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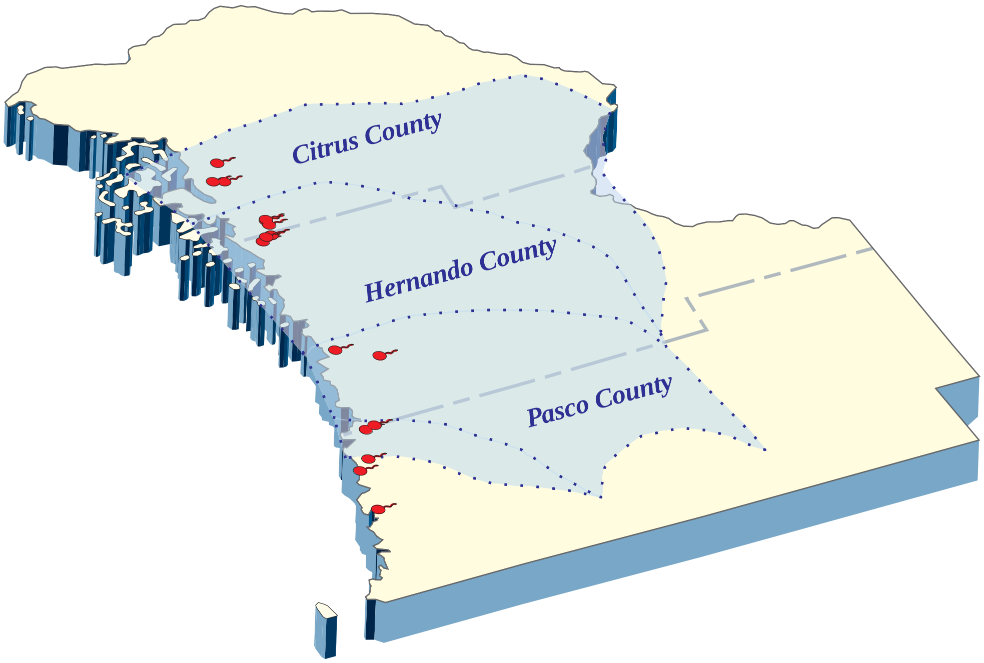
Hydrology of the Coastal Springs Ground-Water Basin and Adjacent Parts of Pasco, Hernando, and Citrus Counties, Florida

Water-Resources Investigations Report 01-4230



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

Prepared in cooperation with the
Southwest Florida Water Management District

Hydrology of the Coastal Springs Ground-Water Basin and Adjacent Parts of Pasco, Hernando, and Citrus Counties, Florida

By Lari A. Knochenmus *and* Dann K. Yobbi

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SOUTHWEST FLORIDA WATER MANAGEMENT DISTRICT

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Tallahassee, Florida
2001

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Conversion Factors, Datums, and Abbreviations

Multiply	By	To obtain
inch (in.)	2.54	centimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
acre	4,047	square meter
acre	0.4047	hectare
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
inch per month (in/mo)	2.54	centimeter per month
inch per year (in/yr)	2.54	centimeter per year

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

Horizontal coordinate information is referenced to the North American Datum of 1927 (NAD of 1927).

Acronyms and Additional Abbreviations

NOAA	National Oceanic and Atmospheric Administration
NWS	National Weather Service
SWFWMD	Southwest Florida Water Management District
USGS	U.S. Geological Survey
d	day
hr	hour
mi^2	square miles
min	minute
yr	year
yrs	years
gal/d	gallons per day
Mgal/d	million gallons per day
µS/cm	microsiemens per centimeter
P	precipitation (rainfall)
ET	evapotranspiration
Q	ground-water withdrawal
R	runoff (spring flow)
GO	ground-water outflow (upward leakage)
ΔS	change in storage
R^2	coefficient of determination
MLR	multiple linear regression
OLS	ordinary least squares
rho (ρ)	probability level
RMSE	root mean square error
tau (τ)	measure of correlation
T	transmissivity in feet squared per day
I	gradient in feet per mile
L	average width of the cross section in miles
ADAPS	Automated Data Processing System
BDR-301	Basic-Data Recorder model 301
CSGWB	Coastal Springs Ground-Water Basin
CSPR	Coastal springs well network
GIS	Geographical Information System
QWDATA	Quality of Water Database
ROMP	Regional Observation Monitor-Well Project

Hydrology of the Coastal Springs Ground-Water Basin and Adjacent Parts of Pasco, Hernando, and Citrus Counties, Florida

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Abstract

The coastal springs in Pasco, Hernando, and Citrus Counties, Florida consist of three first-order magnitude springs and numerous smaller springs, which are points of substantial ground-water discharge from the Upper Floridan aquifer. Spring flow is proportional to the water-level altitude in the aquifer and is affected primarily by the magnitude and timing of rainfall. Ground-water levels in 206 Upper Floridan aquifer wells, and surface-water stage, flow, and specific conductance of water from springs at 10 gaging stations were measured to define the hydrologic variability (temporally and spatially) in the Coastal Springs Ground-Water Basin and adjacent parts of Pasco, Hernando, and Citrus Counties. Rainfall at 46 stations and ground-water withdrawals for three counties, were used to calculate water budgets, to evaluate long-term changes in hydrologic conditions, and to evaluate relations among the hydrologic components.

Predictive equations to estimate daily spring flow were developed for eight gaging stations using regression techniques. Regression techniques included ordinary least squares and multiple linear regression techniques. The predictive equations indicate that ground-water levels in the Upper Floridan aquifer are directly related to spring flow. At tidally affected gaging stations, spring flow is inversely related to spring-pool altitude. The springs have similar seasonal flow patterns throughout the area.

Water-budget analysis provided insight into the relative importance of the hydrologic components expected to influence spring flow. Four water budgets were constructed for small ground-water basins that form the Coastal Springs Ground-Water Basin. Rainfall averaged 55 inches per year and was the only source of inflow to the Basin. The pathways for outflow were evapotranspiration (34 inches per year), runoff by spring flow (8 inches per year), ground-water outflow from upward leakage (11 inches per year), and ground-water withdrawal (2 inches per year). Recharge (rainfall minus evapotranspiration) to the Upper Floridan aquifer consists of vertical leakage through the surficial deposits. Discharge is primarily through springs and diffuse upward leakage that maintains the extensive swamps along the Gulf of Mexico. The ground-water basins had slightly different partitioning of hydrologic components, reflecting variation among the regions.

Trends in hydrologic data were identified using nonparametric statistical techniques to infer long-term changes in hydrologic conditions, and yielded mixed results. No trend in rainfall was detected during the past century. No trend in spring flow was detected in 1931-98. Although monotonic trends were not detected, rainfall patterns are naturally variable from month to month and year to year; this variability is reflected in ground-water levels and spring flows. A decreasing trend in ground-water levels was detected in the Weeki Wachee well (1966-98), but the trend was statistically weak. At current ground-water withdrawal rates, there is no discernible affect on ground-water levels and spring flows. Sporadic data records, lack of continuous data, and inconsistent periods of record among the hydrologic components impeded analysis of long-term changes to the hydrologic system and interrelations among components. The ongoing collection of hydrologic data from index sites could provide much needed information to assess the hydrologic factors affecting the quantity and quality of spring flow in the Coastal Springs Ground-Water Basin.

INTRODUCTION

The intrinsic beauty, ecological diversity, and multiple recreational uses make the coastal springs and estuaries of west-central Florida a unique and important water resource. Three first-order magnitude springs (discharging more than 100 cubic feet per second, (ft^3/s)) and many smaller springs supply freshwater to the estuaries bordering the Gulf of Mexico. The estuarine resources are substantial and support the sport and commercial fishing industries along the west coast of Florida. Biological productivity in these spring-fed estuaries is directly linked to salinity, and the salinity of the estuary is related to the quantity and quality of water discharging from the springs. Demands for potable water will continue to increase as the resident and seasonal tourist populations in Pasco, Hernando, and Citrus Counties continue to grow. Declines in ground-water levels due to increased water use may increase salinity and decrease the flow from springs, especially in coastal areas (Sinclair, 1978; Yobbi, 1989, 1992). Proper protection and management of the coastal springs and estuaries are a concern of municipal, state, and federal officials as well as local citizens. To protect and manage the springs, a thorough understanding of the hydrologic factors affecting the quantity and quality of spring flow is essential.

In 1996, the U.S. Geological Survey (USGS) in cooperation with the Southwest Florida Water Management District (SWFWMD) began a 3.5-year investigation to develop a better understanding of coastal springs and their role and relation to the hydrology of the area. The study area encompasses about 2,000 square miles (mi^2) and includes Pasco, Hernando, and Citrus Counties. This report emphasizes the hydrology of the 850-mi^2 Coastal Springs Ground-Water Basin, which contains four smaller ground-water basins; the Aripeka, Weeki Wachee, Chassahowitzka, and Homosassa Springs Ground-Water Basins (fig. 1). Each ground-water basin contains a discrete flow system, and ground-water discharge occurs as spring flow and diffuse seepage. Weeki Wachee and Homosassa Springs Ground-Water Basins each contain a first-order magnitude spring, Chassahowitzka Springs Ground-Water Basin contains a first-order springs complex, and Aripeka Springs Ground-Water Basin contains numerous smaller springs. This report provides information needed by water managers to assess the hydrologic factors affecting the quantity and quality of spring flow.

Purpose and Scope

This report presents an evaluation of the hydrology of the Coastal Springs Ground-Water Basin and adjacent areas. The data and analyses presented in this report are relevant for understanding the factors affecting the quantity and quality of spring flow. Index wells and springs were selected for a basin-wide monitoring network. Ongoing data collection and analysis from this network will enable long-term monitoring and protection of the springs and estuaries, and assist local and state water managers to provide adequate potable water for all users. Results of this investigation provide an improved understanding of the interaction of the hydrologic components in the Coastal Springs Ground-Water Basin. The report discusses the following topics:

1. Hydrologic setting;
2. Hydrologic conditions during the investigation period (January 1997 through December 1998);
3. Estimates of daily spring flow from selected springs (January 1997 through December 1998);

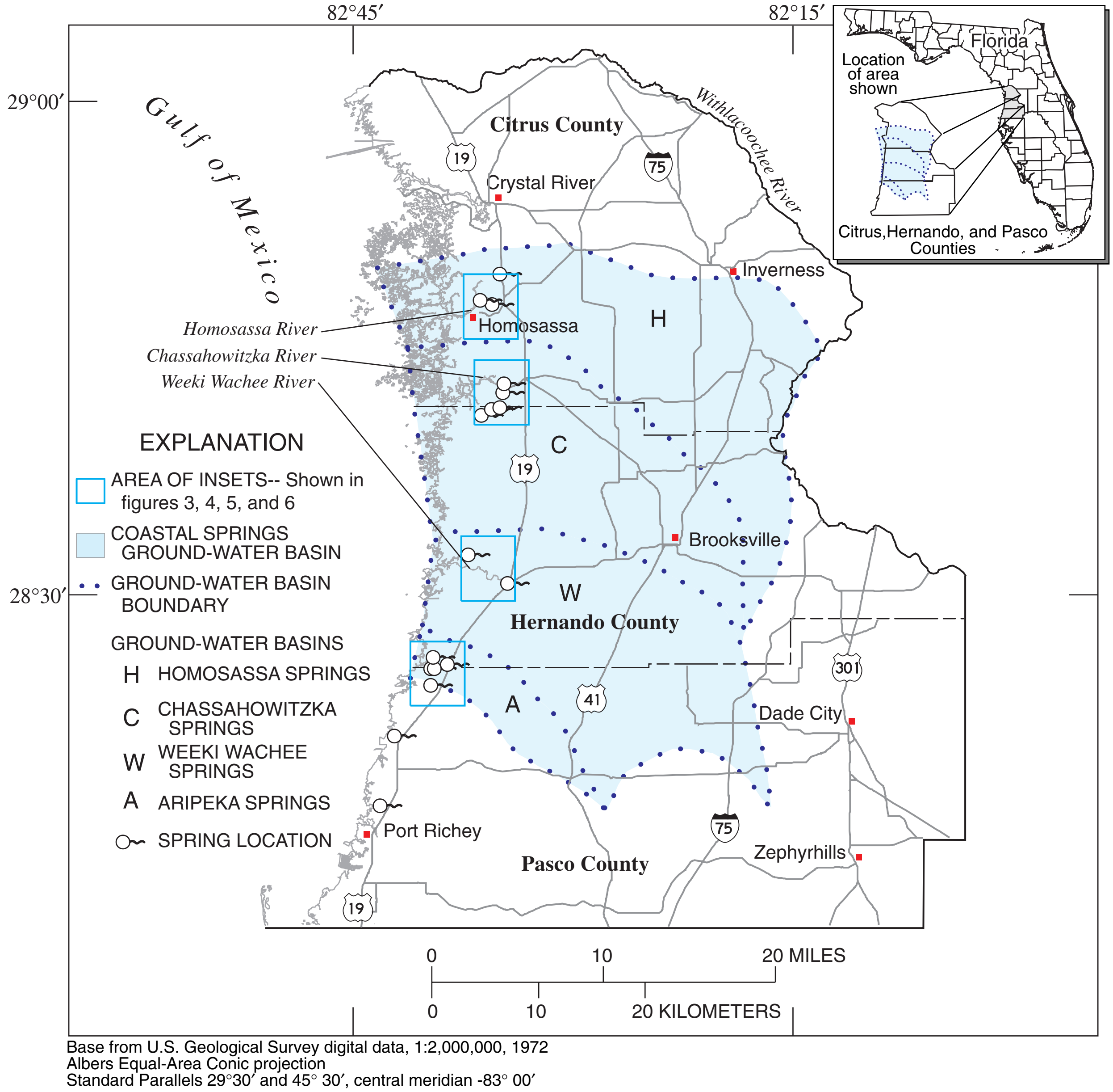


Figure 1. Location of the study area, selected springs, and the Coastal Springs Ground-Water Basin, Pasco, Hernando, and Citrus Counties, Florida.

4. Water budgets for the ground-water basins (January 1997 through December 1998);
5. Analysis of long-term change in hydrologic conditions (variable length of time through 1998); and
6. Discussion of the interrelation among select hydrologic components (variable length of time through 1998).

The hydrologic data analyzed and presented in this report were collected by the USGS and compiled from various sources. The hydrologic data have variable periods of record. Published results were reviewed, historical data were compiled, and a data-collection network was established. The data collected from the established network included periodic (instantaneous) and continuous measurements of ground-water level, surface-water stage, spring flow, and specific conductance of water from springs. A variety of techniques was used to analyze and interpret the hydrologic data.

Previous Investigations

Previous investigations providing data, techniques, and analysis of selected hydrologic components are the foundation for this report. The USGS was the source for historical ground-water levels, surface-water stages, spring flows, water-quality data collected from wells and springs, and for water-use estimates. The SWFWMD was the source of historical water-quality data collected from wells, and for water-use estimates and daily rainfall. The National Oceanic and Atmospheric Administration (NOAA) was the source for daily, monthly, and annual rainfall. Details of the hydrogeologic framework and geomorphic features are presented in Wetterhall (1964, 1965), Cherry and others (1970), White (1970), Rosenau and others (1977), Wolfe (1990), HydroGeoLogic, Inc. (1997), and Southwest Florida Water Management District (1997, 1998). Data, techniques, and preliminary analysis for estimating spring-flow quantity and quality are presented in Rosenau and others (1977), Sinclair (1978), Yobbi (1992), and Southwest Florida Water Management District (1997). Ground-water withdrawal, evapotranspiration, and rainfall data are presented in Southwest Florida Water Management District (1999a, 1999b), Marella (1995, 1999), R.L. Marella, U.S. Geological Survey, written commun. (1999), Bidlake and others (1993), Knowles (1996), Sumner (1996), German (1999), National Oceanic and Atmospheric Administration (1997, 1998), and Southwest Florida Water Management District (written commun., 1999).

Acknowledgments

The authors recognize the invaluable support, cooperation, and teamwork of private citizens, the staff of state and county parks, USGS employees, and USGS Volunteers for Science. Jane and Bill Shaw, Howard Bryant, Homosassa Springs State Park, Hernando County Parks, and Citrus County Parks staff are appreciated for allowing the collection of hydrologic data on their property. Through the teamwork of USGS employees and volunteers, hundreds of spring flow measurements were made during this investigation. The USGS Tampa Subdistrict team included Holly Barnett, Ho Blankenship, James Broska, Lewis Fletcher, Kevin Hubbs, Susan Lane, Bill Lewelling, Patty Metz, Eric Pritchett, Jack Regar, Amy Swancar, Ann Tihansky, Arturo Torres, and Larry Windom. Special thanks is extended to Kevin Hubbs for lending his organizational skills and technical assistance. The Volunteers for Science team included Rachel Brewer, Alexandra Lassi, Darwin Knochenmus, and Linda Knochenmus.

Naming Conventions and Definitions of Selected Terms

The following naming conventions and definitions of selected terms are used in this report. The USGS stores and publishes the daily maximum water level in wells and the daily mean stage and flow in springs and rivers. The water-level and stage records collected during the investigation period are stored as altitudes referenced to sea level. The investigation period or period of hydrologic data collection was calendar years 1997 and 1998. Descriptive statistics and water budgets were based on calendar rather than water years. The term *water year* designates the USGS annual period that begins on October 1 and ends on September 30. The standard definition of runoff is that part of rainfall that falls on or flows directly into streams. In this report, the term *runoff* is defined as the ground-water discharge measured as spring flow at gaging stations. The term *hydrologic component* is defined as a distinct part of the hydrologic cycle, such as rainfall. Values for *ground-water withdrawal* are synonymous with water-use estimates tabulated by the SWFWMD and USGS. The term *spring* is used to designate both a vent and a pool. The term *spring vent* is defined by the geometry of the rock opening. The term *springs complex* is used to signify the group of springs that contribute the major portion of freshwater flow to the rivers. The term *seepage swamp* is used to indicate coastal swamps receiving diffuse upward leakage from the Upper Floridan aquifer. *Karst* is defined as a terrain with distinctive characteristics of relief and drainage arising primarily from a high degree of rock solubility of carbonate rocks in natural waters (Bloom, 1978, p. 136). The term *tidal* or *nontidal spring* is used to denote a spring where flow volume is or is not affected by tides, respectively. The term *spring-flow event* is used when describing a group of discharge measurements collected over a full or partial tidal cycle.

In this report, the combined flow from the Unnamed Tributary to Chassahowitzka River, Chassahowitzka Springs, and Crab Creek is designated as Chassahowitzka River below Crab Creek and is approximately equivalent to the historical measuring section designated as Chassahowitzka River. The combined flow from the Unnamed Tributary to Chassahowitzka River and Chassahowitzka Springs is designated as Chassahowitzka River above Crab Creek and excludes flow from Crab Creek. The names and site identification numbers of the six wells that form the Coastal Springs well network (CSPR) established by the SWFWMD, differ between the USGS and the SWFWMD databases. The USGS uses well names that incorporate location or geographic information, for example Chassahowitzka River Deep well, whereas for the same well, the SWFWMD uses well names that reflect project designations and sequence numbers, for example CSPR-3.

HYDROLOGIC SETTING

The Coastal Springs Ground-Water Basin is bounded by ground-water divides rather than topographic divides because the principal drainage is by way of ground-water flow in the Upper Floridan aquifer. The Withlacoochee River, which is the only major surface-runoff drainage feature, forms the eastern and northern boundaries of the study area (fig. 1). The river is conceptualized as a hydrologic divide because the gradient along reaches of the river as well as between the Upper Floridan aquifer and the river is nearly zero. Although the river is in hydrologic contact with both the Upper Floridan aquifer and an interconnected chain of lakes, the gradient is flat so that ground-water exchange across these boundaries is minimal. Other rivers in the basin are coincident with ground-water discharge from the Upper Floridan aquifer and originate as springs.

Physiography and Soils

Five named physiographic regions including the Coastal Swamps, Gulf Coastal Lowlands, Brooksville Ridge, Tsala Apopka Plain, and Western Valley are found in the study area (White, 1970) (fig. 2). The Western Valley region is south and east of the Brooksville Ridge and is outside the Coastal Springs Ground-Water Basin. This region is not discussed in detail in this report. An additional physiographic region is delineated on the 1:2,000,000 Geographical Information System (GIS) map and is designated as *drowned karst*. The Coastal Swamps region extends 2 to 5 miles (mi) landward of the Gulf of Mexico with land-surface altitudes less than 10 feet (ft). Wetlands predominate in this region, where saturated, poorly drained, organic soils overlie the carbonate rocks of the Upper Floridan aquifer. The western part of the Coastal Swamps region contains bayous, salt marshes, and palm-covered islands; the eastern part contains low-lying hardwood hammocks interspersed with small sand ridges. The Gulf Coastal Lowlands region ranges from sea level to about 100 ft above sea level, and consists of scarps and terraces that create rolling hills capped by aeolian sands. The Pamlico Terrace, an ancient shoreline 25 to 30 ft above the present sea-level stand, parallels the modern shoreline and is the most distinctive topographic feature in this region (White, 1970, p. 143). The Brooksville Ridge trends northwest-southeast and has an irregular land surface. The Brooksville Ridge is characterized by rolling hills that consist of remnant marine deposits modified by subaerial erosion, karstification, and wave action. Land-surface altitudes vary more than 100 ft over short distances and range from 70 to 275 ft above sea level. The Tsala Apopka Plain has land-surface altitudes ranging from 35 to 75 ft above sea level; the plain lies between the Brooksville Ridge to the west and the Withlacoochee River to the east. This region contains interconnected lakes and islands (wetland) hydraulically connected to the Withlacoochee River and the Upper Floridan aquifer. The weakly cemented soils in this region retain rainfall near land surface, which eventually discharges to the Withlacoochee River (HydroGeoLogic, Inc., 1997). The drowned karst region extends offshore from the mouths of the rivers to shallow depths (less than 20 ft) in the Gulf of Mexico. The drowned karst region is characterized by flat topography and brackish water rather than saltwater due to dilution by freshwater discharged from springs and seeps.

Three soil types or categories found in the study area generally coincide with the physiographic regions described by White (1970). Soil type is defined by texture and composition, which can affect the recharge or discharge potential of the Upper Floridan aquifer. A synopsis of the Soil Conservation Service classification of soils and hydrologic potential is presented below. Detailed descriptions of the soil categories and relative hydrologic potential are summarized in reports by the Soil Conservation Service (1976, 1981, and 1986) and by HydroGeoLogic, Inc. (1997). Category 1 soils in upland areas are very well drained (Soil Conservation Service, 1976, 1981, and 1986). Areas overlain by category 1 soils tend to have relatively deep water tables, rapid percolation, internal drainage, and high recharge potential (HydroGeoLogic, Inc., 1997).

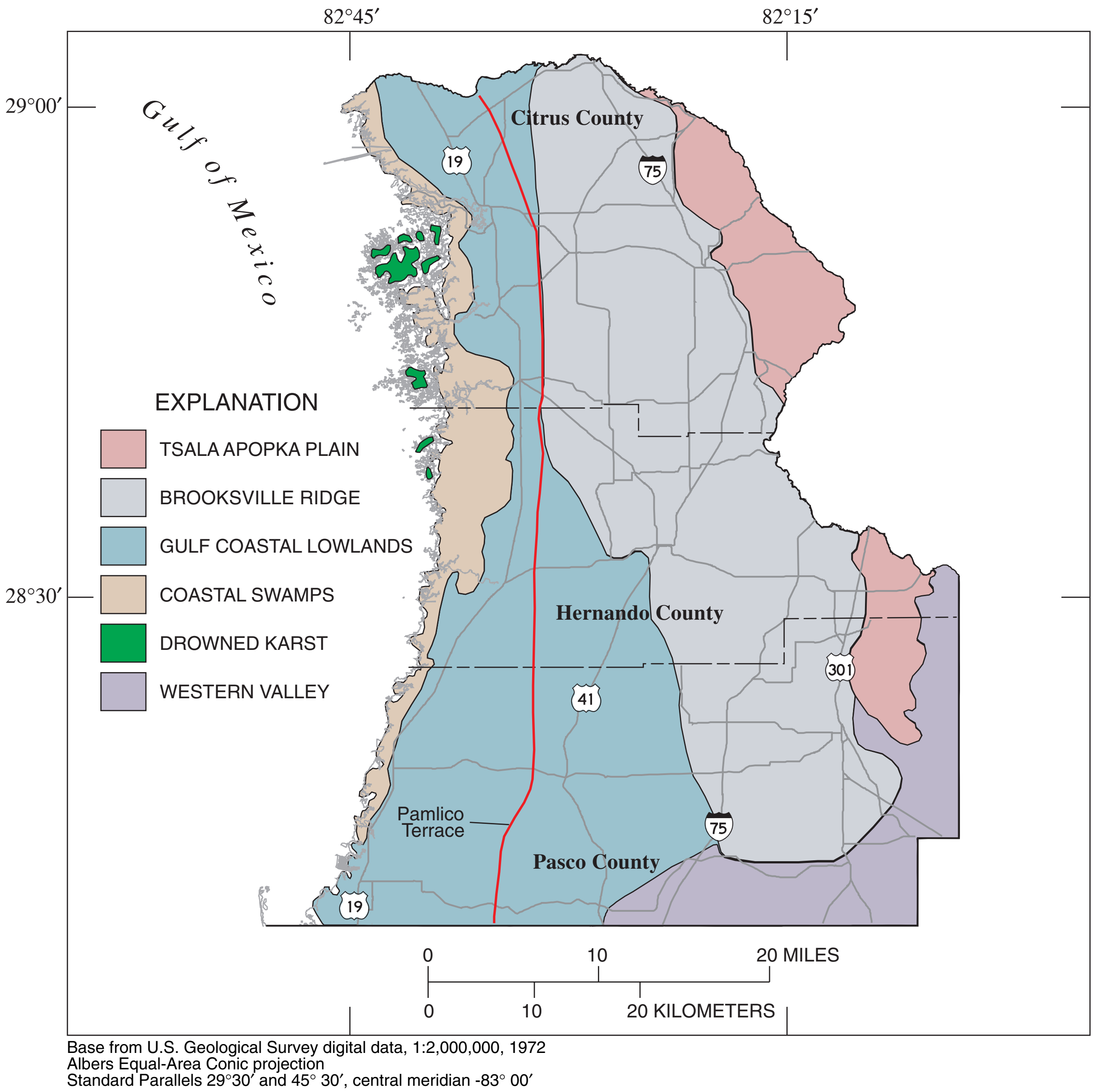


Figure 2. Physiographic regions of the study area, Pasco, Hernando, and Citrus Counties, Florida (modified from White, 1970).

Category 1 soils are dominant in the Brooksville Ridge in Citrus County, in the sand hills of the Gulf Coastal Lowlands, and on the flanks of the Brooksville Ridge at altitudes less than 125 ft in Hernando County (HydroGeoLogic, Inc., 1997). Category 2 soils are moderately poor to poorly drained soils in upland and flatwood areas (Soil Conservation Service, 1976, 1981, and 1986). Areas overlain by category 2 soils tend to have shallow water tables, perched lakes, ephemeral ponds, and wetlands. Lakes in these areas probably reflect the water table of the surficial aquifer system or a perched water table above the Upper Floridan aquifer. Recharge potential generally is moderate to low, but can be high in sinkhole-prone areas (HydroGeoLogic, Inc., 1997). Category 2 soils are dominant at lower altitudes in the Gulf Coastal Lowlands, in the Tsala Apopka Plain, and at higher altitudes (greater than 125 ft above sea level) in the Brooksville Ridge in Hernando County. Category 3 soils are poorly to very poorly drained wetland soils found in swamps, tidal marshes, and river flood plains. Category 3 soils are dominant in the Coastal Swamps region and in the Withlacoochee River floodplain (Tsala Apopka Plain). Areas overlain by category 3 soils coincide with locations where the potentiometric surface of the Upper Floridan aquifer is at or near land surface, and the potential for discharge is high (HydroGeoLogic, Inc., 1997).

Karst

The study area is characterized by numerous sinkholes, internal drainage, and undulating topography typical of karst landscapes. A correlation exists between solution-feature density and soil type in the study area (HydroGeoLogic, Inc., 1997). Solution-feature density was calculated by summing the number of closed circular topographic depressions, as indicated by topographic map contours, per square mile in Hernando County. Solution-feature density reported by HydroGeoLogic (1997) ranges from 10 to 25 features per square mile in the sand hill areas of the Gulf Coastal Lowlands and the Tsala Apopka Plain (category 1 soils); from 0 to 5 features per square mile on the top of the Brooksville Ridge and in lowland areas of the Gulf Coastal Lowlands and Tsala Apopka Plain (category 2 soils); and from 0 to 2 features per square mile in the Coastal Swamps (category 3 soils).

The carbonate rocks of the Upper Floridan aquifer have been extensively and repeatedly subjected to chemical dissolution and deposition processes in response to sea-level fluctuations. These chemical processes are most active near or at the water table (saturated/unsaturated interface) and near or at the saltwater/freshwater interface (mixing zone). The locations of these interfaces are not temporally constant; therefore, multiple horizons of concentrated karst features can be found within the carbonate rocks. The wide fluctuation in sea level stands during the Miocene age, especially the late Miocene, resulted in an intense period of karst development.

The origin of Florida karst is somewhat controversial, due to the absence of dolomitization and the geometry of karst features, indicating that many of the features formed as vadose to shallow phreatic, freshwater caves. Modern ground-water chemistry indicates that shallow ground water in the recharge area is undersaturated with respect to calcite and dolomite, whereas downgradient from the recharge area, chemical equilibrium is achieved and karstification is inhibited. Therefore, the karst features that are the first-order magnitude springs (magnificent discharge points) developed in a recharge area (S.B. Upchurch, ERM. Inc., written commun., 1996).

Hydrogeologic Framework

The hydrogeologic units that form the hydrogeologic framework in the study area include (1) the discontinuous, siliciclastic surficial aquifer system, (2) the discontinuous, siliciclastic intermediate confining unit, and (3) the thick, predominately carbonate Upper Floridan aquifer. Although relatively thick saturated siliciclastic deposits are found in the study area, a hydraulically separated, regionally extensive surficial aquifer system does not exist. The clay confining unit is breached by numerous sinkholes, allowing hydraulic connection between the aquifers. Where clay deposits are sufficiently thick, perched water tables and lakes may be present. The geologic units forming the freshwater part of the Upper Floridan aquifer, from oldest to youngest, are the Avon Park Formation and Ocala Limestone of Eocene age, and the Suwannee Limestone of Oligocene age. The Suwannee Limestone and Ocala Limestone are the uppermost carbonate units south and north of Chassahowitzka River, respectively. A complete description of the lithologic, hydraulic, and chemical properties of the aquifers forming the hydrogeologic framework is presented in Yobbi (1992), HydroGeoLogic, Inc., (1997), and Southwest Florida Water Management District (1997, 1998).

Descriptions of Selected Springs and Spring Runs

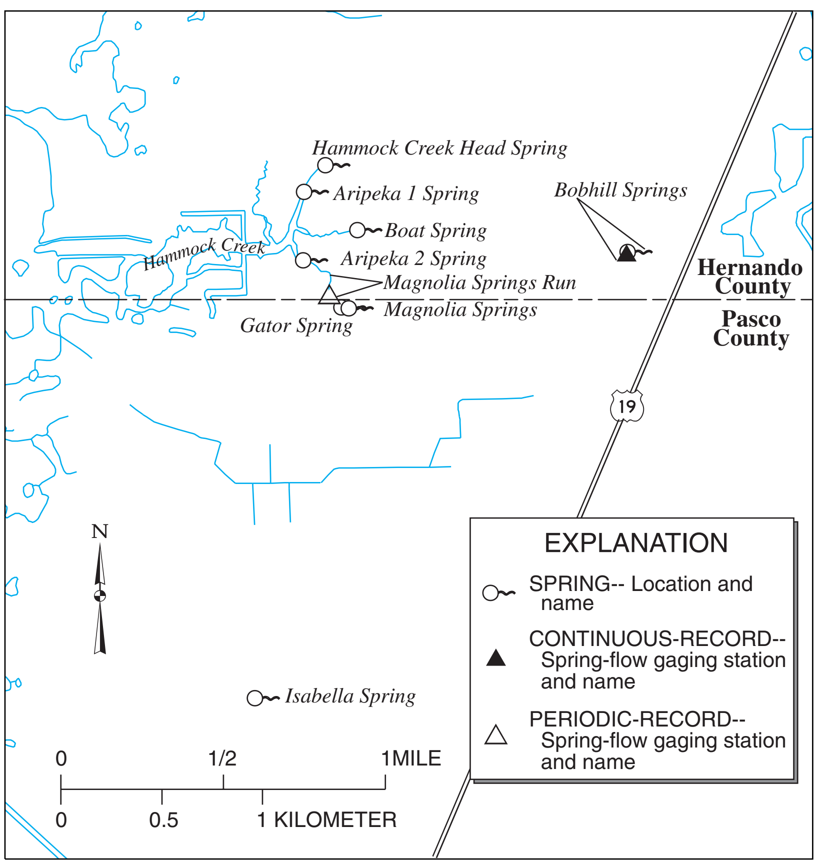
Enlarged pores (vugs) or openings in carbonate rocks concentrate ground-water flow, which could lead to further dissolution of the rocks, creating sinks and springs instead of large areas of diffuse seepage. The size of openings and ultimately the *type* of spring vent formed are related to the degree of induration or cementation of the rocks. Hard, well indurated, and brittle zones in limestone can maintain large openings, and linear-fracture or circular-rock-type spring vents are common. Soft, poorly indurated, or friable zones in limestone generally are filled with unconsolidated sediments, and sediment-filled or sand-boil-type spring vents form. Cave divers have determined that the type of spring vent can vary with depth. Descriptions of selected springs and major surface-water features in the Aripeka, Weeki Wachee, Chassahowitzka, and Homosassa Springs Ground-Water Basins are summarized here and presented in greater detail in a report by the Southwest Florida Water Management District (1997, p. 27-44).

The Aripeka Springs Ground-Water Basin (fig. 1) contains many small springs including Aripeka 1, Hammock Creek Head, Boat, Aripeka 2, Gator, Magnolia, and Bobhill Springs (fig. 3). Aripeka 1, Aripeka 2, and Magnolia Springs are sediment-filled, and Boat and Bobhill Springs are circular-rock-type spring vents. The spring runs, except from Bobhill Springs, form the branching pattern of Hammock Creek, which derives flow from a 1-mi^2 basin. The basin is west of U.S. Highway 19 and straddles the Pasco and Hernando County line. Hammock Creek and Bobhill Springs discharge to the Gulf of Mexico (Southwest Florida Water Management District, 1997, p. 43).

The Weeki Wachee Springs Ground-Water Basin (fig. 1) contains the first-order magnitude spring--Weeki Wachee Springs--and numerous smaller springs, including Little, Salt, and Mud Springs (fig. 4). Located near U.S. Highway 19, the majority of flow in Weeki Wachee River is from Weeki Wachee Springs. The river has a well-defined channel that meanders about 7 mi to the Gulf of Mexico. The spring runs from the smaller springs are tributaries to the Weeki Wachee River. The spring run for Little Springs (also known as Twin Dees) is a 0.2-mi long tributary to the Weeki Wachee River.

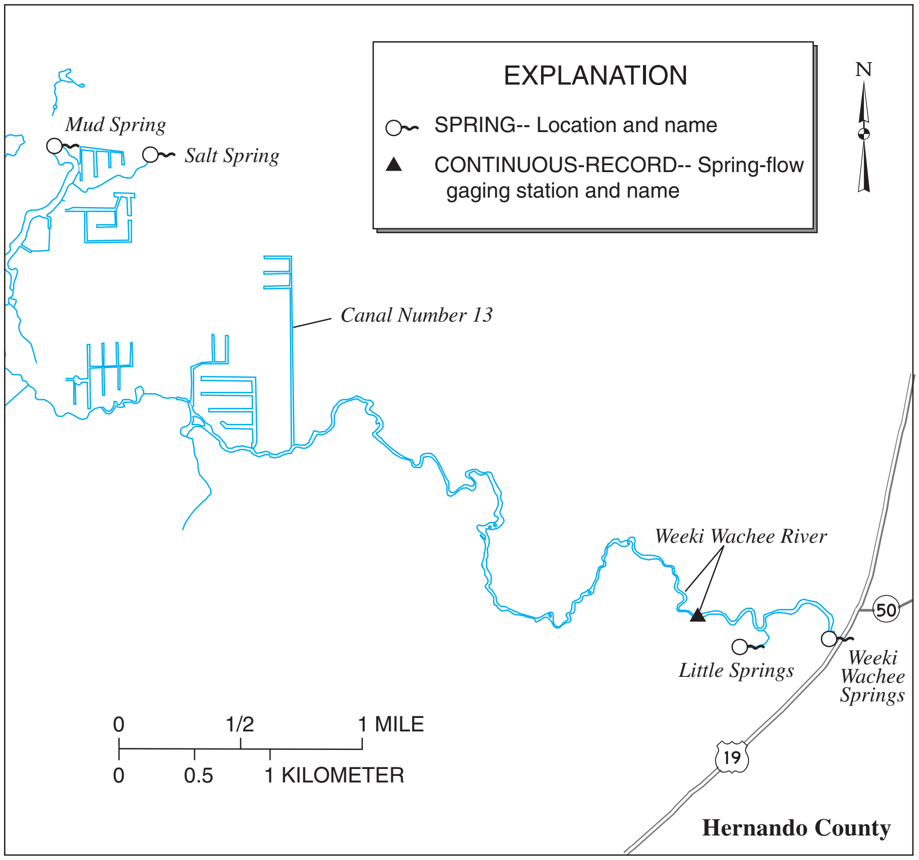
The spring vent at Weeki Wachee Springs is a 150-ft diameter, circular-rock-type vent extending from the riverbed to a depth of 10 ft below the riverbed. Below this depth, a north-south trending, linear-fracture-type vent exists. At a depth of 185 ft below the riverbed, the fracture dimensions are 20 by 3 ft (Southwest Florida Water Management District, 1997). Below a depth of 205 ft, a large cavern with passages exiting from both ends of the room conveys water away from Weeki Wachee Springs (Southwest Florida Water Management District, 1997).

The spring vent at Little Springs is a 4-ft diameter, circular-rock-type vent extending to a depth of about 50 ft. Below this depth, the vent angles north for about 1,500 ft (Rosenau and others, 1977, p. 143-144).



Base from U.S. Geological Survey digital data, 1:24,000, 1988
Albers Equal-Area Conic projection
Standard Parallels 29°30′ and 45° 30′, central meridian -83° 00′

Figure 3. Selected springs and gaging stations in the Aripeka Springs Ground-Water Basin.

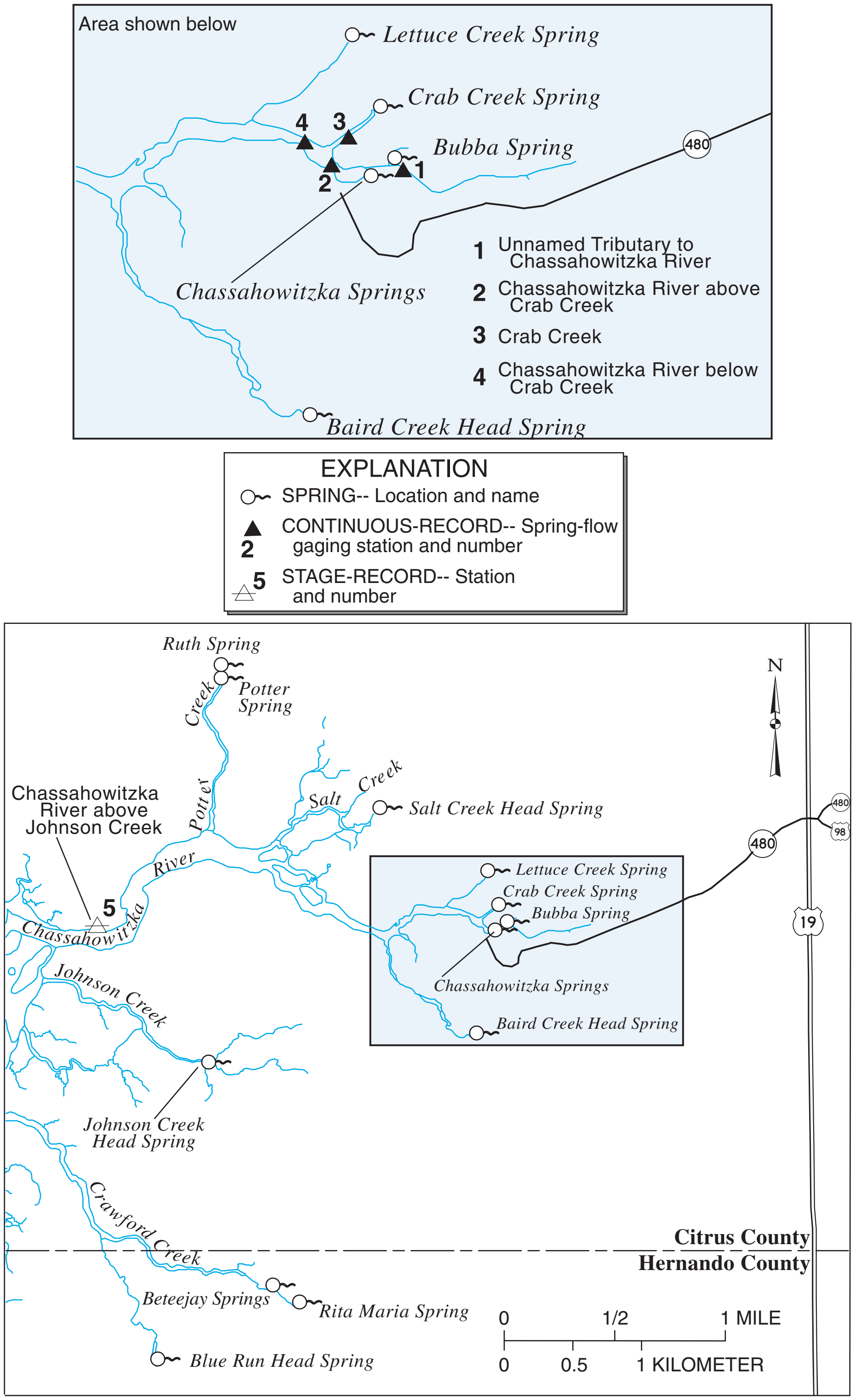


Base from U.S. Geological Survey digital data, 1:24,000, 1988
Albers Equal-Area Conic projection
Standard Parallels 29°30′ and 45° 30′, central meridian -83° 00′

Figure 4. Selected springs and gaging stations in the Weeki Wachee Springs Ground-Water Basin.

Caverns and wide conduits have been explored to a depth of about 300 ft (Southwest Florida Water Management District, 1997). Salt Spring has a 6-ft diameter, circular-rock-type spring vent that extends to a depth of 170 ft. The vent is intersected by multiple horizons of lateral passages below a depth of 60 ft. Mud Spring has a circular-rock-type vent with a 185-ft vertical drop and is located on the west side of a 400 ft spring pool (Sinclair, 1978).

The Chassahowitzka River is a shallow, flat, sluggish stream that meanders through about 6 mi of lowland swamps and tidal marshes and discharges to the Gulf of Mexico. More than a dozen springs contribute flow to the Chassahowitzka River; the majority of fresh-water flow is from Chassahowitzka Springs, unnamed springs upstream from Chassahowitzka Springs, and Crab Creek Spring (fig. 5). Chassahowitzka Springs is a 50-ft wide, cone-shaped, sediment-filled vent located near the center of the river channel in about 20 ft of water (Wetterhall, 1965). Several springs, collectively known as the *unnamed springs*, are found in the 250-ft long natural limestone channel upstream from Chassahowitzka Springs. The combined flow from the unnamed springs and from the man-made canal is measured at the gaging station named the Unnamed Tributary to Chassahowitzka River. The spring vents are circular-rock-type vents (vertical solution pipes) connected by horizontal conduits. The largest spring is Bubba Spring (Chassahowitzka 1), which consists of two vertical pipes connected by a 15-ft long horizontal conduit. The flow from Bubba Spring emanates from a small opening in the horizontal passage midway between the two vertical pipes. Crab Creek is a short tributary to Chassahowitzka River, and has a hummocky limestone bottom. At least four circular-rock-type vents contribute flow to Crab Creek. The largest spring is Crab Creek Spring, located at the head of Crab Creek; the spring lies in 13 ft of water (Wetterhall, 1965). The surface expressions of the spring vents at both Baird Creek Head Spring and Ruth Spring are linear fractures that discharge brackish water.

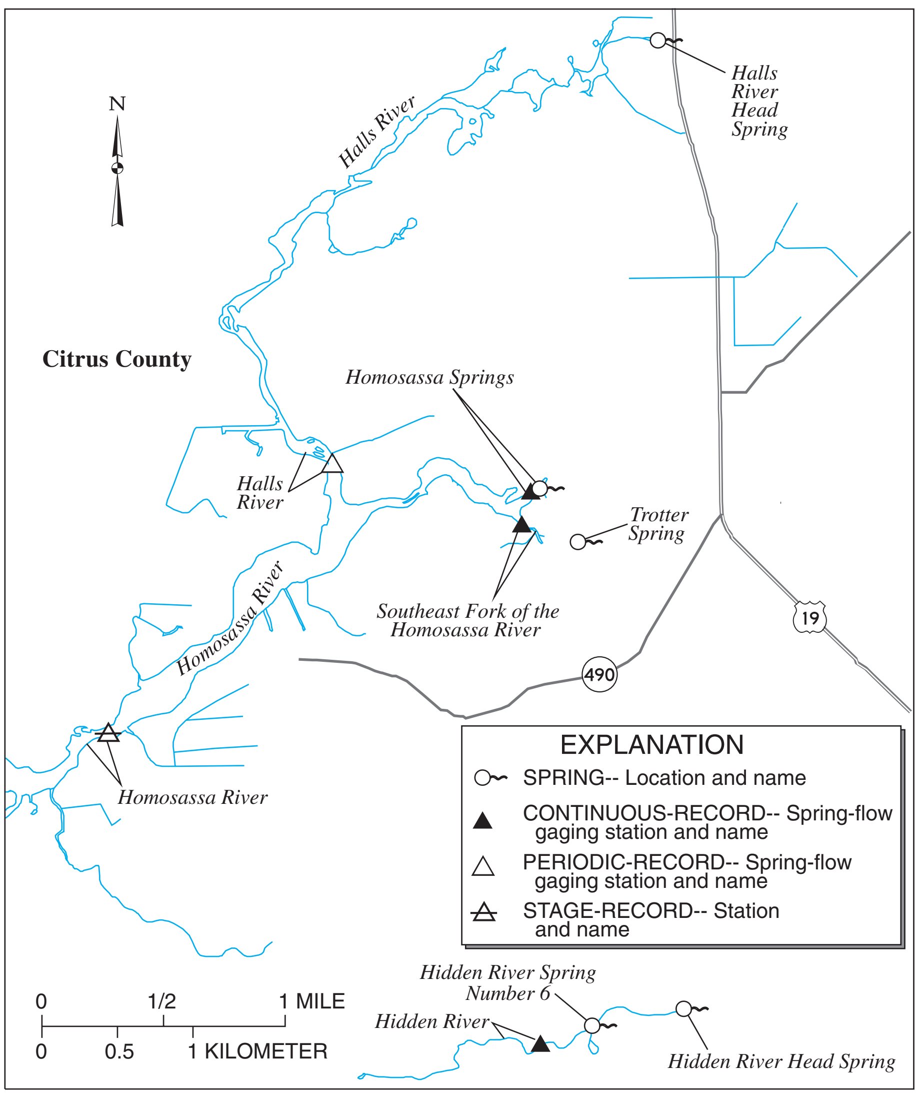


Base from U.S. Geological Survey digital data, 1:24,000, 1988
Albers Equal-Area Conic projection
Standard Parallels 29°30′ and 45° 30′, central meridian -83° 00′

Figure 5. Selected springs and gaging stations in the Chassahowitzka Springs Ground-Water Basin.

A large spring and numerous smaller springs contribute flow to the Homosassa River, which meanders through about 6 mi of lowland swamps and discharges to the Gulf of Mexico (Cherry and others, 1970). Springs that contribute the majority of freshwater flow to Homosassa River include Homosassa Springs, springs supplying flow to the Southeast Fork of the Homosassa River, and springs supplying flow to Halls River (fig. 6). Exploration of Homosassa Springs is limited to a depth of about 70 ft, but past surveys indicate the presence of three large circular-rock-type vents within a collapsed-cavern feature. Several springs with both circular-rock- and linear-fracture-type vents contribute flow to the Southeast Fork of the Homosassa River (Southwest Florida Water Management District, 1997). Flow in the 2.5-mi-long Halls River is derived from many uncharted springs in the wide, shallow, and thickly vegetated river channel. The largest spring supplying flow to Halls River is Halls River Head Spring, a sediment-filled vent without a visible boil located in a 200-ft-wide spring pool.

In this report, hydrologic information and data collected at Hidden River is grouped with discussions of the Homosassa Springs Ground-Water Basin. Hidden River is geographically located between the Chassahowitzka and the Homosassa Rivers. Hidden River is



Base from U.S. Geological Survey digital data, 1:24,000, 1988
Albers Equal-Area Conic projection
Standard Parallels 29°30′ and 45° 30′, central meridian -83° 00′

Figure 6. Selected springs and gaging stations in the Homosassa Springs Ground-Water Basin.

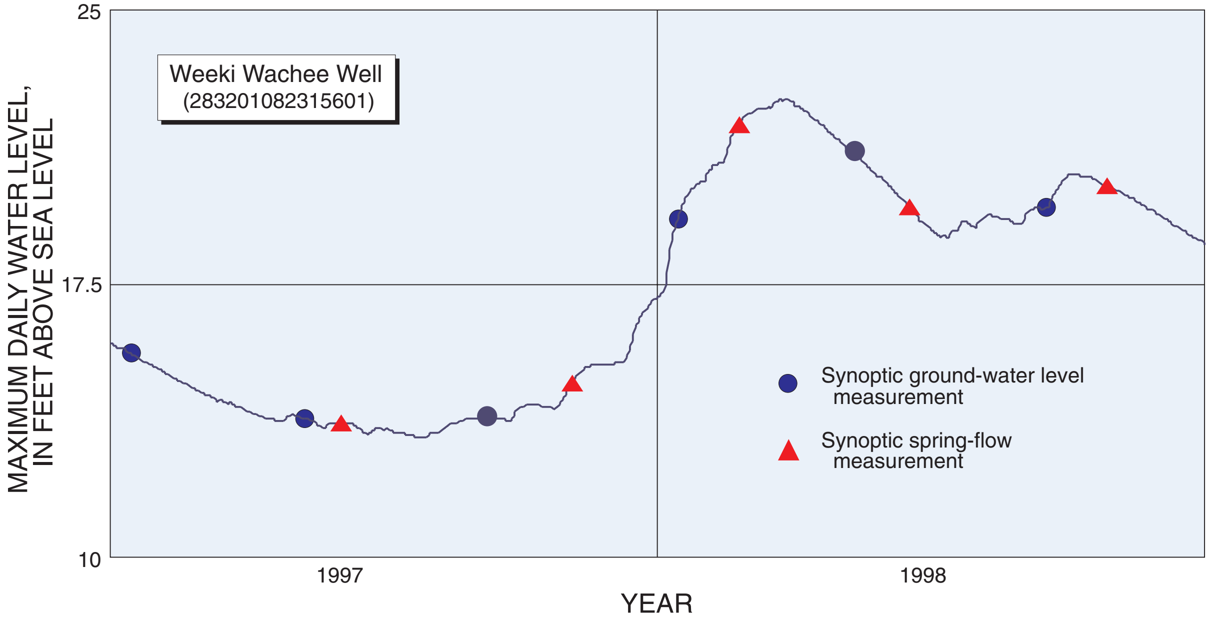


Figure 7. The Weeki Wachee well water-level hydrograph and corresponding synoptic measurement periods (January 1997 through December 1998).

not a typical river because it originates as ground-water discharge from a group of springs, flows overland for about 2 mi, and then disappears underground (fig. 6). Although no surface feature connects Hidden River to Homosassa River, discussions related to Hidden River are grouped with discussions on Homosassa River because the flow in Hidden River probably enters the Homosassa River downstream from the Homosassa River gage (Cherry and others, 1970). Two springs that contribute flow to Hidden River are Hidden River Head Spring and Hidden River Spring number 6 (fig. 6). Both of these springs are shallow (about 5 ft deep) with small sediment-filled vents.

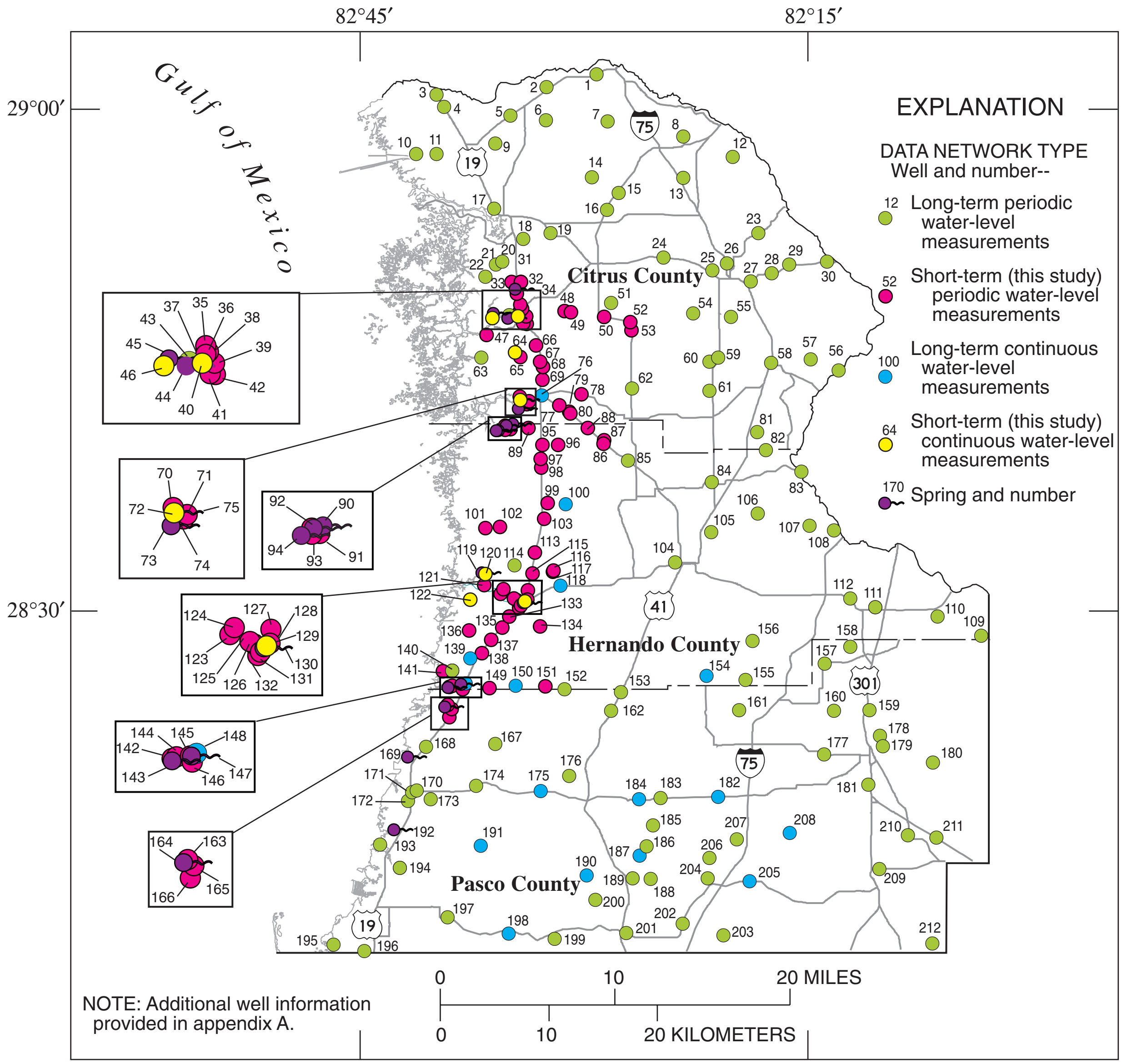
DATA-COLLECTION NETWORK AND METHODS

The data collected during this investigation included periodic (instantaneous) and continuous measurements of ground-water levels, surface-water stage, spring flow, and specific conductance of water from springs. Ground-water levels were collected at more than 200 wells. Surface-water stage and spring flow were collected at 10 gaging stations. Water levels, reflecting the potentiometric surface of the Upper Floridan aquifer, were measured synoptically during January, May, and September of 1997 and 1998.

Spring flows were measured synoptically during June and November of 1997 and during February, June, and October of 1998. The synoptic measurements span the range of hydrologic conditions during the investigation period. The range in hydrologic conditions is illustrated in figure 7, which shows the water-level hydrograph for the Weeki Wachee well; the average period-of-record water level is 17.5 ft above sea level. Figure 7 also illustrates that hydrologic conditions were below average during 1997 and above average during 1998.

Ground-Water Levels

Measurements of continuous and periodic ground-water levels in wells penetrating the Upper Floridan aquifer and spring-pool altitudes were collected from the 212 sites shown in figure 8. Supplemental well information is listed in appendix A. The well network included 25 continuously measured (instrumented) wells and 181 periodically measured (noninstrumented) wells. Of the 25 instrumented wells, 18 are part of the basic data network and the other 7 wells were inventoried for this investigation. The wells instrumented for this investigation were equipped with BDR-301 data loggers and float/weight in conjunction with a Handar shaft encoder to collect water-level measurements at 15-minute (min) or 1-hour (hr) intervals.



Base from U.S. Geological Survey digital data, 1:2,000,000, 1972
Albers Equal-Area Conic projection
Standard Parallels 29°30′ and 45° 30′, central meridian -83° 00′

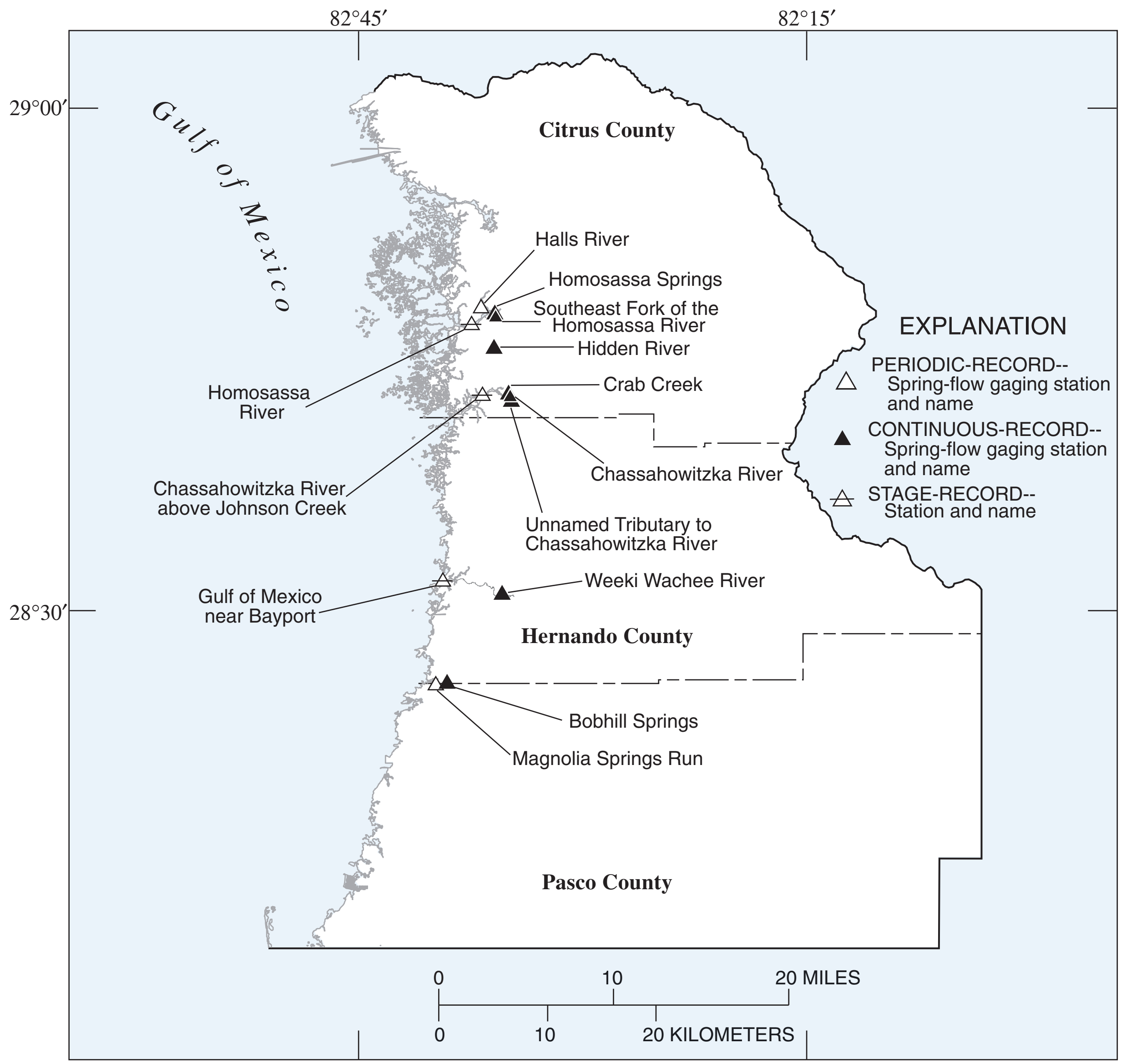
Figure 8. Wells and springs network.

Of the 181 noninstrumented wells, 106 are part of the Tampa Subdistrict semiannual potentiometric-surface mapping network and 75 supplemental wells were inventoried for this investigation. Water levels were measured using a graduated steel or calibrated electric tape.

Upper Floridan aquifer ground-water levels were used to compare water-level patterns among wells, evaluate the magnitude and rate of aquifer response to rainfall, and provide ground-water data for estimating spring flow in the basin. The potentiometric surface of the Upper Floridan aquifer was mapped to illustrate minimum (May-June), median (January-February), and maximum (September-October) ground-water levels during a typical calendar year. The potentiometric-surface maps were used to evaluate the regional ground-water flow, delineate the ground-water basins, and compare dry (low water level) and wet (high water level) hydrologic conditions. The water-level data are published in the USGS annual Water Resources Data Report for Florida, Water Year 1998 (U.S. Geological Survey, 1999).

Surface-Water Stage

Surface-water stage data were collected at 13 stations to provide continuous and periodic surface-water altitudes. Stage data were collected at seven continuously measured (instrumented) and six periodically measured (noninstrumented) stations (fig. 9). The instrumented stations were equipped with electronic data loggers and either a pressure transducer or an electronic shaft encoder to collect 15-min measurements of stage. Weeki Wachee River, Chassahowitzka River, Crab Creek, and Homosassa Springs are located near or at the spring pools. Chassahowitzka River above Johnson Creek and Homosassa River at Homosassa stations are located in river reaches downstream from the spring pools (figs. 5, 6, and 9). Tidal fluctuations are measured at the Gulf of Mexico near Bayport station, located at the mouth of the Weeki Wachee River (fig. 9). The six noninstrumented stations included Halls River, Southeast Fork of the Homosassa River, Hidden River, Unnamed Tributary to Chassahowitzka River, Bobhill Springs, and Magnolia Springs Run (figs. 3, 5, and 6). The noninstrumented stations required manual collection of stage data using a folding



Base from U.S. Geological Survey digital data, 1:2,000,000, 1972
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Figure 9. Periodic and continuous spring-flow and stage-only gaging stations.

engineering rule or calibrated tape to measure the distance between the water surface and a reference point of known altitude. Stage measurements were made before and after each discharge measurement. The stage data were published in the USGS annual Water Resources Data Report for Florida, Water Year 1998 (U.S. Geological Survey, 1999).

Stage data were used to evaluate the seasonal (annual) and diurnal (daily) fluctuations and to provide data for estimating flow from tidal springs in the basin. Annual fluctuation in stage is in response to seasonal climate patterns. Daily fluctuation in stage is in response to tides in the Gulf of Mexico. The stage data collected at or near spring pools were used to quantify the relation between instantaneous water-surface altitude and spring-flow volume. Stage data collected from stations located at river reaches downstream from the springs and at the Gulf of Mexico were used to evaluate the changing gradients among the stations.

Spring Flow

Spring flow was measured at 10 gaging stations to provide data needed to develop statistically based discharge-rating equations. The springs were selected for monitoring using the following criteria: (1) volume of spring flow (largest), (2) nontidal or small fluctuations in stage and specific conductance (freshest), and (3) regional distribution. Locations of the spring-flow stations are shown in figures 3-6 and 9. Spring flow was measured in June and November 1997 and in February, June, and October 1998. Individual spring-flow measurements were collected periodically to characterize the spring flow from nontidal springs, including Bobhill Springs, Magnolia Springs Run, Weeki Wachee River, and Hidden River. Periodic, multiple spring-flow measurements were made hourly during a tidal or partial-tidal cycle at tidal springs, including Chassahowitzka River (above and below Crab Creek), Crab Creek, Unnamed Tributary to Chassahowitzka River, Homosassa Springs, Southeast Fork of the Homosassa River, and Halls River. Spring flow was measured using a Price AA current meter and standard USGS stream-flow measuring techniques (Carter and Davidian, 1968; and Buchanan and Somers, 1969). The spring-flow data are listed in appendix B, and are also published in the USGS annual Water Resources Data Report for Florida, Water Year 1998 (U.S. Geological Survey, 1999).

Specific Conductance

Specific conductance of water from springs was measured to evaluate the annual and daily variations among springs in the study area. The range in magnitude of the specific conductance of water from springs is typically much greater for tidal springs than for nontidal springs, because the vents of the tidal springs intersect the saltwater-freshwater interface. Because the location of the interface is transient, the saltwater-freshwater interface moves horizontally and vertically in the aquifer in response to changes in ground-water levels and tides in the Gulf of Mexico (Yobbi, 1992, p. 25). The ionic composition and strength are controlled by the dynamically changing location of the interface within the Upper Floridan aquifer and along the rivers and creeks. Field measurements of specific conductance were made before and after each discharge measurement using a probe-style conductivity meter. The specific conductance data collected during the investigation are listed in appendix B.

STATISTICAL AND GRAPHICAL METHODS

Statistical methods were used to estimate daily mean spring flow, analyze selected hydrologic data for trends, and evaluate relations among the various hydrologic components. Linear regression analysis was used to develop discharge-rating equations for nontidal springs. The nonparametric Kendall-Theil Robust Line method (Helsel and Hirsch, 1992) was used as a verification of the linear regression analysis. The Mann-Kendall test (Mann, 1945) was used for statistical analysis of trends. Multiple linear regression was used to develop discharge-rating equations for tidal springs and to explore relations among hydrologic components. Graphical methods were used to evaluate data consistency, assess the relation among hydrologic components, and assess long-term change (trends) and patterns among hydrologic components.

Simple Linear Regression

Simple linear regression analysis, using the ordinary least squares (OLS) method, was conducted to describe the covariance among the hydrologic components of interest (for example, spring flow and ground-water levels) by mathematically applying the “best-fit” linear equation between a response variable (y or spring flow) and an explanatory variable (x or ground-water levels). The five general assumptions of the OLS method are: (1) x and y are linearly related, (2) data used to fit the model are representative of the data of interest, (3) variance of the residuals is constant (homoscedastic), (4) residuals are independent, and (5) residuals are normally distributed (Helsel and Hirsch, 1992, p. 225). The number of assumptions that must be met depends upon the reason for using the regression equation (Helsel and Hirsch, 1992, p. 224). Results from linear regression analysis provide a quantitative definition of the coefficient of determination (R^2) and the standard error of the regression. The R^2 values range from 0 to ± 1, and is a measure of the fraction of the variance explained by the regression. The standard error of the regression or the root mean square error (RMSE) is a measure of the dispersion of the data around the regression line (Helsel and Hirsch, 1992, p. 245).

Regression models were developed to evaluate the statistical relations between spring flow and ground-water levels because the spring flow constitutes the regional ground-water discharge from the Upper Floridan aquifer. A single explanatory variable (ground-water level) was used in the regression models to estimate spring flow for the three nontidal springs (Bobhill Springs, Weeki Wachee River, and Hidden River). Additionally, a single explanatory variable (spring flow from a nearby spring in the complex) was used in the regression models to estimate flow at two tidal springs (Unnamed Tributary to Chassahowitzka River and Southeast Fork of the Homosassa River). Predictive equations were used to compute the daily mean spring flow.

In addition to R^2 and RMSE values, software (DataMost Corp., 1995) used for regression analysis provided the best-fit regression equation (slope and intercept) and the F-test and t-test results. Results of F-tests provide determinations of the statistical significance of relations between variables. Results of t-tests provide determinations of whether the coefficients for the explanatory variables differ significantly from zero. The level of significance is the user-selected criterion for accepting the chance that a regression coefficient may be zero, therefore insignificant in predicting the response variable. A significance level of 10 percent was the selected criterion for accepting the explanatory variable coefficient as significant. A linear regression equation and the regression diagnostics (summary statistics) indicate the degree of association between the response and explanatory variables, but are not unique and not truly a cause-effect relation (Henderson and Lopez, 1989, p. 5).

Linear Analysis Using Kendall-Theil Robust Line

The Kendall-Theil Robust Line method (Helsel and Hirsch, 1992) was used as an alternative method to test the significance of a linear dependence between the two continuous variables (y and x) by determining whether the regression slope coefficient for the explanatory variable is significantly different from zero. The test is equivalent to the test for significance of the linear correlation r between y and x, and uses Kendall's tau (τ) to determine the slope (or rate of change) when y is linearly related to x (Helsel and Hirsch, 1992). Unlike OLS regression, the determination of slope is not dependent on the normality of residuals for the validity of significance tests and is not strongly affected by outliers. A spreadsheet was used to compute the median of all possible pair-wise slopes between the ground-water level and spring-flow data pairs. The median slope is defined as the nonparametric slope of the linear relation. The estimate of the intercept is produced from placing the line through the data median, and is efficient in the presence of outliers and nonnormal residuals. The method was applied to data from Bobhill Springs, Weeki Wachee River, and Hidden River. Comparisons were made between the computed slope and intercept determined from the robust line and OLS methods, which were used to validate the regression results.

Multiple Linear Regression

Multiple linear regression (MLR) is the extension of simple linear regression to the case of multiple explanatory variables. MLR is an exploratory tool used to understand causative factors resulting in the observed response variable distribution (Helsel and Hirsch, 1992, p. 295). The goal of MLR is to explain the variation observed in the response variable, leaving as little variation as possible to unexplained noise (Helsel and Hirsch, 1992, p. 295).

MLR was used for two distinct purposes: (1) to develop discharge-rating equations for tidal springs, and (2) to investigate the relation among hydrologic components--specifically, the effects of rainfall and ground-water withdrawal on the magnitude of flow measured at Weeki Wachee River gaging station. The discharge-rating equations or regression models were developed using three explanatory variables (ground-water level, surface-water stage, and rate of change in stage). The stage data and the calculated rate of change in stage, collected at 15-min intervals, were needed to accommodate effects of the tidal amplitude in the Gulf of Mexico on the volume of spring flow.

The regression models developed for Chassahowitzka River (above and below Crab Creek), Crab Creek, and Homosassa Springs used instantaneous measurements of stage, instantaneous rate of change in stage, and daily maximum water level in the Upper Floridan aquifer. Predictive equations were used to compute the daily mean spring flow using: (1) daily mean stage, (2) daily mean rate of change in stage, and (3) daily maximum water level. The daily mean stage and daily mean rate of change in stage were computed using the 96 measurements of stage collected each day. The daily mean rate of change in stage was the average of the 96 differences between consecutive measurements of stage collected each day.

MLR also was used to investigate the affect of rainfall and ground-water withdrawal on the magnitude of spring flow. Data used in the analyses included rainfall records from Brooksville Chinsegut Hill station, ground-water withdrawal records from Pasco, Hernando, and Citrus Counties, and spring-flow records from Weeki Wachee River gaging station. These analyses provided information about the hydrologic and water-resource consequences arising from the year-to-year variability in climate, hydroperiods, and prolonged nonaverage hydrologic conditions.

Analysis for Temporal Trends

An analysis for temporal trends (trend analysis) was conducted using historical hydrologic data to determine whether long-term trends exist. Trend analysis is a determination of whether the probability distribution of the observed data has changed over time (Helsel and Hirsch, 1992, p. 324). Trends were evaluated using the nonparametric Mann-Kendall test (Mann, 1945). The method is a rank-based procedure that examines whether data values tend to increase or decrease with time. The null hypothesis is that there is no trend; however, failing to reject the null hypothesis does not mean that the “no trend” condition is proven, but rather that the evidence available is not sufficient to conclude that there is a trend (Helsel and Hirsch, 1992, p. 324). The selected significance level or the probability value used to accept the significance of the trend was a rho (ρ) value equal to or less than 0.10, which means there is a 90 percent or greater probability that the trend is significant and not a chance arrangement of the data (Henderson and Lopez, 1989, p. 5). The Mann-Kendall test was used because the assumption of normality is not required and is resistant to the effect of extremes, although there must be no serial correlation for the resulting probability values to be correct (Helsel and Hirsch, 1992). Hydrologic data tend to be serially correlated on measurement scales of less than one year, whereas annual data typically do not have a serial correlation problem. Trend analyses were conducted using annual data sets of rainfall, ground-water withdrawal, mean spring flow, and mean ground-water levels. The periods of record were variable. Trend analyses also were conducted using selected quantiles of the annual data set to evaluate whether portions of the seasonal distribution of hydrologic data have changed over time. Using long-term streamflow records, Lins and Slack (1998) detected increasing trends in the low-flow quantiles, indicating that the stream is sustaining longer periods of low flow. In contrast, trends in the high-flow quantiles were not detected except for single-day large-volume rainfall events (Lins and Slack, 1998). Trend analyses on quantile data were conducted using ground-water records from the Weeki Wachee well.

Software (DataMost Corp., 1995) used for trend analyses provided values of τ (a measure of the correlation between two variables); z (number of standard deviations from zero); and ρ (probability that the trend is significant). Values of τ vary from -1 to 1, and provide a measure of the strength of the relation between time and the response variable. Values of τ that are equal to or close to zero may indicate a lack of trend in the data over time; the number of larger subsequent values should be about equal to the number of subsequent smaller values. Values of τ ranging from 0 to 1 define a condition of progressively larger values over time, which may indicate an increasing trend. Values of τ ranging from -1 to 0 define a condition of progressively smaller values over time, which may indicate a decreasing trend.

Double-Mass Curve

The graphical double-mass curve method was used to evaluate data consistency and to assess the relation among hydrologic components. Temporal consistency of data was interpreted from graphs of the cumulative amounts of rainfall, spring flow, ground-water levels, and ground-water withdrawal over time, and was verified by graphs of the cumulative amount of the same hydrologic variable from different stations during the same period. The double-mass curve method was used to: (1) check for the consistency in rainfall data among the four NOAA rainfall stations; (2) assess temporal consistency in the cumulative amounts of rainfall, spring flow, ground-water levels, and ground-water withdrawal over time; and (3) evaluate the relation between rainfall and spring flow.

The theory of the double-mass curve method is that cumulative amounts over time or cumulative amounts between sites will plot as straight lines as long as the relation between the variables is a fixed ratio. A break in slope of a double-mass curve indicates either a changing ratio over time or the relation is not constant at all rates of accumulation. Spurious (year-to-year) breaks in the double-mass curve are caused by the inherent variability in hydrologic data; therefore, breaks lasting less than 5 years should be ignored (Searcy and Hardison, 1960, p. 33-34). Generally, deviations from a linear double-mass curve have been interpreted to signify that some additional stress has been imposed on the system (Geraghty and Miller, 1980, p. 103). Additionally, the method has been used to indicate changes in location or data-collection method at a hydrologic station (Southwest Florida Water Management District, 1990, p. 79).

Frequency Plots

Frequency plots including durations, histograms, and quantile plots were used to assess the variability in the distribution of hydrologic data, and to determine whether the variability reflects monotonic changes in quantity or changes in periodicity. For example, a monotonic or net change in the measured quantity of spring flow appears as vertical offset among similarly shaped cumulative-frequency curves with low, median, and high flow durations that are consistent over time. Periodicity changes are indicated by a change in shape of the frequency curves. Variations in shape commonly are found in the tails (low and peak flows) of the curves, indicating that the frequency of flow in certain quantiles of the data record has changed. Histograms of rainfall data were used to illustrate climatic patterns. The response of spring flow or ground-water levels to rainfall at various temporal scales, including daily, monthly, and annual periods, was evaluated. Daily, monthly, and annual data were compiled for the Brooksville Chinsegut Hill and Weeki Wachee NOAA rainfall stations. The Brooksville Chinsegut Hill and Weeki Wachee stations have fairly long periods of record, 99 and 29 years, respectively, and are strategically located to represent rainfall conditions in the Brooksville Ridge and Gulf Coastal Lowlands physiographic regions, respectively.

WATER-BUDGET METHOD

Water budgets are important tools for understanding the regional hydrologic system, and they aid in the interpretation of the processes affecting spring flow. Water enters the Coastal Springs Ground-Water Basin as rainfall, and is temporally stored in lakes, streams, and aquifers while enroute to points of discharge from the basin. The water budget was computed by measuring or estimating the inflow volume (water gains), outflow volume (water losses), and change in volume of water in Coastal Springs Ground-Water Basin for 1997 and 1998. The water-budget method was used to evaluate the relative magnitude of relevant components of the hydrologic system. These components are expressed in linear units (inches) over the basin, and are the average annual value for 1997-98. The sum of inflows and outflows in the basin is equal to the change in volume of water in the basin. The water-budget components included in the analysis are expressed in inches per year (in/yr). The water-budget equation is:

INFLOW - OUTFLOW = CHANGE IN VOLUME (storage)

$$P - ET - Q - R - GO = \Delta S,$$

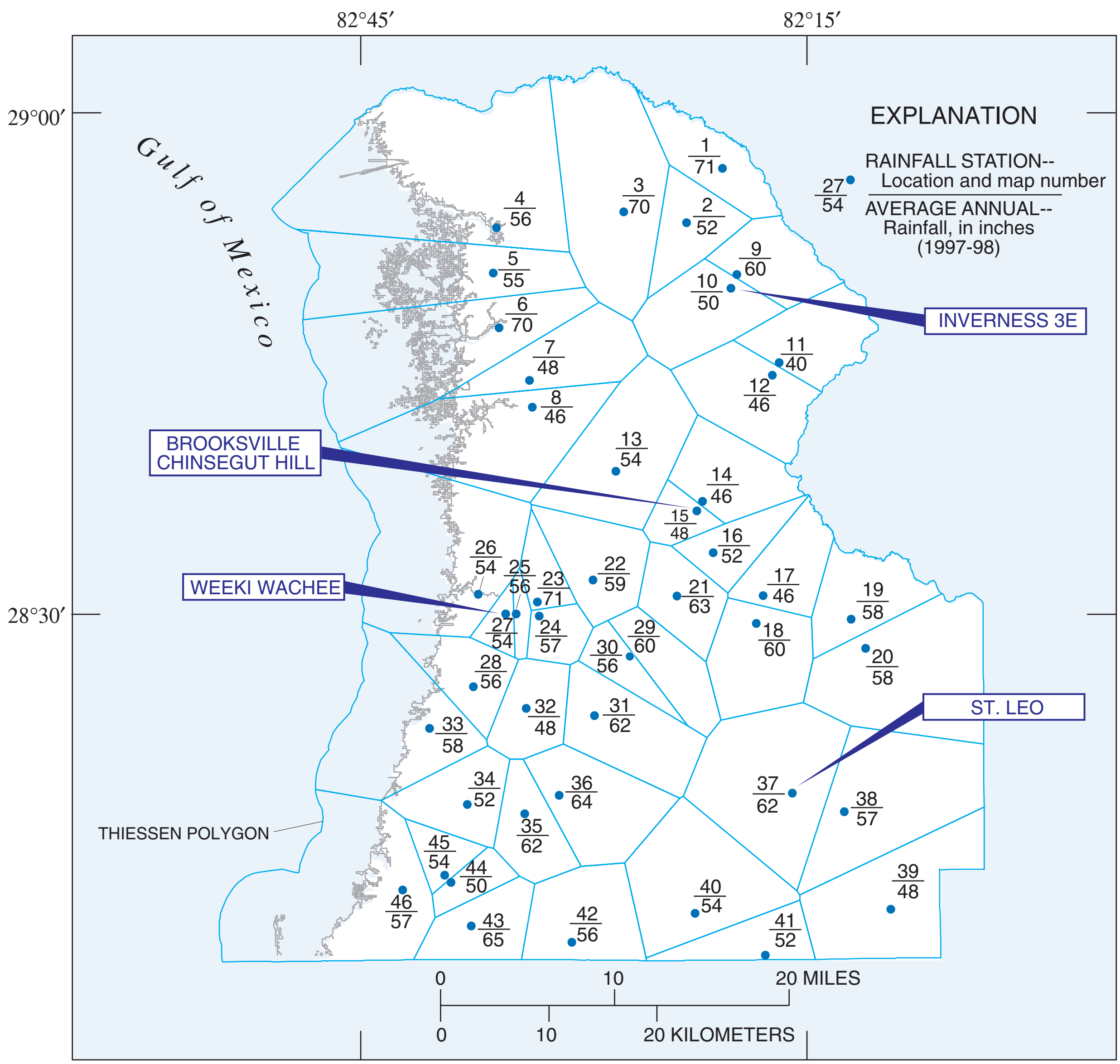
where

P = precipitation (rainfall)
ET = evapotranspiration
Q = ground-water withdrawals
R = runoff (spring flow)
GO = ground-water outflow (upward leakage)
ΔS = change in storage

Water budgets were prepared for the four ground-water basins that form the Coastal Springs Ground-Water Basin. Aripeka, Weeki Wachee, Chassahowitzka, and Homosassa Springs Ground-Water Basins are defined as closed, internally drained basins with negligible ground-water and surface-water inflow. The ground-water basins were delineated for dry (low water level) and wet (high water level) hydrologic conditions using the potentiometric-surface contours and ground-water flow divides interpreted from water levels measured in the Upper Floridan aquifer during September 1997 and May 1998.

Rainfall stations were not operated as part of this investigation; rather, values of annual rainfall for 1997 and 1998 were computed for a network of 46 rainfall stations located in the study area. The network included 4 stations operated by NOAA (Brooksville Chinsegut Hill, Weeki Wachee, St. Leo, and Inverness 3E) and 42 stations in the SWFWMD network (fig. 10, app. C). The average annual rainfall was computed for the Coastal Springs Ground-Water Basin and the four ground-water basins using the Thiessen weighting method described in Viessman and others (1977, p. 217-220).

Evapotranspiration (ET) is the discharge of water from the Earth's surface to the atmosphere by both evaporation from surface-water bodies and soils and by transpiration from plants. ET is an important component in the hydrologic cycle as a large portion of rainfall returns to the atmosphere through ET processes. ET is seasonally variable, with the largest percentage (nearly 100 percent) of rainfall lost to ET during the summer. ET was not measured directly during this investigation because no climate stations collecting the appropriate data, especially solar radiation data, are located in the study area. Instead, ET was estimated



Base from U.S. Geological Survey digital data, 1:2,000,000, 1972
Albers Equal-Area Conic projection
Standard Parallels 29°30′ and 45° 30′, central meridian -83° 00′

Figure 10. Rainfall station numbers, average annual totals (1997-98), and Thiessen polygons.

using ET rates for similar terrains. ET is potentially higher in areas with more surface-water features, higher water tables, poorly-drained soils, and water-tolerant plants; ET is lower in areas with rapidly draining soils, deeper water tables, and drought- and fire-tolerant plants. The study area was divided into subregions, which were classified by various ET-related characteristics using soil maps (Soil Conservation Service, 1976, 1981, and 1986), vegetation maps (Wolfe, 1990), and hydrography maps (U.S. Geological Survey, 1989). ET was calculated by weighting by area ET rates taken from Sumner (1996), Bidlake and others (1993), and German (1999).

Ground-water use (estimated ground-water withdrawal) has been compiled since 1965 and has been tabulated for 1965, 1970, 1975, and each year since 1977 (Marella, 1995, 1999; and the Southwest Florida Water Management District, 1999a, 1999b). Most tabulations of ground-water withdrawals by the USGS and the SWFWMD is for permitted users that pump greater than 100,000 gallons per day (gal/d). Data are summarized by the source of the water, including ground water, surface water, freshwater, and saline water; the data are categorized by water use, including public supply, domestic supply, industrial, mining, and agricultural irrigation. Ground water is the largest source of freshwater used in the study area. Estimated values for the ground-water withdrawal component of the water budget were computed from water-use data compiled from the SWFWMD database (Southwest Florida Water Management District, written commun., 1998). Water-use data included monthly estimates of ground-water withdrawals from Pasco, Hernando, and Citrus Counties during 1997 and 1998.

Values used for the runoff component (spring flow) were computed using measured and estimated spring-flow volumes. The measured part of the spring-flow volume is the averaged daily mean spring flow from the springs monitored during 1997-98. Additional spring-flow volumes were estimated from historical records of spring flow for the smaller (unmonitored) springs in the study area.

The ground-water outflow component is equivalent to the quantity of diffuse upward leakage from the Upper Floridan aquifer, which forms the coastal swamps along the Gulf of Mexico. Values used for ground-water outflow in the water budget were computed by flow-net analysis whose governing equation is a simplified form of Darcy's Law (Walton, 1970, p. 188). Although the governing equation is based on assumptions of an isotropic, homogeneous, and infinite-areal extent aquifer, the analysis is useful for determining reasonable but qualified estimates of diffuse upward leakage in the Coastal Springs Ground-Water Basin. Flow-net analysis was the method used to compute leakage to Tampa Bay (Hutchinson, 1983) and lateral boundary flows in the Northern Tampa Bay Area (Southwest Florida Water Management District, 1996). The method is a relatively simple graphical technique that can be used to estimate the rate of ground-water flow at the midpoint between two adjacent potentiometric contours. Two assumptions of the method are that: (1) the transmissivity values are correct, and (2) the volume of ground water moving between two potentiometric-contour lines ultimately discharges to the Gulf of Mexico. Potentiometric-surface maps and estimates of aquifer transmissivity are needed for the calculations. The altitudes of the potentiometric surface of the Upper Floridan aquifer in September 1997 and in May 1998 were used to calculate the diffuse upward leakage during dry and wet hydrologic conditions, respectively. The 2- and 4-ft contours were the bounding potentiometric-surface contours used in the analysis. The transmissivity values were modified from Yobbi (1989).

HYDROLOGIC CONDITIONS

Analysis of fluctuations in rainfall, ground-water levels, surface-water stage, spring flow, and water quality provided the foundation for characterizing hydrologic conditions during 1997-98. Hydrologic conditions were comparable to long-term average conditions in the Coastal Springs Ground-Water Basin. Although annual values of rainfall, ground-water levels, and spring flow were average during the investigation period, seasonal values were anomalous and drought and flood conditions existed.

Rainfall

The long-term average annual rainfall in Florida and the study area is about 54 inches (National Oceanic and Atmospheric Administration, 1998). The long-term average annual rainfall at the four NOAA rainfall stations in the study area was 56, 53, 55, and 53 inches at Brooksville Chinsegut Hill, Inverness 3E, St. Leo, and Weeki Wachee, respectively. Average annual rainfall during 1997-98 for the 46 stations was about 54 inches, and ranged from 40 to 71 inches (fig. 10 and app. C).

Convection, tropical, and frontal systems are three types of storms that occur in the study area. Convection storms occur in the summer months from June through September. Tropical storms occur during the hurricane season from June through November. Frontal storms occur in the winter from December through March. The El Niño-Southern Oscillation condition, which is caused by higher-than-normal ocean temperatures, results in above normal rainfall during the months from December through April (National Weather Service, written commun., 1999). The distribution in mean monthly rainfall during the year was interpreted from a synthetic monthly rainfall distribution created from 99 years of monthly values at the Brooksville Chinsegut Hill station (fig. 11). Highest monthly rainfall is from June through September. Convection and tropical storms during June through November account for 66 percent of the rainfall. Thirty-four percent of the rainfall occurs during December through May. The distribution in monthly rainfall during 1997-98 was atypical with relatively low rainfall during the summer and high rainfall during the winter. Only 20 inches of rain fell during the summer of 1997, whereas about 40 inches fell during the winter of 1997-98. The El Niño condition during the winter of 1997-98 was one of the strongest documented (National Weather Service, written commun., 1999). The El Niño produced flooding and associated high ground-water levels and spring flows however, no rain fell during the 3 months following this wet winter, causing rapid declines in spring flow. The dry conditions during the summers of 1997 and 1998 and wet conditions during the intervening winter are departures from the normal mean monthly rainfall at the Brooksville Chinsegut Hill stations. In figure 11, bar graphs above the zero or mean line indicate higher than normal rainfall; bar graphs below the zero or mean line indicate lower than normal rainfall.

Ground-Water Flow and Levels in the Upper Floridan Aquifer

Ground-water flow patterns inferred from potentiometric-surface maps of the Upper Floridan aquifer are not substantially different between seasons and among years. Ground water flows downgradient from potentiometric-surface highs of more than 80 ft in central Pasco County to lows near sea level at the coast. The potentiometric-surface maps were constructed using water-level data from 206 wells. A variable (2- to 10-ft) contour interval was used to construct the potentiometric-surface maps. A 2-ft contour interval was used in coastal areas to define the bending of contours around the springs, and larger contour intervals were used where gradients steepen. Typically, dry conditions or low aquifer levels exist in May, and wet conditions or high aquifer levels exist in September. Atypical rainfall patterns resulted in anomalous levels in the Upper Floridan aquifer, with low ground-water levels during September 1997 and high ground-water levels in May 1998 (figs. 12 and 13, respectively).

Annual and daily cyclic fluctuations of ground-water levels are found in the study area. The annual range in ground-water level reflects seasonal variations in rainfall throughout the year; the daily range primarily reflects the diurnal variations in tidal amplitude. The annual range, interpreted from differences in synoptic water-level measurements in September 1997 and May 1998, was from less than 1 ft near the coast in Citrus County to more than 20 ft in north-central Pasco County. Based on hydrographs of daily maximum water levels collected from 12 wells, the annual range was from about 2 to 10 ft with the greatest annual range again occurring farther from the coast, even though the hydrographs are similarly shaped with temporally comparable peaks and valleys (fig. 14). The water-level hydrograph for Chassahowitzka well 1 is shown on both plots in figure 14 to provide a comparison of scale between wells with larger annual ranges in water levels (top graph) and those with smaller ranges (bottom graph). The annual range is relatively large in recharge areas because rainfall is unevenly distributed over time and recharge is sporadic. The annual range is small in discharge areas. For example, the annual range of water levels in wells ROMP 97, ROMP TR 18-3, and Homosassa 3, located about 8, 5, and 3 mi, respectively, from the coast, is about 10, 4, and 2 ft, respectively. In discharge areas, water levels in wells also fluctuate daily, reflecting the response of the Upper Floridan aquifer to tidal loading. The magnitude of the fluctuations becomes progressively larger towards the Gulf of Mexico.

The oldest operating ground-water station in the study area is the Weeki Wachee well. Water-level data from this well reflects the long-term (1966-98) water-level fluctuations in the Upper Floridan aquifer (fig. 15). The historical water-level data show multiple periods of decline followed by periods of rapid water-level rise (fig. 15). Rapid rises ranging from 8 to 10 ft were recorded in 1974, 1982, and 1997-98. The period-of-record (1966-98) minimum, mean, median, and maximum water levels were 12.7, 17.5, 17.2, and 23.9 ft above sea level, respectively. The mean and median

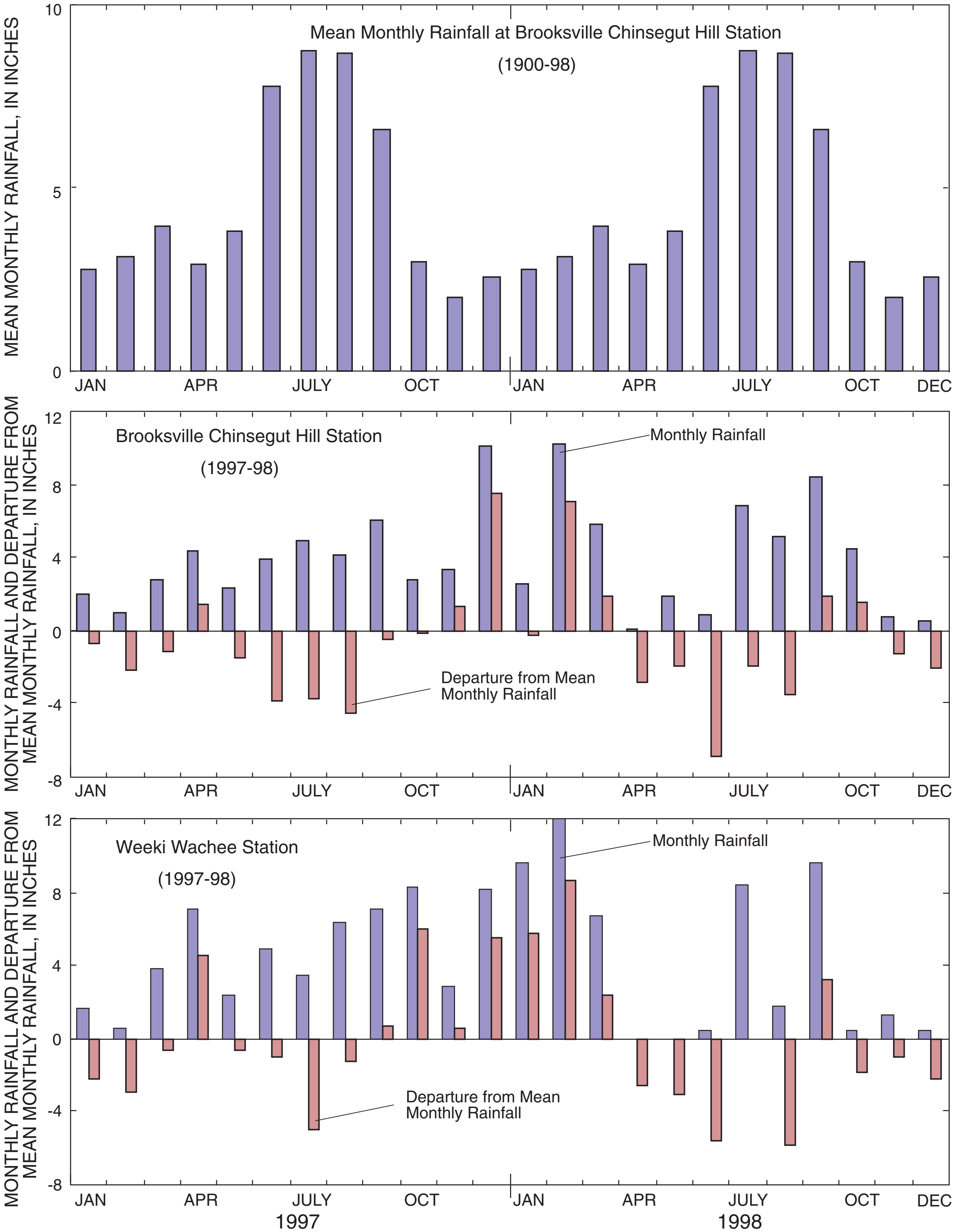
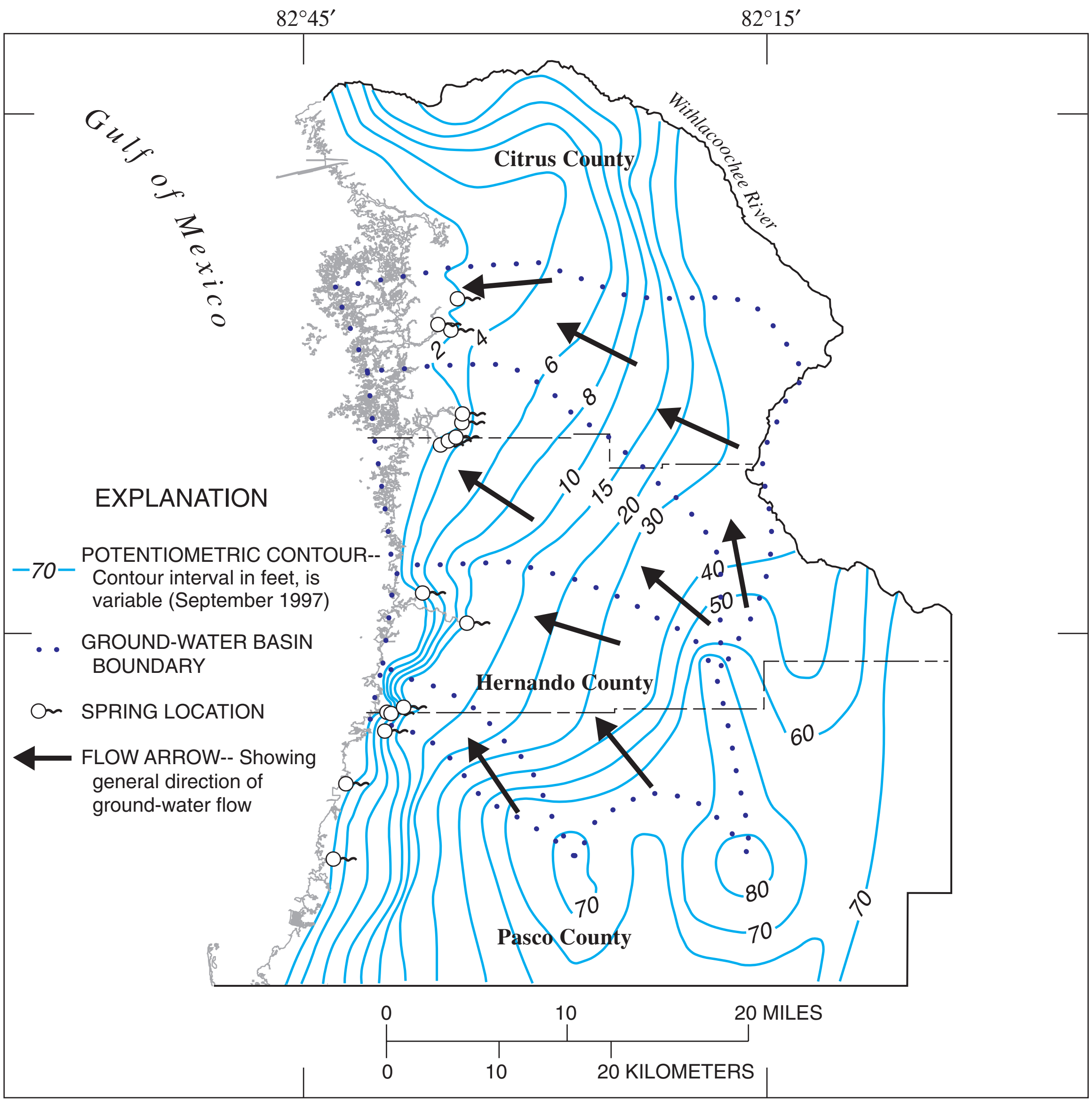


Figure 11. Mean monthly rainfall (1900-98) and monthly rainfall and departure from mean monthly rainfall (1997-98) at the Weeki Wachee and Brooksville Chinsegut Hill NOAA stations.

water levels for 1997-98 were 17.3 and 17.1 ft above sea level, respectively. Average annual water levels existed in 1997-98, but the distribution of daily data was atypical. Water levels in the Weeki Wachee well ranged from a near-record low (13.27 ft) in the fall of 1997 to a near-record high (22.54 ft) in the spring of 1998. The annual water-level fluctuation in 1997 was about 4 ft, ranged from about 13 to 17 ft, and remained low much of the year (figs. 7 and 15). The annual water-level fluctuation during 1998 was about 5 ft, ranged from about 17 to 22 ft, and peaked in March 1998. Effects of El Niño began in December 1997 and continued through March 1998, resulting in a total water-level increase of about 10 ft in the Weeki Wachee well.

Surface-Water Stage

Records of surface-water stage collected during the investigation were evaluated to characterize the variability in range and duration of surface-water altitudes at selected sites in the study area. Typically, the mean daily stage is higher in summer than in winter (Yobbi, 1992); however, higher surface-water stages in



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Albers Equal-Area Conic projection
Standard Parallels 29°30′ and 45° 30′, central meridian -83° 00′

Figure 12. Potentiometric surface of the Upper Floridan aquifer, September 1997 (modified from Metz and others, 1998).

the summer were not observed at Weeki Wachee River, Chassahowitzka River, and Homosassa Springs stations during this investigation (fig. 16). Seasonal periodicity of the data collected from tidal springs can be obscured by the daily fluctuations in stage with larger daily fluctuations in winter than in summer. The larger daily fluctuations are probably caused by winds associated with late fall tropical storms and winter frontal storms. These storms can alter diurnal fluctuations by causing large volumes of water to be stored in estuaries. Excess water is subsequently drained following the storms. The response of surface-water stage to storms is indicated on the stage hydrograph for Chassahowitzka River on February 4 and 5, 1998 (fig. 16).

Stage data collected at the Weeki Wachee River gaging station did not exhibit diurnal patterns. The seasonal range in stage was from about 8 ft (winter of 1996-1997) to about 10 ft above sea level (July 1998); the stage peaked about 3 months after the water level in the Upper Floridan aquifer peaked (fig. 16), so response times were not coincident. Surface-water stage measured at multiple gaging stations on the Chassahowitzka River

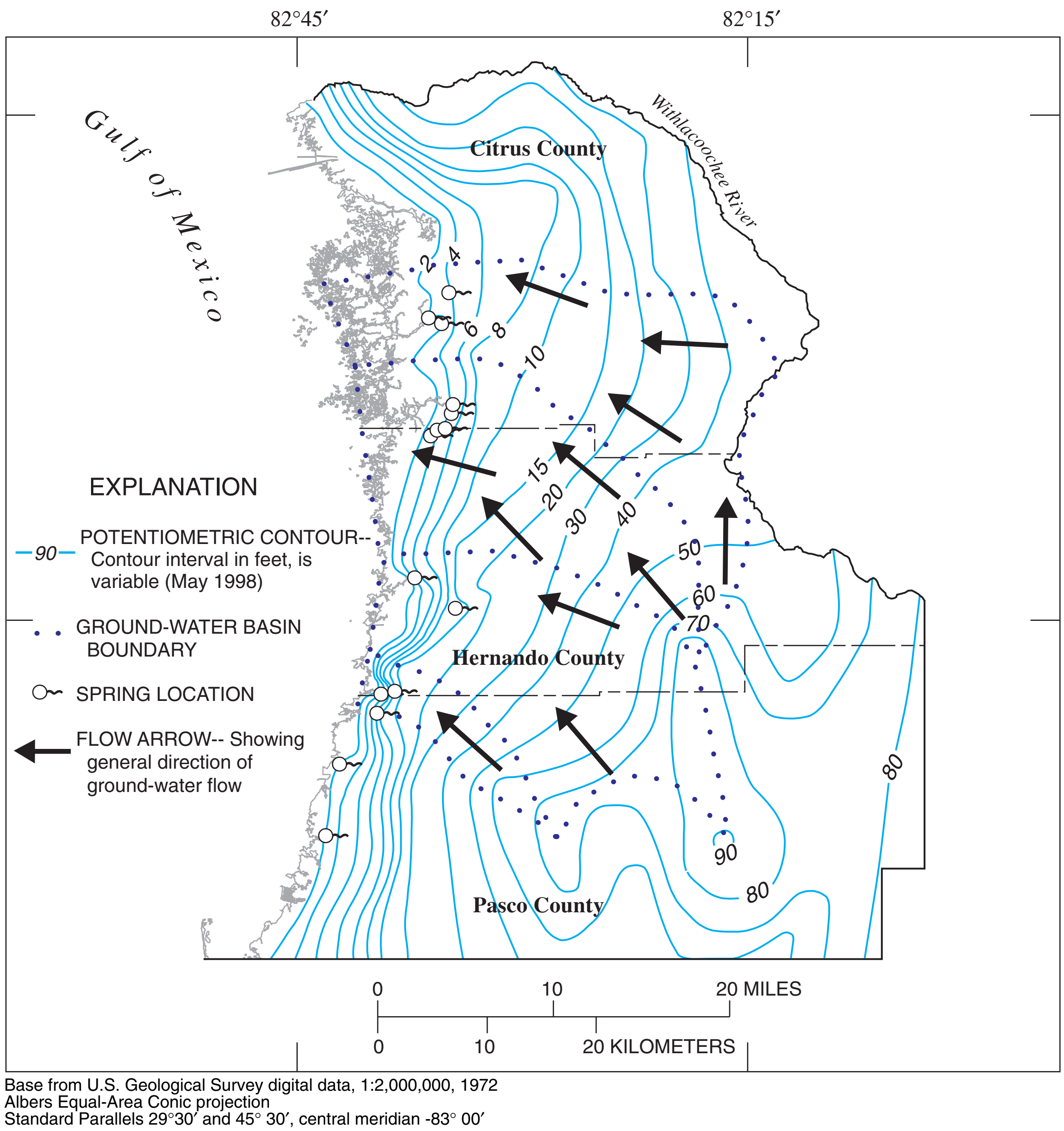
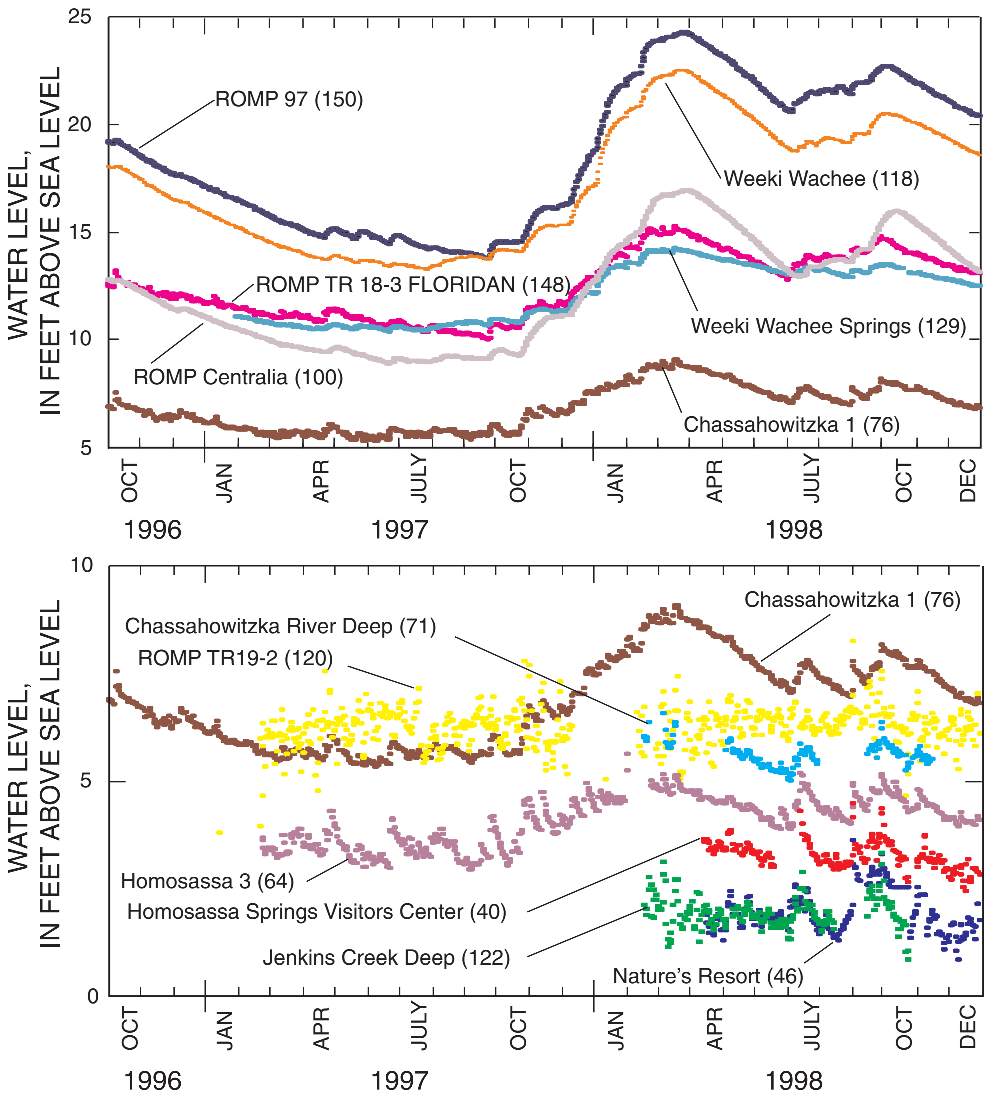


Figure 13. Potentiometric surface of the Upper Floridan aquifer, May 1998 (modified from Broska and others, 1999).



Note: Numbers in parenthesis are map numbers shown in figure 8 and provided in appendix A.

Figure 14. Water-level hydrographs for selected wells (October 1996 through December 1998).

(and tributaries) and Homosassa River (and tributaries) is affected by tides in the Gulf of Mexico; therefore, the daily range in instantaneous stage can be greater than the annual range in daily mean stage. Generally, tidal effects are dampened with increasing distance upstream from the Gulf of Mexico. The magnitude and duration (shape and pattern) of daily stage fluctuations may or may not be similar within a spring complex. For example, hydrographs of stage data from two stations, located about 2 mi apart on the Homosassa River, exhibit a uniform gradient of about 2 ft, whereas, hydrographs of stage data from the three stations in the Chassahowitzka Springs complex, two on Chassahowitzka River and the other on Crab Creek, exhibit temporally variable gradients among the stations (fig. 17). The stage is always higher at the Crab Creek station than at the Chassahowitzka River station, and the difference between synchronous measurements of stage at the Crab Creek and Chassahowitzka River stations ranges from about 0.1 to more than 0.75 ft. The stage is usually higher at the Chassahowitzka River station than at the Chassahowitzka River above Johnson Creek station; the stations are located about 2.5 mi apart on the Chassahowitzka River. The difference between synchronous measurements of stage at the Chassahowitzka River and Chassahowitzka River above Johnson Creek stations ranges from about 0 to 2 ft.

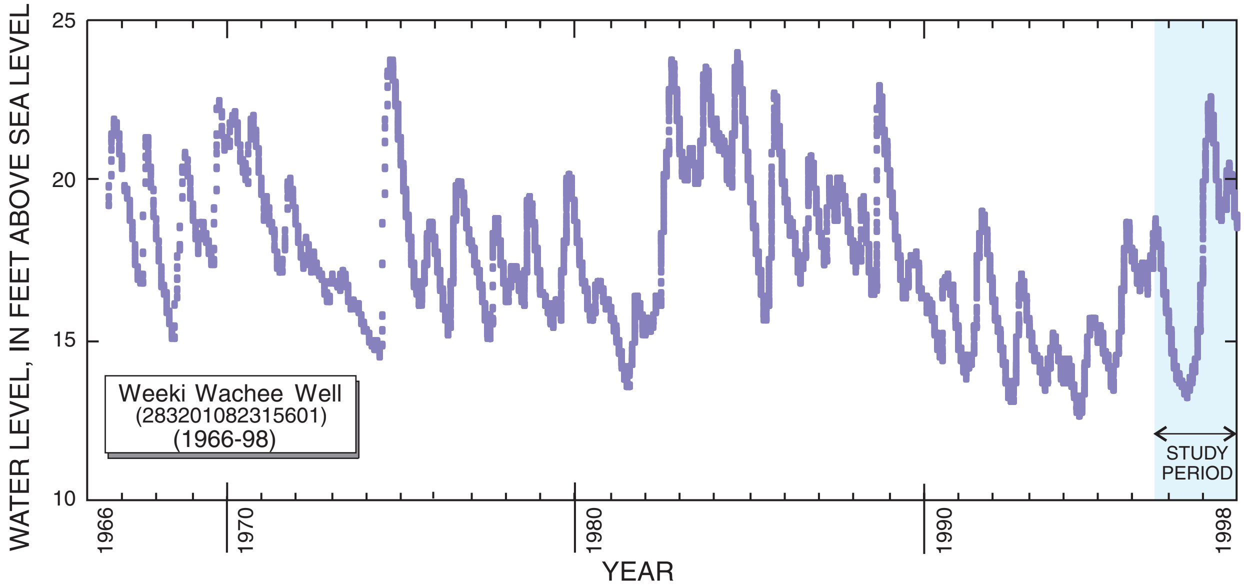


Figure 15. Weeki Wachee well water-level hydrograph (1966-98).

Spring Flow

Spring-flow data were collected from 10 sites in the study area (figs. 3-6, 9). Spring-flow volumes from Bobhill Springs and Magnolia Springs Run in the Aripeka Springs complex are relatively small (app. B). During the investigation period, the measured spring flow from Bobhill Springs ranged from 0 to 3.56 ft^3/s. A no-flow condition (point of zero flow) in September 1997 indicates that Bobhill Springs ceases to flow when water levels in the ROMP TR18-3 Floridan well are less than 10 ft. Measured spring flow from Magnolia Springs Run ranged from 6.3 to 10.4 ft^3/s. The lowest spring flow (6.3 ft^3/s) may not be comparable with the other values because the spring run already was under backwater conditions. Backwater conditions are present during high tide in the Gulf of Mexico when the surface-water stage is high enough to impede spring flow. The largest and freshest spring is Weeki Wachee Springs where measured spring flow ranged from 126 to 233 ft^3/s. The average instantaneous spring flow was 178 ft^3/s, nearly equal to the period-of-record average of 175 ft^3/s. Measured spring flow from the Chassahowitzka River below and above Crab Creek gaging station ranged from 58.9 to 158 ft^3/s and 13 to 112 ft^3/s, respectively. At high tide, Chassahowitzka River above Crab Creek and Unnamed Tributary to Chassahowitzka River are under backwater conditions, so discharge may drop to zero and even become negative. Negative flow (flow upstream across the measuring section) has been observed at the Chassahowitzka River gaging station. The negative-flow condition is present when the gradient is flat along the 2.5-mi stretch of Chassahowitzka River below the spring and a portion of flow from Crab Creek moves up the river. Measured spring flow from Unnamed Tributary to Chassahowitzka River ranged from 0.33 to 66.1 ft^3/s and includes flow that emanates from unnamed springs and the canal upstream from Chassahowitzka Springs. The measured spring flow from Crab Creek ranged from 33.2 to 52.9 ft^3/s, and has a noticeably smaller diurnal range than other tidal springs. Measured spring flow at the Hidden River gaging station ranged from 1.9 to 39.5 ft^3/s. The anomalously high spring flow (39.5 ft^3/s) in February 1998, the corresponding low specific conductance (876 microsiemens per centimeter), and high tannin content (dark color) of the water indicate substantial surface-water runoff to Hidden River, a hydrologic condition not typical at Hidden River. Measured spring flow from Homosassa Springs ranged from 62.1 to 122 ft^3/s. The diurnal range in spring flow from Homosassa Springs, during a 25-hr tidal cycle on June 17 and 18, 1998, ranged from 82.4 to 106 ft^3/s and averaged 95 ft^3/s. Measured spring flow from the Southeast Fork of the Homosassa River ranged from 47.2 to 108 ft^3/s. Measured spring flow from Halls River ranged from 86 to 670 ft^3/s.

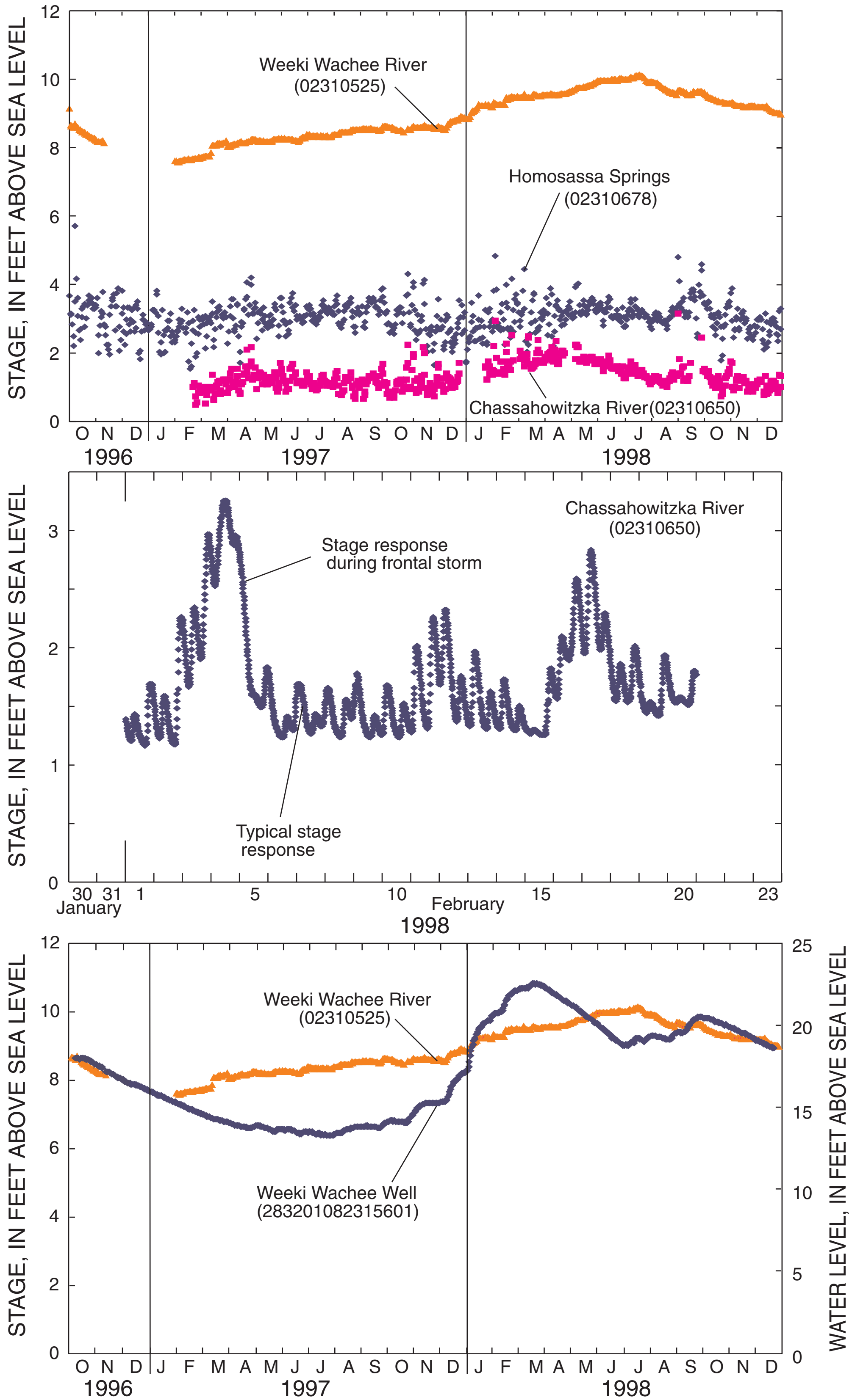


Figure 16. Surface-water stage and ground-water level hydrographs for selected sites (October 1996 through December 1998).

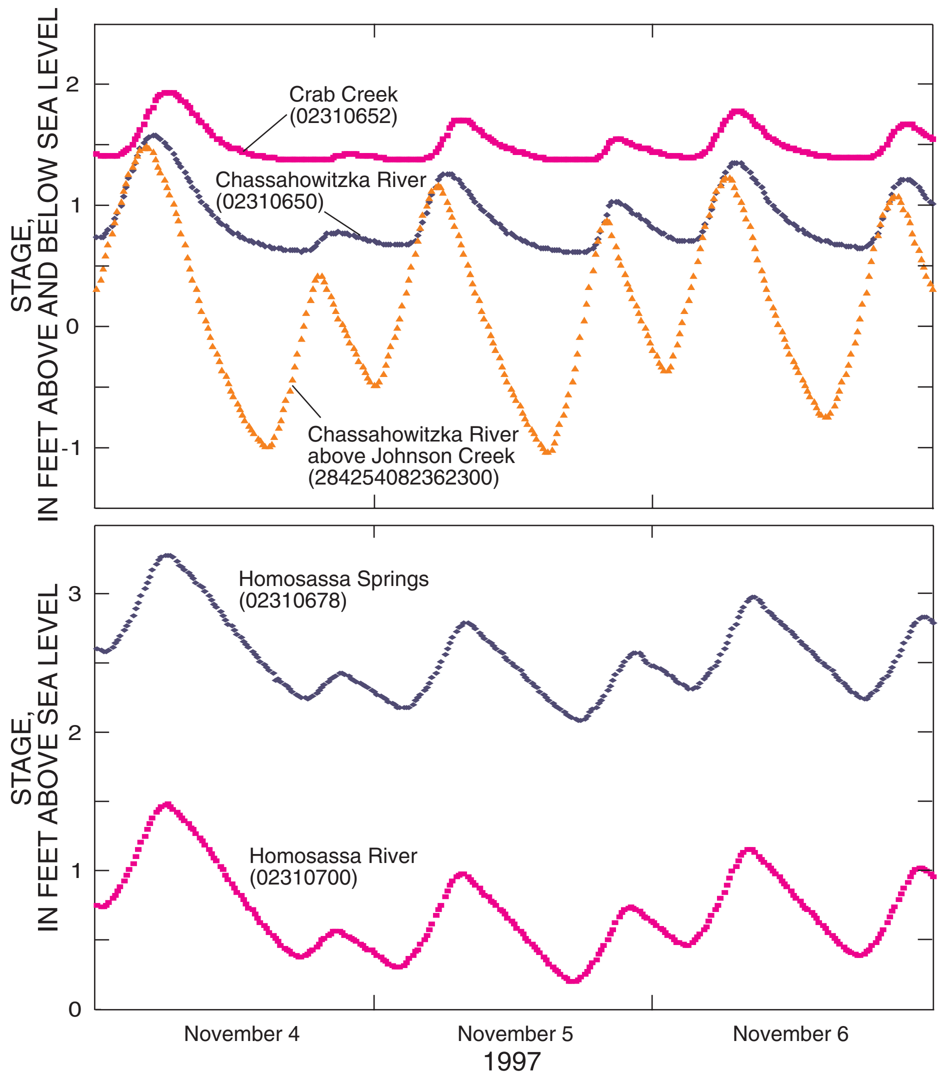
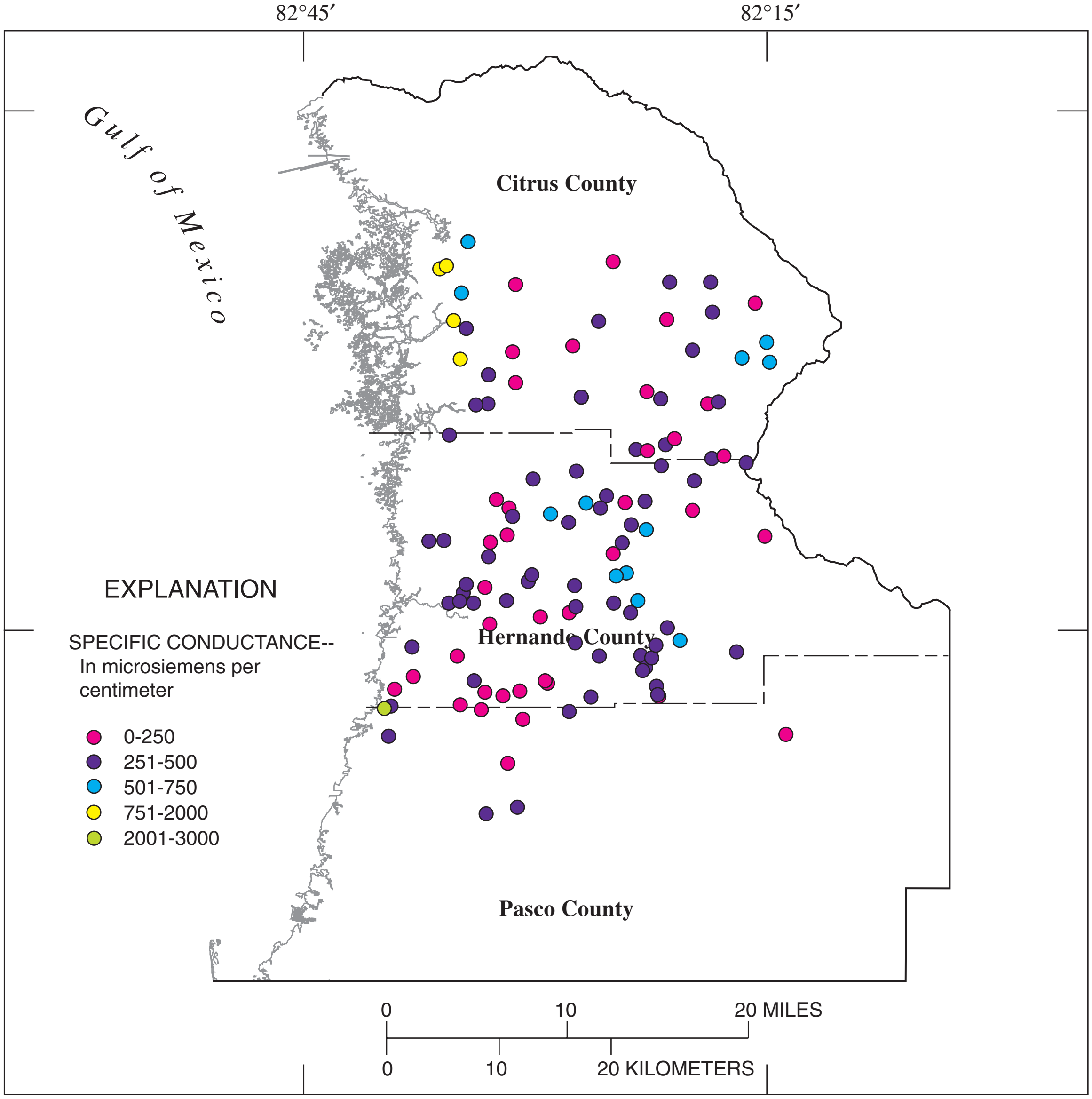


Figure 17. Stage hydrographs at selected gaging stations (November 4-6, 1997).

Water Quality

Ground-water quality, as indicated by specific conductance, is fairly good and generally less than 500 microsiemens per centimeter (µS/cm) throughout most of the study area (fig. 18). Generally, the specific conductance of water from wells increases downgradient from the recharge to discharge areas of the Upper Floridan aquifer with the highest values found in wells near the Gulf of Mexico, particularly near the Aripeka and Homosassa Springs complexes. The thickness of the potable water zone (specific conductance less than 1,000 µS/cm) in the Upper Floridan aquifer, near the spring complexes, has been estimated to range from 250-450 ft at Aripeka, 350-450 ft at Weeki Wachee, 150-250 ft at Chassahowitzka, and less than 150 ft at Homosassa (Southwest Florida Water Management District, 1997, p.25). Elevated specific conductance values (501-750 µS/cm) were measured in water from selected inland wells (fig. 18). Elevated values result from evaporation processes that concentrate the ion content of water prior to recharge, in areas where water covers the land surface for extended periods of time (Sacks and Tihansky, 1996). These processes occur in limestone mining areas where water is pumped from the Upper Floridan aquifer and stored in pits during the mining process. Evaporation of water from these pits concentrates ions prior to recharging the underlying aquifers. Elevated specific conductance of water in wells also is found in the Tsala-Apopka Plain



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Albers Equal-Area Conic projection
Standard Parallels 29°30′ and 45° 30′, central meridian -83° 00′

Figure 18. Specific conductance of water from selected Upper Floridan aquifer wells (1994).

physiographic region due to standing water in the swampy flood plain of the Withlacoochee River (Southwest Florida Water Management District, 1997, p. 53-55).

Differences in water quality among the springs are related to the depth of the spring vent, proximity of the spring to the Gulf of Mexico, and the transient location of the freshwater-saltwater interface, creating a zone of mixing that changes seasonally and diurnally. Calcium-bicarbonate water, transitional or mixed-ion water, and sodium-chloride water are three types of water discharged by springs. The types of water flowing from selected springs are shown in figure 19. In addition to differences in dominant ion species, differences in dissolved-ion concentrations result from the vertical variability in water quality intercepted by the spring vents (Yobbi, 1992, p. 15). Water discharged from Weeki Wachee, Little, Aripeka 1, and Bobhill Springs is predominately a calcium-bicarbonate type water that is low in dissolved-ion concentrations. The chemical constituents comprising the water at these springs reflects limestone dissolution. Aripeka 2, Boat, Bubba, and Magnolia Springs discharge mixed-ion waters that have moderate dissolved-ion concentrations.

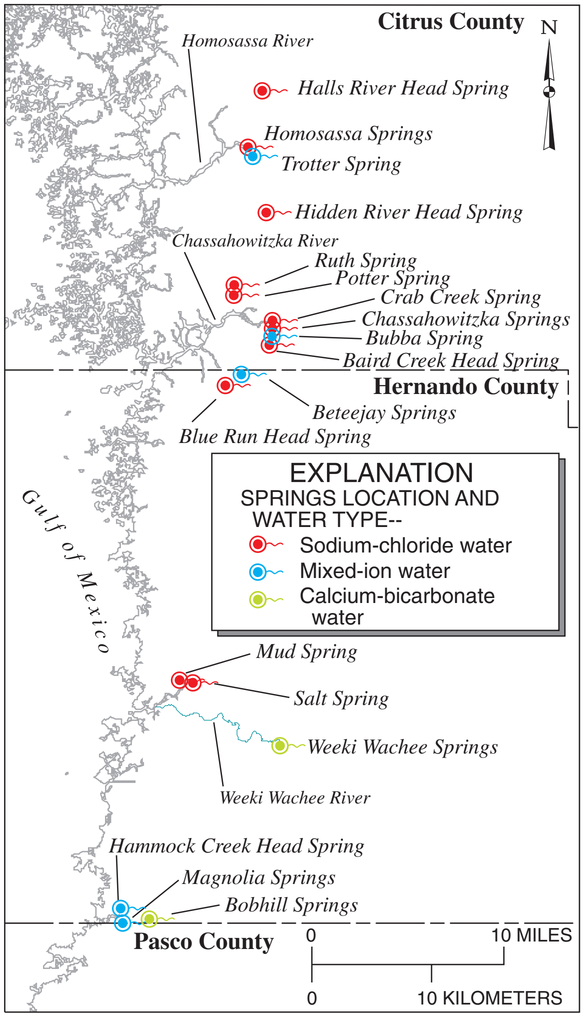

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Figure 19. Major-ion water types for selected springs.

The mixed-ion type has no dominant ion species, and is the result of freshwater and saltwater mixing. Baird Creek Head, Crab Creek, Chassahowitzka, Homosassa, Halls River Head, Hidden River Head and Hidden River number 6 Springs discharge sodium-chloride type water, which is high in dissolved-ion concentrations.

The average specific conductance of water from springs in the Aripeka Springs complex ranged from 269 µS/cm (Bobhill Springs) to 720 µS/cm (Boat Springs) (Southwest Florida Water Management District, 1997). Field measurements of specific conductance for Bobhill Springs ranged from 256 to 280 µS/cm during 1997-98 (app. B). Sporadically measured since 1964, historical specific conductance data ranged from 210 to 280 µS/cm. Field measurements of specific conductance at Magnolia Springs Run ranged from 650 to 1,200 µS/cm during 1997-98 (app. B). The water quality at the Magnolia Spring Run gaging station reflects the contribution of spring flow from several springs with differing chemical characteristics.

The average specific conductance of water from springs in the Weeki Wachee Springs complex ranged from 303 µS/cm (Weeki Wachee Springs) to 33,667 µS/cm (Mud Spring) (Southwest Florida Water Management District, 1997). Field measurements of specific conductance for Weeki Wachee Springs ranged from 294 to 310 µS/cm during 1997-98 (app. B). Historically, specific conductance (since 1961) seems to have increased slightly over time (fig. 20).

The Chassahowitzka Springs complex includes multiple springs, discharging water at variable rates and qualities. The average specific conductance for springs in the Chassahowitzka Springs complex was 770 µS/cm at Bubba Spring, 1,730 µS/cm at Chassahowitzka Springs, and 5,294 µS/cm at Crab Creek Spring (Southwest Florida Water Management District, 1997). Since the 1960's, specific conductance for Chassahowitzka River (at undocumented tidal altitudes) has ranged from about 400 to more than 3,000 µS/cm (fig. 20).

Field measurements of specific conductance at the Chassahowitzka River (above Crab Creek) gaging station ranged from about 720 to 2,500 µS/cm during 1997-98 (fig. 21 and app. B). The specific conductance for the Chassahowitzka River (below Crab Creek) gaging station in June 1997 averaged 7,000 µS/cm, and probably reflected the water quality of Crab Creek rather than Chassahowitzka Springs. The daily range of specific conductance is generally less than 500 µS/cm, but has fluctuated more than 4,000 µS/cm at the Chassahowitzka River gaging station. Field measurements of specific conductance ranged from about 3,300 to 8,535 µS/cm and from about 500 to 1,900 µS/cm during 1997-98 at the Crab Creek and the Unnamed Tributary to Chassahowitzka River gaging stations, respectively (fig. 21 and app. B). Specific conductance increases with rising stage, with the highest tidal amplitudes, and during periods of low ground-water levels.

The Homosassa Springs complex includes multiple springs discharging water at variable rates and qualities (figs. 19 and 21). Historical specific conductance data for Homosassa Springs since the 1960's (at undocumented tidal altitudes) ranged from about 1,000 to more than 4,000 µS/cm (fig. 20). The average

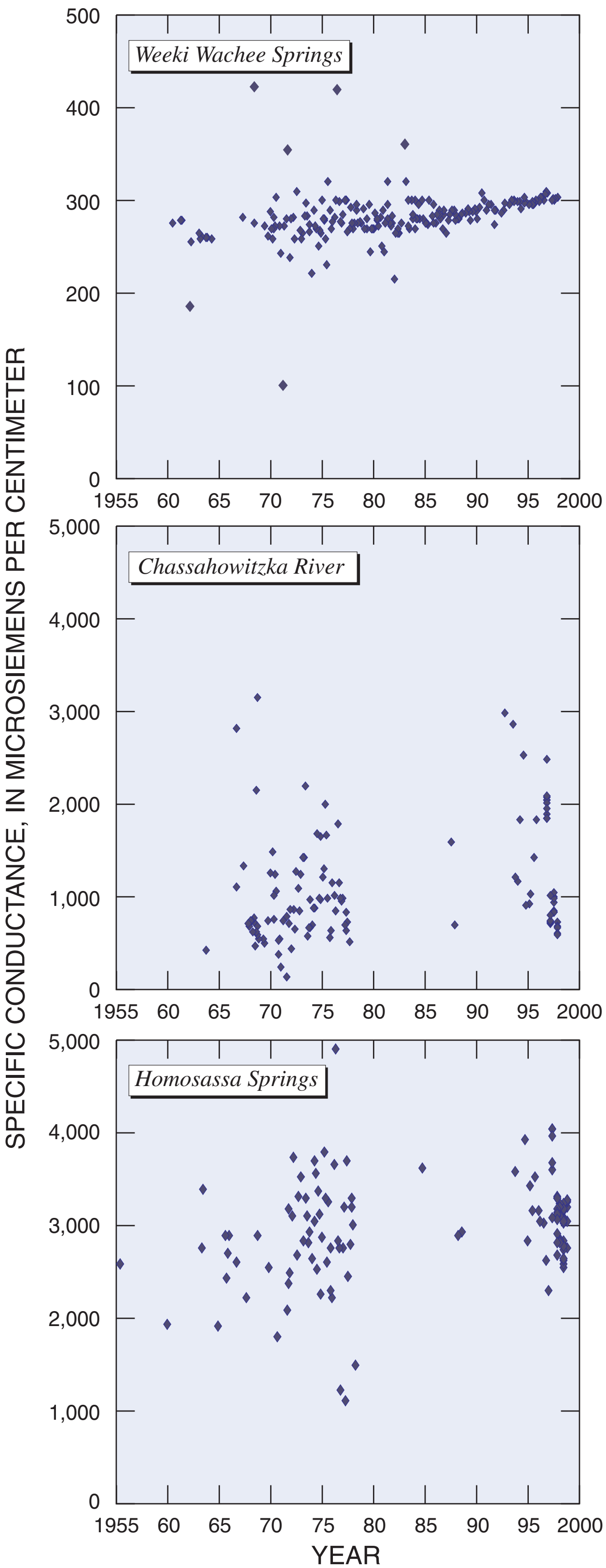


Figure 20. Specific conductance of water from selected springs during period of record (variable).

specific conductance values were 3,245, 5,694, and 1,339 µS/cm for the three spring vents known as Homosassa Springs 1, 2, and 3, respectively, during 1993-97 (Southwest Florida Water Management District, 1997, p. 27-30). The six named spring vents that contribute flow to the tributary, Southeast Fork of the Homosassa River, discharge the freshest water in the complex with specific conductance values less than 500 µS/cm (Southwest Florida Water Management District, 1997). Water flowing past the Halls River gaging station is the combined discharge from Halls River Head Spring and several uncharted springs that discharge sodium-chloride type waters. The specific conductance of water from Halls River Head Spring ranged from about 2,800 to 4,800 µS/cm (Southwest Florida Water Management District, 1997).

Field measurements of specific conductance ranged from 2,540 to 4,050, from 410 to 722, and from 2,840 to 4,860 µS/cm at the Homosassa Springs, Southeast Fork of the Homosassa River, and Halls River gaging stations, respectively, during 1997-98 (fig. 21). Field measurements of specific conductance at the Hidden River gaging station ranged from 876 to 2,720 µS/cm during 1997-98 (app. B). The vertically aligned values of specific conductance shown in figure 21 exhibit the daily variability at the tidally affected gaging stations. At most of the gaging stations, the specific-conductance data represent a composite of the quality of water from multiple springs that flow past the stations.

Ground-Water Withdrawals

Ground-water withdrawals from the Upper Floridan aquifer in Pasco, Hernando, and Citrus Counties averaged about 211 million gallons per day (Mgal/d) during 1997-98 (Southwest Florida Water Management District, 1999a, 1999b). Historical data show that ground-water withdrawals have increased from about 60 to 225 Mgal/d during the period from 1965 to 1990 (Marella, 1995, 1999). The volume of ground water withdrawn has decreased slightly, and has remained steady at slightly more than 200 Mgal/d since 1990 (Marella, 1999; Southwest Florida Water Management District, 1999a, 1999b). Ground-water withdrawals vary from year to year with maximum rates attained in different years among the three counties. The largest annual increases occurred between 1970-75 in Pasco County, between 1975-77 in Hernando County, and between 1983-84 in Citrus County.

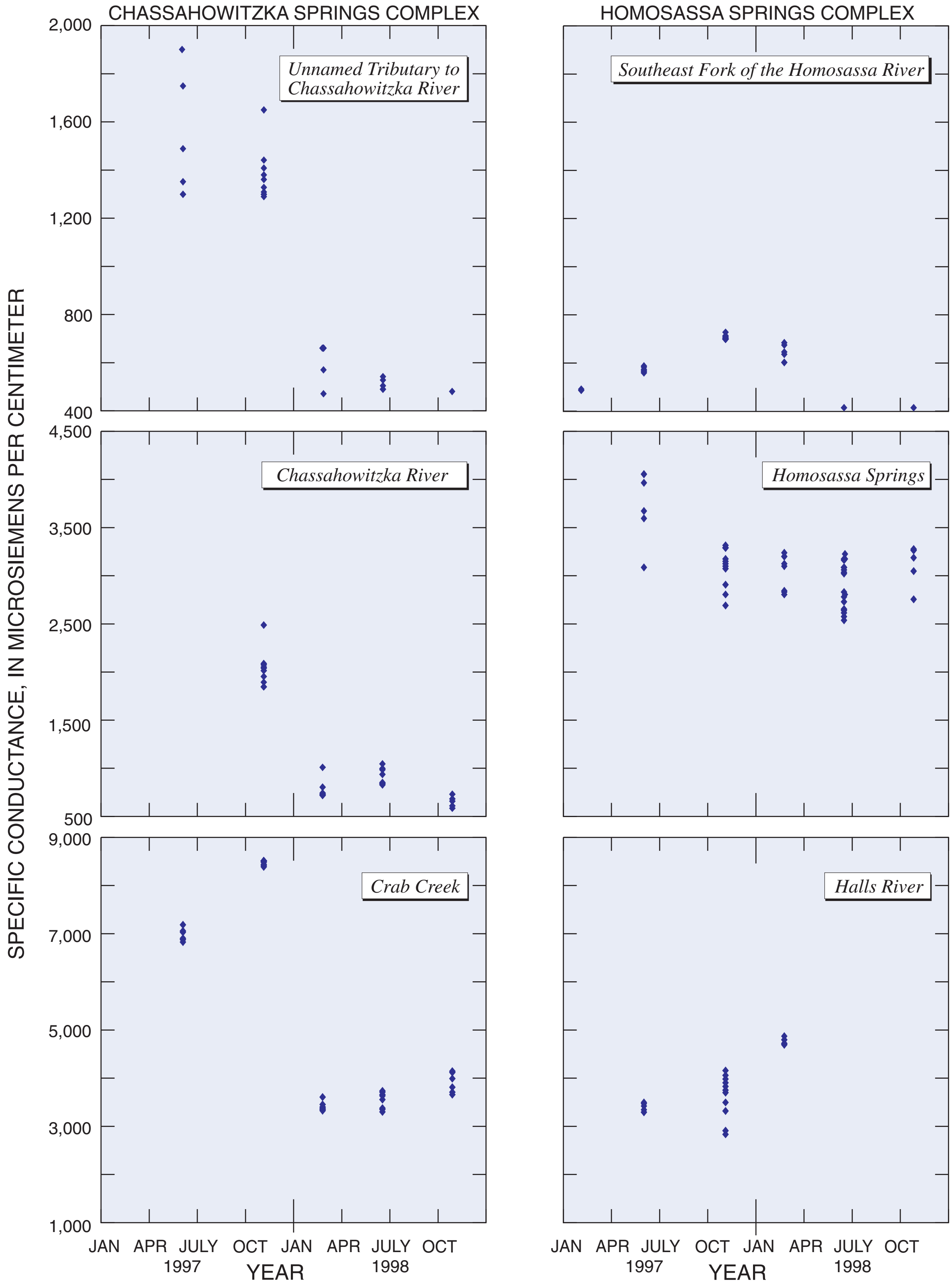
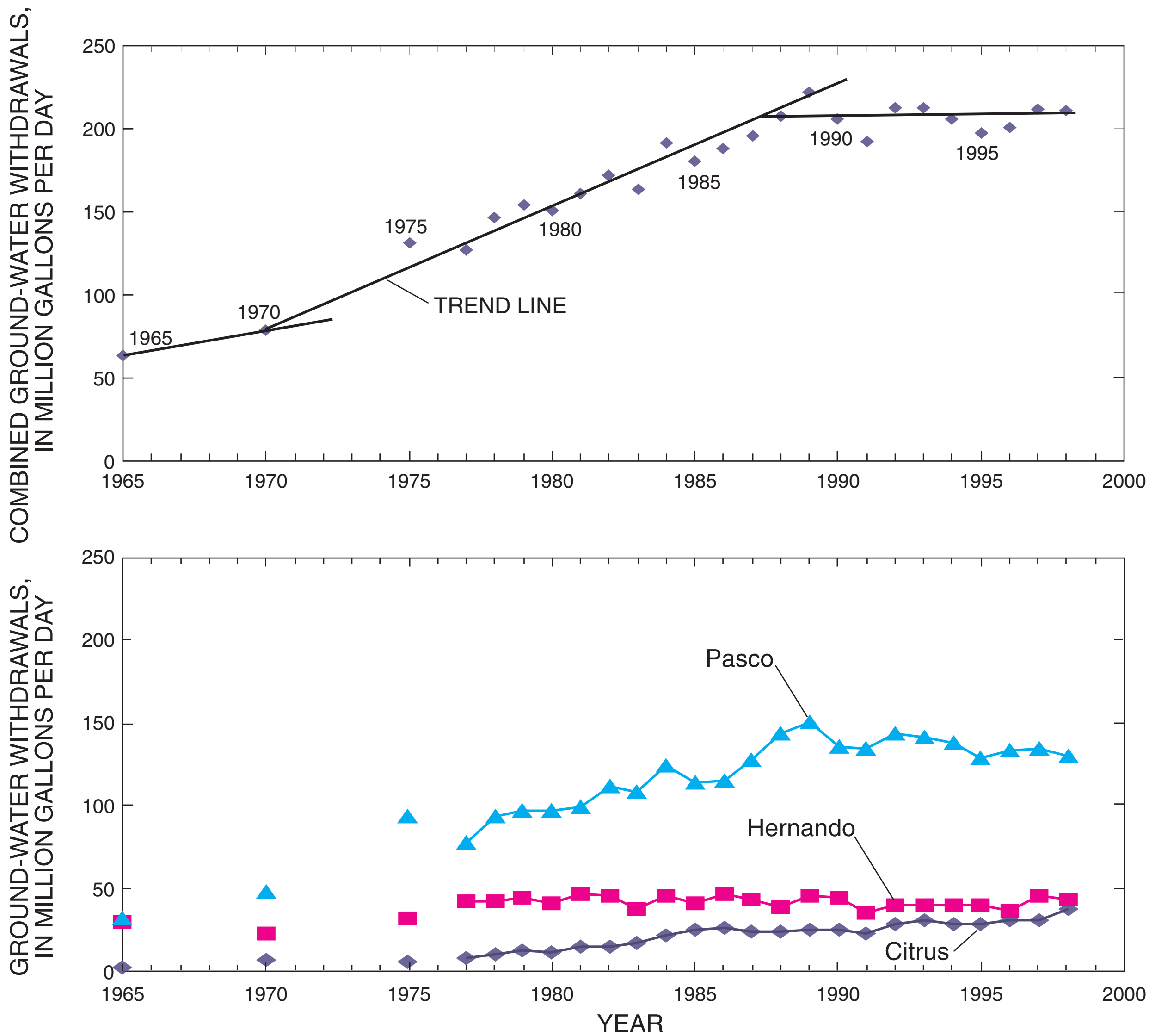


Figure 21. Specific conductance of water from selected springs (1997-98).

Peak annual withdrawals occurred in 1989 in Pasco County, and in 1981 in Hernando County; annual withdrawals have not peaked in Citrus County. Combined ground-water withdrawals from the three counties exhibit three distinct rates of change over time, as indicated by differences in the slopes of the trend lines shown in figure 22. Initially, ground-water withdrawals increased at a rate of about 3 Mgal/d per year (from 1965 to 1970); then withdrawals increased to about 7.5 Mgal/d per year (from 1975 to 1989); and since 1989 withdrawals have stabilized.

ESTIMATES OF DAILY MEAN SPRING FLOW

Daily mean spring flow was determined for 8 of the 10 springs monitored during this investigation and for both of the gaging stations on the Chassahowitzka River (Chassahowitzka River above and below Crab Creek). Appendix B lists the data used in the regression models. The predictive equations and regression statistics used to estimate daily mean spring flow are presented in table 1. Multiple equations are presented for several of the springs. The purpose of presenting



Note: Combined ground-water withdrawals reflect withdrawals from Pasco, Hernando, and Citrus Counties.

Figure 22. Ground-water withdrawals from Pasco, Hernando, and Citrus Counties (1965-98).

Table 1. Predictive equations and regression statistics for estimating spring flow at selected gaging stations

[wl, daily maximum water level; 18-3 fld, Regional Observation Monitor-Well Program (ROMP) TR18-3 Floridan well; www, Weeki Wachee well; wws, Weeki Wachee Springs well; h3, Homosassa 3 well; stg, instantaneous stage; chz, Chassahowitzka River stage; crb, Crab Creek stage; hs, Homosassa Springs stage; ft^3/s, cubic feet per second; Q, spring flow in ft^3/s; Q_{hs}, spring flow at Homosassa Springs; Q_{seflag}, lagged spring flow at Southeast Fork of the Homosassa River; Δstg, average instantaneous stage change; <, less than]

Gaging station name and number	Equation number	Number of data set	Predictive equation	Coefficient of determination	Root mean square error (ft^3/s)	Significance level	Period of record used for equation
Bobhill Springs 02310405	1	15	$Q=(0.66*(wl_{18\text{-}3\ fld}))-6.60$	0.98	0.14	<0.01	1988-98
	2	17	$Q=(0.32*(wl_{www}))-3.91$	0.89	0.36	<0.01	1972-98
Weeki Wachee River 02310525	3	207	$Q=(12.01*(wl_{www}))-41.49$	0.86	12.40	0.00	1966-98
	4	13	$Q=(12.21*(wl_{www}))-35.91$	0.95	8.67	<0.01	1997-98
	5	13	$Q=(28.94*(wl_{wws}))-177.1$	0.95	9.10	<0.01	1997-98
Chassahowitzka River (below Crab Creek) 02310650	6	56	$Q=(6.06*wl_{www})-(stg_{chz}*7.81)-(\Delta stg*825.22)+7.17$	0.93	8.53	<0.01 0.06 <0.01	1985-98
Chassahowitzka River (above Crab Creek)	7	37	$Q=(5.18*wl_{www})-(stg_{chz}*10.81)-(\Delta stg*803.18)-17.1$	0.89	7.38	<0.01 0.01 <0.01	1997-98
Crab Creek 02310652	8	58	$Q=(1.92*wl_{www})-(stg_{crb}*5.54)+21.34$	0.69	3.22	<0.01 0.01	1988-98
Unnamed Tributary to Chassahowitzka River 02310655	9	37	$Q=(Q_{chz}*0.62)+0.18$	0.74	8.03	<0.01	1997-98
	10	37	$Q=(1.95*wl_{www})-(stg_{chz}*8.62)-(\Delta stg*635.96)+13.27$	0.94	4.03	<0.01 <0.01 <0.01	1997-98
Hidden River 02310675	11	18	$Q=(9.35*wl_{h3})-27.76$	0.88	1.80	<0.01	1988-98
	12	11	$Q=(9.08*wl_{h3})-26.32$	0.87	2.00	<0.01	1997-98
	13	18	$Q=(1.38*wl_{www})-15.13$	0.61	3.20	<0.01	1988-98
Homosassa Springs 02310678	14	124	$Q=(2.89*wl_{www})-(stg_{hs}*24.81)+117.89$	0.65	7.50	<0.01 <0.01	1996-98
	15	124	$Q=(2.85*wl_{www})-(stg_{hs}*23.53)-(\Delta stg*100.23)+114.15$	0.68	7.20	<0.01 <0.01 <0.01	1996-98
	16	[1]8	$Q=(3.14*wl_{www})-(stg_{hs}*21.21)+103.29$	0.49	8.60	0.05 0.07	1996-98
Southeast Fork of the Homosassa River 02310688	17	44	$\ln Q_{seflag}=2.60+(0.017*Q_{hs})$	0.78	0.12	0.00	1997-98

[1]Mean measured values used.

multiple equations is: (1) to show how the selection of the data set, such as length of record, affects the regression statistics; and (2) to provide alternative index sites to optimize the number of stations needed to adequately estimate spring flow within the Coastal Springs Ground-Water Basin.

Aripeka Springs Complex

Several measurements of spring flow were made at the Magnolia Springs Run and Bobhill Springs gaging stations in the Aripeka Springs complex. Although six spring-flow measurements were made at Magnolia Springs Run, more data were required to develop a statistical relation. Since 1961, 22 spring-flow measurements have been made at Bobhill Springs; however, the early spring-flow records were not used to develop the regression models because ground-water level records were not available until after 1966 (Weeki Wachee well) and 1988 (ROMP TR18-3 Floridan well). The regression lines and supporting ground-water level (ROMP TR18-3 Floridan and Weeki Wachee wells) and spring-flow data are shown in figure 23.

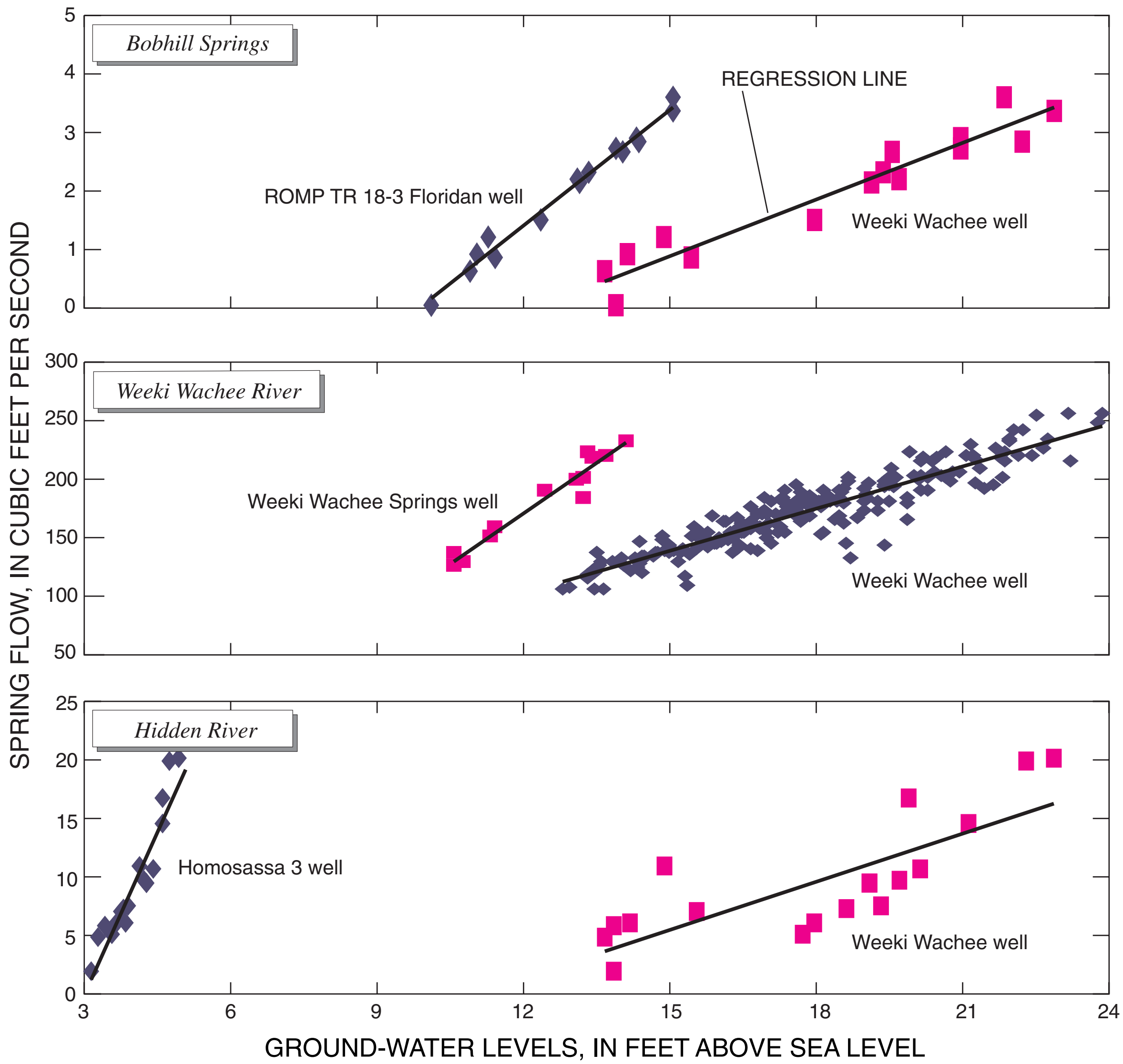


Figure 23. Relation between ground-water levels in the Upper Floridan aquifer and spring flow at selected nontidal springs.

Daily mean spring flow for the Bobhill Springs gaging station is shown in figure 24. Both the distribution of data about the regression line and the smoothing of minor oscillations shown on the hydrographs for Bobhill Springs indicate that spring flow, estimated from water levels in the Weeki Wachee well, may poorly reflect small hydrologic perturbations (such as variations in local rainfall, tidal loading, or varying recharge rate) (figs. 23 and 24). Using the explanatory variable, water levels in ROMP TR18-3 Floridan well, data are less dispersed about the regression line, the regression model has a lower RMSE, and the hydrograph peaks and valleys are not suppressed (table 1, eq. 1 and 2, and figs. 23 and 24).

Weeki Wachee Springs Complex

Spring flow was measured at the Weeki Wachee River gaging station in the Weeki Wachee Springs complex. Spring flow correlates strongly with water levels in the Weeki Wachee well, and because of this, sensitivity testing was performed using different temporal data sets (1966-98 and 1997-98) to evaluate the temporal reliability of the equations. Two regression models were developed using water levels in the Weeki Wachee well as the explanatory variable (fig. 23 and table 1, eqs. 3 and 4). A third regression model was generated using water levels in the Weeki Wachee Springs well (1997-98) (fig. 23 and table 1, eq. 5).

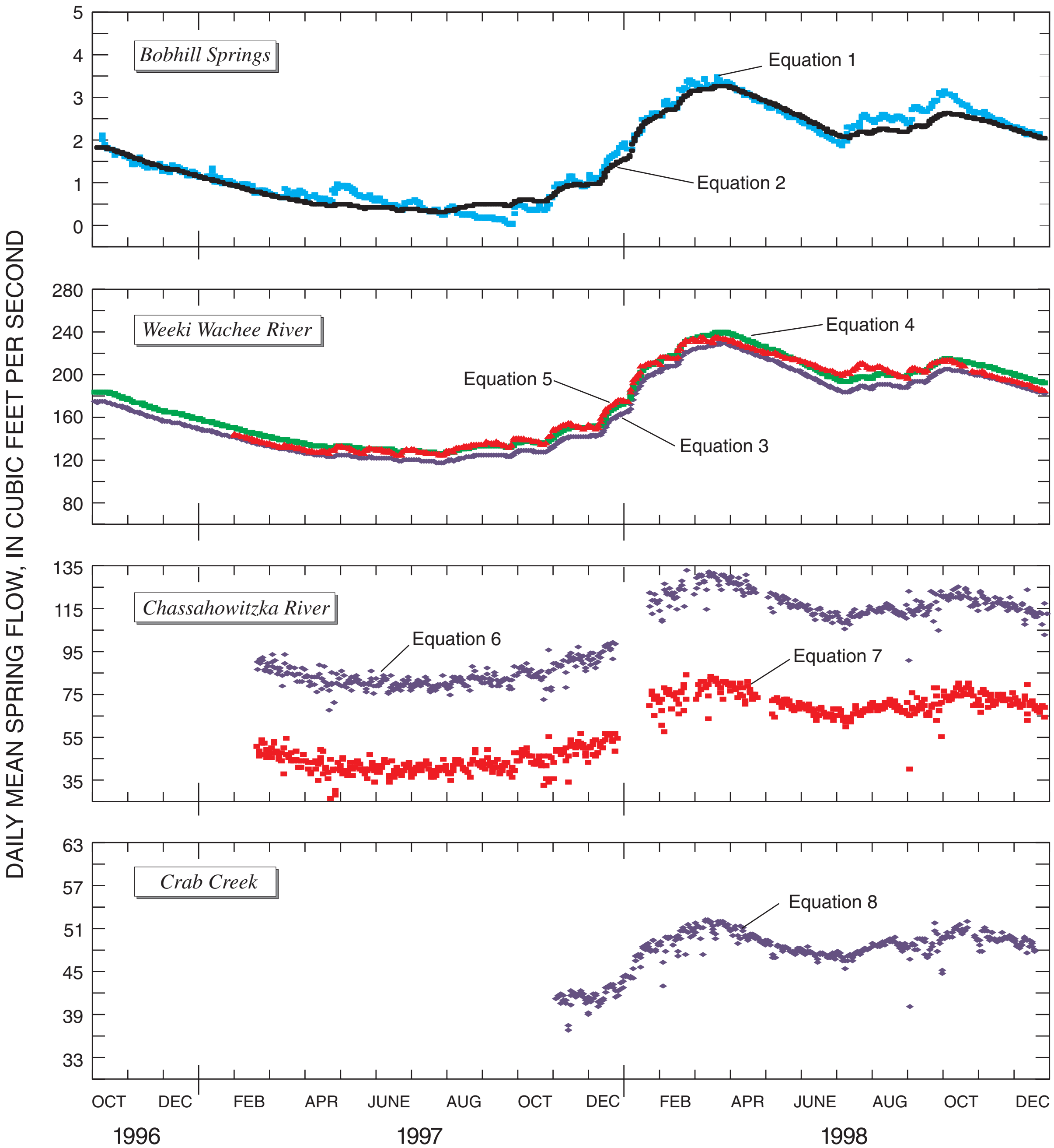


Figure 24. Daily mean spring flow from selected springs (October 1996 through December 1998).

The Weeki Wachee Springs well is an alternate well for acquiring water-level data if water levels cannot be collected from the Weeki Wachee well. The residuals from the three predictive equations did not exhibit trends, and the estimated (calculated) spring flow was within 10 percent of the measured spring flow. The R^2 is higher using the data collected during this investigation, which may indicate that streambed conditions have changed at the measuring section. Vegetation was thick in Weeki Wachee River during 1997-98 and may have affected the measured spring flow. The predictive equations may need to be adjusted to reflect hydrologic change similar to the adjustments made to ratings for typical streams.

Hydrographs of daily mean spring flow at the Weeki Wachee River gaging station are shown for the period from October 1996 through December 1998 (fig. 24). Although similar, calculated spring flow was consistently lower using period-of-record data (1966-98) than 1997-98 data.

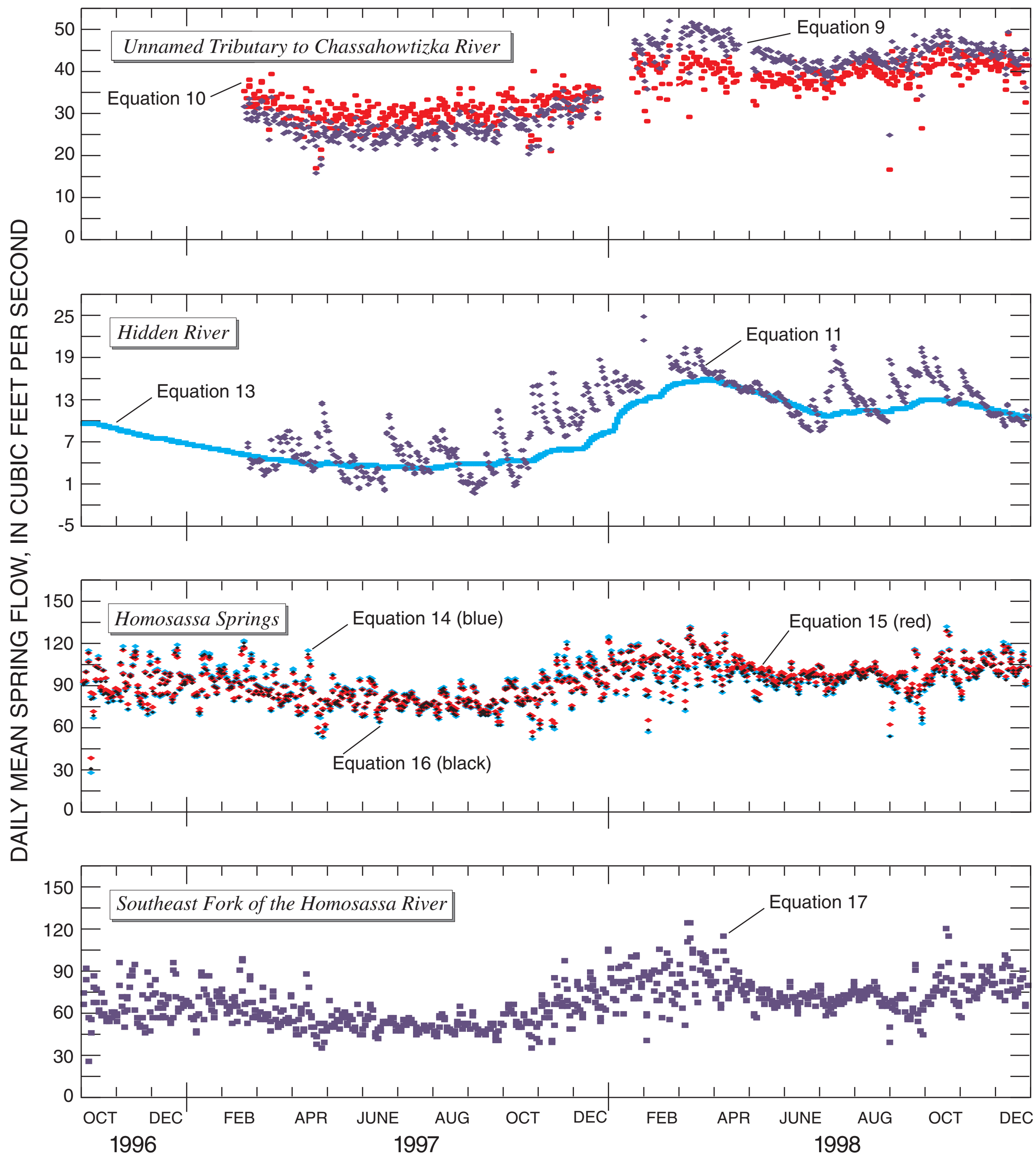


Figure 24. Daily mean spring flow from selected springs (October 1996 through December 1998). (Continued)

Chassahowitzka Springs Complex

Spring flow was measured at the Chassahowitzka River, Crab Creek, and Unnamed Tributary to Chassahowitzka River gaging stations in the Chassahowitzka Springs complex. Spring flow was directly correlated with water levels in the Weeki Wachee well and inversely correlated with surface-water stage. Multiple linear regression models were developed using: (1) instantaneous measurements of spring flow, surface-water stage, and rate of change in stage; and (2) daily maximum ground-water levels. Subsequently, the predictive equations were used to calculate daily mean spring flow. The predictive equations for calculating daily mean spring flow at the Chassahowitzka River (upstream and downstream from Crab Creek), Crab Creek and Unnamed Tributary to Chassahowitzka River gaging stations are presented in table 1.

Regression models were developed for the historical and current location of the Chassahowitzka River gaging station. The historical location was downstream from Crab Creek and the current location is upstream from Crab Creek. The spring-flow volume computed for the Chassahowitzka River downstream from Crab Creek gaging station was the combined spring flow from Crab Creek and Chassahowitzka River upstream from Crab Creek gaging stations. The three explanatory variables used in the regression models included: (1) maximum daily water levels in the Weeki Wachee well, (2) surface-water stage at Chassahowitzka River, and (3) the rate of change in surface-water stage. The predictive equations for estimating daily mean spring flow and regression statistics are listed in table 1. Regression statistics indicate that all of the explanatory variables have a significant correlation with spring flow (table 1, eqs. 6 and 7). Figure 24 shows the spring-flow hydrographs for the Chassahowitzka River above and below Crab Creek gaging stations for the period from January 1997 through December 1998. The spring-flow hydrograph for the Chassahowitzka River below Crab Creek gaging station exhibits less day-to-day variation than the hydrograph for Chassahowitzka River above Crab Creek due to the consistency of flow from Crab Creek.

A regression model was developed for the Crab Creek gaging station that used two explanatory variables, maximum daily water levels in the Weeki Wachee well and surface-water stage at Crab Creek. The predictive equation for estimating the daily mean spring flow and regression statistics are listed in table 1 (eq. 8). Regression statistics indicate that the explanatory variables are significantly correlated with spring flow (table 1). Daily mean spring flow at the Crab Creek gaging station is shown for the period from November 1997 through December 1998 (fig. 24).

Two regression models were developed for the Unnamed Tributary to Chassahowitzka River gaging station. The first model used synchronous spring-flow data from Chassahowitzka River (above Crab Creek) gaging station as the explanatory variable. The second model used maximum daily water levels in the Weeki Wachee well, surface-water stage, and the rate of change in surface-water stage at Chassahowitzka River gaging station as the three explanatory variables. Stage data from the Chassahowitzka River gaging station are used for the Unnamed Tributary to Chassahowitzka River gaging station because the timing and amplitude of stage fluctuations are similar between the two gaging stations. Predictive equations for estimating daily mean spring flow and regression statistics are listed in table 1 (eqs. 9 and 10). Daily mean spring flow at the Unnamed Tributary to Chassahowitzka River gaging station is shown for the period from January 1997 through December 1998 (fig. 24).

Homosassa Springs Complex

Spring flow was measured at the Hidden River, Homosassa Springs, Southeast Fork of the Homosassa River, and Hall River gaging stations in the Homosassa Springs complex. Except for Hidden River, multiple sets of spring-flow measurements were made on a single day at a particular water level in the Upper Floridan aquifer. Spring flow is directly correlated with water levels in the Weeki Wachee well and inversely correlated with surface-water stage.

Regression models developed for the Hidden River gaging station used maximum daily groundwater levels in a well as the explanatory variable. Since 1964, 27 instantaneous spring-flow measurements have been made at Hidden River, but early spring-flow data were not used in the regression analysis because ground-water levels were not available until 1966 (Weeki Wachee well) and 1988 (Homosassa well 3). Two regression models used water levels in the Homosassa well 3. The analysis periods were 1988-98 and 1997-98, respectively (fig. 23). A third regression model used water levels in the Weeki Wachee well (fig. 23). The predictive equations and regression statistics are listed in table 1 (eqs. 11, 12, and 13). Daily mean spring-flow hydrographs for the Hidden River gaging station are shown in figure 24. Smoothing of small oscillations shown on the spring-flow hydrographs indicates that water levels in the Weeki Wachee well can be used to estimate the annual range in spring flow; however, variations in local rainfall, tidal loading, or recharge rates are not reflected as precisely as when water levels from the Homosassa well 3 are used.

Three regression models were developed for the Homosassa Springs gaging station. The first model used maximum daily water levels in the Weeki Wachee well and surface-water stage at Homosassa Springs as the explanatory variables. The second model used the two variables from the first model plus the rate of change in surface-water stage. The third model used the average value for each of the variables measured during a spring-flow event. The predictive equations and regression statistics are listed in table 1 (eqs. 14, 15, and 16). Daily mean spring-flow hydrographs for the Homosassa Springs gaging station are shown in figure 24. Differences among the hydrographs show that the predicted spring flow varied by less than 5 ft^3/s.

A regression model developed for the Southeast Fork of the Homosassa River gaging station used spring-flow data from the Homosassa Springs gaging station as the explanatory variable. The residuals from a linear regression model were nonrandomly distributed; therefore, the data for the explanatory variable (spring flow from Homosassa Springs) were transformed using a natural log function. A natural log transformation or higher-order regression model was used because the ratio of spring flows from Southeast Fork of the Homosassa River and Homosassa Springs was nonlinear and ranged from about 0.58 to 0.90. The ratio was largest when the ground-water level was highest. The predictive equation and regression statistics are listed in table 1 (eq. 17). Daily mean spring flow at the Southeast Fork of the Homosassa River gaging station is shown in figure 24.

Twenty-five spring-flow measurements were made at the Halls River gaging station (app. B). The measurement dates were June 3 and November 4, 1997, and February 24, 1998. The average spring flow on these dates was 152, 220, and 561 ft^3/s, respectively. In the Homosassa Springs complex, the largest spring-flow volume and range were measured at the Halls River gaging station; however, a substantial portion of the volume probably was from surface-water storage. Additional data are needed to develop a regression model and predictive equation to calculate the daily mean spring flow at the Halls River gaging station.

To summarize, spring flow is statistically related to the water level in the Upper Floridan aquifer. Water levels in the Weeki Wachee well can be used to calculate spring flow across the study area. Calculated spring flow from tidal springs required additional explanatory variables to compensate for the diurnal fluctuations in surface-water stage caused by tides in the Gulf of Mexico. Differences between consecutive measurements of stage are not steady but transient; therefore, an explanatory variable quantifying the rate of change in surface-water stage also was used in some of the regression models. The varying difference between consecutive measurements of stage is probably related to changes in channel geometry and variability of stage gradients among stations.

WATER BUDGET

A water-budget analysis for the 2-year period from 1997 through 1998 was conducted for the Coastal Springs Ground-Water Basin and for the four smaller ground-water basins within the Basin. The four ground-water basins delineated from potentiometric-surface contours are bounded by ground-water flow divides. The only source of water entering the basins is rainfall and the pathways for water leaving the basins are evapotranspiration, ground-water withdrawals, runoff, and ground-water outflow. The change in storage was neglected from the analysis because the beginning and ending water levels in the Upper Floridan aquifer and spring-flow volumes were nearly equivalent. A flowchart illustrating the exchanges among hydrologic components used in the water budget is shown in figure 25.

Rainfall varies within the Coastal Springs Ground-Water Basin. Rainfall ranged from about 40 to 71 in/yr among the stations and averaged about 56.5 in/yr in 1997-98 (fig. 10). Results of using the Thiessen polygon method indicate that rainfall values were about 56.5, 59, 53, and 52 in/yr for the Aripeka, Weeki Wachee, Chassahowitzka, and Homosassa Springs Ground-Water Basins, respectively, which averaged 55.1 in/yr for the Coastal Springs Ground-Water Basin (figs. 10 and 25, and table 2).

Evapotranspiration (ET) is the largest outflow component in the water budget and is variable throughout the study area. Five ET subregions were delineated for the study area and were designated by “vegetation type” including scrub, high pine forest, pine flatwood, hammock, and swamps (fig. 26). The scrub and high pine forest subregions were assigned the lowest ET rate, 27 in/yr (Sumner, 1996). These subregions are characterized by sparse vegetation, a relatively deep water table, few surface-water features, and rapidly drained sandy soils. These characteristics minimize ET, maximizing recharge to the Upper Floridan aquifer (Sumner, 1996). The pine flatwood subregion was assigned an ET rate of 42 in/yr (Bidlake and others, 1993). This subregion contains poorly drained soils, an organic hardpan overlain by perched lakes, and a water table that can be near land surface (Wolfe, 1990, p. 116). During periods of wet weather, the land surface may remain saturated for several months. The hammock subregion was assigned an ET rate of 38 in/yr. The hammock subregion is characterized by a wide range in the potential ET rate because the subregion contains poor- to well-drained soils, flat topography, and

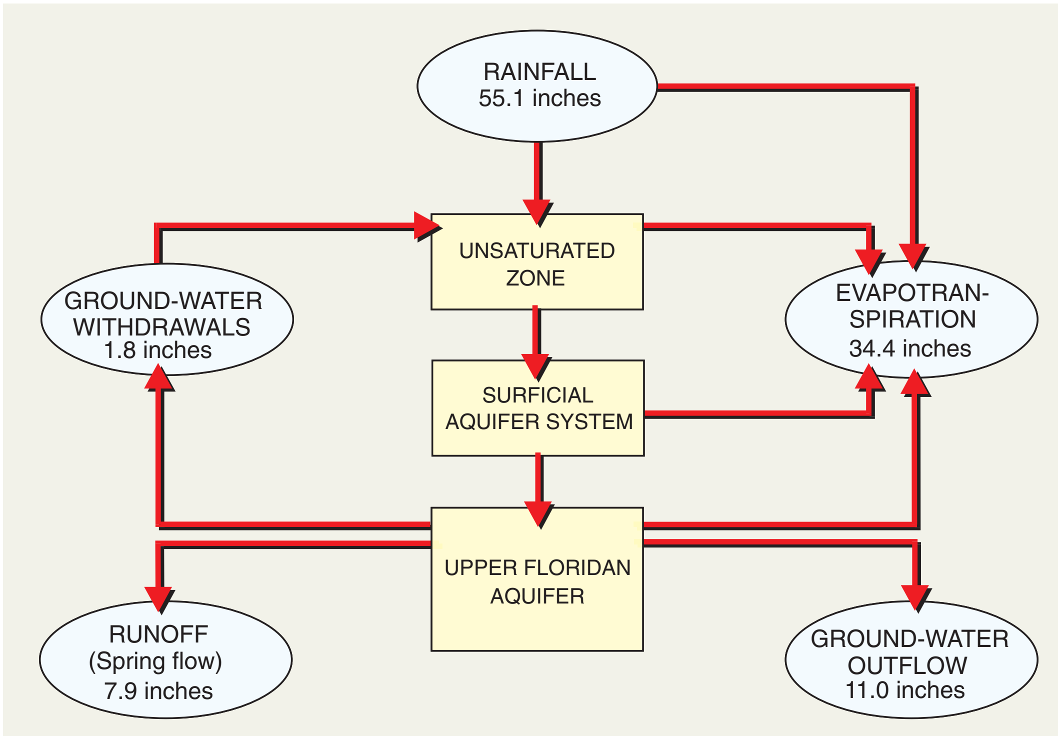


Figure 25. Flowchart showing exchanges among hydrologic components used in the water budget.

Table 2. Average annual water budgets for the four ground-water basins in the Coastal Springs Ground-Water Basin (CSGWB), January 1997 through December 1998

[All units in inches per year]

Budget components	Aripeka	Weeki Wachee	Chassa-howitzka	Homosassa	Average in CSGWB
Rainfall	56.5	59	53	52	55.1
Evapotranspiration	37.5	33.5	34.5	32	34.4
Runoff (spring flow)	3.2	9	7	12.5	7.9
Ground-water withdrawals	0.6	3.6	2.2	0.6	1.8
Ground-water outflow	15.5	13	9	6.7	11.0
Residual	-0.3	-0.1	0.3	0.2	0.02

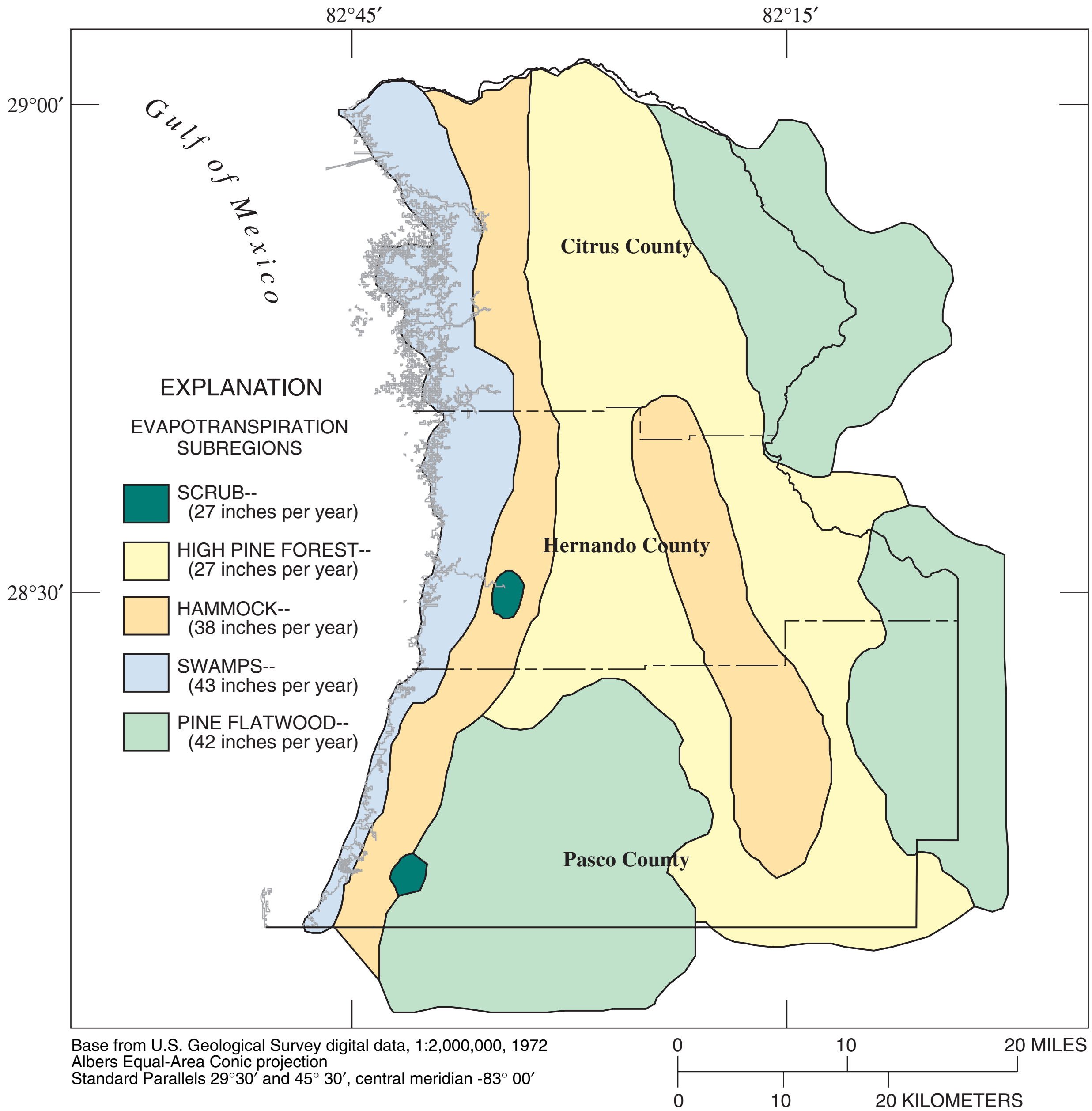


Figure 26. Evapotranspiration subregions and annual rates of evapotranspiration.

limestone that is near land surface (Wolfe, 1990, p.120). The swamps subregion was assigned the highest ET rate, 43 in/yr (German, 1999). This subregion is characterized by standing water, saturated organic soils, and water levels near or at land surface. The calculated ET rates for the Aripeka, Weeki Wachee, Chassahowitzka, and Homosassa Springs Ground-Water Basins were about 37.5, 33.5, 34.5, and 32 in/yr and averaged about 34.4 in/yr in the Coastal Springs Ground-Water Basin (fig. 25 and table 2).

The ground-water withdrawal component is the smallest component in the water budget, accounting for less than 5 percent of the outflow. Little if any of the ground water pumped from the Coastal Springs Ground-Water Basin is exported from the area, and a portion of the pumped volume is returned to the basin. The volume of water returned to the basin, such as from limestone mining or domestic septic systems, is stored in mining pits or applied to the land surface increasing the potential for ET losses. Ground-water withdrawals, tabulated from a list of users permitted to withdraw greater than 100,000 gal/d were 34.8, 1,098, 620, and 73.5 Mgal for the Aripeka, Weeki Wachee, Chassahowitzka, and Homosassa Springs Ground-Water Basins, respectively (fig. 27). The tabulated water use essentially reflect the volume of ground water withdrawn in Pasco and Hernando Counties. Citrus County is predominantly rural, so many of the wells were not tabulated nor included in the analyzed data set because the pumped rates were less than 100,000 gal/d. Based on water-use estimates (Marella, 1999, Southwest Florida Water Management District, 1999a and 1999b) ground-water use by small users (less than 100,000 gal/d) is about twice that of larger users in Citrus County. The volume was therefore adjusted by tripling the tabulated number to account for these small but numerous users in Citrus County. The values used for ground-water withdrawals in the water budget were 0.6, 3.6, 2.2, and 0.6 in/yr in the Aripeka, Weeki Wachee, Chassahowitzka, and Homosassa Springs Ground-Water Basins and averaged 1.8 in/yr for the Coastal Springs Ground-Water Basin (fig. 25 and table 2).

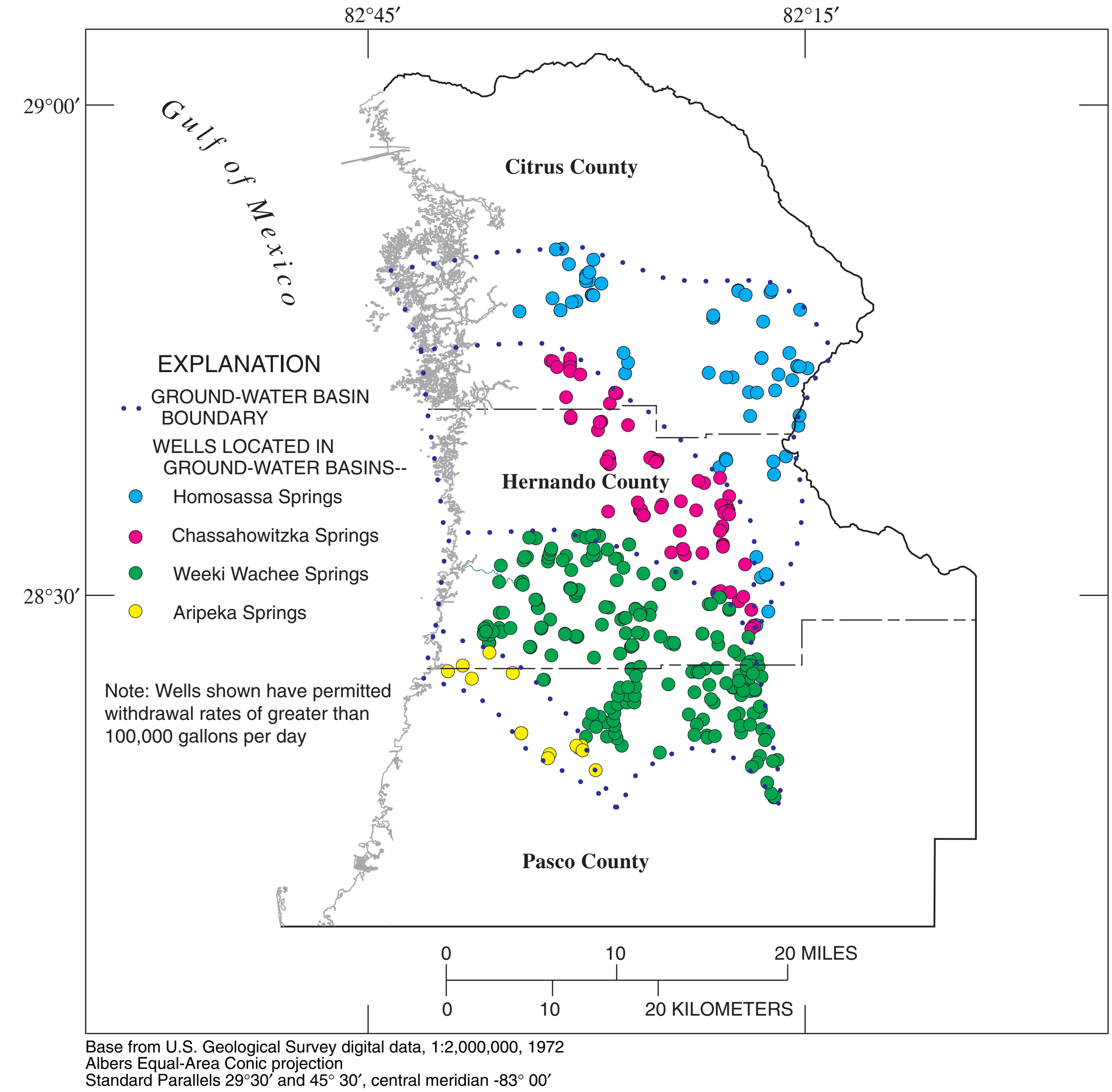


Figure 27. Wells with permitted ground-water withdrawal rates greater than 100,000 gallons per day in the ground-water basins.

The runoff component is a relatively large component of the water budget. The runoff component (spring flow) is unique because the measured surface-water flow is ground-water discharge from springs rather than overland flow to rivers following rainfall events. Overland flow in the study area is insignificant. Estimates of runoff were calculated using measured spring flow (this investigation) at the larger springs and historical flow data from the smaller springs. Spring-flow volumes estimated from historical data account for less than 10 percent of the total spring flow in the study area. The calculated runoff for the Aripeka, Weeki Wachee, Chassahowitzka, and Homosassa Springs Ground-Water Basin was 3.2, 9, 7, and 12.5 in/yr or about 11, 175, 129, and 269 ft^3/s, respectively. The average runoff from the Coastal Springs Ground-Water Basin was about 7.9 in/yr (fig. 25 and table 2).

Ground-water outflow, which is a relatively large component of the water budget, is primarily through diffuse upward leakage from the Upper Floridan aquifer. Ground-water outflow from the Upper Floridan aquifer was about 15.5, 13, 9, and 6.7 in/yr in the Aripeka, Weeki Wachee, Chassahowitzka, and Homosassa Springs Ground-Water Basins, respectively, and averaged about 11 in/yr from the Coastal Springs Ground-Water Basin (fig. 25 and table 2). Ground-water outflow was calculated for the flow channels delineated by no-flow boundaries and bounded by the 2- and 4-ft potentiometric-surface contours (fig. 28). The hydraulic gradient, shape, and computed leakage of the delineated flow channels in the Weeki Wachee and Chassahowitzka Springs Ground-Water Basins were about the same for both dry and wet periods (fig. 28 and table 3). In the Homosassa Springs Ground-Water Basin, estimated ground-water outflow during high ground-water levels in May 1998 was about twice as large as estimated outflow during low ground-water levels in September 1997 (table 3). The difference was due to the flat hydraulic gradient in the Homosassa Springs Ground-Water Basin. The relatively small 2-ft water level difference between dry and wet periods substantially affected the calculations of the gradient (I) and flow channel length (L) between the bounding potentiometric-surface contours.

To summarize, inflow to the Coastal Springs Ground-Water Basin from rainfall was estimated to be about 55 in/yr during 1997-98. Outflows were estimated to be about 2, 8, 11, and 34 in/yr from ground-water withdrawals, spring flow, ground-water outflow (upward leakage), and ET, respectively. ET is the largest outflow component in the water budget, and is nearly three times greater than the next largest outflow component, ground-water outflow, and more than an order of magnitude greater than ground-water withdrawals. Because ground-water withdrawals were a relatively small component of the hydrologic budget, the effect on the long-term equilibrium of the hydrologic system was difficult to assess. The relative contributions of the components to the water budgets varied for each of the four smaller basins. Runoff was lowest in the Aripeka Springs Ground-Water Basin because of the relatively small capacity of springs in the basin. ET was low in the Weeki Wachee, Chassahowitzka, and Homosassa Springs Ground-Water Basins, coinciding with areas of sandy soils, deep water tables, and rapid infiltration in the scrub and high pine forest subregions (fig. 26). Ground-water withdrawals were small relative to the size of the Homosassa Springs Ground-Water Basin because the basin is the least developed.

ANALYSIS OF LONG-TERM CHANGE

Reliable and verifiable data are needed to analyze long-term changes in hydrologic conditions. Before conducting a trend analysis, double-mass and cumulative-frequency curves were plotted to examine the consistency of data records and to indicate changing hydrologic conditions in the study area. Double-mass curves exhibiting linear patterns in hydrologic data verified that hydrologic data sets were reliable and appropriate for conducting trend analyses. Interpretations of hydrologic conditions were reinforced using cumulative-frequency curves of hydrologic data in relation to time.

Trend analysis was conducted using selected hydrologic data to deduce long-term change in hydrologic conditions. Period-of-record data sets were used, and subsets of the data were analyzed for trends to: (1) make comparisons among stations, (2) examine the effect of selecting partial records for analysis, and (3) infer relations among hydrologic components. Long periods of record are needed to conduct meaningful statistical analyses because the results and significance of any trend-analysis method may be biased by the period of record selected for analysis.

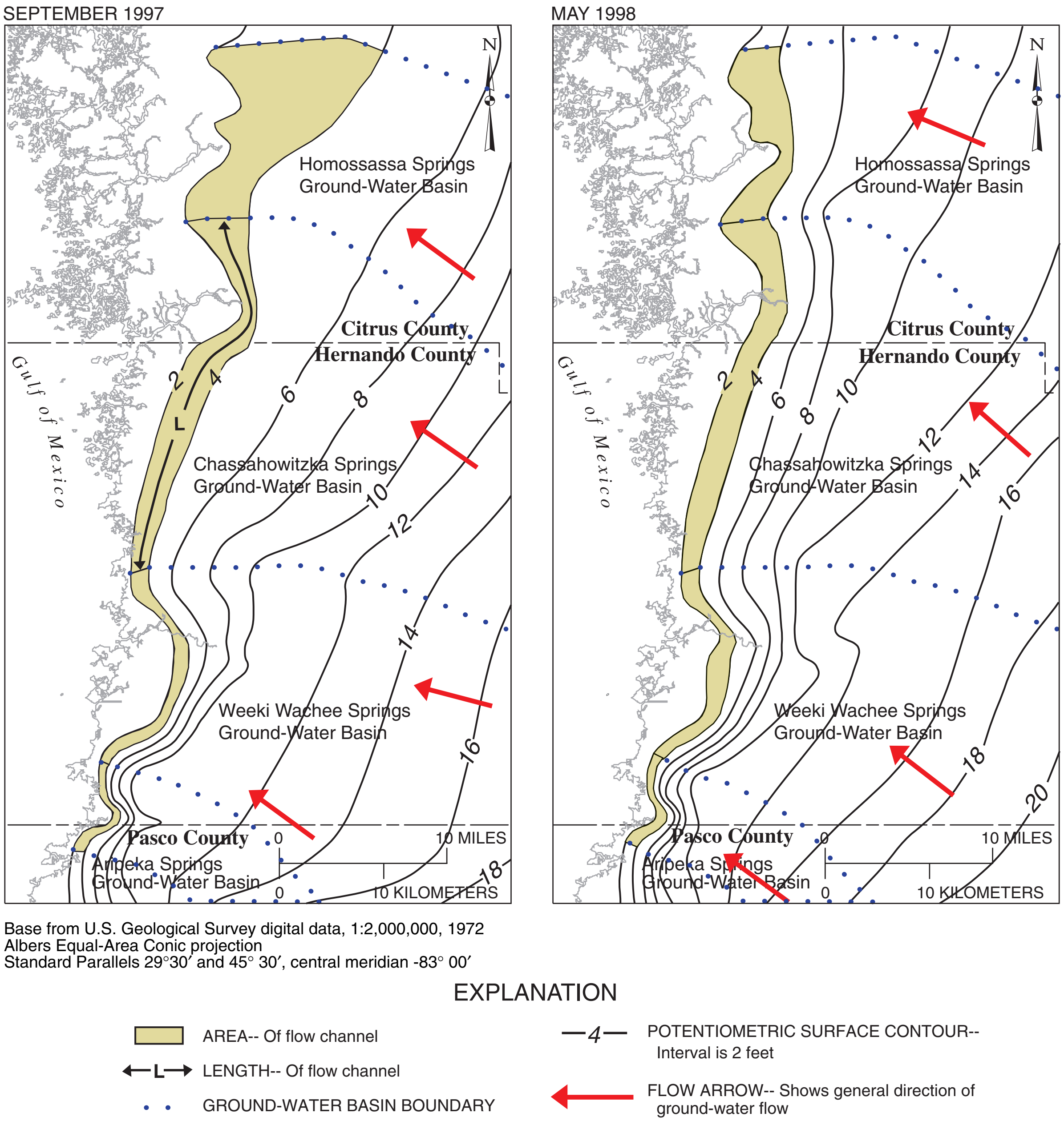


Figure 28. Ground-water outflow region of the Coastal Springs Ground-Water Basin.

Unfortunately, the periods of record differ among hydrologic and rainfall stations in the study area. The periods of record included about 100 years of rainfall at three of the four NOAA stations, about 70 years of spring-flow data at Weeki Wachee River gaging station, about 35 years of water-level records for the Weeki Wachee well, and about 35 years of data on ground-water withdrawals from Pasco, Hernando, and Citrus Counties. All other stations had much shorter periods of record.

Results of the trend analysis provided a statistical measure of whether hydrologic conditions (rainfall, ground-water withdrawals, water level, and spring flow) have changed over time. Results of the trend analysis, conducted using quantiles of annual data, provided a statistical measure of whether the probability distribution of selected portions of the hydrologic range (low or high levels) had changed over time. Detailed results are presented in the following sections.

Table 3. Ground-water outflow computations for the four ground-water basins in the Coastal Springs Ground-Water Basin

[T, transmissivity in feet squared per day; I, gradient in feet per mile; L, length of flow channel in miles; Q_1, outflow in cubic feet per day; Q_2, outflow in inches per year; Q = TIL, Darcy's Equation]

Basin	Hydrologic condition [1]	T	I [2]	L	Q_1	Q_2
Aripeka	Low ground-water levels	170,000	7.7	4	5,400,000	17.8
	High ground-water levels	170,000	6.2	4	4,100,000	14.2
Weeki Wachee	Low ground-water levels	500,000	4	8.8	22,000,000	13.2
	High ground-water levels	500,000	4	8.6	21,000,000	12.8
Chassahowitzka	Low ground-water levels	500,000	2	14.4	14,500,000	9
	High ground-water levels	500,000	2	14	14,500,000	9
Homosassa	Low ground-water levels	1,500,000	0.67	8.1	8,100,000	4.4
	High ground-water levels	1,500,000	1.5	7	16,125,000	9

[1] Anomalous low ground-water levels occurred during September 1997 and high ground-water levels occurred during May 1998.

[2] I = Ci/Wa, Ci is contour interval, in feet; Wa is A′/L, where A′ is the area between two flow lines, L is length of flow channel in miles.

Rainfall

No statistically significant long-term change (trend) in rainfall was deduced using all available rainfall records (period of record), but trends exist for shorter time periods. For example, average rainfall since 1961 is lower than the period from 1900 through 1960 (Southwest Florida Water Management District, 1996). Double-mass curves of cumulative annual rainfall (four NOAA stations) over time indicated no discrepancy in the rainfall records from these stations. Additionally, linear double-mass curves for the cumulative annual rainfall for the four NOAA rainfall stations (evaluated pair wise) validated the proportionality of rainfall in the basin, and no apparent change in meteorological conditions was indicated (fig. 29).

Brooksville Chinsegut Hill rainfall records were analyzed for 1931-98, which coincides with the length of spring-flow records for the Weeki Wachee River gaging station (fig. 30). In figure 30, the rising limbs and peaks in the 1940's represent above average rainfall; falling limbs and valleys in the early 1950's represent periods of drought. The early half of the record (prior to 1966) generally reflects above average rainfall and the later half (after 1965) reflects below average rainfall.

Annual rainfall records from the 46 rainfall stations were analyzed using the Mann-Kendall test. The results of the analysis are listed in appendix C. Trend results indicate that five stations had statistically significant trends in rainfall over time; three stations had increasing trends (higher annual rainfall over time); and two stations had deceasing trends (fig. 31). The significance level ranged from 0.29 to 0.79 at the NOAA stations, indicating no apparent long-term monotonic changes in rainfall.

The Mann-Kendall test results were verified using OLS regression analysis. Results are listed in appendix C. Extremely low correlations between rainfall and time were indicated at most of the rainfall stations. Linear regression results are not presented for 16 of the 42 SWFWMD rainfall stations because less than 10 years of record were available for analysis. The regression results for the other 26 SWFWMD stations had R^2 values of 0.41 or less (app. C). Regression results for the four NOAA stations had R^2 values of nearly zero. Generally, the values of R^2 were higher for the stations with apparent trends in rainfall as indicated by the Mann-Kendall test; all of the values of R^2 were rather low. Although monotonic trends were not detected, natural rainfall patterns exhibit periods of higher- and lower-than-normal annual or monthly rainfall.

Ground-Water Withdrawals

Combined ground-water withdrawal data for Pasco, Hernando, and Citrus Counties over a 34-yr period indicate a long-term increasing trend in ground-water withdrawals. Double-mass curves constructed from cumulative ground-water withdrawal over time are nonlinear with breaks in slope between 1970 and 1975 and between 1989 and 1990 (figs. 22 and 32).

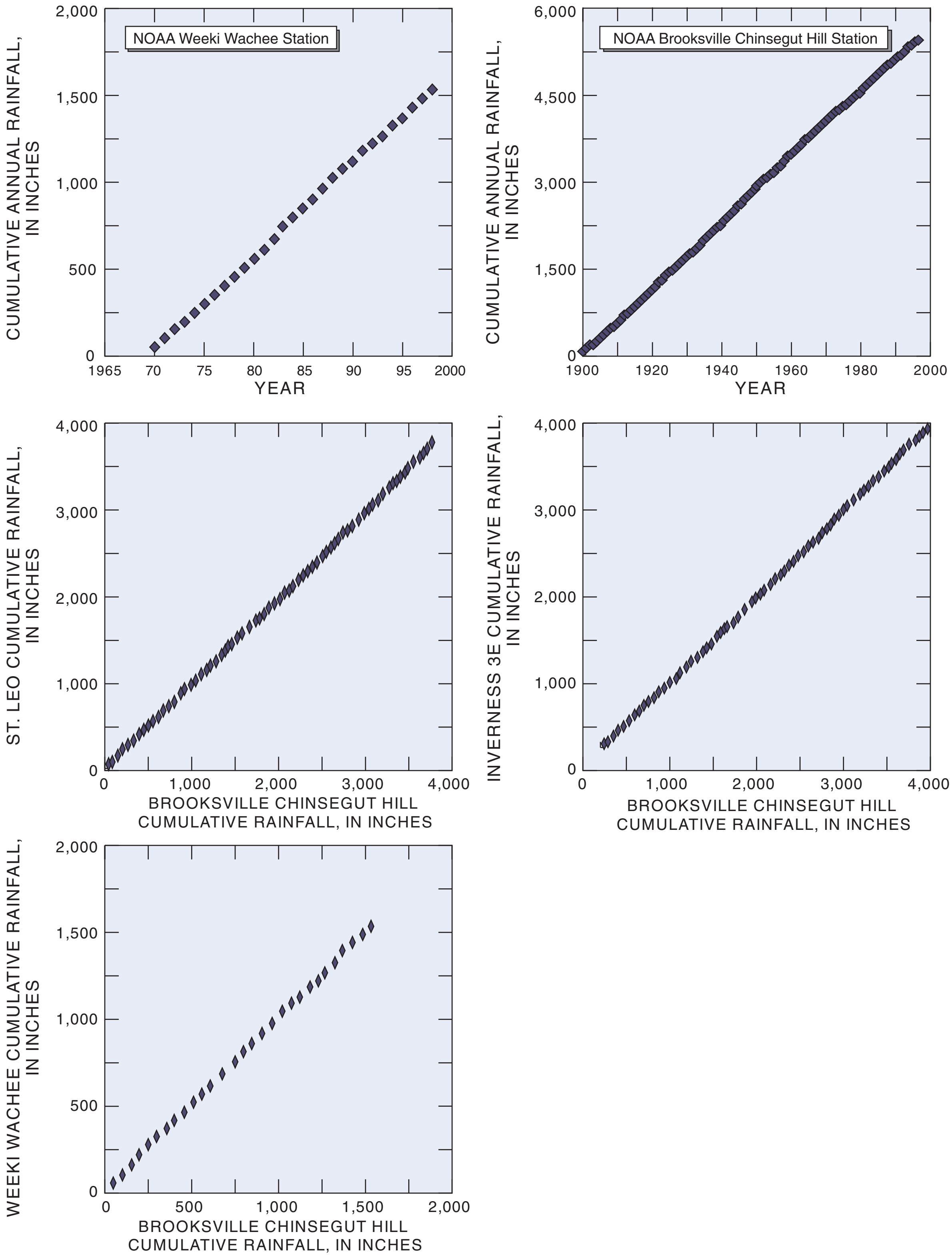


Figure 29. Double-mass curves for the NOAA rainfall stations.

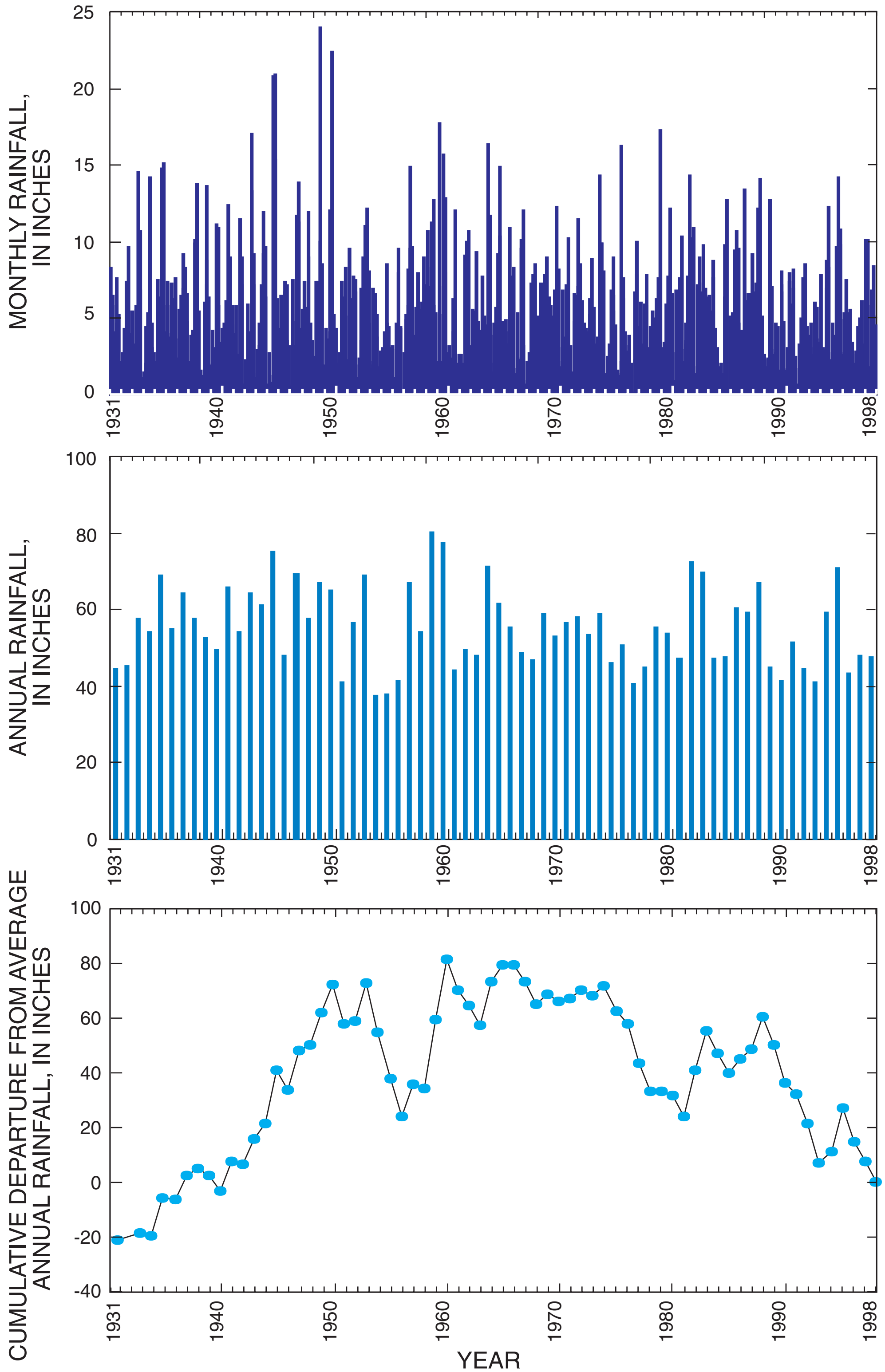
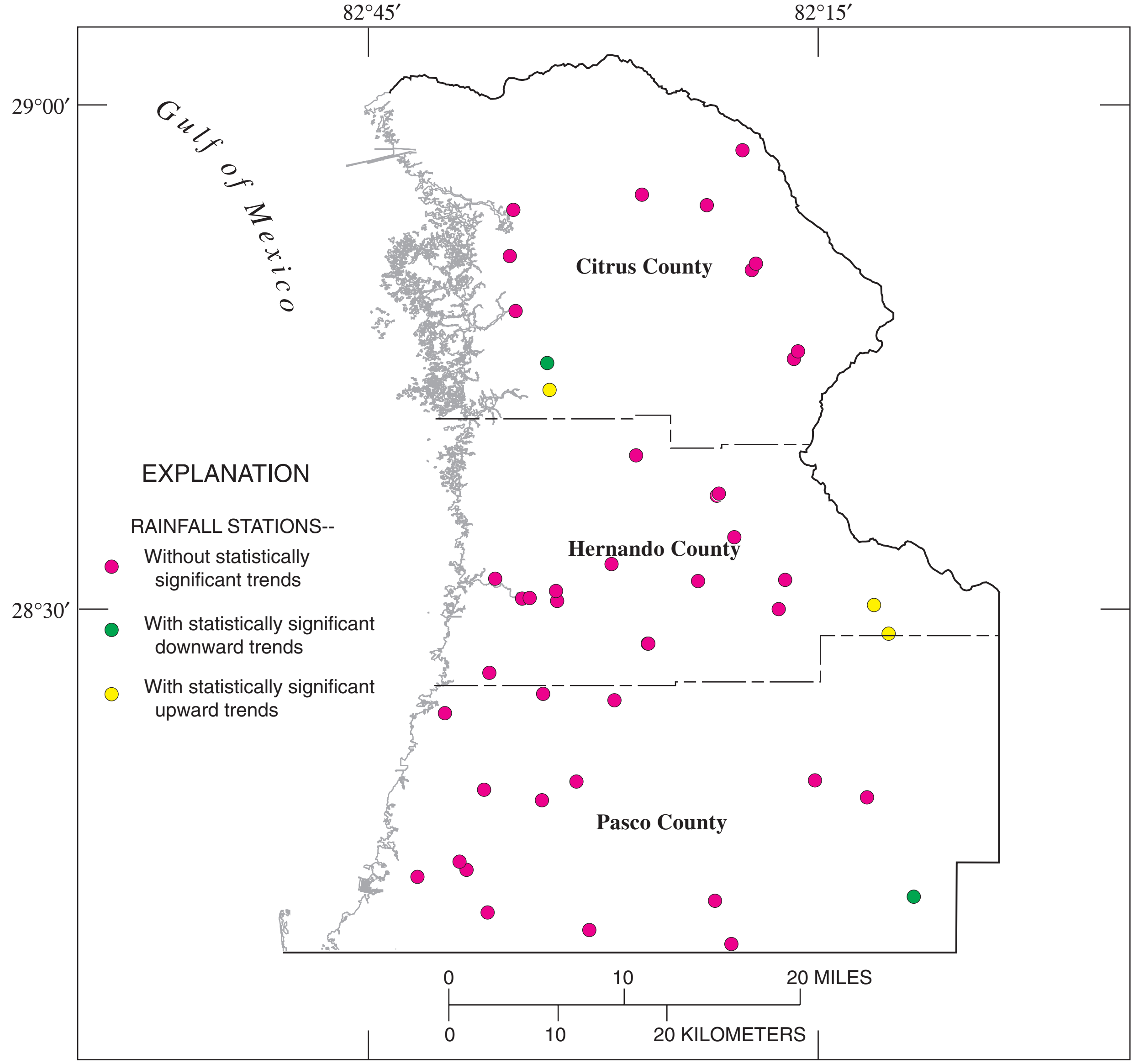


Figure 30. Monthly, annual, and cumulative departure from average annual rainfall at the Brooksville Chinsegut Hill station (1931-98).



Base from U.S. Geological Survey digital data, 1:2,000,000, 1972
Albers Equal-Area Conic projection
Standard Parallels 29°30′ and 45° 30′, central meridian -83° 00′

Figure 31. Significance of temporal trend at selected rainfall stations.

A statistically significant correlation between ground-water withdrawals and time was detected using the Mann-Kendall test. The attained significance level was much lower than 0.10, and a relatively large (0.75) positive value for Kendall's tau indicated an increasing trend over time (table 4). The value of R^2 was 0.86 from the linear regression analysis, which indicates a relatively strong relation between variables; however, the relation is nonlinear.

Ground-water withdrawals have been increasing in the Coastal Springs Ground-Water Basin. Based on the water-budget analysis, the effect of increased ground-water withdrawals on the hydrologic system is minimal at current withdrawal rates because ground-water withdrawals are relatively small in comparison to the available resource. Ground-water withdrawals are estimated to be about 3 percent of the volume in the hydrologic system.

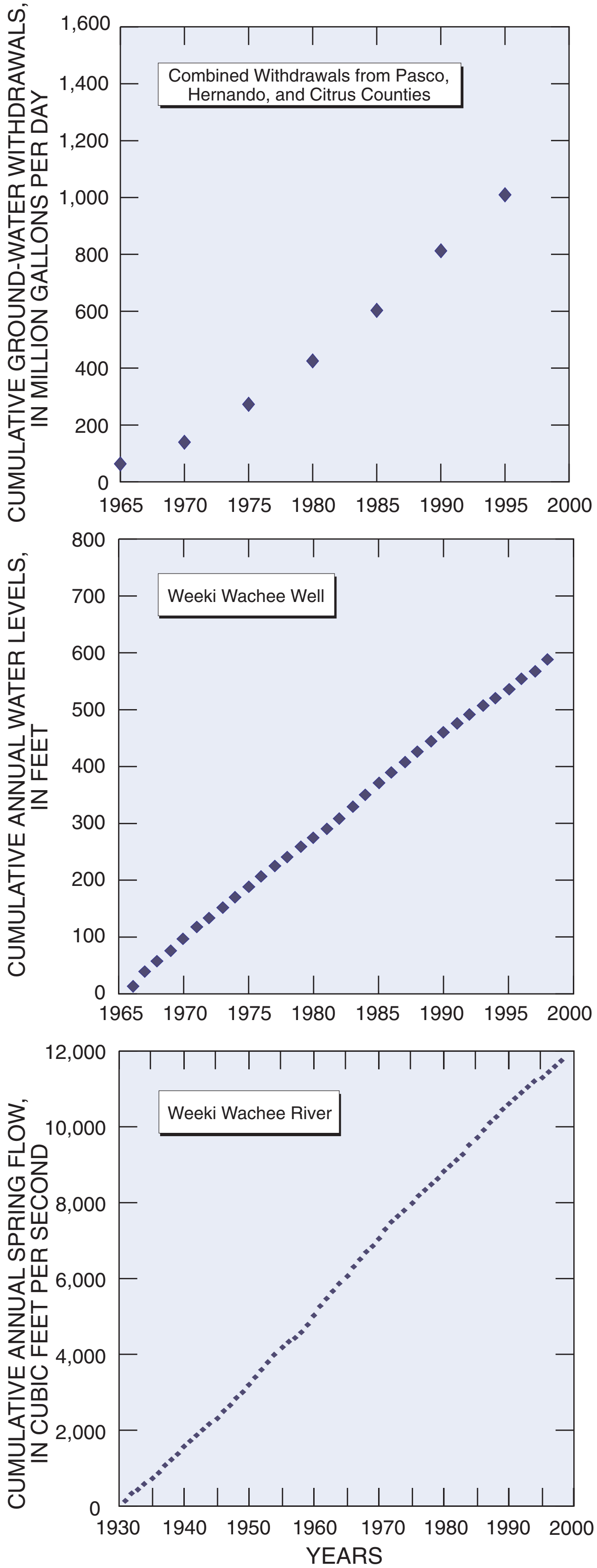


Figure 32. Double-mass curves for selected hydrologic components in relation to time.

Table 4. Summary of Mann-Kendall and linear-regression results for ground-water withdrawals (Pasco, Hernando, and Citrus Counties), ground-water levels (Weeki Wachee well), and spring flows (Weeki Wachee River) for the periods of record and selected periods

[--, not presented because significance level not attained; <, less than; negative numbers indicate decreasing trends]

Years	Number of years	Significance level	Kendall Tau	Coefficient of determination	Trend
Ground-water withdrawal					
1965-98[1]	25	<0.001	0.75	0.86	yes
Ground-water level					
1966-98[2]	33	0.007	-0.33	0.2	yes
1966-77[4]	12	0.07	-0.39	0.24	yes
1978-89[4]	12	0.27	--	--	no
1990-98[4]	9	0.83	--	--	no
Spring flow					
1931-98[3]	68	0.72	--	--	no
1966-98[2]	33	0.02	-0.29	0.17	yes
1966-77[4]	12	0.02	-0.51	0.36	yes
1978-89[4]	12	0.3	--	--	no
1990-98[4]	9	0.3	--	--	no

[1] Period of record.
[2] Period of record Weeki Wachee well.
[3] Period of record Weeki Wachee River.
[4] Periods selected to correspond to change in ground-water withdrawal rate.

Water Levels In Weeki Wachee Well

The double-mass curve of cumulative ground-water levels over time was approximately linear using 33 years (1966-98) of water-level records for the Weeki Wachee well. Small shifts (less than 5 percent) in the data were observed, but definitive breaks in slope were not detected (fig. 32). Cumulative-frequency curves show the percentage of time that daily mean ground-water levels were exceeded. The curve for the period of record (1966-98) is fairly smooth with steep slopes near the upper and lower ends, indicating that water levels in the Weeki Wachee well do not maintain minimum or maximum levels for long (fig. 33). The curve for the period 1996-98 is different from the curve for 1966-98, and reflects the exceptionally low and high water levels in the Upper Floridan aquifer (extreme hydrologic conditions) that occurred during this investigation (fig. 33). Although the curves are shaped differently, the median water levels were about the same.

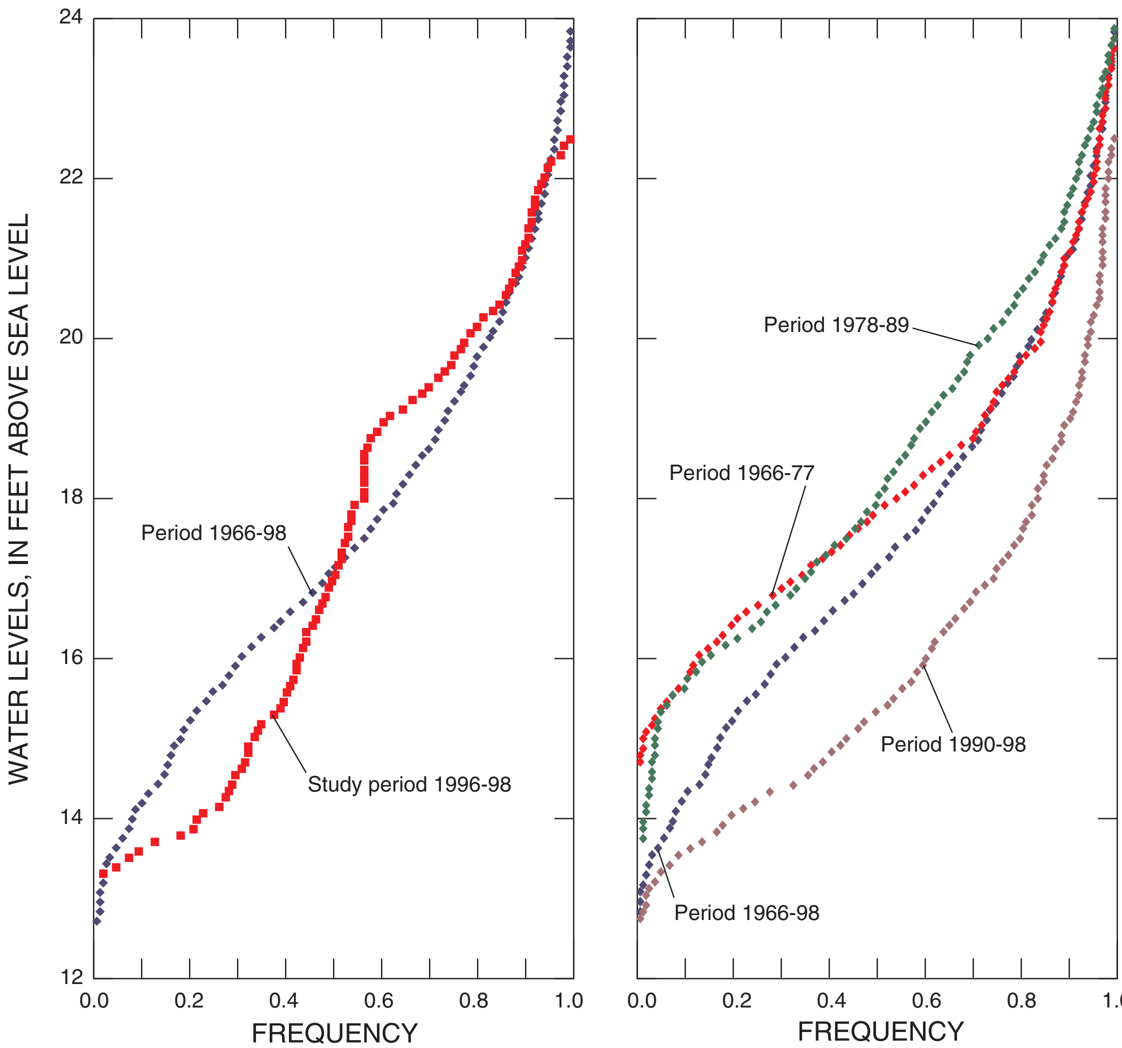


Figure 33. Cumulative-frequency curves for water levels in the Weeki Wachee well.

Results of the Mann-Kendall test and OLS model indicated a statistically significant decreasing trend in ground-water levels in the Weeki Wachee well over time (table 4). Additional Mann-Kendall tests were conducted using quantiles of water-level frequency in the Weeki Wachee well. The selected water-level frequencies that were analyzed for trends included the 10, 30, 50, 70, and 90th percentiles. The values contained in the 10th percentile data set, for example, included the water level for each year of record that was attained 90 percent or more of the time during that year. All the analyzed water-level frequencies had statistically significant decreasing trends (table 5), and confirmed the determinations that water levels in the Upper Floridan aquifer declined during the period from 1966 through 1998.

Table 5. Summary of Mann-Kendall results for selected annual water-level quantiles in the Weeki Wachee well (1966-98)

Quantile	Significance level	Kendall Tau
10	0.06	-0.23
30	0.01	-0.31
50	0.01	-0.33
70	0.01	-0.33
90	0.04	-0.26

Spring Flow In Weeki Wachee River

Analysis of long-term change in spring flow was based on 68 years of record for the Weeki Wachee River gaging station (fig. 34). No definitive break in slope is apparent on the double-mass curve for 1931-98; however, a slight shift may exist in 1950. If the shift is real, the upward break in slope indicates an increase in spring flow over time (fig. 32). Statistically significant trends were not detected using 1931-98 spring-flow data from Weeki Wachee River (table 4). However, a decreasing trend at the 2-percent significance level was detected from 1966-98, coinciding with the period of record for the Weeki Wachee well. The relative strength of the correlation between spring flow and time, estimated from OLS regression, was considered weak based on an R^2 value of about 0.2.

To summarize, the findings and significance of the analysis for temporal trends depended on the period of record of the time-series data set. Hydrologic data from 1931-98 for the Brooksville Chinsegut Hill rainfall station and the Weeki Wachee River gaging station did not exhibit temporal trends. Hydrologic data from 1966-98 for the Weeki Wachee River gaging station and the Weeki Wachee well exhibited statistically significant decreasing trends. Inferring long-term change in hydrologic conditions in the Coastal Springs Ground-Water Basin continues to be ambiguous using records of annual rainfall, spring flow, and ground-water level due to the lack of comparable historical data and the integration of the seasonal fluctuations (data smoothing) represented by annual values.

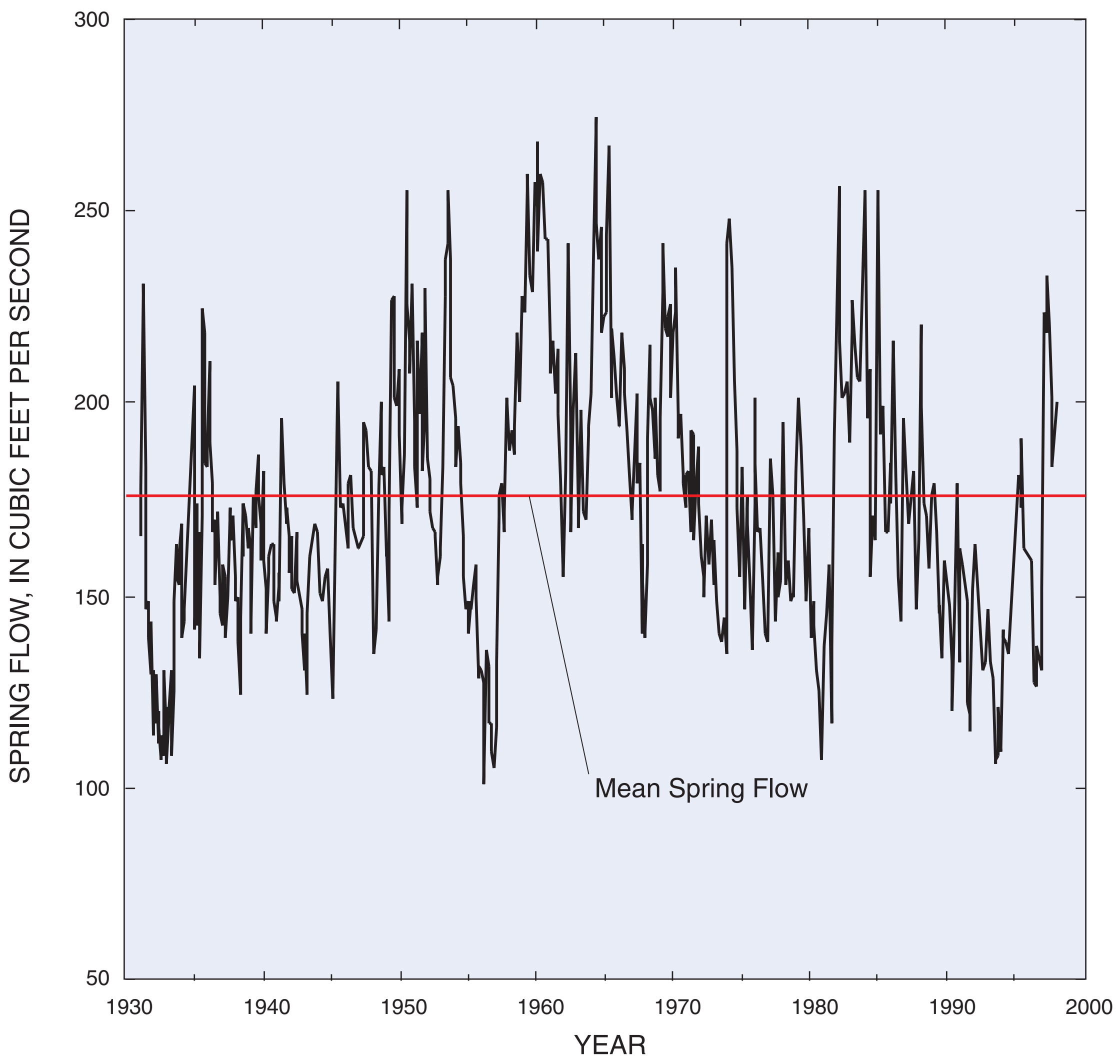


Figure 34. Spring-flow hydrograph for Weeki Wachee River (1931-98).

Comparisons Among Three Investigation Periods

To further describe the temporal variations in hydrologic conditions in the Coastal Springs Ground-Water Basin, records of instantaneous spring flow from the Weeki Wachee River gaging station and monthly rainfall from the Brooksville Chinsegut Hill NOAA station were compared to data published in two previous reports (Cherry and others, 1970, and Yobbi, 1992). The spring-flow and rainfall data are shown in figure 35. Descriptive statistics including the mean, maximum, and minimum instantaneous spring flows for the selected periods 1964-65 (Cherry and others, 1970), 1988-89 (Yobbi, 1992), and 1997-98 (this investigation) are provided in table 6. Comparisons among hydrologic conditions were difficult to evaluate during these periods because each of the periods exhibited unique (atypical) rainfall patterns. For example, rainfall was above normal (about 70 and 60 inches, respectively) during 1964 and 1965; a tropical storm in September 1988 produced more than 10 inches of rain following a wet July and August (about 12 inches of rainfall each month); and the El Niño winter of 1997-98 produced 40 inches of rain. During 1964-65, above normal rainfall fell during most months, especially during the summers, and resulted in above average spring flows for the year. During the following year, 1966, annual average rainfall was recorded, but above average spring flow was maintained. Rapid and often short-lived water-level and spring-flow rises are possible during years of average annual rainfall. Maximum infiltration happens when the major portion of the annual rainfall is during the winter or as excess rain events like tropical storms and hurricanes. Periods of intense rainfall followed by periods of below normal rainfall result in rapid rises and declines in ground-water levels and spring flow. Rapid year-to-year changes (both rises and declines) can be observed in Weeki Wachee spring-flow data, especially since 1995 (fig. 35). Water-level data through 1999 were included to illustrate water-level declines after the investigation ended.

Descriptive statistics based on instantaneous measurements of spring flow from selected gaging stations in the Chassahowitzka and Homosassa Springs complexes are listed in table 6. Based on instantaneous spring-flow data, comparisons among investigation periods can be misleading because most of the historical data are single measurements, whereas multiple sets of measurements are needed to define the hydrologic condition on a single day.

INTERRELATIONS AMONG HYDROLOGIC COMPONENTS

Interrelations among hydrologic components were explored using annual data. Because the definition of annual hydrologic conditions may neglect shorter seasonal fluctuations, interrelations between hydrologic components also were explored using daily and monthly data. Changes in the annual amount and seasonal distribution of rainfall and ground-water withdrawal affect spring-flow volumes and ground-water levels.

The response time and magnitude of peaks on ground-water level and spring-flow hydrographs can differ for equivalent rainfall volumes. The net volume of rainfall available for aquifer replenishment (recharge) is transient because of seasonal variations in plant dormancy and solar radiation. Seasonal variations cause ET rates to be three to four times greater during June and July than during December and January (Sumner, 1996). Therefore, because ET rates are low, sufficient rainfall during the winter months is more likely to recharge the aquifer, raising water levels and increasing spring flow.

Rainfall records from the Weeki Wachee NOAA station and water-level records from the Weeki Wachee well were compared to evaluate the influence of both the timing and quantity of rain on water-level rise (fig. 36). The maximum water level attained and the rate of water-level rise depend on the antecedent conditions and the timing of rainfall. For example, rainfall events during the fall and winter of 1996-97 were insufficient to stabilize or raise water levels in the Upper Floridan aquifer, even during a period of low ET. Rainfall events were sporadic and separated by prolonged periods of little or no rainfall; as a result, soils in the unsaturated zone became progressively drier and declining water levels were observed. Because of the relative dryness of the soils in the unsaturated zone prior to the start of the rainy season, infiltration during the rainy season only replenished the soil moisture, resulting in little or no net rise of the water table during the summer of 1997; infiltration from rain was insufficient to raise water levels to normal altitudes (fig. 36). Large daily rainfall (one event greater than 5 inches) during the El Niño winter of 1997-98 resulted in water-level rises of nearly 10 ft in the Weeki Wachee well and nearly doubled the spring flow at the Weeki Wachee River gaging station. About 40 inches of rain fell during the winter of 1997-98. This exceptionally wet winter was followed by a 3-month period with only trace rainfall.

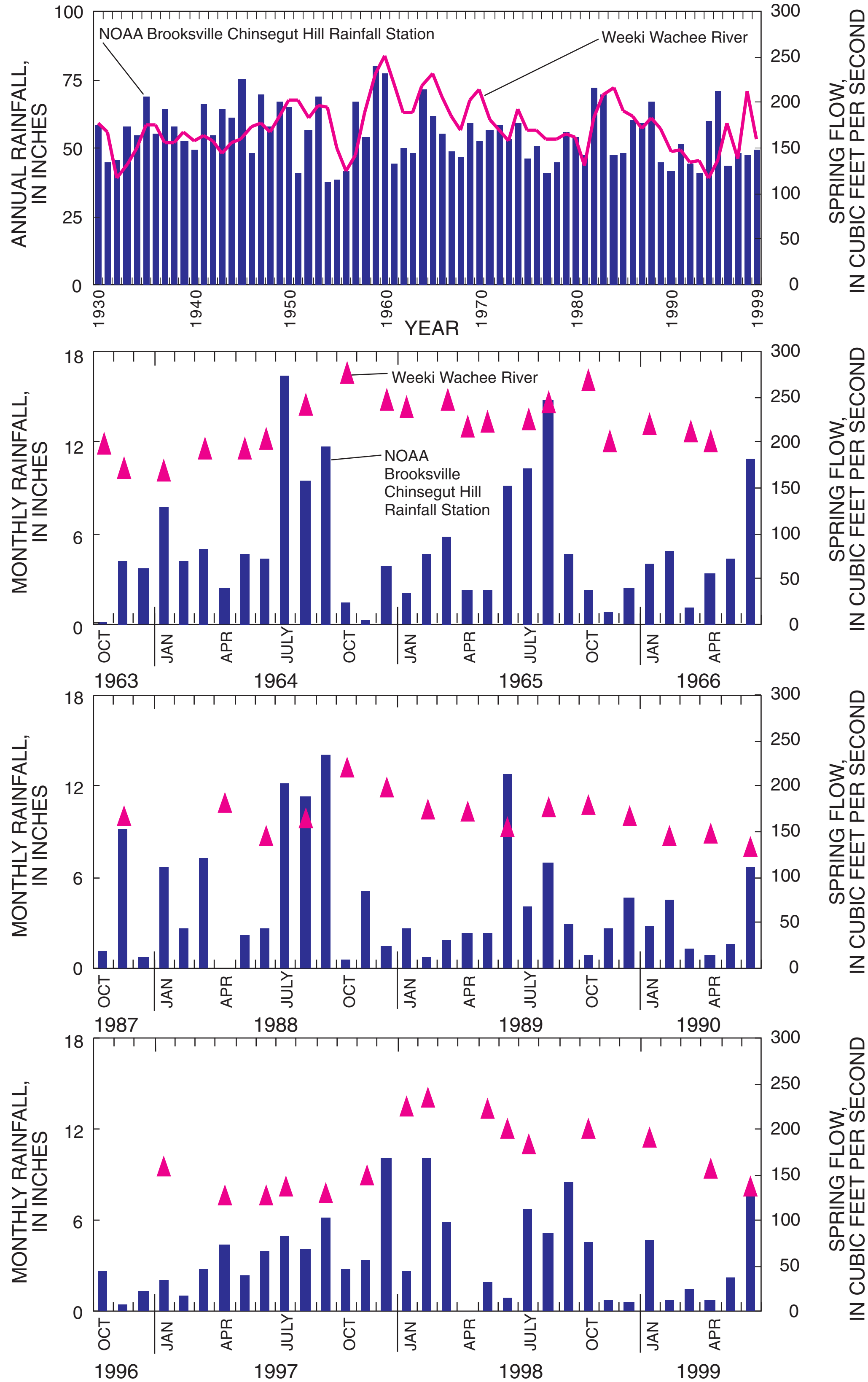


Figure 35. Comparison between spring flow and rainfall at the Weeki Wachee River and Brooksville Chinsegut Hill stations for various temporal periods.

Table 6. Mean, maximum, and minimum instantaneous spring flows, in cubic feet per second, for selected sites during current and previous investigations

[Max, maximum value; Min, minimum value; --, not measured; N, number of measurements]

Gaging station name	Station number	N	1997-98 (Current investigation)			N	1988-89 (Yobbi, 1992)			N	1964-65 (Cherry and others, 1970)		
			Mean	Max	Min		Mean	Max	Min		Mean	Max	Min
Bobhill Springs	02310405	10	1.67	3.56	0.00[1]	5	2.56	3.35	1.49	4	3.64	4.43	3.14
Magnolia Springs Run	282600082392600	6	9.04	10.4	6.30[2]	--	--	--	--	--	--	--	--
Weeki Wachee River	02310525	13	178	233	126	12	173	221	145	--	223	275	170
Chassahowitzka River[3]	02310650	37	114	158	59	--	92.6[4]	--	--	--	140[5a]	--	--
Chassahowitzka River[6]		31	68	112	13	--	--	--	--	--	--	--	--
Crab Creek	02310652	38	44.9	52.9	33.2	20	48.7	55.9	40.1	--	--	--	--
Unnamed Tributary[7] to Chassahowitzka River	02310655	37	42.4	66.1	0.33	--	--	--	--	--	--	--	--
Hidden River[8]	02310675	11	9.80	19.9	1.90	7	9.29	5.05	20.1	7	24.2	65.6	7.00
Homosassa Springs	02310678	58	98.4	122	73.2	11	107	122	85.5	--	140[5b]	--	--
Southeast Fork of the Homosassa River	02310688	47	74.8	108	37.2	--	--	--	--	--	80[5b]	--	--
Halls River	02310690	25	313	670	86	--	--	--	--	--	170[5b]	291	59

[1] No flow exited the spring pool.

[2] May reflect backwater conditions.

[3] Includes spring flow from Crab Creek.

[4] Single measurement made during study.

[5a] From Cherry and others, 1970, p. 22-23.

[5b] From Cherry and others, 1970, p. 19.

[6] Does not include spring flow from Crab Creek.

[7] Includes flow from canal and unnamed springs.

[8] Does not include the largest measured spring flow.

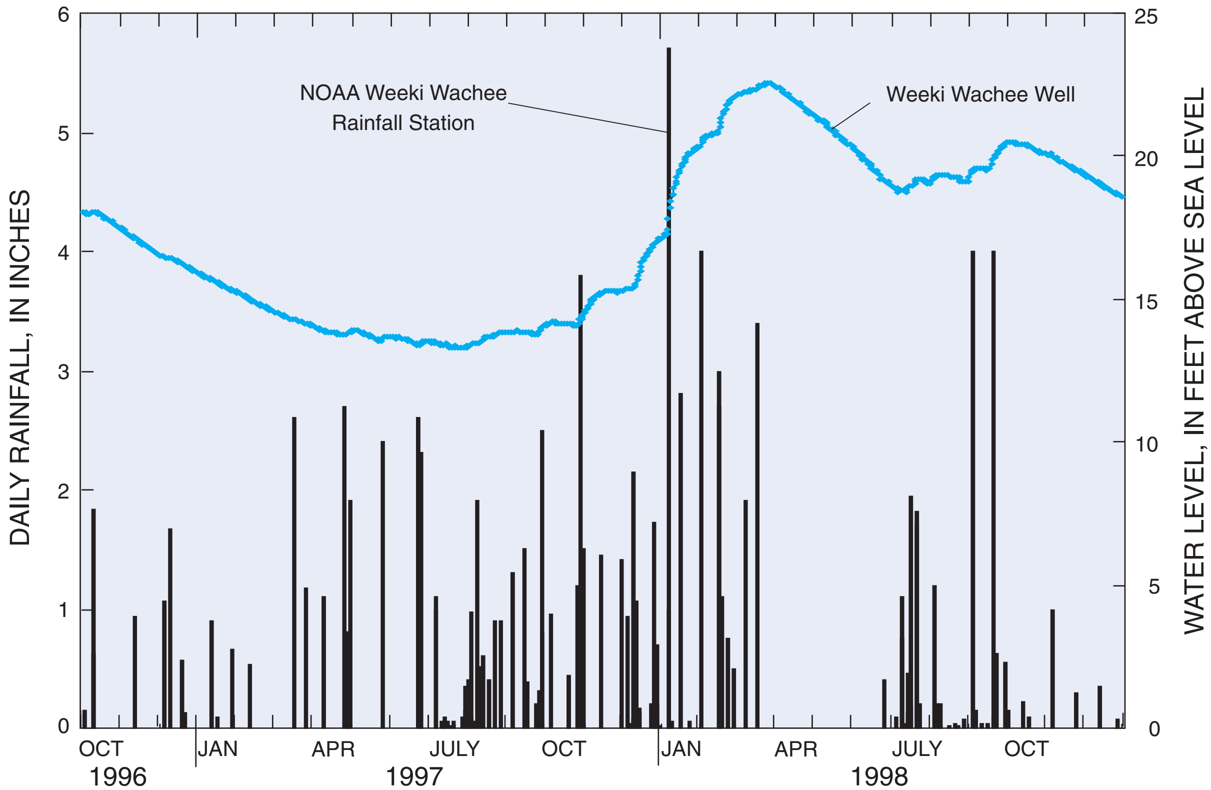


Figure 36. Comparison between daily maximum water level in the Weeki Wachee well and daily rainfall at the Weeki Wachee rainfall station (October 1996 through December 1998).

Water levels and spring flow from April through June 1998, coinciding with the season when plants are actively budding and solar radiation is increasing, had the greatest rate of decline during the investigation (fig. 36).

Comparison of historical rainfall and water-level records (1970-98) indicates that rapidly rising water levels coincide with large rainfall events. Water levels typically decline gradually over time. Figure 37 shows that from 1970 to mid-1974, water levels declined in response to below average rainfall; during the summer of 1974, water levels rose about 10 ft in response to about 39 inches of rainfall. Ignoring seasonal fluctuations, water levels generally declined from about 1974 to 1981; water levels rose about 10 ft in 1982 and were sustained through 1984. Rainfall was 10 inches above normal in 1982 and 20 inches above normal in 1983 at the Brooksville Chinsegut Hill and Weeki Wachee NOAA stations. A general decline in water levels has existed since 1984 with water levels declining to new lows throughout the 1990's.

Relations between annual spring flow and rainfall data (1931-98) were interpreted using spring-flow records from Weeki Wachee River gaging station and rainfall records from Brooksville Chinsegut Hill station. The mean annual spring flow reflects the antecedent as well as current rainfall. Antecedent rainfall has a greater effect than current rainfall on spring flow measured at Weeki Wachee River gaging station. For example, above average annual rainfall in 1949 and 1950 resulted in above average annual spring flow in 1950 and 1951, even though rainfall was substantially below average in 1951. Rainfall patterns consisting of 2 years of above average rainfall followed by a third year of below average rainfall exhibited a 1-yr lag in spring flow. These patterns also were observed in 1959-61, 1963-65, 1983-85 and 1994-96 (fig. 35).

The relative effect of antecedent rainfall conditions on spring flow was explored using multiple linear regression techniques. The explanatory variables included current year, previous year, and year before last rainfall and were ranked second, first, and third in importance, respectively. The correlation statistically

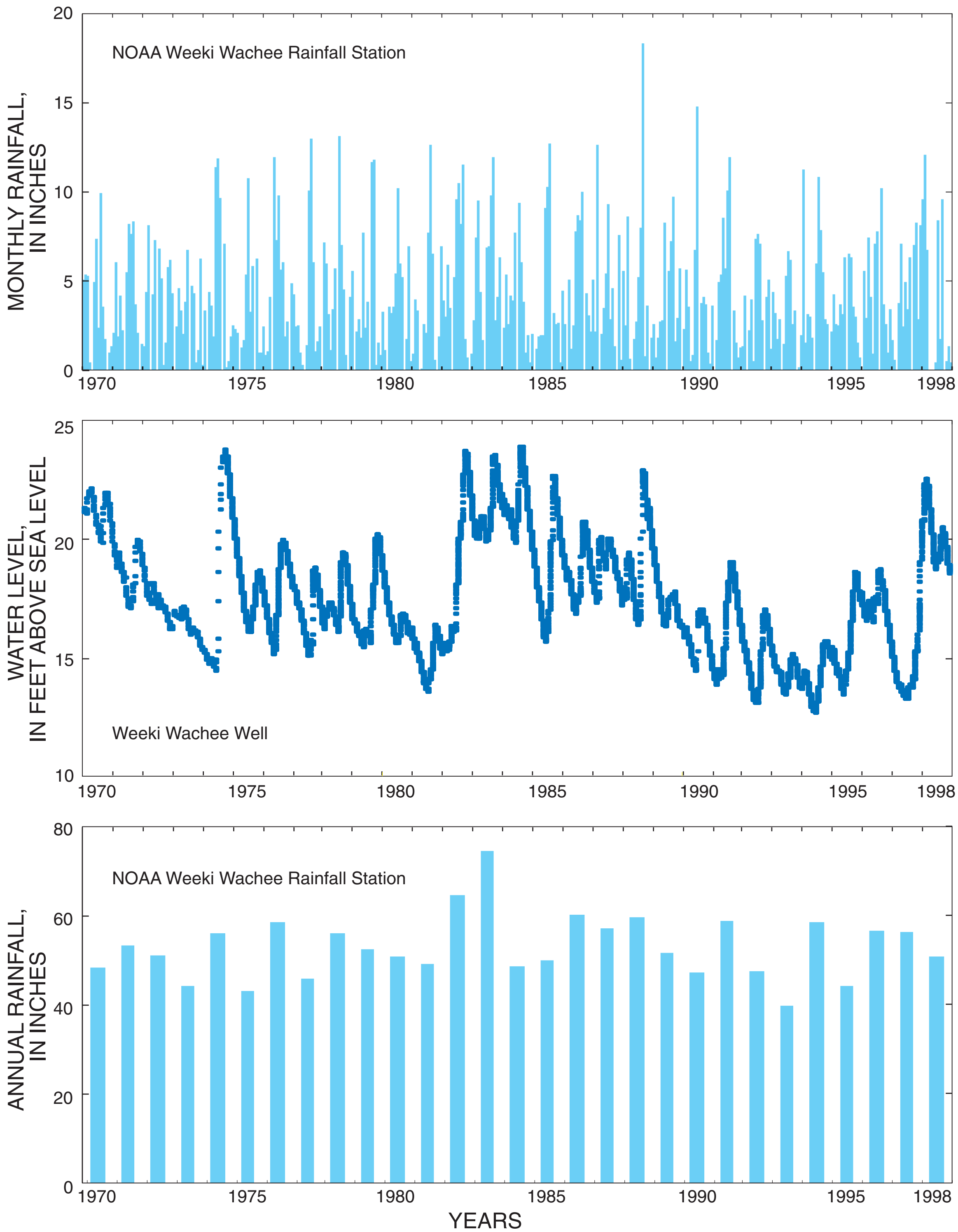


Figure 37. Comparison between monthly and annual rainfall at the Weeki Wachee station and water levels in the Weeki Wachee well.

improved when using the three rainfall variables (table 7); however, the R^2 values were relatively low, about 0.43 using Weeki Wachee rainfall records and about 0.20 using Brooksville Chinsegut Hill rainfall records. The relatively weak correlation between annual values of rainfall and spring flow reflect the importance of the timing and volume of rainfall available for recharge. Sinclair (1978, p. 27) showed that despite a cumulative rainfall deficiency of 45 inches during 1966-75, the normal annual range in spring flow of 150-200 ft^3/s was maintained from the Weeki Wachee River gaging station. Additionally, low flows of less than 110 ft3/s were not indicated during 1966-75, even though the recurrence interval was less than 10 years (Sinclair, 1978, p. 27). The stability of spring flow from large springs, observed by Sinclair (1978), is due to the combined effect of climatic conditions over multiple years.

Double-mass curves were used to evaluate the proportionality between: (1) rainfall and water levels, and (2) rainfall and spring flow. Data from 1970-98 were evaluated using period-of-record annual rainfall records at the Weeki Wachee NOAA station and water-level records from the Weeki Wachee well. Data from 1931-98 were evaluated using annual rainfall records from Brooksville Chinsegut Hill station and period-of-record spring flow at Weeki Wachee River. During 1970-98, no sharp breaks or deviations in slope were apparent, suggesting that the proportion between rainfall and water levels is unchanged during this period (fig. 38). However, using spring-flow data from 1931-98, an apparent break in slope was recorded in 1950 and a slight upward shift was observed, indicating that Weeki Wachee Springs has discharged more water for a given amount of annual rainfall since 1950 than during the prior years of record. A proposed theory for this increase in spring-flow discharge is that sediments deposited in vents of Weeki Wachee Springs were flushed by relatively high flows during the late 1940's. The removal of sediments clogging spring vents could have resulted from above normal annual rainfall or by mechanical flushing of debris from the springs during construction of the Weeki Wachee Springs attraction (Tibbals and others, 1980, p. 59).

Relations between ground-water withdrawals, ground-water levels, and spring flow were evaluated. Several analyses were conducted on subsets of the data (1965-77, 1978-89, and 1990-98) corresponding to the three substantial changes in ground-water withdrawal rates (fig. 22). As indicated earlier, breaks in the slope were not evident on the double-mass curves for spring flow or water levels (fig. 32). However, a statistically significant but weak negative trend in ground-water levels and spring flow was detected for the earliest period, but not for the later two periods (table 4). The OLS results indicated a weak relation between spring flow measured at Weeki Wachee River gaging station and the combined ground-water withdrawals from Pasco, Hernando, and Citrus Counties. The R^2 value for the relation was 0.13 (table 7). Multiple linear regression results indicated a stronger relation with the response variable when incorporating multiple explanatory variables, including the 3 years of rainfall and the combined withdrawals in the study area. The R^2 value was 0.74. Cumulative-frequency curves of water levels from the Weeki Wachee well provided a visual

Table 7. Results of regression analyses that test the interrelation among various hydrologic components and spring flow

Explanatory variable	Years of record	Coefficient of determination	Significant	Significance level
Current year rainfall[1]	1970-98	0.09	yes	0.059
Previous year rainfall[1]	1971-98	0.10	yes	0.055
Two years previous rainfall[1]	1972-98	0.06	marginal	0.106
Combined three-year rainfall[1]	1972-98	0.43	yes	0.004 0.005 0.019
Combined three-county ground-water withdrawal	1970-98	0.13	yes	0.049
Three-year rainfall and three-county ground-water withdrawal	1970-98	0.74	yes	<0.001 <0.001 <0.001 <0.001

[1] NOAA Weeki Wachee station rainfall data.

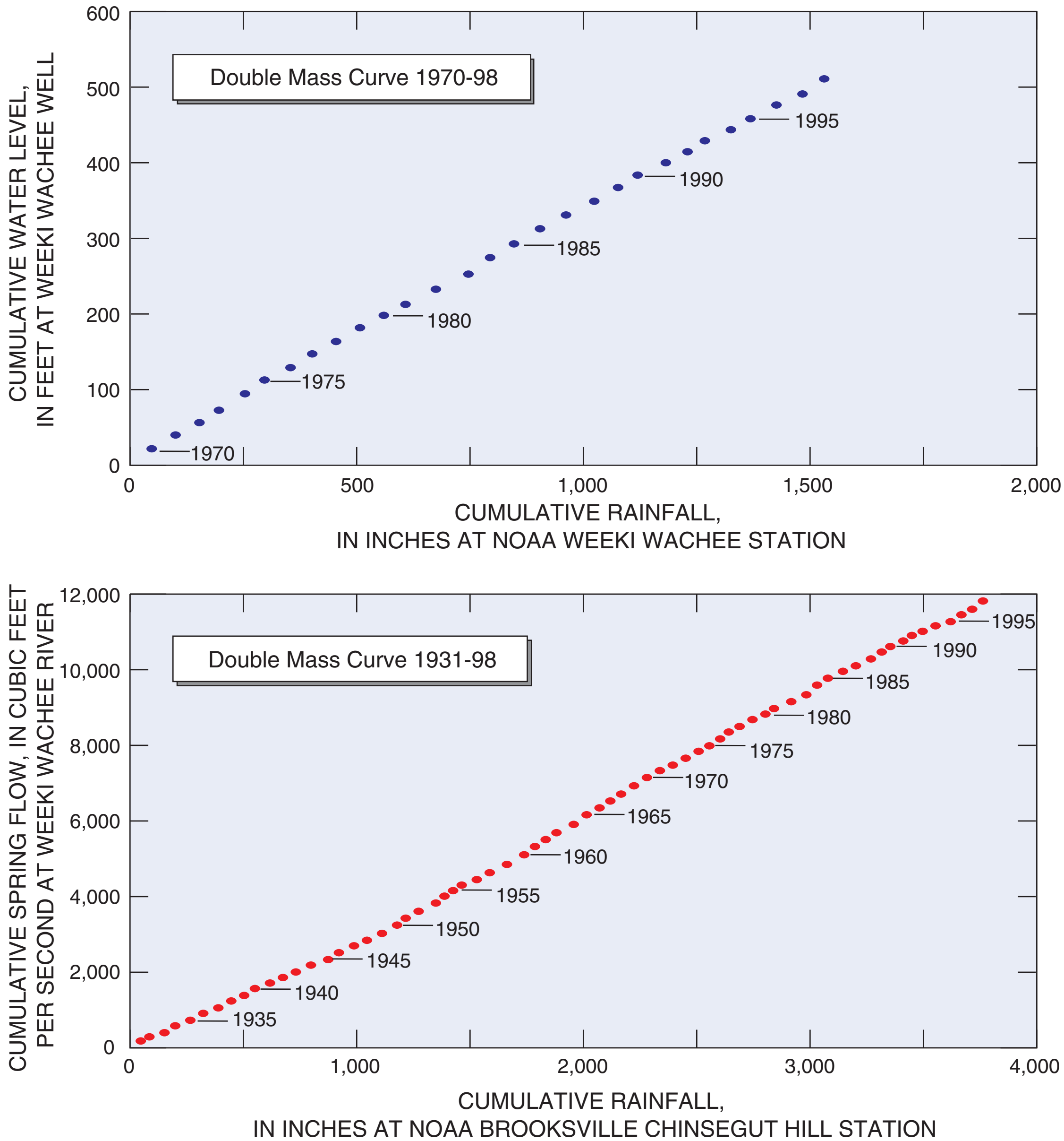


Figure 38. Double-mass curves for water level and spring flow in relation to rainfall.

comparison among the ground-water withdrawal periods (fig. 33). When compared to the period-of-record frequency curve (1966-98), the frequency curve constructed from 1966-77 water levels exhibited a smaller range and was generally 1 to 2 ft higher at frequencies of less than 70 percent; the frequency curve constructed from 1978-89 water levels exhibited a nearly equivalent range, similar shape, and was consistently higher throughout the frequency range, reflecting the higher than normal rainfall in the basin (averaging 55.9 in/yr). Compared to the 1966-98 frequency curve, the frequency curve constructed from 1990-98 water levels exhibited a smaller range, had a flatter shape, and was consistently lower throughout the frequency range reflecting the lower than normal rainfall in the basin (averaging 49.3 in/yr) (fig. 33).

In summary, rainfall is the primary hydrologic component influencing water-level altitudes and spring-flow volumes in the Coastal Springs Ground-Water Basin. Small volumes of water are removed from the system as ground-water withdrawals. The relative importance of rainfall is exhibited by comparable patterns of hydrographs using 5-year moving averages of annual rainfall records from Brooksville Chinsegut Hill station and spring-flow records from Weeki Wachee River gaging station (fig. 39).

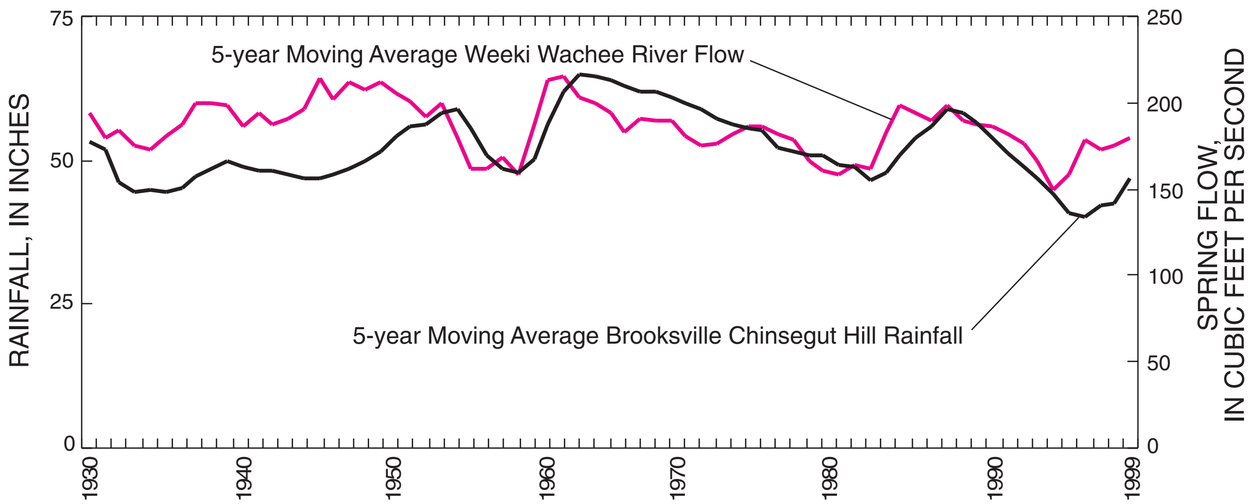


Figure 39. Comparison between 5-year moving average of spring flow at Weeki Wachee River and rainfall at the Brooksville Chinsegut Hill station (1931-99).

LIMITATIONS AND INDEX-SITE NETWORK

The greatest factor impeding the quantitative evaluation of the hydrologic system in the study area is the lack of continuous hydrologic data. Compounding the problem of the limited number of data collection sites are two deficiencies in data at existing sites. The first deficiency is the variable length in the periods of record, making comparison among hydrologic components and between stations of similar component type biased toward the youngest temporal periods (shortest periods of record). For example, water-level records from the Weeki Wachee well can only be related to rainfall records from Weeki Wachee station for the period since 1970. The second deficiency is sporadic data records (discontinuous data) that make long-term change difficult to detect. All of the springs in the study area except Weeki Wachee Springs have discontinuous data records. Spring-flow data from Bobhill Springs and many of the other springs in the study area are available for only three finite investigation periods (Cherry and others, 1970; Yobbi, 1992; and this investigation). The ongoing collection of hydrologic data, including ground-water levels, spring flows, surface-water stage, and salinity is needed. The hydrologic component, ET, needs to be quantified using energy-budget methods. In concert with the collection of additional hydrologic data, an ongoing quantitative analysis of the data, including statistical relations and long-term change, is needed.

Ongoing monitoring of a network of sites, designated *index-site network*, selected from the hydrologic stations monitored during 1997-98, could provide the needed information to assess hydrologic factors affecting the quantity and quality of spring flow. The network includes wells and springs that could provide the minimum hydrologic data needed to monitor ground-water levels and spring flow in the Coastal Springs Ground-Water Basin. Locations of the wells and springs are shown in figure 40, and relevant site information is provided in appendix A.

Of the 75 supplemental wells, 24 could easily be included in the index-site network. These wells were chosen for this study because of their spatial distribution and accessibility. Designated monitoring wells were selected when possible. Water-level measurements in the 24 wells, collected each May and September, could provide additional data used to construct corresponding semiannual potentiometric-surface maps. Continuous water-level monitoring at the Weeki Wachee Springs and Homosassa 3 wells could provide an alternative source of water-level records used to estimate daily mean spring flow.

The index-site network could include 10 springs. Spring-flow measurements, made at regular intervals could provide the data used to refine the regression models and predictive equations. Measurements of spring flow at Weeki Wachee River gaging station, made bimonthly and monitored indefinitely, could continue to provide the needed hydrologic data to estimate spring flow at the oldest station in the study area.

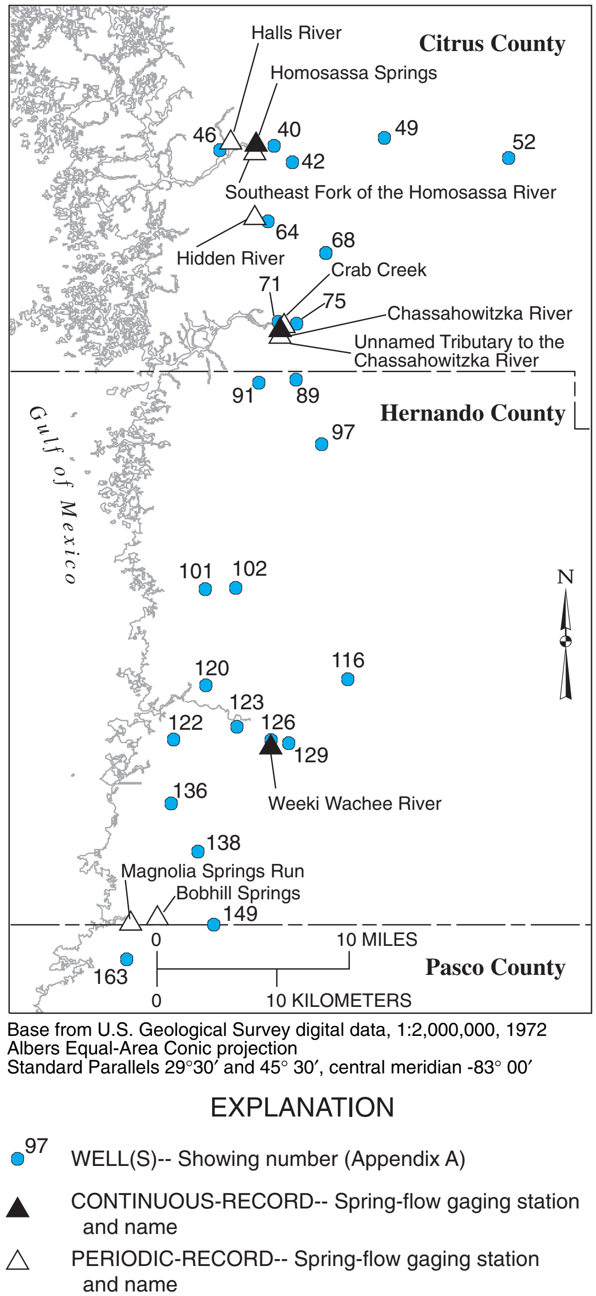


Figure 40. Index-site network.

Measurements of spring flow in the Chassahowitzka and Homosassa Springs Ground-Water Basins, made quarterly and spanning full and partial tidal cycles could provide the data needed to estimate spring flow. Single spring-flow measurements, measured quarterly at Magnolia Springs Run and Bobhill Springs gaging stations could be used to document flows in the Aripeka Springs Ground-Water Basin, and measured quarterly at Hidden River to document flows in the Homosassa Springs Ground-Water Basin.

In addition to the surface-water sites currently monitored in the Coastal Springs Ground-Water Basin, three additional sites could be continuously monitored to provide the stage records needed for estimating daily mean spring flow from tidal springs. The suggested index stations for collecting surface-water stage data are Homosassa Springs, Chassahowitzka River, and Gulf of Mexico near Bayport. Further evaluations of seasonal fluctuations in spring flow could be improved by collecting continuous stage data at all spring-flow gaging stations.

Hydrologic data collected from the index-site network could be used to: (1) provide delineations of ground-water flow around springs, (2) calculate daily mean spring flow from the largest and freshest springs in the basin, (3) provide input to statistical models, and (4) provide a mechanism to monitor long-term hydrologic change in the study area.

SUMMARY AND CONCLUSIONS

Hydrologic data, including ground-water levels in the Upper Floridan aquifer, surface-water stage, spring flow, and specific conductance of water from springs, were measured to define the hydrologic variability (temporally and spatially) in the Coastal Springs Ground-Water Basin and adjacent parts of Pasco, Hernando, and Citrus Counties. Additional hydrologic data, including rainfall and ground-water withdrawals, were used to calculate water budgets, to evaluate long-term change in hydrologic conditions, and to evaluate relations among the hydrologic components.

The Coastal Spring Ground-Water Basin encompasses the ground-water flow system of the Upper Floridan aquifer, which regionally discharges ground water to springs and seeps in the study area. During the investigation, anomalous hydrologic conditions existed, with low ground-water levels measured during the wet season in September 1997 and high levels measured during the dry season in May 1998. Continuous water-level records indicate that the magnitude in seasonal fluctuation in individual wells varied from about 10 ft to about 2 ft. Water-level hydrographs for the wells have comparable timing of the highs and lows and are similar in shape.

In the study area, Upper Floridan aquifer water levels control the magnitude of daily mean spring flow; at tidal springs, the diurnal range and duration of spring-pool stage affect the instantaneous spring flow.

Individual spring-flow measurements collected periodically were adequate to quantify the annual range in spring flow at nontidal springs. At tidal springs, however, multiple measurements of spring flow during a single day were needed. Generally, spring-pool stage is higher in the summer than in the winter, with the largest day-to-day fluctuations in the winter. Large winter fluctuations are probably caused by winds associated with tropical storms in the fall and frontal storms in the winter. Diurnal and seasonal fluctuations in ground-water levels and surface-water stage affect the daily mean spring flow.

Regression models were developed using ordinary least squares and multiple linear regression techniques. At nontidal springs, regression models used a single explanatory variable, ground-water level. The gaging stations included Bobhill Springs, Hidden River, and Weeki Wachee River. At tidal springs, regression models used two or three explanatory variables, ground-water level, surface-water level, and rate of change in stage. The gaging stations included Chassahowitzka River, Crab Creek, and Unnamed Tributary to Chassahowitzka River, and Homosassa Springs. At the Southeast Fork of the Homosassa River and Unnamed Tributary to Chassahowitzka River gaging stations, regression models used a single explanatory variable, spring flow at Homosassa Springs and Chassahowitzka River gaging station, respectively. Predictive equations were used to calculate daily mean spring flow.

Simple water budgets for the period from January 1997 through December 1998 were constructed for the four ground-water basins that form the Coastal Springs Ground-Water Basin. The four basins were defined by the potentiometric surface of the Upper Floridan aquifer. Ground-water and surface-water inflow were considered negligible. In the Coastal Springs Ground-Water Basin, rainfall is the only source of inflow; rainfall averaged about 55 in/yr. The sources of outflow are evapotranspiration (34 in/yr), runoff (8 in/yr), ground-water outflow from upward leakage (11 in/yr), and ground-water withdrawal (2 in/yr). Recharge (rainfall minus evapotranspiration) to the Upper Floridan aquifer consists of vertical leakage through the surficial deposits. Discharge is primarily through springs and diffuse upward leakage that maintains the extensive swamps along the Gulf of Mexico. The ground-water basins had slightly different partitioning of hydrologic components, reflecting variation among the regions. Runoff (spring flow) was lowest in the Aripeka Springs Ground-Water Basin. Evapotranspiration was low in the Weeki Wachee, Chassahowitzka, and Homosassa Springs Ground-Water Basins, coinciding with areas of sandy soils, deep water tables, and rapid infiltration in the scrub and high pine forest subregions. Ground-water withdrawals were low in the Homosassa Springs Ground-Water Basin because the basin is the least developed.

The evaluation of long-term changes in hydrologic conditions in the Coastal Springs Ground-Water Basin was based on period-of-record data sets. Complicating the evaluation was the differing periods of record for the various hydrologic components. Results from the Mann-Kendall test show that no statistically significant trends were detected in rainfall using nearly 100 years of record from three NOAA stations. Although monotonic trends were not detected, rainfall patterns are naturally variable from month to month and year to year. The variability in rainfall is reflected in the ground-water level and spring-flow responses exhibited on hydrographs. A long-term declining trend was detected in the 33 years of water-level records (1966-98) for the Weeki Wachee well. Although the trend was statistically significant at the 10-percent level, the R^2 value of 0.2 indicates a weak relation. A long-term trend was not detected in the 68 years of spring-flow records (1931-98) for the Weeki Wachee River gaging station. A long-term increasing trend was detected in the ground-water withdrawal records (1965-98) available for Pasco, Citrus, and Hernando Counties. The increase is nonlinear but the volume is a relatively small portion of the ground water in the hydrologic system.

The volume of rainfall that becomes recharge is affected by seasonal variations in plant dormancy and solar radiation complicating the linear relation between rainfall and ground-water level or spring flow. During 1997-98, the annual rainfall was nearly equal to the long-term annual average. A large portion of the annual rainfall fell during the winter of 1997-98, rapidly raising ground-water levels and spring flows. A 3-month drought in the spring of 1998 caused rapid declines in ground-water levels and spring flows. Large fluctuations (both rises and falls) have been observed in spring flow at Weeki Wachee Springs since 1995.

Lack of continuous long-term hydrologic data impedes detection of changes to the hydrologic system. The ongoing collection of hydrologic data from the index sites could provide much needed information to assess the hydrologic factors affecting the quantity and quality of spring flow.

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Appendix A

Well and Spring Network Used to Define the Potentiometric Surface of the Upper Floridan Aquifer

Appendix A. Well and spring network used to define the potentiometric surface of the Upper Floridan aquifer

[--, unknown; p, potentiometric-surface map well network; l, potentiometric-surface map well network (this study); s, spring; c, continuous well network (this study); n, continuous data well network; A, alternate well; locations shown in figure 8]

Map number	Identification number	Station name	Type	Depth, in feet	Casing, in feet	County	Field number
1	290216082292001	QW observation well (USGS CE-77)	p	190	--	Citrus	--
2	290132082324201	Emory Cowart well SR 488 West of Dunnellon	p	203	--	Citrus	--
3	290107082400501	US 19/98 North of Cross FL Barge C. (USGS CE-88)	p	58	--	Citrus	--
4	290023082393601	US 19/98 South of Cross FL Barge C. (USGS CE-89)	p	30	--	Citrus	--
5	285951082350901	SR 488 east of Red Level (USGS CE-6)	p	68	--	Citrus	--
6	285935082324501	Melody Johnson	p	176	--	Citrus	--
7	285930082283702	Citrus Springs Golf Course	p	102	--	Citrus	--
8	285833082233301	CE 16 at SR 491 east of Holder	p	--	--	Citrus	--
9	285812082360901	USGS CE 7	p	64	--	Citrus	--
10	285737082413001	FPC Well 2 (Destroyed)	p	47	42	Citrus	--
11	285737082400601	FPC Well 3	p	88	67	Citrus	--
12	285720082201301	ROMP 116 Deep Well	p	55	39	Citrus	--
13	285608082233401	Camp Mining Well (CE-46)	p	91	--	Citrus	--
14	285612082294201	Pine Ridge Well 3	p	200	--	Citrus	--
15	285514082275401	Beverly Hills Well 6-T	p	176	--	Citrus	--
16	285414082284201	North Lecanto Well	p	335	288	Citrus	--
17	285421082361601	Crystal River Deep Well	p	176	162	Citrus	--
18	285234082341901	ROMP TR 21-3	p	252	240	Citrus	--
19	285254082323001	Lecanto Well 7	p	30	20	Citrus	--
20	285112082354401	ROMP TR 21-2 Deep Well	p	111	105	Citrus	77
21	285102082361001	Ozello Well 4	p	75	60	Citrus	76
22	285020082365301	Ozello Well 3	p	41	39	Citrus	75
23	285248082183201	Elmer Heath	p	53	--	Citrus	--
24	285124082245601	ROMP 113	p	150	130	Citrus	--
25	285037082213801	Inverness Village East well	p	--	--	Citrus	--
26	285102082204001	DOT-41 Well at Inverness	p	450	290	Citrus	--
27	284958082190401	SR44 County Park (USGS Citrus 8)	p	48	--	Citrus	--
28	285026082174101	SR44 east of Inverness (USGS Citrus 9)	p	40	--	Citrus	--
29	285056082163001	USGS Citrus 10	p	37	--	Citrus	--
30	285105082135801	USGS on SR 44 West of Withlacoochee River (Citrus 11)	p	31	--	Citrus	--
31	285000082350601	Atlas Drive Storage Well	l	--	--	Citrus	72a
32	285000082342901	FWS Crystal River (Stonebrook-6") (A)	l	--	--	Citrus	73
32	285000082342902	FWS Crystal River (Stonebrook-4")	l	--	--	Citrus	74
33	284935082345000	Halls River Head Spring	s	--	--	Citrus	72
34	284919082344701	South of Abandoned Building Well	l	40	--	Citrus	71g
35	284840082343301	Homosassa Springs Chamber of Commerce	l	--	--	Citrus	71f
36	284825082342501	Fire Station Number 91 Well	l	--	--	Citrus	71e
37	284818082343201	Little Inn Restaurant Well Northeast (A)	l	--	--	Citrus	71d
38	284815082343401	Little Inn Restaurant Well Southwest	l	--	--	Citrus	71c
39	284758082340902	FWS Spring Garden WTF West Well (A)	l	--	--	Citrus	70a
39	284758082340901	FWS Spring Garden WTF East Well	l	--	--	Citrus	70a
40	284759082344101	Homosassa Springs Visitor Center Well (CSPR-1)	c	61	52	Citrus	80
41	284733082342101	New Covenant Church (DKY 34) (A)	l	--	--	Citrus	70
42	284731082340601	Pizza Hut North of Green Acres Street	l	--	--	Citrus	69
43	284803082351701	Norris Cattle Company Well	p	50	44	Citrus	71
44	284751082352301	Southeast Fork of the Homosassa River (02310688)	s	--	--	Citrus	71a
45	284804082361001	Halls River at 490A Bridge (02310690)	s	--	--	Citrus	71b

Appendix A. Well and spring network used to define the potentiometric surface of the Upper Floridan aquifer (Continued)

[--, unknown; p, potentiometric-surface map well network; l, potentiometric-surface map well network (this study); s, spring; c, continuous well network (this study); n, continuous data well network; A, alternate well; locations shown in figure 8]

Map number	Identification number	Station name	Type	Depth, in feet	Casing, in feet	County	Field number
46	284752082362501	Nature's Resort Well (CSPR-4)	c	43	18	Citrus	79
47	284653082364701	Old Dug Well at Riverworks Gallery	l	20	--	Citrus	70b
48	284816082313401	Grover Cleveland Road Well (destroyed)	l	--	--	Citrus	64d
49	284814082311401	4046 S Jody Point Road (Jackson's)	l	--	--	Citrus	64e
50	284755082285601	Homosassa Fire Station Number 93 (on CR 491)	l	--	--	Citrus	64b
51	284844082282801	WSF-Perryman Tract	p	--	--	Citrus	
52	284736082271101	Withlacoochee State Forest Well (CSPR-2)	l	95	55	Citrus	64f
53	284707082270501	Pecan Grove at Renab Ranch (Replaced by 52)	l	--	--	Citrus	64a
54	284805082225701	WSF-Holder Mine Recreation Area	p	--	--	Citrus	--
55	284752082202501	Highlands VFD	p	114	--	Citrus	--
56	284439082131401	Trails End Fish Camp Well	p	30	--	Citrus	--
57	284519082150701	Lammlein Well (Homer N Fisher)	p	60	--	Citrus	--
58	284508082174601	Ferris Packing Company Well	p	400	200	Citrus	--
59	284528082211801	WSF-Mutual Mine Recreation Area	p	--	--	Citrus	--
60	284513082215401	ROMP 110 Flying Eagle Deep	p	260	--	Citrus	--
61	284330082215401	ROMP 109 nr Floral City	p	260	189	Citrus	--
62	284339082270401	Lecanto Well 1	p	168	--	Citrus	64c
63	284532082371001	Homosassa Well 1	p	45	39	Citrus	66
64	284551082345301	Homosassa Well 3	c	99	82	Citrus	67
65	284534082343301	Bell Coupling Well nr Homosassa Well 3	l	21	--	Citrus	67a
66	284614082332901	Rooks Industrial Park Well (Servos)	l	--	--	Citrus	68
67	284517082331301	US 19 North of Whispering Pines MHP	l	--	--	Citrus	65
68	284457082330301	Sugarmill MZ1 Deep	l	155	75	Citrus	64
68	284457082330302	Sugarmill MZ1 Shallow	l	358	340	Citrus	64
69	284412082330501	US 19 South of Firetower	l	--	--	Citrus	63
70	284313082343501	Lykes Campground Well	l			Citrus	61
71	284300082343400	Crab Creek (02310652)	s	--	--	Citrus	60
71	284310082343401	Chassahowitzka River Deep Well	c	75	25	Citrus	61a
72	284254082343500	Chassahowitzka River (02310650)	s	--	--	Citrus	58
73	284230082344000	Baird Creek Head Spring	s	--	--	Citrus	58a
74	284246082340801	Chassahowitzka Fire Station Number 11	l	--	--	Citrus	57
75	284257082335901	P R Wylie Trailer	l	--	--	Citrus	59
76	284317082330601	Chassahowitzka Well 1	n	176	166	Citrus	62
77	284242082315801	Oak Village North West at Oak Village Boulvard	l	--	--	Citrus	56b
78	284320082302701	Southern Woods Country Club Number 2 (East Well)	l	--	--	Citrus	63a
79	284219082311801	FWS Sugarmill Woods Production 9 (A)	l	--	--	Citrus	56
80	284212082311301	Oak Village South East at Greenpark Boulevard	l	--	--	Citrus	56a
81	284101082184301	Oak Forest Submersible	p	274	--	Citrus	--
82	283957082181001	W A Blizzard	p	140	--	Hernando	137
83	283840082154801	Barnhart Well (CE-25)	p	140	--	Hernando	128
84	283806082214801	Eden Christian School	p	155	--	Hernando	136
85	283924082272301	ROMP 107 Deep Well	p	240	140	Hernando	56e
86	284023082290101	Landfill Road Well	l	--	--	Hernando	56f
87	284036082285701	World of Woods (lost)	l	--	--	Hernando	56d
88	284120082300401	Seville Golf 4-inch Well	l	--	--	Hernando	56c
89	284122082340101	McKnight Well (18355 Retriever Road)	l	95	--	Hernando	53
90	284133082350600	Rita Maria Spring	s	--	--	Hernando	52a
91	284117082351301	Rita Maria Springs Well	l	72	--	Hernando	52

Appendix A. Well and spring network used to define the potentiometric surface of the Upper Floridan aquifer (Continued)

[--, unknown; p, potentiometric-surface map well network; l, potentiometric-surface map well network (this study); s, spring; c, continuous well network (this study); n, continuous data well network; A, alternate well; locations shown in figure 8]

Map number	Identification number	Station name	Type	Depth, in feet	Casing, in feet	County	Field number
92	284130082353500	Beteejay Springs	s	--	--	Hernando	54
92	284130082353501	Beteejay Springs Floridan Well	l	60	--	Hernando	55
93	284115082353501	Beteejay Springs Well 2 (by barn; A)	l	--	--	Hernando	55a
94	284113082360600	Blue Run Head Spring	s	--	--	Hernando	55b
95	284020082330501	Seville Subdivision Entrance	l	--	--	Hernando	51
96	284020082320301	Seville Subdivision East	l	--	--	Hernando	51a
97	283932082331301	ROMP TR 20-3 South Well	l	--	--	Hernando	50a
98	283901082331101	House West of US 19 and South of Thrasher Road.	l	--	--	Hernando	50
99	283653082324601	Centralia Road	l	109	--	Hernando	49
100	283650082313301	ROMP Centralia Deep Well	n	170	122	Hernando	48
101	283527082365701	Weeki Well 2	l	125	123	Hernando	45
102	283529082355801	Weeki Well 3	l	140	133	Hernando	46
103	283558082330101	Terranova Construction (DKY 10)	l	--	--	Hernando	47
104	283321082241601	ROMP 105 Deep Well at Brooksville	p	706	700	Hernando	125
104	283321082241602	ROMP 105 Avon Park Well at Brooksville	p	490	--	Hernando	125
105	283508082215101	Clarence Smith	p	361	--	Hernando	133
106	283613082184301	Delmas C Nix	p	219	--	Hernando	135
107	283527082151501	ROMP 103 (Croom Road)	p	198	111	Hernando	126
108	283510082133701	Croom RR Siding Well	p	360	--	Hernando	134
109	282851082035301	E H Boyette	p	83	--	Hernando	137a
110	283001082064701	WSF-Richloam Fire Tower	p	97	--	Hernando	131
111	283036082105501	ROMP 99x (Ridge Manor)	p	222	143	Hernando	127
112	283108082123401	Le Compte Well	p	--	--	Hernando	132
113	283358082333701	Glen Lake Home Owners	l	--	--	Hernando	44
114	283313082350101	ROMP TR 19-3 Deep Well	p	604	440	Hernando	43
115	283243082334901	8200 US 19 North of Ridge Road (Car Lot)	l	--	--	Hernando	37
116	283253082322401	West Hernando Monitor 1	l	392	377	Hernando	41
117	283250082322701	West Hernando Production 3	l	--	--	Hernando	40
118	283201082315601	Weeki Wachee Well	n	259	176	Hernando	34
119	283246082370900	Salt Spring nr Weeki Wachee	s	--	--	Hernando	39
120	283243082365701	ROMP TR 19-2 Deep Well	c	302	277	Hernando	38
121	283203082370201	Presbyterian Youth Camp	l	75	66	Hernando	35
122	283112082375801	Jenkins Creek Deep Well (CSPR-6)	c	98	46	Hernando	23a
123	283133082355701	Weeki Wachee Campgrounds (River Run Subdivision)	l	55	--	Hernando	32
124	283149082354501	The Cole's Well (7159 Cyclops, WW Gardens)	l	--	--	Hernando	36
125	283116082350401	Indian Village Well (Lost)	l	--	--	Hernando	31
126	283110082345201	USGS Weeki Wachee River Gage 4-Inch Well	l	--	--	Hernando	30
127	283143082340601	Friendly Mini Mart (7068 US 19)	l	--	--	Hernando	33
128	283111082341001	Weeki Wachee Center Well (NE Corner US 19 and SR 50)	l	--	--	Hernando	34a
129	283104082341801	Weeki Wachee Springs Well	c	--	--	Hernando	29
130	283100082342501	Weeki Wachee Springs (02310500)	s	--	--	Hernando	123
131	283050082343601	Weeki Wachee Spring Attraction Old Maintenance Building	l	--	--	Hernando	31a
132	283043082344101	Weeki Wachee F	l	--	--	Hernando	28
133	283011082352101	Village Square Center Well	l	--	--	Hernando	27
134	282936082331801	Deltona Corporation Well 13 (FWS Spring Hill 13)	l	484	245	Hernando	16
135	282932082355001	Forest Oaks Center	l	--	--	Hernando	15
136	282923082380301	Hernando Beach Supply Well	l	180	--	Hernando	26
137	282848082363501	First Federal Savings (Living Waters Church)	l	--	--	Hernando	14

Appendix A. Well and spring network used to define the potentiometric surface of the Upper Floridan aquifer (Continued)

[--, unknown; p, potentiometric-surface map well network; l, potentiometric-surface map well network (this study); s, spring; c, continuous well network (this study); n, continuous data well network; A, alternate well; locations shown in figure 8]

Map number	Identification number	Station name	Type	Depth, in feet	Casing, in feet	County	Field number
138	282801082371301	McDonalds North of CR 595 (Timberlakes)	l	--	--	Hernando	13
139	282742082375901	ROMP TR 18-1 Deep Well	n	580	445	Hernando	25
140	282659082391101	ROMP TR 18-2 Lake City	n	790	760	Hernando	24
140	282659082391102	ROMP TR 18-2 Lower Avon Park	p	525	505	Hernando	24
140	282659082391104	ROMP TR 18-2 Upper Avon Park	p	480	447	Hernando	24
141	282657082394801	Indian Creek Well (2 inch)	l	52	--	Hernando	23
142	282600082392600	Magnolia Springs Run (South Prong Hammock Creek)	s	--	--	Pasco	18a
143	282558082392600	Magnolia Springs	s	--	--	Hernando	19a
144	282602082392201	Boat Springs 2-Inch Well	l	32	--	Pasco	18
145	282605082391201	Magnolia Springs Well (Ralstons)	l	110	84	Hernando	19
146	282553082382901	Rainbow Oaks Entrance Well (South of County Line)	l	--	--	Pasco	20a
147	282607082383400	Bobhill Springs (02310405)	s	--	--	Hernando	20
147	282607082383401	Bobhill Springs Well (A)	l	180	--	Hernando	21
148	282613082381701	ROMP TR 18-3 (Floridan) Well	n	378	58	Hernando	22
148	282613082381702	ROMP TR 18-3 (Upper Avon Park) Well	n	510	480	Hernando	22
149	282557082364301	County Line Trade Center	l	--	--	Pasco	11
150	282605082345801	ROMP 97 Deep Well	n	355	310	Hernando	12
151	282602082325801	Seven Hills Well	l	--	--	Hernando	12a
152	282552082314201	Gooch Deep	p	120	92	Pasco	--
153	282540082275701	Masaryktown Deep	p	82	29	Pasco	--
154	282636082221401	Weeki Wachee Well 11	n	69	68	Hernando	124
155	282620082193801	82621901	p	--	--	Hernando	129
156	282839082190801	Russell Blackett well nr Lake Neff	p	428	--	Hernando	130
157	282717082142001	Rossini Well West of Trilby	p	275	--	Pasco	--
158	282816082123701	Tomkow Hay Barn Well	p	--	--	Pasco	--
159	282430082112101	Self Well	p	--	--	Pasco	--
160	282428082134501	Lee Well	p	738	--	Pasco	--
161	282434082200301	Travelers Rest Floridan (Airstream)	p	138	90	Pasco	--
162	282434082283601	D A Sutyak Deep	p	82	--	Pasco	--
163	282458082393001	Aripeka Well nr Aripeka (CSPR-7)	l	110	60	Pasco	17c
164	282452082394100	Isabella Spring	s	--	--	Pasco	17a
165	282442082391301	Proposed Seabird Sanctuary	l	--	--	Pasco	17b
166	282414082392301	Wellwood Funeral Home	l	190	147	Pasco	17
167	282238082362101	Justice Deep nr Hudson	p	110	63	Pasco	10
168	282229082405801	Coastal Pasco Deep Well 2	p	178	156	Pasco	9
169	282152082421100	Hudson Springs	s	--	--	Pasco	8
170	281954082413401	Ponderosa Development Deep	p	100	42	Pasco	6
171	281948082415301	Withlacoochee Electric Well 1	p	94	84	Pasco	5
172	281917082420901	ROMP TR 17-1 Deep Well at Bayonet Point	p	139	131	Pasco	3
173	281922082403901	ROMP TR 17-3 Deep Well nr Bayonet Point	p	200	185	Pasco	4
174	282009082373801	State Highway 52 Deep (nr Hudson)	p	73	59	Pasco	7
175	281949082332001	State Highway 52 (nr Fivay Junction)	n	73	60	Pasco	--
176	282044082312401	H Kent Grove Deep Well	p	650	--	Pasco	--
177	282154082142401	Haycraft Well	p	--	--	Pasco	--
178	282259082104101	Lykes Pasco nr Dade	p	36	--	Pasco	--
179	282221082103001	Collura Well 1	p	30	--	Pasco	--
180	282121082071101	Cummer Office Well	p	--	--	Pasco	--
181	282005082112801	Stearns Well	p	565	--	Pasco	--

Appendix A. Well and spring network used to define the potentiometric surface of the Upper Floridan aquifer (Continued)

[--, unknown; p, potentiometric-surface map well network; l, potentiometric-surface map well network (this study); s, spring; c, continuous well network (this study); n, continuous data well network; A, alternate well; locations shown in figure 8]

Map number	Identification number	Station name	Type	Depth, in feet	Casing, in feet	County	Field number
182	281926082212901	Junction of State Highways 52 and 581 Well	n	113	83	Pasco	--
183	281923082252001	ROMP 93 Deep	p	700	149	Pasco	--
184	281918082264601	State Highway 52 (nr Growers Corne)	n	73	38	Pasco	--
185	281745082255001	Starling DeepWell 809	p	678	139	Pasco	--
186	281631082261601	Catchings Deep Well 849	p	118	36	Pasco	--
187	281558082264601	Pasco Well 13	n	49	43	Pasco	--
188	281435082260101	ROMP 84 Floridan	p	666	90	Pasco	--
189	281437082271401	Nininger Deep Well 857	p	165	60	Pasco	--
190	281448082301801	Bexley Well 2	n	743	44	Pasco	--
191	281636082372001	Moon Lake Deep	n	115	65	Pasco	--
192	281734082430600	Salt Springs at Port Richey	s	--	--	Pasco	2
193	281642082440201	Coastal Pasco Deep Well 4	p	75	68	Pasco	1
194	281518082424301	ROMP TR16-2 Suwannee Well	p	230	--	Pasco	--
194	281518082424302	ROMP TR16-2 Avon Park Well	p	475	--	Pasco	--
195	281046082470801	FPC Well 1	p	159	146	Pasco	--
196	281023082450701	Coastal Pasco Deep Well 13	p	188	176	Pasco	--
197	281222082393401	Seven Springs Deep	p	301	76	Pasco	--
198	281124082353001	Swains Well	n	316	65	Pasco	--
199	281103082322601	Doyles Ranch Deep	p	438	38	Pasco	--
200	281321082294201	Bexley Deep Well 225	p	--	--	Pasco	--
201	281124082274101	Winter Quarters MHP	p	435	258	Pasco	--
202	281155082235401	King Deep Well (Floridan)	p	550	120	Pasco	--
203	281112082211301	Immer Deep Well nr Peble Creek	p	256	--	Pasco	--
204	281435082221301	Angus Valley Floridan	p	366	--	Pasco	--
205	281424082192702	ROMP 85 Floridan Well	n	300	160	Pasco	--
206	281548082220601	Moehle Well (815 222)	p	107	40	Pasco	--
207	281654082201601	Carr Deep Well 846	p	230	185	Pasco	--
208	281715082164401	State Highway 577 (Deep)	n	150	57	Pasco	--
209	281504082104801	ROMP 86 Avon Park Well	p	434	425	Pasco	--
210	281704082085201	Richland Baptist Church Well	p	--	--	Pasco	--
211	281654082065901	US 98 nr Dade City	p	200	41	Pasco	--
212	281037082071801	J O Alston Well	p	55	47	Pasco	--

Appendix B

Spring Flow From Selected Springs and Ancillary Data Including Stage, Specific Conductance, and Ground-Water Levels

Appendix B. Spring flow from selected springs and ancillary data including stage, specific conductance, and ground-water levels

[µS/cm, microsiemens per centimeter; specific conductance*, sampling location changed; Q, discharge in cubic feet per second; Q*, measurement location changed; 18-3 fld, Regional Observation Monitor-Well Program (ROMP) TR18-3 Floridan well; --, no data; locations shown in figures 8 and 9]

Date	Time	Stage, in feet above or below sea level	Specific conductance, in µS/cm	Specific conductance,* in µS/cm	Stage change, in feet	Water level, in feet above sea level, in alternate well	Water level, in feet above sea level, in Weeki Wachee well	Q	Q*
					Bobhill Springs (02310405)[1]				
						18-3 fld[2]			
01/08/1961	--	--	--	--	--	--	--	3.5	--
05/16/1962	--	--	76	--	--	--	--	--	--
07/23/1964	--	6.63	--	--	--	--	--	3.14	--
10/13/1964	--	6.68	210	--	--	--	--	3.71	--
02/04/1965	--	6.66	--	--	--	--	--	3.3	--
08/06/1965	--	6.61	215	--	--	--	--	4.43	--
12/15/1972	--	6.28	246	--	--	--	16.2	2	--
05/28/1981	--	6.23	--	--	--	--	13.9	0.19	--
03/28/1988	--	6.45	243	--	--	13.34	19.37	2.27	--
05/24/1988	--	6.31	--	--	--	12.35	17.95	1.49	--
09/22/1988	--	6.60	--	--	--	15.08	22.89	3.35	--
10/17/1988	--	6.46	247	--	--	14.37	22.24	2.81	--
12/08/1988	--	--	249	--	--	14.32	20.95	2.87	--
01/20/1997	--	6.39	258	--	--	11.43	15.45	0.8	--
03/26/1997	--	6.39	273	--	--	11.06	14.13	0.88	--
06/03/1997	--	6.32	258	--	--	10.92	13.66	0.6	--
09/08/1997	--	6.08	--	--	--	10.11	13.89	0	--
11/06/1997	--	6.36	280	--	--	11.27	14.88	1.2	--
01/13/1998	--	6.50	272	--	--	13.14	19.14	2.11	--
02/23/1998	--	6.75	274	--	--	15.05	21.84	3.56	--
05/15/1998	--	6.48	264	--	--	13.89	20.96	2.7	--
06/16/1998	--	6.45	256	--	--	13.11	19.68	2.15	--
09/14/1998	--	6.62	265	--	--	14.02	19.54	2.67	--
					Magnolia Springs Run (282600082392600)[1]				
01/17/1997	--	3.8	985	--	--	--	15.53	9.21	--
03/26/1997	--	3.87	1,090	--	--	--	14.13	9.38	--
06/04/1997	--	3.68	1,200	--	--	--	13.62	6.3	--
01/13/1998	--	3.8	1,020	--	--	--	17.18	9.48	--
05/15/1998	--	3.85	650	--	--	--	20.96	10.4	--
09/15/1998	--	3.78	700	--	--	--	19.53	9.48	--
					Weeki Wachee River (02310500; 02310525[3])[1]				
08/15/1966	--	--	--	--	--	--	19.5	194	--
10/21/1966	--	--	--	--	--	--	21.8	218	--
11/17/1966	--	--	--	--	--	--	21.4	209	--
01/06/1967	--	--	--	--	--	--	20.2	203	--
02/24/1967	--	--	--	--	--	--	19.6	193	--
04/20/1967	--	--	--	--	--	--	18.3	181	--
06/22/1967	--	--	--	--	--	--	17	170	--
07/25/1967	--	--	--	--	--	--	16.9	172	--
10/12/1967	--	--	--	--	--	--	20.6	203	--

Appendix B. Spring flow from selected springs and ancillary data including stage, specific conductance, and ground-water levels (Continued)

[µS/cm, microsiemens per centimeter; specific conductance*, sampling location changed; Q, discharge in cubic feet per second; Q*, measurement location changed; 18-3 fld, Regional Observation Monitor-Well Program (ROMP) TR18-3 Floridan well; --, no data; locations shown in figures 8 and 9]

Date	Time	Stage, in feet above or below sea level	Specific conductance, in µS/cm	Specific conductance,* in µS/cm	Stage change, in feet	Water level, in feet above sea level, in alternate well	Water level, in feet above sea level, in Weeki Wachee well	Q	Q*
10/31/1967	--	--	--	--	--	--	19.9	179	--
12/19/1967	--	--	--	--	--	--	18.5	185	--
02/28/1968	--	--	--	--	--	--	16.7	140	--
03/21/1968	--	--	--	--	--	--	16.5	163	--
05/01/1968	--	--	282	--	--	--	15.8	155	--
06/19/1968	--	--	--	--	--	--	15.1	139	--
07/16/1968	--	--	--	--	--	--	16.4	158	--
08/28/1968	--	--	--	--	--	--	18.2	191	--
10/09/1968	--	--	--	--	--	--	20.4	215	--
11/19/1968	--	--	--	--	--	--	20.3	202	--
01/23/1969	--	--	--	--	--	--	18.7	198	--
03/04/1969	--	--	--	--	--	--	17.9	186	--
04/03/1969	--	--	--	--	--	--	18.7	202	--
05/13/1969	--	--	275	--	--	--	18.2	181	--
06/26/1969	--	--	--	--	--	--	17.9	177	--
08/11/1969	--	--	--	--	--	--	17.6	196	--
09/16/1969	--	--	--	--	--	--	21.2	229	--
10/27/1969	--	--	--	--	--	--	22.1	242	--
12/09/1969	--	--	--	--	--	--	21.1	220	--
01/19/1970	--	--	--	--	--	--	21.3	217	--
03/03/1970	--	--	--	--	--	--	21.9	223	--
04/14/1970	--	--	--	--	--	--	21.7	226	--
06/02/1970	--	--	272	--	--	--	20.7	201	--
07/07/1970	--	--	--	--	--	--	20.5	218	--
08/17/1970	--	--	--	--	--	--	20.7	224	--
09/29/1970	--	--	--	--	--	--	22	235	--
11/02/1970	--	--	--	--	--	--	21.3	197	--
12/14/1970	--	--	288	--	--	--	20.2	191	--
01/25/1971	--	--	270	--	--	--	19.1	197	--
03/15/1971	--	--	258	--	--	--	19	181	--
04/19/1971	--	--	282	--	--	--	18.6	179	--
06/15/1971	--	--	272	--	--	--	17.5	173	--
07/12/1971	--	--	303	--	--	--	17.1	181	--
08/30/1971	--	--	--	--	--	--	18.1	182	--
10/06/1971	--	--	--	--	--	--	19.9	166	--
11/17/1971	--	--	273	--	--	--	19.6	193	--
01/03/1972	--	--	243	--	--	--	18.6	192	--
02/16/1972	--	--	--	--	--	--	17.7	164	--
03/20/1972	--	--	--	--	--	--	17.4	179	--
05/10/1972	--	--	272	--	--	--	17.7	189	--
06/21/1972	--	--	280	--	--	--	17.5	174	--
07/31/1972	--	--	355	--	--	--	17.3	160	--
09/20/1972	--	--	--	--	--	--	17	155	--

Appendix B. Spring flow from selected springs and ancillary data including stage, specific conductance, and ground-water levels (Continued)

[µS/cm, microsiemens per centimeter; specific conductance*, sampling location changed; Q, discharge in cubic feet per second; Q*, measurement location changed; 18-3 fld, Regional Observation Monitor-Well Program (ROMP) TR18-3 Floridan well; --, no data; locations shown in figures 8 and 9]

Date	Time	Stage, in feet above or below sea level	Specific conductance, in µS/cm	Specific conductance,* in µS/cm	Stage change, in feet	Water level, in feet above sea level, in alternate well	Water level, in feet above sea level, in Weeki Wachee well	Q	Q*
11/15/1972	--	--	239	--	--	--	16.3	150	--
01/08/1973	--	--	280	--	--	--	16.9	171	--
03/07/1973	--	--	281	--	--	--	16.7	158	--
04/30/1973	--	--	259	--	--	--	17.2	170	--
06/29/1973	--	--	310	--	--	--	16.3	153	--
08/21/1973	--	--	--	--	--	--	16.2	164	--
10/25/1973	--	--	268	--	--	--	15.8	148	--
12/13/1973	--	--	258	--	--	--	15.3	140	--
02/12/1974	--	--	265	--	--	--	15	138	--
04/04/1974	--	--	284	--	--	--	15	144	--
05/28/1974	--	--	297	--	--	--	14.5	135	--
07/31/1974	--	--	283	--	--	--	22.3	242	--
09/17/1974	--	--	274	--	--	--	23.8	248	--
10/29/1974	--	--	--	--	--	--	22.8	235	--
12/29/1974	--	--	222	--	--	--	20.8	206	--
02/28/1975	--	--	289	--	--	--	19.1	188	--
04/28/1975	--	--	272	--	--	--	17.5	173	--
06/24/1975	--	--	270	--	--	--	16.5	155	--
09/02/1975	--	--	251	--	--	--	17	184	--
11/03/1975	--	--	265	--	--	--	18.6	146	--
12/11/1975	--	--	--	--	--	--	18.1	176	--
01/06/1976	--	--	300	--	--	--	17.6	169	--
03/01/1976	--	--	--	--	--	--	16.5	154	--
05/03/1976	--	--	258	--	--	--	15.4	136	--
07/01/1976	--	--	321	--	--	--	17.6	174	--
08/03/1976	--	--	--	--	--	--	19.7	201	--
08/31/1976	--	--	--	--	--	--	19.9	185	--
11/06/1976	--	--	--	--	--	--	18.9	167	--
01/12/1977	--	--	--	--	--	--	18	168	--
03/01/1977	--	--	282	--	--	--	17.2	154	--
05/02/1977	--	--	300	--	--	--	16.41	140	--
06/29/1977	--	--	420	--	--	--	15.26	138	--
08/31/1977	--	--	298	--	--	--	18.27	186	--
09/07/1977	--	--	--	--	--	--	18.62	195	--
10/31/1977	--	--	277	--	--	--	17.97	176	--
01/03/1978	--	--	285	--	--	--	16.84	143	--
03/10/1978	--	--	300	--	--	--	17.23	160	--
05/08/1978	--	--	300	--	--	--	17	150	--
06/28/1978	--	--	267	--	--	--	16.25	154	--
11/07/1978	--	--	--	--	--	--	18.13	153	--
01/11/1979	--	--	270	--	--	--	16.49	159	--
03/01/1979	--	--	275	--	--	--	16.13	148	--
05/03/1979	--	--	295	--	--	--	15.5	151	--
06/28/1979	--	--	275	--	--	--	16.04	150	--

Appendix B. Spring flow from selected springs and ancillary data including stage, specific conductance, and ground-water levels (Continued)

[µS/cm, microsiemens per centimeter; specific conductance*, sampling location changed; Q, discharge in cubic feet per second; Q*, measurement location changed; 18-3 fld, Regional Observation Monitor-Well Program (ROMP) TR18-3 Floridan well; --, no data; locations shown in figures 8 and 9]

Date	Time	Stage, in feet above or below sea level	Specific conductance, in µS/cm	Specific conductance,* in µS/cm	Stage change, in feet	Water level, in feet above sea level, in alternate well	Water level, in feet above sea level, in Weeki Wachee well	Q	Q*
09/05/1979	--	--	277	--	--	--	17.85	182	--
10/31/1979	--	--	276	--	--	--	20.2	201	--
01/09/1980	--	--	291	--	--	--	18.57	189	--
03/04/1980	--	--	270	--	--	--	17.33	171	--
05/08/1980	--	--	270	--	--	--	16.23	149	--
07/09/1980	--	--	295	--	--	--	15.88	168	--
09/09/1980	--	--	245	--	--	--	16.84	139	--
11/05/1980	--	--	270	--	--	--	16.21	149	--
01/08/1981	--	--	270	--	--	--	15.8	142	--
03/04/1981	--	--	286	--	--	--	15.5	130	--
05/05/1981	--	--	280	--	--	--	15.19	125	--
06/29/1981	--	--	272	--	--	--	14.35	107	--
09/01/1981	--	--	282	--	--	--	14.73	137	--
11/09/1981	--	--	290	--	--	--	16.01	145	--
01/14/1982	--	--	--	--	--	--	15.57	158	--
03/08/1982	--	--	285	--	--	--	15.34	117	--
05/06/1982	--	--	295	--	--	--	16.32	136	--
07/12/1982	--	--	275	--	--	--	19.04	192	--
09/27/1982	--	--	--	--	--	--	23.19	257	--
11/03/1982	--	--	275	--	--	--	23.27	216	--
12/15/1982	--	--	--	--	--	--	21.86	201	--
03/04/1983	--	--	265	--	--	--	20.65	203	--
05/05/1983	--	--	265	--	--	--	20.96	206	--
07/07/1983	--	--	265	--	--	--	20.34	190	--
09/08/1983	--	--	275	--	--	--	22.45	220	--
11/04/1983	--	--	--	--	--	--	22.7	227	--
01/05/1984	--	--	360	--	--	--	21.89	215	--
03/25/1984	--	--	--	--	--	--	20.98	207	--
05/08/1984	--	--	--	--	--	--	20.47	229	--
08/31/1984	--	--	300	--	--	--	23.9	271	--
11/07/1984	--	--	280	--	--	--	21.65	238	--
01/14/1985	--	--	--	--	--	--	19.59	209	--
03/06/1985	--	--	280	--	--	--	18.17	155	--
05/01/1985	--	--	295	--	--	--	16.84	171	--
07/02/1985	--	--	280	--	--	--	16.12	164	--
09/13/1985	--	--	300	--	--	--	22.55	255	--
11/05/1985	--	--	280	--	--	--	21.5	192	--
01/09/1986	--	--	275	--	--	--	19.43	199	--
03/06/1986	--	--	275	--	--	--	18.43	166	--
05/07/1986	--	--	300	--	--	--	17.76	166	--
07/09/1986	--	--	--	--	--	--	17.35	185	--
09/02/1986	--	--	283	--	--	--	19.33	174	--
11/06/1986	--	--	275	--	--	--	20.19	216	--

Appendix B. Spring flow from selected springs and ancillary data including stage, specific conductance, and ground-water levels (Continued)

[µS/cm, microsiemens per centimeter; specific conductance*, sampling location changed; Q, discharge in cubic feet per second; Q*, measurement location changed; 18-3 fld, Regional Observation Monitor-Well Program (ROMP) TR18-3 Floridan well; --, no data; locations shown in figures 8 and 9]

Date	Time	Stage, in feet above or below sea level	Specific conductance, in µS/cm	Specific conductance,* in µS/cm	Stage change, in feet	Water level, in feet above sea level, in alternate well	Water level, in feet above sea level, in Weeki Wachee well	Q	Q*
01/07/1987	--	--	275	--	--	--	18.47	182	--
03/04/1987	--	--	285	--	--	--	17.41	155	--
05/14/1987	--	--	290	--	--	--	19.43	143	--
07/09/1987	--	--	280	--	-	--	19.55	196	--
09/03/1987	--	--	270	--	--	--	19.54	182	--
11/06/1987	--	--	285	--	--	--	18.49	168	--
04/06/1988	--	--	278	--	--	--	19.3	182	--
06/22/1988	--	--	--	--	--	--	17.09	146	--
08/10/1988	--	--	290	--	--	--	16.7	164	--
10/19/1988	--	--	290	--	--	--	22.18	221	--
12/14/1988	--	--	285	--	--	--	20.78	199	--
02/15/1989	--	--	280	--	--	--	19.02	174	--
04/13/1989	--	--	280	--	--	--	17.61	171	--
06/14/1989	--	--	285	--	--	--	16.41	154	--
08/09/1989	--	--	286	--	--	--	17.45	176	--
10/11/1989	--	--	--	--	--	--	17.74	179	--
12/13/1989	--	--	287	--	--	--	16.4	167	--
02/14/1990	--	--	291	--	--	--	15.95	145	--
04/11/1990	--	--	288	--	--	--	15.72	147	--
06/13/1990	--	--	--	--	--	--	14.71	134	--
08/22/1990	--	--	288	--	--	--	16.88	159	--
11/16/1990	--	--	--	--	--	--	16.07	147	--
01/29/1991	--	--	--	--	--	--	14.5	133	--
02/05/1991	--	--	280	--	--	--	14.44	120	--
05/01/1991	--	--	292	--	--	--	14.41	147	--
07/19/1991	--	--	308	--	--	--	17.45	179	--
09/27/1991	--	--	300	--	--	--	18.74	133	--
10/07/1991	--	--	--	--	--	--	18.58	162	--
12/11/1991	--	--	290	--	--	--	16.89	158	--
03/24/1992	--	--	295	--	--	--	14.86	149	--
04/30/1992	--	--	--	--	--	--	14.21	122	--
06/11/1992	--	--	295	--	--	--	13.34	119	--
06/11/1992	--	--	--	--	--	--	13.34	115	--
07/28/1992	--	--	--	--	--	--	13.5	123	--
09/22/1992	--	--	290	--	--	--	15.59	152	--
10/22/1992	--	--	290	--	--	--	17.05	163	--
06/16/1993	--	--	287	--	--	--	13.63	130	--
08/06/1993	--	--	290	--	--	--	14.32	133	--
10/13/1993	--	--	297	--	--	--	14.96	146	--
12/13/1993	--	--	--	--	--	--	14.04	133	--
02/22/1994	--	--	295	--	--	--	14.39	128	--
04/20/1994	--	--	--	--	--	--	13.47	106	--
06/07/1994	--	--	301	--	--	--	12.78	107	--
07/15/1994	--	--	--	--	--	--	12.97	108	--

Appendix B. Spring flow from selected springs and ancillary data including stage, specific conductance, and ground-water levels (Continued)

[µS/cm, microsiemens per centimeter; specific conductance*, sampling location changed; Q, discharge in cubic feet per second; Q*, measurement location changed; 18-3 fld, Regional Observation Monitor-Well Program (ROMP) TR18-3 Floridan well; --, no data; locations shown in figures 8 and 9]

Date	Time	Stage, in feet above or below sea level	Specific conductance, in µS/cm	Specific conductance,* in µS/cm	Stage change, in feet	Water level, in feet above sea level, in alternate well	Water level, in feet above sea level, in Weeki Wachee well	Q	Q*
08/14/1994	--	--	--	--	--	--	13.64	121	--
10/03/1994	--	--	--	--	--	--	15.4	109	--
12/01/1994	--	--	298	--	--	--	15.58	141	--
01/13/1995	--	--	--	--	--	--	14.93	139	--
03/02/1995	--	--	298	--	--	--	14.8	138	--
04/17/1995	--	--	291	--	--	--	14.44	135	--
01/17/1996	--	--	--	--	--	--	17.65	181	--
03/08/1996	--	--	--	--	--	--	16.68	177	--
04/02/1996	--	--	--	--	--	--	16.93	173	--
04/12/1996	--	--	--	--	--	--	17.37	192	--
06/07/1996	--	--	--	--	--	--	16.51	162	--
01/16/1997	--	7.64	294	--	--	--	15.53	159	--
04/01/1997	--	7.42	300	--	--	--	14.04	127	--
06/05/1997	--	8.24	297	--	--	--	13.57	126	--
07/01/1997	--	8.32	301	--	--	--	13.5	137	--
09/10/1997	--	8.52	303	--	--	--	13.84	130	--
11/06/1997	--	8.6	310	--	--	--	14.8	148	--
01/21/1998	--	9.22	303	--	--	--	19.92	218	--
01/27/1998	--	9.26	--	--	--	--	20.24	224	--
02/26/1998	--	9.48	--	--	--	--	21.97	233	--
05/06/1998	--	9.68	300	--	--	--	21.27	221	--
06/19/1998	--	10	--	--	--	--	19.51	201	--
07/30/1998	--	10.14	--	--	--	--	19.08	184	--
10/29/1998	--	9.31	--	--	--	--	20.13	200	--
Chassahowitzka River (02310650)[1]									
07/18/1985	950	1.64	--	--	-0.02	--	16.13	120	--
07/18/1985	1100	1.52	--	--	-0.02	--	16.13	120	--
07/18/1985	1242	1.42	--	--	0.01	--	16.13	69.8	--
07/18/1985	1340	1.57	--	--	0.06	--	16.13	38.8	--
08/16/1985	1125	1.28	--	--	-0.02	--	18.94	131	--
08/16/1985	1240	1.28	--	--	0.02	--	18.94	100	--
08/16/1985	1352	1.53	--	--	0.07	--	18.94	45.9	--
08/16/1985	1440	1.76	--	--	0.08	--	18.94	25.1	--
10/16/1985	1200	1.5	--	--	-0.06	--	22.09	173	--
10/16/1985	1242	1.35	--	--	-0.05	--	22.09	165	--
10/16/1985	1315	1.23	--	--	-0.05	--	22.09	154	--
10/16/1985	1345	1.17	--	--	-0.04	--	22.09	158	--
10/16/1985	1400	1.12	--	--	-0.02	--	22.09	158	--
12/12/1985	925	1.68	--	--	-0.05	--	20.23	161	--
12/12/1985	1015	1.55	--	--	-0.05	--	20.23	157	--
12/12/1985	1110	1.39	--	--	-0.04	--	20.23	145	--
12/12/1985	1150	1.26	--	--	-0.03	--	20.23	142	--
12/12/1985	1300	1.15	--	--	-0.02	--	20.23	129	--

Appendix B. Spring flow from selected springs and ancillary data including stage, specific conductance, and ground-water levels (Continued)

[µS/cm, microsiemens per centimeter; specific conductance*, sampling location changed; Q, discharge in cubic feet per second; Q*, measurement location changed; 18-3 fld, Regional Observation Monitor-Well Program (ROMP) TR18-3 Floridan well; --, no data; locations shown in figures 8 and 9]

Date	Time	Stage, in feet above or below sea level	Specific conductance, in µS/cm	Specific conductance,* in µS/cm	Stage change, in feet	Water level, in feet above sea level, in alternate well	Water level, in feet above sea level, in Weeki Wachee well	Q	Q*
12/12/1985	1400	1.1	--	--	0	--	20.23	108	--
06/04/1997	710	1.3	7,044	--	-0.02	--	13.62	92	--
06/04/1997	805	1.2	6,850	--	-0.02	--	13.62	95.5	--
06/04/1997	907	1.1	7,230	--	-0.03	--	13.62	92.7	--
06/04/1997	1005	1.02	6,980	--	-0.02	--	13.62	88	--
06/04/1997	1110	0.96	6,880	--	-0.01	--	13.62	75	--
06/04/1997	1206	0.98	6,550	--	0.02	--	13.62	58.9	--
11/05/1997	837	1.06	--	2,285	-0.03	--	14.76	115.7	80
11/05/1997	906	1	--	2,021	-0.03	--	14.76	115.3	78
11/05/1997	1006	0.9	--	2,010	-0.03	--	14.76	116.2	76
11/05/1997	1106	0.81	--	1,865	-0.02	--	14.76	111.1	69
11/05/1997	1206	0.76	--	1,900	-0.02	--	14.76	107.6	68
11/05/1997	1306	0.7	--	1,955	-0.01	--	14.76	109.8	69
11/05/1997	1406	0.66	--	2,010	-0.01	--	14.76	104	64
11/05/1997	1506	0.64	--	2,045	-0.01	--	14.76	108.2	67
11/05/1997	1605	0.62	--	2,055	-0.01	--	14.76	109.1	68
11/05/1997	1704	0.62	--	2,085	0	--	14.76	102.9	62
02/25/1998	1010	1.5	--	1,010	-0.01	--	21.92	132	81
02/25/1998	1110	1.48	--	802	-0.01	--	21.92	131.1	79
02/25/1998	1210	1.46	--	740	0	--	21.92	130	79
02/25/1998	1310	1.44	--	729	0	--	21.92	128.7	79
02/25/1998	1410	1.45	--	734	0	--	21.92	129.9	79
02/25/1998	1510	1.49	--	723	0.02	--	21.92	126.9	74
02/25/1998	1610	1.6	--	719	0.03	--	21.92	98.6	49
06/18/1998	920	1.36	--	830	0.03	--	19.53	103.8	53
06/18/1998	1020	1.5	--	840	0.06	--	19.53	75.6	27
06/18/1998	1120	1.73	--	1,040	0.06	--	19.53	60.2	13
06/18/1998	1215	1.87	--	980	0.02	--	19.53	90.8	40
06/18/1998	1315	1.9	--	1,000	0	--	19.53	118.7	73
06/18/1998	1415	1.86	--	940	-0.02	--	19.53	126.6	76
06/18/1998	1515	1.8	--	850	-0.01	--	19.53	135.5	86
06/18/1998	1615	1.72	--	840	-0.02	--	19.53	146.9	94
10/28/1998	1007	1.73	--	--	-0.03	--	20.16	141.6	94
10/28/1998	1139	1.51	--	586	-0.04	--	20.16	151.8	105
10/28/1998	1306	1.27	--	608	-0.04	--	20.16	157.6	112
10/28/1998	1438	1.06	--	662	-0.04	--	20.16	143.6	94
10/28/1998	1606	0.92	--	683	-0.02	--	20.16	137	87
10/28/1998	1715	0.85	--	731	-0.01	--	20.16	133.8	83
				Crab Creek (02310652)[1]					
03/23/1988	1150	1.8	3,840	--	--	--	19.25	47.2	--
03/23/1988	1257	1.81	3,820	--	--	--	19.25	47	--
03/23/1988	1421	1.81	3,850	--	--	--	19.25	46.9	--
06/01/1988	1445	--	3,770	--	--	--	17.73	51.4	--

Appendix B. Spring flow from selected springs and ancillary data including stage, specific conductance, and ground-water levels (Continued)

[µS/cm, microsiemens per centimeter; specific conductance*, sampling location changed; Q, discharge in cubic feet per second; Q*, measurement location changed; 18-3 fld, Regional Observation Monitor-Well Program (ROMP) TR18-3 Floridan well; --, no data; locations shown in figures 8 and 9]

Date	Time	Stage, in feet above or below sea level	Specific conductance, in µS/cm	Specific conductance,* in µS/cm	Stage change, in feet	Water level, in feet above sea level, in alternate well	Water level, in feet above sea level, in Weeki Wachee well	Q	Q*
07/26/1988	1045	1.71	5,770	--	--	--	16.78	46.3	--
07/26/1988	1240	2	5,690	--	--	--	16.78	41.5	--
07/26/1988	1410	2.19	5,530	--	--	--	16.78	40.1	--
07/26/1988	1525	2.18	5,510	--	--	--	16.78	44.2	--
10/24/1988	1300	1.75	3,600	--	--	--	21.95	53.1	--
10/24/1988	1416	1.94	3,740	--	--	--	21.95	49.2	--
10/24/1988	1530	2.29	3,610	--	--	--	21.95	45.8	--
10/24/1988	1645	2.51	3,250	--	--	--	21.95	43.6	--
10/24/1988	1800	2.49	3,190	--	--	--	21.95	45.4	--
10/26/1988	1407	1.66	3,400	--	--	--	21.87	53.6	--
02/15/1989	1200	1.75	3,060	--	--	--	19.02	55.9	--
02/15/1989	1300	1.76	3,180	--	--	--	19.02	54.2	--
02/15/1989	1400	1.77	3,220	--	--	--	19.02	52.6	--
02/15/1989	1515	1.81	3,320	--	--	--	19.02	52.6	--
02/15/1989	1630	1.83	3,320	--	--	--	19.02	51.5	--
02/15/1989	1735	1.82	3,320	--	--	--	19.02	52.2	--
04/02/1997	1445	--	6,575	--	--	--	14.02	33.2	--
06/04/1997	700	1.85	7,180	--	--	--	13.62	35.6	--
06/04/1997	756	1.78	7,020	--	--	--	13.62	39.2	--
06/04/1997	904	1.67	6,885	--	--	--	13.62	35.5	--
06/04/1997	1000	1.64	6,850	--	--	--	13.62	43.2	--
06/04/1997	1059	1.6	6,880	--	--	--	13.62	38.6	--
06/04/1997	1200	1.61	6,980	--	--	--	13.62	37.6	--
11/05/1997	758	1.68	8,535	--	--	--	14.81	35.7	--
11/05/1997	858	1.59	8,515	--	--	--	14.81	37.3	--
11/05/1997	858	1.54	8,520	--	--	--	14.81	40.2	--
11/05/1997	1058	1.48	8,520	--	--	--	14.81	42.1	--
11/05/1997	1158	1.44	8,520	--	--	--	14.81	39.6	--
11/05/1997	1258	1.42	8,490	--	--		14.81	40.8	--
11/05/1997	1358	1.4	8,480	--	--	--	14.81	40	--
11/05/1997	1458	1.39	8,450	--	--	--	14.81	41.2	--
11/05/1997	1558	1.39	8,410	--	--	--	14.81	41.1	--
11/05/1997	1658	1.38	8,390	--	--	--	14.81	40.9	--
02/25/1998	1000	2.12	3,400	--	--	--	21.92	51	--
02/25/1998	1100	2.11	3,340	--	--	--	21.92	52.1	--
02/25/1998	1200	2.1	3,340	--	--	--	21.92	51	--
02/25/1998	1300	2.1	3,320	--	--	--	21.92	49.7	--
02/25/1998	1400	2.1	3,350	--	--	--	21.92	50.9	--
02/25/1998	1458	2.11	3,445	--	--	--	21.92	52.9	--
02/25/1998	1600	2.16	3,580	--	--	--	21.92	49.6	--
06/18/1998	858	1.88	3,550	--	--	--	19.53	50.8	--
06/18/1998	1002	1.97	3,650	--	--	--	19.53	48.6	--
06/18/1998	1102	2.12	3,720	--	--	--	19.53	47.2	--

Appendix B. Spring flow from selected springs and ancillary data including stage, specific conductance, and ground-water levels (Continued)

[μS/cm, microsiemens per centimeter; specific conductance*, sampling location changed; Q, discharge in cubic feet per second; Q*, measurement location changed; 18-3 fld, Regional Observation Monitor-Well Program (ROMP) TR18-3 Floridan well; --, no data; locations shown in figures 8 and 9]

Date	Time	Stage, in feet above or below sea level	Specific conductance, in μS/cm	Specific conductance,* in μS/cm	Stage change, in feet	Water level, in feet above sea level, in alternate well	Water level, in feet above sea level, in Weeki Wachee well	Q	Q*
06/18/1998	1159	2.22	3,740	--	--	--	19.53	50.8	--
06/18/1998	1302	2.26	3,640	--	--	--	19.53	45.7	--
06/18/1998	1405	2.23	3,380	--	--	--	19.53	50.6	--
06/18/1998	1506	2.18	3,340	--	--	--	19.53	49.5	--
06/18/1998	1600	2.13	3,300	--	--	--	19.53	52.9	--
10/28/1998	957	2.15	3,720	--	--	--	20.16	47.6	--
10/28/1998	1130	1.94	3,660	--	--	--	20.16	46.8	--
10/28/1998	1258	1.8	3,810	--	--	--	20.16	45.6	--
10/28/1998	1428	1.64	4,000	--	--	--	20.16	49.6	--
10/28/1998	1559	1.57	4,130	--	--	--	20.16	50	--
10/28/1998	1653	1.53	4,140	--	--	--	20.16	50.8	--
Unnamed Tributary to Chassahowitzka River (02310655)[1]									
06/04/1997	700	1.3	1,900	--	-0.02	--	13.62	44.4	--
06/04/1997	800	1.2	1,750	--	-0.02	--	13.62	45.3	--
06/04/1997	900	1.1	1,490	--	-0.03	--	13.62	44.5	--
06/04/1997	1000	1.02	1,300	--	-0.02	--	13.62	40.6	--
06/04/1997	1100	0.96	1,300	--	-0.01	--	13.62	34.9	--
06/04/1997	1200	0.98	1,350	--	0.02	--	13.62	18.8	--
11/05/1997	800	1.06	1,650	--	-0.03	--	14.81	59.8	--
11/05/1997	900	1	1,300	--	-0.03	--	14.81	56.6	--
11/05/1997	1000	0.9	1,330	--	-0.03	--	14.81	56	--
11/05/1997	1100	0.81	1,290	--	-0.02	--	14.81	54.1	--
11/05/1997	1200	0.76	1,310	--	-0.02	--	14.81	49.3	--
11/05/1997	1300	0.7	1,380	--	-0.01	--	14.81	44.5	--
11/05/1997	1400	0.66	1,360	--	-0.01	--	14.81	41.6	--
11/05/1997	1500	0.64	1,440	--	-0.01	--	14.81	41.5	--
11/05/1997	1600	0.62	1,410	--	-0.01	--	14.81	39	--
11/05/1997	1700	0.62	1,300	--	0	--	14.81	38.2	--
02/25/1998	1000	1.5	660	--	-0.01	--	21.92	55.5	--
02/25/1998	1100	1.48	660	--	-0.01	--	21.92	50.2	--
02/25/1998	1200	1.46	660	--	0	--	21.92	47.8	--
02/25/1998	1300	1.44	660	--	0	--	21.92	47	--
02/25/1998	1400	1.45	660	--	0	--	21.92	45	--
02/25/1998	1500	1.49	570	--	0.02	--	21.92	35.7	--
02/25/1998	1600	1.6	470	--	0.03	--	21.92	19.2	--
06/18/1998	900	1.36	--	--	0.03	--	19.53	20.5	--
06/18/1998	1000	1.5	--	--	0.06	--	19.53	0.83	--
06/18/1998	1100	1.73	--	--	0.06	--	19.53	0.33	--
06/18/1998	1200	1.87	490	--	0.02	--	19.53	12.2	--
06/18/1998	1300	1.9	488	--	0	--	19.53	37.4	--
06/18/1998	1400	1.86	504	--	-0.02	--	19.53	45.2	--
06/18/1998	1500	1.8	526	--	-0.01	--	19.53	46.5	--
06/18/1998	1600	1.72	540	--	-0.02	--	19.53	47.7	--

Appendix B. Spring flow from selected springs and ancillary data including stage, specific conductance, and ground-water levels (Continued)

[µS/cm, microsiemens per centimeter; specific conductance*, sampling location changed; Q, discharge in cubic feet per second; Q*, measurement location changed; 18-3 fld, Regional Observation Monitor-Well Program (ROMP) TR18-3 Floridan well; --, no data; locations shown in figures 8 and 9]

Date	Time	Stage, in feet above or below sea level	Specific conductance, in µS/cm	Specific conductance,* in µS/cm	Stage change, in feet	Water level, in feet above sea level, in alternate well	Water level, in feet above sea level, in Weeki Wachee well	Q	Q*
10/28/1998	1000	1.73	479	--	-0.03	--	20.16	55.9	--
10/28/1998	1130	1.51	--	--	-0.04	--	20.16	63.2	--
10/28/1998	1257	1.27	--	--	-0.04	--	20.16	66.1	--
10/28/1998	1429	1.06	--	--	-0.04	--	20.16	58	--
10/28/1998	1600	0.92	--	--	-0.02	--	20.16	54.1	--
10/28/1998	1659	0.85	--	--	-0.01	--	20.16	51	--
Hidden River (02310675)[1] Homosassa 3[2]									
04/16/1964	--	--	--	--	--	--	--	26	--
06/04/1964	--	2.1	--	--	--	--	--	6.95	--
07/23/1964	--	2.85	--	--	--	--	--	14	--
10/16/1964	--	3.45	990	--	--	--	--	31	--
02/03/1965	--	3.05	--	--	--	--	--	14.7	--
05/19/1965	--	--	1,500	--	--	--	--	--	--
08/04/1965	--	3.7	350	--	--	--	--	65.6	--
06/30/1966	--	--	1,500	--	--	--	--	11	--
04/06/1988	--	2.33	1,610	--	--	3.86	19.3	7.54	--
04/20/1988	--	2.83	1,700	--	--	4.24	19.06	9.52	--
04/20/1988	--	2.83	1,700	--	--	4.24	19.06	9.41	--
05/06/1988	--	2.38	1,540	--	--	3.78	18.63	7.34	--
05/24/1988	--	2.3	1,520	--	--	3.61	17.95	6.04	--
06/01/1988	--	2.19	--	--	--	3.54	17.73	5.05	--
09/30/1988	--	3.71	1,260	--	--	4.9	22.85	20.1	--
01/16/1997	--	1.8	2,160	--	--	3.73	15.53	7	--
03/25/1997	--	2.05	2,160	--	--	3.8	14.16	6	--
04/16/1997	--	1.92	2,270	--	--	3.37	13.81	5.8	--
06/03/1997	--	2.12	2,020	--	--	3.25	13.66	4.8	--
09/11/1997	--	2.12	--	--	--	3.11	13.84	1.9	--
11/06/1997	--	1.97	1,660	--	--	4.09	14.88	10.9	--
01/20/1998	--	3.17	1,570	--	--	4.58	19.89	16.7	--
02/23/1998	--	3.8	876	--	--	5.03	21.84	39.5	--
03/17/1998	--	3.25	1,150	--	--	4.72	22.3	19.9	--
05/12/1998	--	3.07	--	--	--	4.58	21.11	14.5	--
06/16/1998	--	2.63	2,720	--	--	4.16	19.68	9.66	--
10/29/1998	--	2.7	2,210	--	--	4.36	20.13	10.6	--
Homosassa Springs (02310678)[1]									
02/28/1996	2250	3.03[4]	--	--	0.04	--	16.77	88.38	--
02/28/1996	2348	3.21	--	--	0.04	--	16.77	79.14	--
02/29/1996	45	3.3	--	--	0.02	--	16.77	77.13	--
02/29/1996	145	3.27	--	--	-0.02	--	16.77	80.19	--
02/29/1996	245	3.19	--	--	-0.02	--	16.77	82.65	--
02/29/1996	345	3.09	--	--	-0.03	--	16.77	83.64	--
02/29/1996	445	2.97	--	--	-0.03	--	16.77	89.24	--

Appendix B. Spring flow from selected springs and ancillary data including stage, specific conductance, and ground-water levels (Continued)

[μS/cm, microsiemens per centimeter; specific conductance*, sampling location changed; Q, discharge in cubic feet per second; Q*, measurement location changed; 18-3 fld, Regional Observation Monitor-Well Program (ROMP) TR18-3 Floridan well; --, no data; locations shown in figures 8 and 9]

Date	Time	Stage, in feet above or below sea level	Specific conductance, in μS/cm	Specific conductance,* in μS/cm	Stage change, in feet	Water level, in feet above sea level, in alternate well	Water level, in feet above sea level, in Weeki Wachee well	Q	Q*
02/29/1996	545	2.86	--	--	-0.03	--	16.77	93.03	--
02/29/1996	648	2.75	--	--	-0.02	--	16.77	97.19	--
02/29/1996	748	2.67	--	--	-0.02	--	16.77	102.3	--
02/29/1996	848	2.56	--	--	-0.03	--	16.77	101.9	--
02/29/1996	945	2.45	--	--	-0.03	--	16.77	106	--
02/29/1996	1044	2.36	--	--	-0.02	--	16.77	108.1	--
02/29/1996	1146	2.3	--	--	-0.01	--	16.77	110.1	--
02/29/1996	1243	2.29	--	--	0.01	--	16.77	105.1	--
02/29/1996	1344	2.34	--	--	0.01	--	16.77	105.3	--
02/29/1996	1443	2.39	--	--	0.01	--	16.77	104.6	--
02/29/1996	1544	2.33	--	--	-0.03	--	16.77	107.9	--
02/29/1996	1645	2.29	--	--	-0.01	--	16.77	107.8	--
02/29/1996	1743	2.25	--	--	-0.01	--	16.77	107.5	--
02/29/1996	1843	2.19	--	--	-0.01	--	16.77	109.5	--
02/29/1996	1940	2.12	--	--	-0.02	--	16.77	109.3	--
02/29/1996	2038	2.05	--	--	-0.01	--	16.77	113.1	--
02/29/1996	2136	1.97	--	--	-0.01	--	16.77	108.6	--
02/29/1996	2243	1.94	--	--	0	--	16.77	112.5	--
09/11/1996	1025	3.03	--	--	-0.02	--	18.45	92.5	--
09/11/1996	1110	2.97	--	--	-0.02	--	18.45	82.9	--
09/11/1996	1138	2.95	--	--	-0.01	--	18.45	82	--
09/11/1996	1212	2.98	--	--	0.02	--	18.45	84.5	--
09/11/1996	1239	3.04	--	--	0.04	--	18.45	83.4	--
09/11/1996	1310	3.1	--	--	0.04	--	18.45	80.7	--
09/11/1996	1338	3.19	--	--	0.05	--	18.45	77.5	--
09/11/1996	1411	3.28	--	--	0.05	--	18.45	84.7	--
09/11/1996	1434	3.36	--	--	0.05	--	18.45	89.5	--
09/11/1996	1514	3.46	--	--	0.05	--	18.45	80.8	--
09/11/1996	1541	3.56	--	--	0.05	--	18.45	74.9	--
09/11/1996	1600	3.6	--	--	0.03	--	18.45	76.4	--
09/11/1996	1640	3.67	--	--	0.03	--	18.45	73.6	--
09/11/1996	1710	3.71	--	--	0.02	--	18.45	71.3	--
09/11/1996	1745	3.71	--	--	-0.01	--	18.45	62.1	--
09/11/1996	1810	3.68	--	--	-0.02	--	18.45	64.3	--
09/11/1996	1845	3.65	--	--	-0.02	--	18.45	62.6	--
09/11/1996	1914	3.62	--	--	-0.02	--	18.45	81.6	--
09/11/1996	2023	3.54	--	--	-0.02	--	18.45	83.6	--
09/11/1996	2040	3.52	--	--	-0.02	--	18.45	83.5	--
09/11/1996	2116	3.47	--	--	-0.02	--	18.45	86.6	--
09/11/1996	2243	3.36	--	--	-0.02	--	18.45	89.2	--
09/11/1996	2318	3.3	--	--	-0.03	--	18.45	93.3	--
09/12/1996	12	3.21	--	--	-0.02	--	18.45	96.4	--
09/12/1996	42	3.17	--	--	-0.02	--	18.45	95.7	--
09/12/1996	115	3.13	--	--	-0.02	--	18.45	98.9	--

Appendix B. Spring flow from selected springs and ancillary data including stage, specific conductance, and ground-water levels (Continued)

[µS/cm, microsiemens per centimeter; specific conductance*, sampling location changed; Q, discharge in cubic feet per second; Q*, measurement location changed; 18-3 fld, Regional Observation Monitor-Well Program (ROMP) TR18-3 Floridan well; --, no data; locations shown in figures 8 and 9]

Date	Time	Stage, in feet above or below sea level	Specific conductance, in µS/cm	Specific conductance,* in µS/cm	Stage change, in feet	Water level, in feet above sea level, in alternate well	Water level, in feet above sea level, in Weeki Wachee well	Q	Q*
09/12/1996	140	3.13	--	--	0	--	18.45	98.9	--
09/12/1996	214	3.17	--	--	0.03	--	18.45	98.6	--
09/12/1996	342	3.39	--	--	0.04	--	18.45	95.4	--
09/12/1996	400	3.45	--	--	0.04	--	18.45	92.9	--
09/12/1996	440	3.52	--	--	0.03	--	18.45	91.5	--
09/12/1996	543	3.57	--	--	0.01	--	18.45	85.7	--
09/12/1996	645	3.52	--	--	-0.02	--	18.45	89.7	--
09/12/1996	815	3.43	--	--	-0.02	--	18.45	90.1	--
09/12/1996	840	3.4	--	--	-0.02	--	18.45	90.2	--
09/12/1996	910	3.36	--	--	-0.01	--	18.45	92.5	--
09/12/1996	940	3.34	--	--	-0.01	--	18.45	92.2	--
09/12/1996	1010	3.3	--	--	-0.01	--	18.45	91.2	--
09/12/1996	1040	3.28	--	--	-0.01	--	18.45	91.5	--
09/12/1996	1111	3.26	--	--	-0.01	--	18.45	92.7	--
09/12/1996	1139	3.24	--	--	-0.01	--	18.45	94.2	--
02/04/1997	1028	2.32	--	--	-0.03	--	15.13	95.9	--
02/04/1997	1117	2.23	--	--	-0.02	--	15.13	102.30	--
02/04/1997	1217	2.22	--	--	0	--	15.13	94.6	--
02/04/1997	1316	2.32	--	--	0.04	--	15.13	94.6	--
06/03/1997	737	3.36	3,090	--	-0.02	--	13.66	73.2	--
06/03/1997	820	3.3	3,670	--	-0.02	--	13.66	73.6	--
06/03/1997	913	3.23	3,970	--	-0.02	--	13.66	75.4	--
06/03/1997	1012	3.14	4,050	--	-0.02	--	13.66	77.4	--
06/03/1997	1113	3.1	4,050	--	0	--	13.66	79.1	--
06/03/1997	1213	3.19	3,600	--	0.03	--	13.66	75.6	--
11/04/1997	706	3.2	2,690	--	-0.02	--	14.74	95.7	--
11/04/1997	800	3.15	2,810	--	-0.02	--	14.74	96.5	--
11/04/1997	857	3.05	2,910	--	-0.02	--	14.74	100	--
11/04/1997	958	2.94	3,070	--	-0.03	--	14.74	101.6	--
11/04/1997	1056	2.83	3,120	--	-0.03	--	14.74	105.1	--
11/04/1997	1157	2.72	3,100	--	-0.03	--	14.74	104.4	--
11/04/1997	1258	2.62	3,150	--	-0.02	--	14.74	107.3	--
11/04/1997	1358	2.53	3,180	--	-0.02	--	14.74	108.7	--
11/04/1997	1457	2.43	3,290	--	-0.03	--	14.74	106.9	--
11/04/1997	1559	2.35	3,310	--	-0.02	--	14.74	109.1	--
11/04/1997	1656	2.29	3,290	--	-0.02	--	14.74	115	--
11/04/1997	1755	2.25	3,290	--	0	--	14.74	114.5	--
02/24/1998	1000	3.43	2,810	--	-0.03	--	21.86	109	--
02/24/1998	1100	3.32	2,830	--	-0.03	--	21.86	112	--
02/24/1998	1200	3.21	2,850	--	-0.03	--	21.86	114	--
02/24/1998	1300	3.1	3,100	--	-0.03	--	21.86	115	--
02/24/1998	1400	2.99	3,200	--	-0.02	--	21.86	118	--
02/24/1998	1500	2.9	3,130	--	-0.02	--	21.86	115	--

Appendix B. Spring flow from selected springs and ancillary data including stage, specific conductance, and ground-water levels (Continued)

[µS/cm, microsiemens per centimeter; specific conductance*, sampling location changed; Q, discharge in cubic feet per second; Q*, measurement location changed; 18-3 fld, Regional Observation Monitor-Well Program (ROMP) TR18-3 Floridan well; --, no data; locations shown in figures 8 and 9]

Date	Time	Stage, in feet above or below sea level	Specific conductance, in µS/cm	Specific conductance,* in µS/cm	Stage change, in feet	Water level, in feet above sea level, in alternate well	Water level, in feet above sea level, in Weeki Wachee well	Q	Q*
02/24/1998	1600	2.84	3,200	--	-0.01	--	21.86	122	--
02/24/1998	1700	2.79	3,240	--	-0.02	--	21.86	122	--
06/17/1998	700	3.06	2,650	--	-0.03	--	19.57	94.7	--
06/17/1998	800	3.08	3,040	--	0.01	--	19.57	97.6	--
06/17/1998	900	3.22	2,780	--	0.06	--	19.57	92.2	--
06/17/1998	1000	3.4	2,620	--	0.04	--	19.57	89.2	--
06/17/1998	1100	3.54	2,580	--	0.03	--	19.57	87	--
06/17/1998	1200	3.6	2,540	--	0	--	19.57	82.4	--
06/17/1998	1300	3.53	2,640	--	-0.02	--	19.57	84.9	--
06/17/1998	1400	3.46	2,830	--	-0.02	--	19.57	89	--
06/17/1998	1500	3.36	3,060	--	-0.02	--	19.57	93.3	--
06/17/1998	1600	3.28	3,020	--	-0.03	--	19.57	92.2	--
06/17/1998	1700	3.16	3,180	--	-0.02	--	19.57	95.7	--
06/17/1998	1800	3.05	3,160	--	-0.03	--	19.57	97.4	--
06/18/1998	1900	2.96	3,090	--	-0.02	--	19.57	105	--
06/18/1998	2000	2.93	3,090	--	0.02	--	19.57	104	--
06/18/1998	2100	3.08	3,090	--	0.04	--	19.57	97	--
06/18/1998	2200	3.22	2,730	--	0.04	--	19.57	90.7	--
06/18/1998	2300	3.4	2,650	--	0.03	--	19.57	97.1	--
06/18/1998	100	3.42	2,800	--	-0.02	--	19.57	93.4	--
06/18/1998	300	3.26	--	--	-0.02	--	19.57	102	--
06/18/1998	500	3.05	3,230	--	-0.03	--	19.57	105	--
06/18/1998	700	2.81	3,170	--	-0.02	--	19.57	106	--
10/27/1998	900	3.28	--	--	0	--	20.21	86	--
10/27/1998	1000	3.23	2,750	--	-0.02	--	20.21	87	--
10/27/1998	1130	3.11	3,050	--	-0.02	--	20.21	95.1	--
10/27/1998	1300	2.95	3,280	--	-0.03	--	20.21	97.2	--
10/27/1998	1430	2.78	3,270	--	-0.03	--	20.21	100.4	--
10/27/1998	1600	2.62	3,260	--	-0.02	--	20.21	104.2	--
10/27/1998	1700	2.53	3,190	--	-0.02	--	20.21	108.9	--
Southeast Fork of the Homosassa River (02310688)[1]									
02/04/1997	1028	0.04	485	--	--	--	15.13	60.2	--
02/04/1997	1117	0	484	--	--	--	15.13	60	--
02/04/1997	1217	0.02	482	--	--	--	15.13	47.7	--
06/03/1997	737	1.17	582	--	--	--	13.66	50.5	--
06/03/1997	820	1.1	570	--	--	--	13.66	52.2	--
06/03/1997	913	1.03	565	--	--	--	13.66	53.2	--
06/03/1997	1012	0.94	556	--	--	--	13.66	54.4	--
06/03/1997	1113	0.9	558	--	--	--	13.66	47.3	--
06/03/1997	1213	1.02	580	--	--	--	13.66	37.2	--
11/04/1997	706	1.07	700	--	--	--	14.74	76.9	--
11/04/1997	800	0.98	697	--	--	--	14.74	79.4	--
11/04/1997	857	0.89	697	--	--	--	14.74	81.2	--

Appendix B. Spring flow from selected springs and ancillary data including stage, specific conductance, and ground-water levels (Continued)

[µS/cm, microsiemens per centimeter; specific conductance*, sampling location changed; Q, discharge in cubic feet per second; Q*, measurement location changed; 18-3 fld, Regional Observation Monitor-Well Program (ROMP) TR18-3 Floridan well; --, no data; locations shown in figures 8 and 9]

Date	Time	Stage, in feet above or below sea level	Specific conductance, in µS/cm	Specific conductance,* in µS/cm	Stage change, in feet	Water level, in feet above sea level, in alternate well	Water level, in feet above sea level, in Weeki Wachee well	Q	Q*
11/04/1997	958	0.78	695	--	--	--	14.74	81.2	--
11/04/1997	1056	0.66	694	--	--	--	14.74	84.6	--
11/04/1997	1157	0.53	693	--	--	--	14.74	83.5	--
11/04/1997	1258	0.45	697	--	--	--	14.74	84.3	--
11/04/1997	1358	0.34	699	--	--	--	14.74	86.9	--
11/04/1997	1457	0.24	722	--	--	--	14.74	82.2	--
11/04/1997	1559	0.15	707	--	--	--	14.74	81.3	--
11/04/1997	1656	0.06	705	--	--	--	14.74	80.9	--
02/24/1998	1000	1.27	600	--	--	--	21.86	99.2	--
02/24/1998	1100	1.15	600	--	--	--	21.86	105	--
02/24/1998	1200	1.06	640	--	--	--	21.86	108	--
02/24/1998	1300	0.98	--	--	--	--	21.86	106	--
02/24/1998	1400	0.85	670	--	--	--	21.86	106	--
02/24/1998	1500	0.75	--	--	--	--	21.86	108	--
02/24/1998	1600	0.67	680	--	--	--	21.86	108	--
02/24/1998	1700	0.62	630	--	--	--	21.86	103	--
06/17/1998	700	0.85	410	--	--	--	19.57	73.8	--
06/17/1998	800	0.83	411	--	--	--	19.57	60.8	--
06/17/1998	900	1	411	--	--	--	19.57	53.3	--
06/17/1998	1000	1.17	--	--	--	--	19.57	47.2	--
06/17/1998	1100	1.33	--	--	--	--	19.57	48.4	--
06/17/1998	1200	1.41	--	--	--	--	19.57	66.8	--
06/17/1998	1300	1.34	--	--	--	--	19.57	71.2	--
06/17/1998	1400	1.27	--	--	--	--	19.57	73.2	--
06/17/1998	1500	1.15	--	--	--	--	19.57	74.7	--
06/17/1998	1600	1.07	--	--	--	--	19.57	78.4	--
06/17/1998	1700	0.95	--	--	--	--	19.57	82.9	--
06/17/1998	1800	0.81	--	--	--	--	19.57	83	--
10/27/1998	900	1.11	--	410-700[5]	--	--	20.21	54.9	--
10/27/1998	1000	1.04	--	--	--	--	20.21	64.7	--
10/27/1998	1130	0.93	--	--	--	--	20.21	70	--
10/27/1998	1300	0.73	--	--	--	--	20.21	71.5	--
10/27/1998	1430	0.56	--	--	--	--	20.21	78	--
10/27/1998	1600	0.41	--	--	--	--	20.21	79.4	--
10/27/1998	1700	0.31	--	--	--	--	20.21	76.6	--
				Halls River (02310690)[1]					
06/03/1997	737	1.1	3,300	--	--	--	--	148	--
06/03/1997	820	0.96	3,290	--	--	--	--	166	--
06/03/1997	913	0.89	3,340	--	--	--	--	191	--
06/03/1997	1012	0.79	3,470	--	--	--	--	191	--
06/03/1997	1113	0.77	3,500	--	--	--	--	134	--
06/03/1997	1213	0.88	3,420	--	--	--	--	86	--
11/04/1997	706	1.1	2,840	--	--	--	--	148	--

Appendix B. Spring flow from selected springs and ancillary data including stage, specific conductance, and ground-water levels (Continued)

[µS/cm, microsiemens per centimeter; specific conductance*, sampling location changed; Q, discharge in cubic feet per second; Q*, measurement location changed; 18-3 fld, Regional Observation Monitor-Well Program (ROMP) TR18-3 Floridan well; --, no data; locations shown in figures 8 and 9]

Date	Time	Stage, in feet above or below sea level	Specific conductance, in µS/cm	Specific conductance,* in µS/cm	Stage change, in feet	Water level, in feet above sea level, in alternate well	Water level, in feet above sea level, in Weeki Wachee well	Q	Q*
11/04/1997	800	0.94	2,920	--	--	--	--	183	--
11/04/1997	857	0.85	3,330	--	--	--	--	219	--
11/04/1997	958	0.74	3,500	--	--	--	--	244	--
11/04/1997	1056	0.61	3,700	--	--	--	--	248	--
11/04/1997	1157	0.5	3,750	--	--	--	--	261	--
11/04/1997	1258	0.39	3,840	--	--	--	--	246	--
11/04/1997	1358	0.3	3,900	--	--	--	--	240	--
11/04/1997	1457	0.2	3,970	--	--	--	--	223	--
11/04/1997	1559	0.1	4,060	--	--	--	--	212	--
11/04/1997	1656	0.04	4,170	--	--	--	--	193	--
02/24/1998	1000	1.25	4,860	--	--	--	--	670	--
02/24/1998	1100	1.09	4,790	--	--	--	--	658	--
02/24/1998	1200	1.01	4,800	--	--	--	--	629	--
02/24/1998	1300	0.91	4,700	--	--	--	--	602	--
02/24/1998	1400	0.81	4,690	--	--	--	--	549	--
02/24/1998	1500	0.73	4,730	--	--	--	--	525	--
02/24/1998	1600	0.66	4,720	--	--	--	--	442	--
02/24/1998	1700	0.61	4,720	--	--	--	--	413	--

[1]Station name and number.
[2]Name alternate well.
[3]02310500 is spring head station number and 02310525 is Q measuring section station number.
[4]Stage not referenced to sea level due to benchmark problems.
[5]Specific conductance varied from 400-700 µS/cm from left edge of water to right edge of water.

Appendix C

Rainfall Station Information and Results of Selected Statistical Analysis

Appendix C. Rainfall station information and results of selected statistical analysis

[SWFWMD, Southwest Florida Water Management District; --, not determined due to insufficient data; locations shown in figure 10]

Map number	Latitude longitude	Name	Years of record	Number of years	Average annual rainfall 1997-98, in inches	Coefficient of deter-mination	Significance level	SWFWMD identification number
1	2857210822009	S-353	1996-98	3	71	--	0.12	406
2	2854080822233	Hernando Pool	1996-98	3	52	--	0.60	403
3	2854470822652	Rolling Oaks	1973-98	26	70	0.18	0.11	182
4	2853560923528	Crystal River Utilities.	1986-98	13	56	0.27	0.11	29
5	2851120823544	Ozello (ROMP 21-2)	1992-98	7	55	--	0.65	1
6	2847580823520	Homosassa Park	1995-98	4	70	--	1.00	389
7	2844530823316	Chassahowitzka	1982-98	17	48	0.41	0.01	85
8	2843170823306	Chassahowitzka	1989-98	10	46	0.41	0.03	52
9	2850410821919	Inverness Pool	1996-98	3	60	--	0.60	404
10	2850180821935	NOAA Inverness 3E	1901-98	98	50	0.01	0.29	164
11	2845280821632	Floral City	1996-98	3	40	--	0.60	439
12	2845030821649	Floral City	1996-98	3	46	--	0.60	405
13	2839250822722	ROMP 107	1996-98	3	54	--	0.60	424
14	2837070822154	Chinsegut Hill	1989-98	10	46	0.17	0.13	35
15	2837080822154	NOAA Brooksville Chinsegut Hill	1900-98	99	48	0.00	0.34	unknown
16	2834320822053	Dogwood Water Plant	1988-98	11	52	0.01	0.82	39
17	2832000821730	Hill and Dale Water Plant	1988-98	11	46	0.15	0.24	38
18	2830180821758	Spring Lake	1982-98	17	60	0.01	0.56	111
19	2830290821137	Ridge Manor North	1988-98	11	58	0.37	0.10	37
20	2828470821040	Withlacoochee at Trilby	1988-98	11	58	0.28	0.10	251
21	2831580822317	Hilbert	1982-98	17	63	0.10	0.19	229
22	2833000822904	Brookridge Number 2 Water Plant	1988-98	11	59	0.02	0.94	41
23	2831260823246	Bradford	1987-98	12	71	0.17	0.34	207
24	2830500823240	West Hernando Water Plant	1988-98	11	57	0.18	0.19	42
25	2831010823430	Buccaneer Bay	1987-98	12	56	0.00	0.78	133
26	2832110823647	Weeki Wachee Water Plant	1988-98	11	54	0.18	0.39	43
27	2832120823647	NOAA Weeki Wachee	1970-98	29	54	0.00	0.71	unknown
28	2826380823712	Hunters Lake	1976-98	23	56	0.02	0.51	226
29	2828180822639	SWFWMD III	1976-98	23	60	0.08	0.23	302
30	2828190822638	Campbell Scientific	1995-98	3	56	--	0.12	441
31	2824580822855	Crews Lake East	1977-98	22	62	0.03	0.27	76
32	2825220823337	Shady Hills	1990-98	9	48	--	0.68	24
33	2824160824010	Belcher Mine	1987-98	12	58	0.04	0.68	134
34	2819430823735	Summer Tree	1992-98	7	52	--	0.45	387
35	2819050823344	North Pasco	1991-98	8	62	--	0.80	6
36	2820110823126	Kent Grove	1987-98	12	64	0.03	0.89	129
37	2820100821538	NOAA St. Leo	1902-98	97	62	0.00	0.79	306
38	2819080821212	Lake Pasadena	1989-98	10	57	0.27	0.13	49
39	2813160820908	Zephryhills	1975-98	24	48	0.23	0.03	140
40	2813060822218	Topp of Tampa	1991-98	8	54	--	1.00	8
41	2810330822115	Northwood	1991-98	8	52	--	0.80	7
42	2811260823038	South Pasco	1976-98	23	56	0.01	0.65	113
43	2812300823724	Jay Two Three	1994-98	5	65	--	0.14	431
44	2815000823845	Starkey	1983-98	15	50	0.12	0.32	307
45	2815300823913	Starkey Plant Gauge	1976-98	23	54	0.02	0.38	344
46	2814370824201	New Port Richey East	1992-98	7	57	--	0.88	3