Summary of Level 1 and Level 2 Analyses of Bridge Scour at Selected Sites in the Carson River Basin, Nevada, 1995-96

By Rhea P. Williams, E. James Crompton, and Glenn S. Hale

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CONVERSION FACTORS,VERTICAL DATUM, AND ACRONYMS

Multiply	By	To obtain
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
foot (ft)	0.3048	meter
foot per foot (ft/ft)	1	meter per meter
foot per mile (ft/mi)	0.1894	meter per kilometer
mile (mi)	1.609	kilometer
square foot (ft^2)	0.0929	square meter
square mile (mi^2)	2.590	square kilometer

Temperature: Degrees Celsius (°C) can be converted to degrees Fahrenheit (°F) by using the formula °F = [1.8(°C)]+32. Degrees Fahrenheit can be converted to degrees Celsius by using the formula °C = 0.556(°F-32).

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929, formerly called "Sea-Level Datum of 1929"), which is derived from a general adjustment of the first-order leveling networks of the United States and Canada.

Acronyms used in this report:

FEMA	Federal Emergency Management Agency
FHWA	Federal Highway Administration
NDOT	Nevada Department of Transportation
USGS	U.S. Geological Survey
WSPRO	Water Surface PROfile computations

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Abstract

State-owned bridges in the Carson River Basin of Nevada were surveyed by the U.S. Geological Survey as part of a cooperative study with the Nevada Department of Transportation. Survey data were used to determine the potential and observed scour (Level 1 analysis) for 35 bridges. From the Level 1 analysis, 34 bridge sites were selected for further study. At these 34 sites, the estimated maximum scour depth (Level 2 analysis) was calculated using methods recommended by the Federal Highway Administration.

For the Level 2 analysis, magnitudes of the 100- and 500-year floods were determined from previously published reports or by flood frequencies computed from individual gaging-station records. Water-surface profiles were computed for the 100- and 500-year floods using the Water-Surface PROfile computation program. Results of that computation were used in scour equations as recommended by the Federal Highway Administration.

Computed scour depths for the bridge sites and selected data collected during field surveys are tabulated for the 34 bridge sites selected for Level 2 analyses.

On the basis of the Level 1 and Level 2 analyses a Federal Highway Administration Item-113 ranking was assigned to each bridge. The results indicate that 13 bridges are stable for the calculated scour (ranking value 5 or 8) and 21 bridges are unstable for the calculated scour (ranking value 2 or 3).

INTRODUCTION

In 1994, the U.S. Geological Survey (USGS) and the Nevada Department of Transportation (NDOT) entered into a cooperative agreement to determine the susceptibility to scour-related failure of State-owned highway bridges in the Nevada part of the Carson River Basin. The bridges were evaluated following standard Federal Highway Administration (FHWA) methods for *Evaluating Scour at Bridges* (Richardson and others, 1993) and for determining *Stream Stability at Highway Structures* (Lagasse and others, 1990), which are known as and referred to in this report as HEC-18 and HEC-20, respectively.

Scour, as defined by HEC-18 (Richardson and others, 1993, p. 7), "is the result of the erosive action of flowing water, excavating and carrying away material from the bed and banks of streams."

This study had two objectives. The first was a field reconnaissance, to collect data at selected bridge structures in the Carson River Basin, and to determine potential and observed scour. The second was to use field data with several methods to estimate maximum scour depths.

A complete scour evaluation consists of three parts identified as Level 1, Level 2, and Level 3. A Level 1 analysis is a qualitative geomorphic evaluation to assess the stream stability near a bridge and an examination of the bridge structure for susceptibility to and indications of scour. These analyses are then used as a screening mechanism to identify bridges requiring a more detailed level of analysis. The Level 2 analysis consists of additional field data collection, hydraulic modeling, and computation of the estimated depth of maximum potential scour resulting from a design flood. Level 3 consists of sediment transport modeling and a more detailed geomorphic evaluation. Level 3 was beyond the scope of the initial study reported herein.

Purpose and Scope

The purpose of this report is to present the methods used for the Level 1 and Level 2 scour analyses and the results obtained from these analyses. The report is limited in scope to Level 1 and Level 2 analyses of selected State-owned bridges in the Nevada part of the Carson River Basin.

Level 1 analyses were made at 35 State-owned bridge sites using the assessment methodology and ranking indices developed by the USGS for similar bridge studies in Colorado (Vaill and others, 1995), Indiana (Robinson and Thompson, 1995), and Texas (D.D. Dunn, U.S. Geological Survey, written commun., 1995). For the purposes of this study, where the river flows under a divided highway, the parallel bridges were considered a single bridge site.

On the basis of information obtained in the Level 1 analyses, the sites were rated for inclusion in the Level 2 field survey and evaluation. The Level 2 analysis was performed at 34 of the 35 bridge sites. The Level 2 assessment uses a quantitative method to assess bridge stability and scour analysis; this method is described in report HEC-18 (Richardson and others, 1993).

Study Area

The Carson River and its tributaries constitute a topographically closed river system in the Great Basin Region (Moosburner, 1986). The Carson River Basin is a major hydrographic feature in eastern California and western Nevada (fig. 1).The study area includes five hydrographic areas[1]: Carson Valley, Eagle Valley, Dayton Valley, Churchill Valley, and Carson Desert.

The East Fork and West Fork Carson River originate in the Sierra Nevada south of Lake Tahoe in Alpine County, Calif. These rivers flow out of California and into Nevada, going northward through Carson Valley, Douglas County, where the two forks join to form the main stem. Continuing northward, the river flows through Carson City, then turns east as it enters Lyon County upstream from Dayton Valley. The river continues in an eastward direction and flows into Lahontan Reservoir in Lyon and Churchill Counties. The river terminates at Carson Sink northeast of Fallon. The total extent of the river, from headwaters to sink, is more than 125 mi.

The Carson River Basin has been divided into five segments to aid in describing the geomorphic character: upstream from Carson Valley, Carson Valley to Carson City, Carson City to Dayton Valley, Dayton Valley to Lahontan Reservoir, and downstream from Lahontan Reservoir. In general, the Carson River system has few or no natural levees, both forks and the main stem are not braided, the stream size of the forks is small (less than 100 ft wide), the stream size of the main stem is medium (between 100 ft and 500 ft wide), and the streamflow is characterized as perennial but flashy.

Both forks originate at an altitude of more than 7,500 ft above sea level and descend to Carson Valley. Upstream from the Carson Valley, the geomorphic characteristics are as follows:

- Valley relief is moderate to high.
- Bed material is gravel to boulder.
- Flood plain is little to none.
- Channel is straight to slightly sinuous, with random variation of bars.
- Slope averages 50 ft/mi.

Small quantities of water are diverted from the river upstream from the Carson Valley.

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[1] Formal hydrographic areas in Nevada were delineated systematically by the U.S. Geological Survey and Nevada Division of Water Resources in the 1960's (Rush, 1968; Cardinalli and others, 1968) for scientific and administrative purposes. The official hydrographic-area names, numbers and geographic boundaries continue to be used in Geological Survey scientific reports and Division of Water Resources administrative activities.

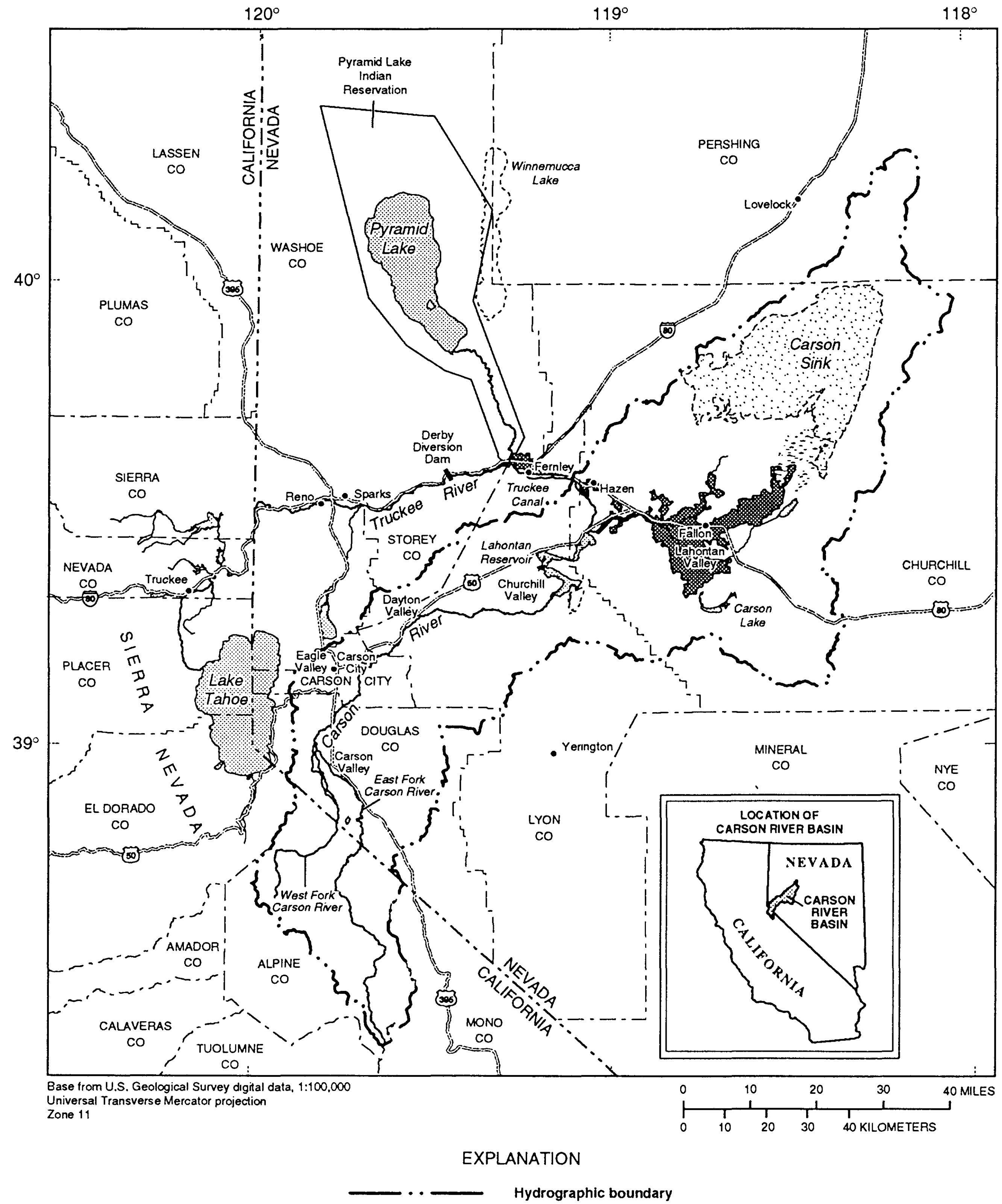

Figure 1. Hydrologic features of Carson River Basin and adjacent areas, eastern California and western Nevada.

The floor of Carson Valley ranges in altitude from 5,000 to 4,600 ft at a gentle north-trending slope. From Carson Valley to Carson City, the geomorphic characteristics are as follows:

- Valley relief is low.
- Bed material is sand to gravel.
- Flood plain is wide.
- Channel is sinuous to meandering, wider at bends, with wide point bars.
- Slope averages 15 ft/mi.

Water in both forks and the main stem is extensively diverted for the flood irrigation of pasture lands and forage crops in this segment.

From Carson City to Dayton Valley, the altitude descends from about 4,600 to 4,400 ft. The geomorphic characteristics are as follows:

- Valley relief is high.
- Bed material is sand to gravel.
- Flood plain is little to none.
- Channel varies from straight to sinuous, with a random variation of bars.
- Slope averages 50 ft/mi.

No water is diverted through this reach.

The Carson River enters Dayton Valley at an altitude of about 4,400 ft, and descends to Lahontan Reservoir at 4,200 ft. The geomorphic characteristics are as follows:

- Valley relief is low.
- Bed material is sand to gravel.
- Flood plain is wide.
- Channel varies from sinuous to meandering, wider at the bends, with wide point bars developing.
- Slope averages 10 ft/mi.

In eastern Lyon County and western Churchill County, lacustrine deposits in the vicinity of Lahontan Reservoir were formed during the Pleistocene age as the Carson River emptied into the prehistoric Lake Lahontan (Houghton, 1976). In this segment, numerous diversions of water are used for irrigation.

Below Lahontan Reservoir, the river continues to its terminus at Carson Sink at an altitude of 4,000 feet. The geomorphic characteristics are as follows:

- Valley relief is low.
- Bed material ranges from silt to gravel.
- Flood plain is wide.
- Channel varies from sinuous to meandering, with the formation of irregular point and lateral bars.
- Slope averages 5 ft/mi.

In this segment, the river is extensively diverted for the flood irrigation of pasture lands and forage crops.

METHODS OF BRIDGE-SCOUR ANALYSES

The Level 1 and Level 2 assessments are described. Level 1 includes the field assessment of the bridge site using qualitative methods to determine potential and observed scour. Level 2 includes surveying the bridge site and quantitative methods for computing the amount of scour for a given discharge. The location of all bridge sites analyzed for Level 1 or Level 2 scour is shown on plate 1.

Level 1

The Level 1 assessment was designed to produce a qualitative index describing the potential for problems resulting from localized scour and general stream instability at a bridge site. Information from the "scour and channel-instability assessment" form was used to determine the ranking value of bridge scour by assessing potential and observed scour. Photographs were taken to provide additional documentation for review.

The "scour and channel-instability assessment" form used for this study was developed by Robinson and Thompson (1993); a blank version of the form is in the Appendix. The data recorded on this form provide insight into the general stability of the stream reach where the bridge is located, including descriptions of bed material, the location of meanders, and the size of scour holes. Another part of the form requests specific information regarding structural components of the bridge that can affect scour, including the number and shape of the piers, the condition of rip-rap, and the angle of the bridge to the stream.

Briefly, two methods of assessing potential scour (channel and bridge characteristics that affect scour) and two methods of assessing observed scour (presence and extent of scour at or near the bridge) were used for the Level 1 assessment. Potential scour was determined using methods developed in Texas and Colorado; both of these methods are based on the work done in Tennessee by Andrew Simon (Simon and others, 1989). Observed scour was determined using methods developed in Texas and Indiana. All four methods are described below.

Potential Scour

A method of determining potential scour at bridge sites in Texas was developed by D.D. Dunn (U.S. Geological Survey, written commun., 1995). This method assigns ranking values to 13 variables. The ranking values are then summed to compute the potential-scour index for each bridge. The total can range from 0 (no scour conditions) to 34 (high scour conditions); the value could be higher if the bridge has piers. The ranking values and index are included on a form in the appendix labeled "Texas Potential Scour." The ranking values assigned to each variable were not weighted for relative importance; however, a decision could be made that certain variables are more critical and higher weights could be assigned.

Sites with a potential-scour index greater than 20 may be considered as having substantial potential for scour problems (D.D. Dunn, U.S. Geological Survey, written commun., 1995).

A method for determining potential scour, for use on bridges in Colorado, was developed by J.E. Vaill (U.S. Geological Survey, written commun., 1994). This method assigns ranking values to 18 variables. The ranking values are then summed to compute the potential-scour index for each bridge. The total can range from 0 (no scour conditions) to 41 (high scour conditions) for a bridge with no piers, with 1 point added for each pier. The ranking values and index are included on a form in the appendix labeled "Colorado Potential Scour."

Observed Scour

The susceptibility of a bridge to scour can be inferred by observed scour. A method of assessing observed scour at bridge sites in Texas was developed by D.D. Dunn (U.S. Geological Survey, written commun., 1995). This method assigns ranking values to six variables. The ranking values are then summed to compute the observed-scour index for each bridge.

Values for a variable are assigned when scour is observed. Values pertaining to scour at piers and abutments are assigned according to the severity of the scour (qualitatively by the inspector). Values are summed for both abutments and for up to nine piers. The summed value can range from 0 (low scour conditions) to 11 (high scour conditions) for a bridge with no piers or bents, to a maximum of 38 if the bridge had 9 piers or bents. The ranking values and index are included on a form in the appendix labeled "Texas Observed Scour."

Another ranking method for assessing observed scour was developed by Robinson and Thompson (1995) for use on bridges in southwestern Indiana. This index ranges from 10 (no observed-streambed scour) to 0 (pier(s) with pile(s) exposed) and is included on a form in the appendix labeled "Indiana Observed Scour." The upper end of the scale (ranking values 10 or 9) indicates those bridges with a low priority for further investigation; the lower end of the scale (ranking values 5 to 0) indicates those bridges with a high priority for further investigation.

Level 2

The Level 2 assessment uses a quantitative method to assess bridge stability. This method is well described in the report HEC-18 (Richardson and others, 1993). Scour analysis requires evaluation of the hydraulic factors that characterize streamflow and channel conditions at the bridge. This was done by surveying each bridge site.

Hydraulic factors were determined from computation of the water-surface profile for a given flood magnitude under the bridge by including the channel-geometry and bridge-shape information. The water-surface profile under the bridge is a result of gradually differing flow characteristics over long distances and rapidly differing flow at constrictions caused by abutments, and piers under the bridge.

To rank the vulnerability of the bridge to scour on the basis of Level 2 analysis, the Federal Highway Administration (1989, p. 74) has developed a form (Item 113). This form is based on scour calculations, analyses, and field inspections. Bridges are ranked on an 11-point scale that ranges from "the bridge not over the waterway" (N) to "the bridge has failed and is closed to traffic" (0). This form is shown in the Appendix as "Item 113."

Site Survey

Data on channel cross-section geometry and related bridge geometry were collected using laser surveying equipment and following standard field-survey techniques (Benson and Dalrymple, 1967). Reference points were established and an arbitrary datum assigned. Datums were determined from topographic maps, or benchmarks. Existing reference marks on the bridges were included in these surveys. Land-surface altitudes and pertinent bridge-point altitudes were noted in a permanent datalog record. Horizontal control was established by setting the initial azimuth of the surveying instrument to approximate true north. Elevation checks were made during the site survey to maintain the vertical datum and horizontal control.

Where possible, at least four cross sections were surveyed at each bridge site. Surveyed cross sections were one bridge width upstream from the bridge (approach section), along the road crossing (road section), at the downstream side from the bridge (bridge section), and one bridge width downstream from the bridge (exit section). Additional cross sections were surveyed downstream from the exit section if substantial changes were observed in channel geometry or bed slope through the stream reach or if the channel was wadable. At sites where dense vegetation or deep channels prohibited surveys of all cross sections, a representative cross section was surveyed and field observations made of the channel geometry through the stream reach. Where the channel was not wadable, depth soundings were made from the upstream and downstream sides of the bridge.

Channel-roughness coefficients were assigned to each cross section on the basis of experience of the inspector and guidelines (Chow, 1959; Barnes, 1967). Values of D_{50} (median particle diameter) for the bed material were determined by visual estimates, by estimated particle counts (Wolman, 1954), or from a previous study (Katzer and Bennett, 1980).

Bridge-geometry features that were surveyed included abutment corners (to define orientation of the bridge to flow), wingwall ends (to determine the angle from the road embankment), pier centerlines (to measure pier skew to the flow), low-steel (chord) altitudes, roadway embankment widths, roadway embankment slopes, and road centerline altitudes. Some of the data collected during the field surveys and general information about the sites are listed in table 1.

Scour Computations

To compute the amount of scour at a bridge site, the quantity of water for the design floods at each bridge site was determined first. These values were then used through the channel reach to determine the water profile and the channel and bridge hydraulics. The hydraulic and channel characteristics were then used to compute the amount of scour.

The 100-year flood (which has an exceedance probability of 0.01) and the 500-year flood (which has an exceedance probability of 0.002) were selected as the design floods for this scour analysis.

Table 1. General information on bridge sites evaluated for this study

[Abbreviations: CC, Carson City; CH, Churchill County; DO, Douglas County; FEMA, Federal Emergency Management Agency; LY, Lyon County; NA, data not available; NDOT, Nevada Department of Transportation; USGS, U.S. Geological Survey.]

NDOT bridge number	Latitude (degrees, minutes, and seconds)	Longitude (degrees, minutes, and seconds)	USGS 7.5-minute topographic map name	FEMA floodway map (County name and panel number)	NDOT contract numbers for bridge construction, or year constructed in parentheses	Altitude (feet above sea level)		
						Bridge deck, USGS survey	Road, NDOT bridge plans	Low steel, field survey
B161	38 53 36.5	119 41 57.5	Gardnerville	DO-105	171, 618, 1332	4,896.34	4,896.54	4,895.25
B333	39 17 36.3	119 15 02.6	Churchill	LY-200	520, 1184, 2193	4,185.76	4,208.91	4,181.48
B464	39 28 57.8	118 52 29.1	Fallon	CH-645	662, 2117	3,993.05	3,993.56	3,988.65
B474	38 58 15.9	119 49 51.4	Minden	DO-85	679	4,675.52	4,680.00	4,673.80
B475	38 58 15.4	119 48 59.6	Minden	DO-85	679	4,679.20	4,683.74	4,677.09
B476	38 58 15.6	119 48 44.5	Minden	DO-85	679	4,682.00	4,688.78	4,680.1
B477	38 58 15.3	119 47 54.0	Minden	DO-85	679	4,687.68	4,691.97	4,685.38
B547	39 30 41.6	118 44 36.7	Indian Lakes	CH-665	797	3,953.16	3,944.52	3,951.07
B553	38 56 46.7	119 46 42.3	Minden	DO-85	792, 997, 2490	4,713.06	4,715.32	4,711.26
B575	38 57 07.6	119 46 41.9	Minden	DO-85	846, 997, 2490	4,710.78	4,709.46	4,708.79
B576	38 53 21.0	119 46 41.4	Minden	DO-95	846, 997, 2490	4,740.51	4,743.62	4,738.34
B580	38 56 36.3	119 46 42.5	Minden	DO-85	874, 997, 2490	4,713.61	4,716.00	4,711.69
B627	38 54 42.2	119 46 41.7	Minden	DO-105	997, 2490	4,723.52	4,723.00	4,721.65
B629	39 28 43.2	118 50 57.9	Fallon	CH-645	957	3,983.64	3,985.48	3,981.52
B637	39 14 14.2	119 35 11.3	Dayton	LY-143	968, 1410, 2397	4,302.78	4,358.69	4,298.16
B638	38 55 49.0	119 44 46.2	Gardnerville	DO-105	972	4,765.50	4,769.89	4,760.48
B677	39 29 37.0	118 46 16.5	Fallon	CH-665	2169	3,961.63	3,961.50	3,957.50
B1238	38 59 51.5	119 49 16.6	Minden	DO-20	1252	4,670.56	4,670	4,668.98
B1239	38 59 52.9	119 49 21.9	Minden	DO-20	1252	4,670.55	4,670	4,669.10
B1240	38 59 55.8	119 49 33.0	Minden	DO-20	1252	4,667.82	4,671.00	4,666.42
B1241	39 00 00.9	119 49 52.7	Genoa	DO-20	1252	4,676.76	4,671.20	4,675.35
B1262	39 02 51.9	119 46 43.8	Genoa	DO-10	1283, 2135	4,655.43	4,656.50	4,653.25
B1263	39 02 57.3	119 46 43.9	Genoa	DO-10	1283, 2135	4,655.4	4,656.50	4,653.3
B1274	39 10 50.3	119 41 44.3	New Empire	CC-45	1315	4,607.85	4,609.26	4,605.48
B1328	39 08 31.2	119 42 14.9	New Empire	CC-130	2348	4,612.22	4,612.17	4,611.19
B1330	38 55 56.0	119 48 22.8	Minden	DO-95	(1957)	4,700.4	4,700	4,698.69
B1491	38 55 56.2	119 49 14.3	Minden	DO-95	1583	4,700.48	4,700	4,698.34
B1492	38 55 56.0	119 47 55.5	Minden	DO-95	1583	4,703.04	4,702	4,700.91
B1557	39 28 48.6	118 48 50.4	Fallon	CH-645	1834	3,976.27	3,976	3,971.71
B1581	39 33 30.8	118 43 32.8	Indian Lakes	CH-675	(1973)	3,927.57	3,927	3,924.35
B1600	38 52 01.1	119 45 34.8	Woodfords	DO-85	(1951)	4,797.77	4,796	4,795.48
B1601	38 54 38.1	119 47 59.6	Minden	DO-115	(1936)	4,700.4	4,710	4,698.7
B1603	38 54 52.9	119 42 59.7	Gardnerville	DO-115	1887 (1982)	4,825.90	4,830.87	4,821.56
B1694	39 10 33.1	119 41 17.4	New Empire	CC-45	(1940)	4,603.42	NA	4,599.39
B1715	39 27 49.9	119 03 16.4	Lahontan	CH-625	(1980)	4,081	NA	NA

Magnitudes of the 100- and 500-year floods at the bridge sites were determined from gaged streamflow data, if available. If not, one of the following three methods was used to determine the 100-year flood. At ungaged sites near either a fork or the main stem, a budget calculation was made where the discharge of the nearby channel was known. Where bridges were located on ungaged sites that originated from principal gaged streams, the flood was limited to the amount that topped the road; this value was usually less than the 100-year flood. Where previous FEMA studies existed, their flood values were used. The 500-year flood was determined at ungaged sites by multiplying the 100-year flood by 1.7 as described by HEC-18 (Richardson and others, 1993). Computed values of the 100- and 500-year floods, and the method used to compute these values, are listed in table 3.

Water-surface profiles for the 100- and 500-year flood discharges were computed using WSPRO, a model for Water-Surface PROfile computations (Shearman, 1990) that uses the field-surveyed data. Stream-channel geometry was input from computer-derived plots and information from the field surveys and notes.

The profile computations used by WSPRO for open-channel flow are equivalent and comparable with other conventional techniques used in existing step-backwater models. Profile computations for free-surface flow through bridges are based on relatively recent developments in bridge-backwater analysis and recognize the effects of bridge-geometry variations.

When computed water-surface altitudes were higher than the surveyed cross-section endpoints, the cross sections were extended on the basis of field observations of channel geometry, extension of slope from the survey, or data from topographic maps. Field-selected roughness coefficients were used in the initial computations. Roughness coefficients were weighted on the basis of observed vegetation and channel change. A single roughness-coefficient value was used for the section when the cross-section shape indicated subdivision was unnecessary. Unwarranted subdivision of a cross section does affect accuracy of the hydraulic terms in the computations.

Bridge type was assigned as one of four as defined by WSPRO documentation (Sherman and others, 1985). Effects of piers and bridge geometry on hydraulic properties in the bridge section were included in the computations. Cross-sectional flow properties for the specified water-surface altitude and the associated streamflow used in the scour analysis were generated by WSPRO.

Data from the water-surface profiles determined by WSPRO were used with the scour equations described in HEC-18 (Richardson and others, 1993) and recommended by FHWA.

BRIDGE-SCOUR ANALYSES

This report summarizes the potential- and observed-scour rankings applied to the 35 bridge sites in the Carson River Basin of Nevada and the determination of scour at the 34 bridge sites analyzed during 1995-96. The results of the Level 1 analyses indicated that no further analysis was needed for bridge B1715.

Level 1 and Level 2 Rankings

Rankings of potential and observed scour for the 35 bridge sites are summarized in table 2. As a comparison, the values determined from Item 113, which uses the results from the Level 2 analysis, also are included in table 2.

The potential- and observed-scour indices may not agree at a given site, because the potential-scour index indicates problems from channel instability in the reach as well as from local scour. The observed-scour indices can be used to identify bridges with immediate scour problems and can provide additional insight into potential for scour at a site. Potential channel changes, except for mass wasting of a bank, usually are not apparent in the field observations and are not considered in the observed-scour index.

As shown in table 2, indices were consistently greater for potential scour than for observed scour. The observed- and potential-scour indices are not comparable values and should not be compared directly. No theoretical relation nor correlation is implied between the two types of indices.

Table 2. Values of the potential- and observed-scour indices and bridge vulnerability from Level 2 analyses

[Abbreviation: NDOT, Nevada Department of Transportation]

NDOT bridge number	Texas potential scour (high 34, low 0)[a]	Colorado potential scour (high 41, low 0)[a]	Texas observed scour (high 11, low 0)[a]	Indiana observed scour (high 0, low 10)	Item 113 (high 0, low 9)
B161	7	17	0	10	8
B333	16	24	2	7	3
B464	11	11	0	9	5
B474	7	14	1	7	5
B475	15	20	7	6	3
B476	14	18	3	8	3
B477	17	19	10	1	3
B547	19	22	0	10	5
B553	16	26	4	6	3
B575	14	21	2	7	3
B576	12	15	9	1	3
B580	16	16	1	6	3
B627	13	17	4	7	3
B629	15	17	6	7	3
B637	7	11	4	6	5
B638	14	18	1	10	5
B677	10	11	1	10	8
B1238	10	18	1	7	3
B1239	15	17	3	7	3
B1240	15	11	1	7	3
B1241	13	16	1	7	3
B1262	20	28	13	1	3
B1263	9	17	0	9	3
B1274	20	26	6	1	3
B1328	10	11	2	7	5
B1330	10	14	1	10	8
B1491	15	17	0	9	3
B1492	14	18	0	10	5
B1557	16	27	0	10	3
B1581	10	19	0	10	8
B1600	11	15	3	8	5
B1601	13	22	0	10	5
B1603	12	13	4	5	3
B1694	14	24	5	6	2
B1715	5	4	4	9	5

[a] High values could be larger if bridge has piers.

Other information is entered into the "scour and channel-instability assessment" form that is not directly included in each calculation of the potential- and observed-scour indices. Some information not included are point bars, impact points, surface vegetation, or features more than 100 ft upstream or downstream from the bridge. This additional information should be used in conjunction with the potential- and observed-scour indices when assessing the scour susceptibility of a bridge.

The observed-scour index describes only scour apparent to the inspector. This scour may or may not affect the structural stability of a bridge. An observation of localized scour near a pier will result in a high observed-scour index whether or not general channel degradation has occurred. The observed-scour index should supplement the potential-scour index as an aid in identifying bridges in need of more detailed analysis.

Depth and Type of Scour

Depth of scour was estimated using the recommended equations from report HEC-18 (Richardson and others, 1993) for contraction, pier, and abutment scour (table 3). Variables used in the scour equations were determined using options in WSPRO to generate velocity-area distributions for 20 streamtubes in the bridge section. Streamtubes are imaginary tubes bounded by streamlines. Each streamtube carries an equal discharge because the discharge between streamlines is constant.

The velocity and areal distributions were computed using a specified water-surface altitude and specified discharge. The specified water-surface altitude is a close approximation of the water-surface altitude at the upstream bridge opening. The sites were analyzed using the computed water-surface altitude at the bridge opening at a specific discharge.

Velocity and area distributions were computed for the 100- and 500-year floods unless road overflow or pressure flow was indicated by initial WSPRO computations. Pressure flow occurs when the bridge deck intersects the flow and just begins to be submerged.

When road overflow or pressure flow was indicated, scour may have been estimated for a discharge less than the 100- or 500-year flood. That discharge was determined by incrementally increasing the discharge flowing under the bridge until a change in flow type from free surface to pressure flow was noted in the WSPRO output. The maximum discharge that could be routed under the bridge was used to generate the velocity and areal distributions for scour analysis; therefore, all scour computations were for free-surface flow conditions; WSPRO does not consider debris as part of the flow or its build up on the bridge. The water-surface altitude at the upstream bridge opening was computed using the maximum discharge and the corresponding water-surface altitudes. The discharge used for each site is included in table 3.

General scour is a lowering of the base altitude of the streambed due to overall degradation effects on the river (HEC-20; Lagasse and others, 1990, p. xvii). General scour was determined by visual observation. During periods of low streamflow, the channel may be only a few feet wide, but evidence of general scour is visible. Some of the conditions used to determine general scour were channel lowering (cutting) below bank roots, below coarser deposits, and below old piers.

"Live-bed scour occurs when the bed material upstream of the crossing is moving" (HEC-18; Richardson and others, 1993, p. 16). "Live-bed contraction scour typically occurs during the rising stage of a runoff event" (HEC-18; Richardson and others, 1993, p. 6). Contraction scour was computed using Laursen's equation for long contractions (HEC-18; Richardson and others, 1993, p. 33). This equation estimates the depth of scour in the contracted section (commonly the bridge section). Bed material is assumed to be transported in the main channel but not in the overbank zones. Discharge at most sites was at main channel capacity (not yet floodplain and prior to pressure flow), thus bedload transport was considered active across the section and at live-bed conditions.

Table 3. Computed discharge, water-surface altitude, and scour depths used for selected bridge sites in Carson River Basin

[Abbreviations: B, budget calculation; F, Multiplication factor of 1.7; FEMA, Federal Emergency Management Agency; NA, not applicable; NDOT, Nevada Department of Transportation; Q, discharge; S, streamflow data. Negative scour values indicate fill]

NDOT bridge number	Q100 (cubic feet per second)	Q500 (cubic feet per second)	Methods used to determine Q100 and Q500	Discharge used (cubic feet per second)	Water-surface altitude at bridge (feet above sea level)	Computed scour depth (feet)					
						General scour	Live-bed contraction	Left abutment	Right abutment	Pier scour	Total scour
B161	overbank		B	[a]270	4,895.25	0.0	3.0	6.6	2.0	NA	3.0
		overbank	B	do.	do.	do.	do.	do.	do.	do.	do.
B333	13,600		S	13,600	4,178.43	3.8	-0.5	37.1	9.2	23.3	27.1
		21,500	S	[a]16,700	4,179.40	do.	2.1	41.7	10.0	25.8	31.7
B464	3,600		FEMA	3,600	3,986.73	-1.0	0.1	9.8	7.7	NA	0.1
		15,500	FEMA	[a]6,900	3,988.60	do.	0.9	14.5	9.9	NA	0.9
B474	5,580		B	[a]2,390	4,673.72	1.0	0.8	10.8	6.9	11.4	13.2
		9,500	F	[b]3,200	4,673.80	do.	-0.8	11.8	7.6	11.7	12.7
B475	5,040		B	[b]2,500	4,674.90	0.5	5.0	7.0	6.9	14.7	20.2
		8,570	F	do.	do.	do.	do.	do.	do.	do.	do.
B476	3,240		B	[a]1,420	4,679.61	2.0	0.4	7.2	6.1	15.8	18.2
		5,510	F	[b]1,680	4,680.10	do.	1.8	8.0	6.6	14.8	18.6
B477	18,900		S, B	[a]12,800	4,685.31	3.0	0.9	9.5	15.2	17.1	21.0
		33,800	S, B	[b]16,500	4,685.38	do.	1.7	10.4	16.7	16.8	21.5
B547	3,100		FEMA	[a]530	3,951.05	-1.0	0.4	5.9	5.2	8.0	8.4
		10,500	FEMA	[b]940	3,951.07	do.	1.5	7.7	6.3	10.0	11.5
B553	21,900		FEMA	[a]9,950	4,707.24	3.0	9.1	12.7	13.4	30.0	42.1
		37,200	B	do.	do.	do.	do.	do.	do.	do.	do.
B575	7,300		B	[a]3,200	4,708.11	2.0	5.6	8.1	11.3	12.0	19.6
		12,400	F	do.	4,708.79	do.	do.	do.	do.	do.	do.
B576	9,700		FEMA	[a]4,230	4,736.09	0.0	3.2	13.5	7.9	16.4	19.6
		16,500	F	do.	do.	do.	do.	do.	do.	do.	do.
B580	4,600		B	[a]2,020	4,710.55	1.0	13.8	10.8	10.0	15.0	29.8
		7,820	F	do.	do.	do.	do.	do.	do.	do.	do.
B627	3,000		FEMA	[a]3,300	4,720.99	1.0	21.7	11.0	16.5	15.8	38.5
		5,100	F	do.	do.	do.	do.	do.	do.	do.	do.
B629	3,600		FEMA	3,600	3,978.16	-1.0	-1.8	12.6	4.8	15.2	15.2
		15,500	FEMA	[b]4,900	3,978.98	do.	-4.2	16.3	5.5	17.4	17.4
B637	36,000		FEMA	[a]34,600	4,296.02	1.5	1.3	46.3	30.2	17.0	19.8
		97,200	FEMA	do.	do.	do.	do.	do.	do.	do.	do.
B638	15,900		S	14,800	4,760.40	2.0	0.0	16.0	21.0	17.2	19.2
		27,200	S	do.	do.	do.	do.	do.	do.	do.	do.
B677	3,100		FEMA	3,100	3,956.69	-1.0	1.8	7.8	7.0	NA	1.8
		10,500	FEMA	[a]5,000	3,957.66	do.	6.6	8.4	8.7	NA	6.6
B1238	7,890		B	[a]3,150	4,668.14	2.0	11.0	14.8	7.5	11.5	24.5
		13,400	F	do.	do.	do.	do.	do.	do.	do.	do.

Table 3. Computed discharge, water-surface altitude, and scour depths used for selected bridge sites in Carson River Basin—Continued

NDOT bridge number	Q100 (cubic feet per second)	Q500 (cubic feet per second)	Methods used to determine Q100 and Q500	Discharge used (cubic feet per second)	Water-surface altitude at bridge (feet above sea level)	Computed scour depth (feet)					
						General scour	Live-bed contraction	Left abutment	Right abutment	Pier scour	Total scour
B1239	19,300		B	[a]7,700	4,667.18	1.0	8.4	20.2	16.4	9.9	19.3
		32,800	F	do.	do.	do.	do.	do.	do.	do.	do.
B1240	3,500		B	[a]1,330	4,666.29	2.0	6.2	10.8	8.0	7.8	16.0
		5,900	F	do.	do.	do.	do.	do.	do.	do.	do.
B1241	5,300		B	[a]2,020	4,674.63	2.0	2.2	11.0	12.9	9.4	13.6
		9,000	F	do.	do.	do.	do.	do.	do.	do.	do.
B1262	36,000		FEMA	[a]21,400	4,650.47	3.0	12.0	25.6	8.8	20.2	35.2
		57,500	S	do.	do.	do.	do.	do.	do.	do.	do.
B1263	4,600		B	[a]3,100	4,652.40	1.0	16.0	8.3	7.0	15.5	32.5
		7,800	F	do.	do.	do.	do.	do.	do.	do.	do.
B1274	36,000		FEMA	36,000	4,594.92	2.0	5.5	22.1	22.4	23.0	30.5
		57,500	S	57,500	4,598.44	do.	8.6	30.8	30.0	26.6	37.2
B1328	36,000		FEMA	[b]35,500	4,601.08	1.0	6.6	26.2	16.0	14.9	22.5
		90,400	FEMA	do.	do.	do.	do.	do.	do.	do.	do.
B1330	4,900		B	[a]1,960	4,698.53	0.0	-.1	10.3	12.3	NA	0
		8,300	F	do.	do.	do.	do.	do.	do.	do.	do.
B1491	5,800		B	[a,b]2,330	4,697.33	1.0	8.6	12.6	12.8	NA	9.6
		9,900	F	do.	do.	do.	do.	do.	do.	do.	do.
B1492	2,000		B	800	4,700.64	0.5	1.7	6.6	5.4	NA	2.2
		3,400	F	do.	do.	do.	do.	do.	do.	do.	do.
B1557	3,100		FEMA	[a]2,380	3,971.87	-1.0	-0.7	10.9	6.5	20.4	20.4
		10,500	FEMA	do.	do.	do.	do.	do.	do.	do.	do.
B1581	3,100		FEMA	[a]1,520	3,924.29	-1.0	0.6	14.5	15.6	NA	0.6
		10,500	FEMA	[b]3,190	3,924.35	do.	1.6	18.2	19.4	NA	1.6
B1600	4,600		S	[a]1,500	4,794.36	1.0	5.4	10.1	13.2	NA	6.4
		7,600	S	do.	do.	do.	do.	do.	do.	do.	do.
B1601	9,700		FEMA	[a]1,050	4,697.26	0.5	1.6	13.2	15.1	NA	2.1
		16,500	F	do.	do.	do.	do.	do.	do.	do.	do.
B1603	15,900		S	[b]15,900	4,816.94	1.0	0.0	14.8	11.1	9.9	10.9
		27,000	S	[b]27,000	4,819.55	do.	0.2	21.1	13.8	14.4	15.6
B1694	36,000		FEMA	[b]19,900	4,591.14	0.0	6.6	28.3	233.2	31.9	38.5
		57,500	S	do.	do.	do.	do.	do.	do.	do.	do.
B1715	4,300		FEMA	4,300	NA	0.5	NA	NA	NA	NA	NA
		15,500	FEMA	do.	do.	do.	do.	do.	do.	do.	do.

[a] Discharge at or just below (±10 cubic feet per second) that for which pressure flow could occur; at higher discharge, scour depths could be higher.

[b] Road overflow occurs; average velocity at greater discharges will decrease.

Pier scour is scour around the pier. Pier-scour depths were estimated using the Colorado State University equation (HEC-18; Richardson and others, 1993, p. 39). The equation estimates equilibrium scour depths. The maximum subsection depth and 100 percent of the maximum subsection velocity for the bridge opening were used in the equation. The maximum velocity was used even though piers typically are not in the thalweg, where maximum velocity occurs. The computed scour depth was applied to all piers in the channel section regardless of their location. This allowed for the possibility of the thalweg shifting and for greater scour at a pier not currently near maximum channel depth.

Pier-scour depths were not computed when the water-surface altitude determined for the upstream bridge opening did not contact the piers or abutments, or if the bridge had no piers.

Abutment scour is scour at or near the bridge abutment. The HIRE equation (HEC-18; Richardson and others, 1993, p. 67) was used to predict abutment scour under worst-case conditions. The equation will estimate the maximum possible scour for an abutment projecting into a flow for which velocities and depths upstream from the abutment are similar to those in the main channel. Abutment scour was included in the analysis but only as a indicator of potential abutment scour.

Total scour was computed by adding general scour, live-bed contraction scour, and pier scour. Computed scour depths are listed in table 3; negative scour values indicate fill.

To evaluate bridge status, estimates of total scour depth require that a relation be established between the arbitrary datum used in the field survey and sea-level datum used on the original bridge plans. For most bridges, values from existing maps by the Federal Emergency Management Agency (FEMA), NDOT, and USGS were used to correct the arbitrary datum values. Ideally, this relation should be established using a common point identified from both surveys. For example, if an accurate altitude of low steel, center line of road, top of pier, or top of abutment can be identified, arbitrary datum is subtracted from sea-level datum for that point. The difference then can be subtracted from sea-level datum for the pier-footing bases, abutment footings, and other pertinent altitudes to correct the arbitrary datum altitudes. Unfortunately, determination of this relation was not always possible. Many points were near each other, therefore datum differences should be considered approximate.

When a relation was established, altitudes of the pier footing bases and abutment footing bases were plotted to the datum on a NDOT bridge plan that shows vertical locations of the bridge abutments and piers. Lines of estimated total scour were drawn on the cross-section plot. The lines of total scour were then compared with the footing altitudes to determine if the depth of total scour is deeper than the base of the footings.

Results from the scour plots were used in assigning the Item-113 rankings listed for each bridge in table 2. Item-113 rankings indicate that 13 bridges are stable for the calculated scour (ranking value 5 or 8) and 21 bridges are unstable for the calculated scour (ranking value 2 or 3).

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APPENDIX

Blank Evaluation Forms

SCOUR AND CHANNEL-INSTABILITY ASSESSMENT FORM

IN-34
05/93

Problem:______________________________

______________________Date:__________

Followup:_____________________________

______________________Date:__________

Action Taken:_________________________

______________________Date:__________

DOT QA:_______________Date:__________

USGS QA:______________Date:__________

Data Input:___________Date:__________

Report QA:____________Date:__________

Lat:______ °________ ′ Long:______ °______

Plan View Sketch of Site

In the Vehicle

Bridge #:________________________ Inspector:___________________

Date:______________ Stream:_________________________________

County #:_____ Nearest Town:__________________ Route #:_________

Total Bridge Length (ft):___________ Overflow Bridge:__ 0=No 1=Yes

Type of Structure:____________________ ADT x 100:______________

Max Span Length:_________Min Span Over Main Channel:_________

From the Roadway

of Overflow Bridges: L:_____ R:_____ Wadeable:____ 0=No 1=Yes

Surface Cover USLB:____USRB:____DSLB:____DSRB:____Overall:____

1=>50% Paved 2=10%-50% Paved 3=Row crop 4=Pasture 5=Brush 6=Forest 7=Wetland

	Higher than Low Steel	Subject to Meander Impact	
Left Approach:	_____	_____	0=No 1=Yes
Right Approach:	_____	_____	0=No 1=Yes

High Flow Angle US/DS (degrees):________ + = Pushes RB - = Pushes LB

Upstream Channel Profile:_____ 1 = Pool 2 = Riffle

Photograph from Bridge Looking Upstream

Roll #:__________Frame #:________Standing:________________________________Bridge

Photograph from Bridge Looking Downstream

Roll #:__________Frame #:________Standing:________________________________Bridge

Downstream Channel Profile:_____ 1 = Pool 2 = Riffle

In the Upstream Channel

Meander Impacts: (1)_____ Bank:_____ Distance:__________(ft)

(2)_____ Bank:_____ Distance:__________(ft)

0 = No 1 = Yes 1 = LB 2 = RB - = Downstream

(Beyond Bridge Right-of-Way for Bank and Channel Observations Only)

Bank Height (ft)		Bank Angle (degrees)		Veg Cover (%)		Bank Material						Bank Erosion	
LB	RB	LB	RB	LB	RB	LB			RB			LB	RB
___	___	___	___	___	___	__	__	__	__	__	__	___	___
		(nearest 5) (degrees)		1=0-25% 3=51-75%	2=26-50% 4=76-100%	1 = Silt/Clay 2 = Sand 3 = Gravel 4 = Cbl/Boulder 5 = Bedrock 6 = Con/Steel						0 = None 1 = Mass Wasting 2 = Fluvial	

US Bankfull Channel Width:________(ft)

Photograph from Upstream Looking Downstream at Bridge

Roll #:_______________ Frame #:_________ Standing:______________________________(ft US)

			Comments
Tributary #1:__	Enters:_______(ft)	On:____	____________________
Tributary #2:__	Enters:_______(ft)	On:____	____________________
Tributary #3:__	Enters:_______(ft)	On:____	____________________

0 = No 1 = Yes - = Downstream 1 = LB 2 = RB

In the Upstream Channel (cont)

Point Bar:____ Location at Widest Point:____% to ____% Distance to Widest Point:________(ft)
0 = No 1 = Yes 0% = LB 100% = RB - = Downstream

Cut Bank:____ Cut Bank Location:____ Distance to Mid Cut Bank:________(ft)
0 = No 1 = Yes 1 = LB 2 = RB - = Downstream

Sketch of Bridge Opening at Upstream Face of Bridge

Under the Bridge

Depth Required for Pressure Flow:______(ft) (999 if > 35) Water Depth at Thalweg:______(ft)

Flow Deflected by Debris:___ Impact Point:___ Distance to Impact Point:________(ft)
0 = No 1 = Yes 1 = LB 2 = RB 0 = At Bridge - = DS

Piers and Columns

Nose Shape	# of Columns (If Shape =) (4, 5, or 6)	Diagonal Member (If Shape =) (4, 5, or 6)	Attack Angle (degrees)	Location LFP	LTB	LB	MCL	MCM	MCR	RB	RTB	RFP	Scour Conditions
				(Circle Appropriate Choices Below)									
1-______	______	______	______	1	2	3	4	5	6	7	8	9	0 1 2 3
2-______	______	______	______	1	2	3	4	5	6	7	8	9	0 1 2 3
3-______	______	______	______	1	2	3	4	5	6	7	8	9	0 1 2 3
4-______	______	______	______	1	2	3	4	5	6	7	8	9	0 1 2 3
5-______	______	______	______	1	2	3	4	5	6	7	8	9	0 1 2 3
6-______	______	______	______	1	2	3	4	5	6	7	8	9	0 1 2 3
7-______	______	______	______	1	2	3	4	5	6	7	8	9	0 1 2 3
8-______	______	______	______	1	2	3	4	5	6	7	8	9	0 1 2 3
9-______	______	______	______	1	2	3	4	5	6	7	8	9	0 1 2 3

1 = Square
2 = Round
3 = Pointed
4 = Square Columns
5 = Round Columns
6 = Pointed Columns

0 = No
1 = Yes

+ = Pushes RB
- = Pushes LB

0 = None
1 = Local scour
2 = Footing Exposed
3 = Piles Exposed

Pier or Column Width:________(ft) Total Pier Length:________(ft)

Under the Bridge (cont)

Abutments

	Attack Angle (degrees)	Abutment Location	Type of Abutment	Scour Conditions	Guide Banks	Upstream Wing Wall/ Apron	Wing Wall/ Apron Condition
Left Abut:	_______	_________(ft)	______	______	______	______	______
Right Abut:	_______	_________(ft)	______	______	______	______	______
	+ = Pushes RB - = Pushes LB	- = Past Bank into Stream 0 = Even w/ Bank + = Set Back from Bank	1 = Vertical If Sloping: 2 = Unhardened 3 = Hardened	0 = None 1 = Footing Exposed 2 = Piles Exposed	0 = No 1 = Yes	0 = Absent 1 = Present	1 = Good 2 = Fair 3 = Poor 4 = Failed

Rip Rap

	Presence	Condition (If Presence = 1)
US LB:	_____	_____
US L WW:	_____	_____
L Bank:	_____	_____
DS L WW:	_____	_____
DS LB:	_____	_____
US RB:	_____	_____
US R WW:	_____	_____
R Bank:	_____	_____
DS R WW:	_____	_____
DS RB:	_____	_____
Bed:	_____	_____
	0 = Absent 1 = Present	2 = Good 3 = Partial 4 = Slumped

Bed Material

US:__ __ __ Under Bridge:__ __ __ DS:__ __ __

1 = Silt/Clay 2 = Sand 3 = Gravel
4 = Cbl/Boulder 5 = Bedrock 6 = Con/Steel

Under Bridge
Bankfull Channel Width:_______(ft)

Debris & Trapping Potential

Debris Potential:_____

Trapping Potential:_____

0 = Low 1 = Medium 2 = High

Debris

Accumulation:_____ 0 = No 1 = Yes

Horizontal:____% to ____%
0% = LB 100% = RB

Vertical: ____% to ____%
0% = Bed 100% = Low Stee

Type of Material:_____
1 = Brush 2 = Whole Trees
3 = Trash 4 = All Others

Scour Holes

	Presence	Stream Pos.	Channel Pos.	Width	Length	Depth
1 -	_____	_______(ft)	_______%	_______(ft)	_______(ft)	_______(ft)
2 -	_____	_______(ft)	_______%	_______(ft)	_______(ft)	_______(ft)
	0 = Absent 1 = Present	+ = US 0 = Under Bridge - = DS	LB = 0% RB = 100%			

In the Downstream Channel

(Beyond Bridge Right-of-Way for Bank and Channel Observations Only)

Bank Height (ft)		Bank Angle (degrees)		Veg Cover (%)		Bank Material		Bank Erosion	
LB	RB	LB	RB	LB	RB	LB	RB	LB	RB
____	____	____	____	____	____	__ __ __	__ __ __	____	____
		(nearest 5) (degrees)		1=0-25% 2=26-50% 3=51-75% 4=76-100%		1 = Silt/Clay 2 = Sand 3 = Gravel 4 = Cbl/Boulder 5 = Bedrock 6 = Con/Steel		0 = None 1 = Mass Wasting 2 = Fluvial	

DS Bankfull
Channel Width:_______(ft)

Blow Hole:_____ 0 = No 1 = Yes

Distance DS to Middle of
Blow Hole:_______(ft)

Blow Hole Width:_______(ft)

Blow Hole Length:_______(ft)

Stage of Reach Evolution:_____

1 = Undisturbed 2 = Constructed
3 = Degradation 4 = Aggradation
5 = Lateral Migration 6 = Stable

Photograph from Downstream Looking Upstream at Bridge

Roll #:____________ Frame #:_______ Standing:____________________(ft DS)

Additional Photographs

Roll #:____________ Frame #:_______ Standing:____________________ Looking At:____________________

Roll #:____________ Frame #:_______ Standing:____________________ Looking At:____________________

Roll #:____________ Frame #:_______ Standing:____________________ Looking At:____________________

Roll #:____________ Frame #:_______ Standing:____________________ Looking At:____________________

Texas Potential Scour: Variables, explanations, diagnostic characteristics, and assigned index values for the calculation of the potential-scour index.

SITE:____ **TOTAL**

1. Bed material-- Bed material indicates the erodibility of the channel in the vicinity of the bridge.

bedrock	boulder/cobble	gravel	sand	unknown alluvium	silt/clay	
0	1	2	3	3.5	4	_____

2. Bed protection-- Bed protection decreases the potential for bed lowering, although bank protection will increase the potential for bed erosion.

yes	no	if no:	1 bank protected	2 banks protected	
0	1		2	3	_____

3. Stage of channel evolution-- The channel evolution model devised by Simon (1989) for channelized streams in western Tennessee is used to indicate the dominance of channel-evolution over time (I = undisturbed, II = new construction, III = degradation, IV = degradation and bank failure, V = aggradation or stable, with bank failure, VI = fully recovered). It is not universally applicable, but it does give an indication of stream-evolution processes over time.

I	II	III	IV	V	VI	
0	1	2	4	3	0	_____

4. Percent of channel constriction-- Scour is more likely to occur when flow is accelerated through a constricting reach.

0-5	6-25	26-50	51-75	76-100	
0	1	2	3	4	_____

5. Number of piers in channel-- Piers in main channel increase a bridge's susceptibility to local scour.

0	1-2	>2	
0	1	2	_____

6, 7, 8. Percent of blockage: Horizontal (6), vertical (7), total (8)-- Debris accumulation can cause flow constriction and flow deflection (divide values by 3 before summing).

0-5	6-25	26-50	51-75	76-100	
0	1	2	3	4	_____

9. Bank erosion (each bank)-- Bank erosion can undermine structural components originally placed out of the main channel.

none	fluvial erosion	mass-wasting	
0	1	2	_____

10. Meander impact point for bridge (feet)-- Migrating meander bends can undermine structural components.

0-25	26-50	51-100	>100	
3	2	1	0	_____

Texas Potential Scour: Variables, explanations, diagnostic characteristics, and assigned index values for the calculation of the potential-scour index.

SITE:____ **TOTAL**

11. Pier Skew for each pier-- Pier skew will increase local scour; it is summed for all piers in the main channel.

yes	no	
1	0	______

12. Mass wasting at pier-- Mass wasting at a pier can cause failure.

yes	no	
3	0	______

13. High flow angle of approach (degrees)-- A high angle of approach at high flow can cause erosion similar to that caused by channel meanders.

0-10	11-25	26-40	41-60	61-90	
0	1	2	2.5	3	______

TOTAL FOR SITE ______

Colorado Potential Scour: Ranking variables and assigned values.

SITE:____ **TOTAL**

1. Number of piers (assign one point for each pier in active channel): ______

2. Pier shape:

round	pointed	square	
0	1	2	______

3. Pier skew (degrees):

0-10	11-20	21-30	31-40	>40	
0	1	2	3	4	______

4. Pier width (feet):

<3	3-4	5-7	8-9	>10	
0	1	2	3	4	______

5. Abutment skew (degrees):

0-10	11-20	21-30	31-40	>40	
0	1	2	3	4	______

6. Flow impinging on abutment or wingwall:

yes	no	
2	0	______

7. Contracting section at bridge (percent of opening to channel):

none (<10)	low (11-25)	medium (26-50)	high (>50)	
0	1	2	3	______

8. Abutment encroachment:

yes	no	
1	0	______

9. Constriction due to channel vegetation:

none	low	medium	high	
0	1	2	3	______

10. Potential for debris/ice accumulation:

none	low	medium	high	
0	1	2	3	______

Colorado Potential Scour: Ranking variables and assigned values.

SITE:____ **TOTAL**

11. Channel capacity:

	low	medium	high			TOTAL
	2	1	0			_____

12. Bridge capacity:

	low	medium	high			TOTAL
	2	1	0			_____

13. Water surface slope:

mild (0.0004)	medium (0.0004 - 0.0015)	steep (>0.0015)	TOTAL
0	1	2	_____

14. Bed material:

bedrock	boulder/cobble	gravel	sand	silt/clay	TOTAL
0	1	2	3	4	_____

15. Channel armored:

	yes	no				TOTAL
	0	1				_____

16. Meander impact distance (feet):

0-25	26-50	51-100	>100		TOTAL
3	2	1	0		_____

17. General river classification:

	stable	aggrading	degrading			TOTAL
	0	1	2			_____

18. Upstream confluence near:

	yes	no				TOTAL
	1	0				_____

TOTAL FOR SITE _____

Texas Observed Scour: Variables, diagnostic characteristics, and assigned index values for the calculation of the observed-scour index (observed-scour index equals the sum of assigned values for each variable).

SITE:____ **TOTAL**

1. Pier/bent scour (local, sum for all up to 9 piers or bents)

if pier:	none	observed	footing exposed	piling exposed	
	0	1	3	3	_____
if bent:	none	observed	moderate	severe	
	0	1	3	3	_____

2. Abutment piling exposure (summed for left and right bank):

left bank		right bank		
none	exposed	none	exposed	
0	1	0	1	_____

3. Failed rip-rap at bridge (sum of both values):

left bank		right bank		
yes	no	yes	no	
1	0	1	0	_____

4. Bed rip-rap moved:

yes	no	
1	0	_____

5. Blowhole observed:

yes	no	
3	0	_____

6. Mass wasting at pier (calculated for each pier):

yes	no	
3	0	_____

TOTAL FOR SITE _____

Indiana Observed Scour: Observed-streambed-scour index.

SITE:______________________________	VALUE
No observed streambed scour	10
Scour hole(s) only	9
Local scour at abutment(s) only	8
Local scour at pier(s) only	7
Local scour at pier(s) and scour hole(s)	6
Blow hole	5
Vertical abutment(s) with footing exposed:	4
Sloping abutment(s) with pile(s) exposed	3
Vertical abutment(s) with pile(s) exposed	2
Pier(s) with footing(s) exposed	1
Pier(s) with pile(s) exposed	0

Item 113: Scour critical bridges.

SITE:____	VALUE
Bridge not over waterway.	N
Bridge foundations (including piles) well above flood water elevations.	9
Bridge foundations determined to be stable for calculated scour conditions: calculated scour is above top of footing.	8
Countermeasures have been installed to correct a previously existing problem with scour. Bridge is no longer scour critical.	7
Scour calculation/evaluation has not been made. (Use only to describe case where bridge has not yet been evaluated for scour potential.)	6
Bridge foundations determined to be stable for calculated scour conditions: scour within limits of footing or piles.	5
Bridge foundations determined to be stable for calculated scour conditions: field review indicates action is required to protect exposed foundations from effects of additional erosion and corrosion.	4
Bridge is scour critical; bridge foundations determined to be unstable for calculated scour conditions: - scour within limits of footing or piles. - scour below spread-footing base or pile tips.	3
Bridge is scour critical; field review indicates that extensive scour has occurred at bridge foundations. Immediate action is required to provide scour countermeasures.	2
Bridge is scour critical; field review indicates that failure of piers/abutments is imminent. Bridge is closed to traffic.	1
Bridge is scour critical. Bridge has failed and is closed to traffic.	0