APPENDIX A

Explanation of Variables in the South Carolina Bridge-Scour Database

Data for this project have been compiled into a database, including photographs, figures, observed scour depths, theoretical scour depths, limited basin characteristics, limited soil data, and theoretical hydraulic data and can be viewed using Microsoft Access[1]. The South Carolina Bridge Scour Database (SCBSD) provides automated report formats that can be used to view data for a given site. The raw data also can be viewed in tabular format. Although most data for a given site can be viewed through the report formats, some data can only be viewed in the raw data tables. Blank data entries that appear in the reports or raw data tables indicate that data are not applicable or are missing. Following is a list and brief description of the automated report formats that are in the SCBSD.

(1) Information Report

- includes site location information, bridge length, construction history, bridge age, drainage area, and channel slope.

(2) Abutment Scour Report

- includes theoretical abutment-scour depths computed with the Froehlich (1989) equation and the variables used to compute those depths; hydraulic variables in this report were estimated with the Water-Surface Profile (WSPRO) model (Shearman, 1990).

(3) Clay Information Report

- includes selected grain-size data for the second set of soil samples obtained at all Piedmont sites and at nine Coastal Plain sites; the second set of samples were collected to better define the percent of clays and silts at the selected sites.

(4) Clearwater Scour Report

- includes theoretical clear-water contraction scour depths computed with the Laursen (1963) equation and the variables used to compute those depths; hydraulic variables in this report were estimated with the WSPRO model (Shearman, 1990).

(5) Field Information Report

- includes selected scour-hole dimensions, observed infill depths, median grain size based on the initial soil samples, and general soil type at the site.

(6) Livebed Scour Report

- includes theoretical live-bed contraction-scour depths computed with the modified Laursen (1960) equation presented in HEC-18 (Richardson and Davis, 1995) and the variables used to compute those depths; live-bed scour was computed only at sites with significant low-flow channels; hydraulic variables in this report were estimated with the WSPRO model (Shearman, 1990).

(7) Pier Scour Report

- includes theoretical pier-scour depths computed with the HEC-18 (Richardson and Davis, 1995) pier scour equation and the variables used to compute those depths; only limited theoretical pier-scour data are included in the SCBSD as described in the "Theoretical Pier

---

[1] Any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

Scour" section of the report; hydraulic variables in this report were estimated with the WSPRO model (Shearman, 1990).

(8) Wspro Report

- includes selected hydraulic variables computed with the WSPRO model (Shearman, 1990).

(9) Photos

- includes photographs and captions for most sites.

(10) Scour Figures

- includes scour contour plots for 80 sites (primarily located in the Coastal Plain).

There are eight raw data tables in the SCBSD; a brief description of each table and the associated variables follows. The headings for the following sections correspond with the table names in the database and are listed in alphabetical order. It should be kept in mind that hydraulic variables in the database are estimates obtained from the WSPRO (Shearman, 1990) model and errors could exist within these estimates.

Abutment_Scour Table

Theoretical abutment-scour depths and the variables used to compute those depths are stored in this table. Theoretical scour was computed for the 100-year flow, index flow, and the maximum historic flow when available. Scour depths were computed using the Froehlich (1989) and the Highways in the River Environment (HIRE) (Richardson and others, 1990) equations as presented in HEC-18 (Richardson and Davis, 1995). For more details about the computation of abutment scour, refer to the "Theoretical Abutment Scour" section of the report. The variables in the database table are briefly defined below:

bridgeno	South Carolina Department of Transportation (SCDOT) bridge identification number
abut_qtype	identifies the flow used in the theoretical computation as the 100-year flow (Q100), the index flow (QAGE), or the maximum historic flow (QHIS)
abut_location	identifies abutment location as either the left or right abutment as determined by an observer looking downstream
abut_blocked cfs	approach flow obstructed by the embankment, in cubic feet per second (ft^3/s)
abut_blocked area	approach flow area obstructed by embankment, in square feet (ft^2)
abut_blocked length	length of embankment blocking flow, in feet (ft)
abut_flowdepth	flow depth directly at abutment toe, in ft
abut_blocked flowdepth	average approach flow depth obstructed by the embankment, in ft
abut_skew	skew of embankment to flow, in degrees; positive skews indicate the embankment points upstream; negative skews indicate the embankment points downstream
abut_tube flowvel	flow velocity at abutment toe determined from the WSPRO stream tube located at the bridge abutment in the bridge cross section, in feet per second (ft/s)
abut_blocked flowvel	average approach flow velocity obstructed by the embankment, in ft/s
abut_k1	coefficient for abutment type
abut_k2	coefficient for embankment skew
abut_froel froude	Froude number for the approach flow obstructed by the embankment

abut_froel scourdepth	theoretical abutment-scour depth computed using the Froehlich (1989) equation, including safety factor
abut_scourdepth wo	theoretical abutment-scour depth computed using the Froehlich (1989) equation, but without safety factor
abut_hire froude	Froude number for HIRE (Richardson and others, 1990) equation
abut_hire scourdepth	theoretical abutment-scour depth computed using the HIRE (Richardson and others, 1990) equation
abut_type	identification of abutment type (spill through or vertical)

Bridge Info Table

This table provides basic site information including bridge identification, location, limited basin characteristics data, construction dates, SCDOT bridge-plan file numbers, and bridge age. The variables are defined below:

bridgeno	SCDOT bridge identification number
county	county in which the bridge is located
long	longitude of bridge, in degrees, minutes, seconds
lat	latitude of bridge, in degrees, minutes, seconds
province	physiographic province in which the bridge is located
road	road type and number
stream	name of stream
drainagearea	drainage area at bridge, in square miles (mi^2)
channel_slope	channel slope at the bridge as determined from U.S. Geological Survey (USGS) 7.5-minute series topographic map, in feet per foot (ft/ft)
bridgelength	bridge length, in ft
bridgeconstdate	calendar year in which bridge was originally constructed
bridgeplannumber	SCDOT road plans file number from which construction date was estimated
widened	indicates if bridge has been widened since original construction date
widendate	calendar year when bridge was widened
widenplannumber	SCDOT road plans file number from which widening date was estimated
bridgeage	age of bridge in 1996; if bridge was widened, an attempt was made to assess if the construction at the time of widening disturbed the area of scour; if the assessment indicated that the area of scour was disturbed, the age was based on the widening date; otherwise the age was based on the original construction date
oldbridge	indicates if an old bridge was in place (but removed) at the time of the original construction of the existing bridge
oldbridgedata	calendar year in which the old structure was constructed

Clay Information Table

This table provides data for the second set of soil samples obtained to better define the percent of clays and silts at all Piedmont sites and at nine Coastal Plain sites that were noted to have clayey surface soils. The median grain size (D_{50}) in the second set of samples often varies from the D_{50} of the original sample. This in part is attributed to the heterogeneous nature of the soils, and indicates that all soil data in this report should be viewed with caution. This table also includes original soil sample data from the 1999 flood sites along the Waccamaw, Pee Dee, and Little Pee Dee Rivers. The variables in the database table are briefly defined below:

bridgeno	SCDOT bridge identification number
clay_50mm	the D_{50} for the second sediment sample, in millimeters (mm)
percentfiner_0625	the percent finer than 0.0625 mm by weight in the second sediment sample
percentfiner_004	the percent finer than 0.004 mm by weight in the second sediment sample

Clearwater_Scour Table

Theoretical clear-water contraction-scour depths and the variables used to compute those depths are stored in this table. Theoretical scour was computed for the 100-year flow, index flow, and the maximum historic flow when available. Scour depths were computed using the Laursen (1963) clear-water contraction-scour equation as presented in HEC-18 (Richardson and Davis, 1995). For more details about the computation of clear-water contraction scour refer to the "Theoretical Clear-Water Contraction Scour" section of the report. The variables in the database table are briefly defined below:

bridgeno	SCDOT bridge identification number
cw_qtype	identifies the flow used in the theoretical computation as either the 100-year flow (Q100), the index flow (QAGE), or the maximum historic flow (QHIS)
cw_location	identifies overbank location as either the left or right overbank as determined by an observer looking downstream or as a swampy channel with no well-defined low-flow channel
cw_scourdepth	theoretical clear-water contraction-scour depth computed using the Laursen (1963) equation and not subtracting the cumulative pier width from the contracted width, in ft
cw_scourdepth_minuspiers	theoretical clear-water contraction-scour depth computed using the Laursen (1963) equation and subtracting the cumulative pier width from the contracted width, in ft
cw_cfs	flow in the contracted section, in ft^3/s
cw_width	width of contracted section, in ft
cw_flowdepth	average flow depth at the contracted section, in ft
cw_d50mm	the D_{50} based on the original soil sample at each site; for sites with a D_{50} less than 0.062 mm, the D_{50}, was set to 0.062 mm; for additional information on these soils, refer to the Clay Information Table
cw_cum_pierwidth	the cumulative pier width within the contracted section, in ft

Field_Observations Table

This table provides field data collected at each site, including scour-hole geometry and soil data for the original soil sample. The variables are defined below:

bridgeno	SCDOT bridge identification number
obs_location	identifies the location where the scour hole was observed; the left and right overbank or abutment is determined by an observer looking downstream; a swampy channel, in general, refers to shorter bridges (240 ft or less) with a single large scour hole developing at the site rather than individual left and (or) right abutment scour hole
scourdepth_floodpn	scour depth referenced to the average floodplain elevation in the region of the observed scour, in ft
scourdepth_channel	scour depth referenced to the average channel bed elevation in the region of the observed scour, in ft This situation often occurs at swampy sites with shorter bridges, where a shallow channel runs through the scoured region; these data were not used in the analysis of this report but are provided here for information.
dataqual_of_scourdepth	subjective indicator of the quality of the measured scour
infill	the amount of infill at the low point of the scour hole, in ft
dataqual_of_infill	subjective indicator of the quality of the measured infill
pierexistence	indicator of existing pier at the low point of the scour hole
piershape	shape of the pier at the low point of the scour hole
pierwidth	width of the pier at the low point of the scour hole, in ft
dist_bridgecenterline_to_hole	the upstream or downstream distance from the low point of the scour hole to the roadway centerline, in ft; Negative numbers are downstream from the roadway centerline and positive numbers are upstream; refer to the “Scour Hole Longitudinal Location” section of this report for more details.
dist_to_leftedgeofhole	distance from the left edge of the scour hole to the abutment toe as determined by an observer looking downstream, in ft Refer to the “Lateral Reference for Scour Hole” section of this report for more details.
dist_to_scourlowpt	distance from the low point of the scour hole to the abutment toe as determined by an observer looking downstream, in ft
dist_to_rightedgeofhole	distance from the right edge of the scour hole to the abutment toe as determined by an observer looking downstream, in ft Refer to the “Lateral Reference for Scour Hole” section of this report for more details.
scourwidth	top width at the low point of the scour hole, in ft Refer to the “Scour Hole Top Width” section of this report for more details.
scourlength	the longitudinal length of the scour hole, in ft
soiltype_unscour	a subjective indicator of the general surface soils in the unscoured region of the observed scour; this information is not necessarily an indicator of the measured grain size and should be viewed with caution; the information can be used to determine if there is a difference between the surface soils and the soils at the bottom of the scour hole; following is a description of each class:

	• clay – a relatively cohesive soil • sand – a sandy soil with relatively low cohesion • layered – alternating layers of clay and sand • mix – a mixture of sand and clay
<comment_d50mm_unscour	indicator if the D_{50} is less than 0.0625 mm, but was assumed to be 0.0625 mm, because the grain-size analysis of the original soil samples did not go below 0.0625 mm
d50mm_unscour	the median grain size, $D_{50,}$of the original sediment sample, in mm
soiltype_scour	a subjective indicator of the general soils at the low point of the scour hole; this information is not necessarily an indicator of the measured grain size and should be viewed with caution; the information can be used to determine if there is a difference between the surface soils and the soils at the bottom of the scour hole; following is a description of each class: • clay – a relatively cohesive soil • sand – a sandy soil with relatively low cohesion • layered – alternating layers of clay and sand • mix – a mixture of sand and clay
formation	a subjective judgment that indicates if the soil at the bottom of the scour hole is a material from an older geologic formation in contrast to the newer surface alluviums; this is more common in the Coastal Plain where scour initially removes the sandy soils and then cuts into an older geologic formation; the soil characteristics of the formation are distinctly different from the surface alluviums and is often a clayey soil
<comment_d50mm_hole	indicator if the D_{50} is less than 0.0625 mm, but was assumed to be 0.0625 mm, because the grain-size analysis of the original soil samples did not go below 0.0625 mm
d50mm_hole	the median grain size, $D_{50,}$ of the original sediment sample, in mm
wide_enough_scour	indicator if abutment scour hole encompasses most of overbank area precluding the development of a separate clear-water contraction scour hole.

Livebed_Scour Table

Theoretical live-bed contraction-scour depths and the variables used to compute those depths are stored in this table. Theoretical scour was computed for the 100-year flow, index flow, and the maximum historic flow when available. Scour depths were computed using a modified version of the Laursen (1960) live-bed-scour equation as presented in HEC-18 (Richardson and Davis, 1995). For more details about the computation of live-bed contraction scour, refer to the “Theoretical Live-Bed Contraction Scour” section of the report. The variables in the database table are briefly defined below:

bridgeno	SCDOT bridge identification number
cw_qtype	identifies the flow used in the theoretical computation as either the 100-year flow (Q100), the index flow (QAGE), or the maximum historic flow (QHIS)

lb_scourdepth	theoretical live-bed contraction-scour depth computed using the modified Laursen (1960) equation presented in HEC-18 (Richardson and Davis, 1995), in ft
lb_flowdepth_approach	average flow depth in the approach channel, in ft
lb_cfs_approach	flow in the approach channel, in ft^3/s
lb_width_approach	bank-to-bank top width at approach channel, in ft
lb_cfs_bridge	flow in the bridge channel, in ft^3/s
lb_width_bridge	bank-to-bank top width at bridge channel, in ft
lb_eslope	slope of the energy grade line between the approach and bridge cross section, in ft/ft
lb_d50mm	the D_{50} in the live-bed channel, in mm; in most cases these data were obtained from level 2 bridge-scour studies; when this information was not available, a grab sample from the channel was obtained and analyzed for grain-size distribution
lb d50mm fallvel	the fall velocity for the D_{50}, in ft/s

Pier_Scour Table

Theoretical pier-scour depths and the variables used to compute those depths are stored in this table. Theoretical scour was computed for the 100-year flow, index flow, and the maximum historic flow when available. Scour depths were computed using the HEC-18 pier-scour equation (Richardson and Davis, 1995). Only limited theoretical pier-scour data are included in the database. For more details about the computation of pier scour and the data included in the database, refer to the "Theoretical Pier Scour" section of the report. The variables in the database table are briefly defined below:

bridgeno	SCDOT bridge identification number
pier_qtype	identifies the flow used in the theoretical computation as either the 100-year flow (Q100), the index flow (QAGE), or the maximum historic flow (QHIS)
pier_location	identifies the general location of the pier within the bridge opening
pier_scourdepth	theoretical pier-scour depth computed using the HEC-18 pier-scour equation (Richardson and Davis, 1995), in ft
pier_flowdepth	average approach flow depth at the pier, in ft
pier_flowvel	approach flow velocity at the pier, in ft/s
pier_width	width of the pier, in ft
pier_length	length of the pier, in ft
pier_skew	the skew of the pier to the approaching flow, in degrees
pier_k1	the dimensionless correction factor for pier nose shape
pier_k2	the dimensionless correction factor for angle of attack
pier_k3	the dimensionless correction factor for bed conditions
pier_k4	the dimensionless correction factor for bed armoring
pier_froude	the approach flow Froude number

WSPRO_Scour Table

This table provides hydraulic data estimated with the WSPRO (Shearman, 1990) model for various flow conditions, including the 100-year flow, the index flow, and the maximum historic flow when available. Hydraulic data for pre- and post-scour conditions are included for bridge sites with relatively deep scour holes (approximately 4 ft or greater). The names of the hydraulic variables in this table are, in most cases, identical to the variables in the WSPRO manual. For more details about the variables refer to the WSPRO manual (Shearman, 1990). For more details on the approach for developing the models in this study refer to the “Estimating Hydraulic Data“ section of this report. The variables in the database table are briefly defined below:

bridgeno	SCDOT bridge identification number
wspro_condition	identifies the model data as pre-scour or post scour condition
wspro_qtype	identifies the flow used in the model as either the 100-year flow (Q100), the index flow (QAGE), or the maximum historic flow (QHIS)
wspro_crosssection	identifies the cross section for the given hydraulic data
lew	station for left edge of water, in ft
area	cross-section flow area, in ft^2
vhd	cross-section velocity head, in ft
hf	friction loss, in ft
egl	energy grade line elevation, in ft
crws	critical water-surface elevation, in ft
q	flow, in ft^3/s
wsel	computed or assumed water-surface elevation, in ft
flen	effective flow length from approach to bridge, in ft
rew	station for right edge of water, in ft
k	cross-section conveyance
alph	velocity head correction factor for uniform velocity distribution
ho	other losses, in ft
fr	Froude number
vel	flow velocity, in ft/s
type	type of bridge opening
ppcd	code to distinguish between piers and piles
flow	indicates flow class for bridge
c	coefficient of discharge for bridge opening
pa	ratio of pier (pile) area to gross area in the bridge opening
lsel	test value for low-chord elevation in a bridge used to test for possible pressure flow
mg	geometric-contraction ratio
mk	conveyance-contraction ratio
kq	conveyance of Kq segment of the approach cross section
xlkq	left station of Kq section
xrkq	right station of Kq section

Selected References

Froehlich, D.C., 1989, Local scour at bridge abutments: Hydraulic Engineering, *in* Proceedings of the 1989 National Conference on Hydraulic Engineering: New York, American Society of Civil Engineering, p. 13-18.

Laursen, E.M., 1960, Scour at bridge crossings: Journal Hydraulic Division, American Society of Civil Engineering, v. 89, no. HY3.

_____ 1963, An analysis of relief bridge scour: Journal Hydraulic Division, American Society of Civil Engineering, v. 92, no. HY3.

Richardson, E.V., and Davis, S.R., 1995, Evaluating scour at bridges: Federal Highway Administration Hydraulic Engineering Circular No. 18, Publication FHWA-IP-90-017, 204 p.

Richardson, E.V., Simons, D.B., and Julien, P.Y., 1990, Highways in the river environment participant notebook: Federal Highway Administration, Publication FHWA-HI-90-016, 650 p.

Shearman, J.O., 1990, User’s manual for WSPRO—A computer model for water-surface profile computations: Federal Highway Administration, Report no. FHWA-IP-89-027, 175 p.