Potential Scour at Bridge A07011, Over the Powwow River at Pond Street in Amesbury, Massachusetts

By PETER J. MURPHY and LISA BRATTON

U.S. Geological Survey
Open-File Report 97-801

Prepared in cooperation with
MASSACHUSETTS HIGHWAY DEPARTMENT

Marlborough, Massachusetts
1998

U.S. DEPARTMENT OF THE INTERIOR
BRUCE BABBITT, *Secretary*

U.S. GEOLOGICAL SURVEY
Mark Schaefer, *Acting Director*

For additional information write to:

Chief, Massachusetts-Rhode Island District
U.S. Geological Survey
Water Resources Division
28 Lord Road, Suite 280
Marlborough, MA 01752

Copies of this report can be purchased from:

U.S. Geological Survey
Branch of Information Services
Box 25286, Federal Center
Denver, CO 80225-0286

CONTENTS

FIGURES

TABLES

CONVERSION FACTORS

Multiply	By	To obtain
inch (in)	25.4	millimeter (mm)
foot (ft)	0.3048	meter
foot per mile (ft/mi)	0.1894	meter per kilometer
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer
foot per second (ft/s)	0.3048	meter per second
cubic foot per second (ft^3/s)	0.02832	cubic meter per second

Potential Scour at Bridge A07011, Over the Powwow River at Pond Street in Amesbury, Massachusetts

By Peter J. Murphy *and* Lisa Bratton

SUMMARY

An analysis for potential contraction, abutment, and pier scour was completed for bridge A07011 over the Powwow River at Pond Street in Amesbury, Massachusetts. This report is one of a series completed for selected bridge sites in Massachusetts. The study of scour at this and the other bridges was conducted by the U.S. Geological Survey in cooperation with the Massachusetts Highway Department.

The bridge is a single arch, stone masonry structure, 33 feet wide and 25 feet long, with no piers and small wingwalls. The land use near the bridge is mainly urban. The streambed material is predominately gravel (d_{50} is 0.035 foot). Cross sections were surveyed upstream and downstream from the bridge site, at a dam downstream from the bridge, along the roadway, and at both the downstream and upstream bridge-face openings. The backwater curves for four flood flow rates, Q_{10}, Q_{50}, Q_{100}, and Q_{500}, corresponding to 10-, 50-, 100-, and 500-year return periods, and also for the maximum discharge before pressure flow under the bridge and road overflow, were calculated using a water-surface-profile analysis. The flood discharges ranged from 921 to 3,630 cubic feet per second. The water-surface-profile analysis of the bridge hydraulics showed high velocities (5.52 to 11.9 feet per second) and indicated a potential for scour at this bridge. Table 1 shows potential contraction and abutment scour depths rounded to the nearest foot. The potential contraction and abutment scour are both significant processes.

INTRODUCTION

The objective of scour depth analysis is to assess and evaluate the stream stability and scour depth at bridge sites. This is one of a series of reports presenting the analysis of scour depths for designated bridges throughout Massachusetts in partial fulfillment of a cooperative agreement between the Massachusetts Highway Department (MHD) and the U.S. Geological Survey (USGS). Each analysis includes a survey of cross sections upstream and downstream of a selected bridge and a survey of the bridge face opening. The survey data were processed and used in a Water-Surface-PROfile (WSPRO) computer model (Shearman, 1990) to determine surface-water levels for four flow rates, Q_{10}, Q_{50}, Q_{100}, and Q_{500} for the 10-, 50-, 100-, and 500-year floods and for the maximum discharge before pressure flow under the bridge. The results of each computer model were used in scour equations to estimate maximum potential scour depths at the bridge site from contraction, abutment, and pier scour (Richardson and Davis, 1995).

OVERVIEW OF BRIDGE SITE

The bridge A07011, is over the Powwow River at Pond Street in Amesbury, Massachusetts. The Powwow River is located in the Merrimack River major drainage basin. The bridge is located in MHD District 4. The bridge is a single arch, stone masonry structure, 33 ft wide and 25 ft long, with no piers and small wingwalls. The drainage area for the site is 50.44 mi^2. The Powwow River at the bridge site has a channel slope of approximately 0.0002 ft/ft (1 ft/mi), an average channel top width of approximately 40 ft and an average channel depth of 10 ft at the 100-year flood. The predominant streambed material is gravel (d_{50} is 0.035 ft or 10.6 mm). The banks are gravel with some silt and sand. The river is regulated at the Wooden Dam, a low dam with a sluice gate, located 262 ft downstream from the bridge.

The land use near the bridge is largely urban. The area on the upstream left side is a grass-covered open area with a house. The words "left" and "right" in this report refer to directions that would be reported by an observer facing downstream. The downstream left side is an old mill building running along the stream to the dam. The upstream right side of the bridge is a grass-covered open area with a house and the downstream right side is a grass-covered area with a sidewalk and a parking lot set back from the stream.

WATER-SURFACE PROFILE ANALYSIS

The Water-Surface Profile (WSPRO) computer model determines water-surface levels based on backwater calculations. The WSPRO analyses assume a fixed bed and a one-dimensional, gradually varied, and steady flow. The model has several options and can determine overall hydraulic conditions at a site or can approximate transverse distributions of downstream velocity for a predetermined discharge and surface-water level by dividing the channel width into 20 equal-conveyance streamtubes. The computer model uses special routines to compute hydraulic conditions in the vicinity of bridges (Shearman and others, 1986; Shearman, 1990).

A WSPRO model was used at bridge site A07011 to determine the water-surface profile through the bridge opening for four flood flow rates, Q_{10}, Q_{50}, Q_{100}, and Q_{500}. The three smaller floods passed under the bridge without causing pressure flow or road overtopping, but pressure flow and road overtopping occurred (at the same flow rate) before the 500-year flood was attained.

Description of Field Data

Cross sections were surveyed for the approach (APPR1), roadway (RDWAY), downstream bridge face (BRIDG), exit (EXIT1 and EXIT2), and downstream dam (DSDAM) sections. The dam's spillway acts as a control, approximated as critical depth over a broad-crested weir. The EXIT2 cross section was located at the upstream face of the dam. The DSDAM cross section was located at the spillway crest. The bridge cross section (BRIDG) was measured at the downstream side of the bridge. The altitude, 497.14 ft, of the top of the arch was used as a local datum. The roadway cross section (RDWAY) was surveyed to anticipate potential overtopping of the bridge by a flood.

The streambed was predominately gravel with some sand and underlying bedrock. Manning's roughness values were determined and a scoop sampler was used for collection of medium- and fine-grained material in the riverbed (Hayes, 1993) at the site when the cross sections were surveyed.

Assumptions and Calculations for Model

Several calculations and assumptions were made before the water-surface model was run:

(1) The flood discharge values for the Q_{10}, Q_{50}, Q_{100}, and Q_{500} were calculated based on relative drainage basin elevation and drainage basin area, using regression equations developed by P.J. Murphy (U.S. Geological Survey, written commun., 1996). The Flood Insurance Study (FIS) for Amesbury (Federal Emergency Management Agency, 1992) based its flood-flow-rate estimate for the 100-year flood on regression equations developed by Wandle (1983), but did not estimate the size of other floods. The FIS estimate for the 100-year flood was 13 percent smaller than the Murphy estimate.

(2) One cross section was templated in this analysis; the full-valley (FULLV) section was developed from the EXIT1 section. The section reference distance (SRD) was set to zero at the downstream face of the bridge. The input file for the WSPRO water-surface analysis (Shearman, 1990) is shown in appendix A.

(3) The critical depth of the water at the spillway crest of the Wooden Dam was used to estimate the starting-water-surface elevation downstream from the bridge for the water-surface-profile computations. The FIS for Amesbury (Federal Emergency Management Agency, 1992) used the tidal elevations of the Merrimack River as the starting-water-surface elevations for the Powwow River in Amesbury.

(4) Survey data were processed for input into WSPRO using an Automated WSPRO Input and Survey Processing Program (AWISPP) (E. Boehmler, U.S. Geological Survey, written commun., 1996). AWISPP calculates many of the parameters required in WSPRO such as section-reference distances, and the

geometry of the bridge, wingwall, abutments, and embankments. AWISPP also was used to calculate channel slope, align cross sections to the left edge of water, process bends in cross section lines, compute the best fit segment line to straighten cross sections, and compute skew angles. The input file for WSPRO created with AWISPP is shown in appendix A.

(5) The left edge of water at the approach, bridge, full valley, and exit cross sections was set to zero to maintain consistency between the sections. This was done in AWISPP by setting the *x*-coordinate of the left edge of water at each station equal to zero.

(6) Because the bridge had vertical abutments, small wingwalls, and a vertical road embankment, the bridge was classified for WSPRO as a type 1A bridge (Shearman, 1990).

(7) The particle-size distribution for the sand and gravel collected at the downstream bridge face was determined using sieve analysis (Folk, 1980). The d_{50} under the bridge is 0.035 ft. This grain-size distribution was assumed to apply to the bed material at the approach and exit sections.

(8) The Manning's roughness coefficients for the various parts of the cross sections at the site were assigned values dependent on the bed grain size and on the channel's and overbanks' shapes and roughnesses (Arcement and Schneider, 1984). The stream channel was assigned a value of 0.035 for the whole length of the site. The Manning's roughness coefficient was designated as 0.060 for all the overbank areas. This overbank value includes the effects of the mill building and houses. A wall was set in the dam cross section to show the location of the mill building on the left side of the exit cross section. The FIS for Amesbury (Federal Emergency Management Agency, 1992) used the same roughness coefficients as were used in this study.

Water-Surface Profile Model Results

The backwater curves for the four flood flow rates, Q_{10}, Q_{50}, Q_{100}, and Q_{500}, and for the maximum discharge before pressure flow under the bridge were calculated using WSPRO analysis. The flow at the exit cross section was subcritical for all five floods because the Wooden Dam, downstream from the bridge, regulates the water levels at the downstream end of the bridge site.

The computer model calculations indicated the water surface reached low chord of the bridge, pressure flow, and road overtopping at approximately 2,160 ft^3/s. The pressure flow occurred before the 500-year flood discharge, but the 500-year flood was included in the water-surface-profile analysis. The results of the computer model calculations are included in appendix B. The WSPRO analysis of the bridge hydraulics showed high velocities at the bridge (5.52 to 11.9 ft/s). The water-surface profiles for the 10-, 50-, 100-, and 500-year floods and for the maximum discharge before pressure flow and road overtopping are shown in figure 1 (at back of report). The FIS for Amesbury showed three water-surface profiles near the bridge at Pond Street that were roughly 1 ft lower than the results of this study. However, the FIS profile for the 500-year flood did not indicate pressure flow or road overtopping and was 3 ft lower than the result of this study.

POTENTIAL SCOUR ANALYSIS

Scour depths were computed using the general guidelines described in Richardson and Davis (1995) and Arneson and others (1992). The hydraulic model WSPRO was used to determine water-surface profiles and other hydraulic variables needed for scour calculations, such as discharge, velocity, and depth.

Assumptions and Calculations for Potential Scour

Several equations that are presented and explained in Richardson and Davis (1995) were used to calculate the potential contraction and abutment scour for this bridge, depending on the situation during each flood event. The Neill equation was used to determine the applicability of the live-bed or clear water equations for potential contraction scour. Based on the results of the Neill equation analysis, the appropriate scour equations were used to determine scour depths for the main channel, left overbank, and right overbank of the approach and bridge sections. The contraction scour depths were determined using the Larsen clear-water contraction scour equation. The abutment scour depths were calculated using the Froehlich equation. This report focuses on contraction and abutment scour because the bridge has no piers.

The HIRE equation (Richardson and Davis, 1995) was not applied to bridges in this study. Although HEC-18 recommended use of the HIRE equation for long ($L_E/Y_E > 25$) embankments blocking flow on flood plains, "where conditions are similar to the field conditions from which the equation was derived," those field conditions did not occur at this bridge. The decision to not use the HIRE equation also was recommended in a discussion with L. Arneson, Regional Engineer, FHWA, Denver on January 8, 1997.

Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution. However, bedrock may underlie the observable channel bed and limit the scour depths.

To clarify the use of variables, different sections of the river reach at the site have been assigned letters associated with the parameters used for the scour calculations from WSPRO output. Variables associated with the approach section are assigned the letter *a*, the variables for the upstream bridge face have a letter *b*, and the downstream bridge face have the letter *c*, with subscripts *m*, *l*, and *r* corresponding to the main channel, left flood plain and right flood plain, respectively (tables 2 through 5, at back of report).

Scour Calculation Results

Scour calculations were done for contraction and abutment scour. The results of the scour depth analysis are presented in tables 3 through 5. The numbers in the tables have been rounded to 3 significant figures unless otherwise written. The scour depths have been rounded to the nearest foot.

Exposed abutment footings and scour holes were not observed during the field inspection. Riprap was not observed near the bridge foundations, but was observed along both banks just upstream from the bridge and extending along the upstream right bank.

The Neill equation was applied at the approach cross section of the Pond Street bridge over the Powwow River in Amesbury. All flood flows filled the main channel and extended onto both flood plains at the approach cross section. The stream channel under the bridge has no left or right overbanks. The results of the analysis with the Neill equation (table 2) showed that the gravel in the main channel of the approach cross section were too large for sediment motion, thus a clear-water scour analysis was applicable at this bridge.

Contraction Scour

Laursen's clear-water contraction-scour equation (Richardson and Davis, 1995) was applied to the main channel at the bridge cross section. The calculations are shown in table 3. The contraction scour results indicated that the d_{50} of the gravel was small enough that clear-water scour would occur at the bridge site for all but the 10-year flood. The contraction scour depths were small, 0 to 6 ft. The altitudes of the bottoms of the potential contraction scour holes for the four floods without pressure flow, referenced to the low chord of the bridge at 497.5 ft, are 486, 483, 481, and 480 ft. The altitude of the potential contraction scour for the maximum discharge before pressure flow is shown in figure 2 (at back of report).

Abutment Scour

Froehlich's abutment scour equation (Richardson and Davis, 1995) was applied to the left and right abutments. Those abutment scour calculations are given in tables 4 and 5. The results show that the right abutment has a range of scour depths from 4 to 7 ft and the left abutment has larger scour depths, from 7 to 12 ft. However, no scour was observed on a visit to the site on October 20, 1994 (M. Lombardo, Environmental Careers Organization, written commun., 1994). The depths of the abutment scour are added to the contraction scour depths to determine total scour at the abutments. The altitudes of the bottoms of the total potential scour holes at the left abutment, referenced to the low chord of the bridge at 497.5 ft, are 482, 480, 479, and 479 ft. The altitudes of the bottoms of the total potential scour holes at the right abutment, referenced to the low chord of the bridge at 497.5 ft, are 489, 488, 488, and 481 ft. The abutment scour depth profile is not shown in figure 2 because the values for abutment scour are not considered to be reliable.

REFERENCES CITED

Arcement, G.J. and Schneider, V.R., 1984, Guide for selecting Manning's roughness coefficients for natural channels and flood plains, Federal Highway Administration Report FHWA-TS-84-204, 62 p.

Arneson, L.A., Shearman, J.O., Jones, J.S., 1992, Evaluating scour at bridges using WSPRO: Transportation Research Board Draft Paper, 40 p.

Federal Emergency Management Agency, 1992, Flood Insurance Study, Town of Amesbury, Massachusetts, Middlesex County, 20 p.

Folk, R.L., 1980, Petrology of sedimentary rocks: Hemphill Publishing Company, Austin, Texas, 184 p.

Hayes, D.C., 1993, Site selection and collection of bridge-scour data in Delaware, Maryland, and Virginia: U.S. Geological Survey Water-Resources Investigations Report 93-4017, 23 p.

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

Shearman, J.O., Kirby, W.H., Schneider, V.R., Flippo, H.N., 1986, Bridge waterways analysis model: research report, Federal Highway Administration Report FHWA/RD-86/108, 126 p.

Shearman, J.O., 1990, User's manual for WSPRO--A computer model for water surface profile computations, FHWA-IP-89-027, September, 1990.

Wandle, S.W., Jr., 1983, Estimating peak discharges of small, rural streams in Massachusetts, U.S. Geological Survey Water-Supply Paper 2214, 26 p.

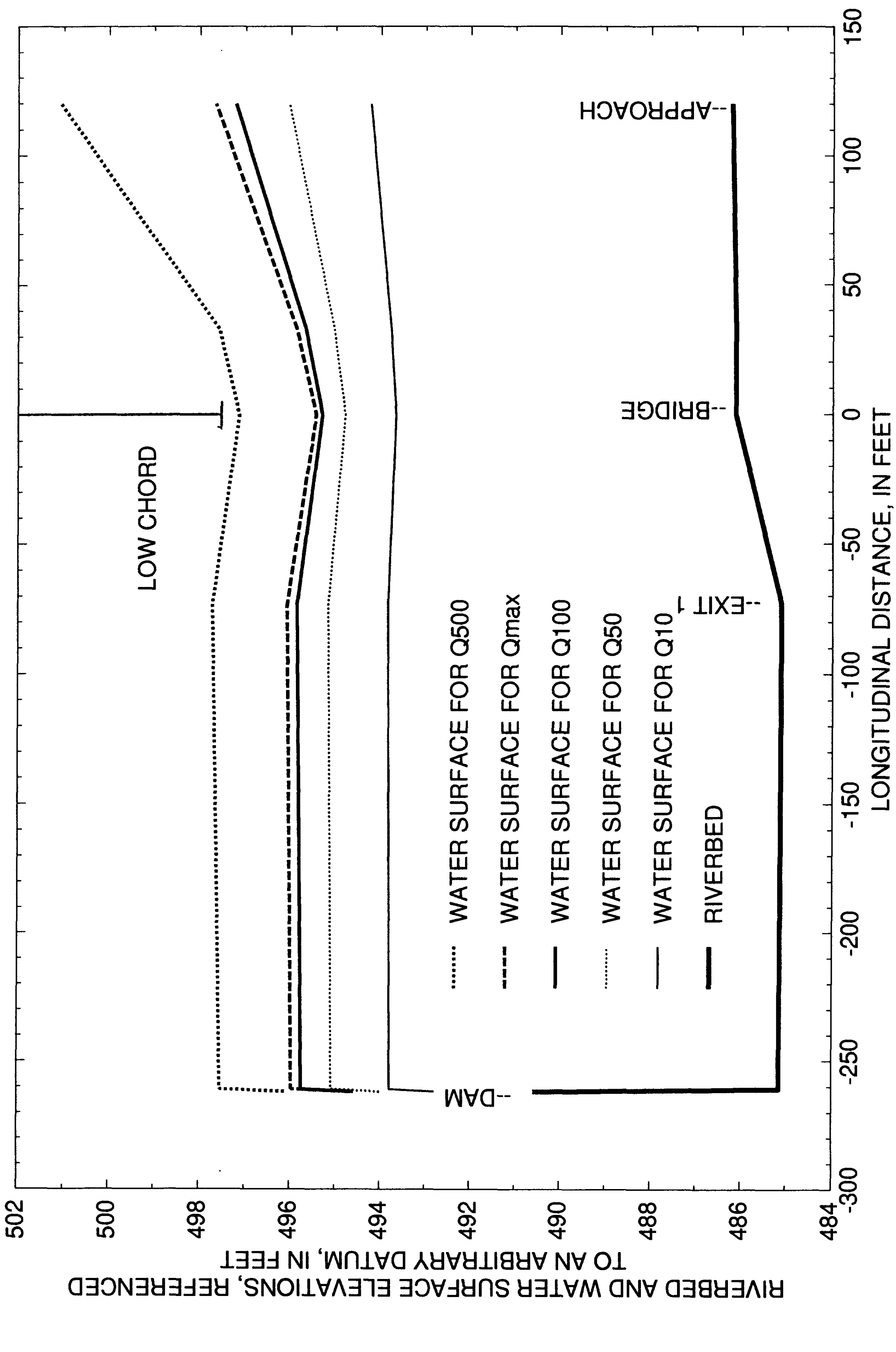

Figure 1. Riverbed and flood water level profiles for bridge A07011 over the Powwow River at Pond Street in Amesbury, Massachusetts.

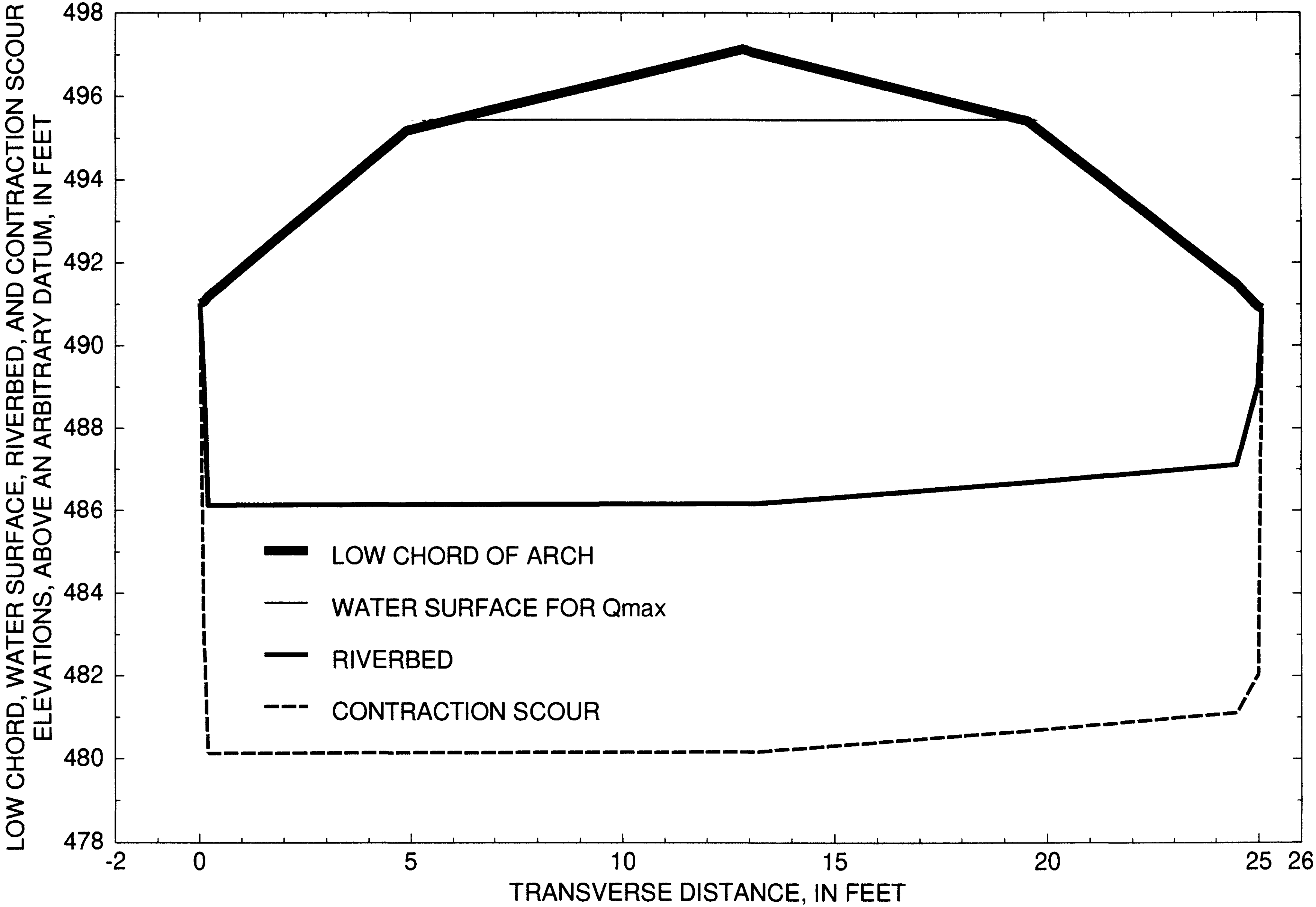

Figure 2. Cross section at the downstream face of bridge A07011, showing the low chord, water surface for the maximum discharge before pressure flow, riverbed and potential contraction scour.

— PAGE 9 FOLLOWS —

TABLES 1-5

— PAGE 11 FOLLOWS —

Table 1. Summary of potential scour depths for bridge A07011, over the Powwow River at Pond Street in Amesbury, Massachusetts

[ft, foot; ft^3/s, cubic foot per second]

Flood return period	Discharge, ft^3/s	Bed transport condition	Scour depths (ft)			
			Contraction	Left abutment	Right abutment	Pier
10-year	921	clear water	0	7	4	None
50-year	1,550	clear water	3	10	6	None
100-year	1,990	clear water	5	11	7	None
Pressure flow[1]	2,150	clear water	6	12	7	None

[1] Maximum discharge that can pass under the bridge before reaching pressure flow and road overtopping. The flood return period is undetermined.

Table 2. Determination of live-bed or clear-water conditions for bridge A07011, over the Powwow River at Pond Street in Amesbury, Massachusetts

[**Symbol:** *a*, approach section; *m*, main channel subarea; C, critical; M, mean; t, total. **Pressure flow:** Maximum discharge that can pass under the bridge before reaching pressure flow and road overtopping. The flood return period is undetermined. ft, foot; ft^2, square foot; ft/s, foot per second; ft^3/s, cubic foot per second]

Parameter	Symbol	Value for indicated recurrence interval			
		10-year	50-year	100-year	Pressure flow
Approach Section					
Total discharge, ft^3/s	$Q_t(a)$	921	1,550	1,990	2,150
Total conveyance, ft^3/s	$K_t(a)$	47,700	71,500	89,300	96,300
Water-surface elevation above arbitrary datum, ft	$h(a)$	494.23	496.04	497.22	497.66
Conveyance of main channel, ft^3/s	$K(a_m)$	43,900	63,800	78,300	84,000
Area of main channel, ft^2	$A(a_m)$	281	351	397	414
Top width of main channel, ft	$T(a_m)$	39	39	39	39
Median grain size, ft	$d_{50}(a_m)$	0.035	0.035	0.035	0.035
Calculated Parameters					
Discharge, ft^3/s, $[K(a_m) / K_t(a)]\, Q_t(a)$	$Q(a_m)$	848	1,380	1,740	1,880
Mean water depth, ft, $A(a_m) / T(a_m)$	$y(a_m)$	7.2	9.0	10.2	10.6
Mean velocity, ft/s, $Q(a_m) / A(a_m)$	$V_M(a_m)$	3.0	3.9	4.4	4.5
Critical velocity, ft/s, Neill equation[1]	$V_C(a_m)$	5.1	5.3	5.4	5.4
Results					
Live bed $[V_M(a_m) > V_C(a_m)]$ or Clear water $[V_M(a_m) < V_C(a_m)]$		Clear water	Clear water	Clear water	Clear water

[1] Neill equation, $V_C(a_m) = 11.21\,[y(a_m)]^{0.1667}[d_{50}(a_m)]^{0.33}$, modified from Richardson and Davis, 1995, p. 28, eq. 15 assuming Shields parameter is 0.039, and specific gravity of bed material is 2.65.

Table 3. Calculation of clear-water contraction scour for bridge A07011, over the Powwow River at Pond Street in Amesbury, Massachusetts

[**Symbol:** *a*, approach section; *c*, downstream bridge-face section; *m*, main channel subarea; p, pier; t, total. **Pressure flow:** Maximum discharge that can pass under the bridge before reaching pressure flow and road overtopping. The flood return period is undetermined. ft, foot; ft^2, square foot; ft/s, foot per second; ft^3/s, cubic foot per second]

Parameter	Symbol	Value for indicated recurrence interval			
		10-year	50-year	100-year	Pressure flow
Approach Section					
Total discharge, ft^3/s	$Q_t(a)$	921	1,550	1,990	2,150
Water-surface elevation above arbitrary datum, ft	$h(a)$	494.23	496.04	497.22	497.66
Area of main channel, ft^2	$A(a_m)$	281	351	397	414
Top width of main channel, ft	$T(a_m)$	39	39	39	39
Downstream Bridge-Face Section					
Total discharge through bridge, ft^3/s	$Q_t(c)$	921	1,550	1,990	2,150
Total conveyance through bridge, ft^3/s	$K_t(c)$	18,200	20,600	21,400	21,500
Water-surface elevation above arbitrary datum, ft	$h(c)$	493.67	494.79	495.30	495.44
Conveyance of main channel, ft^3/s	$K(c_m)$	18,200	20,600	21,400	21,500
Area of main channel, ft^2	$A(c_m)$	167	185	193	195
Total bottom width of main channel (including piers), ft	$B_t(c_m)$	25	25	25	25
Total width of piers in main channel, ft (width measured at base of pier)	$W_p(c_m)$	0	0	0	0
Median grain size, ft	$d_{50}(c_m)$	0.035	0.035	0.035	0.035
Calculated Parameters					
Discharge, ft^3/s, $[K(c_m) / K_t(c)]\ Q_t(c)$	$Q(c_m)$	921	1,550	1,990	2,150
Diameter of smallest non-transportable bed material, ft, 1.25 $d_{50}(c_m)$	$d_n(c_m)$	0.044	0.044	0.044	0.044
Adjusted bottom width of main channel, ft, $B_t(c_m) - W_p(c_m)$	$B(c_m)$	25	25	25	25
Mean water depth at approach, ft, $A(a_m) / T(a_m)$	$y(a_m)$	7.21	9.00	10.2	10.6
Mean water depth at downstream bridge face, ft, $A(c_m) / B(c_m)$	$y(c_m)$	6.68	7.40	7.72	7.80
Mean water depth including contraction scour, ft, Laursen's 1963 equation[1]	$y_2(c_m)$	6.66	10.4	12.9	13.8
Results					
Difference in mean water depth between approach and bridge sections, ft, $y_2(c_m) - y(a_m)$	$y_d(c_m)$	0	1	3	3
Mean scour depth at bridge, ft, $y_2(c_m) - y(c_m)$	$y_s(c_m)$	0	3	5	6

[1] Laursen's 1963 equation: $y_2(c_m) = ([Q(c_m)]^2 / \{131\ [d_n(c_m)]^{0.667}\ [B(c_m)]^2\})^{0.429}$ converted to English units, Richardson and Davis, 1995, p. 32, eqn. 20, 20a.

Table 4. Calculation of local scour at the left abutment for bridge A07011, over the Powwow River at Pond Street in Amesbury, Massachusetts

[**Symbol:** *a*, approach section; *b*, upstream bridge face section; *R*, roadway section; *l*, left overbank subarea; E, embankment; F, flowtube; P, projected; t, total. **Pressure flow:** Maximum discharge that can pass under the bridge before reaching pressure flow and road overtopping. The flood return period is undetermined.; ft, foot; ft^2, square foot; ft/s, foot per second; ft^3/s, cubic foot per second]

Parameter	Symbol	Value for indicated recurrence interval			
		10-year	50-year	100-year	Pressure flow
Approach and Roadway Sections					
Total discharge, ft^3/s	$Q_t(a)$	921	1,550	1,990	2,150
Area of approach section determined by projection of the left embankment, ft^2	$A_P(a_l)$	60	97	124	135
Length of left embankment projected onto approach section, ft	$T_P(a_l)$	19	22	24	25
Total conveyance, ft^3/s	$K_t(a)$	47,700	71,500	89,300	96,300
Conveyance obstructed by projecting left embankment onto approach section, ft^3/s	$K_P(a_l)$	3,130	6,230	8,810	9,880
Parameters and Calculations for Road Overflow					
Discharge over left roadway, ft^3/s	$Q(R_l)$	0	0	0	0
Discharge per equal conveyance flowtube, ft^3/s, $Q_t(a) / 20$	q_F	46.0	77.6	99.4	108
Number of conveyance tubes corresponding to road overflow discharge, $Q(R_l) / q_F$	# tubes	0	0	0	0
Width of conveyance tube corresponding to road overflow discharge, ft. (From HP-2 output).	$L(R_l)$	0	0	0	0
Area of conveyance tube corresponding to road overflow, ft^2,	$A(R_l)$	0	0	0	0
Calculated Parameters					
Embankment length blocking flow, ft, $T_P(a_l) - L(R_l)$	$L_E(a_l)$	19	22	24	25
Area of flow blocked by embankment, ft^2, $A_P(a_l) - A(R_l)$	$A_E(a_l)$	60	97	124	135
Average depth of flow blocked by embankment, ft, $A_E(a_l) / L_E(a_l)$	$Y_E(a_l)$	3.16	4.41	5.17	5.40
Discharge determined by projection of embankment onto approach section, ft^3/s, $[K_P(a_l) / K_t(a)]\ Q_t(a)$	$Q_P(a_l)$	60.5	135	196	221
Discharge blocked by embankment, ft^3/s, $Q_P(a_l) - Q(R_l)$	$Q_E(a_l)$	60.5	135	196	221
Average velocity of flow blocked by embankment, ft/s, $Q_E(a_l) / A_E(a_l)$	$V_E(a_l)$	1.01	1.39	1.58	1.64
Froude number of flow blocked by embankment, $V_E(a_l) / [32.2\ Y_E(a_l)]^{0.5}$	$Fr_E(a_l)$	0.10	0.12	0.12	0.12
Correction factor for abutment type: 1.00, for vertical abutment; or 0.82, for vertical abutment with wingwall; or 0.55, for spillthrough abutment	$k_1(b_l)$	1.00	1.00	1.00	1.00
Angle of embankment to flow, degrees: $\theta = 90$ if embankment is normal to flow, or $\theta < 90$ if embankment is angled downstream, or $\theta > 90$ if embankment is angled upstream	θ	90	90	90	90
Correction factor for angle of embankment to flow, $(\theta/90)^{0.13}$	$k_2(b_l)$	1.00	1.00	1.00	1.00
Results					
Scour depth, ft, Froehlich equation[1]	$y_s(b_l)$	7	10	11	12

[1] Froehlich equation, $y_s(b_l) = \{2.27\ k_1(b_l)\ k_2(b_l)\ [L_E(a_l) / Y_E(a_l)]^{0.43}\ [Fr_E(a_l)]^{0.61} + 1\}\ Y_E(a_l)$ (Richardson and Davis, 1995, p. 48, eqn. 28).

Table 5. Calculation of local scour at the right abutment for bridge A07011, over the Powwow River at Pond Street in Amesbury, Massachusetts

[**Symbol:** *a*, approach section; *b*, upstream bridge-face section; *R*, roadway section; *r*, right overbank subarea; E, embankment; F, flowtube; P, projected; t, total; **Pressure flow:** Maximum discharge that can pass under the bridge before reaching pressure flow and road overtopping. The flood return period is undetermined. ft, foot; ft^2, square foot; ft/s, foot per second; ft^3/s, cubic foot per second]

Parameter	Symbol	Value for indicated recurrence interval			
		10-year	50-year	100-year	Pressure flow
Approach and Roadway Sections					
Total discharge, ft^3/s	$Q_t(a)$	921	1,550	1,990	2,150
Area of approach section determined by projection of the right abutment, ft^2	$A_P(a_r)$	17	31	43	49
Length of right embankment projected onto approach section, ft	$T_P(a_r)$	7	9	13	16
Total conveyance, ft^3/s	$K_t(a)$	47,700	71,500	89,300	96,300
Conveyance obstructed by projecting right embankment onto approach section, ft^3/s	$K_P(a_r)$	3,130	6,230	8,810	9,880
Parameters and Calculations for Road Overflow					
Discharge over right roadway, ft^3/s	$Q(R_r)$	0	0	0	0
Discharge per equal conveyance flowtube, ft^3/s, $Q_t(a) / 20$	q_F	46.0	77.6	99.4	108
Number of conveyance tubes corresponding to road overflow discharge, $Q(R_r) / q_F$	# tubes	0	0	0	0
Width of conveyance tube corresponding to road overflow discharge, ft. (From HP-2 output).	$L(R_r)$	0	0	0	0
Area of conveyance tube corresponding to road overflow discharge, ft^2. (From HP-2 output).	$A(R_r)$	0	0	0	0
Calculated Parameters					
Embankment length blocking flow, ft, $T_P(a_r) - L(R_r)$	$L_E(a_r)$	7	9	13	16
Area of flow blocked by embankment, ft^2, $A_P(a_r) - A(R_r)$	$A_E(a_r)$	17	31	43	49
Average depth of flow blocked by embankment, ft, $A_E(a_r) / L_E(a_r)$	$Y_E(a_r)$	2.43	3.44	3.31	3.06
Discharge determined by projection of embankment onto approach section, ft^3/s, $[K_P(a_r) / K_t(a)]\ Q_t(a)$	$Q_P(a_r)$	12.7	32.5	47.3	52.2
Discharge blocked by embankment, ft^3/s, $Q_P(a_r) - Q(R_r)$	$Q_E(a_r)$	12.7	32.5	47.3	52.2
Average velocity of flow blocked by embankment, ft/s, $Q_E(a_r) / A_E(a_r)$	$V_E(a_r)$	0.75	1.05	1.10	1.07
Froude number of flow blocked by embankment, $V_E(a_r) / [32.2\ Y_E(a_r)]^{0.5}$	$Fr_E(a_r)$	0.08	0.10	0.11	0.11
Correction factor for abutment type:, 1.0, for vertical abutment; or 0.82, for vertical abutment with wingwall; or 0.55, for spill-through abutment	$k_1(b_r)$	1.00	1.00	1.00	1.00
Angle of embankment to flow, degrees: $\theta = 90$ if embankment is normal to flow, or $\theta < 90$ if embankment is angled downstream, or $\theta > 90$ if embankment is angled upstream	θ	90	90	90	90
Correction factor for angle of embankment to flow, $(\theta/90)^{0.13}$	$k_2(b_r)$	1.00	1.00	1.00	1.00
Results					
Scour depth, ft, Froehlich equation[1]	$y_s(b_r)$	4	6	7	7

[1] Froehlich equation, $y_s(b_r) = \{2.27\ k_1(b_r)\ k_2(b_r)\ [L_E(a_r) / Y_E(a_r)]^{0.43}\ [Fr_E(a_r)]^{0.61} + 1\}\ Y_E(a_r)$ (Richardson and Davis, 1995, p. 48, eqn. 28)

APPENDIX A

WSPRO Input Data File for
Bridge A07011, Amesbury, Massachusetts

– PAGE 17 FOLLOWS –

```
T1        U.S. Geological Survey WSPRO Input File a07011.wsp
T2        Hydraulic analysis for structure a07011           Date: 09/29/97
T3        a07011 awispp.x a07011.dca.7 downstream 1a
Q            921      1553     1989     2150     2160     3628
WS          492.79  494.00  494.58  494.28   494.28  494.28
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
XS    DAMDS   -262            0.
GR           -34.8, 508.27    -34.8, 495.01    -18.6, 493.86     -0.3, 493.77
GR             0.0, 490.58     49.6, 490.58     49.9, 493.23     54.7, 493.29
GR            70.9, 495.67     90.9, 496.94    246.9, 501.67
*
*
N           0.060         0.035         0.060
SA                   0.0          49.6
*
*
XS    EXIT2   -261            0.
GR          -365.0, 502.88    -13.3, 499.65    -12.6, 494.13     -8.7, 491.94
GR             0.0, 489.12      9.3, 485.73     24.5, 485.15     38.0, 486.61
GR            44.6, 489.16     66.2, 498.98    118.4, 501.10
*
*
*
XS    EXIT1    -73            0.
GR          -365.0, 502.84    -13.3, 499.61    -12.6, 494.09     -8.7, 491.90
GR             0.0, 489.08      9.3, 485.69     24.5, 485.11     38.0, 486.57
GR            44.6, 489.12     66.2, 498.94    118.4, 501.06
*
N           0.060         0.035         0.060
SA               0.0       44.6
*
*
XS    FULLV      0   * * *   0.0002
*
BR    BRIDG      0   497.5      15.0
GR             0.0, 491.02      0.0, 489.07      0.2, 486.13     13.2, 486.18
GR            24.5, 487.11     25.0, 489.04     25.1, 490.90     19.6, 495.41
GR            12.9, 497.14      4.9, 495.18      0.0, 491.02
*
*         BRTYPE  BRWDTH       WWANGL    WWWID
CD           1       43.6 * *     83.4      0.3
N           0.035
*
XR    RDWAY      18     35.0     1
GR             0.0, 508.27     38.0, 499.95     63.4, 499.71    130.1, 499.34
GR           231.5, 500.80    390.6, 505.40    476.1, 505.55
*
*
*             SRD      LSEL     XSSKEW
* BR    USBRG      0    *******      15.0
* GR            -1.0, 489.32      0.0, 496.99      0.0, 489.11       2.6, 487.00
* GR            11.2, 485.93     22.1, 485.83     24.2, 486.86      33.5, 489.11
* GR            33.5, 496.99     -1.0, 489.32
*
*         BRTYPE  BRWDTH       WWANGL    WWWID
* CD            1       43.6 * *     83.4      0.3
* N           0.035
*
*           EXPECTED SRD =   35 AT ONE BR. LENGTH BUT COMPUTED SRD =  120
```

```
*
AS    APPR1     120              0.
GR          -43.1, 508.27     -23.9, 497.24     -14.7, 491.75       0.0, 489.24
GR            6.5, 486.97      18.5, 486.22      26.8, 486.46      33.0, 486.91
GR           39.0, 489.23      49.2, 496.89      66.6, 499.25
*
N           0.060          0.035          0.060
SA                0.0            39.0
*
* PX   DAMDS
* PX   EXIT1
* PX   FULLV
* PX   BRIDG
* PX   APPR1
*
HP 1 BRIDG  493.67   0.0  493.67
HP 1 BRIDG  494.79   0.0  494.79
HP 1 BRIDG  495.30   0.0  495.30
HP 1 BRIDG  495.44   0.0  495.44
HP 1 BRIDG  497.14   0.0  497.14
*
HP 1 APPR1  494.23   0.0  494.23
HP 1 APPR1  496.04   0.0  496.04
HP 1 APPR1  497.22   0.0  497.22
HP 1 APPR1  497.66   0.0  497.66
HP 1 APPR1  500.02   0.0  500.02
*
EX
ER
```

APPENDIX B

WSPRO Output File for
Bridge A07011, Amesbury, Massachusetts

—PAGE 21 FOLLOWS—

```
WSPRO          FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
V082195            MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

           *** RUN DATE & TIME: 09-29-97  14:59

  T1         U.S. Geological Survey WSPRO Input File a07011.wsp
  T2         Hydraulic analysis for structure a07011           Date: 09/29/97
  T3         a07011 awispp.x a07011.dca.7 downstream 1a
  Q             921     1553    1989     2150     2160    3628
*** Q-DATA FOR SEC-ID, ISEQ =            1
  WS           492.79  494.00  494.58  494.28   494.28  494.28
  *
  J3          6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
  *

*** START PROCESSING CROSS SECTION - "DAMDS"
  XS   DAMDS   -262           0.
  GR           -34.8, 508.27    -34.8, 495.01    -18.6, 493.86     -0.3, 493.77
  GR             0.0, 490.58     49.6, 490.58     49.9, 493.23     54.7, 493.29
  GR            70.9, 495.67     90.9, 496.94    246.9, 501.67
  *
  *                                .
  N            0.060       0.035        0.060
  SA                   0.0          49.6
  *
  *

*** FINISH PROCESSING CROSS SECTION - "DAMDS"
*** CROSS SECTION "DAMDS" WRITTEN TO DISK, RECORD NO. =  1

--- DATA SUMMARY FOR SECID "DAMDS" AT SRD =   -262.  ERR-CODE =      0

     SKEW     IHFNO    VSLOPE        EK        CK
      0.0        0. *********      0.50      0.00

X-Y COORDINATE PAIRS  (NGP =  11):
      X       Y            X       Y            X       Y            X       Y
    -34.8  508.27       -34.8  495.01       -18.6  493.86        -0.3  493.77
      0.0  490.58        49.6  490.58        49.9  493.23        54.7  493.29
     70.9  495.67        90.9  496.94       246.9  501.67

 X-Y MAX-MIN POINTS:
     XMIN       Y            X    YMIN       XMAX       Y            X    YMAX
    -34.8  508.27         0.0  490.58       246.9  501.67       -34.8  508.27

SUBAREA BREAKPOINTS (NSA =  3):
          0.     50.

ROUGHNESS COEFFICIENTS (NSA =  3):
        0.060   0.035   0.060
1

*** START PROCESSING CROSS SECTION - "EXIT2"
  XS   EXIT2   -261           0.
  GR         -365.0, 502.88    -13.3, 499.65    -12.6, 494.13     -8.7, 491.94
  GR            0.0, 489.12      9.3, 485.73     24.5, 485.15     38.0, 486.61
  GR           44.6, 489.16     66.2, 498.98    118.4, 501.10
  *
  *
  *
*** FINISH PROCESSING CROSS SECTION - "EXIT2"
*** NO ROUGHNESS DATA INPUT, WILL PROPAGATE FROM PREVIOUS CROSS SECTION.
*** CROSS SECTION "EXIT2" WRITTEN TO DISK, RECORD NO. =  2
```

```
--- DATA SUMMARY FOR SECID "EXIT2" AT SRD =    -261.  ERR-CODE =       0

      SKEW     IHFNO    VSLOPE        EK        CK
       0.0        0. *********      0.50      0.00

 X-Y COORDINATE PAIRS  (NGP =  11):
        X       Y            X       Y            X       Y            X       Y
   -365.0  502.88      -13.3  499.65      -12.6  494.13       -8.7  491.94
      0.0  489.12        9.3  485.73       24.5  485.15       38.0  486.61
     44.6  489.16       66.2  498.98      118.4  501.10

  X-Y MAX-MIN POINTS:
     XMIN       Y            X    YMIN       XMAX       Y            X    YMAX
   -365.0  502.88       24.5  485.15      118.4  501.10     -365.0  502.88

 SUBAREA BREAKPOINTS (NSA =  3):
          0.     50.

 ROUGHNESS COEFFICIENTS (NSA =  3):
        0.060   0.035   0.060
1

 *** START PROCESSING CROSS SECTION - "EXIT1"
   XS   EXIT1    -73            0.
   GR          -365.0, 502.84    -13.3, 499.61    -12.6, 494.09      -8.7, 491.90
   GR             0.0, 489.08      9.3, 485.69     24.5, 485.11      38.0, 486.57
   GR            44.6, 489.12     66.2, 498.94    118.4, 501.06
   *
   N           0.060        0.035        0.060
   SA                 0.0        44.6
   *
   *

 *** FINISH PROCESSING CROSS SECTION - "EXIT1"
 *** CROSS SECTION "EXIT1" WRITTEN TO DISK, RECORD NO. =  3

 --- DATA SUMMARY FOR SECID "EXIT1" AT SRD =     -73.  ERR-CODE =       0

      SKEW     IHFNO    VSLOPE        EK        CK
       0.0        0. *********      0.50      0.00

 X-Y COORDINATE PAIRS  (NGP =  11):
        X       Y            X       Y            X       Y            X       Y
   -365.0  502.84      -13.3  499.61      -12.6  494.09       -8.7  491.90
      0.0  489.08        9.3  485.69       24.5  485.11       38.0  486.57
     44.6  489.12       66.2  498.94      118.4  501.06

  X-Y MAX-MIN POINTS:
     XMIN       Y            X    YMIN       XMAX       Y            X    YMAX
   -365.0  502.84       24.5  485.11      118.4  501.06     -365.0  502.84

 SUBAREA BREAKPOINTS (NSA =  3):
          0.     45.

 ROUGHNESS COEFFICIENTS (NSA =  3):
        0.060   0.035   0.060
1

 *** START PROCESSING CROSS SECTION - "FULLV"
   XS   FULLV      0  * * *   0.0002
   *

 *** FINISH PROCESSING CROSS SECTION - "FULLV"
 *** NO ROUGHNESS DATA INPUT, WILL PROPAGATE FROM PREVIOUS CROSS SECTION.
 *** CROSS SECTION "FULLV" WRITTEN TO DISK, RECORD NO. =  4
```

```
--- DATA SUMMARY FOR SECID "FULLV" AT SRD =       0.  ERR-CODE =       0

     SKEW     IHFNO    VSLOPE        EK        CK
      0.0        0.    0.0002      0.50      0.00

X-Y COORDINATE PAIRS  (NGP =  11):
      X      Y            X      Y            X      Y             X      Y
   -365.0  502.85     -13.3  499.62      -12.6  494.10        -8.7  491.91
      0.0  489.09       9.3  485.70       24.5  485.12        38.0  486.58
     44.6  489.13      66.2  498.95      118.4  501.07

 X-Y MAX-MIN POINTS:
     XMIN       Y          X    YMIN       XMAX        Y            X    YMAX
   -365.0  502.85      24.5  485.12      118.4  501.07     -365.0  502.85

SUBAREA BREAKPOINTS (NSA =  3):
          0.     45.

ROUGHNESS COEFFICIENTS (NSA =  3):
        0.060   0.035   0.060
1

*** START PROCESSING CROSS SECTION - "BRIDG"
  BR   BRIDG      0   497.5      15.0
  GR            0.0, 491.02      0.0, 489.07      0.2, 486.13      13.2, 486.18
  GR           24.5, 487.11     25.0, 489.04     25.1, 490.90      19.6, 495.41
  GR           12.9, 497.14      4.9, 495.18      0.0, 491.02
  *
  *         BRTYPE  BRWDTH        WWANGL    WWWID
  CD           1      43.6 * *      83.4      0.3
  N          0.035
  *

*** FINISH PROCESSING CROSS SECTION - "BRIDG"
*** CROSS SECTION "BRIDG" WRITTEN TO DISK, RECORD NO. =  5

--- DATA SUMMARY FOR SECID "BRIDG" AT SRD =       0.  ERR-CODE =       0

     SKEW     IHFNO    VSLOPE        EK        CK
     15.0        0.    0.0002      0.50      0.00

X-Y COORDINATE PAIRS  (NGP =  11):
      X      Y            X      Y            X      Y             X      Y
      0.0  491.02       0.0  489.07        0.2  486.13        13.2  486.18
     24.5  487.11      25.0  489.04       25.1  490.90        19.6  495.41
     12.9  497.14       4.9  495.18        0.0  491.02

 X-Y MAX-MIN POINTS:
     XMIN       Y          X    YMIN       XMAX        Y            X    YMAX
      0.0  491.02       0.2  486.13       25.1  490.90       12.9  497.14

ROUGHNESS COEFFICIENTS (NSA =  1):
        0.035

BRIDGE PARAMETERS:
 BRTYPE  BRWDTH     LSEL  USERCD  WWANGL  WWWID ENTRND
    1      43.6   497.50 *******    83.4    0.30 ******

PIER DATA:  NPW =  0     PPCD = **
1

*** START PROCESSING CROSS SECTION - "RDWAY"
  XR   RDWAY      18    35.0     1
  GR            0.0, 508.27    38.0, 499.95    63.4, 499.71    130.1, 499.34
  GR          231.5, 500.80   390.6, 505.40   476.1, 505.55
  *
```

```
   *
   *              SRD     LSEL    XSSKEW
   * BR   USBRG      0    *******      15.0
   * GR            -1.0, 489.32      0.0, 496.99      0.0, 489.11      2.6, 487.00
   * GR            11.2, 485.93     22.1, 485.83     24.2, 486.86     33.5, 489.11
   * GR            33.5, 496.99     -1.0, 489.32
   *
   *          BRTYPE  BRWDTH       WWANGL    WWWID
   * CD            1      43.6 * *      83.4      0.3
   * N           0.035
   *
   *            EXPECTED SRD =   35 AT ONE BR. LENGTH BUT COMPUTED SRD =  120
   *

 *** FINISH PROCESSING CROSS SECTION - "RDWAY"
 *** NO ROUGHNESS DATA INPUT, WILL PROPAGATE FROM PREVIOUS CROSS SECTION.
 *** CROSS SECTION "RDWAY" WRITTEN TO DISK, RECORD NO. =  6

 --- DATA SUMMARY FOR SECID "RDWAY" AT SRD =      18.  ERR-CODE =       0

      SKEW     IHFNO    VSLOPE       EK        CK
       0.0        0.    0.0002      0.50      0.00

 X-Y COORDINATE PAIRS  (NGP =   7):
        X       Y          X       Y          X       Y          X       Y
       0.0  508.27      38.0  499.95      63.4  499.71     130.1  499.34
     231.5  500.80     390.6  505.40     476.1  505.55

  X-Y MAX-MIN POINTS:
      XMIN       Y          X    YMIN      XMAX       Y          X    YMAX
       0.0  508.27     130.1  499.34     476.1  505.55       0.0  508.27

 SUBAREA BREAKPOINTS (NSA =  3):
          0.     45.

 ROUGHNESS COEFFICIENTS (NSA =  3):
        0.060   0.035   0.060

 ROAD GRADE DATA:  IPAVE  RDWID  USERCF
                      1.   35.0 *******

 BRIDGE PROJECTION DATA:  XREFLT  XREFRT  FDSTLT  FDSTRT
                         ******* ******* ******* *******
1

 *** START PROCESSING CROSS SECTION - "APPR1"
   AS   APPR1    120            0.
   GR          -43.1, 508.27    -23.9, 497.24    -14.7, 491.75      0.0, 489.24
   GR            6.5, 486.97     18.5, 486.22     26.8, 486.46     33.0, 486.91
   GR           39.0, 489.23     49.2, 496.89     66.6, 499.25
   *
   N           0.060         0.035         0.060
   SA                  0.0           39.0
   *
   * PX   DAMDS
   * PX   EXIT1
   * PX   FULLV
   * PX   BRIDG
   * PX   APPR1
   *
   HP 1 BRIDG  493.67   0.0  493.67

 *** FINISH PROCESSING CROSS SECTION - "APPR1"
 *** CROSS SECTION "APPR1" WRITTEN TO DISK, RECORD NO. =  7

 --- DATA SUMMARY FOR SECID "APPR1" AT SRD =     120.  ERR-CODE =       0
```

```
     SKEW     IHFNO    VSLOPE        EK        CK
      0.0        0.    0.0002      0.50      0.00

 X-Y COORDINATE PAIRS  (NGP =  11):
       X        Y          X       Y           X       Y           X       Y
    -43.1  508.27     -23.9  497.24      -14.7  491.75        0.0  489.24
      6.5  486.97      18.5  486.22       26.8  486.46       33.0  486.91
     39.0  489.23      49.2  496.89       66.6  499.25

  X-Y MAX-MIN POINTS:
     XMIN       Y          X    YMIN       XMAX       Y           X    YMAX
    -43.1  508.27      18.5  486.22       66.6  499.25      -43.1  508.27

 SUBAREA BREAKPOINTS (NSA =  3):
          0.     39.

 ROUGHNESS COEFFICIENTS (NSA =  3):
        0.060   0.035   0.060

 BRIDGE PROJECTION DATA:  XREFLT  XREFRT  FDSTLT  FDSTRT
                          ******* ******* ******* *******
1
    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      167    18222     18     41                         2883
   493.67           167    18222     18     41  1.00      0     25     2883

  HP 1 BRIDG  494.79   0.0  494.79

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      185    20602     15     44                         3654
   494.79           185    20602     15     44  1.00      0     25     3654

  HP 1 BRIDG  495.30   0.0  495.30

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      193    21412     14     46                         4086
   495.30           193    21412     14     46  1.00      0     25     4086

  HP 1 BRIDG  495.44   0.0  495.44

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      195    21495     13     47                         4270
   495.44           195    21495     13     47  1.00      0     25     4270

  HP 1 BRIDG  497.14   0.0  497.14

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      206    19905      0     60                            0
   497.14           206    19905      0     60  1.00      0     25        0
1
  *
  HP 1 APPR1  494.23   0.0  494.23

    CROSS-SECTION PROPERTIES:  ISEQ =  7;  SECID = APPR1;  SRD =     120.
```

```
    WSEL  SA#     AREA         K    TOPW    WETP  ALPH     LEW     REW       QCR
            1       60      3130      19      20                             608
            2      281     43892      39      40                            4272
            3       17       656       7       8                             149
  494.23           357     47678      65      68  1.28     -18      46      4225

 HP 1 APPR1  496.04   0.0  496.04

   CROSS-SECTION PROPERTIES:  ISEQ =  7;  SECID = APPR1;  SRD =     120.

    WSEL  SA#     AREA         K    TOPW    WETP  ALPH     LEW     REW       QCR
            1       97      6229      22      23                            1157
            2      351     63794      39      40                            5982
            3       31      1495       9      11                             323
  496.04           479     71518      70      74  1.34     -21      48      6149

 HP 1 APPR1  497.22   0.0  497.22

   CROSS-SECTION PROPERTIES:  ISEQ =  7;  SECID = APPR1;  SRD =     120.

    WSEL  SA#     AREA         K    TOPW    WETP  ALPH     LEW     REW       QCR
            1      124      8810      24      26                            1602
            2      397     78324      39      40                            7195
            3       43      2121      13      15                             448
  497.22           564     89255      75      81  1.38     -23      52      7435

 HP 1 APPR1  497.66   0.0  497.66

   CROSS-SECTION PROPERTIES:  ISEQ =  7;  SECID = APPR1;  SRD =     120.

    WSEL  SA#     AREA         K    TOPW    WETP  ALPH     LEW     REW       QCR
            1      135      9884      25      26                            1785
            2      414     84043      39      40                            7666
            3       49      2339      16      18                             490
  497.66           598     96266      80      85  1.41     -24      55      7841

 HP 1 APPR1  500.02   0.0  500.02

   CROSS-SECTION PROPERTIES:  ISEQ =  7;  SECID = APPR1;  SRD =     120.

    WSEL  SA#     AREA         K    TOPW    WETP  ALPH     LEW     REW       QCR
            1      198     16791      29      31                            2940
            2      506    117401      39      40                           10357
            3      105      5863      28      31                            1161
  500.02           809    140055      95     102  1.54     -28      67     10789
1
 *
 EX

+++ BEGINNING PROFILE CALCULATIONS --   6

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

DAMDS:XS   ******      0      110  1.10 *****  493.89  492.79     921  492.79
      -261 ******     50     7921  1.01 ***** *******    1.00    8.36

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                                  "EXIT2"     KRATIO =  6.94

EXIT2:XS        1    -11      387  0.10  0.00  493.89 *******     921  493.79
      -260      1     55    54996  1.13  0.00    0.00    0.19    2.38

EXIT1:XS      188    -11      393  0.10  0.05  493.94 *******     921  493.84
       -72    188     55    56492  1.20  0.00    0.00    0.19    2.34
```

```
FULLV:FV       73     -11       393  0.10  0.02  493.96 *******      921  493.86
        0      73      55     56597  1.20  0.00    0.00    0.19     2.34
        <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPR1:AS      120     -17       335  0.15  0.04  494.03 *******      921  493.88
      120     120      45     43573  1.26  0.02    0.00    0.24     2.75
        <<<<<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       73       0       167  0.51  0.06  494.18  489.99      921  493.67
        0      73      25     18217  1.07  0.17    0.00    0.33     5.52

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  0.966 ******  497.50 ****** ****** ******

    XSID:CODE     SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       18.        <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

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

APPR1:AS       76     -18       358  0.13  0.08  494.37  489.63      921  494.23
      120      79      46     47721  1.28  0.11    0.00    0.22     2.58

      M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     0.604  0.326   32155.     7.    32.   494.20

                        <<<<<END OF BRIDGE COMPUTATIONS>>>>>
1

  FIRST USER DEFINED TABLE.

    XSID:CODE     SRD     LEW     REW       Q        K      AREA      VEL    WSEL
   DAMDS:XS     -262.      0.     50.    921.    7921.      110.     8.36  492.79
   EXIT2:XS     -261.    -12.     55.    921.   54996.      387.     2.38  493.79
   EXIT1:XS      -73.    -12.     55.    921.   56492.      393.     2.34  493.84
   FULLV:FV        0.    -12.     55.    921.   56597.      393.     2.34  493.86
   BRIDG:BR        0.      0.     25.    921.   18217.      167.     5.52  493.67
   RDWAY:RG       18.**************       0.*****************     1.00*******
   APPR1:AS      120.    -19.     46.    921.   47721.      358.     2.58  494.23

    XSID:CODE    XLKQ    XRKQ        KQ
   APPR1:AS        7.     32.    32155.

 SECOND USER DEFINED TABLE.

    XSID:CODE     CRWS       FR#     YMIN     YMAX     HF     HO    VHD     EGL     WSEL
   DAMDS:XS     492.79      1.00   490.58   508.27***********   1.10   493.89   492.79
   EXIT2:XS   ********      0.19   485.15   502.88   0.00   0.00   0.10   493.89   493.79
   EXIT1:XS   ********      0.19   485.11   502.84   0.05   0.00   0.10   493.94   493.84
   FULLV:FV   ********      0.19   485.12   502.85   0.02   0.00   0.10   493.96   493.86
   BRIDG:BR     489.99      0.33   486.13   497.14   0.06   0.17   0.51   494.18   493.67
   RDWAY:RG   ****************   499.34   508.27*********************************
   APPR1:AS     489.63      0.22   486.22   508.27   0.08   0.11   0.13   494.37   494.23
1

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

DAMDS:XS   ******     -20       180  1.28 *****  495.28  493.73     1553  494.00
     -261 ******      60     16513  1.10 ***** *******    1.07     8.65
```

```
 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                                   "EXIT2"     KRATIO =  4.47

EXIT2:XS         1     -12      476  0.19  0.00  495.27 *******    1553  495.08
      -260       1      58    73886  1.17  0.00    0.00    0.24    3.27

EXIT1:XS       188     -12      484  0.20  0.08  495.36 *******    1553  495.16
       -72     188      58    75417  1.25  0.00    0.00    0.24    3.21

FULLV:FV        73     -12      486  0.20  0.03  495.40 *******    1553  495.20
         0      73      58    75754  1.25  0.00    0.00    0.24    3.20
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPR1:AS       120     -20      423  0.27  0.06  495.50 *******    1553  495.22
       120     120      47    60217  1.31  0.04    0.00    0.30    3.67
         <<<<<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        73       0      185  1.09  0.11  495.88  491.41    1553  494.79
         0      73      25    20608  1.00  0.41    0.00    0.42    8.37

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  497.50 ****** ****** ******

    XSID:CODE     SRD   FLEN    HF    VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       18.         <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

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

APPR1:AS        76     -21      479  0.22  0.13  496.26  490.75    1553  496.04
       120      79      48    71543  1.34  0.25    0.01    0.25    3.24

      M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     0.628  0.362   45611.     6.    31.  496.00

                          <<<<<END OF BRIDGE COMPUTATIONS>>>>>
1

  FIRST USER DEFINED TABLE.

    XSID:CODE     SRD    LEW     REW       Q        K       AREA      VEL    WSEL
   DAMDS:XS     -262.   -21.     60.   1553.   16513.      180.     8.65  494.00
   EXIT2:XS     -261.   -13.     58.   1553.   73886.      476.     3.27  495.08
   EXIT1:XS      -73.   -13.     58.   1553.   75417.      484.     3.21  495.16
   FULLV:FV        0.   -13.     58.   1553.   75754.      486.     3.20  495.20
   BRIDG:BR        0.     0.     25.   1553.   20608.      185.     8.37  494.79
   RDWAY:RG       18.**************       0.*****************     1.00********
   APPR1:AS      120.   -22.     48.   1553.   71543.      479.     3.24  496.04

    XSID:CODE    XLKQ   XRKQ        KQ
   APPR1:AS        6.    31.    45611.


  SECOND USER DEFINED TABLE.

    XSID:CODE     CRWS     FR#    YMIN    YMAX     HF     HO    VHD     EGL    WSEL
   DAMDS:XS     493.73    1.07  490.58  508.27************  1.28  495.28  494.00
   EXIT2:XS   ********    0.24  485.15  502.88  0.00   0.00   0.19  495.27  495.08
   EXIT1:XS   ********    0.24  485.11  502.84  0.08   0.00   0.20  495.36  495.16
```

```
   FULLV:FV   ********    0.24  485.12  502.85  0.03  0.00  0.20  495.40  495.20
   BRIDG:BR    491.41     0.42  486.13  497.14  0.11  0.41  1.09  495.88  494.79
   RDWAY:RG   ***************   499.34  508.27*********************************
   APPR1:AS    490.75     0.25  486.22  508.27  0.13  0.25  0.22  496.26  496.04
1

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

 DAMDS:XS   ******    -28      230  1.44 ***** 496.02  494.43    1989  494.58
      -261 ******      63    21871  1.23 ***** *******    1.08    8.66

  ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                                "EXIT2"     KRATIO =  3.87

 EXIT2:XS        1    -12      524  0.27  0.00  496.02 *******    1989  495.75
      -260       1     59    84689  1.19  0.00    0.00    0.27    3.80

 EXIT1:XS      188    -12      534  0.27  0.10  496.13 *******    1989  495.86
       -72     188     59    86310  1.27  0.00    0.00    0.27    3.73

 FULLV:FV       73    -12      536  0.27  0.04  496.18 *******    1989  495.90
         0      73     59    86829  1.27  0.00    0.01    0.27    3.71
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 APPR1:AS      120    -21      471  0.37  0.08  496.30 *******    1989  495.93
       120     120     48    69961  1.33  0.05    0.00    0.33    4.22
         <<<<<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       73      0      193  1.65  0.16  496.95  492.22    1989  495.30
         0      73     25    21409  1.00  0.66    0.00    0.66   10.31

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  497.50 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      18.        <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

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

 APPR1:AS       76    -23      564  0.27  0.16  497.49  491.41    1989  497.22
       120      79     52    89291  1.38  0.38    0.01    0.27    3.53

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.640  0.379   55380.     6.    31.   497.18

                       <<<<<END OF BRIDGE COMPUTATIONS>>>>>
1

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW        Q        K      AREA     VEL    WSEL
   DAMDS:XS    -262.   -29.    63.   1989.   21871.      230.    8.66  494.58
   EXIT2:XS    -261.   -13.    59.   1989.   84689.      524.    3.80  495.75
   EXIT1:XS     -73.   -13.    59.   1989.   86310.      534.    3.73  495.86
   FULLV:FV       0.   -13.    59.   1989.   86829.      536.    3.71  495.90
   BRIDG:BR       0.     0.    25.   1989.   21409.      193.   10.31  495.30
   RDWAY:RG      18.**************       0.*****************    1.00********
   APPR1:AS     120.   -24.    52.   1989.   89291.      564.    3.53  497.22
```

```
    XSID:CODE   XLKQ   XRKQ       KQ
   APPR1:AS       6.    31.   55380.

  SECOND USER DEFINED TABLE.

    XSID:CODE     CRWS      FR#    YMIN     YMAX     HF     HO   VHD       EGL     WSEL
   DAMDS:XS    494.43     1.08  490.58  508.27************  1.44  496.02  494.58
   EXIT2:XS  ********     0.27  485.15  502.88  0.00  0.00  0.27  496.02  495.75
   EXIT1:XS  ********     0.27  485.11  502.84  0.10  0.00  0.27  496.13  495.86
   FULLV:FV  ********     0.27  485.12  502.85  0.04  0.00  0.27  496.18  495.90
   BRIDG:BR    492.22     0.66  486.13  497.14  0.16  0.66  1.65  496.95  495.30
   RDWAY:RG ****************  499.34  508.27**********************************
   APPR1:AS    491.41     0.27  486.22  508.27  0.16  0.38  0.27  497.49  497.22
1

  ===015 WSI IN WRONG FLOW REGIME AT SECID "DAMDS":  USED WSI = CRWS.
                                  WSI,CRWS =    494.28      494.64

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

 DAMDS:XS    ******     -29       235   1.62  *****  496.26   494.64     2150   494.64
       -261  ******      64     22503   1.25  ***** *******     1.13     9.13

  ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                                  "EXIT2"      KRATIO =   3.92

 EXIT2:XS         1     -12       539   0.30   0.00  496.26  *******     2150   495.97
       -260       1      60     88248   1.19   0.00    0.00     0.28     3.99

 EXIT1:XS       188     -12       550   0.30   0.11  496.38  *******     2150   496.08
        -72     188      60     89922   1.28   0.00    0.00     0.28     3.91

 FULLV:FV        73     -12       552   0.30   0.04  496.43  *******     2150   496.13
          0      73      60     90513   1.28   0.00    0.01     0.28     3.89
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 APPR1:AS       120     -21       487   0.41   0.08  496.56  *******     2150   496.16
        120     120      48     73223   1.34   0.05    0.00     0.34     4.41
         <<<<<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        73       0       195   1.89   0.17  497.33   492.49     2150   495.44
          0      73      25     21495   1.00   0.78    0.00     0.70    11.04

     TYPE PPCD FLOW        C     P/A     LSEL    BLEN    XLAB    XRAB
       1. ****    1.  1.000 ******  497.50 ****** ****** ******

    XSID:CODE      SRD    FLEN     HF    VHD       EGL       ERR        Q    WSEL
   RDWAY:RG       18.          <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

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

 APPR1:AS        76     -24       598   0.28   0.18  497.95   491.66     2150   497.66
        120      79      55     96301   1.41   0.44    0.01     0.27     3.59

       M(G)    M(K)        KQ    XLKQ    XRKQ      OTEL
      0.643   0.384    59213.      6.     31.    497.62

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

```
1

   FIRST USER DEFINED TABLE.

     XSID:CODE    SRD    LEW    REW       Q        K      AREA      VEL    WSEL
    DAMDS:XS    -262.   -30.    64.   2150.   22503.     235.     9.13  494.64
    EXIT2:XS    -261.   -13.    60.   2150.   88248.     539.     3.99  495.97
    EXIT1:XS     -73.   -13.    60.   2150.   89922.     550.     3.91  496.08
    FULLV:FV      0.    -13.    60.   2150.   90513.     552.     3.89  496.13
    BRIDG:BR      0.     0.     25.   2150.   21495.     195.    11.04  495.44
    RDWAY:RG     18.**************      0.*****************      1.00********
    APPR1:AS     120.   -25.    55.   2150.   96301.     598.     3.59  497.66

     XSID:CODE   XLKQ   XRKQ      KQ
    APPR1:AS      6.     31.   59213.

  SECOND USER DEFINED TABLE.

     XSID:CODE    CRWS      FR#    YMIN     YMAX     HF     HO   VHD      EGL     WSEL
    DAMDS:XS    494.64     1.13  490.58  508.27************  1.62  496.26  494.64
    EXIT2:XS   ********    0.28  485.15  502.88  0.00   0.00  0.30  496.26  495.97
    EXIT1:XS   ********    0.28  485.11  502.84  0.11   0.00  0.30  496.38  496.08
    FULLV:FV   ********    0.28  485.12  502.85  0.04   0.00  0.30  496.43  496.13
    BRIDG:BR    492.49     0.70  486.13  497.14  0.17   0.78  1.89  497.33  495.44
    RDWAY:RG   ****************  499.34  508.27**********************************
    APPR1:AS    491.66     0.27  486.22  508.27  0.18   0.44  0.28  497.95  497.66
1

  ===015 WSI IN WRONG FLOW REGIME AT SECID "DAMDS":  USED WSI = CRWS.
                                 WSI,CRWS =   494.28     494.66

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

 DAMDS:XS    ******    -29      237   1.62 *****  496.28  494.66     2160  494.66
      -261 ******      64    22707   1.25 ***** *******    1.13     9.10

  ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                                 "EXIT2"     KRATIO =  3.90

 EXIT2:XS         1    -12      540   0.30   0.00  496.28 *******    2160  495.98
      -260        1     60    88470   1.19   0.00    0.00    0.28    4.00

 EXIT1:XS       188    -12      551   0.31   0.11  496.40 *******    2160  496.09
       -72      188     60    90147   1.28   0.00    0.00    0.28    3.92

 FULLV:FV        73    -12      553   0.30   0.04  496.45 *******    2160  496.14
         0       73     60    90744   1.28   0.00    0.01    0.28    3.90
           <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 APPR1:AS       120    -21      488   0.41   0.08  496.58 *******    2160  496.17
       120      120     48    73427   1.34   0.05    0.00    0.34    4.42
           <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

  ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
              WS3,WSIU,WS1,LSEL =    495.45     497.51     497.69     497.50

  ===245 ATTEMPTING FLOW CLASS 2 (5) SOLUTION.

               <<<<<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        73      0      206   1.50 *****  498.64  492.26     2019  497.14
```

```
        0 ******      25     19905  1.00 ***** *******     0.60     9.81

     TYPE PPCD FLOW        C     P/A     LSEL    BLEN    XLAB    XRAB
       1. ****   5.  0.473 ******  497.50 ****** ****** ******

    XSID:CODE     SRD    FLEN     HF    VHD       EGL       ERR        Q     WSEL
   RDWAY:RG       18.     85.   0.02   0.17  500.17      0.01     171.  500.02

             Q    WLEN     LEW     REW   DMAX   DAVG   VMAX   VAVG   HAVG   CAVG
   LT:      0. ****** ****** ****** ***** ***** ***** ***** ***** *****
   RT:    171.   140.     38.    178.    0.7    0.4    3.4    3.1    0.5    3.1

 ===140 AT SECID "APPR1":   END OF CROSS SECTION EXTENDED VERTICALLY.
                              WSEL,YLT,YRT =     500.02        508.3        499.3

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

 APPR1:AS        76     -28       809   0.17   0.12   500.19   491.66     2160   500.02
       120       79      67    140144   1.54   0.44     0.01     0.20     2.67

       M(G)    M(K)        KQ    XLKQ    XRKQ     OTEL
    ****** ****** ******** ****** ****** ********

                       <<<<<END OF BRIDGE COMPUTATIONS>>>>>
1

   FIRST USER DEFINED TABLE.

    XSID:CODE     SRD     LEW     REW        Q          K      AREA      VEL    WSEL
   DAMDS:XS     -262.    -30.     64.    2160.    22707.      237.     9.10  494.66
   EXIT2:XS     -261.    -13.     60.    2160.    88470.      540.     4.00  495.98
   EXIT1:XS      -73.    -13.     60.    2160.    90147.      551.     3.92  496.09
   FULLV:FV        0.    -13.     60.    2160.    90744.      553.     3.90  496.14
   BRIDG:BR        0.      0.     25.    2019.    19905.      206.     9.81  497.14
   RDWAY:RG       18.*******      0.     171.        0.*********     1.00  500.02
   APPR1:AS      120.    -29.     67.    2160.   140144.      809.     2.67  500.02

    XSID:CODE    XLKQ    XRKQ        KQ
   APPR1:AS    ***********************

  SECOND USER DEFINED TABLE.

    XSID:CODE     CRWS      FR#    YMIN     YMAX      HF      HO    VHD      EGL     WSEL
   DAMDS:XS     494.66     1.13  490.58   508.27************    1.62   496.28   494.66
   EXIT2:XS   ********     0.28  485.15   502.88    0.00    0.00    0.30   496.28   495.98
   EXIT1:XS   ********     0.28  485.11   502.84    0.11    0.00    0.31   496.40   496.09
   FULLV:FV   ********     0.28  485.12   502.85    0.04    0.00    0.30   496.45   496.14
   BRIDG:BR     492.26     0.60  486.13   497.14************    1.50   498.64   497.14
   RDWAY:RG   ****************  499.34   508.27    0.02******    0.17   500.17   500.02
   APPR1:AS     491.66     0.20  486.22   508.27    0.12    0.44    0.17   500.19   500.02
1

  ===015 WSI IN WRONG FLOW REGIME AT SECID "DAMDS":   USED WSI = CRWS.
                              WSI,CRWS =     494.28      496.11

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

 DAMDS:XS    ******     -34       388   2.02 *****   498.13   496.11     3628   496.11
      -261 ******        78     40463   1.48 ***** *******     1.08     9.36

  ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                              "EXIT2"     KRATIO =   2.88
```

```
EXIT2:XS         1     -12       656  0.59  0.00  498.13 *******     3628  497.54
      -260       1      63    116413  1.24  0.00    0.00    0.37     5.53

EXIT1:XS       188     -12       673  0.60  0.18  498.32 *******     3628  497.72
       -72     188      64    118783  1.32  0.01    0.01    0.37     5.39

FULLV:FV        73     -12       678  0.59  0.07  498.40 *******     3628  497.81
         0      73      64    120122  1.33  0.00    0.01    0.37     5.35
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPR1:AS       120     -24       613  0.77  0.13  498.62 *******     3628  497.85
       120     120      56     99366  1.42  0.09    0.00    0.45     5.92
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                        WS3N,LSEL =   497.81     497.50

 ===265 ROAD OVERFLOW APPEARS EXCESSIVE.
                   QRD,QRDMAX,RATIO =    1193.        818.    1.46

            <<<<<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        73       0       206  2.20 *****  499.34  493.00     2449  497.14
         0 ******       25     19905  1.00 ***** *******    0.73    11.89

     TYPE PPCD FLOW       C    P/A    LSEL    BLEN   XLAB   XRAB
       1. ****    6.  0.800 ******  497.50 ****** ****** ******

    XSID:CODE     SRD    FLEN    HF   VHD     EGL     ERR      Q    WSEL
   RDWAY:RG       18.     85.  0.04  0.39  501.42    0.00   1193.  501.08

              Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:       0. ****** ****** ****** ***** ***** ***** ***** ***** *****
   RT:   1193.   208.    33.   241.   1.7   1.2   5.7   4.9   1.5   3.1

===140 AT SECID "APPR1":  END OF CROSS SECTION EXTENDED VERTICALLY.
                                 WSEL,YLT,YRT =   501.08      508.3      499.3

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

APPR1:AS        76     -30       911  0.39  0.22  501.47  493.44     3628  501.08
       120      79      67    162951  1.57  0.44    0.00    0.29     3.98

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     ****** ****** ******** ****** ****** ********

                      <<<<<END OF BRIDGE COMPUTATIONS>>>>>
1

   FIRST USER DEFINED TABLE.

    XSID:CODE     SRD     LEW     REW       Q         K      AREA      VEL    WSEL
   DAMDS:XS     -262.    -35.     78.   3628.   40463.      388.     9.36  496.11
   EXIT2:XS     -261.    -13.     63.   3628.  116413.      656.     5.53  497.54
   EXIT1:XS      -73.    -13.     64.   3628.  118783.      673.     5.39  497.72
   FULLV:FV        0.    -13.     64.   3628.  120122.      678.     5.35  497.81
   BRIDG:BR        0.      0.     25.   2449.   19905.      206.    11.89  497.14
   RDWAY:RG       18.*******       0.   1193.        0.*********     1.00  501.08
   APPR1:AS      120.    -31.     67.   3628.  162951.      911.     3.98  501.08

    XSID:CODE   XLKQ   XRKQ       KQ
   APPR1:AS   ***********************
```

SECOND USER DEFINED TABLE.

XSID:CODE	CRWS	FR#	YMIN	YMAX	HF	HO	VHD	EGL	WSEL
DAMDS:XS	496.11	1.08	490.58	508.27	******	******	2.02	498.13	496.11
EXIT2:XS	********	0.37	485.15	502.88	0.00	0.00	0.59	498.13	497.54
EXIT1:XS	********	0.37	485.11	502.84	0.18	0.01	0.60	498.32	497.72
FULLV:FV	********	0.37	485.12	502.85	0.07	0.00	0.59	498.40	497.81
BRIDG:BR	493.00	0.73	486.13	497.14	******	******	2.20	499.34	497.14
RDWAY:RG	********	********	499.34	508.27	0.04	******	0.39	501.42	501.08
APPR1:AS	493.44	0.29	486.22	508.27	0.22	0.44	0.39	501.47	501.08

ER

NORMAL END OF WSPRO EXECUTION.