



In cooperation with the North Dakota Department of Transportation

# **Estimated Level 1.5 Bridge Scour at Selected Sites in North Dakota, 1999-2002**

**Open-File Report 03-134**

**U.S. Department of the Interior  
U.S. Geological Survey**

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**By Tara Williams-Sether**

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**Bismarck, North Dakota  
2003**

**U.S. DEPARTMENT OF THE INTERIOR  
GALE A. NORTON, Secretary**

**U.S. GEOLOGICAL SURVEY  
CHARLES G. GROAT, Director**

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# Estimated Level 1.5 Bridge Scour at Selected Sites in North Dakota, 1999-2002

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## Abstract

The Level 1.5 method is a limited-detail method that is used for quick estimates of bridge scour. The method was developed by the U.S. Geological Survey in Montana and was used to estimate scour depths at 215 bridge sites located on secondary roads throughout North Dakota. The estimated scour depths are presented in tabular form.

## INTRODUCTION

The erosive action of flowing water (scour) can result in the structural failure of bridges by exposing or undermining bridge piers and/or abutment foundations. Historically, pier and abutment foundation scour has been the most common cause of bridge failure within the United States (Richardson and others, 1991). In 1988, the Federal Highway Administration (FHWA) recommended that "every bridge over a scourable stream, whether existing or under design, should be evaluated as to its vulnerability to floods in order to determine the prudent measures to be taken for its protection" (U.S. Department of Transportation, 1988, p. 2). In response to the FHWA's recommendation, the U.S. Geological Survey (USGS) and the North Dakota Department of Transportation (NDDOT) began a cooperative study in 1996 to estimate scour at 495 selected bridge sites located on secondary roads throughout North Dakota. A rapid-estimation technique (Level 1.5 method) developed by the USGS in Montana (Holnbeck and Parrett, 1997) was used to estimate scour at the sites. Results of the study are published in a report by Williams-Sether (1999).

In 1999, the USGS and NDDOT began another cooperative study, using the same techniques as those used in the 1996 study, to estimate scour at an additional 215 selected bridge sites located on secondary roads. The purpose of this report is to present the results of the 1999 study. The information will help the NDDOT decide if existing bridges within the State are at risk from scour. The author thanks the NDDOT for providing bridge site plans and information and for providing general assistance. The author also thanks Brad Sether and Kevin Vining with the USGS for making field measurements at the bridge sites and Ann Dahl, also with the USGS, for providing drainage-area and slope estimates for the bridge sites.

## LEVEL 1.5 METHOD

The Level 1.5 method is a limited-detail method that is used by one person making field measurements to obtain quick estimates (1 hour or less of field work) of bridge scour. Although the method is not intended to replace the more detailed scour analyses used for design purposes, it is considered to be useful for limited-detail efforts of bridge scour assessment and inventory.

The Level 1.5 method uses flow depths and an envelope-curve approach to estimate contraction scour, abutment scour, and pier scour. The method usually results in scour being overestimated rather than underestimated. For contraction-scour estimates, main-channel and flood-plain flow depths and associated lateral distances are used to derive contraction-scour variables and then estimate scour depths on the basis of an envelope curve. For abutment-scour estimates, average flood-plain flow depths adjusted for any main-channel abutment encroachments are used to obtain scour depths. For pier-scour estimates, average pier widths, pier lengths, and flow angles of attack are used to obtain scour depths. Data-collection efforts for estimating pier scour were relatively straightforward, but data-collection efforts for estimating contraction and abutment scour were more time-consuming and required some insight into water flows upstream and around and through a bridge. Further explanation of the development, testing, and use of the Level 1.5 method is described in Holnbeck and Parrett (1997). Application of the Level 1.5 method at numerous bridge sites in North Dakota is described in Williams-Sether (1999).

The estimated contraction, abutment, and pier scour depths for each bridge site in this report are listed in table 1. The bridge numbers listed in table 1 are county bridge numbers derived from a coordinate system that is unique to each county. The identifying numbers are made up of the county number first, then a mile number read to the right (east) from the northwest corner of the county, then a mile number read down (south) from the northwest corner of the county (fig. 1). Further explanation of the county bridge numbering system and other non-county bridge numbering systems are discussed in North Dakota Department of Transportation (1997).

Main-channel and flood-plain flow depths were determined from the 100-year peak discharges at the selected bridge sites. The 100-year peak discharges were estimated using techniques described in Williams-Sether (1992). After the 100-year peak discharge estimate was obtained for a bridge site, a graphical, step-wise approximation method was used to estimate flow depth at the approach section. Flow depth at the approach section also was used to visually estimate the flow angle of attack on the bridge and on the piers.

## REFERENCES

- Holnbeck, S.R., and Parrett, C., 1997, Method for rapid estimation of scour at highway bridges based on limited site data: U.S. Geological Survey Water-Resources Investigations Report 96-4310, 79 p.
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- Richardson, E.V., Harrison, L.J., and Davis, S.R., 1991, Evaluating scour at bridges: U.S. Department of Transportation Publication No. FHWA-IP-90-017 Hydraulic Engineering Circular No. 18, 105 p.
- U.S. Department of Transportation, 1988, Scour at bridges: Washington, D.C., Federal Highway Administration Technical Advisory T 5140.20, 6 p.
- Williams-Sether, Tara, 1992, Techniques for estimating peak-flow frequency relations for North Dakota streams: U.S. Geological Survey Water-Resources Investigations Report 92-4020, 57 p.
- 1999, Estimated and measured bridge scour at selected sites in North Dakota, 1990-97: U.S. Geological Survey Water-Resources Investigations Report 99-4124, 54 p.

**Table 1.** Results of Level 1.5 bridge scour study for selected bridge sites in North Dakota

[Bridge length is provided by the North Dakota Department of Transportation; number in parentheses after county is county number; ft<sup>3</sup>/s, cubic feet per second; Q<sub>100</sub>, discharge estimate for the 100-year recurrence interval; Q<sub>a</sub>, adjusted Q<sub>100</sub> (discharge determined to flow through bridge without overtopping, scour estimates are based on Q<sub>a</sub> when determined); --, not determined]

| Bridge number                | Bridge length (feet) | Stream name             | Flood discharge                       |                                     | Average distance below low-steel to streambed (feet) | Main channel depth (feet) | Estimated scour (feet) |      |       |      |
|------------------------------|----------------------|-------------------------|---------------------------------------|-------------------------------------|--|---------------------------|------------------------|------|-------|------|
|                              |                      |                         | Q <sub>100</sub> (ft <sup>3</sup> /s) | Q <sub>a</sub> (ft <sup>3</sup> /s) |  |                           | Contraction            | Left | Right | Pier |
| <b>Adams County (01)</b>     |                      |                         |                                       |                                     |  |                           |                        |      |       |      |
| 113-02.1                     | 82                   | Chanta Peta Creek       | 4,500                                 | --                                  | 8.0  | 9.5                       | 0.8                    | 20.9 | 20.9  | 6.9  |
| 143-17.0                     | 139                  | Cedar Creek             | 19,150                                | --                                  | 13.0   | 16.3                      | 0.5                    | 17.1 | 20.1  | 17.9 |
| <b>Barnes County (02)</b>    |                      |                         |                                       |                                     |  |                           |                        |      |       |      |
| 117-01.0                     | 109                  | Baldhill Creek          | 6,950                                 | --                                  | 12.0   | 11.2                      | 1.0                    | 24.6 | 24.6  | 21.7 |
| 117-03.0                     | 36                   | Baldhill Creek          | 7,030                                 | 2,520                               | 9.5  | 11.0                      | 5.7                    | 17.1 | 17.1  | --   |
| 118-18.0                     | 122                  | Sheyenne River          | 7,650                                 | --                                  | 11.8   | 10.3                      | 0.0                    | 16.7 | 15.0  | 8.3  |
| 123-35.0                     | 124                  | Sheyenne River          | 6,950                                 | --                                  | 17.0   | 9.8                       | 0.0                    | 0.0  | 0.0   | 4.3  |
| 124-39.0                     | 21                   | Spring Creek            | 2,470                                 | 1,400                               | 8.0  | 12.0                      | 7.0                    | 7.3  | 14.6  | --   |
| 124-39.3                     | 124                  | Sheyenne River          | 8,000                                 | --                                  | 11.0   | 10.4                      | 0.4                    | 17.1 | 11.9  | 5.2  |
| 125-39.0                     | 122                  | Sheyenne River          | 6,950                                 | --                                  | 13.0   | 9.7                       | 2.2                    | 24.5 | 0.0   | 4.3  |
| <b>Benson County (03)</b>    |                      |                         |                                       |                                     |  |                           |                        |      |       |      |
| 130-08.0                     | 73                   | Big Coulee              | 3,330                                 | --                                  | 8.4  | 8.9                       | 1.8                    | 11.9 | 6.0   | --   |
| <b>Billings County (04)</b>  |                      |                         |                                       |                                     |  |                           |                        |      |       |      |
| 103-13.0                     | 48                   | Roosevelt Creek         | 2,180                                 | --                                  | 8.0  | 8.7                       | 0.4                    | 14.6 | 14.6  | --   |
| 104-28.0                     | 142                  | Andrews Creek           | 5,060                                 | --                                  | 12.0   | 8.0                       | 0.1                    | 0.0  | 7.3   | 6.8  |
| 107-18.0                     | 86                   | Franks Creek            | 3,440                                 | --                                  | 8.0  | 8.0                       | 0.1                    | 7.3  | 14.6  | --   |
| <b>Bottineau County (05)</b> |                      |                         |                                       |                                     |  |                           |                        |      |       |      |
| 125-07.0                     | 236                  | Souris River            | 16,000                                | --                                  | 13.9   | 11.0                      | 13.9                   | --   | --    | 13.6 |
| <b>Bowman County (06)</b>    |                      |                         |                                       |                                     |  |                           |                        |      |       |      |
| 133-12.0                     | 66                   | Spring Creek            | 4,590                                 | --                                  | 8.0  | 11.0                      | 9.0                    | 19.8 | 12.1  | --   |
| 136-23.0                     | 116                  | North Fork Grand River  | 9,900                                 | --                                  | 10.0   | 12.4                      | 6.0                    | 22.4 | 17.1  | 4.2  |
| <b>Burke County (07)</b>     |                      |                         |                                       |                                     |  |                           |                        |      |       |      |
| 117-11.0                     | 40                   | Short Creek             | 2,480                                 | 2,000                               | 5.0  | 9.0                       | 26.0                   | 17.1 | 19.8  | --   |
| <b>Burleigh County (08)</b>  |                      |                         |                                       |                                     |  |                           |                        |      |       |      |
| 119-21.0                     | 27                   | West Branch Apple Creek | 2,810                                 | --                                  | 7.0  | 13.5                      | 13.5                   | 21.2 | 17.1  | --   |
| 130-26.0                     | 50                   | East Branch Apple Creek | 5,350                                 | --                                  | 10.8   | 13.7                      | 6.3                    | 11.9 | 0.0   | --   |
| <b>Cass County (09)</b>      |                      |                         |                                       |                                     |  |                           |                        |      |       |      |
| 103-04.0                     | 62                   | Maple River             | 3,500                                 | --                                  | 7.6  | 9.9                       | 0.6                    | 11.9 | 11.9  | 11.7 |
| 103-08.0                     | 72                   | Maple River             | 4,500                                 | --                                  | 8.4  | 10.5                      | 1.4                    | 0.0  | 0.0   | 4.3  |
| 103-13.0                     | 40                   | Maple River Tributary   | 3,900                                 | --                                  | 10.0   | 13.0                      | 2.3                    | 11.9 | 11.9  | --   |
| 103-14.0                     | 56                   | Maple River Tributary   | 3,850                                 | --                                  | 8.0  | 10.8                      | 2.4                    | 11.9 | 0.0   | 4.3  |
| 104-13.0                     | 57                   | Maple River             | 6,700                                 | --                                  | 8.3  | 18.1                      | 12.0                   | 24.9 | 24.9  | --   |
| 104-15.0                     | 38                   | Maple River             | 6,700                                 | 5,000                               | 13.0   | 15.9                      | 7.0                    | 11.9 | 17.1  | 12.1 |
| 104-18.0                     | 70                   | Maple River             | 6,800                                 | 5,500                               | 9.0  | 11.8                      | 1.0                    | 17.1 | 17.1  | 10.1 |
| 104-29.0                     | 65                   | Maple River             | 9,000                                 | 6,000                               | 10.0   | 13.1                      | 1.4                    | 17.1 | 17.1  | 11.9 |
| 104-37.0                     | 93                   | Maple River             | 9,000                                 | --                                  | 13.0   | 12.9                      | 1.8                    | 17.1 | 17.1  | 4.4  |
| 105-18.0                     | 21                   | Maple River Tributary   | 1,300                                 | 1,000                               | 6.5  | 8.9                       | 4.2                    | 17.1 | 17.1  | --   |

**Table 1.** Results of Level 1.5 bridge scour study for selected bridge sites in North Dakota--Continued

[Bridge length is provided by the North Dakota Department of Transportation; number in parentheses after county is county number; ft<sup>3</sup>/s, cubic feet per second; Q<sub>100</sub>, discharge estimate for the 100-year recurrence interval; Q<sub>a</sub>, adjusted Q<sub>100</sub> (discharge determined to flow through bridge without overtopping, scour estimates are based on Q<sub>a</sub> when determined); --, not determined]

| Bridge number                      | Bridge length (feet) | Stream name              | Flood discharge                       |                                     | Average distance below low-steel to streambed (feet) | Main channel depth (feet) | Estimated scour (feet) |      |       |      |
|------------------------------------|----------------------|--------------------------|---------------------------------------|-------------------------------------|--|---------------------------|------------------------|------|-------|------|
|                                    |                      |                          | Q <sub>100</sub> (ft <sup>3</sup> /s) | Q <sub>a</sub> (ft <sup>3</sup> /s) |  |                           | Contraction            | Left | Right | Pier |
| <b>Cass County (09)--Continued</b> |                      |                          |                                       |                                     |  |                           |                        |      |       |      |
| 105-33.0                           | 82                   | Maple River              | 9,000                                 | --                                  | 12.0   | 16.4                      | 4.2                    | 17.1 | 0.0   | 18.8 |
| 110-40.0                           | 60                   | Maple River              | 14,200                                | 5,020                               | 9.0  | 12.3                      | 4.0                    | 17.1 | 11.9  | 11.8 |
| 113-28.0                           | 32                   | Buffalo Creek            | 1,900                                 | --                                  | 9.0  | 9.9                       | 2.5                    | 17.1 | 17.1  | --   |
| 114-03.0                           | 32                   | Elm River                | 1,400                                 | --                                  | 5.5  | 8.4                       | 4.6                    | 11.9 | 11.9  | --   |
| 114-38.0                           | 210                  | Maple River              | 14,500                                | --                                  | 12.0   | 11.8                      | 0.1                    | 0.0  | 14.5  | 7.0  |
| 116-01.1                           | 50                   | Elm River                | 1,900                                 | --                                  | 7.0  | 7.8                       | 4.4                    | 11.9 | 11.9  | 4.3  |
| 117-14.1                           | 40                   | Rush River Tributary     | 1,400                                 | --                                  | 10.0   | 7.5                       | 3.3                    | 0.0  | 6.0   | --   |
| 118-07.0                           | 24                   | Rush River               | 890                                   | --                                  | 10.0   | 7.6                       | 6.0                    | 6.0  | 6.0   | --   |
| 121-26.0                           | 37                   | Swan Creek Tributary     | 800                                   | --                                  | 5.0  | 5.8                       | 0.4                    | 14.5 | 14.5  | --   |
| 124-37.0                           | 27                   | Ditch                    | 550                                   | --                                  | 5.7  | 5.7                       | 2.6                    | 0.0  | 0.0   | --   |
| 125-16.0                           | 60                   | Rush River               | 4,250                                 | --                                  | 8.2  | 11.0                      | 1.1                    | 17.1 | 17.1  | --   |
| 126-17.0                           | 62                   | Rush River               | 4,350                                 | --                                  | 11.0   | 11.7                      | 3.8                    | 0.0  | 17.1  | 4.4  |
| 126-32.0                           | 194                  | Maple River              | 14,700                                | --                                  | 11.0   | 13.8                      | 2.5                    | 15.6 | 0.0   | 4.4  |
| 128-04.0                           | 22                   | Ditch                    | 1,500                                 | 1,000                               | 7.4  | 11.4                      | 32.0                   | 19.7 | 19.7  | --   |
| 128-41.0                           | 28                   | Ditch                    | 520                                   | --                                  | 4.4  | 5.4                       | 11.0                   | 17.1 | 0.0   | --   |
| 129-01.0                           | 38                   | Elm River                | 3,000                                 | --                                  | 10.6   | 11.8                      | 2.3                    | 12.2 | 17.1  | --   |
| 131-19.0                           | 61                   | Rush River               | 4,540                                 | 3,000                               | 8.6  | 11.8                      | 22.0                   | 25.0 | 19.8  | 21.2 |
| 131-24.0                           | 171                  | Maple River              | 15,000                                | --                                  | 10.3   | 12.3                      | 1.4                    | 20.9 | 20.9  | 7.0  |
| 132-19.0                           | 57                   | Ditch                    | 4,540                                 | --                                  | 9.8  | 12.4                      | 13.0                   | 19.8 | 19.8  | 21.2 |
| 132-34.0                           | 34                   | Ditch                    | 1,300                                 | --                                  | 8.6  | 7.8                       | 4.3                    | 0.0  | 0.0   | --   |
| 133-26.0                           | 49                   | Ditch                    | 1,600                                 | --                                  | 6.1  | 7.3                       | 17.7                   | 19.8 | 22.4  | --   |
| 133-28.0                           | 50                   | Ditch                    | 1,500                                 | --                                  | 10.8   | 6.9                       | 5.5                    | 0.0  | 0.0   | --   |
| 134-21.0                           | 60                   | Raymond Coulee           | 1,450                                 | --                                  | 7.5  | 6.5                       | 3.6                    | 17.1 | 19.8  | --   |
| 135-42.0                           | 115                  | Sheyenne River           | 8,000                                 | --                                  | 14.9   | 10.8                      | 0.0                    | 3.7  | 3.7   | 4.2  |
| 136-23.1                           | 70                   | Sheyenne River Diversion | 5,000                                 | --                                  | 11.0   | 10.9                      | 5.4                    | 0.0  | 0.0   | 4.4  |
| 137-05.0                           | 34                   | Ditch                    | 850                                   | --                                  | 6.1  | 6.3                       | 2.2                    | 12.2 | 12.2  | --   |
| 137-17.0                           | 110                  | Ditch                    | 4,900                                 | --                                  | 11.4   | 8.7                       | 2.5                    | 0.0  | 0.0   | 8.9  |
| 137-40.0                           | 202                  | Sheyenne River           | 8,100                                 | --                                  | 10.6   | 8.6                       | 0.0                    | 22.4 | 19.8  | 22.0 |
| 138-23.1                           | 140                  | Sheyenne River           | 6,750                                 | --                                  | 14.8   | 9.0                       | 2.1                    | 11.9 | 11.9  | 9.0  |
| 138-28.2                           | 270                  | Sheyenne River Diversion | 5,000                                 | --                                  | 8.3  | 5.9                       | 0.0                    | 17.1 | 17.1  | 6.5  |
| 139-14.0                           | 29                   | Ditch                    | 1,190                                 | --                                  | 11.6   | 8.2                       | 3.3                    | 17.1 | 12.2  | --   |
| 140-18.1                           | 56                   | Site A                   | 450                                   | --                                  | 6.3  | 3.4                       | 1.3                    | 0.0  | 0.0   | --   |
| 140-29.0                           | 58                   | Ditch                    | 416                                   | --                                  | 6.9  | 3.3                       | 0.0                    | 17.1 | 17.1  | --   |
| 140-41.1                           | 83                   | Wild Rice River          | 14,000                                | 12,000                              | 16.2   | 19.0                      | 3.4                    | 12.2 | 12.2  | 4.2  |
| 141-40.0                           | 252                  | Wild Rice River          | 14,700                                | --                                  | 12.3   | 14.9                      | 4.2                    | 32.0 | 32.0  | 35.9 |
| 142-04.0                           | 420                  | Red River of the North   | 55,600                                | --                                  | 20.0   | 20.9                      | 0.4                    | 30.9 | 20.9  | 14.7 |
| 142-18.0                           | 653                  | Red River of the North   | 30,900                                | --                                  | 16.0   | 10.1                      | 0.0                    | 0.0  | 0.0   | 28.0 |
| 143-33.0                           | 84                   | Wild Rice River          | 14,000                                | 9,900                               | 14.0   | 16.8                      | 3.0                    | 17.1 | 17.1  | 11.6 |
| 144-35.0                           | 390                  | Red River of the North   | 15,000                                | --                                  | 17.0   | 8.8                       | 0.0                    | 0.0  | 0.0   | 20.7 |
| 144-40.0                           | 260                  | Red River of the North   | 14,000                                | --                                  | 10.0   | 9.8                       | 0.3                    | 14.5 | 14.5  | 22.7 |
| FRGO12                             | 310                  | Red River of the North   | 30,000                                | --                                  | 11.0   | 13.8                      | 0.8                    | 11.9 | 6.0   | 17.6 |

**Table 1.** Results of Level 1.5 bridge scour study for selected bridge sites in North Dakota--Continued

[Bridge length is provided by the North Dakota Department of Transportation; number in parentheses after county is county number; ft<sup>3</sup>/s, cubic feet per second; Q<sub>100</sub>, discharge estimate for the 100-year recurrence interval; Q<sub>a</sub>, adjusted Q<sub>100</sub> (discharge determined to flow through bridge without overtopping, scour estimates are based on Q<sub>a</sub> when determined); --, not determined]

| Bridge<br>number                 | Bridge<br>length<br>(feet) | Stream name                | Flood discharge                          |  | Average<br>distance<br>below low-<br>steel to<br>streambed<br>(feet) | Main<br>channel<br>depth<br>(feet) | Estimated scour (feet) |      |       |      |
|----------------------------------|----------------------------|----------------------------|--|--|--|------------------------------------|------------------------|------|-------|------|
|                                  |                            |                            | Q <sub>100</sub><br>(ft <sup>3</sup> /s) | Q <sub>a</sub><br>(ft <sup>3</sup> /s) |  |                                    | Contraction            | Left | Right | Pier |
| <b>Dickey County (11)</b>        |                            |                            |  |  |  |                                    |                        |      |       |      |
| 116-24.0                         | 86                         | Elm River                  | 3,000                                    | --                                     | 6.2  | 7.7                                | 4.2                    | 14.6 | 14.6  | --   |
| 121-07.0                         | 66                         | Maple River                | 3,200                                    | --                                     | 7.8  | 9.0                                | 3.8                    | 14.6 | 14.6  | --   |
| 125-08.0                         | 74                         | Maple River                | 5,200                                    | --                                     | 9.0  | 11.1                               | 2.1                    | 20.9 | 14.6  | --   |
| 142-06.0                         | 156                        | James River                | 11,400                                   | --                                     | 8.6  | 11.1                               | 1.0                    | 14.6 | 14.6  | 7.0  |
| 143-12.0                         | 76                         | Oakes Canal                | 320                                      | --                                     | 8.0  | 2.5                                | 0.1                    | 0.0  | 0.0   | --   |
| 145-13.0                         | 52                         | Oakes Canal                | 320                                      | --                                     | 5.0  | 3.0                                | 0.0                    | 0.0  | 0.0   | --   |
| 145-14.0                         | 60                         | Oakes Canal                | 320                                      | --                                     | 5.5  | 2.9                                | 0.0                    | 0.0  | 0.0   | --   |
| 145-15.0                         | 42                         | Oakes Canal                | 320                                      | --                                     | 6.0  | 3.4                                | 0.0                    | 0.0  | 0.0   | --   |
| 145-16.0                         | 42                         | Oakes Canal                | 320                                      | --                                     | 4.5  | 3.4                                | 0.0                    | 0.0  | 0.0   | --   |
| <b>Dunn County (13)</b>          |                            |                            |  |  |  |                                    |                        |      |       |      |
| 108-38.0                         | 118                        | Knife River                | 4,700                                    | --                                     | 13.0   | 8.5                                | 0.3                    | 0.0  | 0.0   | 14.4 |
| 124-43.0                         | 68                         | Crooked Creek              | 5,690                                    | --                                     | 7.0  | 12.5                               | 4.7                    | 18.6 | 0.0   | --   |
| 130-46.1                         | 129                        | Knife River                | 11,400                                   | --                                     | 12.9   | 12.6                               | 0.0                    | 8.9  | 0.0   | 13.7 |
| 130-49.0                         | 90                         | Deep Creek                 | 8,840                                    | --                                     | 10.0   | 13.1                               | 2.2                    | 14.6 | 14.6  | --   |
| <b>Eddy County (14)</b>          |                            |                            |  |  |  |                                    |                        |      |       |      |
| 101-08.0                         | 91                         | New Rockford Canal         | 1,600                                    | --                                     | 9.0  | 6.5                                | 6.0                    | 0.0  | 0.0   | --   |
| 105-09.0                         | 90                         | New Rockford Canal         | 1,600                                    | --                                     | 9.0  | 5.9                                | 5.5                    | 0.0  | 0.0   | --   |
| 107-09.0                         | 91                         | New Rockford Canal         | 1,600                                    | --                                     | 9.0  | 6.0                                | 5.4                    | 0.0  | 0.0   | --   |
| 109-09.0                         | 90                         | New Rockford Canal         | 1,600                                    | --                                     | 9.0  | 6.0                                | 5.0                    | 0.0  | 0.0   | --   |
| <b>Emmons County (15)</b>        |                            |                            |  |  |  |                                    |                        |      |       |      |
| 113-20.0                         | 77                         | Sand Creek                 | 5,770                                    | --                                     | 11.3   | 12.0                               | 0.0                    | 7.6  | 0.0   | --   |
| 114-26.0                         | 103                        | Beaver Creek Overflow      | 16,300                                   | --                                     | 19.5   | 17.1                               | 1.2                    | 0.0  | 0.0   | 5.8  |
| 118-26.2                         | 28                         | Beaver Creek Overflow      | 1,000                                    | --                                     | 8.0  | 8.4                                | 14.0                   | 22.4 | 0.0   | --   |
| 124-29.0                         | 131                        | Beaver Creek               | 14,800                                   | --                                     | 21.2   | 16.5                               | 6.5                    | 0.0  | 0.0   | 16.0 |
| <b>Golden Valley County (17)</b> |                            |                            |  |  |  |                                    |                        |      |       |      |
| 102-21.0                         | 78                         | Little Beaver Creek        | 4,090                                    | --                                     | 7.8  | 9.5                                | 0.8                    | 14.6 | 7.3   | --   |
| <b>Grand Forks County (18)</b>   |                            |                            |  |  |  |                                    |                        |      |       |      |
| 116-01.0                         | 96                         | Forest River               | 9,000                                    | --                                     | 9.5  | 12.8                               | 0.0                    | 22.4 | 19.8  | 6.9  |
| 135-02.1                         | 140                        | Turtle River               | 16,000                                   | --                                     | 16.5   | 15.7                               | 0.0                    | 17.1 | 17.1  | 10.1 |
| 136-07.0                         | 96                         | Marais River               | 950                                      | --                                     | 8.6  | 4.6                                | 4.8                    | 0.0  | 0.0   | --   |
| <b>Grant County (19)</b>         |                            |                            |  |  |  |                                    |                        |      |       |      |
| 111-17.0                         | 64                         | Antelope Creek             | 3,800                                    | --                                     | 8.2  | 9.9                                | 2.3                    | 14.5 | 14.5  | --   |
| 144-34.0                         | 58                         | Cannonball River Tributary | 2,180                                    | --                                     | 7.2  | 7.9                                | 1.0                    | 14.5 | 14.5  | --   |
| <b>Griggs County (20)</b>        |                            |                            |  |  |  |                                    |                        |      |       |      |
| 116-28.0                         | 124                        | Baldhill Creek             | 6,070                                    | --                                     | 14.0   | 9.0                                | 0.3                    | 20.9 | 20.9  | 14.5 |
| <b>Hettinger County (21)</b>     |                            |                            |  |  |  |                                    |                        |      |       |      |
| 129-19.0                         | 200                        | Cannonball River           | 24,200                                   | --                                     | 17.8   | 17.4                               | 0.4                    | 6.0  | 6.0   | 9.9  |

**Table 1.** Results of Level 1.5 bridge scour study for selected bridge sites in North Dakota--Continued

[Bridge length is provided by the North Dakota Department of Transportation; number in parentheses after county is county number; ft<sup>3</sup>/s, cubic feet per second; Q<sub>100</sub>, discharge estimate for the 100-year recurrence interval; Q<sub>a</sub>, adjusted Q<sub>100</sub> (discharge determined to flow through bridge without overtopping, scour estimates are based on Q<sub>a</sub> when determined); --, not determined]

| Bridge number               | Bridge length (feet) | Stream name           | Flood discharge                       |                                     | Average distance below low-steel to streambed (feet) | Main channel depth (feet) | Estimated scour (feet) |      |       |      |
|-----------------------------|----------------------|-----------------------|---------------------------------------|-------------------------------------|--|---------------------------|------------------------|------|-------|------|
|                             |                      |                       | Q <sub>100</sub> (ft <sup>3</sup> /s) | Q <sub>a</sub> (ft <sup>3</sup> /s) |  |                           | Contraction            | Left | Right | Pier |
| <b>LaMoure County (23)</b>  |                      |                       |                                       |                                     |  |                           |                        |      |       |      |
| 119-22.1                    | 25                   | Maple River           | 2,300                                 | --                                  | 8.5  | 12.6                      | 14.0                   | 17.1 | 17.1  | --   |
| <b>McKenzie County (27)</b> |                      |                       |                                       |                                     |  |                           |                        |      |       |      |
| 103-24.0                    | 60                   | Horse Creek           | 4,510                                 | --                                  | 11.0   | 11.3                      | 2.5                    | 0.0  | 11.9  | --   |
| 104-39.0                    | 52                   | Bennie Peer Creek     | 2,250                                 | --                                  | 7.0  | 8.3                       | 0.1                    | 6.0  | 6.0   | --   |
| 105-39.0                    | 60                   | Spring Creek          | 3,400                                 | --                                  | 10.0   | 9.8                       | 0.3                    | 11.9 | 11.9  | --   |
| 106-39.0                    | 68                   | Bennie Peer Creek     | 5,970                                 | --                                  | 10.0   | 12.5                      | 0.1                    | 6.0  | 6.0   | --   |
| 122-16.0                    | 51                   | Timber Creek          | 3,480                                 | --                                  | 8.0  | 10.7                      | 0.8                    | 17.1 | 17.1  | --   |
| 122-17.0                    | 50                   | Timber Creek          | 3,360                                 | --                                  | 8.0  | 10.8                      | 2.2                    | 20.9 | 20.9  | --   |
| 122-42.0                    | 50                   | Bowline Creek         | 3,090                                 | --                                  | 8.0  | 10.3                      | 1.0                    | 20.9 | 20.9  | --   |
| 125-20.0                    | 43                   | Timber Creek          | 1,820                                 | --                                  | 8.0  | 8.8                       | 1.5                    | 17.1 | 17.1  | --   |
| 135-25.0                    | 60                   | Cherry Creek          | 4,550                                 | --                                  | 8.5  | 11.5                      | 1.6                    | 24.6 | 20.9  | --   |
| 137-22.0                    | 71                   | Cherry Creek          | 6,420                                 | --                                  | 10.0   | 12.7                      | 2.0                    | 20.9 | 20.9  | --   |
| 137-22.1                    | 78                   | Cherry Creek          | 6,550                                 | --                                  | 8.0  | 12.0                      | 0.3                    | 14.6 | 14.6  | --   |
| 137-31.0                    | 48                   | Spring Creek          | 1,990                                 | --                                  | 9.5  | 8.1                       | 0.4                    | 0.0  | 0.0   | --   |
| 142-10.0                    | 84                   | Tobacco Garden Creek  | 5,940                                 | --                                  | 9.0  | 11.1                      | 1.3                    | 20.9 | 20.9  | --   |
| 145-11.0                    | 72                   | Clear Creek           | 5,320                                 | --                                  | 8.6  | 11.5                      | 1.0                    | 20.9 | 20.9  | --   |
| 149-15.0                    | 88                   | Clear Creek           | 3,660                                 | --                                  | 9.6  | 9.0                       | 1.0                    | 0.0  | 14.5  | --   |
| 149-15.1                    | 25                   | Clear Creek Tributary | 1,690                                 | --                                  | 9.0  | 10.9                      | 3.7                    | 17.1 | 11.9  | --   |
| 165-10.0                    | 58                   | Antelope Creek        | 2,610                                 | --                                  | 7.5  | 8.5                       | 1.1                    | 20.9 | 20.9  | --   |
| <b>McLean County (28)</b>   |                      |                       |                                       |                                     |  |                           |                        |      |       |      |
| 159-21.0                    | 110                  | McClusky Canal        | 1,950                                 | --                                  | 11.0   | 8.0                       | 9.0                    | 0.0  | 0.0   | 5.1  |
| 161-21.0                    | 100                  | McClusky Canal        | 1,950                                 | --                                  | 10.0   | 7.4                       | 4.2                    | 0.0  | 0.0   | 5.1  |
| 166-22.0                    | 109                  | McClusky Canal        | 1,950                                 | --                                  | 12.0   | 7.4                       | 5.8                    | 0.0  | 0.0   | 5.1  |
| 166-27.0                    | 99                   | McClusky Canal        | 1,950                                 | --                                  | 15.0   | 7.5                       | 1.3                    | 0.0  | 0.0   | 6.1  |
| 166-29.0                    | 102                  | McClusky Canal        | 1,950                                 | --                                  | 14.3   | 6.6                       | 0.7                    | 0.0  | 0.0   | 5.1  |
| 167-23.0                    | 103                  | McClusky Canal        | 1,950                                 | --                                  | 11.2   | 6.6                       | 0.0                    | 0.0  | 0.0   | 5.1  |
| 167-30.0                    | 237                  | McClusky Canal        | 1,950                                 | --                                  | 27.2   | 6.4                       | 0.2                    | 0.0  | 0.0   | 7.5  |
| 168-31.0                    | 103                  | McClusky Canal        | 1,950                                 | --                                  | 15.0   | 6.6                       | 0.2                    | 0.0  | 0.0   | 5.1  |
| <b>Mercer County (29)</b>   |                      |                       |                                       |                                     |  |                           |                        |      |       |      |
| 105-15.0                    | 31                   | Unnamed Creek         | 2,480                                 | --                                  | 9.5  | 11.7                      | 8.5                    | 17.1 | 17.1  | --   |
| 105-30.0                    | 134                  | Knife River           | 23,020                                | --                                  | 15.0   | 17.9                      | 1.1                    | 7.3  | 7.3   | 7.2  |
| 110-35.1                    | 31                   | Elm Creek             | 2,430                                 | --                                  | 11.0   | 11.6                      | 3.0                    | 20.1 | 17.1  | --   |
| 114-37.0                    | 33                   | Elm Creek             | 1,440                                 | --                                  | 7.0  | 8.4                       | 5.0                    | 17.1 | 17.1  | --   |
| 119-38.0                    | 30                   | Coyote Creek          | 1,570                                 | --                                  | 10.0   | 9.3                       | 3.8                    | 20.1 | 20.1  | --   |
| 120-21.0                    | 106                  | Spring Creek          | 14,870                                | --                                  | 16.0   | 16.9                      | 1.2                    | 14.6 | 14.6  | 22.3 |
| 123-13.0                    | 31                   | Antelope Creek        | 1,880                                 | --                                  | 9.5  | 10.1                      | 7.0                    | 11.9 | 11.9  | --   |
| 125-17.0                    | 60                   | Antelope Creek        | 2,920                                 | --                                  | 8.0  | 9.0                       | 0.6                    | 20.9 | 20.9  | --   |
| 126-18.0                    | 41                   | Antelope Creek        | 5,440                                 | 4,000                               | 10.0   | 13.5                      | 8.5                    | 20.1 | 0.0   | --   |
| 128-18.0                    | 49                   | Antelope Creek        | 5,400                                 | 4,800                               | 10.0   | 13.5                      | 2.4                    | 24.6 | 24.6  | --   |

**Table 1.** Results of Level 1.5 bridge scour study for selected bridge sites in North Dakota--Continued

[Bridge length is provided by the North Dakota Department of Transportation; number in parentheses after county is county number; ft<sup>3</sup>/s, cubic feet per second; Q<sub>100</sub>, discharge estimate for the 100-year recurrence interval; Q<sub>a</sub>, adjusted Q<sub>100</sub> (discharge determined to flow through bridge without overtopping, scour estimates are based on Q<sub>a</sub> when determined); --, not determined]

| Bridge<br>number                     | Bridge<br>length<br>(feet) | Stream name               | Flood discharge                          |  | Average<br>distance<br>below low-<br>steel to<br>streambed<br>(feet) | Main<br>channel<br>depth<br>(feet) | Estimated scour (feet) |      |       |      |
|--------------------------------------|----------------------------|---------------------------|--|--|--|------------------------------------|------------------------|------|-------|------|
|                                      |                            |                           | Q <sub>100</sub><br>(ft <sup>3</sup> /s) | Q <sub>a</sub><br>(ft <sup>3</sup> /s) |  |                                    | Contraction            | Left | Right | Pier |
| <b>Mercer County (29)--Continued</b> |                            |                           |  |  |  |                                    |                        |      |       |      |
| 128-19.0                             | 161                        | Knife River               | 36,780                                   | --                                     | 16.0   | 21.0                               | 1.0                    | 14.5 | 14.5  | 7.3  |
| 128-20.0                             | 50                         | Brady Creek               | 2,780                                    | --                                     | 11.0   | 10.1                               | 1.8                    | 11.9 | 11.9  | --   |
| <b>Morton County (30)</b>            |                            |                           |  |  |  |                                    |                        |      |       |      |
| 118-11.0                             | 86                         | Big Muddy Creek           | 6,110                                    | --                                     | 10.0   | 11.3                               | 1.2                    | 20.9 | 0.0   | --   |
| 129-18.0                             | 120                        | Big Muddy Creek           | 12,000                                   | --                                     | 15.0   | 13.4                               | 0.3                    | 7.2  | 7.2   | 10.6 |
| 143-37.0                             | 64                         | Louise Creek              | 5,650                                    | 5,000                                  | 8.0  | 12.0                               | 1.0                    | 20.8 | 20.8  | --   |
| 146-38.0                             | 70                         | Chanta Peta Creek         | 5,400                                    | --                                     | 8.0  | 12.0                               | 2.0                    | 14.5 | 14.5  | --   |
| 147-31.0                             | 70                         | Unnamed Creek             | 2,170                                    | --                                     | 13.0   | 7.9                                | 5.4                    | 0.0  | 0.0   | --   |
| 155-42.0                             | 24                         | Unnamed Creek             | 550                                      | --                                     | 12.0   | 6.0                                | 0.4                    | 0.0  | 0.0   | --   |
| <b>Mountrail County (31)</b>         |                            |                           |  |  |  |                                    |                        |      |       |      |
| 116-33.0                             | 94                         | Little Knife River        | 6,260                                    | --                                     | --   | 10.9                               | 8.0                    | 0.0  | 22.4  | --   |
| 134-41.0                             | 156                        | East Fork Shell Creek     | 4,350                                    | --                                     | 7.6  | 7.5                                | 0.2                    | 6.0  | 17.1  | 17.2 |
| <b>Nelson County (32)</b>            |                            |                           |  |  |  |                                    |                        |      |       |      |
| 104-30.0                             | 26                         | Sheyenne River Tributary  | 2,170                                    | 1,770                                  | 8.0  | 10.3                               | 12.5                   | 0.0  | 11.9  | --   |
| 129-01.0                             | 35                         | South Branch Forest River | 1,110                                    | --                                     | 10.0   | 7.3                                | 6.0                    | 11.9 | 11.9  | --   |
| <b>Oliver County (33)</b>            |                            |                           |  |  |  |                                    |                        |      |       |      |
| 107-12.0                             | 50                         | Otter Creek               | 3,350                                    | --                                     | 8.0  | 10.7                               | 1.6                    | 14.6 | 14.6  | --   |
| <b>Pembina County (34)</b>           |                            |                           |  |  |  |                                    |                        |      |       |      |
| 122-09.0                             | 69                         | Tongue River              | 5,300                                    | --                                     | 8.7  | 11.6                               | 3.1                    | 17.1 | 19.8  | --   |
| <b>Ramsey County (36)</b>            |                            |                           |  |  |  |                                    |                        |      |       |      |
| 109-16.0                             | 40                         | St. Joes Coulee           | 1,800                                    | --                                     | 6.0  | 8.7                                | 18.3                   | 0.0  | 19.8  | --   |
| 112-16.0                             | 44                         | Starkweather Coulee       | 1,300                                    | --                                     | 6.5  | 6.9                                | 8.5                    | 15.4 | 19.7  | --   |
| <b>Ransom County (37)</b>            |                            |                           |  |  |  |                                    |                        |      |       |      |
| 118-16.0                             | 120                        | Sheyenne River            | 9,300                                    | --                                     | 12.8   | 11.6                               | 1.3                    | 20.9 | 0.0   | 14.7 |
| <b>Renville County (38)</b>          |                            |                           |  |  |  |                                    |                        |      |       |      |
| 112-37.0                             | 72                         | Des Lacs River            | 3,000                                    | --                                     | 8.0  | 8.4                                | 5.2                    | 19.8 | 15.7  | --   |
| <b>Richland County (39)</b>          |                            |                           |  |  |  |                                    |                        |      |       |      |
| 117-34.0                             | 86                         | Wild Rice River           | 3,600                                    | --                                     | 9.6  | 8.5                                | 1.6                    | 0.0  | 20.9  | --   |
| 120-25.0                             | 64                         | Antelope Creek            | 4,900                                    | --                                     | 7.5  | 12.0                               | 1.3                    | 20.9 | 20.9  | --   |
| 122-04.0                             | 124                        | Wild Rice River           | 14,000                                   | --                                     | 14.5   | 14.5                               | 1.4                    | 20.9 | 0.0   | 9.3  |
| 127-22.0                             | 103                        | Antelope Creek            | 9,780                                    | --                                     | 10.5   | 12.9                               | 1.6                    | 20.9 | 0.0   | 14.8 |
| <b>Sargent County (41)</b>           |                            |                           |  |  |  |                                    |                        |      |       |      |
| 135-08.0                             | 60                         | Wild Rice River           | 3,000                                    | --                                     | 6.0  | 9.0                                | 3.0                    | 14.6 | 14.6  | --   |

**Table 1.** Results of Level 1.5 bridge scour study for selected bridge sites in North Dakota--Continued

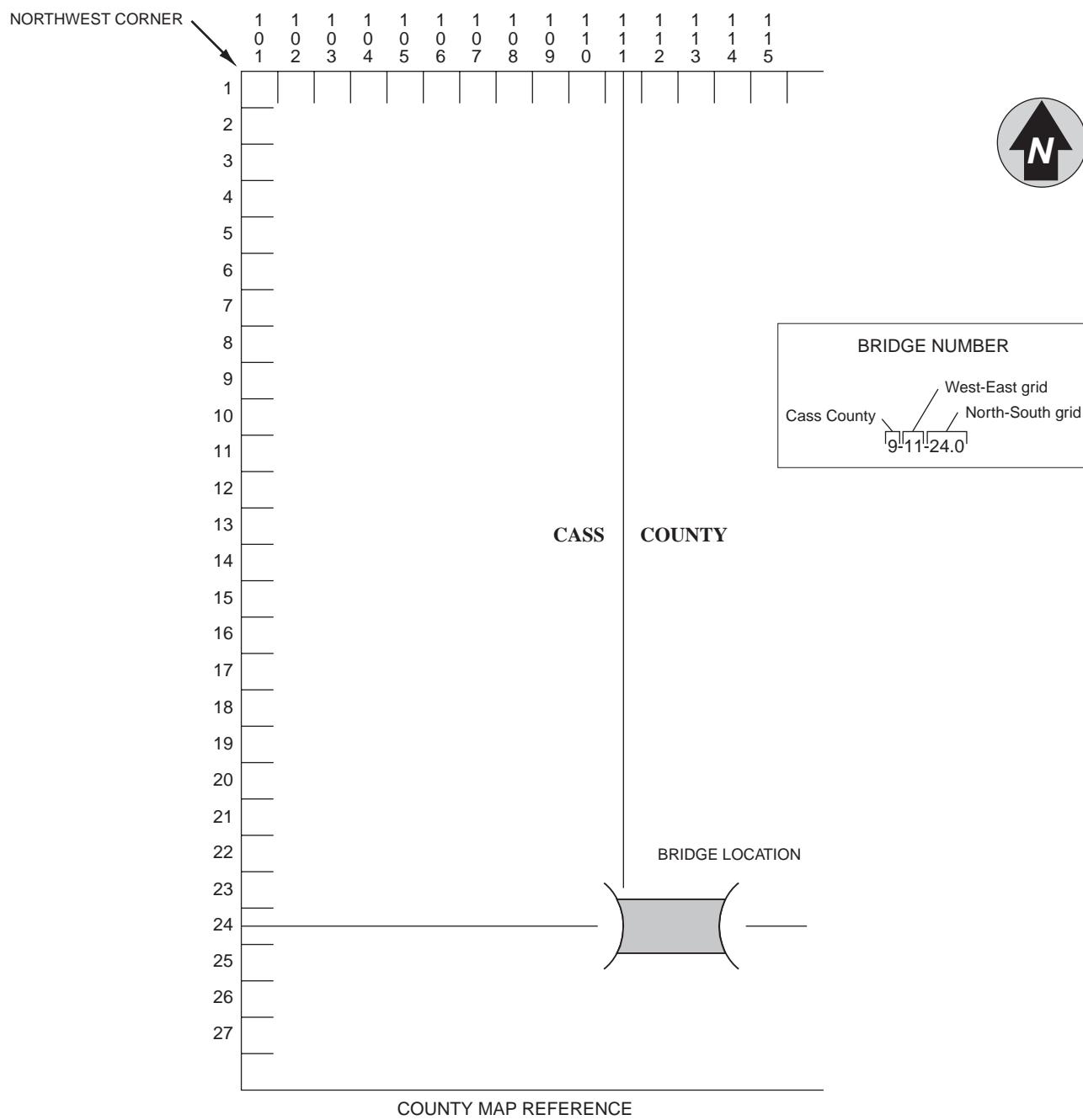
[Bridge length is provided by the North Dakota Department of Transportation; number in parentheses after county is county number; ft<sup>3</sup>/s, cubic feet per second; Q<sub>100</sub>, discharge estimate for the 100-year recurrence interval; Q<sub>a</sub>, adjusted Q<sub>100</sub> (discharge determined to flow through bridge without overtopping, scour estimates are based on Q<sub>a</sub> when determined); --, not determined]

| Bridge number               | Bridge length (feet) | Stream name                         | Flood discharge                       |                                     | Average distance below low-steel to streambed (feet) | Main channel depth (feet) | Estimated scour (feet) |      |       |      |
|-----------------------------|----------------------|-------------------------------------|---------------------------------------|-------------------------------------|--|---------------------------|------------------------|------|-------|------|
|                             |                      |                                     | Q <sub>100</sub> (ft <sup>3</sup> /s) | Q <sub>a</sub> (ft <sup>3</sup> /s) |  |                           | Contraction            | Left | Right | Pier |
| <b>Sheridan County (42)</b> |                      |                                     |                                       |                                     |  |                           |                        |      |       |      |
| 108-35.0                    | 107                  | McClusky Canal                      | 1,950                                 | --                                  | 10.2   | 7.1                       | 4.5                    | 0.0  | 0.0   | 5.2  |
| 109-31.0                    | 106                  | McClusky Canal                      | 1,950                                 | --                                  | 11.0   | 6.8                       | 3.4                    | 0.0  | 0.0   | 5.1  |
| 111-22.0                    | 204                  | McClusky Canal                      | 1,950                                 | --                                  | 17.0   | 8.5                       | 18.0                   | 0.0  | 0.0   | 8.5  |
| 113-19.0                    | 99                   | McClusky Canal                      | 1,950                                 | --                                  | 12.3   | 8.4                       | 9.0                    | 0.0  | 0.0   | 5.1  |
| 114-16.0                    | 115                  | McClusky Canal                      | 1,950                                 | --                                  | 12.0   | 9.4                       | 15.0                   | 0.0  | 0.0   | 5.0  |
| 115-14.0                    | 103                  | McClusky Canal                      | 1,950                                 | --                                  | 12.3   | 11.2                      | 16.0                   | 0.0  | 0.0   | 4.9  |
| 116-11.0                    | 99                   | McClusky Canal                      | 1,950                                 | --                                  | 12.4   | 9.9                       | 6.0                    | 0.0  | 0.0   | 5.0  |
| <b>Sioux County (43)</b>    |                      |                                     |                                       |                                     |  |                           |                        |      |       |      |
| 160-16.0                    | 98                   | Porcupine Creek                     | 9,300                                 | --                                  | 9.0  | 13.3                      | 0.8                    | 14.5 | 14.5  | 9.3  |
| <b>Slope County (44)</b>    |                      |                                     |                                       |                                     |  |                           |                        |      |       |      |
| 123-21.0                    | 62                   | Deep Creek                          | 3,480                                 | --                                  | 7.0  | 9.9                       | 10.5                   | 17.1 | 17.1  | --   |
| 129-22.0                    | 82                   | Deep Creek                          | 3,820                                 | 2,000                               | 6.8  | 8.3                       | 1.9                    | 0.0  | 7.3   | --   |
| 147-21.0                    | 39                   | Cedar Creek Tributary               | 1,440                                 | --                                  | 5.8  | 7.7                       | 2.2                    | 14.5 | 14.5  | --   |
| 149-04.0                    | 87                   | Cannonball River                    | 7,000                                 | --                                  | 12.2   | 11.8                      | 0.8                    | 17.1 | 0.0   | 6.8  |
| 149-21.0                    | 60                   | Cedar Creek                         | 2,880                                 | --                                  | 6.8  | 8.8                       | 2.0                    | 14.5 | 14.5  | --   |
| 151-03.0                    | 94                   | Cannonball River                    | 9,500                                 | --                                  | 13.7   | 14.6                      | 1.8                    | 8.9  | 11.9  | 6.7  |
| <b>Stark County (45)</b>    |                      |                                     |                                       |                                     |  |                           |                        |      |       |      |
| 105-15.0                    | 66                   | South Branch Heart River            | 2,900                                 | --                                  | 8.9  | 8.6                       | 5.1                    | 0.0  | 19.8  | --   |
| 125-15.0                    | 98                   | Antelope Creek                      | 7,350                                 | --                                  | 13.0   | 12.1                      | 4.0                    | 11.9 | 15.2  | 19.8 |
| DKSN12                      | 162                  | Heart River                         | 24,500                                | --                                  | 17.5   | 21.0                      | 5.2                    | 0.0  | 27.6  | 13.5 |
| <b>Steele County (46)</b>   |                      |                                     |                                       |                                     |  |                           |                        |      |       |      |
| 108-03.0                    | 51                   | Beaver Creek                        | 3,070                                 | --                                  | 8.0  | 10.0                      | 2.2                    | 20.9 | 24.6  | --   |
| 108-04.0                    | 52                   | Beaver Creek                        | 3,100                                 | --                                  | 8.5  | 11.0                      | 2.6                    | 20.9 | 20.9  | --   |
| 109-06.1                    | 62                   | Beaver Creek                        | 3,170                                 | --                                  | 10.0   | 9.1                       | 0.6                    | 14.6 | 14.6  | --   |
| 111-28.0                    | 28                   | Maple River                         | 2,570                                 | --                                  | 8.5  | 12.6                      | 19.0                   | 24.0 | 20.7  | --   |
| 114-05.1                    | 68                   | Beaver Creek                        | 3,330                                 | --                                  | 7.0  | 9.0                       | 0.2                    | 14.6 | 14.6  | --   |
| 114-18.0                    | 22                   | Goose River Tributary               | 2,200                                 | --                                  | 6.0  | 14.6                      | 9.4                    | 19.8 | 12.1  | --   |
| 118-12.0                    | 76                   | North Branch Goose River            | 3,350                                 | --                                  | --   | 10.4                      | 2.7                    | 0.0  | 0.0   | --   |
| 118-14.0                    | 64                   | Middle Branch Goose River Tributary | 2,860                                 | --                                  | 5.7  | 9.0                       | 2.7                    | 17.0 | 14.9  | --   |
| 119-01.0                    | 30                   | Goose River                         | 6,620                                 | 1,920                               | 7.5  | 10.3                      | 5.2                    | 24.6 | 24.6  | --   |
| 119-22.0                    | 46                   | South Branch Goose River            | 2,470                                 | --                                  | 7.0  | 9.6                       | 4.2                    | 20.7 | 20.7  | --   |
| 120-01.0                    | 85                   | Goose River                         | 6,300                                 | --                                  | 9.2  | 11.9                      | 2.9                    | 17.1 | 17.1  | --   |
| 120-07.1                    | 67                   | Beaver Creek                        | 4,460                                 | --                                  | 10.0   | 10.9                      | 0.2                    | 14.5 | 14.5  | --   |
| 120-14.0                    | 62                   | Goose River                         | 5,120                                 | --                                  | 11.0   | 11.9                      | 3.6                    | 8.9  | 17.0  | --   |
| 124-08.0                    | 102                  | Goose River                         | 8,650                                 | --                                  | 17.0   | 15.8                      | 1.9                    | 11.9 | 17.0  | 13.3 |
| 124-13.0                    | 73                   | South Branch Goose River            | 4,390                                 | --                                  | 14.0   | 11.0                      | 2.0                    | 0.0  | 0.0   | --   |

**Table 1.** Results of Level 1.5 bridge scour study for selected bridge sites in North Dakota--Continued

[Bridge length is provided by the North Dakota Department of Transportation; number in parentheses after county is county number; ft<sup>3</sup>/s, cubic feet per second; Q<sub>100</sub>, discharge estimate for the 100-year recurrence interval; Q<sub>a</sub>, adjusted Q<sub>100</sub> (discharge determined to flow through bridge without overtopping, scour estimates are based on Q<sub>a</sub> when determined); --, not determined]

| Bridge<br>number   | Bridge<br>length<br>(feet) | Stream name              | Flood discharge                          |  | Average<br>distance<br>below low-<br>steel to<br>streambed<br>(feet) | Main<br>channel<br>depth<br>(feet) | Estimated scour (feet) |      |      |      |
|--------------------|----------------------------|--------------------------|--|--|--|------------------------------------|------------------------|------|------|------|
|                    |                            |                          | Q <sub>100</sub><br>(ft <sup>3</sup> /s) | Q <sub>a</sub><br>(ft <sup>3</sup> /s) |  |                                    | Abutment               |      |      |      |
| Traill County (49) |                            |                          |  |  |  |                                    |                        |      |      |      |
| 104-02.0           | 61                         | North Branch Goose River | 1,920                                    | --                                     | 8.0  | 7.1                                | 1.0                    | 11.9 | 11.9 | --   |
| 105-12.2           | 155                        | Goose River              | 12,400                                   | --                                     | 13.9   | 12.2                               | 0.0                    | 19.8 | 17.1 | 6.8  |
| 112-14.0           | 115                        | Goose River              | 13,800                                   | --                                     | 14.0   | 16.3                               | 0.2                    | 20.9 | 0.0  | 4.3  |
| 119-29.0           | 78                         | Elm River                | 5,680                                    | --                                     | 13.0   | 11.8                               | 1.5                    | 0.0  | 17.1 | 21.7 |
| 123-26.0           | 45                         | North Branch Elm River   | 3,720                                    | 3,500                                  | 10.0   | 11.8                               | 5.6                    | 0.0  | 11.9 | --   |
| 124-17.0           | 182                        | Goose River              | 15,100                                   | --                                     | 20.0   | 14.3                               | 0.1                    | 0.0  | 0.0  | 17.6 |
| Walsh County (50)  |                            |                          |  |  |  |                                    |                        |      |      |      |
| 129-10.0           | 97                         | South Branch Park River  | 8,550                                    | --                                     | 9.0  | 12.1                               | 1.0                    | 14.5 | 14.5 | 7.0  |
| 138-08.0           | 117                        | Ditch                    | 9,140                                    | --                                     | 10.0   | 11.5                               | 0.0                    | 0.0  | 0.0  | 7.0  |
| 139-08.1           | 90                         | Park River               | 10,970                                   | --                                     | 10.0   | 15.0                               | 5.0                    | 20.8 | 20.8 | --   |
| 141-21.2           | 76                         | Forest River             | 12,300                                   | 9,000                                  | 8.2  | 14.7                               | 0.0                    | 19.8 | 19.8 | --   |
| 146-23.0           | 133                        | Unnamed Creek            | 4,140                                    | --                                     | 9.3  | 7.1                                | 2.9                    | 17.1 | 12.2 | 6.6  |
| 150-16.0           | 21                         | Unnamed Creek            | 570                                      | --                                     | 4.8  | 6.8                                | 28.4                   | 17.1 | 19.8 | --   |
| Ward County (51)   |                            |                          |  |  |  |                                    |                        |      |      |      |
| 150-44.0           | 114                        | Souris River             | 9,200                                    | --                                     | 17.1   | 14.1                               | 0.0                    | 0.0  | 0.0  | --   |
| 153-53.1           | 24                         | Oak Creek                | 3,000                                    | --                                     | 14.0   | 16.9                               | 47.0                   | 17.1 | 19.7 | --   |
| Wells County (52)  |                            |                          |  |  |  |                                    |                        |      |      |      |
| 109-10.0           | 91                         | New Rockford Canal       | 1,600                                    | --                                     | 9.0  | 5.9                                | 3.2                    | 0.0  | 0.0  | --   |
| 112-09.0           | 90                         | New Rockford Canal       | 1,600                                    | --                                     | 9.0  | 5.9                                | 2.9                    | 0.0  | 0.0  | --   |
| 114-10.0           | 71                         | James River              | 3,050                                    | --                                     | 4.8  | 8.3                                | 19.0                   | 22.4 | 22.4 | --   |
| 115-09.0           | 90                         | New Rockford Canal       | 1,600                                    | --                                     | 9.0  | 6.0                                | 3.2                    | 0.0  | 0.0  | --   |
| 117-09.0           | 90                         | New Rockford Canal       | 1,600                                    | --                                     | 9.5  | 6.1                                | 3.8                    | 0.0  | 0.0  | --   |
| 119-09.0           | 90                         | New Rockford Canal       | 1,600                                    | --                                     | 10.0   | 5.9                                | 4.0                    | 0.0  | 0.0  | --   |
| 121-09.0           | 90                         | New Rockford Canal       | 1,600                                    | --                                     | 10.0   | 5.8                                | 2.5                    | 0.0  | 0.0  | --   |
| 124-08.0           | 90                         | New Rockford Canal       | 1,600                                    | --                                     | 10.0   | 5.8                                | 1.0                    | 0.0  | 0.0  | --   |
| 131-09.0           | 93                         | New Rockford Canal       | 1,600                                    | --                                     | 10.5   | 5.8                                | 2.9                    | 0.0  | 0.0  | --   |
| 131-92.0           | 92                         | New Rockford Canal       | 1,600                                    | --                                     | 11.0   | 6.8                                | 7.0                    | 0.0  | 0.0  | --   |
| 132-09.1           | 96                         | New Rockford Canal       | 1,600                                    | --                                     | 9.5  | 6.8                                | 6.0                    | 0.0  | 0.0  | --   |



**Figure 1.** North Dakota county bridge number system. (Modified from North Dakota Department of Transportation, 1997).