Methodology and Estimates of Scour at Selected Bridge Sites in Alaska

Water-Resources Investigations Report 00—4151

Prepared in cooperation with the
ALASKA DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES

U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

Cover photograph: Bridge over Castner Creek, Richardson Highway mile 217.2. View from right downstream bank, west end of bridge. Right abutment (left side of photograph) was eroded and required emergency repair. Photograph was taken by author D.E. Langley, approximately 8 hours after peak flow, August 13, 1997.

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Anchorage, Alaska
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U.S. DEPARTMENT OF THE INTERIOR
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CONVERSION FACTORS and VERTICAL DATUM

Multiply	by	To obtain
inch (in.)	25.4	millimeter
foot (ft)	0.3048	meter
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
foot per foot (ft/ft)	1.000	meter per meter

In this report, temperature is reported in degrees Fahrenheit (°F), which can be converted to degrees Celsius (°C) by the equation

$$°C = (°F - 32) / 1.8$$

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. In the adjustment, sea levels from selected tide stations in both countries were held fixed. The year indicates the time of the last general adjustment. This datum should not be confused with mean sea level. Altitudes are the same in both the local coordinate system and the Universal Transverse Mercator system.

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Abstract

The U.S. Geological Survey estimated scour depths at 325 bridges in Alaska as part of a cooperative agreement with the Alaska Department of Transportation and Public Facilities. The department selected these sites from approximately 806 State-owned bridges as potentially susceptible to scour during extreme floods. Pier scour and contraction scour were computed for the selected bridges by using methods recommended by the Federal Highway Administration. The U.S. Geological Survey used a four-step procedure to estimate scour: (1) Compute magnitudes of the 100- and 500-year floods. (2) Determine cross-section geometry and hydraulic properties for each bridge site. (3) Compute the water-surface profile for the 100- and 500-year floods. (4) Compute contraction and pier scour. This procedure is unique because the cross sections were developed from existing data on file to make a quantitative estimate of scour. This screening method has the advantage of providing scour depths and bed elevations for comparison with bridge-foundation elevations without the time and expense of a field survey. Four examples of bridge-scour analyses are summarized in the appendix.

INTRODUCTION

The Federal Highway Administration (FHWA) has established a requirement that all State highway agencies evaluate the bridges on the Federal Aid System for susceptibility to scour-related failure. In 1994, the U.S. Geological Survey (USGS), in cooperation with the Alaska Department of Transportation and Public Facilities (ADOT&PF), began a cooperative study of bridge scour in Alaska. The project was part of a national cooperative effort among the States, the FHWA, and the USGS to analyze scour potential at existing bridge sites. The ADOT&PF screened approximately 800 bridge sites in Alaska, selected 520 sites as scour susceptible, and assigned 340 of these scour-susceptible sites to the USGS for assessment. To date, assessment of scour has been completed for 325 of the 340 sites.

Background

A bridge is described as "scour-critical" if the abutment or pier foundations or both have been determined to be, or have the potential to be, undermined or to become unstable because of hydraulic erosion of the channel bed or banks (Federal Highway Administration, 1988). Scour processes are accelerated during high-flow conditions, and the potential for scour-related problems at a bridge tends to increase during floods. Bridge-scour processes are classified into three components: (1) general long-term aggradation or degradation of the stream channel, (2) contraction scour, and (3) local scour at piers and abutments. The total scour that can occur at a bridge is the sum of these components.

General scour refers to geomorphic processes that cause degradation, such as long-term adjustments of a channel that result from changes in basin hydrology, hydraulics, or sediment movement. *Contraction scour* refers to the general lowering of the channel bed under the bridge. Contraction scour is initiated by increased flow velocities through the bridge opening, change in local base-level elevation, or flow around a bend. The most common cause of contraction scour is the contraction of flow by bridge-approach embankments that encroach on the flood plain, the main channel, or both (Richardson and Davis, 1995). *Local scour* is the removal of material around piers, abutments, spur dikes, and embankments caused by flow acceleration and turbulence near bridge substructural elements and embankments.

Purpose and Scope

Evaluation of the selected 325 bridge sites is being accomplished in two phases. Phase I, which is described in this report, is the preliminary assessment of scour, floods, and basin characteristics for each of the selected sites. Phase II evaluation consists of detailed field surveys, inspections, and additional hydraulic modeling of those bridges that have a high potential for scour as determined by ADOT&PF from reported Phase I results. The results of Phase II scour assessments will be published in a subsequent report.

The purpose of this report is (1) to document the general methodology used to evaluate scour for the selected bridge sites in Alaska and (2) to summarize preliminary scour results, basin characteristics, and calculated estimates of 100- and 500-year peak flows for each of the 325 bridge sites analyzed to date. Fifteen additional sites were not completed because they either are affected significantly by tidal activity or do not have bridge plans readily available.

This study is focused on estimating maximum contraction scour and local pier scour at selected bridge sites associated with floods having annual exceedence probabilities of 0.01 and 0.002, referred to hereafter as the 100- and 500-year floods, respectively. The scour analyses do not include other factors that can affect bridge scour, such as channel migration or long-term aggradation or degradation that may be occurring at the bridge site.

The maximum-scour equations used for this study are those presented in an FHWA report, Hydraulic Engineering Circular 18, by Richardson and Davis (1995)—hereafter referred to as "HEC–18."

METHODOLOGY

An estimate of the maximum scour that may occur at a site during a high-flow event can be made by determining the hydraulic properties of the channel and bridge opening for a flood and using appropriate scour equations.

The techniques developed by the USGS for this Phase I study were in response to requests from ADOT&PF for a low-cost, quantitative scour-estimation technique. When this project was initiated in 1994, two methods were in general use for screening bridge sites for scour potential, and both required initial site visits: (1) Using data entered into a standardized qualitative form to assess geomorphic features of the site, to determine certain bridge parameters, and to identify and rate scour potential for the bridge (Robinson and Thompson, 1993; Huizinga and Waite, 1994). (2) Surveying the cross sections required to develop a hydraulic model of flood flow through the bridge opening, modeling the flow, and extracting variables from the model output to compute scour by empirical techniques described in HEC–18 (Richardson and Davis, 1995).

Doing site-specific field surveys and producing hydraulic models are relatively expensive and time consuming but do provide a quantitative estimate of scour based on current physical conditions at the site. In the past, the less expensive method using standardized qualitative forms commonly was used as a screening method (Phase I) to select sites that may require a more detailed and expensive quantitative estimate of scour (Phase II).

A new technique developed by the USGS provides a relatively low cost, preliminary (Phase I) but quantitative estimate of scour. Channel cross sections and hydraulic models were developed from bridge as-built plans or plans-of-record (provided by ADOT&PF) and other existing bridge and hydrologic information such as bridge inspections, USGS discharge measurements, and USGS indirect flood computations as well as from topographic maps. Scour was computed from these models by the accepted FHWA techniques as described in HEC–18 (Richardson and Davis, 1995).

Phase I scour-estimation techniques described in this report are composed of four essentially discrete steps: (1) Compute magnitudes of the 100- and 500-year floods from regional regression equations or published flood-frequency analyses. (2) Determine cross sections and hydraulic properties for each bridge site based on existing bridge plans and available hydrologic information. (3) Compute the water-surface profile for the 100- and 500-year floods by using Shearman's (1990) step-backwater water-surface profile (WSPRO) model. (4) Compute contraction scour and pier scour by using variables generated by the WSPRO model and techniques recommended by the FHWA in HEC–18 (Richardson and Davis, 1995).

Because of the repetitive and complex nature of the computations, software was developed to automate each of the four steps. This software allowed timely and accurate analyses of sites by automating repetitive tasks and providing quality-assurance tools.

Magnitude of 100- and 500-Year Floods

Alaska has a relatively sparse stream-gaging network. For bridge sites having a sufficient stream-gaging record, floods were estimated by using both standard flood-frequency analyses (Interagency Advisory Committee on Water Data, 1982) and regional regression flood estimates (Jones and Fahl, 1994). Specifically, at sites where both the standard frequency and regression flood estimates were available, floods were combined by using a logarithmic-weighting factor based on the number of years of stream-gaging data and an equivalent factor for the regression-computed floods (Jones and Fahl, 1994).

For ungaged sites, the 100- and 500-year floods were computed by using regional regression equations, which required drainage basin characteristics as outlined by Jones and Fahl (1994). Statistically significant basin characteristics that vary by region throughout the State include basin area, mean basin elevation, mean annual precipitation, mean minimum January temperature, percentage of basin covered by forest or covered by lakes or ponds. Basin characteristics are summarized in table 1. Of more than 300 basins characterized during Phase I of this study, many had no previous data on record. Scour assessments were not done for all the sites included in table 1, such as Chilkoot River bridge 387; scour assessments were done at other sites that do not appear in table 1, such as the Chena River bridge sites where maximum flow is regulated. A geographic-information system (spatial database) was used to automate the process of extracting basin characteristics from maps, and a spreadsheet incorporating regional regression equations was used to automate flood computations.

Cross Sections and Hydraulic Properties

To model water-surface profiles accurately, cross sections and hydraulic properties for the bridge and channel must be determined by surveying or be estimated by other techniques. In this study, nearly all cross sections were derived from existing bridge plans. Almost all bridges in the State were built in the last 60 years, and bridge plans are readily available. These plans generally include an elevation view of the bridge showing the angle of attack (skew) of channel flow relative to the bridge at the time of construction and commonly contain a detailed topographic map showing the shape of the channel and overbank near the bridge.

Some bridge sites have available additional information such as discharge measurements at or near the bridge, stream-gaging records, bridge inspections, surveys for indirect flood computations, and photographs. When possible, such additional information was combined with the bridge-plan information to produce representative cross sections, determine channel-flow angle of attack at the bridge, and delineate breaks between the main channel and overbank.

Table 1. Basin characteristics at selected bridge sites in Alaska

[Bridge ADOT&PF number: **Bold** indicates that corresponding basin-characteristics data are from Jones and Fahl (1994). Flood-frequency area designations are from Jones and Fahl (1994). ADOT&PF, Alaska Department of Transportation and Public Facilities. —, not applicable]

Bridge		Flood-frequency area	Route or junction		Basin		Mean annual precipitation (inches)	Mean minimum January temperature (degrees Fahrenheit)	Subareas relative to basin area	
ADOT&PF number	Name		Name	Mile	Area (square miles)	Mean elevation (feet)			Lakes or ponds (percent)	Forest (percent)
201	Tanana River North Slough	3	Parks Highway	305.3	25,600	3,920	16.0	-15	4.00	56.00
202	Tanana River at Nenana	3	Parks Highway	305.0	25,600	3,920	16.0	-15	4.00	56.00
205	Copper River at Chitina	3	McCarthy Road	34.6	12,600	3,370	20.5	-7	4.56	—
208	Roslyn Creek	1	Cape Chiniak Road	36.7	5.9	531	120.0	24	.12	—
211	Little Willow Creek	2	Parks Highway	74.7	155	1,840	30.0	2	1.00	46.00
212	Kashwitna River	2	Parks Highway	83.2	341	3,368	22.0	-1	.65	27.90
215	Montana Creek	2	Parks Highway	96.5	164	1,930	30.0	0	3.00	54.00
217	Mendenhall River	1	Mendenhall Loop Road	.0	84.8	2,236	145.4	21	1.89	—
230	Sheridan Glacier No. 3	1	Copper River Highway	14.7	106	2,216	177.2	16	2.84	—
232	North Fork Chena River	3	Chena Hot Springs Road	37.8	941	2,270	16.0	-19	.00	58.00
233	North Fork Chena River	3	Chena Hot Springs Road	39.5	939	2,270	16.0	-19	.00	58.00
234	North Fork Chena River	3	Chena Hot Springs Road	44.0	351	2,293	17.0	-19	.00	55.50
235	North Fork Chena River	3	Chena Hot Springs Road	45.7	346	2,293	18.0	-19	.00	55.00
238	Angel Creek	3	Chena Hot Springs Road	49.8	38.1	2,292	15.0	-19	.00	—
240	Little Susitna River	2	Parks Highway	57.1	172	2,298	19.0	2	.40	43.50
242	North Fork Chena River	3	Chena Hot Springs Road	55.3	120	2,460	18.0	-19	.00	54.50
254	Susitna River at Sunshine	2	Parks Highway	104.2	11,100	3,480	35.0	-4	2.00	18.00
259	Honolulu Creek	2	Parks Highway	178.1	66.7	3,586	40.0	-5	.50	14.00
260	East Fork Chulitna River	2	Parks Highway	185.1	154	3,717	40.0	-5	.40	9.50
261	Middle Fork Chulitna River	2	Parks Highway	194.5	53.0	3,838	35.0	-6	1.50	11.00
266	Cripple River	3	Nome–Teller Road	19.4	32.6	797	25.7	-3	.03	—
268	Fox River	3	Nome–Council	68.2	37.2	675	17.7	-5	.00	—
269	Bear River	3	Nome–Council	71.7	30.5	644	17.4	-5	.06	—
270	Little Chena River	3	Chena Hot Springs	11.9	372	1,480	15.0	-16	.00	—
272	Hot Springs Slough	3	Elliot Highway	150.9	36.0	627	15.0	-16	5.67	—
274	Hutlinana Creek	3	Elliot Highway	129.3	88.0	1,791	15.0	-16	.00	—
275	North Fork 12 Mile Creek	3	Steese Highway	93.4	23.0	3,239	19.3	-22	.00	—
277	Taylor Creek	5	Taylor Highway	50.3	40.7	2,479	15.0	-24	.01	96.04
281	Jack River	3	Cantwell Road	—	315	3,459	30.0	-6	1.73	6.00
284	American River	1	Kodiak Island Highway	22.2	24.9	1,047	100.0	24	.13	—

286	Deadman (Small) Creek	1	Kodiak Island Highway	31.0	1.1	1,398	100.0	24	.00	—
287	Olds River	1	Kodiak Island Highway	30.2	15.6	862	100.0	24	.49	—
288	Tonsina River (Lower)	3	McCarthy Road	19.3	827	3,170	58.0	-5	1.80	—
290	East Fork Twin Creek	3	Cape Chiniak Road	40.8	3.5	507	120.0	24	.00	—
291	Kalsin Creek	1	Kodiak Island Highway	1.0	8.3	580	100.9	24	.00	—
292	Myrtle Creek	1	Cape Chiniak Road	33.3	4.9	725	113.9	24	.00	—
293	Pass Creek	3	Parks Highway	208.0	29.0	2,956	28.8	-6	5.52	—
297	Forty Mile River	3	Taylor Highway	112.5	5,880	2,940	17.0	-22	4.00	77.00
298	O'Brien Creek	5	Taylor Highway	113.2	362	2,772	15.1	-22	.00	87.64
299	Walker Fork 40 Mile River	5	Taylor Highway	81.8	388	3,039	15.2	-24	.00	79.48
302	Jack River	3	Parks Highway	209.5	200	3,821	30.0	-6	.90	6.30
303	O'Connor Creek	3	Goldstream Road	.0	12.7	1,227	15.0	-18	.00	—
310	Pilgrim River	3	Nome–Taylor Road	60.4	313	972	28.0	-5	1.67	—
311	Bear Creek	3	Parks Highway	269.4	21.8	1,955	16.0	-9	13.96	—
312	Jenny M Creek	3	Chena Hot Springs Road	20.0	13.4	1,041	15.0	-18	.00	—
313	Panguingue Creek	3	Parks Highway	252.5	17.1	2,076	25.0	-8	.00	—
323	Penny River	3	Nome–Teller Road	12.6	18.9	721	21.5	-3	.00	—
324	Snake River	3	Nome–Teller Road	7.3	85.7	632	30.0	-2	.00	4.00
325	West Fork Tolovana River	3	Elliot Highway	74.9	289	1,512	15.0	-17	.11	—
327	Station 355 Creek	1	Halibut Point Road	7.0	2.0	961	100.0	28	.00	—
328	Granite Creek	1	Halibut Point Road	4.6	2.2	1,167	100.0	28	.00	—
348	Scott Glacier No. 1	1	Copper River Highway	7.8	154	2,262	188.9	16	.63	—
349	Scott Glacier No. 2	1	Copper River Highway	7.9	154	2,262	188.9	16	.63	—
350	Scott Glacier No. 3	1	Copper River Highway	8.4	154	2,262	188.9	16	.63	—
351	Scott Glacier No. 4	1	Copper River Highway	8.8	154	2,262	188.9	16	.63	—
352	Scott Glacier No. 5	1	Copper River Highway	9.6	154	2,262	188.9	16	.63	—
355	Birch Creek	3	Steese Highway	147.1	2,160	2,250	16.8	-22	.36	—
357	Goldstream Creek	3	Sheep Creek Road	—	96.7	1,200	15.0	-16	2.48	—
359	Spinach Creek	3	Goldstream Road	.0	9.9	1,186	15.0	-18	.00	—
367	Sheridan Glacier East Channel	1	Copper River Highway	16.4	106	2,216	177.2	16	2.84	—
381	Eyak River	1	Copper River Highway	5.9	40.2	1,360	174.4	16	10.35	—
383	Peterson Creek	1	Dotson Landing Road	.0	9.4	1,037	80.0	22	1.13	—
386	Felton Creek	1	Kodiak Island Highway	22.0	2.3	873	100.0	24	.00	—
387	Chilkoot River	1	Lutak Spur	.0	127	3,127	64.7	12	2.55	—
395	Alaganik Slough	1	Copper River Highway	22.5	27.8	1,248	144.0	16	5.11	—
396	Deception Creek	2	Fishhook/Willow Road	48.4	58.9	1,128	22.7	2	.40	—
399	King Salmon Creek	2	Naknek–King Salmon	13.2	170	769	24.5	7	.27	—
400	Leader Creek	2	Naknek–King Salmon	3.3	2.4	83	20.0	7	26.18	—
401	Moose Creek	21	Petersville Road	7.1	52.3	800	35.0	-3	9.00	77.00
402	Pauls Creek	2	Naknek–King Salmon	9.5	122	359	23.4	7	6.94	—

Table 1. Basin characteristics at selected bridge sites in Alaska—Continued

[Bridge ADOT&PF number: **Bold** indicates that corresponding basin-characteristics data are from Jones and Fahl (1994). Flood-frequency area designations are from Jones and Fahl (1994). ADOT&PF, Alaska Department of Transportation and Public Facilities. —, not applicable]

Bridge		Flood-frequency area	Route or junction		Basin		Mean annual precipitation (inches)	Mean minimum January temperature (degrees Fahrenheit)	Subareas relative to basin area	
ADOT&PF number	Name		Name	Mile	Area (square miles)	Mean elevation (feet)			Lakes or ponds (percent)	Forest (percent)
403	Portage Creek Overflow No. 1	2	Portage Glacier Road	3.1	45.9	2,046	152.2	11	2.60	—
404	Portage Creek Overflow No. 2	2	Portage Glacier Road	3.5	45.1	2,064	153.0	11	2.64	—
405	Portage Creek Overflow No. 3	2	Portage Glacier Road	4.1	42.1	2,099	156.0	11	2.76	—
406	Scott Glacier No. 6	1	Copper River Highway	9.8	154	2,262	188.9	16	.63	—
407	Scott Glacier No. 7	1	Copper River Highway	10.0	154	2,262	188.9	16	.63	—
411	Scott Glacier No. 11	1	Copper River Highway	11.4	154	2,262	188.9	16	.63	—
419	Gold Run Creek	3	Nome–Teller Road	53.3	24.5	818	15.0	-4	.00	—
421	Feather River	3	Nome–Teller Road	35.5	27.6	1,272	18.6	-3	.12	—
422	Tisuk River	3	Nome–Teller Road	46.9	35.7	1,012	16.5	-4	.14	—
423	Eldorado Creek	3	Nome–Teller Road	46.2	6.0	1,262	17.0	-4	.00	—
429	Blind Slough	1	Crystal Lake Hatchery Road	.0	8.3	1,015	94.5	26	4.13	—
430	Faith Creek	3	Steese Highway	69.1	61.1	2,800	18.0	-20	.00	48.00
432	Sawmill Creek	1	Sawmill Creek Road	6.0	38.5	2,127	167.8	28	2.12	—
440	Tolovana River	3	Elliott Highway	57.1	140.3	1,436	14.0	-15	.00	—
441	Mosquito Fork	5	Taylor Highway	64.3	1,120	2,980	15.3	-22	.26	69.73
442	West Fork Dennison River	5	Taylor Highway	49.1	623.8	2,645	15.0	-22	.17	89.71
455	Anchorage Port Access Overhead	1	Loop Road/C Street	.0	116	2,344	30.7	3	.13	—
460	Nome River	3	Nome–Taylor Road	13.1	77.7	903	25.0	-3	.00	—
467	Ganes Creek	3	Sterling Lake–Ophir Road	.0	94.1	1,440	25.0	-10	.16	—
470	Small Creek	1	Kodiak Island Highway	20.5	1.0	1,179	100.0	24	.00	—
478	Goldstream Creek	3	Goldstream Road	.0	40.9	1,472	15.0	-16	.00	—
503	Gardiner Creek	3	Alaska Highway	1,246.7	308	2,396	15.0	-24	1.26	—
504	Beaver Creek	3	Alaska Highway	1,268.1	31.6	2,706	15.0	-24	.00	—
505	Tanana River Near Tanacross	3	Alaska Highway	1,303.3	6,800	3,860	18.0	-22	2.00	45.00
506	Tok River	3	Alaska Highway	1,309.4	912	3,844	15.0	-21	.27	38.20
507	Yerrick Creek	3	Alaska Highway	1,333.6	33.5	4,190	15.3	-13	.04	—
508	Cathedral Rapids No. 1	3	Alaska Highway	1,338.1	9.0	3,614	15.1	-15	.00	—
509	Robertson River	3	Alaska Highway	1,345.3	576	4,589	15.0	-15	.60	18.20
510	Cathedral Rapids Creek No. 2	3	Alaska Highway	1,338.7	5.2	4,337	15.0	-15	.00	—
511	Cathedral Rapids Creek No. 3	3	Alaska Highway	1,338.8	3.9	4,114	15.0	-15	.00	—

513	Bear Creek	3	Alaska Highway	1,357.3	84.1	3,792	15.4	-12	.92	—
514	Chief Creek	3	Alaska Highway	1,358.6	34.5	2,312	15.0	-13	.11	—
515	Berry Creek	3	Alaska Highway	1,371.4	65.1	3,168	15.1	-12	.27	—
516	Sears Creek	3	Alaska Highway	1,374.4	8.4	2,037	15.0	-12	.00	—
517	Dry Creek	3	Alaska Highway	1,378.1	55.4	3,209	15.0	-12	.31	—
518	Johnson River	3	Alaska Highway	1,380.4	381	5,143	15.0	-12	.15	9.70
519	Little Gerstle River	3	Alaska Highway	1,388.4	66.6	3,577	15.0	-12	.96	56.70
520	Gerstle River	3	Alaska Highway	1,392.7	219	4,684	15.0	-12	.07	15.20
524	Tanana River Big Delta	3	Richardson Highway	275.4	13,500	3,440	22.0	-14	2.00	50.00
525	Shaw Creek	3	Richardson Highway	286.5	393.0	1,612	15.0	-16	21.33	—
526	Banner Creek	3	Richardson Highway	295.4	20.2	1,709	15.0	-15	.00	—
527	Salcha River	3	Richardson Highway	323.3	2,170	2,520	15.0	-19	.00	59.00
528	Clear Creek	3	Richardson Highway	324.0	1.3	780	15.0	-16	.00	—
529	Munsons Slough	3	Richardson Highway	325.4	1.6	785	15.0	-16	.00	—
530	Little Salcha River	3	Richardson Highway	328.4	73.5	1,275	15.0	-16	.00	—
532	Chena River (North Hall Street)	3	Steese Highway	—	2,000	1,770	15.0	-18	2.00	80.00
534	Ship Creek	2	Glenn Highway	133.5	92.2	2,923	33.0	2	.32	—
535	Eagle River North Crossing	2	Glenn Highway	140.1	192.0	3,120	40.0	6	.50	15.00
538	Goat Creek	2	Old Glenn Highway	6.1	15.0	3,579	28.0	7	.00	—
539	Knik River	2	Old Glenn Highway	8.6	1,180	4,000	100.0	9	4.00	11.00
541	Moose Creek	2	Glenn Highway	54.7	61.4	2,849	30.0	5	1.04	36.20
542	Eska Creek	2	Glenn Highway	60.9	14.0	2,720	38.0	5	.14	—
543	Granite Creek	2	Glenn Highway	62.4	61.9	3,925	30.0	4	.00	10.00
544	King River	2	Glenn Highway	66.4	153	4,029	51.1	4	.12	—
546	Puritan Creek	2	Glenn Highway	89.0	8.6	3,260	30.0	3	.70	—
547	Hicks Creek	2	Glenn Highway	96.5	46.0	4,295	30.0	4	.17	9.40
548	Caribou Creek	2	Glenn Highway	106.9	289.0	4,190	25.0	2	.00	—
549	Little Nelchina River	3	Glenn Highway Spur	.0	283	3,700	20.0	2	1.00	—
551	Mendeltna Creek	3	Glenn Highway	152.8	193	2,682	16.5	-5	6.66	—
552	Tolsona Creek	3	Glenn Highway	173.1	193	2,472	15.0	-8	7.96	—
556	Valdez Glacier Stream	1	Richardson Highway	.9	158	4,032	150.0	8	.17	—
557	Lowe River Lower Crossing	1	Richardson Highway	14.8	222	3,533	82.0	7	.04	—
558	Lowe River Upper Crossing	1	Richardson Highway	16.5	201	3,520	80.0	6	.04	—
559	Sheep Creek	1	Richardson Highway	18.7	29.4	4,050	110.5	8	.03	—
565	Stuart Creek	3	Richardson Highway	45.5	37.6	4,120	83.8	2	.74	—
569	Tonsina River (Upper)	3	Richardson Highway	79.2	420	3,584	89.0	-4	1.49	—
570	Squirrel Creek	3	Richardson Highway	79.6	70.5	3,100	15.0	-9	4.00	—
572	Klutina River	3	Old Rich–Copper Cent	—	880	3,500	30.0	-7	4.00	36.00
573	Tazlina River	3	Richardson Highway	110.7	2,670	3,450	30.0	4	5.00	30.00
574	Gulkana River	3	Richardson Highway	126.9	1,910	2,716	18.0	-6	14.60	27.50

Table 1. Basin characteristics at selected bridge sites in Alaska—Continued

[Bridge ADOT&PF number: **Bold** indicates that corresponding basin-characteristics data are from Jones and Fahl (1994). Flood-frequency area designations are from Jones and Fahl (1994). ADOT&PF, Alaska Department of Transportation and Public Facilities. —, not applicable]

Bridge		Flood-frequency area	Route or junction		Basin		Mean annual precipitation (inches)	Mean minimum January temperature (degrees Fahrenheit)	Subareas relative to basin area	
ADOT&PF number	Name		Name	Mile	Area (square miles)	Mean elevation (feet)			Lakes or ponds (percent)	Forest (percent)
575	Sourdough Creek	3	Richardson Highway	147.7	75.5	2,244	17.0	-10	14.62	—
577	One Mile Creek	3	Richardson Highway	184.7	8.8	3,281	25.0	-7	1.63	—
589	Lower Suzy Q Creek	3	Richardson Highway	224.5	1.0	3,295	40.0	-7	.00	—
591	One Mile Creek	3	Richardson Highway	228.4	4.8	4,006	35.0	-7	.00	—
592	Darling Creek	3	Richardson Highway	231.0	6.3	4,514	35.0	-7	.00	—
593	Bear Creek	3	Richardson Highway	233.3	6.8	4,355	34.1	-7	.00	—
594	Ruby Creek	3	Richardson Highway	234.7	5.2	3,392	25.0	-7	.00	—
595	Jarvis Creek	3	Richardson Highway	264.8	246	3,242	20.0	-8	2.14	—
596	Resurrection River No. 1	1	Seward Highway	2.8	169	2,270	100.0	12	.00	—
597	Resurrection River No. 2	1	Seward Highway	3.0	169	2,270	100.0	12	.00	—
598	Resurrection River No. 3	1	Seward Highway	3.1	169	2,270	100.0	12	.00	—
599	Clear Creek	1	Seward Highway	3.8	12.8	2,407	110.0	11	.00	—
600	Salmon Creek	1	Seward Highway	5.9	23.9	1,569	110.0	12	6.13	—
601	Bear Creek	1	Seward Highway	6.6	6.8	1,066	110.0	12	11.36	—
603	Snow River West Channel	2	Seward Highway	17.1	163	2,670	158.0	11	1.50	—
605	Snow River Center Channel	2	Seward Highway	17.5	163	2,670	158.0	11	1.50	—
608	Ptarmigan Creek	2	Seward Highway	23.1	32.6	2,800	90.0	10	6.00	—
609	Falls Creek	2	Seward Highway	25.0	11.8	3,480	80.0	10	.00	—
610	Trail River	2	Seward Highway	25.4	181	2,470	90.0	6	2.00	—
612	Canyon Creek	2	Seward Highway	56.4	96.3	2,183	53.4	10	.50	—
613	Dry Gulch Creek	2	Seward Highway	57.0	5.0	993	50.0	8	.00	—
627	Placer River Overflow	2	Seward Highway	77.9	122	2,083	113.6	11	.26	—
629	Placer River Main Crossing	2	Seward Highway	78.3	122	2,083	113.6	11	.26	—
630	Portage Creek No. 1	2	Seward Highway	79.0	55.8	1,886	138.6	11	2.71	—
634	Twenty Mile River	2	Seward Highway	80.7	163	2,200	112.0	11	5.10	—
639	Glacier Creek	2	Seward Highway	89.7	58.2	2,610	70.0	10	.00	—
643	Bird Creek	2	Seward Highway	101.4	75.9	2,645	49.0	6	.07	—
644	Indian Creek	2	Seward Highway	102.9	17.6	2,331	34.0	6	.00	—
646	Gakona River	3	Tok Cutoff Highway	1.8	620	3,030	25.0	-9	8.00	18.00
648	Sinona Creek	3	Tok Cutoff Highway	34.6	157.8	2,758	18.5	-12	3.38	—

649	Chistochina River No. 1	3	Tok Cutoff Highway	35.4	623	3,761	40.0	-10	3.99	—
650	Chistochina River No. 2	3	Tok Cutoff Highway	35.6	623	3,761	40.0	-10	3.99	—
651	Indian River	3	Tok Cutoff Highway	43.9	108	3,468	19.0	-16	1.03	57.30
653	Porcupine Creek	3	Tok Cutoff Highway	64.1	23.6	3,957	25.4	-18	.95	—
654	Slana River	3	Tok Cutoff Highway	75.6	327	3,962	42.2	-18	1.12	—
658	Little Tok River	3	Old Tok Highway	.0	263	3,720	34.8	-19	.72	—
663	Tok River	3	Tok Cutoff Highway	104.1	762	4,049	34.7	-21	.44	—
666	South Fork Anchor River	2	Sterling Highway	161.0	137	1,147	24.8	16	.05	—
668	Deep Creek	2	Sterling Highway	136.7	221	1,326	23.0	12	13.21	—
669	Ninilchik River	2	Sterling Highway	135.0	141	650	21.1	11	.10	—
670	Kasilof River	2	Sterling Highway	109.4	738	1,810	50.0	10	15.00	—
671	Kenai River at Soldotna	2	Sterling Highway	96.0	2,010	1,750	50.0	8	5.00	—
673	Kenai River at Schooners Bend	2	Sterling Highway	53.1	758	2,704	96.6	10	4.71	—
674	Cooper Creek	3	Sterling Highway	50.6	48.6	2,486	59.7	9	6.84	—
675	Kenai River Cooper Land	2	Sterling Highway	47.8	642	2,736	104.5	10	4.93	—
678	Little Goldstream Creek	3	Parks Highway	314.8	41.7	678	15.0	-17	.35	—
685	Maclaren River	2	Denali Highway	41.9	274	4,367	47.7	-6	1.56	—
686	Clearwater Creek	3	Denali Highway	55.9	126	4,036	29.4	-5	.87	—
687	Susitna River	2	Denali Highway	79.2	919	4,421	51.7	-6	1.78	—
688	Canyon Creek	3	Denali Highway	94.8	15.0	3,429	25.0	-6	6.64	—
690	Seattle Creek	3	Denali Highway	110.9	34.7	3,464	25.0	-6	.32	—
693	Carlo Creek	3	Parks Highway	224.0	18.7	3,979	26.0	-7	.00	—
694	Nenana River Park Bend	3	Parks Highway	231.2	1,180	3,545	32.6	-6	2.19	—
695	Riley Creek	3	Parks Highway	237.2	130	3,716	31.9	-7	.22	—
697	Kingfisher Creek	3	Parks Highway	238.2	.6	3,043	25.0	-6	.00	—
732	Gold Creek	1	Egan Drive	1.1	9.8	2,242	125.7	22	.07	—
735	Eagle River	1	Glacier Highway	28.3	48.9	3,061	96.9	22	.33	—
736	Herbert River	1	Glacier Highway	27.6	56.7	2,787	108.0	22	.83	—
737	Mendenhall River	1	Glacier Highway	.0	105	2,891	134.0	21	1.53	—
742	Chilkat River	1	Haines Highway	23.8	794	3,920	85.3	-2	1.38	—
749	Carlanna Creek	1	North Tongass Highway	.0	2.5	1,323	180.0	28	.93	—
799	Long Creek	3	Steese Highway	45.5	9.2	1,874	15.0	-18	.00	—
816	Crooked Creek	3	Steese Highway	40.4	9.1	1,800	15.0	-18	.00	—
819	Deadwood Creek	3	Circle Hot Springs	2.8	35.3	2,334	15.0	-24	.00	—
822	Belle Creek	3	Steese Highway	41.5	18.1	1,917	15.0	-17	.00	—
823	McKay Creek	3	Steese Highway	42.7	7.4	1,909	18.0	-18	.00	—
826	Reed Creek	3	Steese Highway	88.6	4.3	3,254	20.0	-22	.00	—
827	Willow Creek	3	Steese Highway	95.7	3.3	2,950	20.0	-22	.00	—
828	Bear Creek	3	Steese Highway	97.6	9.9	3,304	18.3	-22	.00	—
831	Mammoth Creek	3	Steese Highway	116.5	40.4	2,869	15.0	-23	.00	—

Table 1. Basin characteristics at selected bridge sites in Alaska—Continued

[Bridge ADOT&PF number: **Bold** indicates that corresponding basin-characteristics data are from Jones and Fahl (1994). Flood-frequency area designations are from Jones and Fahl (1994). ADOT&PF, Alaska Department of Transportation and Public Facilities. —, not applicable]

Bridge		Flood-frequency area	Route or junction		Basin		Mean annual precipitation (inches)	Mean minimum January temperature (degrees Fahrenheit)	Subareas relative to basin area	
ADOT&PF number	Name		Name	Mile	Area (square miles)	Mean elevation (feet)			Lakes or ponds (percent)	Forest (percent)
832	Boulder Creek	3	Steese Highway	125.3	9.8	4,300	40.0	0	0.00	3.00
833	Albert Creek	3	Steese Highway	131.2	113	1,757	15.0	-23	.17	—
836	Chatanika River	3	Elliott Highway	11.0	529	1,921	17.3	-18	.06	—
838	Washington Creek	3	Elliott Highway	18.3	46.2	1,490	15.0	-17	.00	—
839	South Fork 40 Mile River	5	Taylor Highway	75.3	2,730	2,777	15.1	-22	.22	81.27
844	Heney Creek	1	Point Whitshed Road	.0	1.8	958	158.4	17	.00	—
851	Dry Creek	3	Parks Highway	249.8	38.3	3,284	25.0	-12	.00	—
852	Dry Creek Overflow	3	Parks Highway	249.3	3.0	2,141	25.0	-12	.00	—
853	Salmon Creek	1	Nash Road	3.3	41.3	1,542	110.0	12	5.33	—
854	Small Creek	1	Nash Road	1.9	10.7	1,850	110.0	12	.40	—
855	Small Creek	1	Nash Road	2.0	10.7	1,850	110.0	12	.40	—
857	Nenana River at Healy	3	Healy Road	3.2	1,910	3,500	34.0	-8	1.00	—
858	Slana River	3	Nabesna Road	1.5	720	3,707	34.0	-15	.92	—
861	Jack Creek	3	Nabesna Road	37.1	115	4,340	30.0	-19	1.00	—
864	Trollers Creek	1	Knudson Cove Road	.0	1.2	466	114.7	29	.63	—
865	Indian River	1	Sawmill Creek Road	1.0	12.0	1,275	105.9	28	.00	—
868	Falls Creek	1	Mitkof Highway	10.8	16.6	720	98.6	25	.10	—
888	Carlson Creek	3	Tok Cutoff Highway	67.8	10.4	3,832	25.0	-18	2.15	—
940	Fish Camp Creek	3	Northway Road	2.6	19.3	1,706	15.0	-23	14.88	—
969	Campbell Creek Lake Otis	2	Lake Otis Parkway	.0	45.2	2,387	24.4	6	.83	—
970	Campbell Creek Arctic	2	Arctic Boulevard	.0	69.7	1,879	23.0	5	1.65	—
971	Campbell Creek	2	C Street Northbound	—	69.7	1,921	23.0	5	1.65	—
979	North Fork Anchor River	2	Chakok Road	—	224	1,111	23.0	14	.00	—
983	Red Cloud River	1	Kodiak Island Highway	7.9	3.8	1,137	100.0	24	.00	—
986	Buskin River No. 5	1	Kodiak Island Highway	6.8	18.9	878	100.0	23	2.70	—
988	Buskin River No. 7	1	Kodiak Island Highway	1.5	12.0	928	100.0	23	3.77	—
989	Sargent Creek	1	Kodiak Island Highway	10.3	11.7	1,399	100.0	24	.42	—
992	Salonie Creek No. 1	1	Kodiak Island Highway	12.4	16.2	1,249	100.0	24	.07	—
999	Glacier Creek	2	Alyeska Road	2.3	45.9	2,525	70.0	10	.00	—
1008	Cripple Creek	3	Chena Ridge/Pump Road	12.1	40.9	959	15.0	-18	.85	—

1009	Goldstream Creek	3	Ballaine Road	.0	74.8	1,249	15.0	-18	.00	—
1025	Resurrection Creek	2	Hope Road	16.9	161	2,584	25.0	7	.36	—
1075	Dragonfly Creek	3	Parks Highway	242.4	.7	3,021	25.0	-8	.00	—
1085	Hartney Bay	1	Point Whitshed Road	2.2	8.0	837	106.9	17	.29	—
1092	Little Tok River	3	Tok Cutoff	83.1	353	3,733	20.0	-19	.58	46.20
1094	Situk River	1	Yakut/Alsek Road	8.7	35.8	379	140.0	18	6.74	—
1098	Smith Creek	3	Deering Road	25.7	22.3	34	10.0	-16	10.16	—
1121	Knik River No. 1	2	Glenn Highway	30.3	1,220	3,926	100.0	9	3.87	—
1124	Matanuska River	2	Glenn Highway	31.4	2,100	3,950	35.0	4	.00	—
1131	Ketchikan Creek Fair Street	1	Ketchikan City Street	.0	12.3	1,455	189.4	28	8.48	—
1132	Ketchikan Creek Park–Upper Crossing	1	Ketchikan City Street	.0	12.4	1,440	189.0	28	8.37	—
1141	Antler Creek	3	Parks Highway	244.6	1.4	2,965	29.0	-8	.00	9.40
1142	Bison Gulch	3	Parks Highway	243.6	1.1	3,250	29.0	-9	.00	19.40
1143	Nenana River at Moody	3	Parks Highway	242.8	1,890	3,703	34.0	-7	1.43	—
1145	Hornet Creek	3	Parks Highway	240.2	2.2	3,410	25.0	-9	.00	—
1146	Iceworm Gulch	3	Parks Highway	240.0	1.5	3,381	25.0	-9	.00	—
1147	Nenana River Park Station	3	Parks Highway	237.9	1,870	3,713	34.0	-7	1.45	—
1149	Kenai River at Kenai	2	Kenai River Road	—	2,140	1,655	50.0	8	6.37	—
1153	Whipple Creek	1	North Tongass Highway	11.6	5.4	989	140.3	29	.00	—
1155	Peters Creek–North Crossing	2	Glenn Highway	149.3	87.8	3,436	36.0	2	.00	—
1156	Wasilla Creek	2	Parks Highway	37.8	38.9	796	19.0	5	.60	79.00
1157	Campbell Creek East Frontage	2	Brayton Drive	124.9	46.0	2,353	24.3	5	.81	—
1193	Chokosna River	3	McCarthy Road	60.6	37.6	4,089	24.0	-7	.03	—
1194	Gilahina River	3	McCarthy Road	62.7	50.2	3,635	19.0	-6	.23	—
1196	Lost River	1	Lost River Road	.0	19.3	46	140.0	19	.23	—
1203	Solomon Creek	1	Dayville Road	.0	19.2	2,239	116.2	9	1.15	—
1204	Abercrombie Creek	1	Dayville Road	.0	6.8	2,325	110.0	9	.00	—
1207	Lowe River Main Channel	1	Dayville Road	.0	358	3,211	125.7	7	.05	—
1208	Lowe River North Channel	1	Dayville Road	.0	358	3,211	125.7	7	.05	—
1213	Hess Creek	3	Dalton Highway	23.8	666	1,362	14.9	-16	.33	—
1220	Cowee Creek	1	Glacier Highway	1.9	43.1	2,072	89.6	22	.00	—
1222	Tiekel River No. 2	3	Richardson Highway	50.7	99.9	3,572	104.1	-2	.10	—
1228	Antlen River	1	Yakut/Alsek Road	24.9	1.7	96	160.0	18	3.29	—
1229	Ahrnklin River	1	Yakut/Alsek Road	25.3	31.5	1,238	160.4	18	.07	—
1230	Eklutna River Northbound	2	Glenn Highway	26.3	170	3,340	47.0	6	2.94	—
1234	Ketchum Creek	3	Circle Hot Springs	5.7	12.3	2,047	15.0	-24	.00	—
1241	Little Nelchina River	3	Glenn Highway	137.4	283	3,687	20.0	-8	1.11	—
1243	Nenana River at Windy	3	Parks Highway	215.6	710	3,506	33.0	-6	2.83	—
1250	Tulsona Creek	3	Tok Cutoff Highway	17.6	93.9	2,162	17.0	-12	7.47	—
1255	Fish Creek	3	Dalton Highway	114.0	102	2,199	17.7	-18	.00	—

Table 1. Basin characteristics at selected bridge sites in Alaska—Continued

[Bridge ADOT&PF number: **Bold** indicates that corresponding basin-characteristics data are from Jones and Fahl (1994). Flood-frequency area designations are from Jones and Fahl (1994). ADOT&PF, Alaska Department of Transportation and Public Facilities. —, not applicable]

Bridge		Flood-frequency area	Route or junction		Basin		Mean annual precipitation (inches)	Mean minimum January temperature (degrees Fahrenheit)	Subareas relative to basin area	
ADOT&PF number	Name		Name	Mile	Area (square miles)	Mean elevation (feet)			Lakes or ponds (percent)	Forest (percent)
1256	North Fork Bonanza Creek	3	Dalton Highway	125.7	100	2,123	18.5	-17	0.00	—
1257	South Fork Bonanza Creek	3	Dalton Highway	124.7	122	1,994	18.2	-18	.00	—
1258	Prospect Creek	3	Dalton Highway	135.1	108	1,826	17.2	-18	.04	—
1259	Jim River No. 1	3	Dalton Highway	140.1	258	2,456	17.7	-17	.59	—
1260	South Fork Koyukuk River	3	Dalton Highway	156.1	696	2,417	19.9	-17	1.16	—
1261	Middle Fork Koyukuk River No. 1	3	Dalton Highway	188.5	1,160	3,267	27.7	-17	.69	—
1273	Chester Creek	1	C Street	.0	29.2	658	22.1	5	.20	—
1274	Monashka Creek	1	Pillar Creek Road	10.8	5.3	881	100.0	24	1.60	—
1282	Middle Fork Koyukuk River No. 2	3	Dalton Highway	190.8	904	3,287	27.4	-17	.87	—
1283	Middle Fork Koyukuk River No. 3	3	Dalton Highway	204.3	801	3,420	27.7	-17	.96	—
1284	Middle Fork Koyukuk River No. 4	3	Dalton Highway	204.5	801	3,420	27.7	-17	.96	—
1295	Box Canyon Creek	1	Resurrection River Road	.0	2.1	1,567	110.0	11	.00	—
1320	Ship Creek	2	Reeve Boulevard	.0	109	2,488	31.3	6	.09	—
1329	Little Chena River	3	Nordale Road	.0	399	1,506	15.0	-18	.02	—
1332	Slate Creek	3	Dalton Highway	175.1	74.1	2,299	24.2	-17	.37	—
1333	Atigun River No. 2	3	Dalton Highway	271.1	297.4	4,448	23.0	-16	1.47	—
1334	No Name Creek	3	Dalton Highway	79.1	123	1,125	16.9	-18	.19	—
1335	Minnie Creek	3	Dalton Highway	187.2	52.1	3,221	25.0	-17	.72	—
1336	Hammond River	3	Dalton Highway	190.6	246	3,207	28.9	-17	.09	—
1337	Dietrich River	3	Dalton Highway	207.0	349	3,554	29.8	-17	.04	—
1338	Kanuti River	3	Dalton Highway	105.7	159	2,095	17.9	-17	.37	—
1341	Eagle River South Crossing	2	Glenn Highway	139.9	192	3,120	40.0	6	.50	15.00
1344	Peters Creek Southbound	2	Glenn Highway	149.2	87.8	3,436	36.0	2	.00	—
1350	Campbell Creek West Frontage	2	Homer Drive	124.9	46.0	2,353	24.3	5	.81	—
1355	Harris River	1	Hydaburg Road	.0	13.2	1,367	100.0	30	.38	—
1356	Fubar Creek	1	Hydaburg Road	.2	3.8	1,033	100.0	30	.29	—
1363	Steelhead River	1	Big Salt Lake Road	12.3	16.5	1,102	100.0	30	.03	—
1383	Lowe River Lower Keystone	1	Richardson Highway	15.3	218	3,538	82.0	7	.04	—
1384	Lowe River Upper Keystone	1	Richardson Highway	15.4	218	3,538	82.0	7	.04	—
1389	Unnamed Creek	1	Exit Glacier Road	—	3.0	2,735	110.0	12	.00	—

1390	Resurrection River	1	Exit Glacier Road	—	106	2,391	106.0	12	0.57	—
1394	Globe Creek	3	Elliott Highway	37.0	31.1	1,614	15.0	-17	.00	—
1400	Tatalina River	3	Elliott Highway	44.9	86.9	1,251	15.0	-16	.00	—
1436	Jim River No. 2	3	Dalton Highway	141.0	257	2,457	17.8	-18	.58	—
1437	Jim River No. 3	3	Dalton Highway	144.1	224	2,580	17.7	-17	.09	—
1439	Atigun River No. 1	3	Dalton Highway	253.1	48.8	4,899	27.3	-16	.00	—
1443	Campbell Creek	2	Minnesota Drive Southbound	.0	67.4	1,750	23.3	5	.78	—
1444	Campbell Creek at Minnesota Drive	2	Minnesota Drive Frontage	.0	67.4	1,750	23.3	5	.78	—
1445	Campbell Creek at Minnesota Drive	2	Minnesota Drive Frontage	.0	67.4	1,750	23.3	5	.78	—
1455	Control Creek	1	Thorne Bay Road	1.4	9.6	867	100.0	29	2.07	—
1461	Goose Creek	1	Thorne Bay Road	11.7	19.3	787	104.7	29	2.59	—
1462	Thorne River	1	Thorne Bay Road	13.4	151	852	103.2	30	2.25	—
1508	Campbell Creek Dimond Drive	2	Dimond Drive	.0	69.3	1,704	23.2	5	.76	—
1513	Fort Hamlin Hills Creek	3	Dalton Highway	72.6	36.0	1,249	16.1	-17	.18	—
1514	Gold Creek	3	Dalton Highway	197.0	16.4	2,737	25.0	-17	.00	—
1519	Roche Moutonnee Creek	3	Dalton Highway	265.1	31.7	5,097	25.0	-16	.00	—
1520	Holden Creek	3	Dalton Highway	267.5	11.0	4,534	17.0	-16	.00	—
1521	Dan Creek	3	Dalton Highway	330.8	34.8	1,424	10.0	-16	5.46	—
1536	False Pass Creek	1	Airfield Road	.0	7.3	1,177	70.0	27	.00	—
1560	Douglas Creek	3	Dalton Highway	141.8	16.5	2,051	17.0	-17	.06	—
1629	Chester Creek	1	A Street	.0	29.2	658	22.1	5	.20	—
1676	Starrigavan Creek	1	Rodman Bay Road	.6	6.4	1,247	104.2	28	.29	—
1694	Campbell Creek	2	Minnesota Drive Northbound	.0	67.4	1,750	23.3	5	.78	—
1746	Klutina River	3	Richardson Highway	.0	890	3,371	82.4	-7	3.71	—
1786	Jordan Creek, Juneau	1	Trout Street	.0	.9	315	90.0	22	.00	—
1820	Salmon Creek	1	Bruno Road	.0	6.2	2,746	110.0	12	.00	—
1864	Eklutna River Southbound	2	Glenn Highway	26.3	170	3,340	47.0	6	2.94	—

Manning's *n* values (roughness coefficients) were assumed to be 0.035 in the main channel and 0.10 in the overbank area. These typical values were changed if information from photographs, site visits, surveys, or other sources indicated a more appropriate value. In general, winding natural streams filled with weeds have *n* values of about 0.035 and mountain streams flowing over rocky beds have *n* values on the order of 0.04–0.05 (Fetter, 1994).

Friction slope and valley slope were estimated from topographic information (from 1:63,360-scale USGS quadrangle maps or from bridge-plan maps), from discharge measurements (by back-calculation using Manning's equation), or from information derived through surveying or by a site visit. Slopes for many of the Phase I sites were estimated from USGS topographic maps and have associated uncertainties on the order of ±50 percent.

Bridge hydraulic parameters—including bridge width, embankment slope and elevation, low-steel elevation, pier widths, and bridge type—were obtained from existing bridge plans.

Automated procedures were developed to increase the efficiency and accuracy of entering this information. The process is outlined as follows:

(1) Digitize bridge, full-valley, and pier information from existing bridge plans using AutoCAD. Export data to a spreadsheet.
(2) Modify cross sections with improved information from measurements or surveys.
(3) Enter additional hydraulic parameters into the Excel workbook.
(4) Run a series of Visual Basic for Applications programs that use the hydraulic data to create a WSPRO input file.
(5) Export the WSPRO input file to the UNIX system for model processing.

Computation of Water-Surface Profile Using WSPRO Step-Backwater Model

Water-surface profiles for the 100- and 500-year flood discharges were calculated using the WSPRO step-backwater model (Shearman, 1990), which is a water-surface profile computational model for one-dimensional, gradually varied, steady flow in open channels.

Typical cross sections used in the WSPRO model are shown in figure 1 and were described in detail by Shearman (1990). Cross sections are referenced as follows: Sections upstream from the bridge are called approach sections; sections at the bridge location without the bridge structure, full-valley sections; sections with the bridge structure in place, bridge sections; and sections downstream from the bridge, exit sections. One bridge length (*b*) is the recommended distance between cross sections (Shearman, 1990).

Hydraulic models resulting from WSPRO computations can vary depending on the information available; however, most of the models used in this study were one of two types:

(1) Models based on the bridge and full-valley cross section. Three exit and one approach section were templated from the full-valley section.
(2) Models based on the bridge and full-valley cross section and an approach section read from the bridge plan topographic map. Three exit sections were templated from the full-valley section.

Channel slope is an important parameter for this method because it is used both to template the elevation change for the additional sections and to estimate the starting friction slope for the model. The chosen slope affects the depth and velocity of the flow, both of which are important factors in scour computations. WSPRO model parameters are reviewed and adjusted as needed to ensure that model parameters, and the resulting output, are within known ranges of natural physical systems. Flow properties for the hydraulic sections were generated from WSPRO computations for use in scour equations.

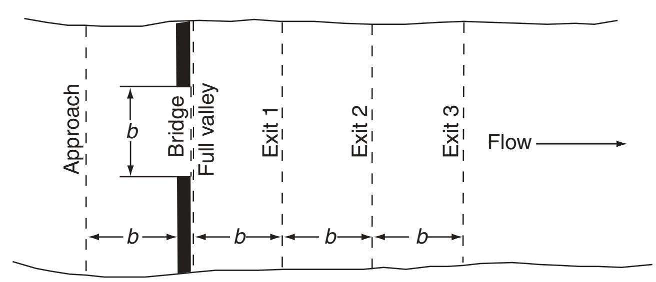

Figure 1. Plan view showing approach, bridge, full-valley, and exit cross sections used in water-surface-profile computational model WSPRO. *b*, bridge length.

ESTIMATES OF CONTRACTION SCOUR AND PIER SCOUR

Scour was estimated by applying FWHA techniques and equations presented in HEC–18 (Richardson and Davis, 1995), assuming WSPRO model-derived hydraulic properties. In this Phase I scour assessment, the USGS and ADOT&PF chose to compute the two principal types of scour that occur at bridges: contraction scour and local scour at piers. Although techniques for estimating abutment scour exist, they have large associated uncertainties. Furthermore, most abutments on Alaskan bridges are armored by riprap to inhibit local scour (Mark Miles, Alaska Department of Transportation and Public Facilities, oral commun., 1995).

Contraction scour is affected by the sediment-transport characteristics of the stream; therefore, HEC–18 (Richardson and Davis, 1995) included contraction-scour equations for both live-bed and clear-water sediment-transport conditions. For this study, maximum contraction scour was estimated (table 2) assuming live-bed transport at all selected bridge sites. Live-bed transport is a reasonable assumption for Alaska's alluvial streams and rivers and yields a more conservative estimate of scour. The bed material was assumed to have a median diameter of 10 millimeters (0.34 in), and an associated fall velocity of 2.60 ft/s, at all bridges except bridge 331 and 332 on the Copper River Delta. Median diameter grain size at bridge 331 is 15 millimeters (0.59 in) and at bridge 332 is 0.4 millimeter (0.03 in) (Brabets, 1994). Bed-material fall velocities were derived according to methods presented in HEC–18 (Richardson and Davis, 1995, p. 32), assuming a water temperature of 32°F. Thus, the derived fall velocity for bed material at bridge 331 is 3.67 ft/s and at bridge 332 is 0.14 ft/s.

Pier scour (table 2) was calculated according to procedures outlined in HEC–18 (Richardson and Davis, 1995). Flow at the bridge was divided into 20 stream tubes of equal conveyance by using an option in the WSPRO model program. The highest velocity stream tube was selected and assumed to be directed at the widest pier. This assumption provides the maximum estimate of pier scour. The HEC–18 pier-scour equation is recommended to be used for both live-bed and clear-water sediment-transport conditions and is relatively sensitive to changes in pier geometry and angle of attack. Scour computations were automated using Excel spreadsheet and Visual Basic programs to extract the required variables from the WSPRO output.

At several sites, pressure scour is a potential problem because estimated floods partly or fully submerge the bridge. These sites are noted in the "Comments" column of table 2. However, pressure-scour values were not calculated because of the lack of a generally accepted method for estimating pressure-flow scour under live-bed conditions, according to HEC–18 (Richardson and Davis, 1995).

Four selected examples of Phase I bridge-scour analyses are summarized in the appendix. The examples were selected to illustrate the wide range of information that may be available for a given site and the procedures used to estimate scour. Examples sites included in the appendix are bridge 528, Clear Creek; bridge 407, Scott Glacier No. 7; bridge 527, Salcha River; and bridge 857, Nenana River at Healy.

SUMMARY AND CONCLUSIONS

Potential scour computations were completed for 325 of the 340 sites selected for assessment by ADOT&PF. The 15 sites not completed either are affected tidally or do not have bridge plans readily available. Maximum contraction scour and local pier scour were calculated for each bridge by using FHWA scour equations from HEC–18 (Richardson and Davis, 1995). The discharges used to calculate scour were the 100- and 500-year floods. Floods were calculated using methods outlined in Jones and Fahl (1994).

Calculated scour depths reported herein represent conditions at a bridge at a single point in time. Channel migration and aggradation or degradation of the streambed that may have occurred during the period of streamflow since the bridge was constructed were not considered in this preliminary assessment. However, greater depths of scour suggest a greater likelihood of scour-related problems occurring at a bridge and, as such, the scour depths summarized in table 2 provide a valuable quantitative scour assessment that can help ADOT&PF identify the need for additional investigation at a particular site. This screening method has the advantage of providing scour depths and bed elevations for comparison with foundation elevations without the time and expense of a field survey. Examples of automated scour analysis for ADOT&PF bridges 407, 527, 528, and 857 are included in the appendix.

Table 2. Computed Phase I contraction- and pier-scour depths at selected bridge sites in Alaska

[Manning's roughness coefficients are for main channel at bridge. ADOT&PF, Alaska Department of Transportation and Public Facilities. Q_{100}, 100-year flood; Q_{500}, 500-year flood. —, not applicable]

Bridge		Discharge (cubic feet per second)		Angle of attack (degrees)	Valley slope (feet per foot)	Manning's roughness coefficient n	Computed scour depth (feet)				Comments
							Contraction scour		Pier scour		
ADOT&PF number	Name	Q_{100}	Q_{500}				Q_{100}	Q_{500}	Q_{100}	Q_{500}	
201	North Slough Tanana River	12,400	15,500	0	0.0080	0.035	0.3	0.4	8.5	9.0	
202	Tanana River at Nenana	162,000	203,000	15	.0010	.030	.2	.7	43.5	44.8	
205	Copper River at Chitina	126,000	151,000	0	.0010	.030	1.0	1.1	13.7	14.0	
206	Copper River	422,000	538,000	0	.0006	.030	.5	.4	32.8	34.8	
208	Roslyn Creek	2,390	2,950	0	.0070	.035	.0	.0	4.0	4.1	
209	Noyes Slough (Aurora)	2,100	2,100	0	.0005	.035	.8	.8	2.9	2.9	
210	Willow Creek	7,510	9,550	0	.0008	.035	.0	.0	4.8	5.0	
211	Little Willow Creek	4,510	5,680	0	.0007	.035	.6	.6	4.4	4.6	
212	Kashwitna River	3,920	4,650	0	.0020	.035	.0	.0	3.7	3.9	
213	Sheep Creek	3,120	3,820	0	.0022	.035	.1	.0	4.4	4.5	
215	Montana Creek	8,270	11,700	0	.0040	.035	.0	.0	5.7	6.1	
216	Nenana River at Rex	30,100	35,900	0	.0030	.035	6.0	7.3	—	—	
217	Mendenhall River	17,200	20,700	0	.0023	.040	3.7	4.4	9.5	10.1	
230	Sheridan Glacier No. 3	16,300	20,200	20	.0015	.030	1.6	2.1	18.4	25.0	Pressure flow
231	Chena River	12,000	12,000	0	.0002	.030	.1	.1	4.5	4.5	
232	North Fork Chena River	16,270	18,240	0	.0020	.030	.1	.1	4.1	4.2	
233	North Fork Chena River	22,100	27,400	10	.0015	.035	8.3	15.9	8.0	8.8	
234	North Fork Chena River	8,800	10,800	10	.0050	.035	4.9	7.4	6.5	6.7	
235	North Fork Chena River	9,240	11,200	0	.0030	.035	.5	.5	4.0	4.2	
237	North Fork Chena River	9,220	11,200	0	.0050	.035	.0	.0	3.8	3.9	
238	Angel Creek	1,630	2,090	0	.0120	.035	.0	.0	—	—	
239	West Fork Chena River	9,380	11,300	0	.0070	.035	1.0	1.0	4.6	4.7	
240	Little Susitna River	3,800	4,570	30	.0003	.035	.0	.0	10.3	10.8	
242	North Fork Chena River	4,220	5,220	0	.0070	.045	.8	.8	4.5	4.7	
254	Susitna River at Sunshine	186,000	206,000	0	.0020	.030	6.2	6.5	16.7	17.3	
255	Chulitna River	83,200	103,000	20	.0080	.030	.4	.4	23.8	25.0	
256	Troublesome Creek	2,250	2,900	0	.0100	.040	.9	1.0	2.8	3.1	
257	Byers Creek	2,030	2,580	10	.0025	.035	1.0	1.2	3.2	3.4	
259	Honolulu Creek	3,180	3,900	5	.0500	.035	1.6	1.9	5.3	5.6	
260	East Fork Chulitna River	6,680	8,070	20	.0100	.045	.4	.4	9.1	9.7	

261	Middle Fork Chulitna River	1,880	2,300	0	0.0080	0.045	0.0	0.0	2.3	2.4	
263	Chena River University Ave.	12,000	12,000	0	.00015	.030	.4	.4	4.8	4.8	
266	Cripple River	2,480	3,060	0	.0040	.035	.6	.8	3.4	3.6	
268	Fox River	2,380	2,980	0	.0030	.035	.0	.0	3.3	3.5	
269	Bear River	2,030	2,560	0	.0040	.035	.0	.0	—	—	
270	Little Chena River	7,050	11,000	10	.0005	.030	2.1	8.0	6.6	7.2	
272	Hot Springs Slough	1,550	2,030	0	.0005	.035	.1	.1	4.9	5.2	
274	Hutlinana Creek	3,290	4,130	0	.0050	.035	1.5	2.0	—	—	
275	North Fork 12 Mile Creek	1,150	1,470	0	.0200	.045	.9	1.3	2.7	3.0	
277	Taylor Creek	1,350	2,360	0	.0027	.035	4.4	.9	—	—	Pressure flow
281	Jack River	6,750	8,230	0	.0050	.035	.0	.0	3.2	3.4	
283	Noyes Slough (Illinois)	2,100	2,100	0	.0005	.035	.3	.3	2.8	2.8	
284	American River	6,830	8,510	0	.0050	.035	.4	.4	3.8	4.0	
286	Deadman (Small) Creek	911	1,130	0	.0170	.035	.3	.4	3.2	3.4	
287	Olds River	4,230	5,270	0	.0065	.035	.4	.4	3.9	4.0	
288	Tonsina River (Lower)	26,100	29,500	0	.0050	.035	.5	.5	8.5	8.7	
290	East Fork Twin Creek	1,120	1,320	0	.0160	.035	.2	.2	3.4	3.5	
291	Kalsin Creek	2,960	3,690	0	.0080	.035	.0	.0	3.4	3.4	
292	Myrtle Creek	1,530	1,790	0	.0080	.047	.0	.0	2.5	2.7	
293	Pass Creek	1,230	1,590	0	.0055	.035	1.8	2.2	2.4	2.6	
295	Noyes Slough (Minnie Street)	2,100	2,100	10	.0005	.035	.3	.3	6.9	6.9	
297	Forty Mile River	76,700	90,000	0	.0010	.035	.4	.3	15.5	16.0	
298	O'Brien Creek	6,950	9,320	0	.0033	.040	.1	.1	6.0	6.4	
299	Walker Fork 40 Mile River	7,440	9,850	0	.0017	.035	2.9	4.1	5.6	6.0	
302	Jack River	6,090	7,380	0	.0040	.035	.0	.0	3.4	3.4	
303	O'Connor Creek	827	1,080	0	.0072	.035	.1	.2	—	—	
310	Pilgrim River	11,700	13,900	0	.0020	.035	2.1	2.6	6.6	7.0	
311	Bear Creek	704	957	0	.0280	.035	.3	.3	3.9	4.2	
312	Jenny M Creek	895	1,160	0	.0120	.035	.1	.1	—	—	
313	Panguingue Creek	1,180	1,490	0	.0170	.035	.1	.2	3.3	3.5	
323	Penny River	1,540	1,940	0	.0048	.035	2.7	3.1	—	—	
324	Snake River	5,060	5,830	0	.0008	.044	2.5	2.7	7.9	8.3	
325	West Fork Tolovana River	8,380	10,200	0	.0035	.035	.3	.4	4.4	4.6	
327	Station 355 Creek	1,040	1,290	0	.0050	.035	.6	.7	2.9	3.0	
328	Granite Creek	1,100	1,360	0	.0050	.045	.9	1.2	2.8	3.0	

Table 2. Computed Phase I contraction- and pier-scour depths at selected bridge sites in Alaska—Continued

[Manning's roughness coefficients are for main channel at bridge. ADOT&PF, Alaska Department of Transportation and Public Facilities. Q_{100}, 100-year flood; Q_{500}, 500-year flood. —, not applicable]

Bridge		Discharge (cubic feet per second)		Angle of attack (degrees)	Valley slope (feet per foot)	Manning's roughness coefficient *n*	Computed scour depth (feet)				Comments
							Contraction scour		Pier scour		
ADOT&PF number	Name	Q_{100}	Q_{500}				Q_{100}	Q_{500}	Q_{100}	Q_{500}	
331	Copper River Delta	103,000	130,000	0	.00056	.030	3.4	3.9	13.3	14.1	Grain size 15 millimeter (0.59 in)
332	Copper River Delta	47,200	59,900	10	.00018	.030	2.6	2.8	10.3	10.8	Grain size 0.4 millimeter (0.03 in)
333	Copper River Delta	12,600	16,000	25	.0002	.030	.8	1.4	6.5	6.8	
334	Copper River Delta	42,100	53,400	20	.0004	.030	1.2	.9	24.7	25.7	
336	Copper River Delta	3,590	4,560	0	.0001	.030	1.0	1.1	4.8	4.9	
339	Copper River Delta	30,800	39,000	0	.0007	.030	3.4	4.0	7.7	8.1	
340	Copper River Delta	30,800	39,000	25	.0016	.030	5.0	6.0	9.6	10.4	
342	Copper River Delta	144,000	182,000	0	.0005	.029	1.9	2.0	8.9	9.3	Pressure flow (Q_{500})
344	Copper River Delta	3,080	3,900	0	.0005	.030	.1	.1	4.2	4.3	
345	Copper River Delta	7,700	9,760	0	.0010	.030	.0	.0	4.8	5.1	
348	Scott Glacier No. 1	1,880	2,320	0	.0014	.035	3.0	3.2	3.0	3.1	
349	Scott Glacier No. 2	4,480	5,520	0	.0007	.035	6.1	7.2	3.7	3.8	
350	Scott Glacier No. 3	—	—	—	—	—	—	—	—	—	Site visit indicated inactive channels
351	Scott Glacier No. 4	—	—	—	—	—	—	—	—	—	Site visit indicated inactive channels
352	Scott Glacier No. 5	—	—	—	—	—	—	—	—	—	Site visit indicated inactive channels
355	Birch Creek	36,000	42,000	0	.0011	.030	.6	.8	9.1	9.5	
357	Goldstream Creek	3,140	4,000	0	.0020	.035	.0	.0	3.7	4.1	
359	Spinach Creek	687	902	0	.0050	.035	.6	.9	—	—	
367	Sheridan Glacier East Channel	—	—	—	—	—	—	—	—	—	
381	Eyak River	4,980	6,160	0	.0002	.035	1.6	2.1	2.8	2.9	
386	Felton Creek	1,050	1,300	0	.0070	.035	.1	.1	3.4	3.6	
390	Chena River (Cushman)	12,000	12,000	0	.0006	.035	.0	.0	10.8	10.8	
396	Deception Creek	1,600	2,060	0	.0040	.035	.3	.3	3.3	3.5	
401	Moose Creek	4,360	7,010	0	.0100	.038	2.0	9.6	—	—	Pressure flow (Q_{500})
403	Portage Creek Overflow No. 1	2,500	3,000	20	.0060	.035	.0	.0	3.1	4.7	
404	Portage Creek Overflow No. 2	5,400	7,140	0	.0050	.035	.0	.0	6.3	7.0	
405	Portage Creek Overflow No. 3	1,350	2,360	0	.0050	.035	4.4	.9	—	—	Pressure flow
406	Scott Glacier No. 6	13,600	16,800	0	.0018	.035	.2	.2	3.7	3.9	
407	Scott Glacier No. 7	1,760	2,170	10	.0010	.035	3.9	4.5	4.6	4.9	
408	Scott Glacier No. 8	5,430	6,690	0	.0010	.035	3.9	4.3	3.9	4.0	

411	Scott Glacier No. 11	3,610	4,450	0	.0018	.035	.2	.3	3.4	3.5	
419	Gold Run Creek	1,870	2,390	0	.0025	.035	.0	.0	2.8	3.0	
421	Feather River	1,620	2,050	0	.0140	.035	.0	.0	3.6	3.8	
422	Tisuk River	1,960	2,490	30	.0050	.035	1.2	1.4	7.3	7.8	
423	Eldorado Creek	826	1,160	0	.0180	.038	9.1	10.9	—	—	
430	Faith Creek	5,750	9,480	0	0.0080	0.045	12.5	5.6	4.9	5.0	Pressure flow
440	Tolovana River	4,810	5,970	10	.0030	.035	.0	1.2	7.6	7.6	
441	Mosquito Fork	17,400	22,700	0	.0023	.035	.4	.5	6.6	7.0	
442	West Fork Dennison River	10,600	14,100	0	.0007	.035	2.9	3.4	5.3	5.7	
455	Anchorage Port Access Overhead	5,780	7,970	0	.0050	.035	—	—	8.7	9.8	
460	Nome River	4,630	5,600	0	.0020	.035	.5	.6	4.3	4.5	
470	Small Creek	542	673	0	.0860	.035	.2	.2	3.7	3.9	
478	Goldstream Creek	1,920	2,450	0	.0060	.035	1.1	1.3	3.9	4.2	
503	Gardiner Creek	6,870	8,530	0	.0020	.035	.0	.0	—	—	
504	Beaver Creek	1,350	1,740	0	.0010	.035	2.9	2.9	—	—	
505	Tanana River near Tanacross	51,900	59,700	30	.00016	.035	.0	.0	28.1	28.7	
506	Tok River	13,400	16,400	0	.0035	.035	.0	.2	—	—	
507	Yerrick Creek	1,270	1,640	5	.0300	.035	.1	.0	6.4	6.5	
508	Cathedral Rapids Creek No. 1	483	643	0	.0190	.040	.0	.0	—	—	
509	Robertson River	9,520	11,700	25	.0050	.040	—	—	21.6	22.4	
510	Cathedral Rapids Creek No. 2	303	410	0	.0960	.040	.3	.3	—	—	
511	Cathedral Rapids Creek No. 3	245	333	0	.0480	.040	.0	.0	—	—	
513	Bear Creek	2,360	3,020	0	.0110	.040	.0	.2	—	—	
514	Chief Creek	1,480	1,900	0	.0070	.035	1.9	2.8	—	—	
515	Berry Creek	3,240	4,720	0	.0480	.035	2.5	3.0	—	—	
516	Sears Creek	528	700	0	.0080	.035	3.0	3.8	—	—	
517	Dry Creek	2,720	3,350	0	.0060	.035	2.2	4.1	—	—	Pressure flow (Q_{500})
518	Johnson River	7,520	9,250	40	.0110	.040	—	—	26.6	28.1	
519	Little Gerstle River	1,970	2,540	0	.0020	.035	.0	.0	3.7	3.9	
520	Gerstle River	5,100	6,340	25	.0075	.060	.1	.2	18.5	19.0	
524	Tanana River Big Delta	86,700	95,600	35	.0002	.030	1.3	1.3	37.5	38.7	
525	Shaw Creek	6,090	7,820	0	.0010	.035	2.9	3.4	3.4	3.6	
526	Banner Creek	1,570	2,320	0	.0130	.040	3.5	4.7	—	—	
527	Salcha River	50,600	64,900	10	.0012	.030	3.3	3.9	20.7	21.7	
528	Clear Creek	162	221	0	.0030	.035	1.9	2.4	—	—	
529	Munsons Slough	188	256	0	.0020	.035	4.8	5.6	—	—	
530	Little Salcha River	3,130	3,920	15	.0050	.050	1.5	2.2	10.7	11.3	
532	Chena River (North Hall Street)	12,000	12,000	0	.0005	.035	.3	.3	7.6	7.6	
534	Ship Creek	3,180	3,960	0	.0100	.043	4.4	5.2	—	—	
535	Eagle River North Crossing	6,920	8,710	0	.0054	.040	2.1	3.0	9.9	10.6	

Table 2. Computed Phase I contraction- and pier-scour depths at selected bridge sites in Alaska—Continued

[Manning's roughness coefficients are for main channel at bridge. ADOT&PF, Alaska Department of Transportation and Public Facilities. Q_{100}, 100-year flood; Q_{500}, 500-year flood. —, not applicable]

Bridge		Discharge (cubic feet per second)		Angle of attack (degrees)	Valley slope (feet per foot)	Manning's roughness coefficient n	Computed scour depth (feet)				Comments
							Contraction scour		Pier scour		
ADOT&PF number	Name	Q_{100}	Q_{500}				Q_{100}	Q_{500}	Q_{100}	Q_{500}	
538	Goat Creek	498	642	30	.0090	.035	.0	.0	—	—	
539	Knik River	79,400	104,000	0	.0006	.046	11.7	13.4	10.8	11.7	
541	Moose Creek	1,630	2,060	0	.0050	.040	.7	.8	3.9	4.1	
542	Eska Creek	1,060	1,860	10	.0070	.035	.7	2.4	—	—	
543	Granite Creek	1,920	2,390	55	.0150	.045	.4	.5	16.6	17.6	
544	King River	7,600	9,310	15	.0090	.035	2.0	2.4	19.6	20.6	
547	Hicks Creek	1,370	1,700	25	.0100	.045	.0	.0	12.0	12.5	
548	Caribou Creek	9,550	11,800	25	.0060	.035	4.5	5.0	30.1	31.6	
549	Little Nelchina River	6,760	8,300	30	.0080	.035	1.7	1.9	27.8	29.2	
551	Mendeltna Creek	3,950	5,050	0	.0030	.035	.0	.0	—	—	
552	Tolsona Creek	3,730	4,810	0	.0068	.035	.0	.0	—	—	
556	Valdez Glacier Stream	24,400	30,600	0	.0060	.035	5.8	7.3	3.9	4.3	
557	Lowe River Lower Crossing	22,100	28,500	0	.0080	.040	1.1	1.5	7.2	7.7	
558	Lowe River Upper Crossing	19,400	25,100	20	.0040	.040	.3	.3	17.2	18.3	
559	Sheep Creek	5,410	6,870	0	.0120	.040	.0	.0	—	—	
565	Stuart Creek	3,430	4,750	0	.0200	.050	.7	1.3	—	—	
569	Tonsina River (Upper)	10,400	12,300	0	.0050	.035	.3	.3	5.5	5.7	
570	Squirrel Creek	1,210	1,630	0	.0080	.037	2.9	2.8	—	—	
572	Klutina River	10,700	11,800	0	.0070	.040	.6	.5	15.5	15.8	
573	Tazlina River	79,400	109,000	35	.0020	.036	2.9	2.8	31.7	34.4	
574	Gulkana River	18,400	22,200	0	.0006	.035	5.3	6.3	6.8	6.9	
575	Sourdough Creek	2,330	3,570	0	.0060	.035	.0	.1	—	—	
577	One Mile Creek	529	696	0	.0320	.040	2.2	2.9	3.2	3.4	
589	Lower Suzy Q Creek	155	205	0	.0740	.040	.1	.1	—	—	
592	Darling Creek	530	680	0	.0100	.040	.0	.0	—	—	
593	Bear Creek	558	716	0	.0470	.035	.8	.7	—	—	
595	Jarvis Creek	5,840	7,240	0	.0040	.040	4.3	4.8	7.1	7.5	
596	Resurrection River No. 1	6,200	7,870	20	.0020	.040	.1	.1	12.0	12.6	
597	Resurrection River No. 2	9,500	12,100	0	.0020	.040	.5	.9	5.0	5.2	
598	Resurrection River No. 3	8,400	10,700	0	.0020	.040	.2	.4	4.5	4.7	

599	Clear Creek	3,070	3,880	0	.0060	.035	2.2	2.5	—	—	
600	Salmon Creek	2,580	3,250	0	.0011	.040	1.7	1.2	—	—	
601	Bear Creek	765	964	0	.0100	.040	2.1	2.4	—	—	
603	Snow River West Channel	2,100	2,600	20	.0015	.035	.6	.7	8.7	9.1	
605	Snow River Center Channel	21,600	27,000	0	.0010	.040	1.2	1.2	7.5	7.9	
608	Ptarmigan Creek	1,610	2,070	0	0.0080	0.035	0.1	0.1	6.7	7.0	
609	Falls Creek	1,220	1,750	0	.0120	.040	.5	.6	3.4	3.7	
610	Trail River	9,260	11,800	45	.0001	.030	1.9	2.1	2.9	3.0	
613	Dry Gulch Creek	560	789	0	.1800	.040	.4	.4	9.8	10.3	
634	Twenty Mile River	32,500	35,600	0	.0005	.035	4.1	4.4	4.1	4.2	
639	Glacier Creek	11,100	16,700	0	.0060	.035	.7	.9	6.3	6.9	
643	Bird Creek	4,390	5,560	0	.0010	.035	2.3	2.3	3.5	3.7	
644	Indian Creek	844	1,110	0	.0100	.035	.5	.7	3.1	3.3	
646	Gakona River	14,500	19,300	0	.0030	.035	.4	.4	—	—	
649	Chistochina River No. 1	15,000	17,700	0	.0050	.040	2.2	2.6	5.9	6.2	
650	Chistochina River No. 2	15,000	17,700	0	.0050	.040	2.2	2.6	5.9	6.2	
651	Indian River	3,730	4,630	5	.0100	.035	.0	.0	3.9	4.0	
653	Porcupine Creek	1,140	1,460	0	.0180	.040	.4	.5	—	—	
654	Slana River	5,980	7,020	0	.0014	.032	.0	.0	4.5	4.6	
658	Little Tok River	9,430	11,200	5	.0040	.035	.0	.0	4.5	4.7	Pressure flow
663	Tok River	20,000	23,100	0	.0030	.035	3.6	3.6	5.1	5.3	
666	South Fork Anchor River	6,520	10,400	0	.0085	.038	3.1	1.8	—	—	Pressure flow
668	Deep Creek	2,170	2,740	0	.0060	.035	.5	.6	4.1	4.3	
669	Ninilchik River	2,010	2,720	0	.0069	.035	2.2	2.8	7.6	8.2	
670	Kasilof River	14,500	16,900	0	.0010	.035	.8	.8	7.1	7.3	
671	Kenai River at Soldotna	40,000	48,400	0	.0013	.035	.3	.4	8.2	8.5	
673	Kenai River at Schooners Bend	36,900	46,900	0	.0030	.035	.9	1.4	6.3	6.7	
674	Cooper Creek	2,680	3,290	0	.0190	.040	.0	.0	—	—	
675	Kenai River Cooper Land	34,400	44,000	0	.0006	.035	.2	.2	2.9	3.1	
678	Little Goldstream Creek	2,260	2,870	0	.0005	.040	2.5	1.8	3.5	3.7	
685	Maclaren River	10,900	13,200	0	.0015	.035	.1	.1	6.9	7.1	
686	Clearwater Creek	4,420	5,400	25	.0100	.035	1.1	1.6	11.3	11.8	
687	Susitna River	37,600	48,200	20	.0009	.030	.3	.5	18.4	19.1	
688	Canyon Creek	648	861	0	.0380	.045	.4	.5	—	—	
690	Seattle Creek	3,090	5,730	0	.0150	.045	5.9	.0	—	—	Pressure flow
693	Carlo Creek	1,080	1,380	0	.0180	.035	1.0	1.1	—	—	
694	Nenana River Park Bend	25,400	30,300	0	.0040	.035	.2	.2	12.5	12.9	
695	Riley Creek	5,220	6,290	0	.0140	.045	.1	.1	7.3	7.5	
697	Kingfisher Creek	84	115	0	.2300	.040	.0	.0	—	—	
735	Eagle River	10,400	13,000	20	.0050	.035	.0	.0	19.8	20.8	

Table 2. Computed Phase I contraction- and pier-scour depths at selected bridge sites in Alaska—Continued

[Manning's roughness coefficients are for main channel at bridge. ADOT&PF, Alaska Department of Transportation and Public Facilities. Q_{100}, 100-year flood; Q_{500}, 500-year flood. —, not applicable]

Bridge		Discharge (cubic feet per second)		Angle of attack (degrees)	Valley slope (feet per foot)	Manning's roughness coefficient n	Computed scour depth (feet)				Comments
							Contraction scour		Pier scour		
ADOT&PF number	Name	Q_{100}	Q_{500}				Q_{100}	Q_{500}	Q_{100}	Q_{500}	
736	Herbert River	10,100	12,400	10	.0020	.035	.3	.4	15.8	16.5	
737	Mendenhall River	18,900	23,200	0	.0010	.033	.1	.0	5.9	5.8	
742	Chilkat River	32,600	42,900	0	.0006	.035	.3	.3	4.2	4.5	
799	Long Creek	577	763	0	.0170	.040	.0	.0	—	—	
816	Crooked Creek	578	763	0	.0090	.035	.0	.0	—	—	
819	Deadwood Creek	1,530	1,970	0	.0110	.035	2.3	3.0	—	—	
822	Belle Creek	964	1,250	0	.0090	.035	2.1	2.8	3.1	3.3	
823	McKay Creek	534	703	0	.0240	.035	.0	.0	4.2	4.4	
826	Reed Creek	326	434	0	.0290	.035	.0	.0	—	—	
827	Willow Creek	269	360	0	.0260	.045	.2	.2	—	—	
828	Bear Creek	584	767	0	.0190	.035	.0	.0	—	—	
831	Mammoth Creek	1,610	2,060	0	.0140	.035	3.2	5.6	—	—	
832	Boulder Creek	2,130	3,840	0	.0145	.045	.7	.3	—	—	Pressure flow (Q_{500})
833	Albert Creek	3,890	4,860	0	.0060	.035	2.2	2.8	—	—	Pressure flow (Q_{500})
836	Chatanika River	13,600	16,200	0	.0010	.035	.0	.0	4.4	4.5	
838	Washington Creek	4,210	6,710	0	.0120	.040	2.3	2.3	4.7	5.2	
839	South Fork 40 Mile River	37,200	48,700	0	.0015	.035	1.7	1.9	7.3	7.8	
851	Dry Creek	1,930	2,420	0	.0300	.040	.0	.0	2.8	3.0	
852	Dry Creek Overflow	307	404	0	.0300	.040	.0	.0	2.5	2.7	
853	Salmon Creek	4,190	5,290	0	.0060	.035	1.3	1.7	4.1	4.3	
854	Small Creek	903	1,140	0	.0250	.040	3.3	5.4	—	—	Pressure flow
855	Small Creek	1,520	1,910	0	.0250	.040	.8	1.0	—	—	
857	Nenana River at Healy	47,200	57,800	15	.0100	.040	7.3	9.6	33.9	36.2	Footing scour
858	Slana River	18,400	21,400	0	.0026	.035	7.9	8.8	8.0	8.2	
868	Falls Creek	5,050	6,290	0	.0030	.035	2.6	3.4	5.7	6.2	
888	Carlson Creek	559	738	0	.0320	.040	.2	.2	—	—	
940	Fish Camp Creek	637	871	0	.0005	.035	4.4	4.4	—	—	
969	Campbell Creek Lake Otis	1,090	1,500	0	.0050	.035	.5	.7	4.1	4.4	
970	Campbell Creek Arctic	1,390	1,780	0	.0050	.035	.0	.0	3.3	3.5	
971	Campbell Creek	1,380	1,770	0	.0050	.035	.9	1.4	3.3	3.6	

983	Red Cloud River	1,580	1,960	0	0.0200	0.045	0.0	0.0	3.2	3.3	
986	Buskin River No. 5	3,460	4,330	0	.0015	.035	.2	.4	—	—	
999	Glacier Creek	7,020	10,200	20	.0150	.040	3.3	4.4	9.2	9.9	
1008	Cripple Creek	1,920	2,470	0	.0040	.035	.0	.0	—	—	
1009	Goldstream Creek	3,190	3,990	0	.0020	.035	1.2	2.4	—	—	Pressure flow
1025	Resurrection Creek	4,590	6,520	0	.0100	.035	1.8	2.4	7.5	8.1	
1075	Dragonfly Creek	95	130	0	.1400	.050	.0	.0	—	—	
1092	Little Tok River	7,970	9,750	0	.0020	.035	.0	.4	3.9	3.9	
1094	Situk River	4,330	5,400	0	.0006	.035	.0	.0	5.7	6.2	Pressure flow (Q_{500})
1131	Ketchikan Creek Fair Street	2,920	3,550	0	.0200	.035	.1	.1	6.8	7.2	
1132	Ketchikan Creek Park–Upper Crossing	2,960	3,600	0	.0200	.035	.2	.2	6.8	7.2	
1141	Antler Creek	169	226	0	.1030	.045	.0	.0	6.2	6.5	
1142	Bison Gulch	136	183	0	.1040	.040	.1	.0	4.6	4.9	
1143	Nenana River at Moody	43,700	54,400	0	.0050	.045	.0	.2	—	—	
1145	Hornet Creek	212	283	0	.1100	.040	.0	.0	—	—	
1146	Iceworm Gulch	164	221	0	.1100	.040	.3	.3	—	—	
1147	Nenana River Park Station	43,200	53,600	0	.0050	.040	.8	1.7	9.9	10.3	
1153	Whipple Creek	3,500	4,740	0	.0320	.040	.2	.1	13.0	13.8	
1155	Peters Creek North Crossing	2,260	2,890	0	.0270	.035	.3	.4	8.4	8.8	
1156	Wasilla Creek	570	767	0	.0020	.035	.0	.0	—	—	
1157	Campbell Creek East Frontage	1,120	1,540	0	.0040	.035	.4	.4	—	—	
1187	Copper River Delta	54,400	69,000	35	.00015	.030	2.6	2.9	18.3	18.7	
1191	Chena River (Peger Road)	12,000	12,000	0	.0002	.030	1.9	1.9	4.5	4.5	
1196	Lost River	5,850	7,240	0	.0011	.030	.6	.6	3.6	3.9	Pressure flow (Q_{500})
1203	Solomon Creek	3,300	4,090	0	.0054	.035	.0	.0	—	—	
1204	Abercrombie Creek	1,710	2,170	0	.2700	.040	.1	.2	—	—	
1207	Lowe River Main Channel	37,300	47,300	20	.0030	.035	.5	.7	14.9	15.8	
1208	Lowe River North Channel	5,090	6,460	0	.0030	.035	.1	.1	4.6	4.8	
1212	Chena River	12,000	12,000	0	.0010	.035	.0	.0	5.6	5.6	
1213	Hess Creek	13,500	17,200	0	.0004	.035	3.6	3.5	—	—	
1220	Cowee Creek	9,870	12,400	0	.0040	.035	3.2	.7	4.9	5.0	Pressure flow
1222	Tiekel River No. 2	8,000	9,030	0	.0100	.040	.0	.0	12.8	13.1	
1228	Antlen River	546	672	0	.0020	.035	.3	.3	3.4	3.6	
1229	Ahrnklin River	9,690	11,900	0	.0030	.035	1.5	2.0	6.5	6.9	
1230	Eklutna River Northbound	5,090	6,210	10	.0130	.040	8.2	8.7	—	—	
1234	Ketchum Creek	704	925	0	.0160	.040	1.2	1.7	—	—	
1241	Little Nelchina River	6,760	8,300	0	.0096	.040	1.2	1.6	8.5	8.9	
1243	Nenana River at Windy	13,000	15,400	0	.0042	.050	.0	.0	6.9	7.2	
1250	Tulsona Creek	2,400	3,110	0	.0050	.035	.0	.0	—	—	
1255	Fish Creek	3,800	4,710	20	.0060	.035	1.4	1.9	9.5	10.1	

Table 2. Computed Phase I contraction- and pier-scour depths at selected bridge sites in Alaska—Continued

[Manning's roughness coefficients are for main channel at bridge. ADOT&PF, Alaska Department of Transportation and Public Facilities. Q_{100}, 100-year flood; Q_{500}, 500-year flood. —, not applicable]

Bridge		Discharge (cubic feet per second)		Angle of attack (degrees)	Valley slope (feet per foot)	Manning's roughness coefficient *n*	Computed scour depth (feet)				Comments
							Contraction scour		Pier scour		
ADOT&PF number	Name	Q_{100}	Q_{500}				Q_{100}	Q_{500}	Q_{100}	Q_{500}	
1256	North Fork Bonanza Creek	3,870	4,790	0	.0050	.040	.9	1.5	2.8	3.0	
1257	South Fork Bonanza Creek	4,530	5,590	0	.0040	.035	.0	.0	3.1	3.3	
1258	Prospect Creek	7,210	8,980	0	.0030	.035	2.9	3.8	3.5	3.7	
1259	Jim River No. 1	2,920	3,640	0	.0050	.035	1.7	2.0	2.8	3.0	
1260	South Fork Koyukuk River	14,900	17,900	0	.0020	.030	.1	.2	3.0	3.2	
1261	Middle Fork Koyukuk River No. 1	25,100	28,500	10	.0230	.028	.9	1.0	7.2	7.4	
1273	Chester Creek	1,650	2,260	0	.0007	.035	1.0	1.4	3.5	3.7	Pressure flow (Q_{500})
1282	Middle Fork Koyukuk River No. 2	20,300	23,400	10	.0030	.030	.3	.4	12.8	13.3	
1283	Middle Fork Koyukuk River No. 3	10,300	12,000	0	.0013	.035	1.5	3.1	3.4	3.4	Pressure flow (Q_{500})
1284	Middle Fork Koyukuk River No. 4	7,880	9,180	0	.0020	.035	1.5	1.6	3.1	3.2	
1320	Ship Creek	3,520	4,550	0	.0060	.035	.5	.7	6.8	7.2	
1329	Little Chena River	7,910	11,800	0	.0010	.035	.0	.0	5.1	5.8	Pressure flow
1332	Slate Creek	3,480	4,300	0	.0050	.035	1.3	1.3	3.2	3.3	
1333	Atigun River No. 2	6,990	8,550	0	.0040	.035	1.0	1.1	2.6	2.7	
1334	No Name Creek	4,930	6,080	0	.0030	.035	.0	.0	3.4	3.6	
1335	Minnie Creek	2,230	2,790	0	.0040	.037	1.2	1.7	3.2	3.4	
1336	Hammond River	8,560	10,200	0	.0030	.035	3.0	3.7	3.7	3.9	
1337	Dietrich River	11,200	13,100	10	.0040	.035	.3	.4	6.3	6.5	
1338	Kanuti River	5,140	6,340	15	.0010	.035	.9	1.3	6.3	6.7	
1341	Eagle River South Crossing	6,920	8,710	0	.0120	.035	1.8	1.7	12.9	13.6	
1344	Peters Creek Southbound	2,260	2,890	0	.0270	.035	.0	.0	8.4	8.8	
1350	Campbell Creek West Frontage	1,120	1,540	0	.0040	.035	.1	.2	—	—	
1355	Harris River	4,380	5,420	0	.0070	.035	.7	.8	—	—	
1356	Fubar Creek	1,640	2,020	0	.0170	.040	2.7	3.2	—	—	
1383	Lowe River Lower Keystone	21,400	27,600	50	.0050	.040	.6	.4	15.4	16.3	
1384	Lowe River Upper Keystone	21,400	27,600	35	.0070	.040	.0	.0	13.2	14.2	
1389	Unnamed Creek	980	1,230	25	.0500	.035	.1	.1	3.5	3.7	
1390	Resurrection River	14,100	17,800	0	.0012	.035	.0	.0	10.5	11.2	Pressure flow (Q_{500})
1394	Globe Creek	1,520	1,960	0	.0060	.035	1.2	2.5	—	—	
1400	Tatalina River	3,570	4,460	0	.0050	.035	2.9	3.4	—	—	

1436	Jim River No. 2	2,910	3,620	20	0.0050	0.035	0.6	1.2	7.7	8.1
1437	Jim River No. 3	6,570	8,040	0	.0090	.035	1.2	1.4	3.3	3.4
1439	Atigun River No. 1	2,190	2,730	0	.0100	.035	4.9	5.9	2.8	2.9
1443	Campbell Creek	1,600	2,070	0	.0050	.035	.4	.5	—	—
1444	Campbell Creek at Minnesota Drive	1,600	2,070	0	.0050	.035	.4	.5	—	—
1445	Campbell Creek at Minnesota Drive	1,600	2,070	0	.0050	.035	.4	.5	—	—
1455	Control Creek	2,480	3,070	0	.0010	.035	2.9	3.2	—	—
1461	Goose Creek	4,240	5,250	0	.0005	.035	3.4	3.5	6.7	7.1
1462	Thorne River	23,500	29,100	0	.0020	.035	.0	.3	—	—
1513	Fort Hamlin Hills Creek	1,830	2,330	0	.0050	.035	1.8	2.6	—	—
1514	Gold Creek	1,060	1,350	0	.0170	.040	1.7	2.1	—	—
1519	Roche Moutonnee Creek	1,250	1,480	0	.0360	.063	1.2	1.4	—	—
1520	Holden Creek	563	743	0	.0380	.040	.2	.3	—	—
1521	Dan Creek	1,000	1,360	0	.0110	.035	1.2	1.7	—	—
1536	False Pass Creek	2,260	2,850	0	.0170	.040	.0	.0	4.3	4.5
1560	Douglas Creek	932	1,210	0	.0060	.040	1.8	3.2	—	—
1629	Chester Creek	1,650	2,260	0	.0050	.035	.0	.0	—	—
1694	Campbell Creek	1,600	2,070	0	.0050	.035	.4	.5	—	—
1746	Klutina River	11,900	12,800	0	.0060	.035	.0	.0	8.4	8.5
1864	Eklutna River Southbound	5,090	6,210	0	.0130	.040	8.2	8.7	—	—

Those sites selected by ADOT&PF for additional investigation (Phase II) analyses may require on-site inspections and(or) detailed hydraulic cross sections to more accurately estimate scour potential.

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APPENDIX

SUMMARY EXAMPLES OF FOUR PHASE I BRIDGE-SCOUR ANALYSES

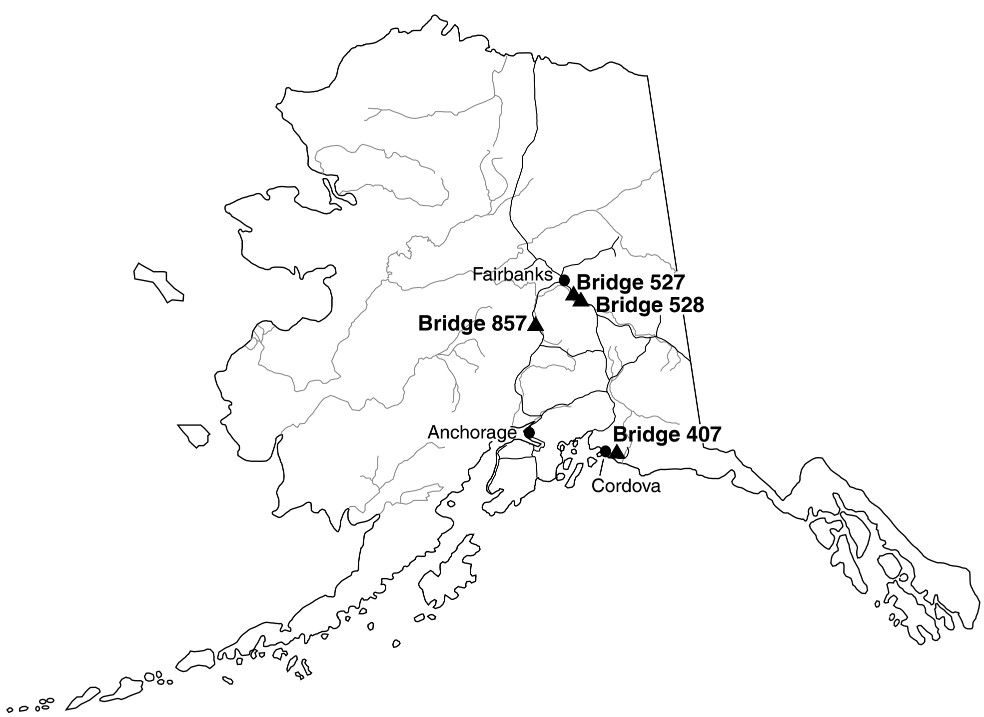
In this appendix are four examples of data summaries from Phase I bridge-scour analyses for four bridges (see location map, below). Examples of raw output from the bridge-site files (Excel spreadsheets), they were chosen to illustrate the wide range of information that may be available for a given site and the procedures used to estimate scour at the site. The examples are presented in ascending order according to the amount of useful hydraulic information available for the site. Thus, bridge 528 has very little background information available, whereas bridge 857 has information available that would be equivalent to a Phase II on-site survey including recent flood-discharge measurements. Examples of spreadsheet output, including summary information and automatic calculations, are provided as follows:

Example 1—Bridge 528, Clear Creek

Example 2—Bridge 407, Scott Glacier No. 7

Example 3—Bridge 527, Salcha River

Example 4—Bridge 857, Nenana River at Healy



Phase I site locations, bridges 407, 527, 528, and 857

Example 1

Bridge 528, Clear Creek, Richardson Highway mile 324.0:
Bridge 528 is a single-span bridge at an ungaged site.

Data available: As-built plans were provided by the Alaska Department of Transportation and Public Facilities.

Summary information included: Cross sections and scour computations.

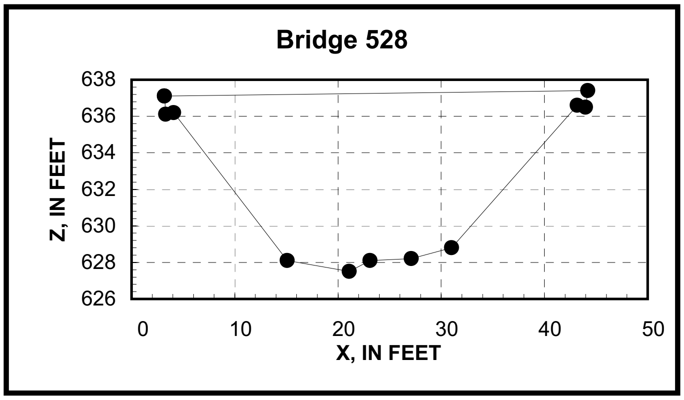
Derivations, assumptions, and remarks: Geometry of the stream channel at the full-valley and approach cross sections was derived from the as-built topographic map. A slope of 0.0030 ft/ft was measured from a U.S. Geological Survey topographic-quadrangle map; this slope was used as the valley slope for templating cross sections and as the initial friction slope for the WSPRO model run. We assumed a Manning's *n* value of 0.035 and a bed-material grain size of 10 millimeters (0.39 in).

Bridge 528. Clear Creek bridge and full valley cross-sections.

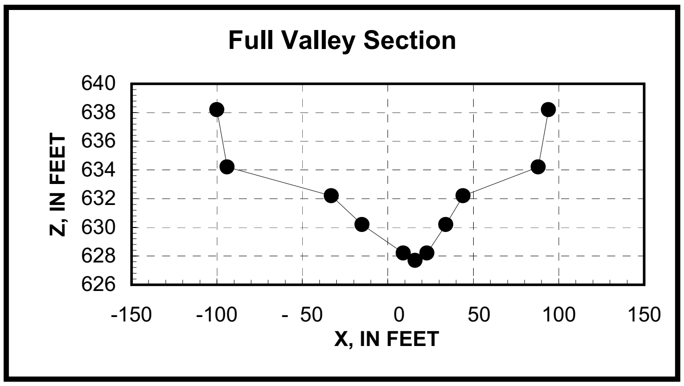
[X is an arbitrary horizontal coordinate. Z is the elevation read from the as-built bridge plans. Approach was measured 47 feet upstream of the bridge.]

X (feet)	Z (feet)	Notes
Bridge geometry		
3.2	637.1	from as-builts
3.3	636.1	from as-builts
4.1	636.2	from as-builts
15.1	628.1	from as-built topo
21.1	627.5	from as-built topo
23.1	628.1	from as-built topo
27.1	628.2	from as-built topo
31.0	628.8	from as-built topo
43.2	636.6	from as-builts
44.0	636.5	from as-builts
44.2	637.4	from as-builts
3.2	637.1	from as-builts
Full valley section		
-100.0	638.2	extended up
-94.0	634.2	from as-built topo
-33.0	632.2	from as-built topo
-15.0	630.2	from as-built topo
9.0	628.2	from as-built topo
16.0	627.7	from as-built topo
23.0	628.2	from as-built topo
34.0	630.2	from as-built topo
44.0	632.2	from as-built topo
88.0	634.2	from as-built topo
94.0	638.2	extended up
Approach section		
-75.0	644.0	extended up
-62.0	634.0	from as-built topo
-54.0	632.0	from as-built topo
-17.0	630.0	from as-built topo
3.0	628.0	from as-built topo
10.0	627.8	from as-built topo
17.0	628.0	from as-built topo
40.0	630.0	from as-built topo
68.0	632.0	from as-built topo
85.0	634.0	from as-built topo
100.0	644.0	extended up

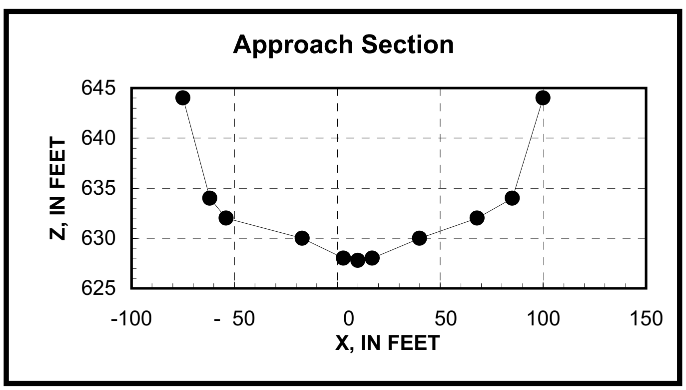
Clear Creek
Bridge 528
Alaska HIghway mile 258.5



Bridge 528 bridge cross-section.



Bridge 528 full valley cross-section.



Bridge 528 approach cross-section.

Bridge 528. Clear Creek bridge scour computations.

Clear Creek
Bridge 528
Alaska Highway mile 258.5

LIVE-BED CONTRACTION SCOUR

$$\frac{y_2}{y_1} = \left(\frac{Q_2}{Q_1}\right)^{\frac{6}{7}} \left(\frac{W_1}{W_2}\right)^{K_1}$$

$y_{cs} = y_2 - y_1$ = (average scour depth)

Notes:

		100 Year	500 Year
Computed floods: total discharge (cfs)	**Q**	**162**	**221**
Hydraulic radius of approach section (ft)	R	1.64	1.88
Friction slope (ft/ft)	S	0.0023	0.0024
Average shear stress at bed (lbs/ft^2)	$\tau=\rho gRS$	0.24	0.28
Shear velocity (ft/s)	$V^*=(\tau/\rho)^{½}$	0.35	0.38
Fall velocity of bed material (ft/s)	w	2.60	2.60
Ratio	V*/w	0.13	0.15
Exponent determined from mode of bed material transport	k_1 =f(V*/w)	0.59	0.59
Discharge in main channel of approach section (cfs)	Q_1	162	221
Percentage of total discharge		100%	100%
Discharge in main channel of contracted (bridge) section (cfs)	Q_2	162	221
Percentage of total discharge		100%	100%
Width of main channel of approach section (ft)	W_1	78	90
Width of main channel of contracted (bridge) section (ft)	W_2	21	22
Average depth of main channel of approach section (ft)	y_1	1.6	1.9
Average depth in contracted (bridge) section (ft)	y_2	3.6	4.3
CONTRACTION SCOUR (ft)	**Y_{cs}**	**1.9**	**2.4**

PIER SCOUR

$$\frac{y_{ps}}{y_1} = 2.0K_1K_2K_3\left(\frac{a}{y_1}\right)^{0.65} Fr^{0.43}$$

Notes: This bridge has no piers.

		100 Year	500 Year
Speed of maximum velocity stream tube (ft/s)	v_1		
Depth of maximum velocity stream tube (ft)	y_1		
Froude number of maximum velocity stream tube	$Fr=v_1/(gy_1)^{½}$		
Pier shape			
Pier shape correction factor	K_1		
Angle of attack (deg)	AA		
Pier width (ft)	a		
Pier length (ft)	L		
Ratio	L/a		
Angle of attack correction factor	K_2=f(AA,L/a)		
Bed condition (dunes) correction factor	K_3		
PIER SCOUR (ft)	**Y_{ps}**	**n/a**	**n/a**

TOTAL SCOUR

$T_s = y_{cs} + y_{ps}$

		100 Year	500 Year
Contraction scour (ft)	**Y_{cs}**	**1.9**	**2.4**
Pier scour (ft)	**Y_{ps}**	**n/a**	**n/a**
TOTAL SCOUR (ft)	**T_s**	**1.9**	**2.4**

Example 2

Bridge 407, Scott Glacier No. 7, Copper River Highway mile 10.0

Bridge 407 has piers and is at an ungaged site.

Data available: This bridge was surveyed for bridge-scour assessment on August 30, 1996. As-built plans were provided by the Alaska Department of Transportation and Public Facilities.

Summary information included: Cross sections and scour computations.

Derivations, assumptions, and remarks: Flood flow was allocated among the 11 Scott Glacier bridges by dividing flow computed from an August 30, 1996, discharge measurement among the 11 bridges. Approximately 6 percent of the total Scott Glacier discharge measured on that date passed through bridge 407. As a best approximation based on available data, we routed 6 percent of the Q_{100} and Q_{500} flows through the bridge, with the understanding that the actual percentage of flow through the bridge may vary significantly with changes in total flow.

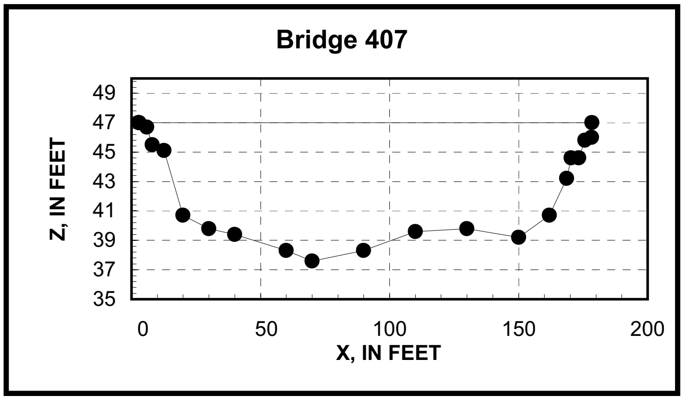
Geometry from the as-built plans was combined with soundings made during the August 30, 1996, discharge measurement of 444 ft^3/s (25 percent of Q_{100}) to construct the full-valley cross section. This geometry was used to template approach and exit sections for the WSPRO model. On the basis of field observations, the approach section was scaled to be 300 percent of the full-valley width at the bridge. Active sediment transport was assumed for two-thirds of the approach. Friction slope was back-calculated from the discharge measurement assuming a Manning's *n* value of 0.035. This slope was used as the valley slope for templating cross sections and as the initial friction slope for the WSPRO model run.

Because the piles are separated by less than five pile diameters, pier scour was computed for a composite pier length.

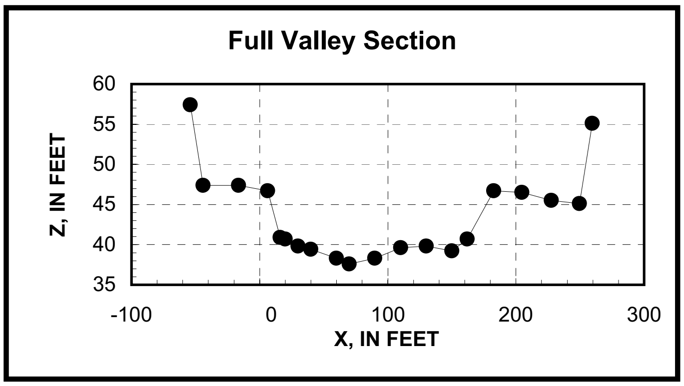
Bridge 407. Scott Glacier No. 7 bridge and full valley cross-sections.
[X is an arbitrary horizontal coordinate. Z is the elevation read from the as-built bridge plans. USGS soundings made 8/30/96.]

X (feet)	Z (feet)	Notes
Bridge geometry		
2.9	47.0	from as-builts
3.0	47.0	from as-builts
5.9	46.7	from as-builts
8.1	45.5	from as-builts
12.7	45.1	from as-builts
20.0	40.7	USGS sounding
30.0	39.8	USGS sounding
40.0	39.4	USGS sounding
60.0	38.3	USGS sounding
70.0	37.6	USGS sounding
90.0	38.3	USGS sounding
110.0	39.6	USGS sounding
130.0	39.8	USGS sounding
150.0	39.2	USGS sounding
162.0	40.7	USGS sounding
168.7	43.2	from as-builts
170.4	44.6	from as-builts
173.3	44.6	from as-builts
175.7	45.8	from as-builts
178.3	46.0	from as-builts
178.4	47.0	from as-builts
2.9	47.0	from as-builts
Full valley section		
-54.2	57.4	extended up
-44.2	47.4	from as-builts
-16.5	47.4	from as-builts
6.2	46.7	from as-builts
16.1	40.9	from as-builts
20.0	40.7	USGS sounding
30.0	39.8	USGS sounding
40.0	39.4	USGS sounding
60.0	38.3	USGS sounding
70.0	37.6	USGS sounding
90.0	38.3	USGS sounding
110.0	39.6	USGS sounding
130.0	39.8	USGS sounding
150.0	39.2	USGS sounding
162.0	40.7	USGS sounding
182.7	46.7	from as-builts
204.8	46.5	from as-builts
227.6	45.5	from as-builts
249.6	45.1	from as-builts
259.6	55.1	extended up

Scott Glacier No. 7
Bridge 407
Copper River HIghway mile 10.1



Bridge 407 bridge cross-section.



Bridge 407 full valley cross-section.

Bridge 407. Scott Glacier No. 7 bridge scour computations.

Scott Glacier No. 7
Bridge 407

Copper River Highway mile 10.1

LIVE-BED CONTRACTION SCOUR

$$\frac{y_2}{y_1} = \left(\frac{Q_2}{Q_1}\right)^{\frac{6}{7}} \left(\frac{W_1}{W_2}\right)^{K_1}$$

$y_{cs} = y_2 - y_1$ = (average scour depth)

Notes:

		100 Year	500 Year
Computed floods: total discharge (cfs)	**Q**	**1760**	**2170**
Hydraulic radius of approach section (ft)	R	3.18	3.58
Friction slope (ft/ft)	S	0.0007	0.0008
Average shear stress at bed (lbs/ft^2)	$\tau = \rho gRS$	0.14	0.18
Shear velocity (ft/s)	$V^* = (\tau/\rho)^{½}$	0.27	0.30
Fall velocity of bed material (ft/s)	w	2.60	2.60
Ratio	V*/w	0.10	0.12
Exponent determined from mode of bed material transport	k_1 =f(V*/w)	0.59	0.59
Discharge in main channel of approach section (cfs)	Q_1	1162	1432
Percentage of total discharge		66%	66%
Discharge in main channel of contracted (bridge) section (cfs)	Q_2	1760	2170
Percentage of total discharge		100%	100%
Width of main channel of approach section (ft)	W_1	307	311
Width of main channel of contracted (bridge) section (ft)	W_2	143	144
Average depth of main channel of approach section (ft)	y_1	3.2	3.6
Average depth in contracted (bridge) section (ft)	y_2	7.1	8.1
CONTRACTION SCOUR (ft)	Y_{cs}	**3.9**	**4.5**

PIER SCOUR

$$\frac{y_{ps}}{y_1} = 2.0 K_1 K_2 K_3 \left(\frac{a}{y_1}\right)^{0.65} Fr^{0.43}$$

Notes:

		100 Year	500 Year
Speed of maximum velocity stream tube (ft/s)	v_1	5.20	5.64
Depth of maximum velocity stream tube (ft)	y_1	4.2	4.6
Froude number of maximum velocity stream tube	$Fr = v_1/(gy_1)^{½}$	0.45	0.46
Pier shape		round nose	
Pier shape correction factor	K_1	1.0	1.0
Angle of attack (deg)	AA	10	10
Pier width (ft)	a	1.3	1.3
Pier length (ft)	L	8	8
Ratio	L/a	6	6
Angle of attack correction factor	K_2=f(AA,L/a)	1.5	1.5
Bed condition (dunes) correction factor	K_3	1.1	1.1
PIER SCOUR (ft)	Y_{ps}	**4.6**	**4.9**

TOTAL SCOUR

$T_s = y_{cs} + y_{ps}$

		100 Year	500 Year
Contraction scour (ft)	Y_{cs}	**3.9**	**4.5**
Pier scour (ft)	Y_{ps}	**4.6**	**4.9**
TOTAL SCOUR (ft)	T_s	**8.6**	**9.3**

Example 3

Bridge 527, Salcha River, Richardson Highway mile 323.3

Bridge 527 has piers and is near a U.S. Geological Survey gaging station.

Data available: An active U.S. Geological Survey gaging station (15484000, Salcha River near Salchaket, Alaska) is approximately 1,000 ft upstream from the bridge. The gaging station has been in operation since September 1948. Discharge measurements from the bridge are available. As-built plans were provided by the Alaska Department of Transportation and Public Facilities. Flood estimates are from Jones and Fahl (1994).

Summary information included: Cross sections and scour computations.

Derivations, assumptions, and remarks: Geometry from the as-built bridge plans was combined with soundings made during the September 23, 1993 discharge measurement (4,860 ft^3/s, or 10 percent of Q_{100}). This geometry was used to template additional sections for the WSPRO model. Friction slope was back-calculated from the discharge measurement assuming a Manning's *n* value of 0.035. This slope was used as the valley slope for templating cross sections and as the initial friction slope for the WSPRO model run. Good agreement was obtained between the model and a high discharge measurement.

The flood of record at the gaging station (97,000 ft^3/s on August 14, 1967) exceeded the Q_{500} discharge, so an additional WSPRO run and scour calculation were done for 97,000 ft^3/s. Computed contraction scour was 4.7 ft, and pier scour, 23.7 ft.

Bridge 527. Salcha River bridge and full valley cross-sections.

[X is an arbitrary horizontal coordinate. Z is the elevation read from the as-built bridge plans. USGS soundings made on 9/23/93]

X (feet)	Z (feet)	Notes
Bridge geometry		
0.0	656.9	from as-builts
0.0	656.0	from as-builts
6.0	656.0	from as-builts
45.0	640.0	USGS sounding
51.0	636.5	USGS sounding
60.0	635.7	USGS sounding
70.0	635.1	USGS sounding
80.0	634.3	USGS sounding
90.0	632.9	USGS sounding
100.0	632.8	USGS sounding
104.0	634.0	USGS sounding
109.0	634.0	USGS sounding
120.0	635.1	USGS sounding
140.0	633.8	USGS sounding
160.0	631.7	USGS sounding
165.0	631.4	USGS sounding
170.0	631.4	USGS sounding
180.0	631.0	USGS sounding
185.0	630.6	USGS sounding
200.0	630.5	USGS sounding
210.0	630.2	USGS sounding
215.0	630.3	USGS sounding
220.0	629.9	USGS sounding
235.0	629.6	USGS sounding
245.0	630.1	USGS sounding
250.0	631.5	USGS sounding
262.0	631.8	USGS sounding
324.0	638.0	from as-builts
422.0	638.0	from as-builts
446.0	640.0	from as-builts
464.0	641.0	from as-builts
494.0	656.0	from as-builts
500.0	656.0	from as-builts
500.0	656.9	from as-builts
0.0	656.9	from as-builts

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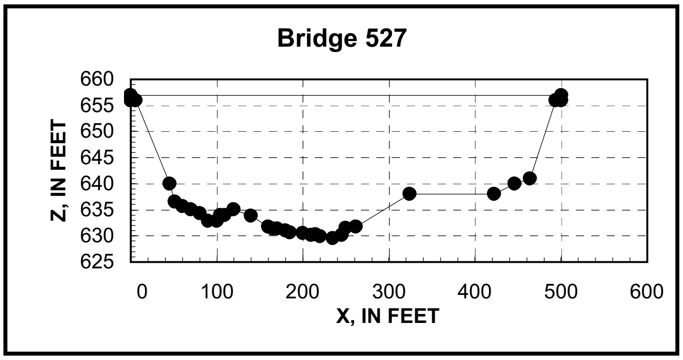
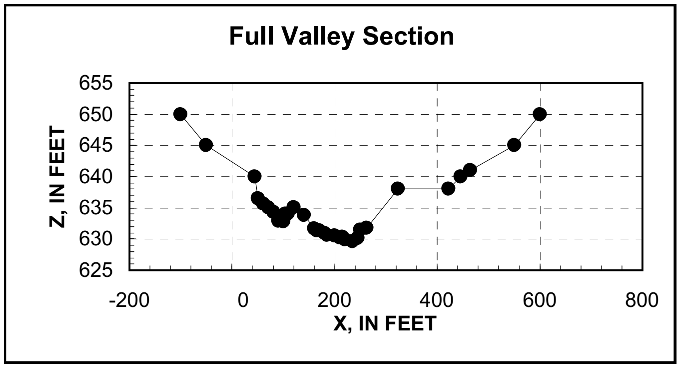
Salcha River
Bridge 527
Alaska HIghway mile 255.2



Bridge 527 bridge cross-section.

Bridge 527. Salcha River, **continued**

Full valley section		
-100.0	650.0	extended up
-50.0	645.0	extended up
45.0	640.0	USGS sounding
51.0	636.5	USGS sounding
60.0	635.7	USGS sounding
70.0	635.1	USGS sounding
80.0	634.3	USGS sounding
90.0	632.9	USGS sounding
100.0	632.8	USGS sounding
104.0	634.0	USGS sounding
109.0	634.0	USGS sounding
120.0	635.1	USGS sounding
140.0	633.8	USGS sounding
160.0	631.7	USGS sounding
165.0	631.4	USGS sounding
170.0	631.4	USGS sounding
180.0	631.0	USGS sounding
185.0	630.6	USGS sounding
200.0	630.5	USGS sounding
210.0	630.2	USGS sounding
215.0	630.3	USGS sounding
220.0	629.9	USGS sounding
235.0	629.6	USGS sounding
245.0	630.1	USGS sounding
250.0	631.5	USGS sounding
262.0	631.8	USGS sounding
324.0	638.0	from as-builts
422.0	638.0	from as-builts
446.0	640.0	from as-builts
464.0	641.0	from as-builts
550.0	645.0	extended up
600.0	650.0	extended up



Bridge 527 full valley cross-section.

Bridge 527. Salcha River bridge scour computations.

Salcha River
Bridge 527
Alaska Highway mile 255.2

LIVE-BED CONTRACTION SCOUR

$$\frac{y_2}{y_1} = \left(\frac{Q_2}{Q_1}\right)^{\frac{6}{7}} \left(\frac{W_1}{W_2}\right)^{K_1}$$

$y_{cs} = y_2 - y_1$ = (average scour depth)

Notes:

		100 Year	500 Year
Computed floods: total discharge (cfs)	**Q**	**50600**	**64900**
Hydraulic radius of approach section (ft)	R	15.99	18.24
Friction slope (ft/ft)	S	0.0013	0.0014
Average shear stress at bed (lbs/ft^2)	$\tau = \rho gRS$	1.30	1.59
Shear velocity (ft/s)	$V^* = (\tau/\rho)^{1/2}$	0.82	0.91
Fall velocity of bed material (ft/s)	w	2.60	2.60
Ratio	V*/w	0.31	0.35
Exponent determined from mode of bed material transport	k_1 =f(V*/w)	0.59	0.59
Discharge in main channel of approach section (cfs)	Q_1	44912	56126
Percentage of total discharge		89%	86%
Discharge in main channel of contracted (bridge) section (cfs)	Q_2	44021	55357
Percentage of total discharge		87%	85%
Width of main channel of approach section (ft)	W_1	275	275
Width of main channel of contracted (bridge) section (ft)	W_2	195	195
Average depth of main channel of approach section (ft)	y_1	16.1	18.4
Average depth in contracted (bridge) section (ft)	y_2	19.4	22.2
CONTRACTION SCOUR (ft)	$\mathbf{Y_{cs}}$	**3.3**	**3.9**

PIER SCOUR

$$\frac{y_{ps}}{y_1} = 2.0 K_1 K_2 K_3 \left(\frac{a}{y_1}\right)^{0.65} Fr^{0.43}$$

Notes:

		100 Year	500 Year
Speed of maximum velocity stream tube (ft/s)	v_1	14.67	15.79
Depth of maximum velocity stream tube (ft)	y_1	19.3	21.6
Froude number of maximum velocity stream tube	$Fr = v_1/(gy_1)^{1/2}$	0.59	0.60
Pier shape		round nose	
Pier shape correction factor	K_1	1.0	1.0
Angle of attack (deg)	AA	10	10
Pier width (ft)	a	4.0	4.0
Pier length (ft)	L	30	30
Ratio	L/a	8	8
Angle of attack correction factor	K_2=f(AA,L/a)	1.7	1.7
Bed condition (dunes) correction factor	K_3	1.1	1.1
Submerged low steel multiplier	$f(Fr_{approach})$		
PIER SCOUR (ft)	$\mathbf{Y_{ps}}$	**20.7**	**21.7**

TOTAL SCOUR

$T_s = y_{cs} + y_{ps}$

		100 Year	500 Year
Contraction scour (ft)	$\mathbf{Y_{cs}}$	**3.3**	**3.9**
Pier scour (ft)	$\mathbf{Y_{ps}}$	**20.7**	**21.7**
TOTAL SCOUR (ft)	$\mathbf{T_s}$	**23.9**	**25.5**

Example 4

Bridge 857, Nenana River at Healy, Healy Road, mile 3.2

Bridge 857 has piers and exposed footings. The bridge is near a U.S. Geological Survey gaging station that has available numerous U.S. Geological Survey discharge measurements.

Data available: A U.S. Geological Survey gaging station (15518000, Nenana River near Healy, Alaska) is approximately 1.2 mi upstream from the bridge. The gaging station was in operation during the years 1951–79. Another gaging station (15518040, Nenana River at Healy) that was located at the bridge was in operation during 1990–91. A flood survey was performed at the bridge from September 25 to October 2, 1990. Flood discharge was 31,200 ft^3/s. As-built plans were provided by the Alaska Department of Transportation and Public Facilities.

Summary information included: Cross sections and scour computations for contraction and pier and for contraction and footing.

Derivations, assumptions, and remarks: Geometry from the as-built bridge plans was combined with the flood-survey data. Surveyed water-surface slope was used as the initial friction slope for the WSPRO model run. Manning's *n* values were estimated in the field. Good agreement was obtained between the model and the surveyed water-surface profile.

This model is complicated by a railroad bridge located about 100 feet upstream. One span of the railroad bridge has been filled, thus reducing the channel width. To model this situation, the highway and railroad bridge were treated as one very wide bridge. Scour was computed for just the highway bridge.

The flood survey revealed that the pier footings were exposed. Local scour was computed for both the pier geometry and the footing geometry. Footing scour was greater and should be used as a worst-case scenario.

Bridge 857. Nenana River at Healy, bridge and full valley cross-sections.

[X is an arbitrary horizontal coordinate. Z is the elevation read from the as-built bridge plans. USGS sounding made on 9/7/90]

X (feet)	Z (feet)	Notes
Bridge geometry		
114.0	1267.6	from as-builts
114.0	1250.7	from as-builts
118.0	1250.5	USGS sounding
143.0	1245.6	USGS sounding
158.0	1243.3	USGS sounding
163.0	1241.7	USGS sounding
168.0	1241.0	USGS sounding
173.0	1240.3	USGS sounding
178.0	1238.5	USGS sounding
183.0	1240.6	USGS sounding
188.0	1242.9	USGS sounding
198.0	1245.0	USGS sounding
203.0	1245.3	USGS sounding
208.0	1245.9	USGS sounding
213.0	1246.4	USGS sounding
218.0	1247.5	USGS sounding
228.0	1248.1	USGS sounding
238.0	1246.5	USGS sounding
245.0	1244.2	USGS sounding
246.0	1244.2	USGS sounding
256.0	1244.4	USGS sounding
261.0	1244.4	USGS sounding
273.0	1247.6	USGS sounding
283.0	1248.2	USGS sounding
303.0	1251.4	USGS sounding
318.0	1252.7	USGS sounding
341.0	1254.4	USGS sounding
353.0	1255.0	USGS sounding
363.0	1256.1	USGS sounding
373.0	1255.1	USGS sounding
381.0	1251.6	USGS sounding
391.0	1251.6	USGS sounding
393.0	1251.4	USGS sounding
403.0	1251.4	USGS sounding
418.0	1252.7	USGS sounding
433.0	1254.4	USGS sounding
443.0	1256.3	USGS sounding
453.0	1256.9	USGS sounding
463.0	1257.0	USGS sounding
473.0	1263.7	USGS sounding
483.0	1265.4	USGS sounding
500.0	1267.6	USGS sounding
114.0	1267.6	from as-builts

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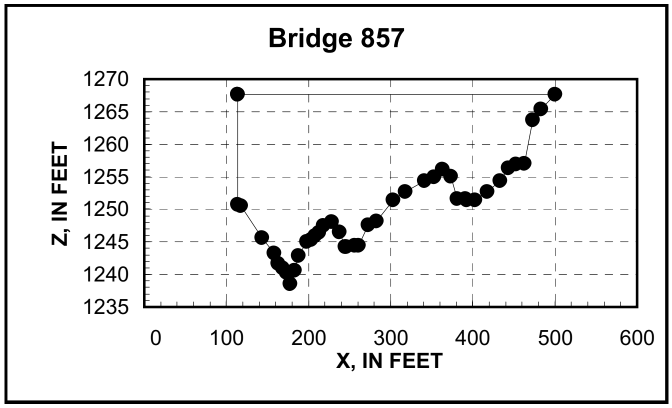
Nenana River at Healy
Bridge 857
Healy Road mile 3.2



Bridge 857 bridge cross-section.

Bridge 857. Nenana River at Healy, **continued**

Full valley section		
-50.0	1270.5	extended up
43.0	1257.9	USGS sounding
53.0	1257.3	USGS sounding
63.0	1257.2	USGS sounding
73.0	1256.9	USGS sounding
83.0	1256.8	USGS sounding
93.0	1257.2	USGS sounding
103.0	1255.5	USGS sounding
106.0	1254.4	USGS sounding
118.0	1250.5	USGS sounding
143.0	1245.6	USGS sounding
158.0	1243.3	USGS sounding
163.0	1241.7	USGS sounding
168.0	1241.0	USGS sounding
173.0	1240.3	USGS sounding
178.0	1238.5	USGS sounding
183.0	1240.6	USGS sounding
188.0	1242.9	USGS sounding
198.0	1245.0	USGS sounding
203.0	1245.3	USGS sounding
208.0	1245.9	USGS sounding
213.0	1246.4	USGS sounding
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228.0	1248.1	USGS sounding
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246.0	1244.2	USGS sounding
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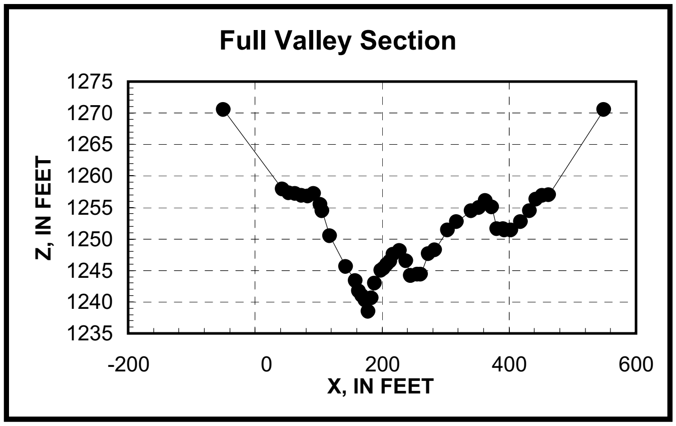
393.0	1251.4	USGS sounding
403.0	1251.4	USGS sounding
418.0	1252.7	USGS sounding
433.0	1254.4	USGS sounding
443.0	1256.3	USGS sounding
453.0	1256.9	USGS sounding
463.0	1257.0	USGS sounding
550.0	1270.5	extended up



Bridge 857 full valley cross-section.

Bridge 857. Nenana River at Healy bridge scour computations.

Nenana River at Healy
Bridge 857
Healy Road mile 3.2

LIVE-BED CONTRACTION SCOUR

$$\frac{y_2}{y_1} = \left(\frac{Q_2}{Q_1}\right)^{\frac{6}{7}} \left(\frac{W_1}{W_2}\right)^{K_1}$$

$y_{cs} = y_2 - y_1$ = (average scour depth)

Notes: Using surveyed channel geometry.

		100 Year	500 Year
Computed floods: total discharge (cfs)	**Q**	**47200**	**57800**
Hydraulic radius (ft)	R	14.05	16.34
Friction slope (ft/ft)	S	0.0017	0.0018
Average shear stress at bed (lbs/ft^2)	$\tau=\rho gRS$	1.49	1.84
Shear velocity (ft/s)	$V^*=(\tau/\rho)^{1/2}$	0.88	0.97
Fall velocity of bed material (ft/s)	w	2.60	2.60
Ratio	V^*/w	0.34	0.37
Exponent determined from mode of bed material transport	$k_1 = f(V^*/w)$	0.59	0.59
Discharge in main channel of approach section (cfs)	Q_1	31574	36608
Percentage of total discharge		67%	63%
Discharge in main channel of contracted (bridge) section (cfs)	Q_2	47200	57800
Percentage of total discharge		100%	100%
Width of main channel of approach section (cfs)	W_1	390	390
Width of main channel of contracted (bridge) section (cfs)	W_2	345	346
Average depth of main channel of approach section (ft)	y_1	14.1	16.4
Average depth in contracted (bridge) section (ft)	y_2	21.4	26.0
CONTRACTION SCOUR (ft)	$\mathbf{Y_{cs}}$	**7.3**	**9.6**

PIER SCOUR

$$\frac{y_{ps}}{y_1} = 2.0 K_1 K_2 K_3 \left(\frac{a}{y_1}\right)^{0.65} Fr^{0.43}$$

Notes:

		100 Year	500 Year
Speed of maximum velocity stream tube (ft/s)	v_1	17.61	20.55
Depth of maximum velocity stream tube (ft)	y_1	20.7	21.3
Froude number of maximum velocity stream tube (ft/s)	$Fr=v_1/(gy_1)^{1/2}$	0.68	0.79
Pier shape		round nose	
Pier shape correction factor	K_1	1.0	1.0
Angle of attack (deg)	AA	15	15
Pier width (ft)	a	3.0	3.0
Pier length (ft)	L	32	32
Ratio	L/a	11	11
Angle of attack correction factor	K_2=f(AA,L/a)	2.4	2.4
Bed condition (dunes) correction factor	K_3	1.1	1.1
PIER SCOUR (ft)	$\mathbf{Y_{ps}}$	**26.4**	**28.3**

TOTAL SCOUR

$T_s = y_{cs} + y_{ps}$

		100 Year	500 Year
Contraction scour (ft)	$\mathbf{Y_{cs}}$	**7.3**	**9.6**
Pier scour (ft)	$\mathbf{Y_{ps}}$	**26.4**	**28.3**
TOTAL SCOUR (ft)	$\mathbf{T_s}$	**33.7**	**38.0**

Bridge 857. Nenana River at Healy bridge scour computations.

Nenana River at Healy
Bridge 857
Healy Road mile 3.2

LIVE-BED CONTRACTION SCOUR

$$\frac{y_2}{y_1} = \left(\frac{Q_2}{Q_1}\right)^{\frac{6}{7}} \left(\frac{W_1}{W_2}\right)^{K_1}$$

$y_{cs} = y_2 - y_1$ = (average scour depth)

Notes: Using surveyed channel geometry.

		100 Year	500 Year
Computed floods: total discharge (cfs)	**Q**	**47200**	**57800**
Hydraulic radius (ft)	R	14.05	16.34
Friction slope (ft/ft)	S	0.0017	0.0018
Average shear stress at bed (lbs/ft^2)	$\tau = \rho gRS$	1.49	1.84
Shear velocity (ft/s)	$V^* = (\tau/\rho)^{1/2}$	0.88	0.97
Fall velocity of bed material (ft/s)	w	2.60	2.60
Ratio	V*/w	0.34	0.37
Exponent determined from mode of bed material transport	k_1 =f(V*/w)	0.59	0.59
Discharge in main channel of approach section (cfs)	Q_1	31574	36608
Percentage of total discharge		67%	63%
Discharge in main channel of contracted (bridge) section (cfs)	Q_2	47200	57800
Percentage of total discharge		100%	100%
Width of main channel of approach section (cfs)	W_1	390	390
Width of main channel of contracted (bridge) section (cfs)	W_2	345	346
Average depth of main channel of approach section (ft)	y_1	14.1	16.4
Average depth in contracted (bridge) section (ft)	y_2	21.4	26.0
CONTRACTION SCOUR (ft)	$\mathbf{Y_{cs}}$	**7.3**	**9.6**

PIER SCOUR

$$\frac{y_{ps}}{y_1} = 2.0K_1K_2K_3\left(\frac{a}{y_1}\right)^{0.65} Fr^{0.43}$$

Notes: Footing scour.

		100 Year	500 Year
Speed of maximum velocity stream tube (ft/s)	v_1	14.28	16.59
Depth of maximum velocity stream tube (ft)	y_1	6.0	6.0
Froude number of maximum velocity stream tube (ft/s)	$Fr=v_1/(gy_1)^{1/2}$	1.03	1.19
Pier shape		square nose	
Pier shape correction factor	K_1	1.1	1.1
Angle of attack (deg)	AA	15	15
Pier width (ft)	a	14.5	14.5
Pier length (ft)	L	37	37
Ratio	L/a	3	3
Angle of attack correction factor	K_2=f(AA,L/a)	1.3	1.3
Bed condition (dunes) correction factor	K_3	1.1	1.1
PIER SCOUR (ft)	$\mathbf{Y_{ps}}$	**33.9**	**36.2**

TOTAL SCOUR

$T_s = y_{cs} + y_{ps}$

		100 Year	500 Year
Contraction scour (ft)	$\mathbf{Y_{cs}}$	**7.3**	**9.6**
Pier scour (ft)	$\mathbf{Y_{ps}}$	**33.9**	**36.2**
TOTAL SCOUR (ft)	$\mathbf{T_s}$	**41.2**	**45.8**