LEVEL II SCOUR ANALYSIS FOR BRIDGE 120 (LEICUS00070120) on U. S. ROUTE 7, crossing the LEICESTER RIVER, LEICESTER, VERMONT

U.S. Geological Survey
Open-File Report 97-3

Prepared in cooperation with

VERMONT AGENCY OF TRANSPORTATION

and

FEDERAL HIGHWAY ADMINISTRATION

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Pembroke, New Hampshire

1997

U.S. DEPARTMENT OF THE INTERIOR
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CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

Multiply	By	To obtain
	Length	
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Slope	
foot per mile (ft/mi)	0.1894	meter per kilometer (m/km)
	Area	
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
cubic foot (ft^3)	0.02832	cubic meter (m^3)
	Velocity and Flow	
foot per second (ft/s)	0.3048	meter per second (m/s)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
cubic foot per second per square mile [$(ft^3/s)/mi^2$]	0.01093	cubic meter per second per square kilometer [$(m^3/s)/km^2$]

OTHER ABBREVIATIONS

BF	bank full	LWW	left wingwall
cfs	cubic feet per second	MC	main channel
D_{50}	median diameter of bed material	RAB	right abutment
DS	downstream	RABUT	face of right abutment
elev.	elevation	RB	right bank
f/p	flood plain	ROB	right overbank
ft^2	square feet	RWW	right wingwall
ft/ft	feet per foot	TH	town highway
JCT	junction	UB	under bridge
LAB	left abutment	US	upstream
LABUT	face of left abutment	USGS	United States Geological Survey
LB	left bank	VTAOT	Vermont Agency of Transportation
LOB	left overbank	WSPRO	water-surface profile model

In this report, the words “right” and “left” refer to directions that would be reported by an observer facing downstream.

Sea level: In this report, “sea level” refers to the National Geodetic Vertical Datum 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.

In the appendices, the above abbreviations may be combined. For example, USLB would represent upstream left bank.

LEVEL II SCOUR ANALYSIS FOR BRIDGE 120 (LEICUS00070120) ON U. S. ROUTE 7, CROSSING THE LEICESTER RIVER, LEICESTER, VERMONT

By **Erick M. Boehmler and Timothy Severance**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure LEICUS00070120 on U. S. Route 7 crossing the Leicester River, Leicester, Vermont (figures 1–8). A Level II study is a basic engineering analysis of the site, including a quantitative analysis of stream stability and scour (U.S. Department of Transportation, 1993). Results of a Level I scour investigation also are included in Appendix E of this report. A Level I investigation provides a qualitative geomorphic characterization of the study site. Information on the bridge, gleaned from Vermont Agency of Transportation (VTAOT) files, was compiled prior to conducting Level I and Level II analyses and is found in Appendix D.

The site is in the Green Mountain section of the New England physiographic province in west-central Vermont. The 23.0-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover consists of shrubs, brush, and pasture with some trees except for the upstream left overbank area which is forest.

In the study area, the Leicester River has a sinuous channel with a slope of approximately 0.002 ft/ft, an average channel top width of 52 ft and an average channel depth of 3 ft. The predominant channel bed material is sand and gravel with a median grain size (D_{50}) of 3.10 mm (0.0102 ft). The geomorphic assessment at the time of the Level I and Level II site visit on September 18, 1995, indicated that the reach was laterally unstable. Lateral instability was evident with the presence of some bank material failure and fallen or leaning vegetation at cut-banks upstream and downstream of this site. Point bars also were found near this site.

The U. S. Route 7 crossing of the Leicester River is a 108-ft-long, two-lane bridge consisting of two 52-foot steel-beam spans (Vermont Agency of Transportation, written communication, March 13, 1995). The bridge is supported by vertical, concrete abutment walls with stone fill spill-through embankments on each abutment and one pier. The channel is skewed approximately 30 degrees to the opening while the opening-skew-to-roadway is 15 degrees.

The only scour protection measure at the site was type-3 stone fill (less than 48 inches diameter) on the spill-through embankments of each abutment. Additional details describing conditions at the site are included in the Level II Summary and Appendices D and E.

Scour depths and rock rip-rap sizes were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and others, 1995). Total scour at a highway crossing is comprised of three components: 1) long-term streambed degradation; 2) contraction scour (due to accelerated flow caused by a reduction in flow area at a bridge) and; 3) local scour (caused by accelerated flow around piers and abutments). Total scour is the sum of the three components. Equations are available to compute depths for contraction and local scour and a summary of the results of these computations follows.

Contraction scour for all modelled flows ranged from 3.8 to 6.1 ft. The worst-case contraction scour occurred at the 500-year discharge. Abutment scour ranged from 4.0 to 6.7 ft. The worst-case abutment scour also occurred at the 500-year discharge. Pier scour ranged from 9.1 to 10.2. The worst-case pier scour occurred at the 500-year discharge. Additional information on scour depths and depths to armoring are included in the section titled “Scour Results”. Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

It is generally accepted that the Froehlich equation (abutment scour) gives “excessively conservative estimates of scour depths” (Richardson and others, 1995, p. 47). Usually, computed scour depths are evaluated in combination with other information including (but not limited to) historical performance during flood events, the geomorphic stability assessment, existing scour protection measures, and the results of the hydraulic analyses. Therefore, scour depths adopted by VTAOT may differ from the computed values documented herein.

East Middlebury, VT. Quadrangle, 1:24,000, 1944
Photorevised, 1972; Photoinspected 1983

NORTH

Figure 1. Location of study area on USGS 1:24,000 scale map.

Figure 2. Location of study area on Vermont Agency of Transportation town highway map.

LEVEL II SUMMARY

Structure Number LEICUS00070120 *Stream* Leicester River

County Addison *Road* U.S. 7 *District* 3

Description of Bridge

Bridge length 108 *ft* *Bridge width* 38.0 *ft* *Max span length* 52 *ft*

Alignment of bridge to road (on curve or straight) Straight

Abutment type Spill-through *Embankment type* Sloping

Stone fill on abutment? Yes *Date of inspection* 9/18/95

Description of stone fill Type-3, on the spill-through embankments in front of each concrete vertical abutment wall.

Brief description of piers/abutments The pier and abutment walls are concrete. The pier is a solid concrete wall, narrows in width from the streambed to low steel, has a rounded nose, and is 38.5 feet long.

Is bridge skewed to flood flow according to Y *survey?* Y *Angle* 30

There is a moderate channel bend in the upstream reach. Flow impacts the right abutment spill-through embankment.

Debris accumulation on bridge at time of Level I or Level II site visit:

	Date of inspection	*Percent of channel blocked horizontally*	*Percent of channel blocked vertically*
Level I	9/18/95	0	0
Level II	9/18/95	0	0

Potential for debris Moderate. There is some debris accumulation along the left bank side of the channel upstream and under the bridge.

Describe any features near or at the bridge that may affect flow (include observation date) None evident on 9/18/95.

Description of the Geomorphic Setting

General topography The river is located in a low relief valley setting, with narrow, irregular flood plains and steep to moderately sloping valley walls.

Geomorphic conditions at bridge site: downstream (DS), upstream (US)

Date of inspection 9/18/95

DS left: Moderately sloping channel bank to flood plain and a steep valley wall.

DS right: Slightly sloping channel bank to a narrow overbank.

US left: Steep channel bank to a narrow overbank and steep valley wall.

US right: Slightly sloping channel bank to flood plain.

Description of the Channel

Average top width 52 ***ft*** ***Average depth*** 3 ***ft***

Predominant bed material Sand / Gravel ***Bank material*** Silt & Clay

Perennial and meandering with alluvial channel boundaries and swampy surroundings downstream.

9/18/95

Vegetative co Trees, shrubs, and brush

DS left: Grass and brush

DS right: Trees

US left: Short grass and brush with a few trees.

US right: Y

Do banks appear stable? - ***If not, describe location and type of instability and date of observation.***

The assessment of 9/18/95 indicated the pier was located in the channel and some debris had lodged on the left side of the pier.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 23.0 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

Physiographic province/section	*Percent of drainage area*
New England / Green Mountain	100

Is drainage area considered rural or urban? Rural ***Describe any significant urbanization:***

Is there a USGS gage on the stream of interest? No

USGS gage description --

USGS gage number --

Gage drainage area -- ***mi²***

Is there a lake/p Yes

The outlet of Lake Dunmore is located about 1.5 miles upstream and likely will curtail the peak discharge on the Leicester River. However, a rating is not available for the outlet. Therefore, empirical discharge frequency equations, which consider storage, were assumed sufficient to determine the Q100 and Q500.

Calculated Discharges

Q100 1,500 ***ft³/s*** ***Q500*** 2,250 ***ft³/s***

The 100- and 500-year discharges are based on discharge frequency curves computed from several empirical equations (Benson, 1962; FHWA, 1983; Johnson and Tasker, 1974; Potter, 1957a&b; and Talbot, 1887) and a drainage area relationship [(23.0/37.2)exp 0.67] with VTAOT database values (written communication, May, 1995) for bridge number 4 (TH 12) in Leicester. The drainage area above bridge number 4 is 37.2 square miles. The 100- and 500-year discharges from the New England Hills and Lowlands equation (Potter, 1957a) were selected for this hydraulic analysis due to the central tendency of the curve to the others.

Description of the Water-Surface Profile Model (WSPRO) Analysis

Datum for WSPRO analysis (USGS survey, sea level, VTAOT plans) USGS survey

Datum tie between USGS survey and VTAOT plans Subtract 0.44 feet from the USGS survey to obtain VTAOT plans' datum to the nearest foot.

Description of reference marks used to determine USGS datum. RM1 is the center of an engraved triangle in a brass VTAOT survey mark on top of the concrete curb at the upstream left corner of the bridge deck (elev. 210.65 ft, arbitrary survey datum). RM2 is the center point of a chiseled "X" on top of the concrete curb at the downstream right corner of the bridge deck. (elev. 209.20 ft, arbitrary survey datum).

Cross-Sections Used in WSPRO Analysis

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
EXITX	-92	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	23	1	Road Grade section
APPRO	109	3	Modelled Approach section

[1] For location of cross-sections see plan-view sketch included with Level I field form, Appendix E.
For more detail on how cross-sections were developed see WSPRO input file.

Data and Assumptions Used in WSPRO Model

Hydraulic analyses of the reach were done by use of the Federal Highway Administration's WSPRO step-backwater computer program (Shearman and others, 1986, and Shearman, 1990). The analyses reported herein reflect conditions existing at the site at the time of the study. Furthermore, in the development of the model it was necessary to assume no accumulation of debris or ice at the site. Results of the hydraulic model are presented in the Bridge Hydraulic Summary, Appendix B, and figure 7.

Channel roughness factors (Manning's "n") used in the hydraulic model were estimated using field inspections at each cross section following the general guidelines described by Arcement and Schneider (1989). Final adjustments to the values were made during the modelling of the reach. Channel "n" values for the reach ranged from 0.035 to 0.040, and overbank "n" values ranged from 0.045 to 0.055.

The Leicester River enters Salisbury Swamp immediately downstream of this site before entering Otter Creek approximately 2.9 miles downstream. Although backwater from Otter Creek and the swamp is likely, no backwater effects were assumed. Hence, normal depth at the exit section (EXITX) was assumed as the starting water surface. This depth was computed by use of the slope-conveyance method outlined in the user's manual for WSPRO (Shearman, 1990). The slope used was 0.0023 ft/ft, which was estimated from the surveyed water surface between the approach and exit cross-sections.

The approach section was surveyed 147 feet upstream of the bridge and was transposed to a point 109 feet upstream. Since the streambed elevation rises in a downstream direction, but the overbank elevations do not change, or fall slightly toward the bridge, only the channel point elevations were increased by 0.46 feet to establish the modelled approach section (APPRO). The distance of 109 feet is one bridge length distance upstream of the bridge as recommended by Shearman and others (1986). This method also provides consistency with the technique for determining scour variables at other sites in Vermont.

For the 500-year discharge, WSPRO assumes critical depth at the bridge section. A supercritical model was developed for this discharge. Analyzing both the supercritical and subcritical profiles, it can be determined that the water surface profile does pass through critical depth within the bridge opening. Thus, the assumption of critical depth at the bridge is a satisfactory solution.

Bridge Hydraulics Summary

Average bridge embankment elevation 208.9 *ft*
Average low steel elevation 205.3 *ft*

100-year discharge 1,500 *ft^3/s*
Water-surface elevation in bridge opening 194.0 *ft*
Road overtopping? No *Discharge over road* -- *ft^3/s*
Area of flow in bridge opening 199 *ft^2*
Average velocity in bridge opening 7.5 *ft/s*
Maximum WSPRO tube velocity at bridge 9.0 *ft/s*

Water-surface elevation at Approach section with bridge 195.7 *ft*
Water-surface elevation at Approach section without bridge 194.6 *ft*
Amount of backwater caused by bridge 1.1 *ft*

500-year discharge 2,250 *ft^3/s*
Water-surface elevation in bridge opening 194.6 *ft*
Road overtopping? No *Discharge over road* -- *ft^3/s*
Area of flow in bridge opening 236 *ft^2*
Average velocity in bridge opening 9.5 *ft/s*
Maximum WSPRO tube velocity at bridge 11.4 *ft/s*

Water-surface elevation at Approach section with bridge 197.2 *ft*
Water-surface elevation at Approach section without bridge 195.0 *ft*
Amount of backwater caused by bridge 2.2 *ft*

Incipient overtopping discharge -- *ft^3/s*
Water-surface elevation in bridge opening -- *ft*
Area of flow in bridge opening -- *ft^2*
Average velocity in bridge opening -- *ft/s*
Maximum WSPRO tube velocity at bridge -- *ft/s*

Water-surface elevation at Approach section with bridge -- *ft*
Water-surface elevation at Approach section without bridge -- *ft*
Amount of backwater caused by bridge -- *ft*

Scour Analysis Summary

Special Conditions or Assumptions Made in Scour Analysis

Scour depths were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and others, 1995). Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution. The results of the scour analysis are presented in tables 1 and 2 and a graph of the scour depths is presented in figure 8.

Contraction scour was computed by use of Laursen’s clear-water contraction scour equation (Richardson and others, 1995, p. 32, equation 20). For contraction scour computations, the average depth in the contracted section (AREA/TOPWIDTH) is subtracted from the depth of flow computed by the scour equation (Y2) to determine the actual amount of scour.

Pier scour was computed by use of a modified equation developed at Colorado State University (Richardson and others, 1995, p. 36, equation 21) for all discharges modeled. Variables for the pier scour equation include pier length, pier width, average depth and maximum velocity (for the froude number) immediately upstream of the bridge, and four correction factors for pier shape, flow attack angle, streambed-form, and streambed armoring.

Abutment scour was computed by use of the HIRE equation (Richardson and others, 1995, p. 49, equation 29) because the HIRE equation is recommended when the length to depth ratio of the embankment blocking flow exceeds 25. Variables for the HIRE equation include the Froude number of the flow approaching the embankments, the length of the embankment blocking flow, and the depth of flow approaching the embankment less any roadway overtopping.

Because the influence of scour processes on the spill-through embankment material is uncertain, the scour depth at the vertical concrete abutment walls is unknown. Therefore, the total scour depths were applied for the entire spill-through embankment area below the elevation at the toe of each embankment, as shown in figure 8.

Scour Results

Contraction scour:	*100-yr discharge*	*500-yr discharge*	*Incipient overtopping discharge*
		(Scour depths in feet)	
Main channel			
Live-bed scour	--	--	--
Clear-water scour	3.8	6.1	--
Depth to armoring	N/A	N/A	--
Left overbank	--	--	--
Right overbank	--	--	--
Local scour:			
Abutment scour			
Left abutment	4.0	5.8	--
Right abutment	4.4	6.7	--
Pier scour			
Pier 1	9.1	10.2	--
Pier 2	--	--	--
Pier 3	--	--	--

Riprap Sizing

	100-yr discharge	*500-yr discharge*	*Incipient overtopping discharge*
		(D_{50} in feet)	
Abutments:			
Left abutment	1.3	1.6	--
Right abutment	1.3	1.6	--
Piers:			
Pier 1	0.9	1.4	--
Pier 2	--	--	--
	--	--	--

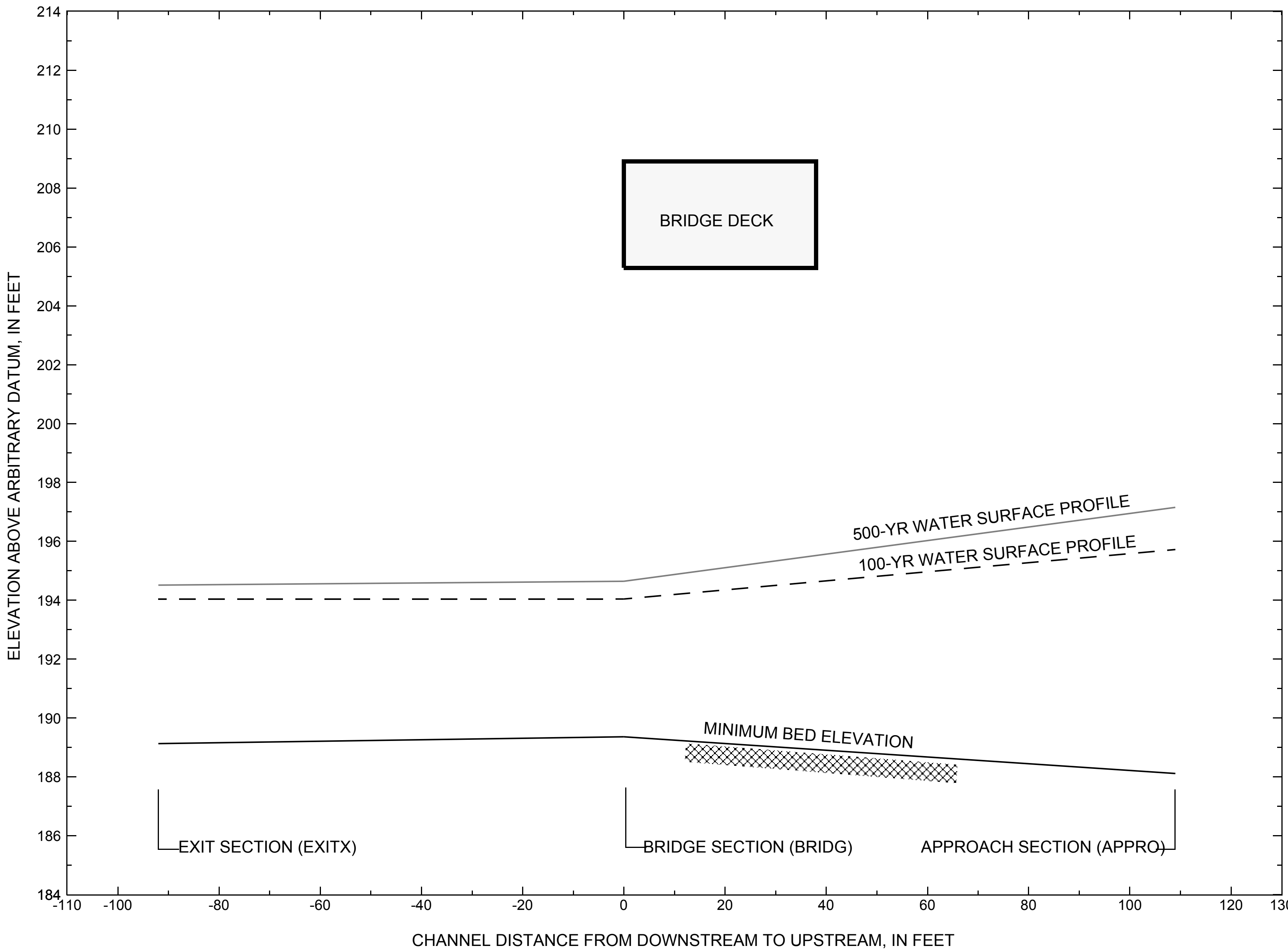

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure LEICUS00070120 on U. S. Route 7, crossing the Leicester River, Leicester, Vermont.

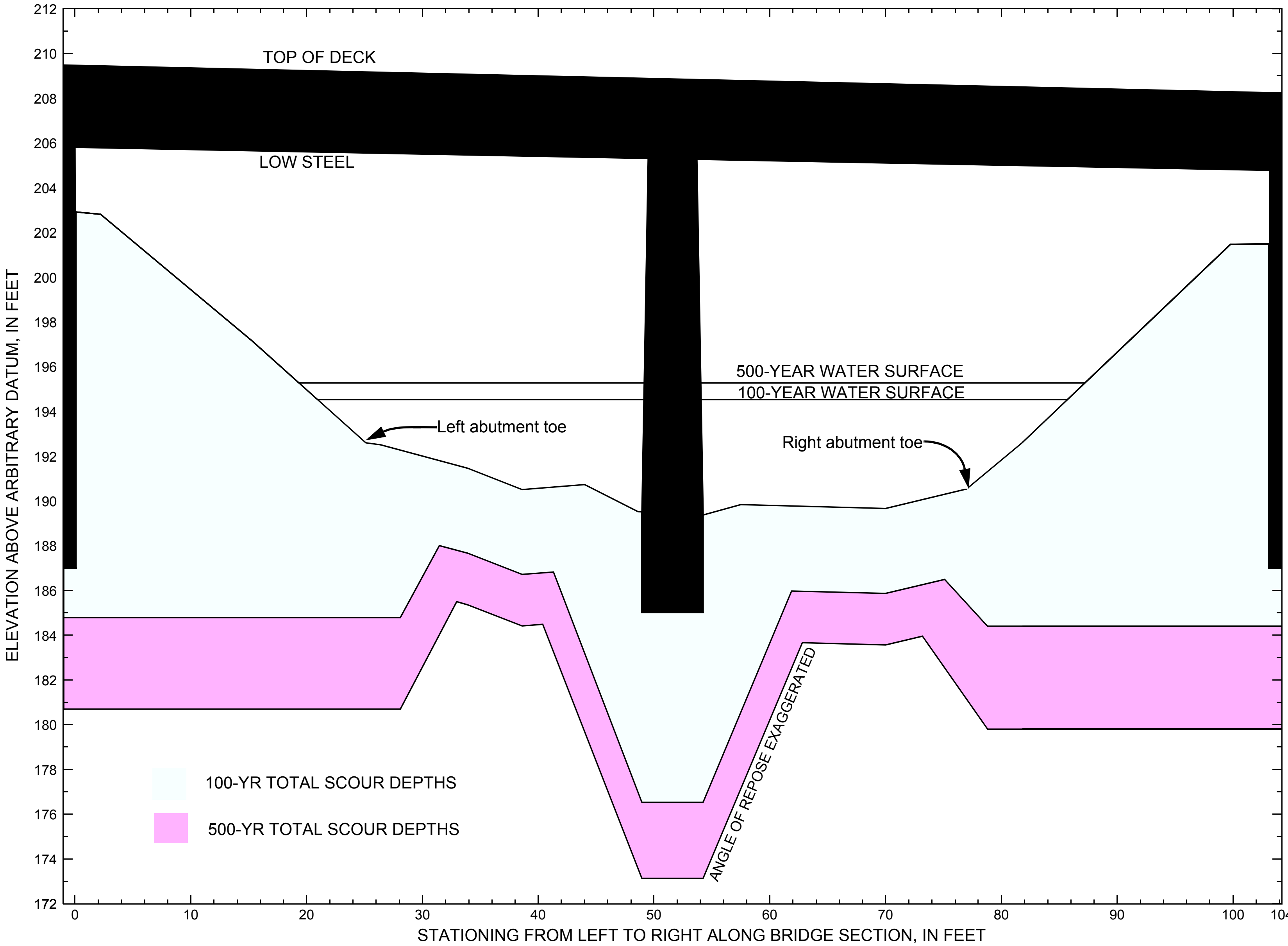

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure LEICUS00070120 on U. S. Route 7, crossing the Leicester River, Leicester, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure LEICUS00070120 on U. S. Route 7, crossing the Leicester River, Leicester, Vermont.
[VTAOT, Vermont Agency of Transportation; --,no data]

Description	Station[1]	VTAOT bridge seat elevation (feet)	Surveyed Bridge seat elevation[2] (feet)	Bottom of footing elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
100-yr. discharge is 1,500 cubic-feet per second											
Left abutment	0.0	206.4	205.8	187	202.9	--	--	--	--	--	-2
Left abutment toe	25.1	--	--	--	192.6	3.8	4.0	--	7.8	184.8	--
Pier	51.6	--	205.3	185	189.4	3.8	--	9.1	12.9	176.5	-8
Right abutment toe	81.8	--	--	--	192.6	3.8	4.4	--	8.2	184.4	--
Right abutment	103.2	205.0	204.8	187	201.5	--	--	--	--	--	-3

1.Measured along the face of the most constricting side of the bridge.
2.Arbitrary datum for this study.

Table 2. Remaining footing/pile depth at abutments for the 500-year discharge at structure LEICUS00070120 on U. S. Route 7, crossing the Leicester River, Leicester, Vermont.
[VTAOT, Vermont Agency of Transportation; --, no data]

Description	Station[1]	VTAOT bridge seat elevation (feet)	Surveyed Bridge seat elevation[2] (feet)	Bottom of footing elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
500-yr. discharge is 2,250 cubic-feet per second											
Left abutment	0.0	206.4	205.8	187	202.9	--	--	--	--	--	-6
Left abutment toe	25.1	--	--	--	192.6	6.1	5.8	--	11.9	180.7	--
Pier	51.6	--	205.3	185	189.4	6.1	--	10.2	16.3	173.1	-12
Right abutment toe	81.8	--	--	--	192.6	6.1	6.7	--	12.8	179.8	--
Right abutment	103.2	205.0	204.8	187	201.5	--	--	--	--	--	-7

1.Measured along the face of the most constricting side of the bridge.
2.Arbitrary datum for this study.

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U.S. Geological Survey, 1944, East Middlebury, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Photorevised 1972, Photoinspected, 1983; Contour interval, 20 feet, Scale 1:24,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File leic120.wsp
T2        Hydraulic analysis for structure LEICUS00070120   Date: 11-OCT-96
T3        U.S. Route 7 Crossing the Leicester River, Leicester, VT           EMB
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           1500.0   2250.0
SK          0.0023   0.0023
*
XS   EXITX    -92
GR         -399.4, 216.80   -367.5, 193.18   -274.3, 192.88   -108.2, 193.05
GR           -6.1, 193.29      7.5, 193.34     21.6, 193.58     26.0, 192.03
GR           30.1, 189.65     40.2, 189.13     57.8, 189.87     58.7, 190.63
GR           68.4, 191.07     71.8, 192.04     75.6, 192.60    158.8, 192.77
GR          187.1, 194.47    216.2, 201.81    247.5, 203.72
*
*          The points below were removed to prevent wspro from putting water
*          on this right over bank field. The points below were surveyed
*          across another small stream on the right overbank through a field.
*           559.6, 197.68    772.5, 195.26    781.9, 194.33    795.5, 195.78
*          1152.0, 197.57   1194.4, 200.14   1259.5, 205.93
*
N           0.055        0.040        0.055
SA                  26.0         71.8
*
XS   FULLV      0  * * *   0.0040
*
*              SRD     LSEL    XSSKEW
BR   BRIDG     0    205.29      15.0
GR            0.0, 205.80      0.1, 202.91      2.2, 202.81     15.3, 197.14
GR           25.1, 192.59     26.4, 192.51     33.9, 191.46     38.6, 190.51
GR           44.0, 190.73     48.6, 189.52     54.2, 189.36     57.5, 189.83
GR           70.0, 189.66     77.0, 190.53     81.8, 192.60     99.8, 201.47
GR          103.1, 201.49    103.2, 204.77      0.0, 205.80
*
*            49.4, 205.27     53.7, 205.24  <-- these are pier points used
*                                               in supercritical model.
PW 0      189.44, 5.3   205.26, 4.2
*
*         BRTYPE  BRWDTH    EMBSS   EMBELV
CD            3      46.5      2.0    208.9
N           0.035
*
*              SRD    EMBWID   IPAVE
XR   RDWAY     23      38.0     1
GR         -551.7, 228.21   -545.0, 215.06   -522.8, 215.78   -162.4, 210.87
GR          -53.0, 210.20     -7.7, 209.47     -7.5, 210.04      0.0, 210.03
GR           46.5, 210.01    100.0, 209.33    100.6, 208.24    103.2, 208.74
GR          526.8, 204.75    855.1, 204.88   1221.3, 206.43   1302.4, 207.05
GR         1559.7, 211.32   1596.2, 216.06
*
AS   APPRO    109
GR         -113.5, 218.99    -81.6, 195.37    -72.0, 193.54    -50.6, 192.93
GR           -2.0, 194.01     21.0, 194.01     25.1, 193.16     26.0, 192.61
GR           27.4, 189.70     29.4, 188.46     32.3, 188.11     38.7, 188.68
GR           48.8, 190.49     54.9, 191.75     68.7, 191.93     72.6, 192.54
GR           73.9, 192.71    125.0, 192.70    184.2, 193.67    400.2, 193.82
```

```
GR          426.1, 195.47    484.1, 205.77    502.2, 208.83    515.1, 209.96
*
*           The channel points were raised 0.46 feet when moving section from
*           srd 147 to 109 because the channel slopes up to the bridge
*           section but the overbank elevations do not change as much over
*           the distance moved.
BP          0.0
N           0.055        0.040        0.045
SA                  26.0         72.6
HP 1 BRIDG  194.04 1 194.04
HP 2 BRIDG  194.04 * * 1500
HP 2 BRIDG  194.52 * * 1500
HP 1 APPRO  195.72 1 195.72
HP 2 APPRO  195.72 * * 1500
*
HP 1 BRIDG  194.64 1 194.64
HP 2 BRIDG  194.64 * * 2250
HP 2 BRIDG  195.27 * * 2250
HP 1 APPRO  197.15 1 197.15
HP 2 APPRO  197.15 * * 2250
*
EX
ER
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
        U.S. Geological Survey WSPRO Input File leic120.wsp
        Hydraulic analysis for structure LEICUS00070120   Date: 11-OCT-96
        U.S. Route 7 Crossing the Leicester River, Leicester, VT           EMB
           *** RUN DATE & TIME: 11-01-96  15:57

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      199     18423     61     62                          2048
   194.04           199     18423     61     62  1.00     22     85     2048

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

         WSEL     LEW     REW    AREA        K        Q    VEL
       194.04    22.0    84.7   199.1   18423.    1500.   7.53

X STA.        22.0       33.1       37.5       40.7       44.0       46.7
  A(I)            17.0       12.2       10.8       10.6        9.8
  V(I)            4.42       6.13       6.97       7.10       7.63

X STA.        46.7       49.0       50.9       52.8       54.7       56.7
  A(I)             9.4        8.4        8.6        8.3        8.5
  V(I)            8.00       8.88       8.71       9.01       8.81

X STA.        56.7       58.7       60.8       62.9       65.0       67.0
  A(I)             8.5        8.5        8.6        8.6        8.4
  V(I)            8.84       8.84       8.68       8.69       8.89

X STA.        67.0       69.1       71.2       73.6       76.5       84.7
  A(I)             8.8        8.8        9.7       10.4       15.2
  V(I)            8.55       8.53       7.76       7.22       4.93

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

         WSEL     LEW     REW    AREA        K        Q    VEL
       194.52    20.9    85.7   228.7   22679.    1500.   6.56

X STA.        20.9       32.0       36.6       39.8       43.0       46.0
  A(I)            19.3       13.9       12.1       11.9       11.6
  V(I)            3.88       5.39       6.19       6.30       6.46

X STA.        46.0       48.3       50.4       52.4       54.3       56.3
  A(I)            10.5       10.0        9.8        9.6        9.7
  V(I)            7.18       7.51       7.67       7.80       7.76

X STA.        56.3       58.5       60.6       62.7       64.9       67.0
  A(I)             9.9        9.8        9.7        9.9        9.9
  V(I)            7.59       7.62       7.76       7.59       7.58

X STA.        67.0       69.1       71.4       73.9       76.9       85.7
  A(I)             9.8       10.4       11.1       12.0       17.8
  V(I)            7.65       7.24       6.74       6.24       4.20

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =     109.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      225      9934    108    109                          1847
             2      245     26674     47     49                          3193
             3      763     42055    355    355                          6346
   195.72          1233     78663    510    513  1.45    -81    428     9056

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =     109.

         WSEL     LEW     REW    AREA        K        Q    VEL
       195.72   -82.1   427.5  1233.4   78663.    1500.   1.22

X STA.       -82.1      -42.7       -2.4       29.6       33.7       37.8
  A(I)            86.9       87.2       72.3       30.6       29.9
  V(I)            0.86       0.86       1.04       2.45       2.50

X STA.        37.8       42.2       47.9       56.8       68.3       86.1
  A(I)            30.2       33.4       40.7       44.3       56.0
  V(I)            2.48       2.24       1.84       1.69       1.34

X STA.        86.1      105.7      125.3      147.3      175.1      211.3
  A(I)            59.1       59.1       62.3       67.5       74.6
  V(I)            1.27       1.27       1.20       1.11       1.01

X STA.       211.3      249.6      287.3      326.8      367.5      427.5
  A(I)            77.3       75.1       77.6       78.8       90.5
  V(I)            0.97       1.00       0.97       0.95       0.83
```

```
      U.S. Geological Survey WSPRO Input File leic120.wsp
      Hydraulic analysis for structure LEICUS00070120   Date: 11-OCT-96
      U.S. Route 7 Crossing the Leicester River, Leicester, VT           EMB
         *** RUN DATE & TIME: 11-01-96  15:57

  CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

   WSEL  SA#     AREA         K  TOPW   WETP  ALPH    LEW    REW      QCR
           1      236     23805    63     65                         2595
 194.64           236     23805    63     65  1.00     21     86     2595

  VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL     LEW     REW    AREA        K        Q    VEL
   194.64    20.7    85.9   236.2   23805.    2250.   9.52

X STA.       20.7       31.7       36.3       39.6       42.7       45.8
  A(I)           19.7       14.4       12.8       12.1       12.0
  V(I)           5.72       7.83       8.77       9.29       9.38

X STA.       45.8       48.2       50.2       52.3       54.3       56.2
  A(I)           10.7       10.3       10.1       10.1        9.9
  V(I)          10.48      10.91      11.13      11.14      11.40

X STA.       56.2       58.4       60.6       62.7       64.9       67.0
  A(I)           10.2       10.1       10.0       10.2       10.2
  V(I)          11.02      11.08      11.28      11.04      11.03

X STA.       67.0       69.2       71.4       73.9       77.0       85.9
  A(I)           10.4       10.7       11.2       12.8       18.3
  V(I)          10.82      10.49      10.08       8.79       6.15

  VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL     LEW     REW    AREA        K        Q    VEL
   195.27    19.3    87.2   276.7   30118.    2250.   8.13

X STA.       19.3       30.5       35.2       38.7       41.8       44.8
  A(I)           22.9       16.9       14.9       14.0       13.5
  V(I)           4.92       6.64       7.56       8.03       8.35

X STA.       44.8       47.5       49.7       51.8       53.9       55.9
  A(I)           13.0       12.1       11.7       11.7       11.6
  V(I)           8.63       9.28       9.58       9.59       9.70

X STA.       55.9       58.1       60.4       62.6       64.8       67.1
  A(I)           11.8       12.0       11.6       11.9       12.2
  V(I)           9.57       9.37       9.69       9.49       9.25

X STA.       67.1       69.3       71.7       74.3       77.4       87.2
  A(I)           12.2       12.5       13.5       14.6       22.2
  V(I)           9.26       9.00       8.36       7.69       5.07

  CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =     109.

   WSEL  SA#     AREA         K  TOPW   WETP  ALPH    LEW    REW      QCR
           1      381     23515   110    111                         4029
           2      312     39816    47     49                         4579
           3     1276     97651   363    363                        13577
 197.15          1969    160982   520    523  1.22    -83    436    19714

  VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =     109.

     WSEL     LEW     REW    AREA        K        Q    VEL
   197.15   -84.0   435.6  1969.3  160982.    2250.   1.14

X STA.      -84.0      -45.6      -12.7       27.6       34.2       40.3
  A(I)          132.4      123.2      135.8       57.3       52.3
  V(I)           0.85       0.91       0.83       1.96       2.15

X STA.       40.3       48.0       60.1       75.0       95.7      116.4
  A(I)           57.9       69.6       75.6       91.9       92.0
  V(I)           1.94       1.62       1.49       1.22       1.22

X STA.      116.4      137.6      161.6      190.5      221.8      252.7
  A(I)           92.9       97.1      104.9      108.4      106.3
  V(I)           1.21       1.16       1.07       1.04       1.06

X STA.      252.7      284.1      316.1      348.8      382.0      435.6
  A(I)          107.6      108.7      110.3      111.3      133.7
  V(I)           1.05       1.03       1.02       1.01       0.84
```

WSPRO OUTPUT FILE (continued)

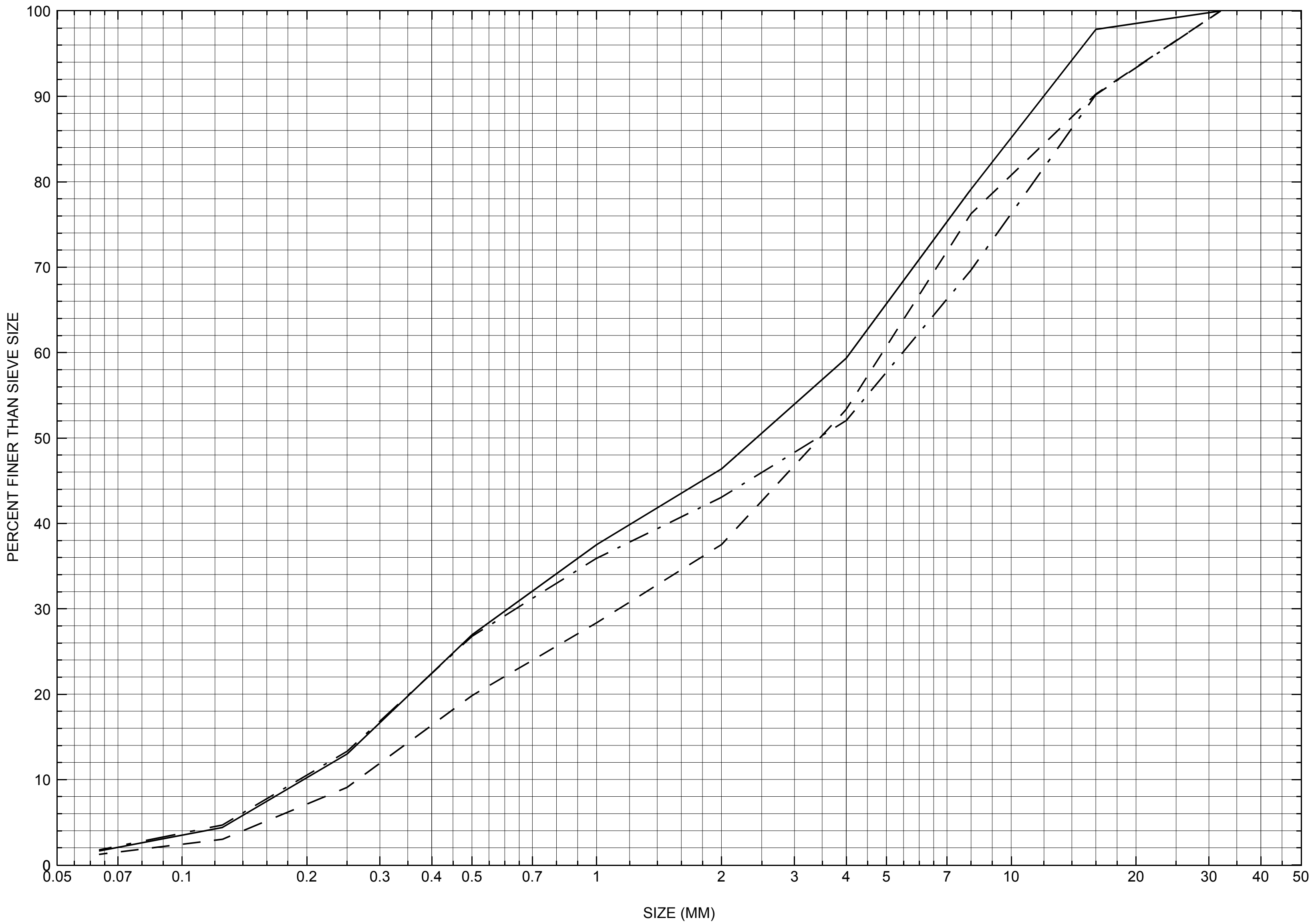
```
+++ BEGINNING PROFILE CALCULATIONS --   2
        U.S. Geological Survey WSPRO Input File leic120.wsp
        Hydraulic analysis for structure LEICUS00070120   Date: 11-OCT-96
        U.S. Route 7 Crossing the Leicester River, Leicester, VT          EMB
           *** RUN DATE & TIME: 11-01-96  15:57

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

EXITX:XS   ******   -368      701  0.18 *****  194.22  193.64    1500  194.04
       -91 ******    180    31260  2.49 ***** *******    0.53    2.14

FULLV:FV       92   -367      617  0.24  0.25  194.50 *******    1500  194.26
         0     92    177    26902  2.64  0.03    0.00    0.65    2.43
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS      109    -77      674  0.15  0.27  194.76 *******    1500  194.60
       109    109    413    34079  1.99  0.00   -0.01    0.47    2.23
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

            <<<<<RESULTS REFLECTING THE CONSTRICTED FLOW FOLLOW>>>>>

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

BRIDG:BR       92     22      199  1.11  0.36  195.15  193.68    1500  194.04
         0     92     85    18404  1.26  0.57    0.00    0.82    7.54

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       3.   0.   1.  0.892  0.119  205.29 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      23.        <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

APPRO:AS       63    -81     1234  0.03  0.12  195.76  194.12    1500  195.72
       109     80    428    78763  1.45  0.48    0.00    0.17    1.22

      M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     0.870  0.632   29002.    17.    80.   195.70

                     <<<<<END OF BRIDGE COMPUTATIONS>>>>>

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW      Q        K      AREA     VEL    WSEL
   EXITX:XS     -92.  -369.   180.   1500.   31260.     701.    2.14  194.04
   FULLV:FV      0.  -368.   177.   1500.   26902.     617.    2.43  194.26
   BRIDG:BR      0.    22.    85.   1500.   18404.     199.    7.54  194.04
   RDWAY:RG      23.**************      0.******************    1.00********
   APPRO:AS     109.   -82.   428.   1500.   78763.    1234.    1.22  195.72

    XSID:CODE   XLKQ   XRKQ      KQ
   APPRO:AS      17.    80.   29002.

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
   EXITX:XS    193.64    0.53  189.13  216.80************  0.18  194.22  194.04
   FULLV:FV  ********    0.65  189.50  217.17  0.25  0.03  0.24  194.50  194.26
   BRIDG:BR    193.68    0.82  189.36  205.80  0.36  0.57  1.11  195.15  194.04
   RDWAY:RG  ****************  204.75  228.21**********************************
   APPRO:AS    194.12    0.17  188.11  218.99  0.12  0.48  0.03  195.76  195.72
```

WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File leic120.wsp
        Hydraulic analysis for structure LEICUS00070120   Date: 11-OCT-96
        U.S. Route 7 Crossing the Leicester River, Leicester, VT           EMB
           *** RUN DATE & TIME: 11-01-96  15:57

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

EXITX:XS   ******   -368      961  0.18 *****  194.69  193.95    2250  194.51
       -91 ******    187    46915  2.09 ***** *******    0.45    2.34

FULLV:FV       92   -368      876  0.23  0.24  194.95 *******    2250  194.73
         0     92    185    41488  2.20  0.02    0.00    0.53    2.57
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS      109    -79      895  0.17  0.27  195.22 *******    2250  195.05
       109    109    420    49684  1.70  0.00    0.00    0.43    2.51
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                 SECID "BRIDG"     Q,CRWS =    2250.     194.64

            <<<<<RESULTS REFLECTING THE CONSTRICTED FLOW FOLLOW>>>>>

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

BRIDG:BR       92     21      236  1.80 *****  196.44  194.64    2250  194.64
         0     92     86    23799  1.27 ***** *******    0.98    9.53

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       3.   0.   1.  0.886  0.113  205.29 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      23.        <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

APPRO:AS       63    -83     1969  0.02  0.11  197.17  194.42    2250  197.15
       109     84    436   160948  1.22  0.63    0.01    0.11    1.14

       M(G)   M(K)      KQ   XLKQ   XRKQ    OTEL
      0.869  0.709   46620.    29.    94.   197.14

                      <<<<<END OF BRIDGE COMPUTATIONS>>>>>

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL   WSEL
   EXITX:XS     -92.  -369.   187.   2250.   46915.     961.    2.34  194.51
   FULLV:FV       0.  -369.   185.   2250.   41488.     876.    2.57  194.73
   BRIDG:BR       0.    21.    86.   2250.   23799.     236.    9.53  194.64
   RDWAY:RG      23.**************      0.******************    1.00********
   APPRO:AS     109.   -84.   436.   2250.  160948.    1969.    1.14  197.15

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS      29.    94.   46620.

 SECOND USER DEFINED TABLE.

    XSID:CODE     CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS     193.95    0.45  189.13  216.80************  0.18  194.69  194.51
   FULLV:FV   ********    0.53  189.50  217.17  0.24  0.02  0.23  194.95  194.73
   BRIDG:BR     194.64    0.98  189.36  205.80************  1.80  196.44  194.64
   RDWAY:RG   ***************  204.75  228.21**********************************
   APPRO:AS     194.42    0.11  188.11  218.99  0.11  0.63  0.02  197.17  197.15
  ER

 NORMAL  END  OF  WSPRO  EXECUTION.
```

APPENDIX C:

BED-MATERIAL PARTICAL-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for three channel composite samples at the approach of structure LEICUS00070120, in Leicester, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number LEICUS00070120

General Location Descriptive

Data collected by *(First Initial, Full last name)* E. BOEHMLER

Date *(MM/DD/YY)* 03 / 13 / 95

Highway District Number *(I - 2; nn)* 03

County *(FIPS county code; I - 3; nnn)* 001

Town *(FIPS place code; I - 4; nnnnn)* 39325

Mile marker *(I - 11; nnn.nnn)* 003200

Waterway *(I - 6)* LEICESTER RIVER

Road Name *(I - 7)*: -

Route Number US007

Vicinity *(I - 9)* 6.4 MI N JCT. VT.73 W

Topographic Map East Middlebury

Hydrologic Unit Code: 02010002

Latitude *(I - 16; nnnn.n)* 43534

Longitude *(i - 17; nnnnn.n)* 73063

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 20001901200109

Maintenance responsibility *(I - 21; nn)* 01

Maximum span length *(I - 48; nnnn)* 0052

Year built *(I - 27; YYYY)* 1943

Structure length *(I - 49; nnnnnn)* 000108

Average daily traffic, ADT *(I - 29; nnnnnn)* 005546

Deck Width *(I - 52; nn.n)* 380

Year of ADT *(I - 30; YY)* 92

Channel & Protection *(I - 61; n)* 7

Opening skew to Roadway *(I - 34; nn)* 15

Waterway adequacy *(I - 71; n)* 6

Operational status *(I - 41; X)* A

Underwater Inspection Frequency *(I - 92B; XYY)* N

Structure type *(I - 43; nnn)* 302

Year Reconstructed *(I - 106)* 1968

Approach span structure type *(I - 44; nnn)* 000

Clear span (*nnn.n ft*) -

Number of spans *(I - 45; nnn)* 002

Vertical clearance from streambed (*nnn.n ft*) 15.0

Number of approach spans *(I - 46; nnnn)* 0000

Waterway of full opening (*nnn.n ft*^{2}) -

Comments:

The structural inspection report of 9/23/93 indicates the structure is a two span steel stringer type bridge. The left and right abutments are noted as concrete skeleton type abutments. The left abutment is noted in good condition with the exception of some minor cracking and scaling. The channel is noted as making a moderate bend into the structure. The flow passes through the right most span predominantly. There is some minor scour at the nose of the pier, but the footing is not exposed. Stone fill is reported protecting each abutment. Some minor debris build-up is noted under the left span, consisting of limbs and small logs. Vegetation is noted growing on both banks up and downstream.

Bridge Hydrologic Data

Is there hydrologic data available? N *if No, type ctrl-n h* VTAOT Drainage area *(mi²)*: -

Terrain character: -

Stream character & type: -

Streambed material: -

Discharge Data *(cfs)*: $Q_{2.33}$ - Q_{10} - Q_{25} -

Q_{50} - Q_{100} - Q_{500} -

Record flood date *(MM / DD / YY)*: - / / Water surface elevation *(ft)*: -

Estimated Discharge *(cfs)*: - Velocity at Q - *(ft/s)*: -

Ice conditions *(Heavy, Moderate, Light)* : - Debris *(Heavy, Moderate, Light)*: -

The stage increases to maximum highwater elevation (*Rapidly, Not rapidly*): -

The stream response is (*Flashy, Not flashy*): -

Describe any significant site conditions upstream or downstream that may influence the stream's stage: -

Watershed storage area (*in percent*): - %

The watershed storage area is: - (*1-mainly at the headwaters; 2- uniformly distributed; 3-immediatly upstream oi the site*)

Water Surface Elevation Estimates for Existing Structure:

Peak discharge frequency	$Q_{2.33}$	Q_{10}	Q_{25}	Q_{50}	Q_{100}
Water surface elevation (*ft*)	-	-	-	-	-
Velocity (*ft / sec*)	-	-	-	-	-

Long term stream bed changes: -

Is the roadway overtopped below the Q_{100}? (*Yes, No, Unknown*): U Frequency: -

Relief Elevation (*ft*): - Discharge over roadway at Q_{100} (*ft³/ sec*): -

Are there other structures nearby? (*Yes, No, Unknown*): U *If No or Unknown, type ctrl-n os*

Upstream distance (*miles*): - Town: - Year Built: -

Highway No. : - Structure No. : - Structure Type: -

Clear span (*ft*): - Clear Height (*ft*): Full Waterway (*ft²*): -

Downstream distance (*miles*): - Town: - Year Built: -

Highway No. : - Structure No. : - Structure Type: -

Clear span (*ft*): - Clear Height (*ft*): - Full Waterway (ft^2): -

Comments:

-

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* 23.0 mi^2

Lake and pond area 2.16 mi^2

Watershed storage *(ST)* 9.3 %

Bridge site elevation 360 ft

Headwater elevation 3125 ft

Main channel length 9.5 mi

10% channel length elevation 450 ft

85% channel length elevation 2000 ft

Main channel slope *(S)* 217. ft / mi

Watershed Precipitation Data

Average site precipitation ________ in

Average headwater precipitation ________ in

Maximum 2yr-24hr precipitation event *(I24,2)* ________ in

Average seasonal snowfall *(Sn)* ________ ft

Bridge Plan Data

Are plans available? Y *If no, type ctrl-n pl* Date issued for construction *(MM / YYYY)*: 06 / 1968

Project Number BMA 6718 Minimum channel bed elevation: 190.0

Low superstructure elevation: USLAB 206.42 DSLAB 206.32 USRAB 204.98 DSRAB 205.08

Benchmark location description:

There is no benchmark information on the plans. An elevation is provided on the top of the concrete that forms the base for the bridge's guard rail on the left abutment. The lower end, the elevation is 210.11 and on the higher end of the abutment it is 210.21. Direction of the flow along the abutment is not shown on the plans. The reference point and datum are unknown but are probably arbitrary.

Reference Point (*MSL, Arbitrary, Other*): - Datum (*NAD27, NAD83, Other*): -

Foundation Type: 1 (*1-Spreadfooting; 2-Pile; 3- Gravity; 4-Unknown*)

If 1: Footing Thickness - Footing bottom elevation: 187.0

If 2: Pile Type: ____ (*1-Wood; 2-Steel or metal; 3-Concrete*) Approximate pile driven length: ____

If 3: Footing bottom elevation: ____

Is boring information available? N *If no, type ctrl-n bi* Number of borings taken: -

Foundation Material Type: 3 (*1-regolith, 2-bedrock, 3-unknown*)

Briefly describe material at foundation bottom elevation or around piles:

-

Comments:

The benchmark described above is based on the plan drawing of the left abutment. No drawing scale was found and hence no footing thickness was estimated. These plans are listed under the last project number which is "BMA6718". The low superstructure elevations for the pier are: upstream end 205.77(left), 205.74(right) and downstream end 205.66(left), 205.64(right). The footing bottom elevation for the pier is 185. The pier footing is 3 feet thick.

Cross-sectional Data

Is cross-sectional data available? N *If no, type ctrl-n xs*

Source (*FEMA, VTAOT, Other*)? -

Comments: **NO CROSS SECTION INFORMATION**

Station	-	-	-	-	-	-	-	-	-	-	-
Feature	-	-	-	-	-	-	-	-	-	-	-
Low cord elevation	-	-	-	-	-	-	-	-	-	-	-
Bed elevation	-	-	-	-	-	-	-	-	-	-	-
Low cord to bed length	-	-	-	-	-	-	-	-	-	-	-

Station	-	-	-	-	-	-	-	-	-	-	-
Feature	-	-	-	-	-	-	-	-	-	-	-
Low cord elevation	-	-	-	-	-	-	-	-	-	-	-
Bed elevation	-	-	-	-	-	-	-	-	-	-	-
Low cord to bed length	-	-	-	-	-	-	-	-	-	-	-

Source (*FEMA, VTAOT, Other*)? -

Comments: **NO CROSS SECTION INFORMATION**

Station	-	-	-	-	-	-	-	-	-	-	-
Feature	-	-	-	-	-	-	-	-	-	-	-
Low cord elevation	-	-	-	-	-	-	-	-	-	-	-
Bed elevation	-	-	-	-	-	-	-	-	-	-	-
Low cord to bed length	-	-	-	-	-	-	-	-	-	-	-

Station	-	-	-	-	-	-	-	-	-	-	-
Feature	-	-	-	-	-	-	-	-	-	-	-
Low cord elevation	-	-	-	-	-	-	-	-	-	-	-
Bed elevation	-	-	-	-	-	-	-	-	-	-	-
Low cord to bed length	-	-	-	-	-	-	-	-	-	-	-

APPENDIX E:

LEVEL I DATA FORM

U. S. Geological Survey
Bridge Field Data Collection and Processing Form

Qa/Qc Check by: **MAI** Date: **11/24/95**

Computerized by: **MAI** Date: **11/24/95**

Reviewd by: **EMB** Date: **12/3/96**

Structure Number **LEICUS00070120**

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* **T**. **Severance** Date *(MM/DD/YY)* **09** / **18** / 19**95**

2. Highway District Number **3** Mile marker **003200**

County **Addison (001)** Town **Leicester (39325)**

Waterway *(I - 6)* **Leicester River** Road Name **US 7**

Route Number **US 7** Hydrologic Unit Code: **02010002**

3. Descriptive comments:

The bridge is 6.4 miles north from the junction of VT 73 with U.S. 7.

B. Bridge Deck Observations

4. Surface cover... LBUS **6** RBUS **4** LBDS **5** RBDS **5** Overall **4**
*(2b us,ds,lb,rb: **1**- Urban; **2**- Suburban; **3**- Row crops; **4**- Pasture; **5**- Shrub- and brushland; **6**- Forest; **7**- Wetland)*

5. Ambient water surface... US **1** UB **1** DS **1** *(**1**- pool; **2**- riffle)*

6. Bridge structure type **2** *(**1**- single span; **2**- multiple span; **3**- single arch; **4**- multiple arch; **5**- cylindrical culvert; **6**- box culvert; or **7**- other)*

7. Bridge length **108.0** *(feet)* Span length **52.0** *(feet)* Bridge width **38.0** *(feet)*

Road approach to bridge:

8. LB **2** RB **1** *(**0** even, **1**- lower, **2**- higher)*

9. LB **1** RB **1** *(**1**- Paved, **2**- Not paved)*

10. Embankment slope (*run / rise in feet / foot*):
US left **1.9:1** US right **2.2:1**

	Protection			
	11.Type	12.Cond.	13.Erosion	14.Severity
LBUS	0	-	2	1
RBUS	0	-	2	0
RBDS	0	-	2	0
LBDS	0	-	2	1

*Bank protection types: **0**- none; **1**- < 12 inches; **2**- < 36 inches; **3**- < 48 inches; **4**- < 60 inches; **5**- wall / artificial levee*

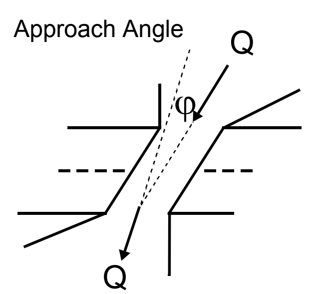
*Bank protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*

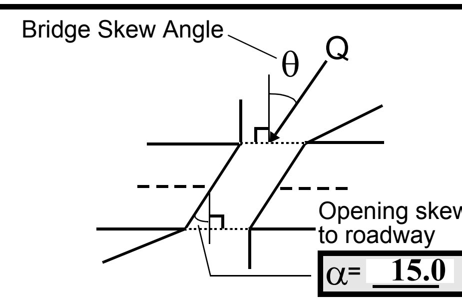
*Erosion: **0** - none; **1**- channel erosion; **2**- road wash; **3**- both; **4**- other*

*Erosion Severity: **0** - none; **1**- slight; **2**- moderate; **3**- severe*

Channel approach to bridge (BF):

15. Angle of approach: **5** 16. Bridge skew: **30**





17. Channel impact zone 1: Exist? **Y** *(Y or N)*
Where? **RB** *(LB, RB)* Severity **0**
Range? **0** feet **US** *(US, UB, DS)* to **65** feet **US**

Channel impact zone 2: Exist? **Y** *(Y or N)*
Where? **LB** *(LB, RB)* Severity **1**
Range? **80** feet **US** *(US, UB, DS)* to **120** feet **US**

*Impact Severity: **0**- none to very slight; **1**- Slight; **2**- Moderate; **3**- Severe*

18. Bridge Type: **3**

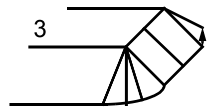
1a- Vertical abutments with wingwalls

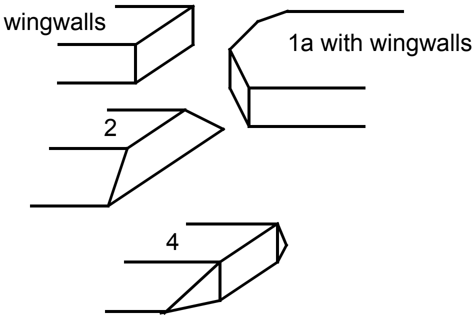
1b- Vertical abutments without wingwalls

2- Vertical abutments and wingwalls, sloping embankment
Wingwalls perpendicular to abut. face

3- Spill through abutments

4- Sloping embankment, vertical wingwalls and abutments
Wingwall angle less than 90°.





19. Bridge Deck Comments (surface cover variations, measured bridge and span lengths, bridge type variations, approach overflow width, etc.)

4. LBUS: forested but not thick (young forest), RBUS: pasture with harvested row crops beyond 300 feet, LBDS: is pasture but brush and trees have been allowed to grow, RBDS: beyond 100 feet the bank is tree-lined with pasture.
7. The measured bridge width 38.2 feet.
13. There are signs of road wash at all four corners.

The river appears to be about 2 feet above normal flow for the season with flowers/ grass 2 feet underwater.

C. Upstream Channel Assessment

20. SRD	21. Bank height (BF) LB	21. Bank height (BF) RB	22. Bank angle (BF) LB	22. Bank angle (BF) RB	26. % Veg. cover (BF) LB	26. % Veg. cover (BF) RB	27. Bank material (BF) LB	27. Bank material (BF) RB	28. Bank erosion (BF) LB	28. Bank erosion (BF) RB
101.5	**4.0**			**2.5**	**2**	**1**	**1**	**1**	**2**	**0**

23. Bank width **60.0** 24. Channel width **5.0** 25. Thalweg depth **49.0** 29. Bed Material **23**

30 .Bank protection type: LB **0** RB **0** 31. Bank protection condition: LB **-** RB **-**

SRD - Section ref. dist. to US face *% Vegetation (Veg) cover: **1**- 0 to 25%; **2**- 26 to 50%; **3**- 51 to 75%; **4**- 76 to 100%*
*Bed and bank Material: **0**- organics; **1**- silt / clay, < 1/16mm; **2**- sand, 1/16 - 2mm; **3**- gravel, 2 - 64mm; **4**- cobble, 64 - 256mm; **5**- boulder, > 256mm; **6**- bedrock; **7**- manmade*
*Bank Erosion: **0**- not evident; **1**- light fluvial; **2**- moderate fluvial; **3**- heavy fluvial / mass wasting*
*Bank protection types: **0**- absent; **1**- < 12 inches; **2**- < 36 inches; **3**- < 48 inches; **4**- < 60 inches; **5**- wall / artificial levee*
*Bank protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*

32. Comments (bank material variation, minor inflows, protection extent, etc.):

29. Bed material varies with even distribution of coarse sand to fine gravel, finer material is farther US about 100 feet with coarser material dominant within 100 feet of the bridge. Some finer (silty) materials towards/ at the banks and coarse material in the channel.

25. Thalweg depth measured 3.5. Approach surveyed through scour at channel bend.

33. Point/Side bar present? Y (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: 109 35. Mid-bar width: 16

36. Point bar extent: 70 feet US (US, UB) to 140 feet US (US, UB, DS) positioned 80 %LB to 100 %RB

37. Material: 2

38. Point or side bar comments (Circle Point or Side; Note additional bars, material variation, status, etc.):

Point bar overgrown with grass.
37. The material is fine sand.
Second bar along the left bank 0 to 60 feet US. Mid-bar distance 35 feet and width 16 feet. Positioned 0% left to 30% right bank.

39. Is a cut-bank present? Y (Y or if N type ctrl-n cb) 40. Where? LB (LB or RB)

41. Mid-bank distance: 95 42. Cut bank extent: 60 feet US (US, UB) to 140 feet US (US, UB, DS)

43. Bank damage: 1 (*1*- eroded and/or creep; *2*- slip failure; *3*- block failure)

44. Cut bank comments (eg. additional cut banks, protection condition, etc.):

Two feet of steepened bank with root exposure.
Base of bank material consist of very slippery clay.

45. Is channel scour present? Y (Y or if N type ctrl-n cs) 46. Mid-scour distance: 100

47. Scour dimensions: Length 26 Width 8 Depth : 1.5 Position 0 %LB to 50 %RB

48. Scour comments (eg. additional scour areas, local scouring process, etc.):

Average thalweg US is 3.5 feet. At the scoured zone the total water depth is 5 feet.

49. Are there major confluences? N (Y or if N type ctrl-n mc) 50. How many? -

51. Confluence 1: Distance - 52. Enters on - (LB or RB) 53. Type - (*1*- perennial; *2*- ephemeral)

Confluence 2: Distance - Enters on - (LB or RB) Type - (*1*- perennial; *2*- ephemeral)

54. Confluence comments (eg. confluence name):

NO MAJOR CONFLUENCES

D. Under Bridge Channel Assessment

55. Channel restraint (BF)? LB 2 RB ____ (*1*- natural bank; *2*- abutment; *3*- artificial levee)

56. Height (BF) LB	56. Height (BF) RB	57 Angle (BF) LB	57 Angle (BF) RB	61. Material (BF) LB	61. Material (BF) RB	62. Erosion (BF) LB	62. Erosion (BF) RB
21.5		5.0		2	7	7	-

58. Bank width (BF) 10.0 59. Channel width (Amb) 9.0 60. Thalweg depth (Amb) 25.0 63. Bed Material -

*Bed and bank Material: **0**- organics; **1**- silt / clay, < 1/16mm; **2**- sand, 1/16 - 2mm; **3**- gravel, 2 - 64mm; **4**- cobble, 64 - 256mm; **5**- boulder, > 256mm; **6**- bedrock; **7**- manmade*

*Bank Erosion: **0**- not evident; **1**- light fluvial; **2**- moderate fluvial; **3**- heavy fluvial / mass wasting*

64. Comments (bank material variation, minor inflows, protection extent, etc.):

3
Spill through type abutment protection. Main channel flow passes to the right of the pier with some around the base. Able to penetrate 1.5 feet into/ below upper bed material layer. The material below the gravel bed is clayey.

65. **Debris and Ice** Is there debris accumulation? ____ (Y or N) 66. Where? Y____ (1- Upstream; 2- At bridge; 3- Both)

67. Debris Potential 2____ (1- Low; 2- Moderate; 3- High) 68. Capture Efficiency 1____ (1- Low; 2- Moderate; 3- High)

69. Is there evidence of ice build-up? 2___ (Y or N) Ice Blockage Potential Y____ (1- Low; 2- Moderate; 3- High)

70. Debris and Ice Comments:

2

The aggregate is exposed at the upstream face of the pier.

66. Debris along the channel, left of the pier.

Abutments	71. Attack ∠(BF)	72. Slope ∠ (Qmax)	73. Toe loc. (BF)	74. Scour Condition	75. Scour depth	76. Exposure depth	77. Material	78. Length
LABUT		0	40	0	0	-	-	25.0
RABUT	1	15	35			2	0	100.5

Pushed: LB or RB *Toe Location (Loc.): 0- even, 1- set back, 2- protrudes*
Scour cond.: 0- not evident; 1- evident (comment); 2- footing exposed; 3-undermined footing; 4- piling exposed; 5- settled; 6- failed
Materials: 1- Concrete; 2- Stone masonry or drywall; 3- steel or metal; 4- wood

79. Abutment comments (eg. undermined penetration, unusual scour processes, debris, etc.):

-

-

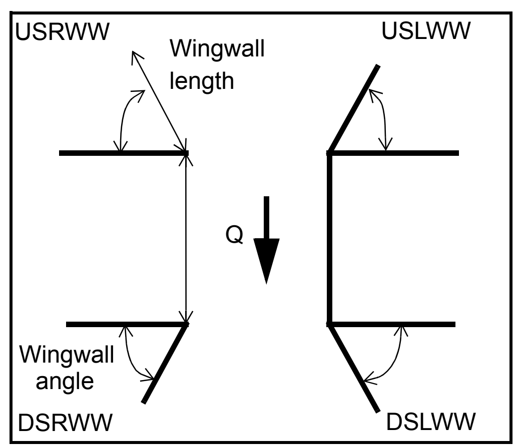
1

72. Stone fill protection is present on each spill-through embankment. The left and right embankments slope at 40 and 35 degrees respectively.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						55.0	
USRWW:	N		-		0	3.0	
DSLWW:	-		-		N	46.5	
DSRWW:	-		0		-	46.5	

Wingwall materials: 1- Concrete; 2- Stone masonry or drywall; 3- steel or metal; 4- wood



82. **Bank / Bridge Protection**:

Location	USLWW	USRWW	LABUT	RABUT	LB	RB	DSLWW	DSRWW
Type	-	0	N	-	-	-	1	1
Condition	N	-	-	-	-	-	1	1
Extent	-	-	0	-	-	3	3	-

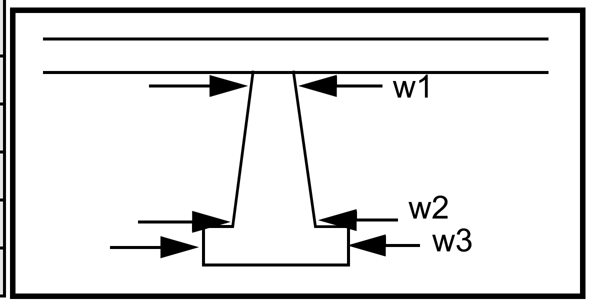
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):
-
-
-
-
-
-
-
-
-
-
-

Piers:

84. Are there piers? Th (Y or if N type ctrl-n pr)

85. Pier no.	width (w) feet			elevation (e) feet		
	w1	w2	w3	e@w1	e@w2	e@w3
Pier 1	-	-	-	-	-	-
Pier 2	-	4.2	-	-	205.3	-
Pier 3	5.3	-	-	189.4	-	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	e left	pre-	spill		LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP
87. Type	and	vious	thro		1- Solid pier, 2- column, 3- bent
88. Material	right	ly	ugh		1- Wood; 2- concrete; 3- metal; 4- stone
89. Shape	abut	men-	type		1- Round; 2- Square; 3- Pointed
90. Inclined?	ment	tione	of		Y- yes; N- no
91. Attack ∠ (BF)	pro-	d	abut	Y	
92. Pushed	tec-	laid	ment	MC	LB or RB
93. Length (feet)	-	-	-	-	
94. # of piles	tion	stone	.	M	
95. Cross-members	con-	s		1	0- none; 1- laterals; 2- diagonals; 3- both
96. Scour Condition	sist	that		2	0- not evident; 1- evident (comment); 2- footing exposed; 3- piling exposed; 4- undermined footing; 5- settled; 6- failed
97. Scour depth	of	form		1	
98. Exposure depth	the	a		Y	

99. Pier comments (eg. undermined penetration, protection and protection extent, unusual scour processes, etc.):
0
-
-
0
0
-
-
-
-
-

E. Downstream Channel Assessment

100.

SRD	Bank height (BF) LB	Bank height (BF) RB	Bank angle (BF) LB	Bank angle (BF) RB	% Veg. cover (BF) LB	% Veg. cover (BF) RB	Bank material (BF) LB	Bank material (BF) RB	Bank erosion (BF) LB	Bank erosion (BF) RB
-	-			-	-	-	-	-	-	-

Bank width (BF) - Channel width (Amb) **38.4** Thalweg depth (Amb) - Bed Material -

Bank protection type (Qmax): LB - RB - Bank protection condition: LB - RB -

SRD - Section ref. dist. to US face *% Vegetation (Veg) cover:* ***1****- 0 to 25%;* ***2****- 26 to 50%;* ***3****- 51 to 75%;* ***4****- 76 to 100%*
Bed and bank Material: ***0****- organics;* ***1****- silt / clay, < 1/16mm;* ***2****- sand, 1/16 - 2mm;* ***3****- gravel, 2 - 64mm;* ***4****- cobble, 64 - 256mm;* ***5****- boulder, > 256mm;* ***6****- bedrock;* ***7****- manmade*
Bank Erosion: ***0****- not evident;* ***1****- light fluvial;* ***2****- moderate fluvial;* ***3****- heavy fluvial / mass wasting*
Bank protection types: ***0****- absent;* ***1****- < 12 inches;* ***2****- < 36 inches;* ***3****- < 48 inches;* ***4****- < 60 inches;* ***5****- wall / artificial levee*
Bank protection conditions: ***1****- good;* ***2****- slumped;* ***3****- eroded;* ***4****- failed*

Comments (eg. bank material variation, minor inflows, protection extent, etc.):
-
-
-
-
-
-
-
-
-
-
-
-
-
-
-

101. Is a drop structure present? - (*Y or N, if N type ctrl-n ds*) 102. Distance: - feet

103. Drop: - feet 104. Structure material: - (***1****- steel sheet pile;* ***2****- wood pile;* ***3****- concrete;* ***4****- other*)

105. Drop structure comments (eg. downstream scour depth):
-
-
-
-
-
There is no scour at the pier with regards to the average US and DS thalweg. The water depth at mid pier was

106. Point/Side bar present? 2 (Y or N. if N type ctrl-n pb) Mid-bar distance: feet Mid-bar width: with

Point bar extent: the feet pie (US, UB, DS) to r feet end (US, UB, DS) positioned s at %LB to 3 %RB

Material: fee

Point or side bar comments (Circle Point or Side; note additional bars, material variation, status, etc.):

t.

Is a cut-bank present? _____ (Y or if N type ctrl-n cb) Where? _____ (LB or RB) Mid-bank distance: _____

Cut bank extent: _____ feet ____ (US, UB, DS) to 2 feet 1 (US, UB, DS)

Bank damage: 1 (1- eroded and/or creep; 2- slip failure; 3- block failure)

Cut bank comments (eg. additional cut banks, protection condition, etc.):

1
1
1
32

Is channel scour present? 0 (Y or if N type ctrl-n cs) Mid-scour distance: 0

Scour dimensions: Length - Width - Depth: Bed Positioned mat %LB to eria %RB

Scour comments (eg. additional scour areas, local scouring process, etc.):

l is a distribution of coarse sand and fine gravel, similar to 100 feet US. Not as consistently large as within 100 feet US of the bridge.
There is a clay outcrop mid channel 90 feet DS. After several probes with the range pole, penetration was over 3 feet into clay.

Are there major confluences? _____ (Y or if N type ctrl-n mc) How many? Thal

Confluence 1: Distance weg Enters on dept (LB or RB) Type h (1- perennial; 2- ephemeral)

Confluence 2: Distance mea- Enters on sure (LB or RB) Type d (1- perennial; 2- ephemeral)

Confluence comments (eg. confluence name):

3.2.

F. Geomorphic Channel Assessment

107. Stage of reach evolution _____

1- Constructed
2- Stable
3- Aggraded
4- Degraded
5- Laterally unstable
6- Vertically and laterally unstable

108. Evolution comments *(Channel evolution not considering bridge effects; See HEC-20, Figure 1 for geomorphic descriptors)*:

N

-

NO DROP STRUCTURE

109. G. Plan View Sketch

point bar (pb)	debris	flow (Q)	stone wall
cut-bank (cb)	rip rap or stone fill	cross-section	other wall
scour hole		ambient channel	

APPENDIX F:

SCOUR COMPUTATIONS

SCOUR COMPUTATIONS

Structure Number:	LEICUS00070120	Town:	Leicester
Road Number:	US 7	County:	Addison
Stream:	Leicester River		

Initials EMB Date: 11/19/96 Checked: SAO

Analysis of contraction scour, live-bed or clear water?

Critical Velocity of Bed Material (converted to English units)
Vc=11.21*y1^0.1667*D50^0.33 with Ss=2.65
(Richardson and others, 1995, p. 28, eq. 16)

Approach Section Characteristic	100 yr	500 yr	other Q
Total discharge, cfs	1500	2250	0
Main Channel Area, ft2	245	312	0
Left overbank area, ft2	225	381	0
Right overbank area, ft2	763	1276	0
Top width main channel, ft	47	47	0
Top width L overbank, ft	108	110	0
Top width R overbank, ft	355	363	0
D50 of channel, ft	0.0102	0.0102	0.0102
D50 left overbank, ft	0	0	0
D50 right overbank, ft	0	0	0
y1, average depth, MC, ft	5.2	6.6	ERR
y1, average depth, LOB, ft	2.1	3.5	ERR
y1, average depth, ROB, ft	2.1	3.5	ERR
Total conveyance, approach	78663	160982	0
Conveyance, main channel	26674	39816	0
Conveyance, LOB	9934	23515	0
Conveyance, ROB	42055	97651	0
Percent discrepancy, conveyance	0.0000	0.0000	ERR
Qm, discharge, MC, cfs	508.6	556.5	ERR
Ql, discharge, LOB, cfs	189.4	328.7	ERR
Qr, discharge, ROB, cfs	801.9	1364.8	ERR
Vm, mean velocity MC, ft/s	2.1	1.8	ERR
Vl, mean velocity, LOB, ft/s	0.8	0.9	ERR
Vr, mean velocity, ROB, ft/s	1.1	1.1	ERR
Vc-m, crit. velocity, MC, ft/s	3.2	3.3	N/A
Vc-l, crit. velocity, LOB, ft/s	0.0	0.0	N/A
Vc-r, crit. velocity, ROB, ft/s	0.0	0.0	N/A

Results

Live-bed(1) or Clear-Water(0) Contraction Scour?			
Main Channel	0	0	N/A

Clear Water Contraction Scour in MAIN CHANNEL

y2 = (Q2^2/(131*Dm^(2/3)*W2^2))^(3/7)   Converted to English Units
ys=y2-y_bridge
(Richardson and others, 1995, p. 32, eq. 20, 20a)

Approach Section	Q100	Q500	Qother
Main channel Area, ft2	245	312	0
Main channel width, ft	47	47	0
y1, main channel depth, ft	5.21	6.64	ERR
Bridge Section			
(Q) total discharge, cfs	1500	2250	0
(Q) discharge thru bridge, cfs	1500	2250	0
Main channel conveyance	18423	23805	0
Total conveyance	18423	23805	0
Q2, bridge MC discharge,cfs	1500	2250	ERR
Main channel area, ft2	199	236	0
Main channel width (skewed), ft	58.6	59.9	0.0
Cum. width of piers in MC, ft	5.1	5.1	0.0
W, adjusted width, ft	53.5	54.8	0
y_bridge (avg. depth at br.), ft	3.72	4.31	ERR
Dm, median (1.25*D50), ft	0.01275	0.01275	0.01275
y2, depth in contraction,ft	7.50	10.39	ERR
ys, scour depth (y2-ybridge), ft	3.77	6.08	N/A
ARMORING			
D90	0.0477	0.0477	0
D95	0.0576	0.0576	0
Critical grain size,Dc, ft	0.1251	0.1914	ERR
Decimal-percent coarser than Dc			
Depth to armoring,ft	ERR	ERR	ERR

Abutment Scour

Froehlich's Abutment Scour
Ys/Y1 = 2.27*K1*K2*(a'/Y1)^0.43*Fr1^0.61+1
(Richardson and others, 1995, p. 48, eq. 28)

Characteristic	Left Abutment 100 yr Q	500 yr Q	Other Q	Right Abutment 100 yr Q	500 yr Q	Other Q
(Qt), total discharge, cfs	1500	2250	0	1500	2250	0
a', abut.length blocking flow, ft	106.2	107.4	0	344.8	352.3	0
Ae, area of blocked flow ft2	234	377.3	0	732.6	1228	0
Qe, discharge blocked abut.,cfs	212.1	325.8	0	764.3	1305	0
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	0.91	0.86	ERR	1.04	1.06	ERR
ya, depth of f/p flow, ft	2.20	3.51	ERR	2.12	3.49	ERR
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	0.55	0.55	0.55	0.55	0.55	0.55
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	75	75	75	105	105	105
K2	0.98	0.98	0.98	1.02	1.02	1.02
Fr, froude number f/p flow	0.108	0.081	ERR	0.126	0.100	ERR
ys, scour depth, ft	5.85	7.54	N/A	8.95	11.43	N/A

HIRE equation (a'/ya > 25)
ys = 4*Fr^0.33*y1*K/0.55
(Richardson and others, 1995, p. 49, eq. 29)

a'(abut length blocked, ft)	106.2	107.4	0	344.8	352.3	0
y1 (depth f/p flow, ft)	2.20	3.51	ERR	2.12	3.49	ERR
a'/y1	48.20	30.57	ERR	162.28	101.07	ERR
Skew correction (p. 49, fig. 16)	0.95	0.95	0.00	1.03	1.03	0.00
Froude no. f/p flow	0.11	0.08	N/A	0.13	0.10	N/A
Ys w/ corr. factor K1/0.55:						
vertical	7.29	10.60	ERR	8.04	12.23	ERR
vertical w/ ww's	5.98	8.69	ERR	6.59	10.02	ERR
spill-through	4.01	5.83	ERR	4.42	6.72	ERR

Abutment riprap Sizing

Isbash Relationship
D50=y*K*Fr^2/(Ss-1) and D50=y*K*(Fr^2)^0.14/(Ss-1)
(Richardson and others, 1995, p112, eq. 81,82)

Characteristic	Q100	Q500	Qother			
Fr, Froude Number	0.82	1	0	0.82	1	0
(Fr from the characteristic V and y in contracted section--mc, bridge section)						
y, depth of flow in bridge, ft	3.72	4.31	0.00	3.72	4.31	0.00
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (spillthrough abut.)	ERR	ERR	0.00	ERR	ERR	0.00
Fr>0.8 (spillthrough abut.)	1.30	1.59	ERR	1.30	1.59	ERR

Pier Scour(both live-bed and clear water scour)

ys/y1=2.0*K1*K2*K3*K4*(a/y1)^0.65*Fr1^0.43
(Richardson and others, 1995, p. 36, eq. 21)

K1, corr. factor for pier nose shape
Sharp nose, 0.9; round nose, cylinder, or cylinder grp., 1.0; square nose, 1.1

K2, corr. factor attack angle (see Table 3, p 37)
K2=[cos(attackangle)+L/a*sin(attackangle)]^0.65

K3, corr. factor for bed condition
Clear-water, plane bed, antidune, 1.1; med. dunes, 1.1-1.2 (see Tab.4,p37)

K4, corr. factor for armoring (the following equations are in Si units)
K4=[1-0.89*(1-Vr)^2]^0.5
Vr=(V1-Vi)/(Vc90-Vi)
V1=0.645*((D50/a)^0.053)*Vc50
Vc=6.19*(y^1/6)*(Dc^1/3)

Note for round nose piers:
ys<=2.4 times the pier width (a) for Fr<=0.8
ys<=3.0 times the pier width (a) for Fr>0.8

Pier 1	Q100	Q500	Qother
Pier stationing, ft	51.6	51.6	0
Area of WSPRO flow tube, ft2	9.6	11.6	0
Skewed width of flow tube, ft	1.8	1.9	0
y1, pier approach depth, ft	5.33	6.11	ERR
y1 in meters	1.626	1.861	N/A
V1, pier approach velocity, ft/s	7.8	9.7	0
a, pier width, ft	5.1	5.1	0
L, pier length, ft	38.5	38.5	0
Fr1, Froude number at pier	0.595	0.692	ERR
Pier attack angle, degrees	0	0	0
K1, shape factor	1	1	0
K2, attack factor	1.00	1.00	ERR
K3, bed condition factor	1.1	1.1	0
D50, ft	0.0102	0.0102	0.0102
D50, m	0.003109	0.003109	0.003109
D90, ft	0.0477	0.0477	0
D90, m	0.014538	0.014538	0
Vc50,critical velocity(D50),m/s	0.980	1.002	N/A
Vc90,critical velocity(D90),m/s	1.638	1.675	N/A
Vi,incipient velocity,m/s	0.455	0.465	ERR
Vr, velocity ratio	1.624	2.058	ERR
K4, armor factor	0.00	0.00	N/A
ys, scour depth (K4 applicable) ft	ERR	ERR	ERR
ys, scour depth (K4 not applied)ft	9.12	10.20	ERR

D50=0.692(K*V)^2/(Ss-1)*2*g
(Richardson and others, 1995, p.115, eq. 83)

Pier-shape coefficient (K), round nose, 1.5; square nose, 1.7
Characteristic avg. channel velocity, V, (Q/A):
(Mult. by 0.9 for bankward piers in a straight, uniform reach,
up to 1.7 for a pier in main current of flow around a bend)

Pier 1	Q100	Q500	Qother
K, pier shape coeff.	1.5	1.5	0
V, char. aver. velocity, ft/s	7.8	9.7	0
D50, median stone diameter, ft	0.89	1.38	0.00