b]	52.6	4.33[c]
S23101	03050109010010	65.8	65.8
S23102	03050109020010[b]	142	39.1[c]
S28101	03050104070020[b]	90.6	19.6[c]
S29104	03040202070030[b]	81.7	37.4[c]
S30101	03050109160010[b]	78.5	21.8[c]
S30102	03050109130030[b]	103	1.84[c]
	03050109130010	93.6	93.6
	03050109130020	134	134
		Total intake DA = 229	
S30103	03050108040010[b]	105	43.5[c]
S30106	03050109130030[b]	103	0.44[c]
	03050109130010	93.6	93.6
	03050109130020	134	134
		Total intake DA = 228	
S32103	03050109210040[b]	44.8	5.23[c]
	03050109210030	80.7	80.7
		Total intake DA = 85.9	
S32104	03050203010020[b]	94.5	59.3[c]
S32105	03050203010010[b]	111	3.78[c]
S34101	03040201070010	149	149
S35102	03060107010090[b]	68.8	38.6[c]
S37102	03060101080010	45.8	45.8
S37103	03060102120030[b]	97.9	16.3[c]
S39103	03060101060020[b]	39.9	39.0[c]
S39104	03060101060010[d]	48.4	48.4
	03060101060020[d]	39.9	39.9
		Total intake DA = 88.3	
S39105	03060101090010[b]	89.7	25.8[c]
S42102	03050105150010[b]	18.6	13.6[c]
S42103	03050105150010[b]	18.6	1.86[c]
S46101	03050103010010[b]	118	20.8[c]
S46102	03050106020010[b]	84.3	2.05[c]
S46103	03050106020010[b]	84.3	14.6[c]

[a]Bower and others, 1999.
[b]Intake lies within 14-digit HUC basin.
[c]Drainage area from the intake to the upstream boundary of the HUC basin that contains the intake.
[d]Intake lies at intersection of two 14-digit HUC basins.

INTAKES WITH PRIMARY AND SECONDARY SOURCE-WATER PROTECTION AREAS

Several intakes in South Carolina have large source-water protection areas with streams, tributaries, and reservoirs that extend upstream from the computed 24-hr travel distance. The source-water protection area for some intakes extend into the neighboring States of North Carolina and Georgia. These source-water protection areas can be divided into primary and secondary protection areas by using the computed 24-hr travel distance and the 14-digit HUC basins (Bower and others, 1999), which range in size from 12.1 km^2 to 162 km^2, or the 8-digit HUC basins (Seaber and others, 1987), which generally exceed 1,810 km^2, for intakes having larger secondary source-water protection areas. The smaller drainage area size of the 14-digit HUC basins provided greater definition of the primary source-water protection area thereby reducing the time for inventory of potential contaminant sources within the primary source-water protection area. The 8-digit HUC basins were used for intakes where the secondary source-water protection area encompassed the entire 8-digit HUC basin. By using 8-digit HUC basins for such an intake, the table used to identify the secondary source-water protection areas was reduced in size.

Determination of the 24-hour Travel Time Distance

The travel distance methods (T.H. Lanier and W.F. Falls, U.S. Geological Survey, written commun., 1998) were applied to 40 intakes in South Carolina, which include the 3 pilot project intakes, to determine the 24-hr travel distance that is used to delineate primary and secondary source-water protection areas. If an intake lay within a reservoir, the 24-hr travel distance from the headwaters was computed by using the 10-percent exceedance flow on all major streams and tributaries that entered the reservoir. Several intakes were located near neighboring State boundaries; therefore, the 24-hr travel distance was computed into these neighboring States. Including the 29 intakes with only primary source-water protection areas, these methods were successfully applied to 69 intakes, thereby verifying the methods.

Five intakes along the South Carolina coast are located in tidal rivers or tidal reservoirs. Travel distances could not be determined by using the methods of Lanier and Falls (1999). Therefore, dynamic flow models were used to estimate the travel distances. These tidally influenced sites are located on the Waccamaw River (intake S22102), Atlantic Intracoastal Waterway (S26101), Bull Creek (S26102), Foster Creek (S10102), and Bushy Park Reservoir (S10104) (fig. 4). For the intakes located on the Waccamaw River, Atlantic Intracoastal Waterway, and Bull Creek (fig. 4A), one-dimensional dynamic flow and transport models (Drewes and Conrads, 1995) were used to simulate the transport of a contaminant for selected flow conditions. For intakes located on Foster Creek and Bushy Park Reservoir (fig. 4B), a one-dimensional model described by Bower and others (1993) was used to simulate particle tracking for selected flow conditions.

The following procedures were used to determine the 24-hr travel distance for the Waccamaw River, Atlantic Intracoastal Waterway, and Bull Creek intakes.

1. Concurrent flow periods near the 10-, 50-, and 90-percent exceedance flows for the upstream boundaries (Pee Dee River at Route U.S. 701 and Waccamaw River at Route U.S. 501 Bypass) were selected from the 1990–94 water years (Bennett and others, 1990–93; Cooney and others, 1994). A water year is the 12-month period from October 1 through September 30 of the following year, and is identified by the calendar year in which it ends.

2. The flow periods were simulated using the BRANCH unsteady flow model (Schaffranek and others, 1981). Simulations were begun 3 days prior to the flow periods of interest so the model would stabilize before final computations were made.

3. The flow field data simulated by the BRANCH model were converted to the flow field for the Branched Langrangian Transport Model (BLTM) (Jobson and Schoellhamer, 1987). Flows at 15-minute time steps of the BRANCH model were averaged to produce 60-minute time-step flows for the BLTM. Non-branching internal junctions were removed in the conversion to the BLTM.

4. The BLTM was used to simulate a slug of contaminant injected at the upstream boundaries of the model. For the low-flow (90-percent exceedance) simulation, a slug of contaminant also was injected at the downstream boundary. During low-flow periods, the net streamflow can be upstream due to reversing flows in tidal reaches.

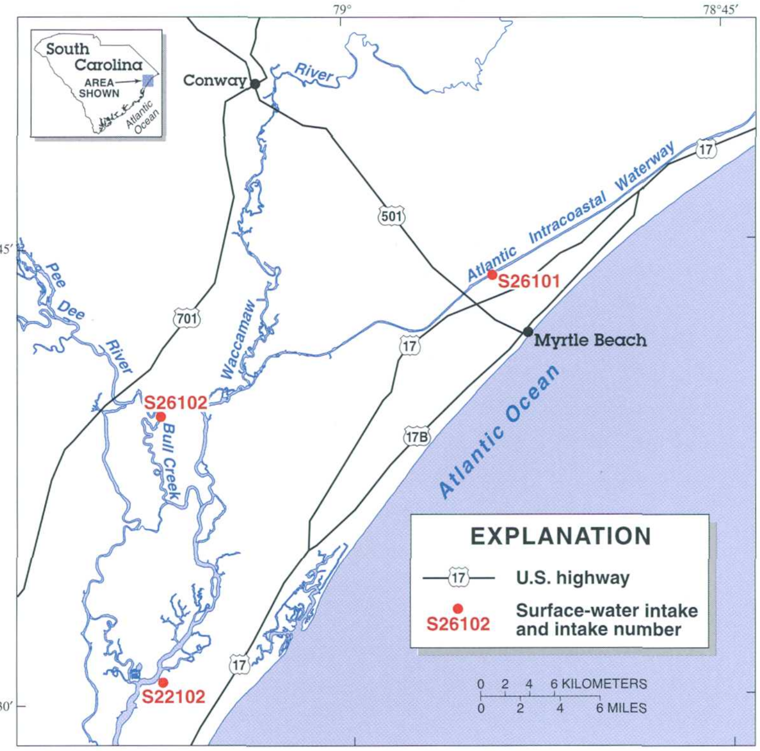
5. The location of the 24-hr travel distance was determined by analyzing the output from the BLTM. A post-processing program was used to generate time series of concentrations at the intakes and selected upstream locations.

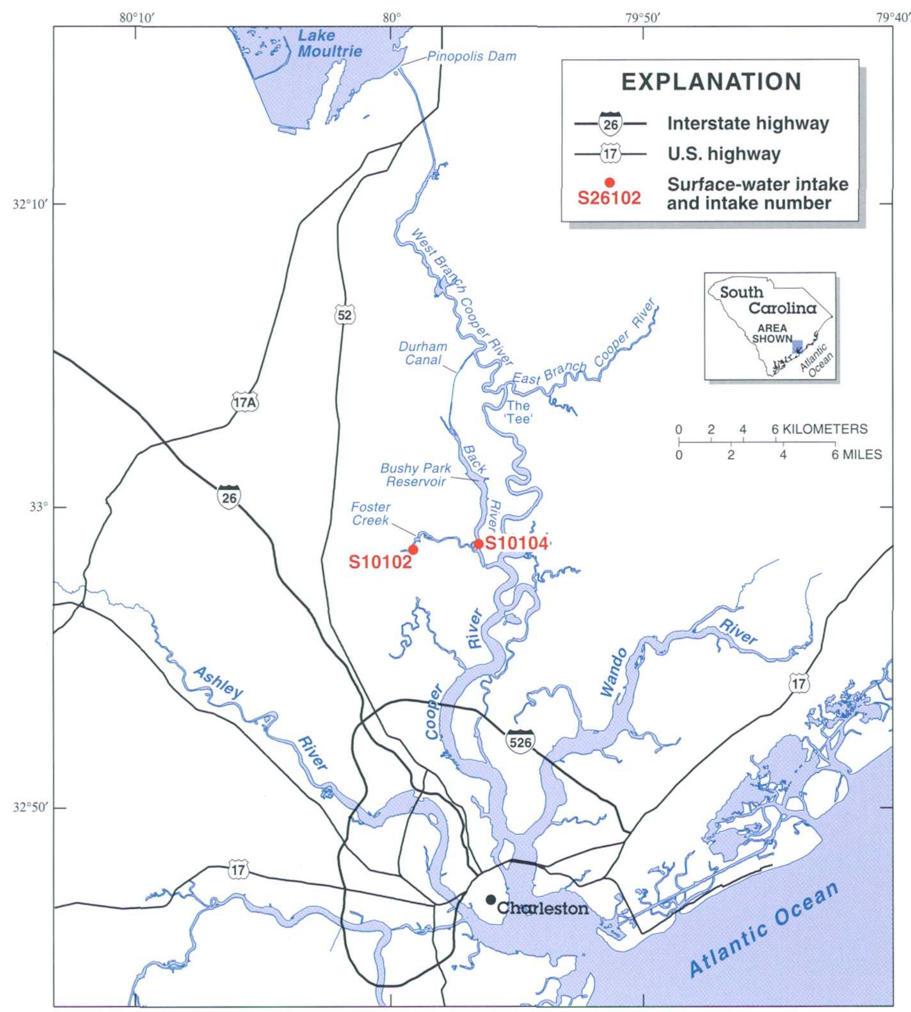
6. The time of peak concentration at the intake was determined, and then the location of the peak concentration in the previous 24 hrs was determined.

For the intakes on Foster Creek and Bushy Park Reservoir (fig. 4B), the particle-tracking utility of the BRANCH model was used to simulate the advection of particles. The schematization of the model is described in Bower and others (1993). The flow periods selected for this analysis are near the 10-, 50-, and 90-percent exceedance flows from the Pinopolis Dam on the West Branch of the Cooper River (fig. 4B). The flow rate of the Foster Creek intake for the simulation period was used. However, the Bushy Park Reservoir intake was not online during the period of the data base, so no flow rates were available for this intake.

A particle was released 1.61 km downstream from the Foster Creek and Bushy Park Reservoir

(A)





(B)

Figure 4. Locations of surface-water intakes on (A) the Waccamaw River, Atlantic Intracoastal Waterway, and Bull Creek; and (B) Foster Creek and Bushy Park Reservoir, South Carolina.

intakes for the low-flow simulation period of July 28–August 9, 1993 (Bennett and others, 1993). It took approximately 50 hrs for the particle located downstream from the Foster Creek intake to move upstream toward the intake. The particle located downstream from the Bushy Park Reservoir intake did not reach the intake during the simulation period. The flow rate of the Foster Creek intake was then set to zero to evaluate the sensitivity of particle advection to flow rate. At a flow rate of zero, the particle took approximately 210 hrs to move 4.83 km downstream to the confluence with the Back River. Intermediate- and high-flow periods were evaluated with similar results.

These results indicate that the flows at the intakes in Foster Creek and the Bushy Park Reservoir were not affected by the flows of the Cooper River, but were strongly affected by the intake flow rates. Although the water levels of Foster Creek and the lower reach of Bushy Park Reservoir are tidally influenced, the flows in the system also are influenced by other factors such as wind-driven currents (Bower and others, 1993). Rainfall events affect the flows in the headwaters of Foster Creek, and tidal exchange with Durham Canal affects the flows in the upper reach of Bushy Park Reservoir. Therefore, the primary source-water protection area for the Foster Creek (S10102) intake and the Bushy Park Reservoir (S10104) intake will be the 14-digit HUC's that include Foster Creek and Bushy Park Reservoir.

The 24-hr travel time distance was computed for 45 intakes in South Carolina, of which 3 intakes were analyzed as part of the 1998 pilot project. The results of the computations are listed in table 3 (p. 16).

Determination of Primary and Secondary Source-Water Protection Areas

The primary source-water protection area for an intake encompasses all 14-digit HUC basins adjoining the stream within the computed 24-hr (10-percent exceedance flow) travel distance upstream from the intake. If an intake is located on any part of a reservoir, the primary source-water protection area for the reservoir intake includes all 14-digit HUC basins adjoining the reservoir and the feeder streams within a 24-hr travel distance upstream from the headwaters of the reservoir. The primary source-water protection area is limited to the base of the upstream reservoir's dam (D. Baize, South Carolina Department of Health and Environmental Control, oral commun., July 1999) if the primary source-water protection area of an intake extends into one of the following lakes: Blewett Falls, Greenwood, Hartwell, Jocassee, Keowee, Marion, Moultrie, Murray, Norman, Richard B. Russell, J. Strom Thurmond, Wateree, Wylie, or Fishing Creek Reservoir (fig. 2). If the drainage basin for an intake is larger than the primary source-water protection area, the remaining drainage area upstream from the primary source-water protection area is designated as the secondary source-water protection area. Table 4 (p. 20) lists the primary and secondary source-water protection areas for 45 intakes, of which 3 intakes were analyzed as part of the 1998 pilot project.

SUMMARY

In a 1998 pilot project, the U.S. Geological Survey, in cooperation with the South Carolina Department of Health and Environmental Control, developed methods to determine in-stream travel distance and the primary and secondary source-water protection areas for surface-water intakes in South Carolina. These methods were applied to three intakes in South Carolina. In June 1999, the U.S. Geological Survey entered into a cooperative agreement with the South Carolina Department of Health and Environmental Control to verify the statewide applicability of the source-water protection methods previously developed. These methods were successfully applied to 69 intakes in South Carolina, thereby verifying the methods.

The 24-hour distance for the 10-, 50-, and 90-percent exceedance flow was determined on the main streams and tributaries upstream from all intakes with drainage areas that are estimated to have more than 24 hours of in-stream travel time between the intake and the 14-digit Hydrologic Unit Code basins in the headwaters of the drainage basin. The 24-hour travel distance from an intake computed for the 10-percent exceedance flow is the primary travel distance used to segment the primary and secondary source-water protection areas. All 14-digit Hydrologic Unit Code basins that adjoin the surface-water flow system between an intake and the upstream 10-percent exceedance, 24-hour travel distance were designated as the primary source-water protection area for that intake. The remainder of the source-water protection area upstream from the primary source-water protection area was designated as the secondary source-water protection area. For this study, the effect

of reservoirs with volumes less than that of Fishing Creek Reservoir was not included in the calculation of the primary travel distance. However, for intakes with primary travel times that extended into larger reservoirs, the base of the larger reservoir's dam was the upstream limit of the primary source-water protection area. The 24-hour distance and the primary and secondary source-water protection areas were determined for 45 intakes in South Carolina.

Some of the surface-water intakes in South Carolina have drainage areas that are equal to or less than one 14-digit Hydrologic Unit Code basin, or are estimated to have less than 24-hours of in-stream travel time between the intake and the 14-digit Hydrologic Unit Code basin(s) in the headwaters of the drainage basin. For such an intake, the entire drainage area is designated as the primary source-water protection area and the 24-hour travel distance does not have to be determined. Twenty-nine intakes meet these criteria and the 24-hour travel distance was not calculated.

The source-water protection methods were not applicable for the Waccamaw River, Atlantic Intracoastal Waterway, Bull Creek, Foster Creek, and Bushy Park Reservoir intakes because these intakes are located along the South Carolina coast and are tidally influenced. Therefore, the 24-hour distance and the primary and secondary source-water protection areas for these five intakes were determined by using one-dimensional dynamic flow and transport models.

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Table 3. Twenty-four-hour travel distances for surface-water intakes in South Carolina, 1999

[TOT_{10}, TOT_{50}, and TOT_{90}, time of travel for 10-, 50-, and 90-percent exceedance flows, respectively; RK, river kilometer; EB, entire basin affected; NE, no effect; NC, not calculated]

Intake no. (fig. 1)	Stream	24-hour TOT_{10} point (RK)	24-hour TOT_{50} point (RK)	24-hour TOT_{90} point (RK)
S01101	Rocky River[a]	35.7	23.5	17.2
	Beaverdam Creek[a]	EB	EB	EB
	Coldwater Creek[a]	EB	EB	EB
	Big Generostee Creek[a]	EB	EB	EB
S02101	Shaw Creek[b]	43.8	41.2	39.0
	Paces Branch[c]	3.8	1.8	NE
S02103	Savannah River[b]	J. Strom Thurmond Dam (J. Strom Thurmond Lake)		
	Stevens Creek[c]	54.0	27.5	18.1
	Horn Creek[c]	26.1	13.7	5.6
	Turkey Creek[c]	15.5	NE	NE
	Kiokee Creek[c]	26.4	14.3	9.8
S02105	Horse Creek[b]	EB	EB	EB
S04101	Three and Twenty Creek[a]	EB	EB	EB
	Eighteen Mile Creek[a]	EB	EB	EB
	Twelve Mile Creek[a]	39.8	31.2	25.0
	Coneross Creek[a]	34.0	26.5	22.3
	Chauga River[a]	44.3	33.7	25.8
	Tugaloo River[a]	61.4	45.2	32.5
	Tallulah River[c]	45.4	29.6	17.5
	Stekoa Creek[c]	26.0	15.7	6.3
	Warwoman Creek[c]	8.8	NE	NE
	West Fork Chattooga[c]	1.0	NE	NE
S04105	Saluda River[b]	135.7	120.1	109.6
	Big Creek[c]	EB	17.2	13.5
	Grove Creek[c]	EB	17.0	11.7
	Hurricane Creek[c]	EB	8.5	3.0
	Brushy Creek[c]	14.8	5.1	NE
	Middle Branch[c]	5.5	NE	NE
	Georges Creek[c]	3.9	NE	NE
S07101	Savannah River[b]	86.1	54.3	43.2
	Cypress Creek[c]	34.3	14.6	3.9
	Clear Water Creek[c]	2.4	NE	NE
	Ebenezer Creek[c]	35.9	10.1	2.4
S08104	Lake Moultrie[a]	Santee Dam (Lake Marion)		
S10101	Edisto River[b]	62.8	35.5	22.7
	Fourhole Swamp[c]	48.5	19.3	8.6
	Dean Swamp[c]	9.9	NE	NE
	Indianfield Swamp[c]	23.8	7.0	1.1
	Cattle Creek[c]	4.5	NE	NE
S10102[d]	Foster Creek[b]	NC	NC	NC
S10104[d]	Bushy Park Reservoir[b]	NC	NC	NC
S11102	Broad River[b]	117.6	103.5	93.4
	First Broad River[c]	40.2	26.8	19.7
	Sandy Run Creek[c]	26.8	18.2	11.8
	Second Broad River[c]	29.3	16.4	8.1
	Green River[c]	5.5	NE	NE
S12101	Catawba River[b]	Catawba Dam (Lake Wylie)		29.4
	Twelve Mile Creek[c]	28.4	12.9	4.5
	Sugar Creek[c]	24.8	9.3	NE
	McAlpine Creek[c]	10.3	NE	NE
S13101	Great Pee Dee River[b]	Blewett Falls Dam (Blewett Falls Lake)		31.4
	S. Fork Jones Creek[c]	24.8	13.2	4.6
	Hitchcock Creek[c]	23.4	10.3	1.4

Table 3. Twenty-four-hour travel distances for surface-water intakes in South Carolina, 1999--Continued

[TOT_{10}, TOT_{50}, and TOT_{90}, time of travel for 10-, 50-, and 90-percent exceedance flows, respectively; RK, river kilometer; EB, entire basin affected; NE, no effect; NC, not calculated]

Intake no. (fig. 1)	Stream	24-hour TOT_{10} point (RK)	24-hour TOT_{50} point (RK)	24-hour TOT_{90} point (RK)
S13104	Thompson Creek[b]	EB	EB	EB
S13105	Lynches River[b]	EB	EB	EB
S19101	Savannah River[b]	J. Strom Thurmond Dam (J. Strom Thurmond Lake)		
	Stevens Creek[c]	58.6	31.2	20.5
	Horn Creek[c]	28.7	17.1	9.0
	Turkey Creek[c]	20.1	NE	NE
	Kiokee Creek[c]	EB	EB	EB
S22101	Great Pee Dee River[b]	100.7	65.0	47.1
	Lynches River[c]	38.4	13.5	2.1
	Singleton Swamp[c]	17.6	NE	NE
	Catfish Creek[c]	13.3	NE	NE
	Jefferies Creek[c]	7.0	NE	NE
S22102[d]	Waccamaw River/Bull Creek/Pee Dee River[b]	39.6	16.6	10.0
	Waccamaw River[b]	NE	NE	12.6[e]
	Great Pee Dee River[c]	1.5	NE	NE
S23103	Flat Shoals River[a]	EB	EB	EB
S23104	South Tyger River[b]	EB	EB	EB
S24101	Cane Creek[a]	EB	EB	EB
	Long Lick Branch[a]	EB	EB	EB
	Mulberry Creek[a]	EB	EB	EB
	Turkey Creek[a]	EB	24.8	20.3
	Rabon Creek[a]	EB	EB	EB
	North Rabon Creek[c]	18.2	10.0	3.7
	South Rabon Creek[c]	18.2	9.7	3.7
	Reedy River[a]	55.8	41.3	31.1
	Walnut Creek[c]	EB	EB	11.7
	Horse Creek[c]	11.9	2.9	NE
	Saluda River[a]	106.1	88.6	78.1
	Broad Mouth Creek[c]	20.8	12.7	6.4
	Mountain Creek[c]	15.9	8.7	2.6
	Big Creek[c]	10.0	NE	NE
	Hurricane Creek[c]	0.4	NE	NE
	Grove Creek[c]	8.7	NE	NE
S26101[d]	Atlantic Intracoastal Waterway/Waccamaw River[b]	21.7	11.3	9.3
	Atlantic Intracoastal Waterway[b]	NE	NE	6.0[f]
S26102[d]	Bull Creek/Little Pee Dee River[b]	62.8	47.2	20.9
	Great Pee Dee River[c]	70.2	37.8	13.2
	Lynches River[c]	17.9	NE	NE
	Singleton Swamp[c]	4.2	NE	NE
	Catfish Creek[c]	0.5	NE	NE
S28102	Little Wateree Creek[a]	EB	EB	EB
	Catawba River[a]	Fishing Creek Dam (Fishing Creek Reservoir)		
	Rocky Creek[c]	39.6	21.9	14.6
	Fishing Creek[c]	42.8	21.2	12.7
	South Fork Fishing Creek[c]	2.9	NE	NE
S29106	Catawba River[b]	Catawba Dam (Lake Wylie)		28.3
	Twelve Mile Creek[c]	35.1	19.2	12.1
	Sugar Creek[c]	33.7	16.6	7.8
	McAlpine Creek[c]	18.5	1.3	NE
S30104	Enoree River[b]	89.6	74.1	65.8
S32101	Congaree Creek[b]	EB	EB	EB
S32102	Saluda River[b]	Saluda Dam (Lake Murray)		
	Twelve Mile Creek[c]	EB	EB	EB

Table 3. Twenty-four-hour travel distances for surface-water intakes in South Carolina, 1999--Continued

[TOT_{10}, TOT_{50}, and TOT_{90}, time of travel for 10-, 50-, and 90-percent exceedance flows, respectively; RK, river kilometer; EB, entire basin affected; NE, no effect; NC, not calculated]

Intake no. (fig. 1)	Stream	24-hour TOT_{10} point (RK)	24-hour TOT_{50} point (RK)	24-hour TOT_{90} point (RK)
S32107	Little Saluda River[a]	EB	EB	EB
	Clouds Creek[a]	EB	EB	EB
	Bush River[a]	33.0	18.6	12.1
	Saluda River[a]	Buzzard Roost Dam (Lake Greenwood)		22.8
	Little River[c]	33.0	18.9	10.9
	Ninety Six Creek[c]	13.3	2.6	NE
	Wilson Creek[c]	11.0	NE	NE
S35101	Long Cane Creek[a]	41.7	26.3	19.0
	Little River (South Carolina)[a]	44.8	27.9	20.2
	Calhoun Creek[a]	24.5	12.1	6.2
	Middle Creek[a]	EB	EB	EB
	Little River (Georgia)[a]	46.5	24.9	16.4
	Fishing Creek[a]	EB	EB	EB
	Broad River[a]	59.2	39.2	28.5
	Long Creek[c]	40.0	26.3	19.3
	South Fork Broad River[c]	18.0	0.6	NE
S36101	Saluda River[b]	Buzzard Roost Dam (Lake Greenwood)		24.2
	Little River[c]	33.7	19.6	11.6
	Ninety Six Creek[c]	13.9	3.3	NE
	Wilson Creek[c]	11.9	NE	NE
S36102	Enoree River[b]	49.9	33.7	21.6
S36103	Duncan Creek[b]	41.9	31.5	22.8
S37101	Flat Shoals River[a]	EB	EB	EB
S37104	Chauga River[b]	40.6	32.7	24.9
S38101	North Edisto River[b]	43.6	32.0	24.6
	Bull Swamp Creek[c]	14.9	6.6	1.0
S39101	Saluda River[b]	44.9	35.6	29.4
	North Saluda River[c]	29.6	22.6	15.3
	South Saluda River[c]	20.7	10.7	3.8
S39106	Twelve Mile Creek[b]	37.6	29.5	24.9
S40101	Broad River[b]	77.2	52.9	38.5
	Little River[c]	30.6	12.3	5.5
	Cannons Creek[c]	EB	EB	EB
	Enoree River[c]	10.1	NE	NE
	Tyger River[c]	5.1	NE	NE
S40102	Little Saluda River[a]	EB	EB	EB
	Clouds Creek[a]	EB	EB	EB
	Bush River[a]	33.0	18.6	12.1
	Saluda River[a]	Buzzard Roost Dam (Lake Greenwood)		22.8
	Little River[c]	33.0	18.9	10.9
	Ninety Six Creek[c]	13.3	2.6	NE
	Wilson Creek[c]	11.0	NE	NE
S42101	South Pacolet River[b]	EB	EB	EB
S42104	Middle Tyger River[b]	EB	EB	EB
S44101	Broad River[b]	70.5	49.0	36.2
	Turkey Creek[c]	32.4	22.6	15.8
	Pacolet River[c]	38.0	23.1	13.8
	Bullock Creek[c]	25.5	15.6	8.1
	Thicketty Creek[c]	26.3	NC	NC
	Kings Creek[c]	16.2	4.3	NE
	Buffalo Creek[c]	9.2	NE	NE

Table 3. Twenty-four-hour travel distances for surface-water intakes in South Carolina, 1999--Continued

[TOT_{10}, TOT_{50}, and TOT_{90}, time of travel for 10-, 50-, and 90-percent exceedance flows, respectively; RK, river kilometer; EB, entire basin affected; NE, no effect; NC, not calculated]

Intake no. (fig. 1)	Stream	24-hour TOT_{10} point (RK)	24-hour TOT_{50} point (RK)	24-hour TOT_{90} point (RK)
S46109	Catawba River[a]	Cowans Ford Dam (Lake Norman)		27.8
	South Fork Catawba[c]	51.4	35.9	27.6
	Clark Creek[c]	7.7	NE	NE
	Dutchmans Creek[c]	EB	EB	EB

[a]RK zero is at the headwaters of the lake.
[b]RK zero is at the intake.
[c]RK zero is at the confluence with receiving stream.
[d]Tidally influenced intake.
[e]Southwestern direction resulting from flow reversal/tidal conditions.
[f]Northeastern direction resulting from flow reversal/tidal conditions.

Table 4. Identifying information for primary and secondary source-water protection areas for 45 surface-water intakes in South Carolina, 1999

[SWPA, source-water protection area; DA, drainage area; km^2, square kilometer; HUC, Hydrologic Unit Code; N/A, not applicable; IND, indeterminate, flow tidally affected]

Intake no. (fig. 1)	Intake DA[a] (km^2)	Primary SWPA: 14-digit HUC basins	Primary SWPA: HUC basin DA (km^2)	Secondary SWPA: HUC basins	Secondary SWPA: HUC basin DA (km^2)
S01101	7,470	03060103030 010 - 130	996	03060101[b]	2,640
		03060103040 010 - 030	319	03060102[b]	2,580
		03060103070 010 - 050	507	03060103020 010	202
		03060103080 010	230		
		Total primary DA = 2,050		Total secondary DA = 5,420	
S02101	180.0	03050204020 010	87.0	N/A	
		03050204020 020	93.0[c]		
		Total primary DA = 180			
S02103	18,500	03060106030 010 - 050	661	03060101[b]	2,640
		03060106050 010	65.4[c]	03060102[b]	2,580
		03060107010 080	61.5	03060103[b]	4,740
		03060107010 100	38.8	03060104[b]	3,880
		03060107020 040	126	03060105[b]	1,980
		03060107020 080	28.7	03060107010 010 - 070	475
		03060107030 010	113.0	03060107010 090	68.8
		03060107040 010 - 070	532	03060107020 010 - 030	286
				03060107020 050 - 070	186
		Total primary DA = 1,630		Total secondary DA = 16,800	
S02105	155	03060106060 010 - 020	154	N/A	
		03060106060 030	0.75[c]		
		Total primary DA = 155			
S04101	5,420	03060101040 010 - 070	546	03060101010 010 - 030	250
		03060101060 010 - 060	275	03060101020 010	129
		03060101070 010 - 020	126	03060101030 010 - 030	319
		03060101080 010 - 020	194	03060101050 010 - 050	425
		03060101090 010 - 020	154	03060102010 020	113
		03060101100 010 - 020	239	03060102070 010 - 020	128
		03060102010 010	172		
		03060102010 030	35.0		
		03060102060 010 - 080	739		
		03060102070 030 - 080	362		
		03060102120 010 - 040	286		
		03060102130 010 - 070	727		
		03060103020 010	202		
		Total primary DA = 4,060		Total secondary DA = 1,360	
S04105	1,240	03050109040 020 - 050	248	03050109010 010 - 020	196
		03050109050 010	85.4	03050109020 010 - 030	316
		03050109060 010 - 020	54.4	03050109030 010	127
		03050109070 010	50.7	03050109040 010	121
		03050109080 010	40.8		
		Total primary DA = 479		Total secondary DA = 760	

Table 4. Identifying information for primary and secondary source-water protection areas for 45 surface-water intakes in South Carolina, 1999--Continued

[SWPA, source-water protection area; DA, drainage area; km^2, square kilometer; HUC, Hydrologic Unit Code; N/A, not applicable; IND, indeterminate, flow tidally affected]

Intake no. (fig. 1)	Intake DA[a] (km^2)	Primary SWPA		Secondary SWPA	
		14-digit HUC basins	HUC basin DA (km^2)	HUC basins	HUC basin DA (km^2)
S07101	26,400	03060109020 010	236	03060101[b]	2,640
		03060109020 030 - 040	206	03060102[b]	2,580
		03060109020 060 - 070	148	03060103[b]	4,740
		03060109030 020 - 030	386	03060104[b]	3,880
		03060109050 010	38.0	03060105[b]	1,980
		03060109060 010	79.3[c]	03060106[b]	4,750
		03060109060 020 - 050	314	03060107[b]	1,920
				03060108[b]	2,200
				03060109020 020	43.5
				03060109020 050	132
				03060109030 010	124
		Total primary DA = 1,410		Total secondary DA = 25,000	
S08104	38,200	03050201010 010 - 020	230	03050101[b]	6,100
		03050201010 030	86.0[c]	03050102[b]	1,700
				03050103[b]	3,550
				03050104[b]	3,130
				03050105[b]	6,420
				03050106[b]	3,340
				03050107[b]	2,100
				03050108[b]	1,890
				03050109[b]	6,420
				03050110[b]	1,830
				03050111[b]	1,410
		Total primary DA = 316		Total secondary DA = 37,900	
S10101	7,050	03050205010 040	103	03050203[b]	1,970
		03050205020 020	84.4	03050204[b]	2,240
		03050205030 010 - 020	188	03050205010 010 - 030	225
		03050205040 010 - 040	413	03050205020 010	85.9
		03050205050 010	40.7	03050206010 010 - 020	208
		03050205060 010	6.34[c]	03050206020 010 - 040	294
		03050206040 010	105	03050206030 010 - 020	176
		03050206040 040 - 050	99.4	03050206040 020 - 030	64.9
		03050206060 010 - 040	270	03050206050 010 - 020	156
		03050206070 010 - 040	319		
		Total primary DA = 1,630		Total secondary DA = 5,420	
S10102	IND	03050201060 010 - 020	199	03050101[b]	6,100
				03050102[b]	1,700
				03050103[b]	3,550
				03050104[b]	3,130
				03050105[b]	6,420
				03050106[b]	3,340
				03050107[b]	2,100
				03050108[b]	1,890
				03050109[b]	6,420
				03050110[b]	1,830
				03050111[b]	1,410
				03050201030 010	146
				03050201010 010 - 030	355
				03050201020 010 - 040	328
		Total primary DA = 199		Total secondary DA = 38,700	

Table 4. Identifying information for primary and secondary source-water protection areas for 45 surface-water intakes in South Carolina, 1999--Continued

[SWPA, source-water protection area; DA, drainage area; km^2, square kilometer; HUC, Hydrologic Unit Code; N/A, not applicable; IND, indeterminate, flow tidally affected]

Intake no. (fig. 1)	Intake DA[a] (km^2)	Primary SWPA: 14-digit HUC basins	Primary SWPA: HUC basin DA (km^2)	Secondary SWPA: HUC basins	Secondary SWPA: HUC basin DA (km^2)
S10104	IND	03050201060 010 - 020	199	03050101[b]	6,100
				03050102[b]	1,700
				03050103[b]	3,550
				03050104[b]	3,130
				03050105[b]	6,420
				03050106[b]	3,340
				03050107[b]	2,100
				03050108[b]	1,890
				03050109[b]	6,420
				03050110[b]	1,830
				03050111[b]	1,410
				03050201030 010	146
				03050201010 010 - 030	355
				03050201020 010 - 040	328
		Total primary DA = 199		Total secondary DA = 38,700	
S11102	3,360	03050105020 040	97.6	03050105010 010	110
		03050105030 010	137	03050105020 010 - 030	290
		03050105040 090	63.1	03050105040 010 - 080	662
		03050105050 010 - 040	334	03050105060 010 - 020	117
		03050105070 030	90.3	03050105070 010 - 020	232
		03050105070 050 - 080	256	03050105070 040	67.6
		03050105080 060 - 070	207	03050105080 010 - 050	467
		03050105080 090 - 110	166		
		03050105090 010	59.1[c]		
		Total primary DA = 1,410		Total secondary DA = 1,950	
S12101	9,370	03050103010 010 - 030	279	03050101[b]	6,100
		03050103010 040	58.2[c]	03050102[b]	1,700
		03050103020 010 - 050	570	03050103020 060 - 070	87.6
		03050103020 080	54.9		
		03050103030 010 - 030	518		
		Total primary DA = 1,480		Total secondary DA = 7,890	
S13101	18,900	03040201010 010 - 100	1028	03040101[b]	6,270
		03040201020 010	68.5	03040102[b]	2,370
		03040201030 010	83.2	03040103[b]	3,060
		03040201040 010	80.2	03040104[b]	2,230
		03040201050 010	37.2[c]	03040105[b]	3,680
		Total primary DA = 1,300		Total secondary DA = 17,600	
S13104	382	03040201060 010	108	N/A	
		03040201060 015	81.3		
		03040201060 020 - 040	183		
		03040201060 050	10.0[c]		
		Total primary DA = 382			
S13105	452	03040202010 010	132	N/A	
		03040202020 010	60.6		
		03040202030 010 - 020	129		
		03040202040 010	126		
		03040202050 010	4.14[c]		
		Total primary DA = 452			

Table 4. Identifying information for primary and secondary source-water protection areas for 45 surface-water intakes in South Carolina, 1999--Continued

[SWPA, source-water protection area; DA, drainage area; km^2, square kilometer; HUC, Hydrologic Unit Code; N/A, not applicable; IND, indeterminate, flow tidally affected]

Intake no. (fig. 1)	Intake DA[a] (km^2)	Primary SWPA: 14-digit HUC basins	Primary SWPA: HUC basin DA (km^2)	Secondary SWPA: HUC basins	Secondary SWPA: HUC basin DA (km^2)
S19101	18,400	03060106030 010 - 050	661	03060101[b]	2,640
		03060106050 010	5.44[c]	03060102[b]	2,580
		03060107010 080 - 100	169	03060103[b]	4,740
		03060107020 040	126	03060104[b]	3,880
		03060107020 080	28.7	03060105[b]	1,980
		03060107030 010	113	03060107010 010 - 070	475
		03060107040 010 - 070	532	03060107020 010 - 030	286
				03060107020 050 - 070	186
		Total primary DA = 1,640		Total secondary DA = 16,800	
S22101	28,200	03040201120 030	60.0	03040201010 010 - 100	1,028
		03040201130 030	76.3	03040201020 010	68.5
		03040201140 010 - 030	237	03040201030 010	83.2
		03040201150 050	114	03040201040 010	80.2
		03040201160 010 - 030	241	03040201050 010 - 100	913
		03040201160 040	123[c]	03040201060 010 - 100	897
		03040202120 030 - 040	216	03040201070 010 - 020	201
		03040202130 010	154	03040201080 010 - 020	180
		03040202170 010	94.7	03040201090 010 - 040	322
				03040201100 010 - 050	442
				03040201110 010 - 100	756
				03040201120 010 - 020	281
				03040201130 010 - 020	257
				03040201130 040 - 060	221
				03040201150 010 - 040	337
				03040202010 010	132
				03040202020 010	60.5
				03040202030 010 - 020	129
				03040202040 010	126
				03040202050 010 - 060	480
				03040202060 010	108
				03040202070 010 - 040	352
				03040202080 010 - 020	161
				03040202090 010 - 060	513
				03040202100 010 - 070	436
				03040202110 010 - 020	141
				03040202120 010 - 020	224
				03040202140 010	80.3
				03040202150 010	104
				03040202160 010	146
				03040101[b]	6,270
				03040102[b]	2,370
				03040103[b]	3,060
				03040104[b]	2,230
				03040105[b]	3,680
		Total primary DA = 1,320		Total secondary DA = 26,900	

Table 4. Identifying information for primary and secondary source-water protection areas for 45 surface-water intakes in South Carolina, 1999--Continued

[SWPA, source-water protection area; DA, drainage area; km^2, square kilometer; HUC, Hydrologic Unit Code; N/A, not applicable; IND, indeterminate, flow tidally affected]

Intake no. (fig. 1)	Intake DA[a] (km^2)	Primary SWPA		Secondary SWPA	
		14-digit HUC basins	HUC basin DA (km^2)	HUC basins	HUC basin DA (km^2)
S22102	IND	03040201160 040	155	03040101[b]	6,270
		03040201170 010 - 030	302	03040102[b]	2,370
		03040204070 060	88.4	03040103[b]	3,060
		03040206150 010 - 030	218	03040104[b]	2,230
				03040105[b]	3,680
				03040201010 010 - 100	1,028
				03040201020 010	68.5
				03040201030 010	83.2
				03040201040 010	80.2
				03040201050 010 - 100	913
				03040201060 010 - 100	897
				03040201070 010 - 020	201
				03040201080 010 - 020	180
				03040201090 010 - 040	322
				03040201100 010 - 050	442
				03040201110 010 - 100	756
				03040201120 010 - 030	341
				03040201130 010 - 060	555
				03040201140 010 - 030	237
				03040201150 010 - 050	451
				03040201160 010 - 030	241
				03040202[b]	3,600
				03040203[b]	4,530
				03040204010 010 - 070	480
				03040204020 010 - 030	193
				03040204030 010 - 070	483
				03040204040 010 - 040	330
				03040204048 010	87.7
				03040204050 010 - 040	395
				03040204060 010	54.8
				03040204070 010 - 050	543
				03040204070 070	91.4
				03040204080 010 - 060	563
				03040204081 010	7.88
				03040204090 010 - 020	215
				03040206010 010 - 070	827
				03040206020 010 - 040	202
				03040206030 010	172
				03040206040 010	48.1
				03040206050 010	24.5
				03040206060 010 - 060	589
				03040206090 010 - 030	307
				03040206100 010	91.9
				03040206102 010	52.0
				03040206110 010	137
				03040206120 010 - 050	228
				03040206130 010 - 030	338
				03040206140 010 - 030	322
				03040207020 130 - 150	144
		Total primary DA = 763		Total secondary DA = 39,500	

Table 4. Identifying information for primary and secondary source-water protection areas for 45 surface-water intakes in South Carolina, 1999--Continued

[SWPA, source-water protection area; DA, drainage area; km^2, square kilometer; HUC, Hydrologic Unit Code; N/A, not applicable; IND, indeterminate, flow tidally affected]

Intake no. (fig. 1)	Intake DA[a] (km^2)	Primary SWPA		Secondary SWPA	
		14-digit HUC basins	HUC basin DA (km^2)	HUC basins	HUC basin DA (km^2)
S23103	1,120	03060101030 010 - 030	319	03060101010 010 - 030	250
		03060101050 010 - 050	425	03060101020 010	129
		Total primary DA = 744		Total secondary DA = 379	
S23104	170	03050107010 010	123	N/A	
		03050107010 020	47.4		
		Total primary DA = 170			
S24101	3,020	03050109040 020 - 050	248	03050109010 010 - 020	196
		03050109070 010	50.7	03050109020 010 - 030	316
		03050109080 010 - 090	688	03050109030 010	127
		03050109090 010 - 020	88.2	03050109040 010	121
		03050109120 010 - 040	284	03050109050 010	85.4
		03050109130 010 - 030	330	03050109060 010 - 030	95.7
				03050109100 010 - 080	298
				03050109110 010	92.4
		Total primary DA = 1,690		Total secondary DA = 1,330	
S26101	IND	03040206140 020 - 030	226	03040206010 010 - 070	827
		03040206150 010	76.0	03040206020 010 - 040	202
		03040207020 150	68.7	03040206030 010	172
				03040206040 010	48.1
				03040206050 010	24.5
				03040206060 010 - 060	589
				03040206090 010 - 030	307
				03040206100 010	91.9
				03040206102 010	52.0
				03040206110 010	137
				03040206120 010 - 050	228
				03040206130 010 - 030	338
				03040206140 010	99.7
		Total primary DA = 371		Total secondary DA = 3,120	
S26102	IND	03040201140 010 - 030	237	03040101[b]	6,270
		03040201150 050	114	03040102[b]	2,370
		03040201160 010 - 040	396	03040103[b]	3,060
		03040201170 010 - 020	162	03040104[b]	2,230
		03040202120 040	90.6	03040105[b]	3,680
		03040202170 010	94.7	03040201010 010 - 100	1,028
		03040204070 040 - 070	426	03040201020 010	68.5
				03040201030 010	83.2
				03040201040 010	80.2
				03040201050 010 - 100	913
				03040201060 010 - 100	897
				03040201070 010 - 020	201
				03040201080 010 - 020	180
				03040201090 010 - 040	322
				03040201100 010 - 050	442
				03040201110 010 - 100	756
				03040201120 010 - 030	341
				03040201130 010 - 060	555
				03040201150 010 - 040	337
				03040202010 010	132
				03040202020 010	60.5
				03040202030 010 - 020	129
				03040202040 010	126

Table 4. Identifying information for primary and secondary source-water protection areas for 45 surface-water intakes in South Carolina, 1999--Continued

[SWPA, source-water protection area; DA, drainage area; km^2, square kilometer; HUC, Hydrologic Unit Code; N/A, not applicable; IND, indeterminate, flow tidally affected]

Intake no. (fig. 1)	Intake DA[a] (km^2)	Primary SWPA		Secondary SWPA	
		14-digit HUC basins	HUC basin DA (km^2)	HUC basins	HUC basin DA (km^2)
S26102 (Continued)					
				03040202050 010 - 060	480
				03040202060 010	108
				03040202070 010 - 040	352
				03040202080 010 - 020	161
				03040202090 010 - 060	513
				03040202100 010 - 070	436
				03040202110 010 - 020	141
				03040202120 010 - 030	349
				03040202130 010	154
				03040202140 010	80.3
				03040202150 010	104
				03040202160 010	146
				03040203[b]	4,530
				03040204010 010 - 070	480
				03040204020 010 - 030	193
				03040204030 010 - 070	483
				03040204040 010 - 040	330
				03040204048 010	87.7
				03040204050 010 - 040	395
				03040204060 010	54.8
				03040204070 010 - 030	297
				03040204080 010 - 060	563
				03040204081 010	7.88
				03040204090 010 - 020	215
		Total primary DA = 1,520		Total secondary DA = 34,900	
S28102	12,200	03050103010 050	33.4	03050101[b]	6,100
		03050103060 020	107	03050102[b]	1,700
		03050103060 060 - 080	205	03050103010 010 - 040	393
		03050103070 010	68.7	03050103020 010 - 080	708
		03050103080 010	106	03050103030 010 - 030	518
		03050103090 010 - 050	518	03050103040 010 - 060	424
		03050104010 010 - 090	845	03050103050 010	129
		03050104020 010	151	03050103060 010	76.9
				03050103060 030 - 050	162
		Total primary DA = 2,030		Total secondary DA = 10,200	
S29106	9,130	03050103010 010 - 020	164	03050101[b]	6,100
		03050103010 030	68.0[c]	03050102[b]	1,700
		03050103020 010 - 050	570	03050103020 060	38.4
		03050103020 070 - 080	104		
		03050103030 010 - 020	382		
		Total primary DA = 1,290		Total secondary DA = 7,840	
S30104	911	03050108010 040	105	03050108010 010 - 030	166
		03050108010 070 - 090	332	03050108010 050 - 060	75.0
		03050108020 010	52.5[c]		
		03050108020 020	37.8		
		03050108030 010 - 020	143		
		Total primary DA = 670		Total secondary DA = 241	
S32101	310	03050110020 010 - 020	178	N/A	
		03050110020 040 - 050	108		
		03050110020030	23.5[c]		
		Total primary DA = 310			

Table 4. Identifying information for primary and secondary source-water protection areas for 45 surface-water intakes in South Carolina, 1999--Continued

[SWPA, source-water protection area; DA, drainage area; km^2, square kilometer; HUC, Hydrologic Unit Code; N/A, not applicable; IND, indeterminate, flow tidally affected]

Intake no. (fig. 1)	Intake DA[a] (km^2)	Primary SWPA: 14-digit HUC basins	Primary SWPA: HUC basin DA (km^2)	Secondary SWPA: HUC basins	Secondary SWPA: HUC basin DA (km^2)
S32102	20,300	03050106010 050	29.4	03050105[b]	6,420
		03050106050 010 - 070	592	03050106010 010 - 040	283
		03050106060 010 - 100	601	03050106020 010 - 040	379
		03050106070 030	80.8	03050106030 010	137
		03050106070 050	146	03050106040 010 - 050	423
		03050106080 010 - 020	152	03050106070 010 - 020	163
		03050106090 010 - 030	261	03050106070 040	87.0
		03050107050 060 - 070	137	03050107010 010 - 070	445
		03050108050 030	108	03050107020 010	90.6
		03050109210 010 - 070	265	03050107030 010 - 030	137
		03050110010 010	2.51[c]	03050107040 010 - 030	221
				03050107050 010 - 050	423
				03050107060 010 - 110	639
				03050108010 010 - 090	677
				03050108020 010 - 050	338
				03050108030 010 - 020	143
				03050108040 010 - 040	311
				03050108050 010 - 020	251
				03050108050 040	67.4
				03050109010 010 - 020	196
				03050109020 010 - 030	316
				03050109030 010	127
				03050109040 010 - 050	369
				03050109050 010	85.4
				03050109060 010 - 030	95.7
				03050109070 010	50.7
				03050109080 010 - 090	688
				03050109090 010 - 020	88.2
				03050109100 010 - 080	298
				03050109110 010	92.4
				03050109120 010 - 040	284
				03050109130 010 - 030	330
				03050109140 010 - 040	373
				03050109150 010 - 080	738
				03050109160 010 - 090	595
				03050109170 010 - 060	615
				03050109180 010 - 020	258
				03050109190 010 - 090	612
				03050109200 010	57
		Total primary DA = 2,370		Total secondary DA = 17,900	

Table 4. Identifying information for primary and secondary source-water protection areas for 45 surface-water intakes in South Carolina, 1999--Continued

[SWPA, source-water protection area; DA, drainage area; km^2, square kilometer; HUC, Hydrologic Unit Code; N/A, not applicable; IND, indeterminate, flow tidally affected]

Intake no. (fig. 1)	Intake DA[a] (km^2)	Primary SWPA: 14-digit HUC basins	Primary SWPA: HUC basin DA (km^2)	Secondary SWPA: HUC basins	Secondary SWPA: HUC basin DA (km^2)
S32107	6,270	03050109140 010	92.6	03050109010 010 - 020	196
		03050109140 030 - 040	172	03050109020 010 - 030	316
		03050109150 010 - 080	738	03050109030 010	127
		03050109160 020	56.2	03050109040 010 - 050	369
		03050109160 040 - 090	420	03050109050 010	85.4
		03050109170 010 - 060	615	03050109060 010 - 030	95.7
		03050109180 010 - 020	258	03050109070 010	50.7
		03050109190 010 - 090	612	03050109080 010 - 090	688
		03050109200 010	57	03050109090 010 - 020	88.2
				03050109100 010 - 080	298
				03050109110 010	92.4
				03050109120 010 - 040	284
				03050109130 010 - 030	330
				03050109140 020	108
				03050109160 010	78.5
				03050109160 030	40.4
		Total primary DA = 3,020		Total secondary DA = 3,250	
S35101	15,900	03060103100 010 - 100	1,170	03060101[b]	2,640
		03060103140 030	90.0	03060102[b]	2,580
		03060103140 070 - 130	486	03060103020 010	202
		03060103150 020	69.3	03060103030 010 - 130	996
		03060103150 040 - 100	416	03060103040 010 - 030	319
		03060104030 020 - 040	283	03060103070 010 - 050	507
		03060104040 040 - 060	316	03060103080 010	230
		03060104050 010 - 070	689	03060103140 010 - 020	166
		03060104060 010 - 060	602	03060103140 040 - 060	138
		03060105010 040 - 050	217	03060104010 010 - 090	782
		03060105020 010 - 060	651	03060104020 010 - 110	798
		03060105030 010 - 030	296	03060104030 010	106
		03060105040 010 - 040	489	03060104040 010 - 030	320
				03060105010 010 - 030	336
		Total primary DA = 5,770		Total secondary DA = 10,100	
S36101	4,210	03050109140 010	92.6	03050109010 010 - 020	196
		03050109140 030 - 040	172	03050109020 010 - 030	316
		03050109150 010 - 030	219	03050109030 010	127
		03050109150 080	4.35[c]	03050109040 010 - 050	369
		03050109160 020	56.2	03050109050 010	85.4
		03050109160 040 - 090	420	03050109060 010 - 030	95.7
				03050109070 010	50.7
				03050109080 010 - 090	688
				03050109090 010 - 020	88.2
				03050109100 010 - 080	298
				03050109110 010	92.4
				03050109120 010 - 040	284
				03050109130 010 - 030	330
				03050109140 020	108
				03050109160 010	78.5
				03050109160 030	40.4
		Total primary DA = 964		Total secondary DA = 3,250	

Table 4. Identifying information for primary and secondary source-water protection areas for 45 surface-water intakes in South Carolina, 1999--Continued

[SWPA, source-water protection area; DA, drainage area; km^2, square kilometer; HUC, Hydrologic Unit Code; N/A, not applicable; IND, indeterminate, flow tidally affected]

Intake no. (fig. 1)	Intake DA[a] (km^2)	Primary SWPA: 14-digit HUC basins	Primary SWPA: HUC basin DA (km^2)	Secondary SWPA: HUC basins	Secondary SWPA: HUC basin DA (km^2)
S36102	1,140	03050108020 010	66.4	03050108010 010 - 090	677
		03050108020 030 - 040	104	03050108020 020	37.8
		03050108020 050	116[c]	03050108030 010	47.5
		03050108030 020	95.2		
		Total primary DA = 382		Total secondary DA = 762	
S36103	295	03050108040 010 - 020	213	N/A	
		03050108040 030	19.7[c]		
		03050108040 040	62.6		
		Total primary DA = 295			
S37101	1,120	03060101030 010 - 030	319	03060101010 010 - 030	250
		03060101050 010 - 050	425	03060101020 010	129
		Total primary DA = 744		Total secondary DA = 379	
S37104	174	03060102120 010 - 020	132	N/A	
		03060102120 030	41.5[c]		
		Total primary DA = 174			
S38101	1,770	03050203040 050 - 070	202	03050203010 010 - 020	206
		03050203050 020 - 040	172	03050203020 010 - 030	240
		03050203060 010 - 050	215	03050203030 010 - 020	177
		03050203070 010 - 020	208	03050203040 010 - 040	265
		03050203080 010	6.94[c]	03050203050 010	79.8
		Total primary DA = 804		Total secondary DA = 968	
S39101	760	03050109010 010 - 020	196	N/A	
		03050109020 010 - 030	316		
		03050109030 010	127		
		03050109040 010	121		
		Total primary DA = 760			
S39106	338	03060101060 010 - 060	275	N/A	
		03060101070 010	21.1[c]		
		03060101070 020	41.4		
		Total primary DA = 338			
S40101	13,800	03050106010 050	29.4	03050105[b]	6,420
		03050106050 010 - 070	592	03050106010 010 - 040	283
		03050106060 010 - 100	601	03050106020 010 - 040	379
		03050106070 030	80.8	03050106030 010	137
		03050106070 050	146	03050106040 010 - 050	423
		03050106080 010 - 020	152	03050106070 010 - 020	163
		03050106090 010 - 030	261	03050106070 040	87.0
		03050107050 060 - 070	137	03050107010 010 - 070	445
		03050108050 030	108	03050107020 010	90.6
		03050110010 010	0.62[c]	03050107030 010 - 030	137
				03050107040 010 - 030	221
				03050107050 010 - 050	423
				03050107060 010 - 110	639
				03050108010 010 - 090	677
				03050108020 010 - 050	338
				03050108030 010 - 020	143
				03050108040 010 - 040	311
				03050108050 010 - 020	251
				03050108050 040	67.4
		Total primary DA = 2,110		Total secondary DA = 11,640	

Table 4. Identifying information for primary and secondary source-water protection areas for 45 surface-water intakes in South Carolina, 1999--Continued

[SWPA, source-water protection area; DA, drainage area; km^2, square kilometer; HUC, Hydrologic Unit Code; N/A, not applicable; IND, indeterminate, flow tidally affected]

Intake no. (fig. 1)	Intake DA[a] (km^2)	Primary SWPA		Secondary SWPA	
		14-digit HUC basins	HUC basin DA (km^2)	HUC basins	HUC basin DA (km^2)
S40102	6,260	03050109140 010	92.6	03050109010 010 - 020	196
		03050109140 030 - 040	172	03050109020 010 - 030	316
		03050109150 010 - 080	738	03050109030 010	127
		03050109160 020	56.2	03050109040 010 - 050	369
		03050109160 040 - 090	420	03050109050 010	85.4
		03050109170 010 - 060	615	03050109060 010 - 030	95.7
		03050109180 010 - 020	258	03050109070 010	50.7
		03050109190 010 - 090	612	03050109080 010 - 090	688
		03050109200 010	51	03050109090 010 - 020	88.2
				03050109100 010 - 080	298
				03050109110 010	92.4
				03050109120 010 - 040	284
				03050109130 010 - 030	330
				03050109140 020	108
				03050109160 010	78.5
				03050109160 030	40.4
		Total primary DA = 3,010		Total secondary DA = 3,250	
S42101	236	03050105160 010	144	N/A	
		03050105160 020	91.5[c]		
		Total primary DA = 236			
S42104	179	03050107040 010 - 020	159	N/A	
		03050107040 030	19.5[c]		
		Total primary DA = 179			
S44101	6,910	03050105090 010 - 030	367	03050105010 010	110
		03050105100 030	166	03050105020 010 - 040	388
		03050105110 010	60.4	03050105030 010	137
		03050105120 010 - 020	178	03050105040 010 - 090	726
		03050105130 030 - 040	221	03050105050 010 - 040	334
		03050105140 010 - 030	313	03050105060 010 - 020	117
		03050105190 010 - 020	264	03050105070 010 - 080	646
		03050106010 010	81.9[c]	03050105080 010 - 110	840
		03050106010 020	33.7	03050105100 010 - 020	292
		03050106020 010 - 040	379	03050105130 010 - 020	186
				03050105150 010 - 020	304
				03050105160 010 - 020	237
				03050105170 010 - 040	310
				03050105180 010 - 020	220
		Total primary DA = 2,060		Total secondary DA = 4,850	

Table 4. Identifying information for primary and secondary source-water protection areas for 45 surface-water intakes in South Carolina, 1999--Continued

[SWPA, source-water protection area; DA, drainage area; km^2, square kilometer; HUC, Hydrologic Unit Code; N/A, not applicable; IND, indeterminate, flow tidally affected]

Intake no. (fig. 1)	Intake DA[a] (km^2)	Primary SWPA		Secondary SWPA	
		14-digit HUC basins	HUC basin DA (km^2)	HUC basins	HUC basin DA (km^2)
S46109	7,820	03050101160 010 - 050	443	03050101010 010 - 060	469
		03050101170 010 - 040	379	03050101020 010 - 030	221
		03050101180 010 - 030	463	03050101030 010 - 070	419
		03050101190 010 - 020	172	03050101040 010 - 020	256
		03050102030 020	65.1	03050101050 050	158
		03050102040 030 - 040	102	03050101060 010 - 050	307
		03050102050 010 - 020	273	03050101070 010 - 040	547
		03050102060 010 - 020	178	03050101080 010 - 030	309
		03050102070 010 - 030	251	03050101090 010 - 030	270
				03050101100 010 - 030	299
				03050101110 010 - 020	173
				03050101120 010 - 050	259
				03050101130 010	68.2
				03050101140 010	204
				03050101150 010 - 040	687
				03050102010 010 - 030	296
				03050102020 010 - 020	250
				03050102030 010	103
				03050102030 030	67.6
				03050102040 010 - 020	125
		Total primary DA = 2,330		Total secondary DA = 5,490	

[a]Difference in intake DA and sum of primary and secondary DA's caused by rounding.
[b]Includes entire 8-digit HUC basin.
[c]Partial drainage area of 14-digit HUC basin.

Supplemental Data

Pilot study estimation of travel time for the intake on Shaw Creek in Aiken, S.C.
(T.H. Lanier and W.F. Falls, U.S. Geological Survey, written commun., 1998)

PILOT STUDY ESTIMATION OF TRAVEL TIME FOR THE INTAKE ON SHAW CREEK IN AIKEN, S.C.

Steps to estimate the 24-hr travel distance for an intake are as follows:

1. Determine drainage area at the intake and stream distances
2. Determine reach slope (Piedmont sites only)
3. Select an appropriate index gaging station
4. Determine the 24-hr range
5. Delineate drainage areas within the 24-hr range
6. Determine average drainage areas and final velocities
7. Determine the 24-hr travel distance

A 24-hr time-of-travel study was completed for the Aiken, S.C., intake on Shaw Creek, which is approximately 55 km long. The intake drainage area (IDA) (step 1) for the Aiken intake is 180 km^2 and is located at river kilometer (RK) 21.9, approximately 33 km downstream from the basin headwaters. Because the Shaw Creek drainage basin lies in the upper Coastal Plain, the determination of the reach slope (step 2) is not required.

There are no current or discontinued USGS gaging stations on Shaw Creek (Cooney and others, 1997). However, two active gaging stations are present in nearby basins—Station 02172640 on Dean Swamp Creek near Salley, S.C., and Station 02196689 on Little Horse Creek near Graniteville, S.C. (fig. S-1). Station 02172640 has 17 years of record and a drainage area of 80.8 km^2. Station 02196689 has 9 years of record and a drainage area of 68.9 km^2. Due to a longer period of record, station 02172640 was chosen as the index station for Shaw Creek (step 3). The following data for Station 02172640 were used to compute the travel-time points and primary travel-time segment for the Aiken source-water protection area:

Drainage area (GDA) = 80.8 km^2,
Mean flow (MGQ) = 0.70 m^3/s,
10-percent exceedance flow (GQ_{10}) = 0.91 m^3/s,
50-percent exceedance flow (GQ_{50}) = 0.68 m^3/s, and
90-percent exceedance flow (GQ_{90}) = 0.48 m^3/s.

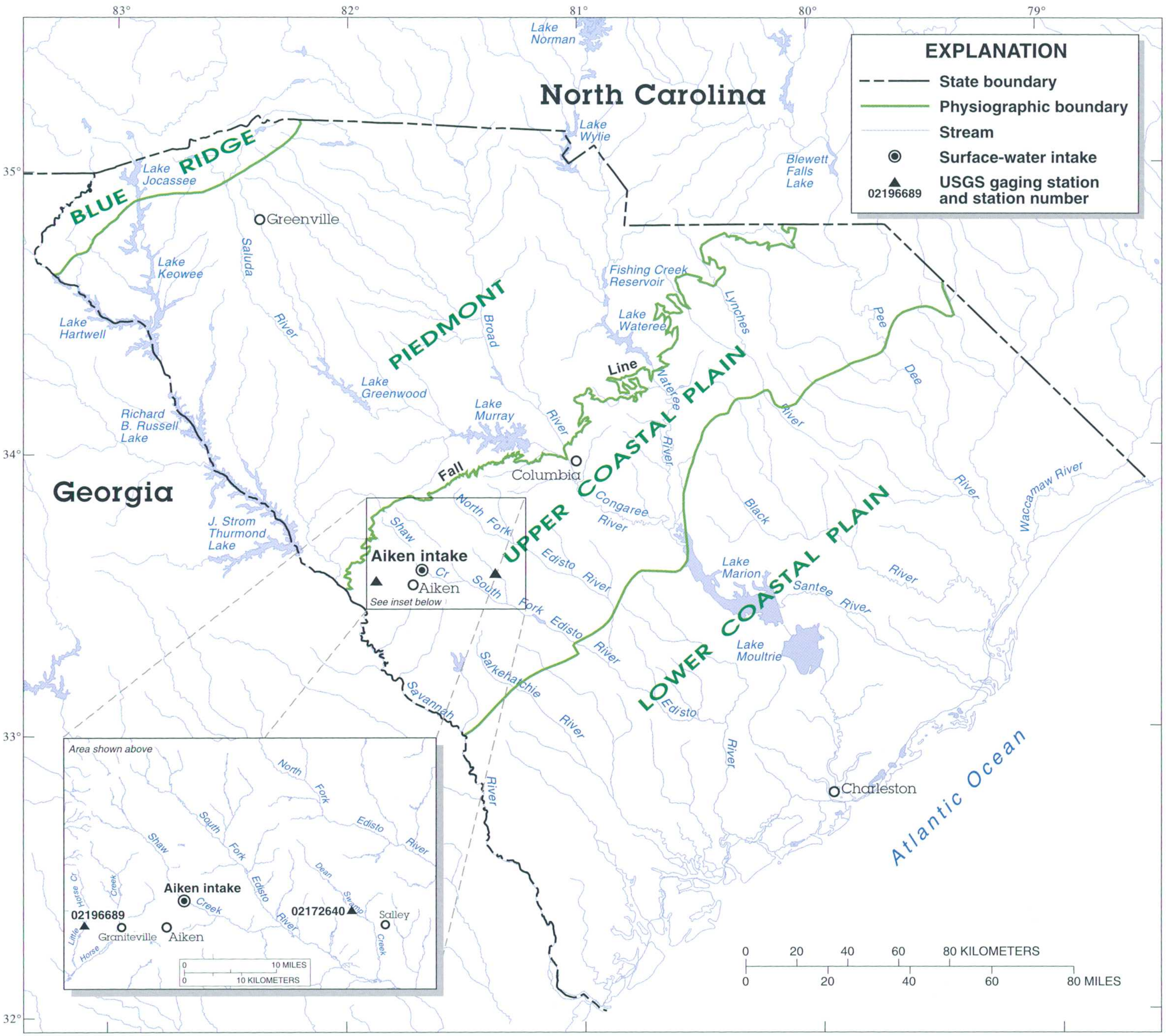
Computation of the 24-hour range

In step 4, the minimum 24-hr distance is computed by using the Coastal Plain equation where

D_a = IDA/2 = 180/2 = 90 km^2;
average 90-percent exceedance flow (Q_{90}) = 0.48 x (90/80.8) = 0.53 m^3/s;
average mean flow (Q_a) = 0.70 x (90/80.8) = 0.78 m^3/s;
$D'_a = (9.8^{0.5} \times (90 \times 10^6)^{1.25})/0.78 = 35.2 \times 10^9$ (dimensionless); and
$Q'_{a90} = 0.53/0.78 = 0.68$ (dimensionless).

The Coastal Plain velocity is determined by using equation 2 from this report for Coastal Plain streams.

$$V_{p90} = 0.020 + 0.051\ (35.2 \times 10^9)^{\ 0.821}(0.68)^{-0.465}(0.53/90 \times 106) = 0.18 \text{ m/s}$$



Base from U.S. Geological Survey
1:2,000,000 scale Digital Line Graphs

Figure S-1. Location of the Aiken surface-water intake in South Carolina.

The 24-hr travel $distance_{90}$ for the 90-percent exceedance flow is as follows.

Travel $distance_{90}$ = (0.18 m/s)(24 hrs)(3,600 seconds per hour(s/hr)) (0.001 km/m) = 15.5 km upstream from the intake or RK 37.4.

The maximum 24-hr distance is computed by using the Coastal Plain equation where

D_a = IDA = 180 km^2;
average 10-percent exceedance flow (Q_{10}) = 0.91 x (180/80.8) = 2.03 m^3/s;
average mean flow (Q_a) = 0.70 x (180/80.8) = 1.56 m^3/s;
$D'_a = (9.8^{0.5} \times (180 \times 10^6)^{1.25})/1.56 = 41.8 \times 10^9$ (dimensionless); and
$Q'_{a10} = 2.03/1.56 = 1.30$ (dimensionless).

The Coastal Plain velocity is determined by using equation 2 from this report for Coastal Plain streams.

$$V_{p10} = 0.020 + 0.051\ (41.8 \times 10^9)^{0.821}\ (1.30)^{-0.465}\ (2.03/180 \times 10^6) = 0.29 \text{ m/s}$$

The 24-hr travel $distance_{10}$ for the 10-percent exceedance flow is as follows:

Travel $distance_{10}$ = (0.29 m/s)(24 hrs)(3,600 s/hr)(0.001km/m) = 25.1 km upstream from the intake or RK 47.0.

This defines a 24-hr range within the Shaw Creek Basin with the minimum and maximum 24-hr distances at RK 37.4 and RK 47.0, respectively, which are shown in figure S-2.

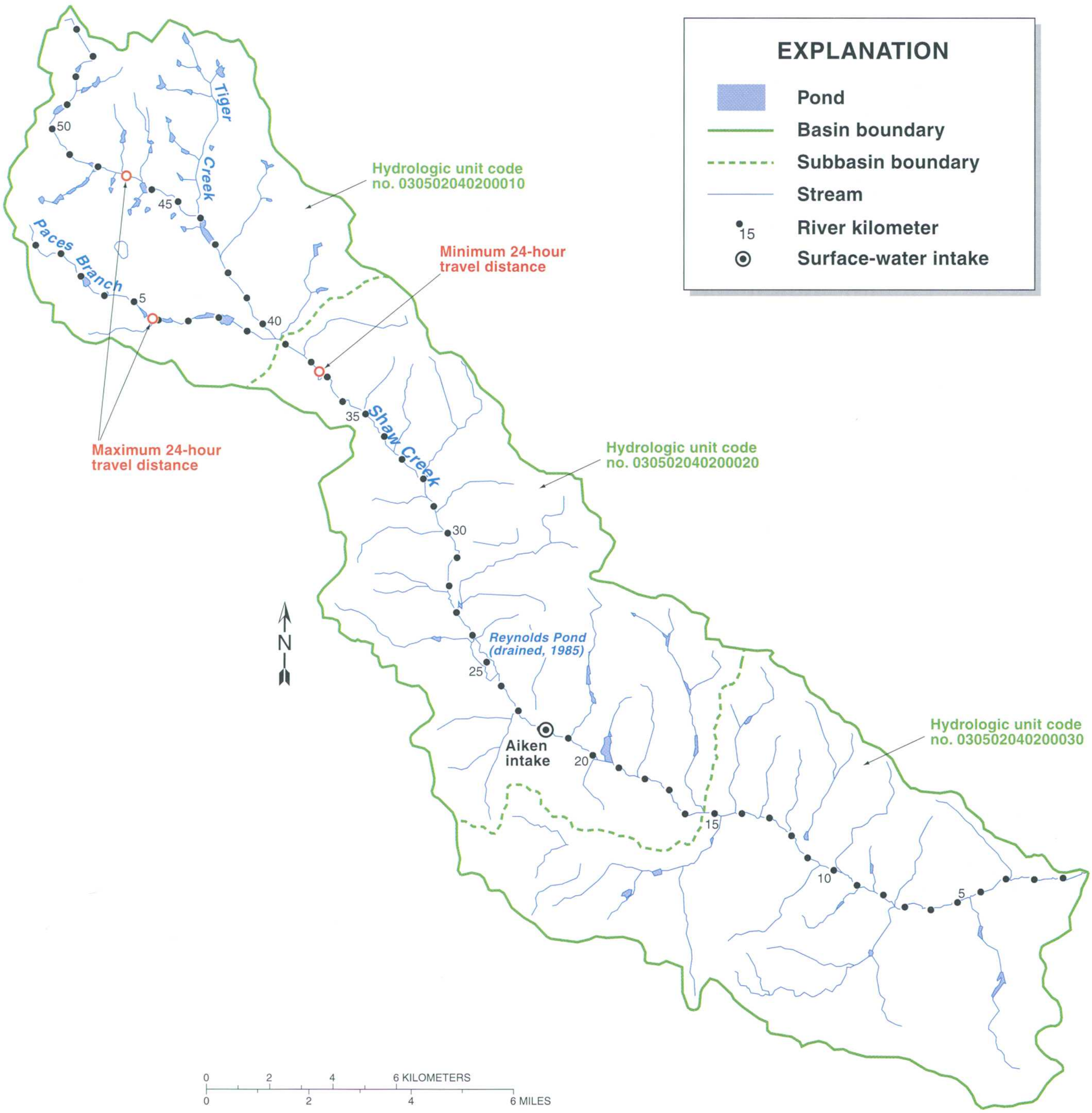


Figure S-2. Maximum and minimum 24-hour distances for the Aiken intake on Shaw Creek, South Carolina.

Delineation of drainage areas within the 24-hour range

Drainage areas of 95.6 km^2 and 25.1 km^2 were computed at the minimum and maximum 24-hr travel points, respectively (step 5). The basin was subdivided at the confluences of Tiger Creek (RK 44.0) and Paces Branch (RK 39.1) because these tributaries contributed more than 30 percent of the total drainage area at the confluence point. The drainage area of Shaw Creek just below and above the Tiger Creek confluence is 40.4 km^2 and 24.6 km^2, respectively, and the drainage area just below and above the Paces Branch confluence is 78.7 km^2 and 57.5 km^2, respectively. The basin was further subdivided at RK 42.8 to determine a drainage area of 43.5 km^2, so that no segment would have a change of more than 30 percent between the maximum and minimum drainage areas.

Computation of the average drainage area and final velocities for each segment

The drainage areas for Shaw Creek were tabulated from the IDA to the maximum 24-hr TOT point and are listed in table S-1 (step 6). The D_a and velocities were computed for each segment by using the 10-, 50-, and 90-percent exceedance flows. An example of these computations is shown below, and the results are listed in table S-1.

Table S-1. Drainage areas for Shaw Creek, S.C., calculated from the intake drainage area to the maximum 24-hour time-of-travel point

[V_{10}, V_{50}, and V_{90}, velocity calculated at 10-, 50-, and 90-percent exceedance flows, respectively; TOT_{10}, TOT_{50}, and TOT_{90}, time of travel for 10- , 50-, and 90-percent exceedance flows, respectively; km, kilometer, km^2, square kilometer; m/s, meter per second; hr, hour]

Location	River kilometers (km)	Drainage area (km^2)	Average drainage area (km^2)	V_{10} (m/s)	V_{50} (m/s)	V_{90} (m/s)	TOT_{10} (hr)	TOT_{50} (hr)	TOT_{90} (hr)
Intake	21.9	180.0							
			137.8	0.27	0.23	0.20	15.9	18.7	21.5
Minimum 24-hour point	37.4	95.6							
			87.2	0.24	0.21	0.18	2.0	2.2	2.6
Downstream from Paces Branch confluence[a]	39.1	78.7							
			68.1	0.23	0.20	0.17	0.0	0.0	0.0
Upstream from Paces Branch confluence[b]	39.1	57.5							
			50.5	0.22	0.19	0.16	4.7	5.4	6.4
River kilometer 42.8[c]	42.8	43.5							
			42.0	0.21	0.18	0.16	1.6	1.9	2.1
Downstream from Tiger Creek confluence[d]	44.0	40.4							
			32.5	0.20	0.18	0.15	0.0	0.0	0.0
Upstream from Tiger Creek confluence[e]	44.0	24.6							
			21.9	0.19	0.16	0.14	4.4	5.2	6.0
Maximum 24-hour point	47.0	19.2							

[a]Paces Branch enters into Shaw Creek.
[b]Shaw Creek drainage area upstream from Paces Branch confluence.
[c]Delineation due to 30-percent rule.
[d]Tiger Creek enters into Shaw Creek.
[e]Shaw Creek drainage area upstream from Tiger Creek confluence.

The computations for the segment between IDA and the minimum 24-hr travel point at RK 37.4 for the 10-percent exceedance flow are as follows:

D_a = (95.6+180.0)/2 = 137.8 km^2;
average 10-percent exceedance flow (Q_{10}) = 0.91 x (137.8/80.8) = 1.55 m^3/s;
average mean flow (Q_a) = 0.70 x (137.8/80.8) = 1.19 m^3/s;
$D'_a = (9.8^{0.5} \times (137.8 \times 10^6)^{1.25})/1.19 = 39.3 \times 10^9$ (dimensionless); and
Q'_{a10} = 1.55/1.19 = 1.30 (dimensionless).

The Coastal Plain velocity equation is applied as follows:

$$V_{p10} = 0.020 + 0.051(39.3 \times 10^9)^{0.821}(1.30)^{-0.465}(1.55/137.8 \times 10^6) = 0.27 \text{ m/s}.$$

The time of travel for this segment is:

Time of travel = ((37.4 km - 21.9 km)(1,000 m/km))/((0.27 m/s)(3,600 s/hr)) = 15.9 hr.

This calculation can be repeated for the other subreaches.

Computation of the 24-hour travel distance

From table S-1, the 24-hr travel distance can be computed directly (step 7).

For the 10-percent exceedance flow:

Summed TOT_{10} = 15.9 + 2.0 + 4.7 + 1.6 = 24.2 hrs;
$Remainder_{10}$ = summed TOT_{10} - 24-hr TOT = 24.2 - 24.0 = 0.2 hr or 720 seconds(s); and
Final 24-hr TOT $point_{10}$ = (upper RK where 24 hrs was exceeded) - ($remainder_{10}$ multiplied by the velocity of the segment where 24 hrs was exceeded) = 44.0 - [(720 s)(0.21 m/s)(0.001km/m)] = RK 43.8 (21.9 km upstream from the intake).

For the 50-percent exceedance flow:

Summed TOT_{50} = 18.7 +2.2 + 5.4 = 26.3 hrs;
$Remainder_{50}$ = 26.3 - 24.0 = 2.3 hrs or 8,280 s; and
Final 24-hr TOT $point_{50}$ = 42.8 - [(8,280 s)(0.19 m/s)(0.001km/m)] = RK 41.2 (19.3 km upstream from the intake).

For the 90-percent exceedance flow:

Summed TOT_{90} = 21.5 + 2.6 = 24.1 hrs;
$Remainder_{90}$ = 24.1 - 24.0 = 0.1 hr or 360 s; and
Final 24-hr TOT $point_{90}$ = 39.1 - [(360 s)(0.18 m/s)(0.001km/m)] = RK 39.0 or 17.1 km upstream from the intake.

The 24-hr travel points are shown in figure S-3.

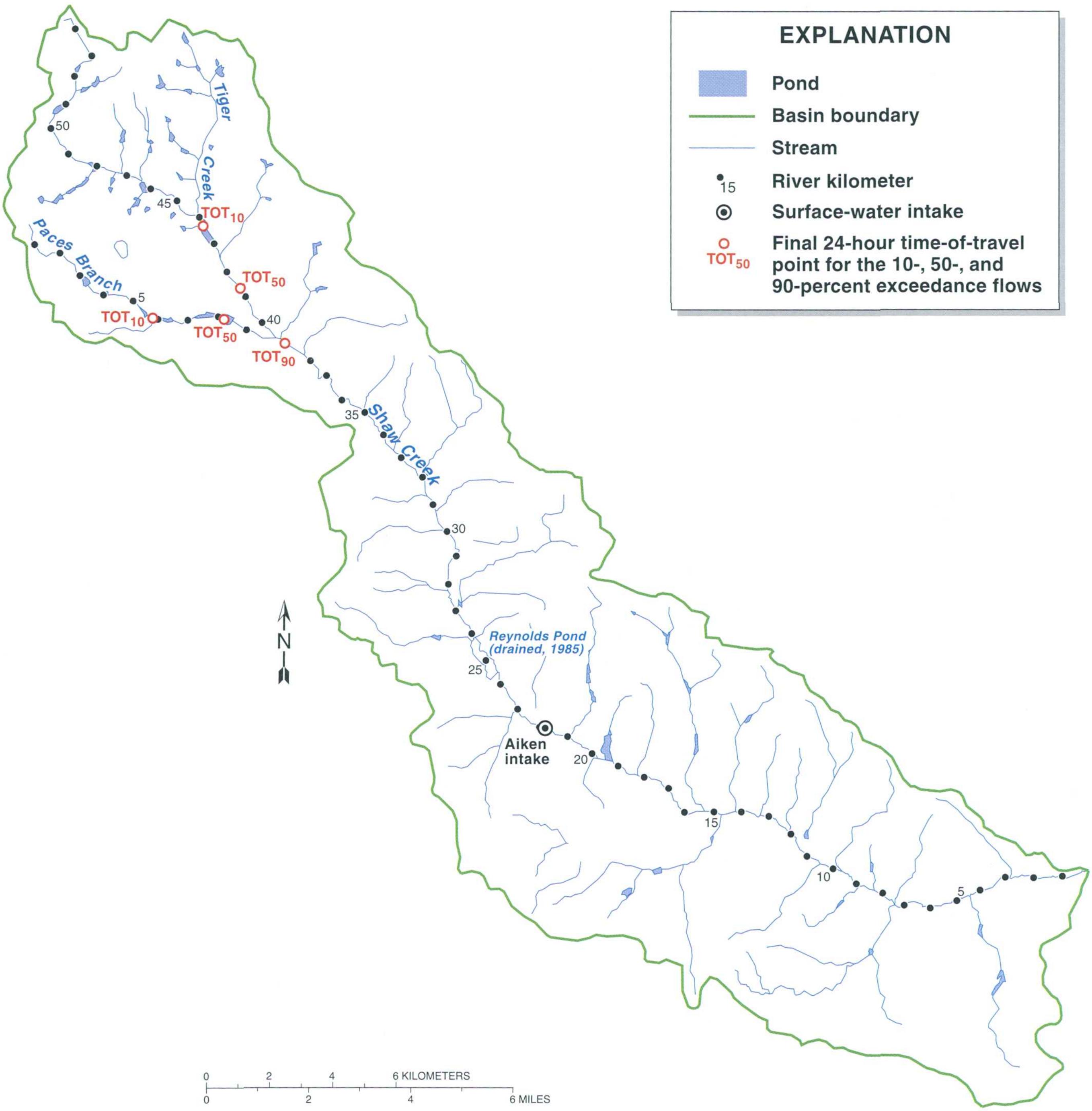


Figure S-3. Final 24-hour time-of-travel points for the 10-, 50-, and 90-percent exceedance flows for the Aiken intake on Shaw Creek, South Carolina.

Paces Branch, a tributary to Shaw Creek, falls within the 24-hr source-water protection area for Shaw Creek for the 10- and 50-percent exceedance flows. Computations similar to those completed on Shaw Creek were completed on Paces Branch tributary. The velocities were determined by solving equation 2. The IDA for Paces Branch is the drainage area at the mouth. The same index gaging station used for Shaw Creek is used for Paces Branch. TOT from the mouth of Paces Branch to the intake on Shaw Creek for the 10- and 50-percent exceedance flows is 17.9 and 20.9 hrs, respectively (table S-1). Because the 90-percent exceedance flow on Shaw Creek does not affect Paces Branch, the minimum range for Paces Branch is computed by using the 50-percent exceedance flow. The maximum and minimum distances are computed as follows:

Maximum distance = (24 hr - 17.9 hrs)(3,600 s/hr)(0.19 m/s)(0.001 km/m) = 4.2 km
Minimum distance = (24 hr - 20.9 hrs)(3,600 s/hr)(0.15 m/s)(0.001 km/m) = 1.7 km

The maximum and minimum velocities of 0.19 and 0.15 m/s, respectively, were computed by using the same methodology as described in the section on computation of the 24-hr range. The maximum point of 4.2 km is shown in figure S-2.

Drainage areas were computed on Paces Branch at RK 0, 1.3, and 4.2. The drainage area at RK 1.3 was used because it had been previously delineated. Table S-2 lists the drainage areas of the delineated subareas, the computed velocities at the 10- and 50-percent exceedance flows, and the time of travel for the two flows. The 24-hr TOT distance can be computed directly by using table S-2.

Table S-2. Drainage areas of delineated subareas of Paces Branch, S.C., computed velocities at the 10- and 50-percent exceedance flows, and associated travel times

[V_{10} and V_{50}, velocity calculated at 10- and 50-percent exceedance flows, respectively; TOT_{10} and TOT_{50}, time of travel for 10- and 50-percent exceedance flows, respectively; km, kilometer, km^2, square kilometer; m/s, meter per second; hr, hour]

Location	River kilometers (km)	Drainage area (km^2)	Average drainage area (km^2)	V_{10} (m/s)	V_{50} (m/s)	TOT_{10} (hr)	TOT_{50} (hr)
Mouth of Paces Branch	0.0	21.1					
			19.5	0.18	0.16	2.0	2.2
River kilometer 1.3[a]	1.3	17.9					
			13.6	0.17	0.15	4.7	5.4
Maximum 24-hour point	4.2	9.3					

[a]Previously delineated drainage area used for the minimum point.

For the 10-percent exceedance flow:

Summed TOT_{10} = 2.0 + 4.7 = 6.7 hrs;
$Remainder_{10}$ = 6.7 - (24 - 17.9) = 0.6 hr or 2,160 s; and
Final 24-hr TOT $point_{10}$ = 4.2 - [(2,160 s)(0.17 m/s)(0.001 km/m)] = 3.8 km upstream from the mouth.

For the 50-percent exceedance flow:

Summed TOT_{50} = 2.2 + 5.4 = 7.6 hrs;
$Remainder_{50}$ = 7.6 - (24 - 20.9) = 4.5 hrs or 16,200 s; and
Final 24-hr TOT $point_{50}$ = 4.2 - [(16,200 s)(0.15 m/s)(0.001 km/m)] = 1.8 km upstream from the mouth.

These 24-hr travel points are shown in figure S-3.

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