EFFECTS OF CHANNEL RELOCATION AND PROPOSED BRIDGE CONSTRUCTION ON FLOODFLOWS OF THE CATAWBA RIVER NEAR MARION, NORTH CAROLINA

By T.C. Stamey

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ABSTRACT

The relocation of a part (about one-half a mile) of the Catawba River near Marion, North Carolina, and the proposed addition of a main bridge and an overflow bridge of U.S. Highway 221 have created the need for a current evaluation of the effects of these physical changes on floodflow in the river. The 100-year flood discharge, elevation-discharge relations, flood profiles, floodway, and flooding effects were determined for 1988 and for proposed bridge conditions.

Analysis of data indicates that for the 100-year flood, the maximum amount of backwater effect from the proposed bridges would be 1.2 feet, and backwater would extend upstream about 6,800 feet. The 100-year flood elevation in the relocated channel reach will be about 6 feet lower than elevations determined in a 1983 U.S. Soil Conservation Service flood study.

INTRODUCTION

About two or three percent of the land in McDowell County is located on flood plains. Even with this small percentage, the flood-plain lands are significant to the total amount of developable land in the county (U.S. Department of Agriculture, 1983).

The steepness of the land in the county imposes severe limitations on access and construction. Only about 10 percent of the land is suitable for light industry development, and only about 20 percent of the area is suitable for the construction of roads and streets (U.S. Department of Agriculture, 1983). Therefore, the demand for accessible land for development has resulted in encroachment into flood-prone areas.

The Catawba River is located in McDowell County near the town of Marion, North Carolina (fig. 1). Parts of adjoining low-land areas are subject to periodic flooding and have been previously designated by McDowell County as flood-prone areas. In early 1987, the Federal Emergency Management Agency (FEMA) also designated these same areas as flood-prone areas for inclusion into their National Flood Insurance Program (C. Campbell, Federal Emergency Management Agency, oral commun., 1987).

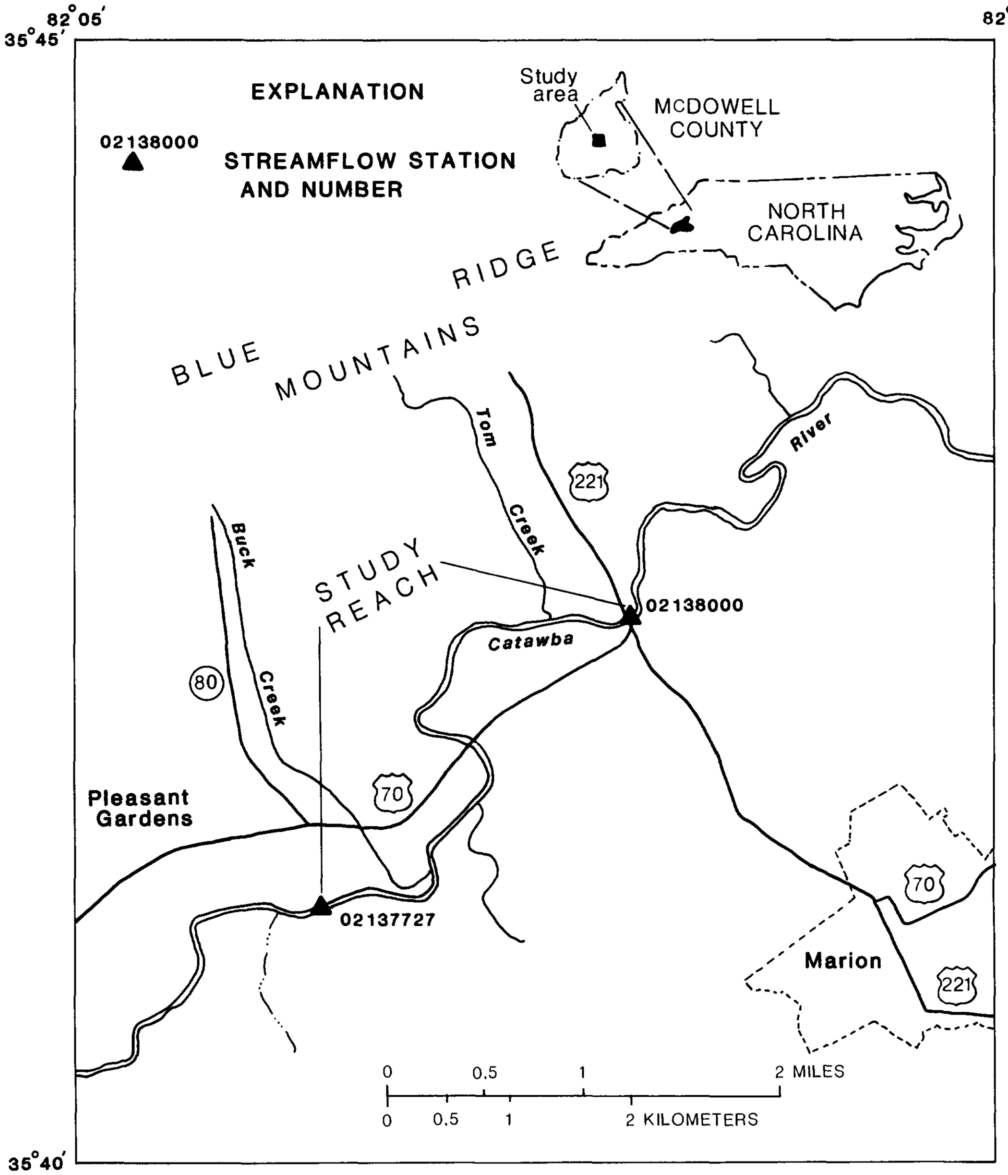

Figure 1.--Location of study reach and streamflow stations.

With increasing population along with development and construction planned for this area, up-to-date flood information is needed by the county to better administer the local flood-plain management program. The population of McDowell County is about 35,135, according to the 1980 census, and is projected to increase to about 45,000 by the year 2000 (U.S. Department of Agriculture, 1983).

Since 1983, a part of the Catawba River downstream of U.S. Highway 70 has been physically relocated and altered by local gravel-mining operations. The new channel was cut through a part of the old flood plain and merged with the old channel about 3,300 feet (ft) downstream of U.S. Highway 70 as shown in figure 2. Recently, the North Carolina Department of Transportation (NCDOT) announced plans to construct a new road and bridge expanses across the river about 3,500 ft downstream from the lower limit of the relocated channel. The plan includes the construction of a 330-foot bridge over the main channel and a 210-foot over-flow bridge about 1,000 ft upstream of the existing bridges on Highways 221 and 226 (fig. 2). The U.S. Geological Survey (Survey), in cooperation with McDowell County, initiated a study in April 1987 to evaluate the effects of the new channel and the proposed new bridges on floodflows along a 3-mile reach of the Catawba River upstream from U.S. Highway 221.

The implementation of land-use regulations governing the development of flood-prone areas is a major part of community participation in the National Flood Insurance Program. The information and technical data from this study can be used as a basis for administering regulations governing the use and development of flood-prone areas along the study reach of the Catawba River in McDowell County. The information can also be used as a basis for further study and planning of flood-prone areas in McDowell County and for developing and evaluating alternative long-term solutions to local flooding problems.

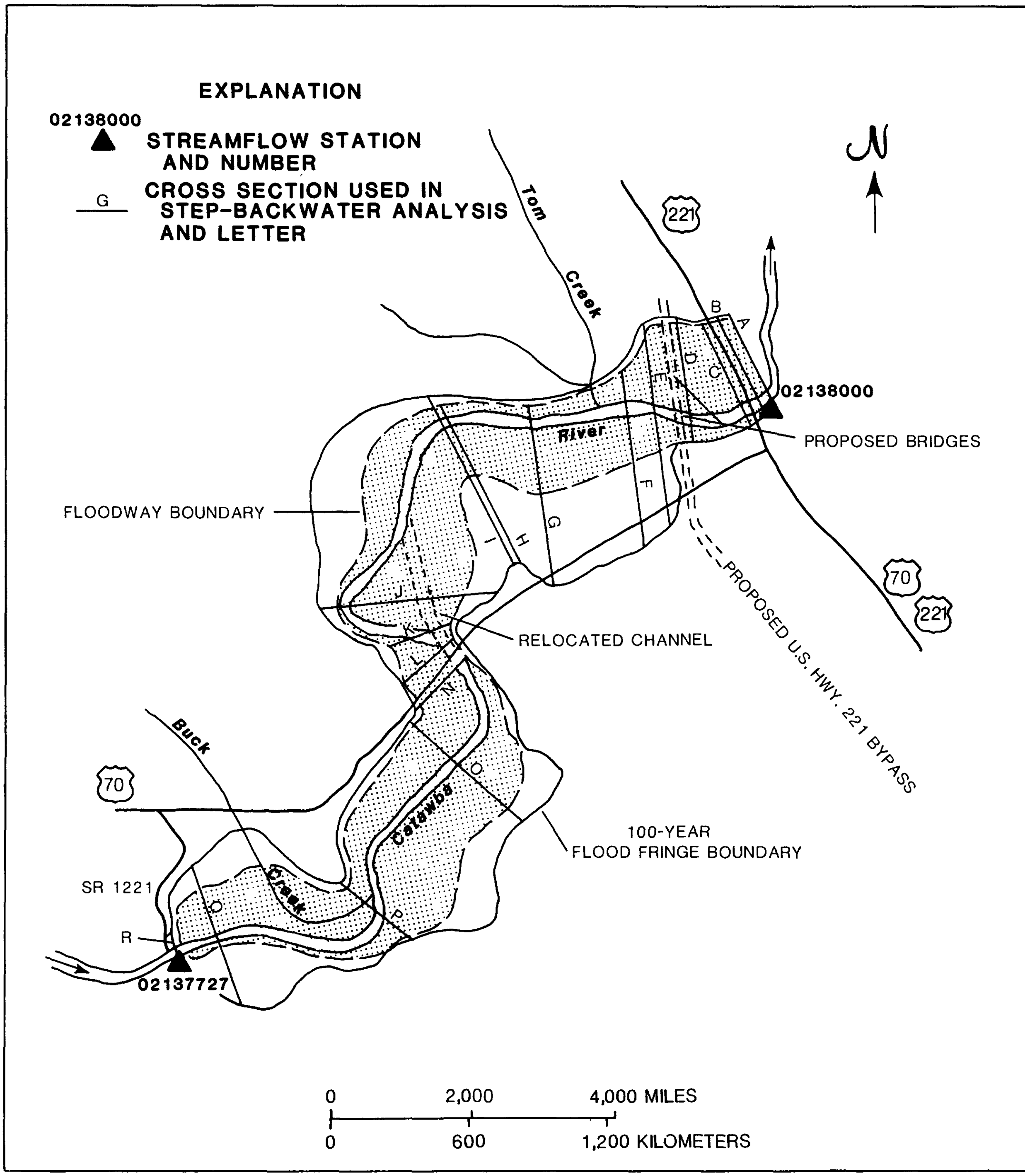

Figure 2.--Relocated channel, proposed bridges, cross sections, 100-year flood boundary, and floodway in the study reach.

Purpose and Scope

The purpose of this report is to describe the floodflow characteristics and the hydraulic effects of a relocated channel and the proposed new bridges on a 3-mile reach of the Catawba River upstream from U.S. Highway

221 near Marion, North Carolina. The data presented include the 100-year flood discharges and elevations, flood profiles, and floodways for current 1988 conditions and for the proposed bridge conditions. Also included is a comparison of these data to the 1983 Soil Conservation Service flood study. Backwater effects estimated from step-backwater computations based on measured geometry of the relocated channel and proposed bridge designs are also presented in this report.

Study Reach

The Catawba River originates in the eastern slopes of the Blue Ridge Mountains and flows southeast through the central part of the State. With the steep terrain, stream runoff is rapid and stream velocities can easily exceed 12 feet per second during significant floods.

The study reach includes about 3 miles (mi) of the Catawba River in McDowell County about 2 mi north of Marion, North Carolina (fig. 1). This reach begins 200 ft downstream of U.S. Highway 221 (drainage area, 172 square miles) and extends upstream to Secondary Road 1221 (drainage area, 126 square miles) (fig. 2). Land-surface elevations range from about 1,206 to 1,257 ft above sea level. The average stream gradient in the study reach is about 8.9 feet per mile (fig. 3).

Available Data

Streamflow data are available at two gaging stations operated on the Catawba River by the U.S. Geological Survey; one at U.S. Highway 221 (station 02138000) was operated from 1941 to 1981 and another at Secondary Road 1221 (station 02137727) which was operated from 1980 to the present (1988) (fig. 2). Land-surface elevations (in feet above sea level) of the stream channel and flood-plain cross sections at various locations along the stream were surveyed by personnel of the Survey in 1987 (fig. 2). Drainage areas for various locations were planimetered on Survey 7.5-minute quadrangle topographic maps.

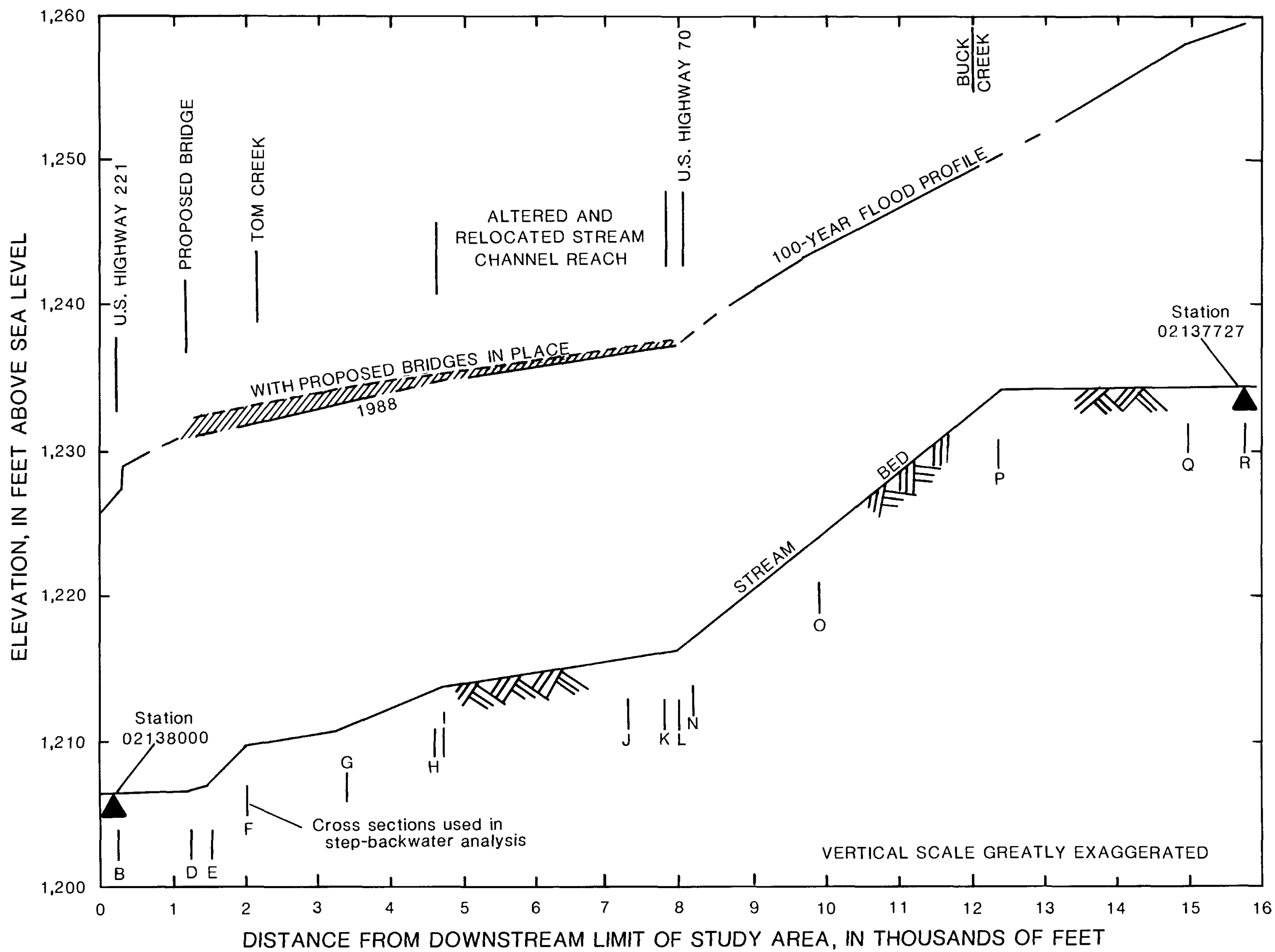

Figure 3.--One hundred-year flood profiles of study reach for 1988 and for projected conditions with proposed bridges in place.

Acknowledgments

The author gratefully acknowledges the cooperation of McDowell County and the North Carolina Department of Transportation for making bench-mark data and bridge-design data readily available. Bench-mark descriptions and elevations were furnished by McDowell County Engineering Department, and proposed bridge-design data were supplied by the NCDOT.

Previous Investigations

Two countywide flood investigation reports have been published for McDowell County, both of which cover areas of the Catawba River basin. One report was published by the U.S. Army Corps of Engineers (1971) and the other was published by the Soil Conservation Service (SCS) of the U.S. Department of Agriculture (1983). The information contained in the SCS report is being used by the county in their present flood-plain management program.

FLOODFLOW CHARACTERISTICS

Floodflow characteristics determined in this study include the 100-year flood discharges and elevations at both streamflow stations, flood profiles, floodways, and floodflow effects for 1988 and for proposed bridge conditions within the study reach. The 100-year flood profile and floodway computations were determined using the Water Surface Profile Computer Model "WSPRO" (Shearman and others, 1986). Each of these is discussed in the following sections.

Flood Frequency

The SCS has previously published a 100-year flood discharge of 54,700 cubic feet per second (ft^3/s) for station 02138000, Catawba River near Marion (U.S. Department of Agriculture, 1983). They employed the "TR 20" model that translated a 100-year, 24-hour rainfall over the Catawba River basin into flood runoff (H. Fox, Soil Conservation Service, oral commun., 1988). This established the 100-year discharge and other 100-year discharges for sites elsewhere in the basin that were used for this study.

Confirmation of the reasonability of the 100-year flood discharge published by SCS was made by examining the annual peaks for the gaging station, Catawba River near Marion, which are available from 1942 to 1981. Historical peaks also are available for extremely large floods that occurred in 1916 (105,500 ft^3/s) and in 1940 (71,400 ft^3/s). These data were used in a flood-frequency analysis to compute an estimated value of 45,500 ft^3/s for the 100-year flood discharge using the weighted and regional flood-frequency values reported by Gunter and others (1987).

FEMA guidelines do not recommend a revision of an established flood discharge unless a subsequent value differs by more than 25 percent (Federal Emergency Management Agency, 1985). Because the 100-year discharge determined using both the station record and the methods in Gunter and others (1987) are within 25 percent of the established value, the 100-year discharge of 54,700 ft^3/s published by SCS was used. Also, because historic floods since 1916 have been higher than 54,700 ft^3/s, a lesser value is probably not reasonable. The 100-year flood discharge values as determined by the Survey and SCS methods for locations in the study area are given in table 1.

Flood Profiles

The step-backwater model "WSPRO" (Shearman and others, 1986) was used to compute the 100-year flood profiles for the study reach. The model requires a beginning elevation and discharge at the initial downstream cross section. After a successful energy balance is attained between the first two cross sections, the model steps to the next upstream cross section in the same manner. The model continues in this way until the entire study reach is completed.

Table 1.--*One hundred-year flood discharges for selected sites on the Catawba River near Marion, North Carolina*

[ft, feet; mi^2, square miles; ft^3/s, cubic feet per second]

Site[1/]	Upstream reference distance (ft)	Drainage area (mi^2)	Discharge[2/] (ft^3/s) Survey	SCS
02138000	0	172	45,500	54,700
U.S. Highway 70	8,050	161	42,300	53,500
02137727	15,800	126	33,000	45,000

[1/]Site locations shown on figures 1 and 2.
[2/]Values rounded to 3 significant figures (U.S. Department of Agriculture, 1983).

The beginning stage for the step-backwater analysis was determined from an existing stage-discharge relation for streamflow station 02138000. As shown in table 1, the SCS 100-year flood discharge at that site is 54,700 ft^3/s. Based on the well-defined stage-discharge relation for the site, the corresponding elevation of the 100-year flood is 1,226.0 ft at the site.

The beginning stage and discharge were entered into the model along with the required roughness coefficients (Manning's n-value) for each cross section in the study reach. The roughness coefficients were estimated from field observations in the study reach and from published reports (Barnes, 1967; Arcement and Schneider, 1984). Roughness coefficients were adjusted during model calibration until the computed water surface elevations at the upper end of the study reach (station 02137727) were in agreement with the stage-discharge rating at that site. Channel roughness coefficients ranged from 0.055 to 0.065, and those for the flood plains ranged from 0.065 to 0.085.

The calibrated model was used with these data to compute the 100-year flood elevations at each of the measured cross sections. Geometric data for the proposed bridges were added to the channel geometry data, and another set of 100-year flood elevations were computed for each of the measured cross sections. Computed flood elevations for 1988 and for projected future conditions with the proposed bridges in place are listed in table 2.

Floodway Computations

The floodway is the stream channel and that part of the adjacent flood plain that must remain open and unobstructed to permit safe passage of flood waters. The flood waters flow deepest and swiftest in the floodway, and structures located in this area are subject to the greatest dangers during flooding. The remainder of the inundated flood plain or flood-fringe area contains more shallow water, which may have little or no movement. Most communities will, therefore, usually permit limited development in the flood fringe provided that (1) buildings are above the 100-year flood elevation or otherwise protected from the 100-year flood and (2) the enchroachment does not cause an increase in the 100-year flood height by more than 1 foot as specified in the National Flood Insurance Program. Each community can set a lesser amount of increase, if desired. The 1-foot maximum was used in this study.

The floodway computations were made by using the Survey step-backwater computer program "WSPRO" (Shearman and others, 1986). Floodway computations for current (1988) conditions with the proposed bridges on the Catawba River in place are shown in table 2.

EFFECTS OF CHANNEL RELOCATION AND PROPOSED BRIDGE CONSTRUCTION

In the part of the main channel of the Catawba River that was relocated as a result of gravel-mining operations, model results indicated that for the 100-year flood, the flood elevation would be about 6 ft lower than the elevation reported in the previous report (SCS, 1983). This large decrease in the 100-year flood elevation in this reach can be attributed to the widening, straightening, and deepening of the stream channel.

Table 2.--*One hundred-year flood elevations and floodway data in the study reach for 1988 and for projected conditions with proposed bridges in place*

		1988				Proposed bridges in place			
			Water surface elevation				Water surface elevation		
Cross section[1/]	Upstream reference distance (feet)	Floodway width (feet)	Without floodway (feet above sea level)	With floodway (feet above sea level)	Elevation difference (feet)	Floodway width (feet)	Without floodway (feet above sea level)	With floodway (feet above sea level)	Elevation difference (feet)
A	0	1,323	1,226.0	1,227.0	1.0	1,323	1,226.0	1,227.0	1.0
B	200	1,326	1,227.1	1,227.9	.8	1,326	1,227.1	1,227.9	.8
C	280	1,331	1,229.1	1,229.6	.5	1,331	1,229.1	1,229.6	.5
D	1,200	1,234	1,231.0	1,231.5	.5	1,234	1,231.0	1,231.5	.5
E	1,500	1,239	1,231.2	1,231.7	.5	1,908	1,232.3	1,232.6	.3
F	2,000	1,408	1,231.6	1,232.0	.4	1,520	1,232.8	1,233.2	.4
G	3,400	1,435	1,233.0	1,233.6	.6	1,470	1,233.8	1,234.2	.4
H	4,650	1,312	1,234.7	1,235.5	.8	1,385	1,235.0	1,235.6	.6
I	4,700	1,318	1,234.7	1,235.6	.9	1,392	1,235.1	1,235.7	.8
J	7,300	1,895	1,236.6	1,237.6	1.0	1,917	1,236.8	1,237.7	.9
K	7,800	722	1,236.8	1,237.6	.8	728	1,236.9	1,237.7	.8
L	8,000	994	1,237.1	1,238.1	1.0	994	1,237.1	1,238.1	1.0
M	8,050	994	1,237.3	1,238.3	1.0	994	1,237.3	1,238.3	1.0
N	8,200	1,017	1,238.2	1,239.0	.8	1,017	1,238.2	1,239.0	.8
O	9,900	1,800	1,243.4	1,243.7	.3	1,800	1,243.4	1,243.7	.3
P	12,400	1,218	1,249.1	1,249.7	.6	1,218	1,249.1	1,249.7	.6
Q	15,000	868	1,257.1	1,257.5	.4	868	1,257.1	1,257.5	.4
R	15,800	241	1,258.4	1,259.0	.6	241	1,258.4	1,259.0	.6

[1/] Cross section location shown in figure 3.

Backwater that might be expected with the construction of the proposed main channel bridge and an overflow bridge were evaluated using data furnished by the NCDOT and the Survey step-backwater model. The results of this analysis indicated that backwater would increase flood stages by a maximum of about 1.2 ft during the 100-year flood and that the backwater effects would extend upstream no further than 6,800 ft or to about cross section L (table 2).

SUMMARY AND CONCLUSIONS

With the relocation of a part of the main channel of the Catawba River, resulting from local gravel-mining operations, and with the proposed addition of a main bridge and an overflow bridge for U.S. Highway 221, McDowell County needed a current evaluation of the effects of these physical changes on floodflows to better administer their flood-plain ordinances. The U.S. Geological Survey, as a participant in a program of water-resources investigations in cooperation with McDowell County, studied the floodflow characteristics and the effects of the relocated channel and proposed bridges on a designated reach of the Catawba River near the town of Marion, North Carolina. Discharge, flood elevations, flood profiles, and floodways were determined for the 100-year flood for 1988 conditions and for projected conditions with the proposed new bridges in place. Analyses of these data using a Survey step-backwater model indicate that in the relocated channel reach downstream of U.S. Highway 70, the 100-year flood elevation will be about 6 ft lower than the previously determined 100-year flood elevation. During the 100-year flood, the maximum backwater effect from the proposed bridges would be about 1.2 ft, and effects from the backwater would extend about 6,800 ft upstream.

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GLOSSARY

Some of the technical terms frequently used in this report are defined in this section. See Dalrymple (1960) and Langbein and Iseri (1960) for additional information regarding flood-frequency analysis and associated terminology.

Computed flood is an estimated future flood based on a hydraulic analysis of the potential storm runoff from an area and flow of water through the flood plain.

Cross section of a flood plain is a vertical section of the flood plain surface, normally taken at right angles to the direction of floodflow.

Discharge is the volume of water (or more broadly, total flow(s)) that moves past a given point within a specified period of time.

Drainage area of a stream at a specified location is the area measured in a horizontal plane, which is enclosed by a topographic divide. Upstream from the specified location, direct surface runoff normally drains by gravity into the stream.

Elevation-discharge rating is an empirical relation between stream stage and discharge. Ratings are normally developed from concurrent field measurements of discharge and stage and may change with time due to changes in physical characteristics of the stream channel, such as scouring or deposition of sediment and debris.

Flood boundary is the estimated outermost limit the waters of a flood of a certain magnitude will reach.

Flood-frequency analysis is a procedure to determine flood magnitude that will, on the average, be exceeded once within a specified number of years. The U.S. Geological Survey uses the log-Pearson Type III distribution for analyzing annual maximum floods for gaged sites on streams. The distribution and procedure are described by the U.S. Water Resources Council (1981).

Flood-plain management is a term applied to the full range of public policy and action for ensuring wise use of the flood plains. It includes, but is not limited to, collection and dissemination of flood-control information, acquisition of flood-plain lands, enactment and administration of flood-plain regulations, including building codes, and construction of flood-modifying structures.

Flood-plain regulation is a term applied to the full range of codes, ordinances, and other regulations relating to the use of land and construction within designated flood-plain limits.

Flood profile is a graph showing the variation in stage along a stream reach for a specified flood discharge.

Flood stage is the water-surface elevation above a selected datum. Sea level is used in this study.

Floodway is the channel of the stream and those parts of the adjoining flood plain that carry and discharge floodwaters of a particular flood event.

Manning's roughness coefficient, n, is a factor used with open-channel flow equations and is a measure of channel boundary roughness. Typical values of roughness are tabulated for various boundary conditions in a variety of open-channel hydraulic texts. Value of roughness coefficients are estimated from aerial photographs, streamflow records, and field-site surveys.

100-year flood is a flood that is expected to be equaled or exceeded, on the average, once every 100 years and has a one-percent chance of occurring in any given year. Percentage is determined by dividing one by the recurrence interval and multiplying by 100.

Recurrence interval as applied to floods is the average time interval within which a flood of a specified magnitude is expected to be exceeded at least once.

Reach are segments of a stream which mark boundaries such as the limits of a study, corporate limits, State or county lines, or other definable features.

Step-backwater analysis is a procedure used by the U.S. Geological Survey to determine water-surface elevation for specified discharge at points along a stream reach where dimensions of channel geometry are known. The procedure is based upon the principle of conservation of energy between adjacent cross sections.

Streamflow station is a site on a stream where systematic records of stage and discharge are obtained. Stage records are normally collected by means of continuous recorders.

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