UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

HYDROLOGY OF THE CHICOD CREEK BASIN, NORTH CAROLINA, PRIOR TO CHANNEL IMPROVEMENTS

By Clyde E. Simmons and Mary C. Aldridge

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INTERNATIONAL SYSTEM UNITS

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

Multiply	By	To obtain
	Length	
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
cubic foot (ft^3)	0.02832	cubic meter (m^3)
	Flow	
cubic foot per second (ft^3/s)	28.32	liters per second (L/s)
	0.02832	cubic meter per second (m^3/s)
	Temperature	
degree Fahrenheit (°F)	5/9 (°F-32)	degree celsius (°C)
	Mass	
ton (short, 2000 pounds)	907.2	kilogram (kg)
	Flow per Area	
cubic foot per second per square mile [($ft^3/s/mi$]	0.01093	cubic meter per second per square kilometer [($m^3/s)/km^2$]

<u>National Geodetic Vertical Datum of 1929</u> is a geodetic datum derived from the average sea level over a period of many years at 26 tide stations along the Atlantic, Gulf of Mexico, and Pacific Coasts and as such does not necessarily represent local mean sea level at any particular place. To establish a more precise nomenclature, the terms "NGVD" or "NGVD of 1929" are used in place of "Sea Level Datum of 1929" or "mean sea level."

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By C. E. Simmons and M. C. Aldridge

ABSTRACT

Extensive modification and excavation of stream channels in the 60-square mile Chicod Creek basin began in mid 1979 to reduce flooding and improve stream runoff conditions. The effects of channel improvements on this Coastal Plain basin's hydrology will be determined from data collected prior to, during, and for several years following channel alterations. This report summarizes the findings of data collected prior to these improvements.

During the 3-year study period, flow data collected from four stream gaging stations in the basin show that streams are dry approximately 10 percent of the time. Chemical analyses of water samples from the streams and from eight shallow ground-water observation wells indicate that water discharged from the surficial aquifer is the primary source of streamflow during rainless periods. Concentrations of Kjeldahl nitrogen, total nitrogen, and total phosphorus were often 5 to 10 times greater at Chicod Creek sites than those at nearby baseline sites. It is probable that runoff from farming and livestock operations contributes significantly to these elevated concentrations in Chicod Creek.

The only pesticides detected in stream water were low levels of DDT and dieldrin, which occurred during storm runoff. A much wider range of pesticides, however, are found associated with streambed materials.

The ratio of fecal coliform counts to those of fecal streptococcus indicate that the streams receive fecal wastes from livestock and poultry operations.

INTRODUCTION AND ACKNOWLEDGMENTS

The improvement of stream channels in the Chicod Creek basin in Pitt and Beaufort Counties, North Carolina, began in mid 1979. The improvements, consisting primarily of channel excavation and snagging operations, are designed to increase the drainage efficiency of the stream channels and reduce flooding. Recent concerns have developed, however, regarding the effects of channel excavation on the environment, but data are inadequate to predict these effects. The alterations to streams in the Chicod Creek basin, therefore, present a unique opportunity to study the hydrologic conditions in a Coastal Plain basin prior to, during, and following channel improvements.

This report, prepared in cooperation with the Soil Conservation Service (SCS) of the U.S. Department of Agriculture, presents the results of studies made prior to channel excavation. The primary objectives of the overall study, which began in 1975, are to determine the effects of the excavations on (1) runoff characteristics of the streams, (2) surface-water quality, and (3) ground-water conditions. The channel excavations are scheduled for completion in late 1980. The collection of data will continue during and for several years following construction. A final report will be prepared upon completion of the study which will compare basin characteristics before and after channelization.

Special acknowledgment is given to Mr. J.C. Galloway, Greenville, N.C. for his devoted efforts in collecting daily suspended-sediment samples on Chicod Creek during the study period. SCS personnel in Greenville provided level data and local weather information which were critical to project operations. Mr. W.R. Folsche, Assistant State Conservationist with the SCS in North Carolina, provided technical reviews of the text.

BASIN DESCRIPTION

The Chicod Creek basin is an area of about 60 square miles in the central part of the Coastal Plain region of eastern North Carolina. Approximately 90 percent of the basin is in Pitt County and 10 percent is in Beaufort County (fig. 1). Chicod Creek originates in the western part of Beaufort County and flows north to the Tar River. Major tributaries are Cow Swamp and Juniper

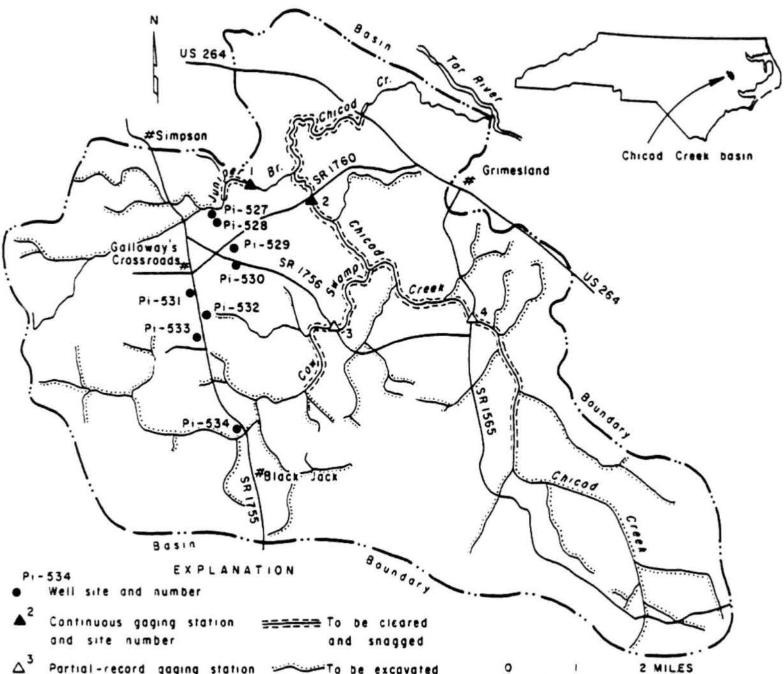

Figure 1.--Chicod Creek basin, location of data-collection network, and proposed channel improvements (base map by Soil Conservation Service).

Branch. Chicod Creek has a nearly flat gradient of about 0.3 foot per mile. Scattered swampy upland flats and gently-sloping interstream areas are characteristic surface features of the basin. Land-surface altitudes range from 10 to 50 feet above National Geodetic Vertical Datum (NGVD) of 1929.

The basin is sparsely populated, and most of the land is in forest or row crops. About 45 percent of the land is used for crops and pastures (Lawrence Clark, SCS, personal commun., 1978). Dense forests of both hard wood and pine account for approximately 50 percent of the land use; and, residential areas, roadways, and water courses account for the remaining 5 percent.

A reconnaissance of the basin was conducted during the summer of 1978 to determine the prevalence and types of livestock and agricultural land-use activities in the basin. Although only a small number of cattle and horses were observed (less than 100), the basin contains many poultry and swine farms. Several poultry farms, each having 80,000 or more chickens, are in close proximity to streams. With the exception of direct outlets to streams from holding ponds adjacent to poultry and livestock shelters, no point sources of pollution were observed in the basin. In almost every case, farm fields are separated from streams by buffer zones of forest and heavy undergrowth.

The basin is underlain by 900 to 1200 feet of water-bearing sands, clays and calcareous sediments. Only the uppermost sediments, however, are of significance to the interpretation of the study data and these include the surficial deposits and the Tertiary Yorktown Formation and Castle Hayne Limestone.

The surficial deposits are composed primarily of sand and silt ranging from 10 to 20 feet in thickness. These deposits supply water to numerous shallow wells and are also a major source of baseflow to the streams. The Yorktown Formation lies immediately under the surficial deposits. Layers of gray silty clay comprise the upper part of the formation, whereas the lower part is composed of dark blue-gray sandy clay containing shells and other remains of marine organisms. The Yorktown Formation averages about 40 feet in thickness except where thinned by erosion. The Castle Hayne Limestone underlies the Yorktown Formation in about three-fourths of the basin. The Castle Hayne Limestone consists of white, calcareous sand, green clay, and gray sandy limestone and is one of the major sources of water supply for deep wells in the basin.

DATA COLLECTION PROGRAM

The data collection network includes sites for measuring characteristics of both surface water and ground water in the basin. The quantity and quality of runoff are determined at four streamflow sites, and changes in groundwater levels are measured at eight observations wells (fig. 1).

Site 1, located on Juniper Branch, is equipped with a continuous stage recorder for determining stream discharge. Site 2, located on Chicod Creek at Secondary Road 1760, is equipped with a continuous stage recorder, a continuous conductance and temperature recorder, and an automatic sediment sampler. The sediment sampler is stage controlled and automatically collects samples at regular intervals during floods. A sediment sample is also collected manually each day at site 2 to permit calculations of daily sediment loads. Sites 3 and 4 are partial-record streamflow sites equipped with staff and crest-stage gages.

The eight groundwater observation wells mentioned previously are located near site 1 and are installed at distances ranging from 150 feet to 3-1/4 miles laterally from Juniper Branch across the divide between Juniper Branch and Cow Swamp (fig. 1). The depths of the wells range from 9 to 21 feet. Three of the wells, Pi-527, Pi-528, and Pi-534, extend into the Yorktown Formation and the others monitor water levels in the surficial deposits. Wells Pi-527, Pi-528, Pi-529, Pi-532, Pi-533, and Pi-534 are equipped with automatic recorders. Ground-water levels at Pi-530 and Pi-531 are measured monthly with a steel tape. Additional information regarding the observation wells is presented in table 1.

Water-quality data are collected at each of the four streamflow sites. Types of chemical and physical analyses and frequency of sampling are shown in table 2. Analyses are made in accordance with methods set forth by the Federal Interagency Work Group on Designation of Standards for Water Quality Data Acquisition (1972). All streamflow and water-quality data collected at the Chicod Creek sites are published annually in U.S. Geological Survey Water-Data Reports (1976-78).

Table 1.--Description of ground-water wells in data collection network.

Well No.	Property owner	Land surface elevation (ft, NGVD)	Depth (ft)	Diameter (inches)	Well screen elevation (ft, NGVD)	Type casing	Mean water level 1977-78 (ft, NGVD)	Water-bearing material	Lateral distance from Juniper Br (ft)	Type record
Pi-527	J.H. Galloway	27.4	14.6	6	12.8-15.8	PVC	22.78	Yorktown Fm sand and clay	150	continuous
Pi-528	J.H. Galloway	34.8	14.2	6	20.6-23.6	PVC	27.71	Yorktown Fm sand and clay	250	continuous
Pi-529	L.R. Hardee	49.3	14.4	6	34.9-37.9	PVC	45.40	Surficial sand and clay	3100	continuous
Pi-530	L.R. Hardee	51.5	21.1	2	30.4-33.4	Galv steel	48.01	Surficial sand and clay	4100	periodic
Pi-531	J.E. May	57.3	20.4	2	36.9-39.9	Galv steel	53.77	Surficial sand and clay	5400	periodic
Pi-532	W.S. Hudson	56.1	10.9	6	45.2-48.2	PVC	51.99	Surficial sand and clay	7300	continuous
Pi-533	R.L. Edwards	52.2	9.3	6	42.9-45.9	PVC	49.36	Surficial sand and clay	8900	continuous
Pi-534	Frank Dixon	32.0	9.6	6	22.4-25.4	PVC	30.66	Yorktown Fm sand and clay	17,300	continuous

Table 2.—Types of data and frequency of collection at sites in the Chicod basin.

Site Number	Station Name	Drainage area (square miles)	Type of data and sampling frequency									
			Major dissolv. constit.	Nutrients	Minor elements	Dissolved oxygen	Pesticides	Temperature	Conductance	Bottom material	Suspended sediment	Stream discharge
1	Juniper Branch near Simpson	7.5	Q	Q	Q	Q	T	Q	Q	Y	M	C
2	Chicod Creek at SR 1760 near Simpson	45	M	M	M	M	T	C	C	Y	D	C
3	Cow Swamp near Grimesland	17	Q	Q	Q	Q	T	Q	Q	Y	M	M
4	Chicod Creek at SR 1565 near Grimesland	19	Q	Q	Q	Q	T	Q	Q	Y	M	M

C = continuous, M = monthly, D = daily, Q = quarterly,
T = twice yearly, Y = yearly.

Water-quality samples were also collected from the project's observation wells. Data obtained from this onetime occasion, which occurred during July 1977, were used to determine the chemical quality of the basin's ground water. These data are included in a later section of this report, but, unlike the stream-quality data mentioned previously, are not published in U.S. Geological Survey Water-Data Reports.

HYDROLOGIC RELATIONS

A comparison of data collected prior to, during, and after channel excavations will provide a clearer understanding of the changes caused by man. The following is a discussion of the basin's characteristics prior to the excavations as determined from data collected from late 1976 to mid 1979.

Ground Water

As noted previously the Chicod Creek basin is underlain primarily by sand and other premeable materials. Although some of the rainfall percolates into the deep aquifers, most of it seeps only into the shallow surficial deposits or Yorktown Formation where the major portion is eventually withdrawn as evapotranspiration or discharges to streams. In a recent study of the Creeping Swamp basin in Pitt County, Winner and Simmons (1977, p. 19) estimated that over half of the stream runoff was derived from ground-water discharge. Because similar conditions exist in the Chicod Creek basin, the influence of ground water upon stream quantity and quality is a key factor.

The observation wells in the basin are used to observe changes in ground-water levels in the shallow aquifers. Locations of the wells relative to Juniper Branch and Cow Swamp are shown in figure 2 which also includes information regarding ground-water characteristics. As depicted in figure 2,

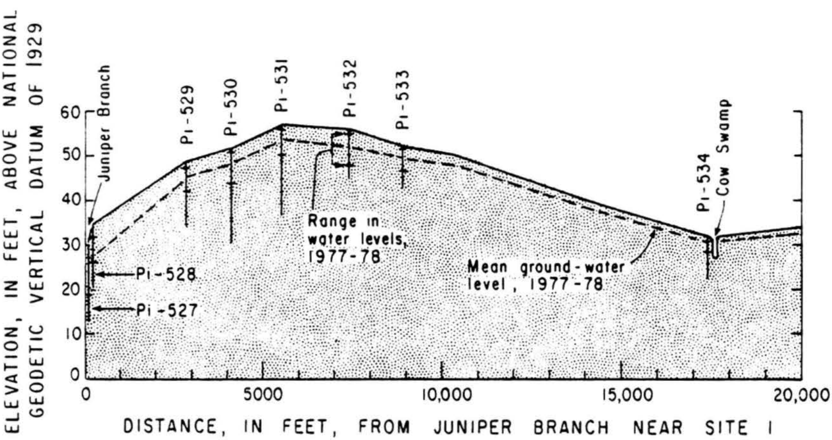

Figure 2.--Cross section showing approximate ground-surface profile between Juniper Branch and Cow Swamp, location of observation wells, and water-level characteristics during 1977-78.

annual mean levels in the shallow aquifers are within a few feet of ground surface and a profile of water levels generally conforms to the shape of the land surface. It should be mentioned that water levels in Pi-534 rose above ground level during the flood of January 1978 when Cow Swamp inundated the floodplain around the well; otherwise water levels in the shallow aquifers have not been observed to exceed ground elevations. Water-level fluctuations range from 4 to 6 feet annually.

Water levels in the surficial deposits, Yorktown Formation, and streams respond directly to climatic conditions. As shown in figure 3, levels throughout the basin rise abruptly during heavy rains and decline during rainless periods.

During periods of little or no rain, streamflow in the basin is derived from ground water discharge. During these dry periods a direct relation exists between stream stage and discharge and the water levels in nearby shallow wells. A typical relation is shown in figure 4 for base flows in Juniper Branch and in Chicod Creek and the water level in well Pi-532. Well Pi-532 is located more than 1-1/4 miles from the nearest channel excavation and may be out of the zone in which water levels will be significantly affected by the channel improvements. A similar plot of data collected after the channel excavations are completed can be used to show changes, if they occur, that are caused by the channelization.

Surface Water

Streamflow in the basin is composed primarily of ground-water discharge. In varying amounts, there is a rather continuous flow of ground water into the streams except, of course, during periods when streams are dry. Overland runoff occurs only during periods of intense rainfall when soils are saturated or the infiltration capacity of the soils is exceeded.

Channel excavation is expected to change some of the streamflow characteristics in the Chicod Creek basin. Enlargement of the channels will permit storm runoff to move more rapidly from the basin, thereby reducing the period of high flow but increasing peak rates of flow. Based on recent studies of flow characteristics in nearby streams (Winner and Simmons, 1977, p. 40-42, and Wilder, Robinson and Lindskov, 1978, p. 36), deepening the channels into the shallow aquifer will at times increase the rate of ground-water discharge to streams of which the most obvious effect will be larger flows during droughts.

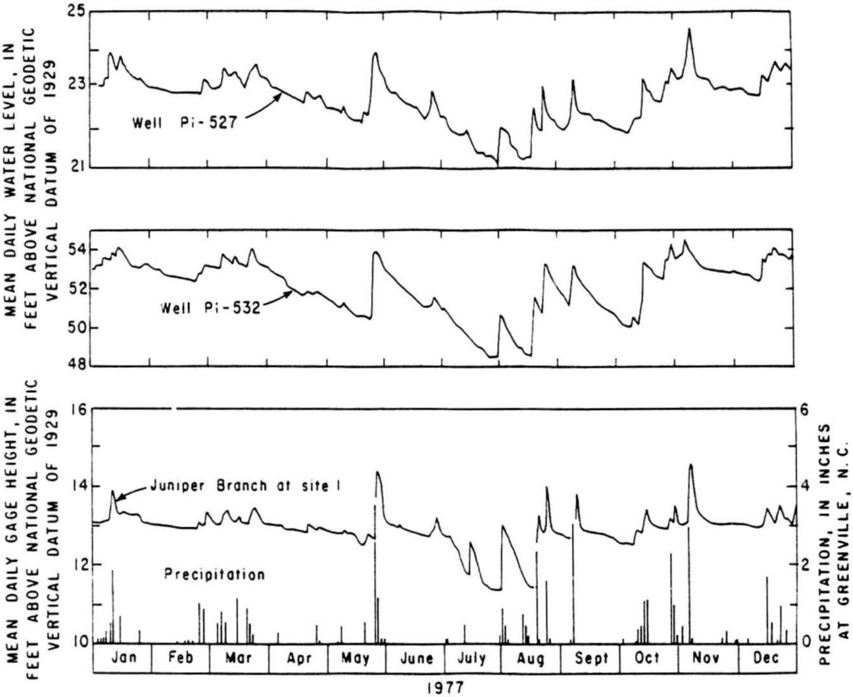

Figure 3.--Hydrographs of wells Pi-527 and Pi-532, stage of Juniper Branch, and daily precipitation at Greenville, N.C.

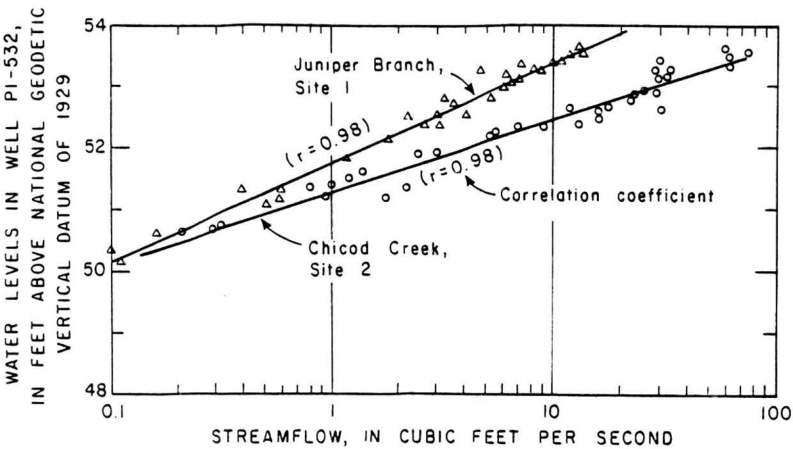

Figure 4.--Relation between base flow in Chicod Creek and Juniper Branch and ground-water level in well Pi-532.

Flow duration curves for Juniper Branch and Chicod Creek for the period 1976-79 are shown in figure 5. It is interesting to note that both streams cease to flow about 10 percent of the time. By comparing these curves with similar curves prepared after the channels are excavated, the changes in flow regimes caused by construction can be determined.

STREAM-QUALITY CHARACTERISTICS

The purpose of this section is to briefly describe the physical and chemical-quality characteristics of the streams in the Chicod Creek basin under the present prechannel-improvement conditions. Although one of the primary objectives of this study is to determine the concentrations of stream-borne constituents, it is important that the sources of these constituents also be determined where possible. In the Chicod Creek basin, changes in stream quality in excess of those contributed by natural processes are

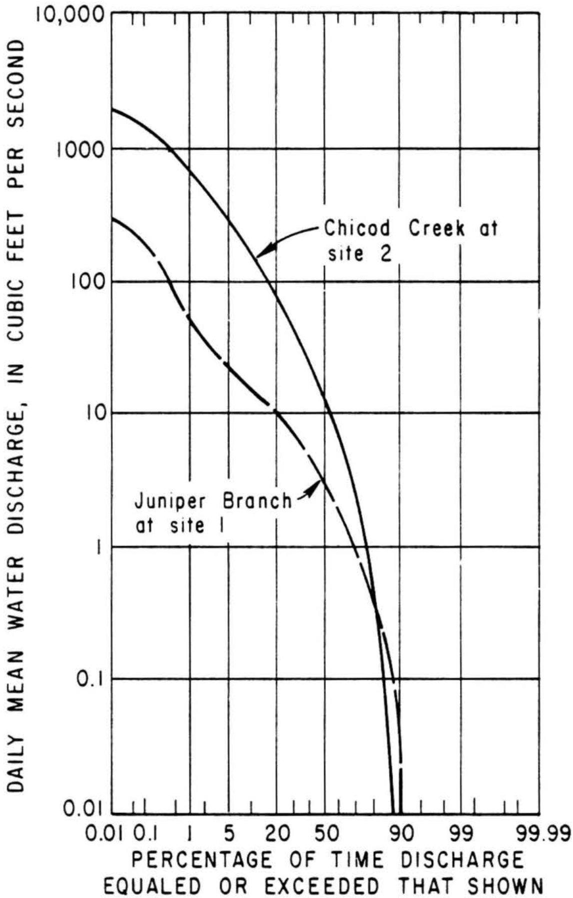

Figure 5.--Flow-duration curves for Juniper Branch and Chicod Creek prior to channel improvements 1976-79.

attributable primarily to agricultural and livestock activities, air pollution, and, to a lesser extent, to septic-tank seepage and other domestic activities. Recent studies (Kuenzler and others, 1977, and Winner and Simmons, 1977) indicate that concentrations of some constituents of stream water are often increased by channelization.

Physical Characteristics

The physical characteristics discussed in this section are suspended sediment, dissolved oxygen, and stream temperature.

Suspended-sediment concentrations in streams vary primarily with stream discharge, land use, soil type and cover, slope, and rainfall intensity. While farming activities in the basin create large areas of exposed land, the flat topography, sluggish streams, and permeable soils tend to minimize sediment transport except during periods of intense rainfall when overland runoff occurs. It is during these intense storms that overland runoff transports most of the sediment that is derived from cultivated fields, road ditches, and other exposed areas.

Suspended-sediment data for the two continuous-record stations are presented in table 3. Sediment-transport curves, showing graphic relations

Table 3.--Suspended-sediment data for Juniper Branch and Chicod Creek for the 1977-78 water years.

Parameter	Site 1 Juniper Branch		Site 2 Chicod Creek	
	1977	1978	1977	1978
Mean water discharge, in ft^3/s	5.3	13	40	90
Mean daily suspended-sediment concentration, in mg/L	10	65	26	93
Annual suspended-sediment yield, in $tons/mi^2$	7.2	111	23	183
Ranges of instantaneous suspended-sediment concentrations, in mg/L	0-67	0-1260	0-293	0-886

between stream discharge and suspended-sediment discharge, are shown in figure 6. These curves are well defined by numerous data collected during 1976-79, and comparisons with similar curves developed from post-construction data will show any changes in sediment discharge caused by channelization.

The reasons for the large variations in sediment values noted in table 3 are not known but data indicate that larger concentrations of sediment occur at Chicod Creek site 2. As discussed previously, climatic factors have a considerable effect on erosion and sediment transport. Rainfall was more

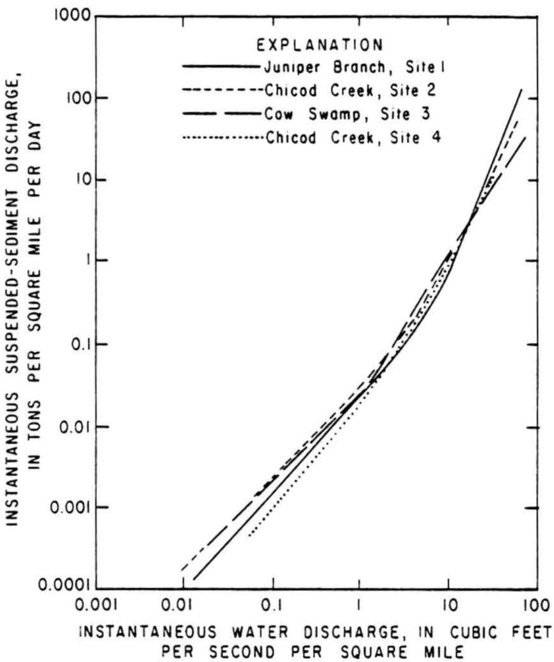

Figure 6.--Relations between water and suspended-sediment discharge at study sites in the Chicod Creek basin.

plentiful during 1978 than in 1977; and, consequently, as shown in table 3, stream discharges and sediment concentrations were also greater at both sites during 1978. The fact that the sediment yield at Chicod Creek site is almost twice that in Juniper Branch might be related directly to differences in land use practices in the two basins; however, additional basin reconnaissance information is needed to determine the exact cause.

Analyses of particle sizes being transported as suspended sediment during a period of high flow in early 1978 showed that most of the material was clay and silt size (approximately 98 percent finer than 0.062 mm). Due to the low natural gradient of streams in the watershed, flow velocities are not high enough to transport coarser material.

Concentrations of dissolved-oxygen in Chicod Creek are related to flow and temperature and to the biological processes of decomposition, respiration, photosynthesis, and oxidation. Two 24-hour surveys, conducted during 1976 and 1977, demonstrate the direct effects of these processes on concentrations of dissolved oxygen (fig 7). Both temperature and dissolved oxygen reached a maximum in the afternoon probably coinciding with maximum oxygen production by photosynthesis of phytoplankton and aquatic plants. Minimum values of temperature and dissolved oxygen concentrations occurred during the predawn hours (0400-0600) probably coinciding with nocturnal oxygen utilization by respiring plants, bacteria, and algae.

Dissolved-oxygen concentrations were also randomly sampled over variable flow conditions. The minimum value, 0.8 mg/L, occurred at Site 3 during low-flow conditions and the maximum value, 14 mg/L, occurred at Site 1 during high-flow conditions. Turbulent high-flow conditions increased aeration and caused oxygen concentrations to reach maximum levels. During periods of base flow which generally occur during late summer, little or no turbulence as well as the bacterial decomposition of bottom materials cause the streams to approach anaerobic conditions.

Both the immediate and long-range effects of channel improvements on physical characteristics are unknown. Because the natural stream banks and channels will be disturbed, large increases in suspended sediment are expected during and at least for a short period immediately following construction. Channelization will increase flow velocities, thereby enabling the streams to transport greater quantities of sediment and also larger diameter

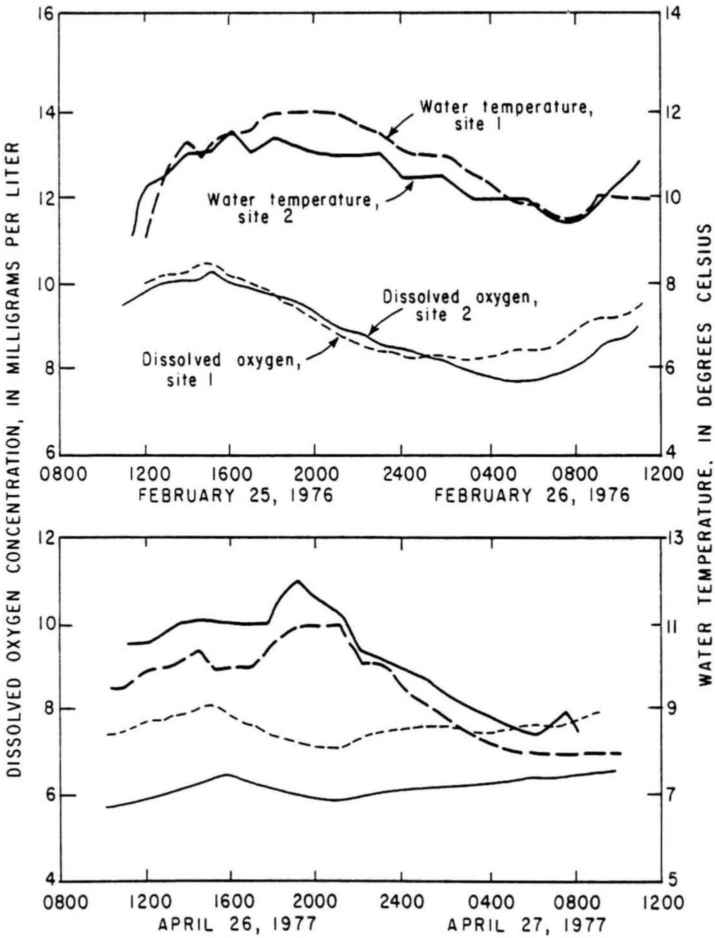

Figure 7.--Comparison of hourly dissolved-oxygen concentrations and water temperatures for two 24-hour periods in 1976 and 1977 at sites 1 and 2.

materials. Stream sediment characteristics should gradually return toward preconstruction levels as the banks and spoil areas become stabilized with vegetation and as the stream channel approaches a state of near equilibrium.

The greater flow velocities following channelization should create more stream turbulence and improve the stream's dissolved-oxygen conditions. Average stream temperatures might also increase slightly as a result of more direct exposure to sunlight following removal of tree and brush cover.

Chemical Characteristics

Mean concentrations of major dissolved constituents, nutrients, and minor elements are shown in tables 4 and 5 for base runoff and storm runoff conditions, respectively. The base runoff values were determined from samples collected during extended dry periods, thus they represent the quality of water reaching the stream from the ground-water system. The storm runoff values represent mean analytical values for samples obtained during the highest flow conditions when the flow is composed primarily of shallow ground water and overland runoff.

The analyses of water samples collected from shallow wells and stream site 1 in the Juniper Branch basin during a period of baseflow are presented in table 6. These data indicate that concentrations of most major dissolved constituents increase with depth in the ground-water system. It is interesting to note from table 6 that minimum concentrations occur in the upper surficial aquifer and were in close agreement with average concentrations from the stream, thereby indicating that base runoff is derived mainly from these surficial deposits. The maximum concentration of total dissolved solids occurred in samples collected from the Yorktown Formation (370 mg/L). Water from the Yorktown shows particularly high bicarbonate (335 mg/L), probably due to the solution of marine shell and marl layers in the formation.

Whereas major dissolved constituents reach maximum concentrations during base flow, levels of most nutrients and minor elements are greatest during intense storm runoff. It is characteristic of many of the minor elements and nutrients to sorb on soil particles. During low flows these particles are generally stationary on the ground or streambed and their concentrations in waters are subsequently quite low. During storm runoff, when the stream

Table 4.--Concentrations of major dissolved constituents in surface waters of the Chicod Creek Basin prior to channel improvements.

Parameter	Runoff condition	Concentrations, in milligrams per liter							
		Site 1		Site 2		Site 3		Site 4	
		Mean	Range	Mean	Range	Mean	Range	Mean	Range
Calcium	Base	19	14-29	16	7.1-27	28	21-41	13	3.3-22
	Storm	5.4	3.3-9.9	5.2	4.0-6.5	5.1	3.2-7.5	2.6	2.2-2.9
Magnesium	Base	2.6	2.1-33	2.6	1.3-5.1	3.8	2.6-6.5	3.8	1.0-6.6
	Storm	1.2	0.9-1.6	1.1	0.9-1.3	1.1	0.7-1.7	0.9	0.8-1.0
Sodium	Base	7.2	6.7-8.0	7.5	5.6-9.3	9.4	8.0-12	7.8	4.6-11
	Storm	3.0	2.0-5.0	3.2	2.4-4.3	3.1	1.7-4.3	2.6	2.2-3.5
Potassium	Base	3.0	2.4-3.7	4.5	2.8-7.2	9.8	6.8-20	3.5	2.2-4.8
	Storm	2.5	2.2-3.0	2.7	2.4-3.0	2.6	2.0-3.6	2.2	1.6-3.0
Bicarbonate	Base	33	20-57	36	14-58	86	35-140	3.5	3.0-4.0
	Storm	5.2	4.0-7.0	9.0	8.0-10	7.8	4.0-13	5.4	3.0-9.0
Sulfate	Base	28	13-61	19	6.7-66	18	2.9-49	40	8.0-71
	Storm	12	8.8-20	10	6.9-12	9.9	6.0-15	7.5	5.4-10
Chloride	Base	12	11-15	12	8.3-14	15	11-19	11	8.1-13
	Storm	4.9	2.8-8.0	5.4	3.4-6.9	5.5	2.5-8.2	4.4	2.4-6.0
Fluoride	Base	0.2	0.1-0.4	0.2	0.0-0.8	0.2	0.1-0.5	0.1	0.0-0.1
	Storm	0.2	0.1-0.3	0.2	0.1-0.3	0.2	0.1-0.3	0.1	0.0-0.2
Silica	Base	11	9.2-14	9.1	6.9-11	11	8.8-13	11	8.5-13
	Storm	3.1	2.0-5.3	4.0	2.4-4.8	3.5	1.9-7.1	3.6	2.6-4.7
Total dissolved solids (SUM)	Base	101	76-141	91	58-150	138	110-184	91	39-143
	Storm	36	24-56	37	30-43	39	26-54	27	22-31
Number of Analyses	Base	5	5	6	6	5	5	2	2
	Storm	5	5	4	4	6	6	5	5

Table 5.--Concentrations of nutrients and minor elements in surface waters prior to channel improvements.

Parameter	Runoff Condition	Site 1		Site 2		Site 3		Site 4	
		Mean	Range	Mean	Range	Mean	Range	Mean	Range
Total nitrite nitrogen (mg/L)	Base	0.01	0.0-0.01	0.01	0.01-0.02	0.05	0.04-0.06	0.01	0.01
	Storm	.08	.02-.12	.03	.01-.04	.06	.02-.12	.04	.00-.06
Total nitrate nitrogen (mg/L)	Base	.6	.13-1.3	.86	.05-1.5	.56	.33-.78	.90	.90
	Storm	1.0	.89-1.3	.64	.30-.96	.63	.53-.88	.34	.15-.45
Total kjeldahl nitrogen (mg/L)	Base	.63	.37-1.1	.96	.69-1.3	3.6	1.6-5.6	1.2	.83-1.5
	Storm	1.9	.67-3.5	1.4	1.0-2.5	2.1	.84-4.4	1.6	.60-2.8
Total nitrogen (mg/L)	Base	1.1	.49-1.9	1.8	.83-2.7	4.1	2.4-6.2	2.1	1.7-2.4
	Storm	3.2	2.1-4.7	2.2	1.3-3.5	2.8	1.4-5.2	2.0	.75-3.3
Total phosphorus (mg/L)	Base	.12	.02-.20	.20	.16-.23	1.3	.60-2.6	.06	.04-.07
	Storm	.53	.16-.93	.42	.15-.77	.43	.23-.63	.26	.05-.48
Total copper (mg/L)	Base	2.0	.0-3.0	2.5	2.0-3.0	3.0	2.0-6.0	1.5	1.0-2.0
	Storm	9.0	3.0-14	8.0	2.0-22	7.5	3.0-15	5.6	1.0-10
Total iron (mg/L)	Base	1080	500-1400	1030	300-1600	1590	760-2700	800	100-1500
	Storm	6520	1100-13,000	4050	1000-9700	5090	660-9000	2890	670-5800
Total lead (mg/L)	Base	8.4	20-17	5.3	.0-17	5.2	.0-14	6.0	5.0-7.0
	Storm	16	4.0-45	9.8	.0-23	11	.0-38	4.6	.0-7.0
Total mercury (mg/L)	Base	.2	.0-.5	.2	.0-.5	.2	.0-.5	.05	.0-.1
	Storm	.2	.0-.5	.4	.3-.5	.3	.0-.5	.3	.0-.5
Total zinc (mg/L)	Base	14	10-20	13	10-20	16	10-20	15	10-20
	Storm	42	20-60	58	40-100	37	20-60	26	10-40
Number of Analyses	Base	5	5	6	6	5	5	2	2
	Storm	5	5	4	4	6	6	5	5

Table 6.--Comparison of surface-water and ground-water quality at Site 1 during a period of base flow, May 19, 1977.

Source	Number of sites sampled	Mean constituent value (mg/L)												
		Calcium	Magnesium	Sodium	Potassium	Bicarbonate	Sulfate	Chloride	Silica	Total dissolved solids (SUM)	Total nitrate & nitrite	Total kjeldahl nitrogen	Total nitrogen	Total phosphorus
Stream (Juniper Branch)	1	17	2.3	7.0	2.6	37	13	12	9.2	82	0.38	0.54	0.92	0.20
Surficial aquifer (2 to 5 feet below land surface)	3	6.5	3.1	8.6	1.7	8	22	14	11	71	-	-	-	-
Surficial aquifer (10 to 15 feet below land surface)	3	13	4.0	10	10	23	52	14	6.7	117	.40	.56	.97	.02
Yorktown Formation	2	122	6.1	9.7	1.6	335	40	11	7.3	362	.01	.45	.47	.18

velocities are high, the particles are picked up by the stream and become waterborne; thus, concentrations of minor elements and nutrients often increase significantly during periods of high runoff (table 5).

Because of the numerous farming activities in the basin, a major water-quality concern is the level of nutrients in the basin's streams. Of the four stream sampling sites, the greatest concentrations of total phosphorus, total nitrogen and Kjeldahl nitrogen occurred at Site 3 during base-flow conditions. During storm runoff nutrient values were similar at all Chicod Creek sites. The extent of man's effects on stream quality can sometimes be estimated by comparisons with data for nearby streams which are operated by the U.S. Geological Survey as baseline indicators of water quality (Simmons and Heath, 1979, p. 4-5). The network of stations used to define unpolluted or baseline conditions in Coastal Plain streams is shown in figure 8. In comparison to the baseline water-quality sites, mean concentrations of nutrients in Chicod Creek were greater regardless of flow conditions (fig. 9).

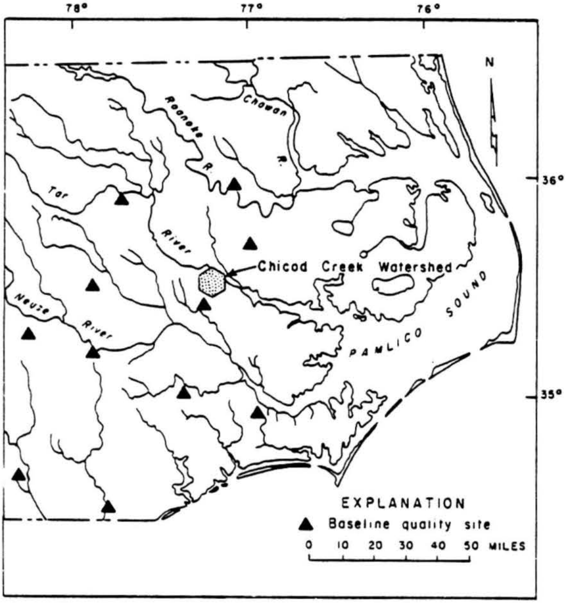

Figure 8.--Location of U.S. Geological Survey baseline-quality network sites in the Coastal Plain region.

Pesticide analyses were made on samples of surface water and bottom materials during periods of low base flow and storm runoff (table 7). The only pesticides detected in surface water samples were minute traces of DDT and dieldrin which occured during high flow. DDT was detected in surface water only at Site 3 and concentrations were less than 0.01 ug/L. Dieldrin occurred at Sites 2, 3, and 4, with concentrations ranging from .01-.02 ug/L.

The most frequently detected pesticides in bottom materials were DDT (0.1-15 ug/kg), DDE (1.8-30 ug/kg), DDD (1.5-56 ug/kg) and dieldrin (1.4-4.5 ug/kg). Endrin was also found at Sites 1 and 2 during high flow conditions at concentrations less than 0.2 ug/kg.

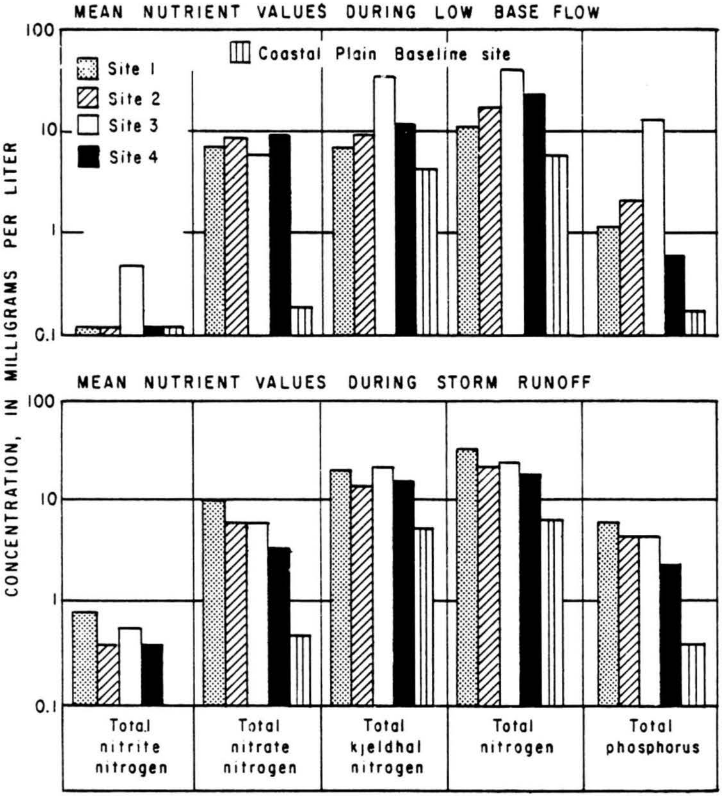

Figure 9.--Comparisons of mean nutrient concentratious during low base flow and storm runoff at Chicod Creek basin and baseline-quality sites.

Table 7.--Comparison of pesticides in surface water with pesticides in bottom materials.

Sample Site	Flow Condition	DDD		DDE		DDT		Diazinon		Dieldrin		Endrin	
		Water	Bottom material	Water	Bottom material	Water	Bottom material	Water	Bottom material	Water	Bottom material	Water	Bottom material
Site 1	Base	0	1.8	0	7.1	0	2.3	0	0	0	3.1	0	0
	Storm	0	56	0	30	0	9.4	0	0	0	5.6	0	1.0
Site 2	Base	0	22	0	6	0	0.1	0	0	0	4.3	0	0
	Storm	0	12	0	15	0	6.5	0	0	.01	3.4	0	.2
Site 3	Base	0	2.6	0	1.8	0	0	0	0	0	1.4	0	0
	Storm	0	1.5	0	0	.01	0	0	0	.02	0	0	0
Site 4	Base	0	9.0	0	2.5	0	0	0	0	0	1.8	0	0
	Storm	0	9.5	0	9.0	0	15	0	0	.01	1.9	0	0

NOTE: Concentrations in surface water, in micrograms per liter; concentrations in bottom materials, in micrograms per kilogram.
Zero values above indicate "none present."

The above characteristics indicate that: (1) the pesticides are associated with stream-bed materials both of which become waterborne due to turbulence caused by high flows; (2) the pesticides are sorbed to or associated with sediments or other materials recently washed into the stream by storm runoff from fields and farm facilities; or (3) the pesticides are derived from a combination of the previous two sources.

Few significant changes in the chemical quality of streams in the basin are expected from channel improvement. Because concentrations of several major dissolved constituents, such as calcium, appear to increase with depth below land surface, lowering the channels will probably increase the discharge of ground-water from the deeper part of aquifers where the water has greater concentrations of these constituents. Increases in constituent levels will be greatest during base flow and will probably include calcium, bicarbonate, and sulfate.

In determining the effects of channel excavation on surface-water quality, due consideration must also be given to changes in large-scale agricultural or livestock operations which might occur during the study period. For instance, changes in waste disposal procedures for a single large livestock or poultry operation, providing it is located near a stream, might completely mask any changes caused by channelization.

Bacteria

Certain bacteria, specifically fecal streptococcus and fecal coliform, are important indicators of pollution caused by fecal-waste contamination from warm-blooded animals including man. The ratio of fecal coliform (FC) counts to those of fecal streptococcus (FS) is often used by biologists to determine the source of the bacteria. A FC/FS ratio equal to or less than 0.7 is an indication that the pollution or bacteria are derived predominantly or entirely from livestock or poultry wastes (Millipore Corporation, 1972). Bacteriological data for sites in the Chicod Creek basin are shown in table 8. These data indicate that bacterial counts are greatest during high flows. The FC/FS ratio is characteristic of overland runoff from areas occupied by farm animals.

Based on samples collected periodically, a maximum fecal coliform count of 8,600 colonies per 100 ml occurred at sites 2 and 3 during a period of high flow. It was noted during the 1978 basin reconnaissance that numerous farm animals have direct access to stream waters in the vicinity of site 3, which probably contributes greatly to the high values at both sites.

Table 8.--Comparison of water discharge with bacteriological data.

Location	Site 1		Site 2			Site 3					Site 4		
Date of Sample	Apr 26 1978	Apr 26 1978	Nov 8 1977	Nov 10 1977	Apr 27 1978	Nov 8 1977	Nov 10 1977	Apr 26 1978	Apr 26 1978	Apr 26 1978	Nov 8 1977	Nov 10 1977	Apr 26 1978
Time	1645	2100	1700	1200	0400	1800	1400	0400	1800	2400	1930	1630	1845
Discharge (ft^3/S)	600	410	960	260	2020	132	47	576	1355	1075	380	119	576
Fecal coliform (colonies/100 ml)	3500	3700	160	120	8600	210	140	8600	7100	6100	42	12	2100
Fecal strep (colonies/100 ml)	7200	7400	1400	1200	>2000	1500	1700	>2000	>2000	7800	1020	600	>2000
FC/FS Ratio	.49	.50	.11	.10	NA	.14	.08	NA	NA	.78	.04	.02	NA

NA - not available

$$\text{FC/FS ratio} = \frac{\text{Fecal coliform, in counts per 100 ML}}{\text{Fecal streptococcus, in counts per 100 ML}}$$

SUMMARY

The main sources of streamflow in the Chicod Creek basin are surface runoff from heavy rains and ground-water discharge from the shallow surficial aquifers. Water-level fluctuations in shallow wells in the basin are similar. Excellent relationships generally exist between water levels in shallow aquifers and the stage and flow of streams. During the 1976-79 study period most streams in the basin were dry at least 10 percent of the time.

Stream quality in the Chicod Creek basin is influenced primarily by natural processes and by constituents derived from farming and domestic animal activities. Concentrations of suspended sediment in these sluggish swampy streams are low, ranging from zero during periods of low flow to nearly 1000 mg/L during periods of intense storm runoff. Concentrations of dissolved oxygen range from near anaerobic conditions at low flows to saturated conditions during floods.

Chemical characteristics of the water in streams are largely influenced by flow conditions and environmental factors. Whereas major dissolved constituents reach maximum concentrations during base flow, maximum levels of nutrients and minor elements generally occur during storm runoff. For instance mean concentrations of total dissolved solids during base flow in the basin are 3 to 4 times those which occur during floods. Of the four study sites, concentrations of major dissolved constituents and nutrients during base flow are significantly greater in Cow Swamp, however, concentrations during storm runoff are relatively similar at all sites.

Nutrient concentrations in the Chicod basin are significantly greater than concentrations at unpolluted baseline sites in the Coastal Plain. Values of Kjeldahl nitrogen, total nitrogen and total phosphorus were often 5 times greater at Chicod sites than those at baseline sites during storm runoff and as much as 10 times greater during base flow conditions. Excessive nutrient levels in the Chicod Creek watershed are apparently related to direct drainage into streams from livestock, poultry, and agricultural operations.

Although no pesticides were detected in surface water during periods of base flow, minute traces of DDT and dieldrin occur during storm runoff. Detectable quantities of a number of pesticides are found in the streambed materials.

The ratio of fecal coliform counts to those of fecal streptococcus indicate that all of the streams receive fecal wastes from livestock and poultry operations.

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