APPENDIX A

STUDY SITE INFORMATION

RED RIVER VALLEY WATER NEEDS ASSESSMENT

PHASE 1B

INSTREAM FLOW NEEDS ASSESSMENT

STUDY SITE INFORMATION
AQUATIC LIFE MAINTENANCE FLOW NEEDS ASSESSMENT

Staff from Reclamation's Technical Service Center, Denver, Colorado, conducted field work between October 21 and November 5, 1997, and June 8-11, 1998, to: (1) select study sites representative of specific portions of the Sheyenne River and the Red River of the North; (2) determine habitat types within each study site; (3) estimate the proportion of each habitat type within each study site; and, (4) place transects within the various habitat types and collect stream geometry data as well as depth and velocity information along the transects. As a result, six study sites were selected as representative of the following portions of the Sheyenne River and the Red River of the North (generally following ecoregion boundaries for North Dakota):

Sheyenne River

1. Warwick Study Site - Sheyenne River above Lake Ashtabula (near Warwick, North Dakota, Eddy County, T150N, R63W, NW1/4NW1/4 of Sec. 22). Although data were twice collected at this site, the HEC-RAS Model was unable to be calibrated utilizing the data collected. Lisbon Study Site data were used in the Warwick Study Site analysis [the Lisbon Study Site was very similar to the Warwick Site in associated instream habitat, vegetation, and channel geometry (see Appendix E for information comparing Warwick and Lisbon Study Site channel geometry)], however, ultimately, Houston Engineering, Inc. (1997) study site data were used in quantifying the relationship between available fishery habitat and flow.

2. Ft. Ransom Study Site - Sheyenne River below Lake Ashtabula (near Fort Ransom, North Dakota, Ransom County, T135N, R57W, NE1/4SW1/4 of Sec. 17).

3. Lisbon Study Site - Sheyenne River below Lake Ashtabula (near Lisbon, North Dakota, Ransom County, T135N, R57W, SW1/4SE1/4 of Sec. 12).

4. Pigeon Point Study Site - Sheyenne River through the Sandhills (at Pigeon Point Wildlife Area, North Dakota, Ransom, County, T135N, R53W, NW1/4NE1/4 of Sec. 18).

5. Norman Study Site - Sheyenne River through the Agassiz Lake Plain (near Norman, North Dakota, Cass County, T137N, R50W, SW1/4SW1/4 of Sec. 24).

Red River of the North

1. Red River Study Site - Red River of the North near Fargo (at Fargo, North Dakota, Lindenwood Park downstream of I-94 Bridge, Cass County, T139N, R48W, SW1/4SE1/4 of Sec. 18).

Written descriptions for each study site including location maps and photographs are provided below. Tables A-1 contains study site data and field notes collected during field work activities. These data were used in the instream flow analysis, Modified Habitat Preference Method evaluation.

Warwick Study Site

The Warwick Study Site is located on the Sheyenne River above Lake Ashtabula (near Warwick, North Dakota, Eddy County), adjacent to and downstream of the county highway bridge, and downstream of USGS gaging station 05056000, approximately 3.3 miles south of Warwick. The site consists of a mixture of habitat types - pool, riffle, and run habitats. The substrate varies considerably from the upstream to downstream transects (mud/silt/clay to gravel/cobble/boulders to silt/sand/mud/clay). Five transects (cross sections) were initially placed within the study site (October 23, 1997). Five additional transects were subsequently placed during a resurvey of the site on June 9, 1998. Additional data collection was also accomplished on June 9, 1998.

Transect A - run/pool habitat (most downstream transect)
Transect B - run/pool habitat
Transect C - run/pool habitat (discharge measurement transect on June 9, 1998)
Transect 1 - run habitat (discharge measurement transect on October 23, 1997)
Transect 2 - base of riffle habitat
Transect 2a - head of riffle habitat
Transect 3 - pool habitat
Transect 4 - middle of riffle habitat
Transect 4a - head of riffle habitat
Transect 5 - pool habitat (most upstream transect)

Ft. Ransom Study Site

The Ft. Ransom Study Site is located on the Sheyenne River below Lake Ashtabula (near Fort Ransom, North Dakota, Ransom County), adjacent to and immediately upstream of a county bridge, and downstream of Ft. Ransom approximately 3 miles. The substrate is relatively uniform throughout this study reach, consisting primarily of sand, gravel, and cobble. Six transects (cross sections) were placed within the study site (November 3, 1997).

Transect 1 - riffle/run habitat (discharge measurement transect on November 3, 1997)(most downstream transect)
Transect 2 - run habitat
Transect 3 - run/pool habitat
Transect 4 - run/pool habitat
Transect 5 - run/pool habitat
Transect 6 - run\pool habitat (most upstream transect)

Lisbon Study Site

The Lisbon Study Site is located on the Sheyenne River below Lake Ashtabula (between Fort Ransom, and Lisbon, North Dakota, Ransom County), adjacent to and immediately downstream of an abandoned railroad embankment, approximately 5 miles upstream of Lisbon. The substrate varies considerably from the upstream to downstream transects (mud/silt/clay with boulders to sand/rock/mud/clay with gravels and cobble). Five transects (cross sections) were placed within the study site (October 24, 1997).

Transect 1 - riffle/run habitat (discharge measurement transect on October 24, 1997)
(most downstream transect)
Transect 2 - run/pool habitat
Transect 3 - pool habitat
Transect 4 - pool habitat
Transect 5 - pool habitat (most upstream transect)

Pigeon Point Study Site

The Pigeon Point Study Site is located on the Sheyenne River below Lake Ashtabula through the Sandhills at the Pigeon Point Wildlife Area (between Lisbon and Kindred, North Dakota, County), upstream of the county bridge (Larson Bridge), approximately 15 miles upstream of Kindred. The substrate is relatively uniform throughout this study reach, consisting primarily of sand, gravel, mud/clay and submerged structures (downed trees). Five transects (cross sections) were placed within the study site (October 31, 1997).

Transect 1 - run habitat (discharge measurement transect on October 31, 1997)
(most downstream transect)
Transect 2 - run habitat
Transect 3 - run habitat
Transect 4 - run habitat
Transect 5 - run habitat (most upstream transect)

Norman Study Site

The Norman Study Site is located on the Sheyenne River below Lake Ashtabula through the Agassiz Lake Plain (between Kindred and Norman, North Dakota, Cass County), adjacent and upstream and downstream of the county bridge immediately west of Norman. The substrate varies considerably from the upstream to downstream transects (sand/gravel/mud/clay to gravel/cobble/rock/boulders to sand/gravel/mud/clay). Five transects (cross sections) were placed within the study site (October 19-30, 1997).

Transect 1 - run/pool habitat (discharge measurement transect on October 30, 1997)
(most downstream transect)

Transect 2 - pool habitat
Transect 3 - run/riffle habitat
Transect 4 - run/riffle habitat
Transect 5 - pool habitat (most upstream transect)

Red River Study Site

The Red River Study Site is located at Fargo, North Dakota, just downstream of the Interstate 94 bridge across the Red River of the North (Lindenwood Park downstream of the Interstate 94 bridge, Cass County). The substrate is relatively uniform throughout this study reach, consisting primarily of sand, gravel, mud/clay with a few submerged structures (downed trees and concrete slabs/large boulders). Seven transects (cross sections) were placed within the study site (October 27-28, 1997).

Transect 1 - pool habitat (discharge measurement transect on October 28, 1997)
(most downstream transect)
Transect 2 - pool habitat
Transect 3 - pool habitat
Transect 4 - pool habitat
Transect 5 - pool habitat
Transect 6 - pool habitat
Transect 7 - pool habitat (most upstream transect)

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BUREAU OF RECLAMATION
DAKOTAS AREA OFFICE
PO BOX 1017
BISMARCK, ND 58502
(701)-250-4242

APPENDIX B

DESCRIPTION OF HYDROLOGICALLY BASED METHODS

RED RIVER VALLEY WATER NEEDS ASSESSMENT

PHASE 1B

INSTREAM FLOW NEEDS ASSESSMENT

DESCRIPTION OF HYDROLOGICALLY BASED METHODS
AQUATIC LIFE MAINTENANCE FLOW NEEDS ASSESSMENT

Six hydrologically based methods were used to assist in developing the aquatic life maintenance seasonal instream flow regime for representative river reaches along both the Sheyenne River and the Red River of the North. The six hydrologic methods that were used are: (1) Annual Mean Flow (AMF) Comparison; (2) Average (Mean) Flow for All Water Years - High (Spawning)/Low (Maintenance) Period Comparison; (3) Tennant Method; (4) 25% of the Annual Mean Flow (AMF) Comparison; (5) Water Year Type Flow Comparison for Dry-Average-Wet Years for High (Spawning)/Low (Maintenance) Period Flow Comparisons; and (6) the Wetter Perimeter versus Flow Comparison. Flow data for selected gaging stations was determined from USGS Water Resources Data (U.S. Geological Survey 1990) available for the same hydrological modeling period of record being used for the Red River Valley MR&I Water Needs Assessment, 1931-1984. The USGS data used in the analysis were gaged and estimated monthly streamflows for the period 1931-1984 (same as used in the Phase I, Part A study) for selected sites in the Red River of the North basin in North Dakota and Minnesota (U.S. Geological Survey 1990).

<u>Annual Mean Flow (AMF) Comparison</u>

The annual mean flow (AMF) for selected gaging stations was determined from U.S. Geological Survey (USGS) Water Resources Data (U.S. Geological Survey 1990) available for the same hydrological modeling period of record being used for the Red River Valley MR&I Water Needs Assessment, 1931-1984. The USGS data used in the analysis were gaged and estimated monthly streamflows (natural or unregulated streamflow) for the period 1931-1984 for selected sites in the Red River of the North basin in North Dakota and Minnesota. AMF, in cubic feet per second (cfs), is displayed in Table B-1 (and Table 3 of the Phase I, Part B Instream Flow Needs Assessment), by gaging station. Specific gaging station data found in Tables B-2 were used in calculating Table B-1 AMF information.

Results

The flows derived using hydrologic methods displayed in Table B-1 are fairly self-descriptive. For example, on the Sheyenne River near Warwick, North Dakota, the annual mean flow (AMF) for the period of record from 1931 to 1984, derived from USGS gaging station data, was 49 cfs. As expected, as the drainage basin increases in size, downstream AMF’s increase (e.g., Cooperstown, North Dakota, AMF is 90 cfs). The same situation is true for the Red River of the North (e.g., 524 cfs at Wahpeton, North Dakota, to 3,589 cfs at Emerson, Manitoba, Canada). The 25% AMFs are self-descriptive as well and follow the same type of downstream increasing pattern.

Average (Mean) Flow for all water years - High (Spawning)/Low (Maintenance) Period Comparison

For all water years from 1931-1984, the average (mean) flow (cfs) for the High (Spawning - March-June) period and the Low (Maintenance - July-February) period was determined from USGS Water Resources Data (U.S. Geological Survey 1990). Average flow (in cfs) per defined high and low flow periods of the year are displayed in Table B-1, by gaging station. Average flows displayed include all water year types (i.e., dry, average, wet). Specific gaging station data found in Tables B-2 were used in calculating Table B-1 high and low period flow information.

Results

For both the high flow (March-June) and low flow (July-February) periods, average (mean) flows (in cfs) show a similar increasing downstream pattern from above Harvey, North Dakota (21 and 2 cfs, respectively), to the mouth of the Sheyenne River (566 and 94 cfs, respectively), and from Wahpeton, North Dakota (927 and 328 cfs, respectively), to Emerson, Manitoba, Canada (7589 and 1588 cfs, respectively), on the Red River of the North.

Tennant Method

The Tennant Method, a technique developed in the State of Montana, is based on the premise that habitat is related to a percentage of the mean annual flood. Tennant (1976) developed the method by studying the percentage change in the widths, depths, and velocities relative to the change in the AMF for 58 streams in Montana, Wyoming, and Nebraska. The approach suggests that aquatic habitat conditions are similar for streams with similar AMF.

Recommended instream flows using the Tennant Method are summarized in Table B-1. One seeming advantage of the Tennant method is the ability to separate minimum flow requirements by season, i.e., the minimum flow required during the low flow period (e.g., October - March), and suitable flow conditions for aquatic biota and recreational activities during the high flow period (e.g., April - September), as defined by Tennant (Tennant 1976). Separation of the season into low and high flow periods can vary by region of the country. Reviewing the gaging station records for the Sheyenne River and the Red River of the North, the low and high flow periods were defined as:

River	Low Flow Period	High Flow Period
Sheyenne River	July-February	March-June
Red River of the North	July-February	March-June

Determining instream flow requirements using the Tennant method is obtained rather simply. First, the AMF for a particular stream reach is calculated using data from a representative gage. The AMF is then multiplied by the percentages indicated in Table B-1 for each of the seasons.

Tennant (1976) suggested field observations be combined with the calculation procedure to ensure a relationship between habitat and AMF.

Although Tennant developed the method for streams and rivers in the Western United States, the method has been used throughout North America. Comparisons between the Tennant Method and habitat based methods (e.g., Physical Habitat Simulation Model) often show general agreement. A Modified Tennant Method has been used in some cases [i.e., a percentage of the AMF different from those in Table B-1 or a percentage based on the mean monthly flow (e.g., 25% of the Annual Mean Flow used in Atlantic Canada)]. Specific gaging station data found in Tables B-2 were used in calculating Table B-1 Tennant Method flow information.

Results

The flows derived by applying the Tennant Method to the AMF's are also self-descriptive. Optimum flows (60%-100% AMF) ranged from 5 to 8 cfs above Harvey, North Dakota, from 83 to 139 cfs at Lisbon, North Dakota, on the Sheyenne River, from 347 to 578 cfs at Fargo, North Dakota, on the Red River of the North. The flows displayed again follow the same downstream increasing flow pattern as described above. Depending upon the habitat goals desired by the resource agencies responsible for fishery management (e.g., the North Dakota Game and Fish Department), instream flows using the Tennant Method could vary by river and river reach (e.g., the Sheyenne River upstream of Lake Ashtabula and downstream from Baldhill Dam as well as the Red River of the North upstream of Fargo, North Dakota, and downstream of the Buffalo River confluence near Halstad, Minnesota). For example, maintaining good habitat on the Sheyenne River at Warwick, North Dakota, would require a flow of 20 cfs from March-June and a flow of 10 cfs from July-February. These flows correspond to the high and low flow periods which were defined in this study for the Sheyenne River. Comparing these flows to the high and low flow average (mean) flows for the period of record from 1931 to 1984 (encompassing all water year types), the actually occurring high flows are quite a bit greater (124 vs. 20 cfs), but the low flows were similar (10 vs. 11 cfs).

To maintain good habitat on the Red River of the North at Fargo, North Dakota, requires a flow of 231 cfs from March-June and 116 cfs from July-February. These flows also correspond to the high and low flow periods which were defined in this study for the Red River of the North. Comparing these flows to the high and low flow average (mean) flows for the period of record from 1931 to 1984 (encompassing all water year types), the high and low flows are much lower (231 vs. 1120 cfs for high flows; and, 116 vs. 307 cfs for low flows). The Tennant Method flows to maintain good habitat quality are also much less than those displayed for an average water year type (231 vs. 946 cfs), but they do approximate flows associated with a dry water year type (116 vs. 107 cfs). An evaluation of how frequently low flows might occur and the amount of time required for aquatic community recovery would assist the resource agencies in setting habitat goals utilizing the Tennant Method.

25% of the Annual Mean Flow (AMF) Method

The 25% of the AMF Method is a derivative of the Tennant Method and is similar to the 30% of AMF Method outlined in Annear and Conder (1983). The 25% of the AMF Method is also the most commonly used method throughout Atlantic Canada. In this method, 25% of the AMF is deemed the minimum flow required to maintain aquatic life, regardless of season or species. A fixed percentage of AMF is best suited to water abstraction systems whose intake structures correspond to a specific stream water elevation. Specific gaging station data found in Tables B-2 were used in calculating Table B-1, 25% of the AMF information.

Results

The 25% AMFs displayed in Table B-1 are self-descriptive and follow a increasing pattern as you move downstream.

Water Year Type Comparison for Dry-Average-Wet Years for High (Spawning)/Low (Maintenance) Period Flows

For all water years from 1931-1984, the average flow (cfs) for the High (Spawning - March-June) Flow period and the Low (Maintenance - July-February) Flow periods, by water year type (Dry, Average, and Wet) was determined from USGS Water Resources Data (U.S. Geological Survey 1990). Average flow (in cfs) per defined high and low flow periods of the year, for each water year type, are displayed in Table B-1, by gaging station. Water year types were defined as follows:

Dry Water Year = those years of record between 1931-1984 whose annual discharge was in the lower 33 percent of years of record, by gaging station.

Average Water Year = those years of record between 1931-1984 whose annual discharge was in the 33 to 67 percent of years of record, by gaging station.

Wet Water Year = those years of record between 1931-1984 whose annual discharge was greater than 67 percent of years of record, by gaging station.

Specific gaging station data found in Tables B-2 were used in calculating Table B-1 Dry-Average-Wet Water Year information.

Results

The average flow (cfs) for the High (Spawning - March-June) Flow and the Low (Maintenance - July-February) Flow periods, by water year type (Dry, Average, and Wet Water Year Types) were determined from USGS Water Resources Data. The percentage ratio of time that water year type was Dry-Average-Wet for 1931-1984, by river was: Sheyenne River = 41:31:28 and

Red River = 36:35:29. Average water year type flows are similar to the average flows reported for the same high and low flow periods of the year. The flow pattern range between dry and wet water year types is readily evident.

<u>Wetted Perimeter versus Flow Method Comparison</u>

O'Shea (1995) developed a wetted perimeter versus flow comparison method to estimate minimum instream flow requirements for Minnesota streams using hydrologic data and watershed characteristics. Minimum instream flow recommendations, identified as the inflection point on the curve describing the relation between stream discharge and wetted perimeter, were developed for 27 Minnesota streams with annual mean discharges ranging from 41 to 568 cubic feet per second (cfs). The relation of instream flow recommendations to hydrologic and watershed variables was also examined to develop models for rapid assessment.

Instream flow recommendations (IFR) were most strongly correlated with annual mean discharge (QMean) (r = 0.97) and drainage area (r = 0.85). Two linear regression models were developed for estimating the instream flow recommendations. The first model (Model A) used only annual mean discharge as a predictor:

Model A IFR = 14.898 + 0.654(QMean)

Because gaging stations are not located on all streams, the second model (Model B) used drainage (DR) and soil type (SOIL) as predictors:

Model B $\log_{10}(IFR) = 2.033 + 8.394*10^{-4}(DA) - 0.007(SOIL)$

The instream flow recommendations, expressed as a percentage of the annual mean discharge, decreased as stream size increased.

Wetted Perimeter versus Flow Comparisons are displayed in Table B-1, by gaging station. Model A was used in calculating flows.

Results and Houston Engineering Analysis of the O'Shea Methodology

Wetted perimeter versus flow methodology flow results were usually less than average water year type flows but greater than dry water year type flows. They were less than average (mean) flows over the period of record for the spawning period (March-June) and maintenance period (July-February), for the Red River of the North. They were less than the average (mean) flows over the period of record for the spawning period (March-June), but were greater than average (mean) flows for gaging stations located upstream of Kindred, North Dakota, on the Sheyenne River. This difference between the two river systems is attributable to the need to provide more flow in smaller watershed streams during the low flow period of the year.

Houston Engineering, Inc., evaluated the applicability of the linear regression equation for use in eastern North Dakota by plotting wetted perimeter data versus streamflow exclusively from riffle habitat obtained from the Sheyenne River [i.e., Houston Engineering, Inc. (1997)], study performed for the Garrison Diversion Conservancy District study (Houston Engineering, Inc. 1999). The evaluation plotted wetted perimeter data versus stream flow exclusively from riffle habitat obtained from the Sheyenne River, i.e., the Garrison Diversion Conservancy District study, (Figures B-1 through B-4). Comparison of the flows at the inflection point of each curve and the instream flow recommendations obtained from the linear regression equation shows that O'Shea's method overestimates the flow at which the inflection point occurs.

The reason for the overestimation of instream flow recommendations made by O'Shea's method may be attributed to the geomorphologic differences in the streams from which the linear regression equation was developed and then later applied. The character of most streams, e.g., bankfull discharge, located in eastern Minnesota is markedly different than that of streams located in eastern North Dakota. As a result, O'Shea's method is not applicable for streams located in eastern North Dakota. The data used to construct Figures 1 through 4, however, can be utilized to derive a relationship specific to the Sheyenne River.

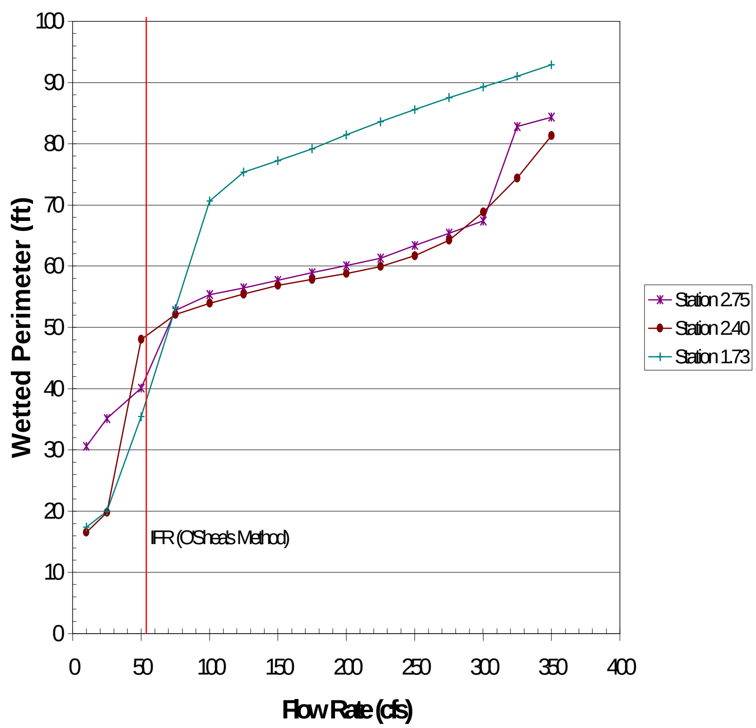

Figure B-1. Wetted perimeter versus flow rate relationships for the riffle habitat areas of the Warwick site in the GDCD study.

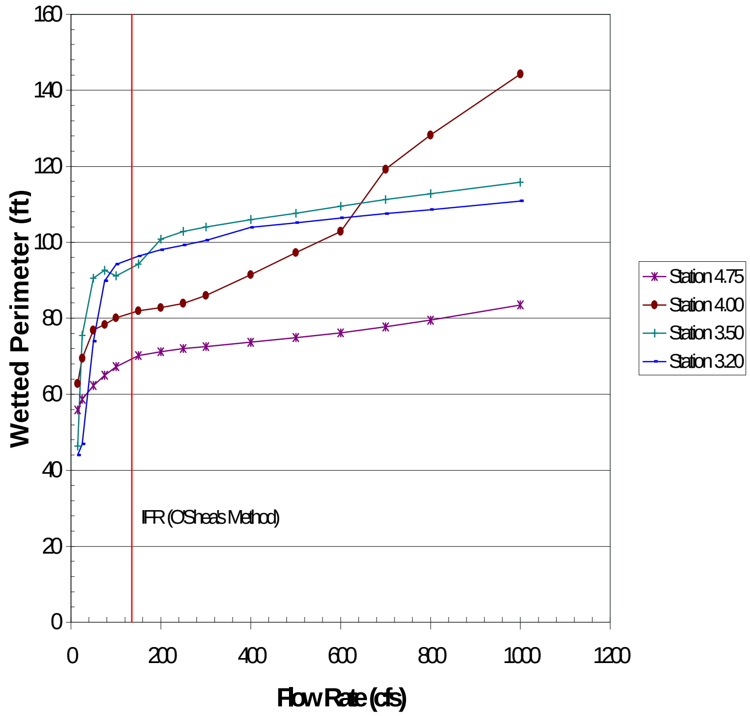

Figure B-2. Wetted perimeter versus flow rate relationships for the riffle habitat areas of the Lisbon site in the GDCD study.

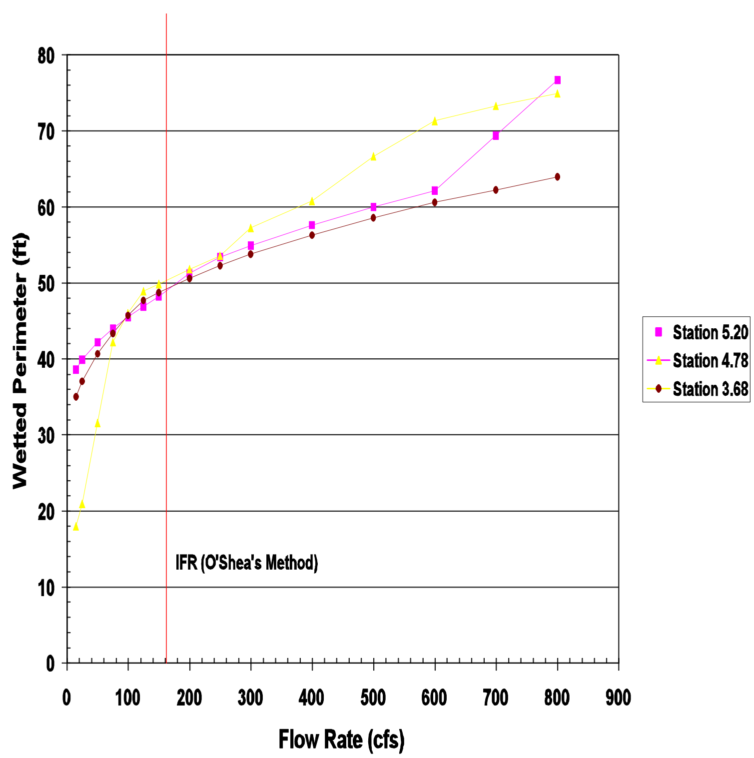

Figure B-3. Wetted perimeter versus flow rate relationships for the riffle habitat areas of the Kindred site in the GDCD study.

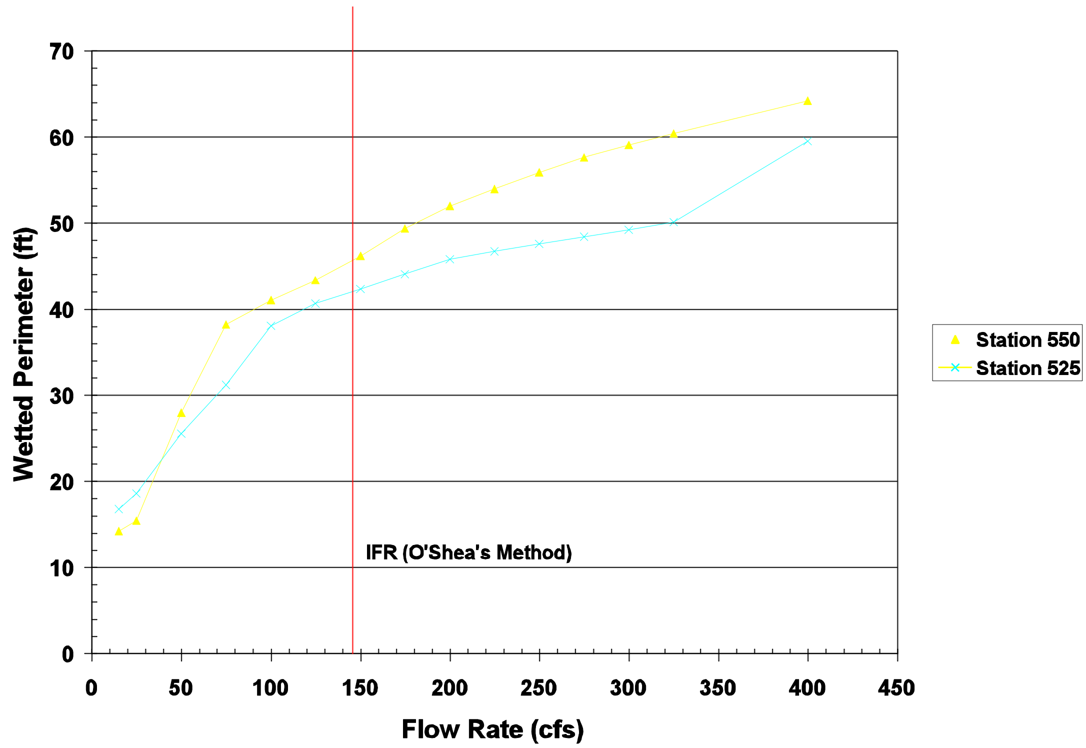

Figure B-4. Wetted perimeter versus flow rate relationships for the riffle habitat areas of the Horace site in the GDCD study.

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Table B-1. Sheyenne River and Red River of the North Methodology Results and Aquatic Life Maintenance Seasonal Instream Flow Regime.

	05054500 Sheyenne River above Harvey, ND 1931-1984		05056000 Sheyenne River near Warwick, ND 1931-1984		05057000 Sheyenne River near Cooperstown, ND 1931-1984	
Annual Mean Flow (AMF) in cubic feet per second (cfs)	8		49		90	
Flow Period (High/Low) [Mean (Avg) cfs/period] and Monthly Mean (Avg)	Mar-Jun 21 18/40/15/10	Jul-Feb 2 5/1/1/2/2/1/.5/.2	Mar-Jun 124 86/266/93/51	Jul-Feb 11 29/12/9/10/10/6/4/27	Mar-Jun 226 129/485/187/103	Jul-Feb 22 56/25/19/21/20/13/9/9
Tennant Method: Flushing Flow (200% AMF)	16		98		180	
Optimum Range (60-100% AMF)	5-8		29-49		54-90	
Outstanding (60/40% AMF)	5	3	29	20	54	36
Excellent (50/30% AMF)	4	2	24	15	45	27
Good (40/20% AMF)	3	2	20	10	36	18
Fair (30/10% AMF)	2	1	15	5	27	9
Poor (10/10% AMF)	1	1	5	5	9	9
25% AMF Method	2		12		23	
Dry Water Year [Mean (Avg)]	Mar-Jun 7 8/9/5/4	Jul-Feb 1 2/1/1/1/1/1/.5/1	Mar-Jun 34 32/54/28/23	Jul-Feb 7 15/7/8/6/6/4/3/3	Mar-Jun 61 54/108/46/36	Jul-Feb 11 26/10/11/10/13/8/6/6
Average Water Year [Mean (Avg)]	Mar-Jun 22 26/39/15/8	Jul-Feb 1 3/1/1/1/2/1/.2/1	Mar-Jun 115 103/250/63/45	Jul-Feb 12 25/13/10/12/11/6/4/1 3	Mar-Jun 195 123/418/109/131	Jul-Feb 22 57/22/25/21/20/12/8/13
Wet Water Year [Mean (Avg)]	Mar-Jun 48 30/101/36/23	Jul-Feb 3 10/2/2/2/2/1/1/5	Mar-Jun 266 147/596/222/97	Jul-Feb 17 56/18/9/16/14/8/5/11	Mar-Jun 486 236/1073/474/159	Jul-Feb 35 97/48/23/35/30/21/12/10
Wetted Perimeter vs. Flow Method	Mar-Jun 29 27/41/25/21	Jul-Feb 16 18/16/16/16/16/15/15/16	Mar-Jun 96 71/189/76/48	Jul-Feb 28 48/34/23/21/22/21/19 / 18/20	Mar-Jun 163 99/332/137/83	Jul-Feb 29 52/31/28/28/28/24/21/21

Table B-1 (Cont'). Sheyenne River and Red River of the North Methodology Results and Aquatic Life Maintenance Seasonal Instream Flow Regime.

	05058000 Sheyenne River below Baldhill Dam, ND 1931-1984		05058500 Sheyenne River at Valley City, ND 1931-1984		05058700 Sheyenne River at Lisbon, ND 1931-1984	
Annual Mean Flow (AMF) in cubic feet per second (cfs)	110		118		139	
Flow Period (High/Low)[Mean (Avg) cfs/period] and Monthly Mean (Avg)	Mar-June 250 142/489/236/135	July-Feb 39 67/29/28/32/45/37/35/40	Mar-June 273 163/532/251/146	July-Feb 41 74/31/30/33/45/36/34/41	Mar-June 321 204/609/298/175	July-Feb 47 106/36/33/36/48/40/36/43
Tennant Method: Flushing Flow (200% AMF)	220		236		278	
Optimum Range (60-100% AMF)	66-110		71-118		83-139	
Outstanding (60/40% AMF)	66	44	71	47	83	55
Excellent (50/30% AMF)	55	33	59	35	69	42
Good (40/20% AMF)	44	22	47	24	55	28
Fair (30/10% AMF)	33	11	35	12	42	14
Poor (10/10% AMF)	11	11	12	12	14	14
25% AMF Method	28		30		35	
Dry Water Year [Mean (Avg)]	Mar-Jun 66 68/98/45/53	Jul-Feb 22 32/17/21/17/25/22/22/22	Mar-Jun 75 79/110/51/61	Jul-Feb 23 35/19/23/18/24/21/21/23	Mar-Jun 96 107/138/64/74	Jul-Feb 31 46/23/37/29/37/26/23/28
Avg Water Year [Mean (Avg)]	Mar-Jun 213 95/476/144/138	Jul-Feb 39 67/22/39/39/45/34/32/33	Mar-Jun 231 111/514/151/149	Jul-Feb 41 80/26/41/40/45/33/31/32	Mar-Jun 311 179/675/203/187	Jul-Feb 46 132/30/28/32/37/34/35/38
Wet Water Year [Mean (Avg)]	Mar-Jun 573 306/1101/628/258	Jul-Feb 65 120/54/28/48/75/64/57/75	Mar-Jun 621 348/1197/664/275	Jul-Feb 67 128/57/31/49/76/63/55/78	Mar-Jun 708 387/1335/777/332	Jul-Feb 75 180/65/31/51/75/69/58/74
Wetted Perimeter vs. Flow Method	Mar-Jun 179 108/334/169/103	Jul-Feb 41 59/34/33/36/44/39/38/41	Mar-Jun 194 122/363/179/111	Jul-Feb 42 64/35/35/37/44/39/37/42	Mar-Jun 225 148/413/210/129	Jul-Feb 46 84/39/37/38/46/41/38/43

Table B-1 (Cont'). Sheyenne River and Red River of the North Methodology Results and Aquatic Life Maintenance Seasonal Instream Flow Regime.

	05059000 Sheyenne River near Kindred, ND 1931-1984		05059500 Sheyenne River at West Fargo, ND 1931-1984		05060400 Sheyenne River at Harwood, ND 1931-1984	
Annual Mean Flow (AMF) in cubic feet per second (cfs)	174		177		251	
Flow Period (High/Low)[Mean (Avg) cfs/period] and Monthly Mean (Avg)	Mar-June 374 206/658/392/241	July-Feb 73 171/73/57/57/68/55/48/55	Mar-June 379 191/671/401/253	July-Feb 75 181/78/57/58/70/56/48/55	Mar-June 566 331/1099/497/337	July-Feb 94 280/93/66/67/79/60/50/56
Tennant Method: Flushing Flow (200% AMF)	348		354		502	
Optimum Range (60-100% AMF)	104-174		106-177		151-251	
Outstanding (60/40% AMF)	104	70	106	71	151	100
Excellent (50/30% AMF)	87	52	89	53	126	75
Good (40/20% AMF)	70	35	71	35	100	50
Fair (30/10% AMF)	52	17	53	18	75	25
Poor (10/10% AMF)	17	17	18	18	25	25
25% AMF Method	44		44		63	
Dry Water Year [Mean (Avg)]	Mar-Jun 132 130/205/102/89	Jul-Feb 39 74/35/26/35/41/30/31/36	Mar-Jun 133 127/221/105/79	Jul-Feb 38 68/36/27/36/41/30/31/35	Mar-Jun 199 174/319/157/146	Jul-Feb 58 115/56/57/52/62/44/37/41
Average Water Year [Mean (Avg)]	Mar-Jun 328 184/627/292/210	Jul-Feb 71 133/63/75/60/72/58/49/59	Mar-Jun 326 166/625/282/229	Jul-Feb 74 157/68/73/60/72/59/46/56	Mar-Jun 524 338/1077/380/301	Jul-Feb 69 162/63/51/56/63/54/47/56
Wet Water Year [Mean (Avg)]	Mar-Jun 775 344/1322/939/493	Jul-Feb 123 360/139/73/83/100/86/71/73	Mar-Jun 749 302/1275/924/495	Jul-Feb 123 352/142/71/83/104/85/72/77	Mar-Jun 1116 548/2217/1067/633	Jul-Feb 163 602/169/90/98/115/87/70/76
Wetted Perimeter vs. Flow Method	Mar-Jun 260 150/445/272/172	Jul-Feb 63 127/63/52/52/60/51/47/51	Mar-Jun 263 140/454/277/180	Jul-Feb 64 134/66/52/53/61/52/46/51	Mar-Jun 385 232/733/340/235	Jul-Feb 79 198/76/58/59/87/54/47/51

Table B-1 (Cont'). Sheyenne River and Red River of the North Methodology Results and Aquatic Life Maintenance Seasonal Instream Flow Regime.

	05051500 Red River of the North at Wahpeton, ND 1942-1984		05051522 Red River of the North at Hickson, ND 1976-1984	
Annual Mean Flow (AMF) in cubic feet per second (cfs)	524		511	
Flow Period (High/Low) [Mean (Avg) cfs/period] and Monthly Mean (Avg)	Mar-Jun 927 570/1168/977/993	Jul-Feb 328 704/357/249/276/275/258/250/254	Mar-Jun 966 620/1677/790/776	July-Feb 284 588/311/199/239/230/224/230/252
Tennant Method: Flushing Flow (200% AMF)	1048		1022	
Optimum Range (60-100% AMF)	314-524		307-511	
Outstanding (60/40% AMF)	314	210	307	204
Excellent (50/30% AMF)	262	157	256	153
Good (40/20% AMF)	210	105	204	102
Fair (30/10% AMF)	157	52	153	51
Poor (10/10% AMF)	52	52	51	51
25% AMF Method	131		128	
Dry Water Year [Mean (Avg)]	Mar-Jun 347 385/405/309/290	Jul-Feb 201 324/181/136/193/203/187/181/199	Mar-Jun 335 458/447/242/194	Jul-Feb 188 200/179/152/215/202/182/168/203
Average Water Year [Mean (Avg)]	Mar-Jun 749 492/906/832/765	Jul-Feb 279 448/270/211/274/275/255/253/242	Mar-Jun 905 660/1511/767/680	Jul-Feb 279 401/238/129/282/284/265/305/327
Wet Water Year [Mean (Avg)]	Mar-Jun 1485 756/1930/1571/1684	Jul-Feb 461 1216/574/360/326/318/304/289/298	Mar-Jun 1847 810/3426/1536/1614	Jul-Feb 417 1230/537/308/244/232/252/262/268
Wetted Perimeter vs. Flow Method	Mar-Jun 621 388/779/654/664	Jul-Feb 229 475/248/178/196/195/184/178/181	Mar-Jun 771 421/1262/648/752	Jul-Feb 201 400/219/145/172/165/161/165/180

Table B-1 (Cont'). Sheyenne River and Red River of the North Methodology Results and Aquatic Life Maintenance Seasonal Instream Flow Regime.

	05054000 Red River of the North at Fargo, ND 1931-1984	05064500 Red River of the North at Halstad, MN 1931-1984

Annual Mean Flow (AMF) in cubic feet per second (cfs)	578		1326	
Flow Period (High/Low) [Mean (Avg) cfs/period] and Monthly Mean (Avg)	Mar-June 1120 598/1810/1014/1059	July-Feb 307 814/339/227/240/233/204/198/202	Mar-Jun 2760 1251/5230/2422/2136	Jul-Feb 610 1702/655/487/488/518/393/319/314
Tennant Method: Flushing Flow (200% AMF)	1156		2652	
Optimum Range (60-100% AMF)	347-578		796-1326	
Outstanding (60/40% AMF)	347	231	796	530
Excellent (50/30% AMF)	289	173	663	398
Good (40/20% AMF)	231	116	530	265
Fair (30/10% AMF)	173	58	398	133
Poor (10/10% AMF)	58	58	133	133
25% AMF Method	145		332	
Dry Water Year [Mean (Avg)]	Mar-Jun 309 311/431/271/224	Jul-Feb 107 229/89/77/91/92/87/88/105	Mar-Jun 971 539/1778/882/685	Jul-Feb 246 535/231/194/211/254/192/168/180
Average Water Year [Mean (Avg)]	Mar-Jun 946 639/1312/902/929	Jul-Feb 297 550/277/244/275/288/265/240/233	Mar-Jun 2571 1556/4257/2175/2294	Jul-Feb 617 1258/589/597/610/672/529/350/334
Wet Water Year [Mean (Avg)]	Mar-Jun 2331 936/4121/1985/2281	Jul-Feb 581 1863/719/407/401/364/299/301/293	Mar-Jun 5492 1884/11229/4874/3979	Jul-Feb 1110 3870/1328/767/730/704/512/494/477
Wetted Perimeter vs. Flow Method	Mar-Jun 748 406/1199/678/707	Jul-Feb 216 547/237/163/172/167/148/145/147	Mar-Jun 1820 833/3435/1599/1412	Jul-Feb 414 1128/443/334/334/354/272/224/220

Table B-1 (Cont'). Sheyenne River and Red River of the North Methodology Results and Aquatic Life Maintenance Seasonal Instream Flow Regime.

	05082500 Red River of the North at Grand Forks, ND 1931-1984		05092000 Red River of the North at Drayton, ND 1931-1984		05102500 Red River of the North at Emerson, Manitoba, Canada 1931-1984	
Annual Mean Flow (AMF) in cubic feet per second (cfs)	2698		3180		3589	
Flow Period (High/Low)[Mean (Avg) cfs/period] and Monthly Mean (Avg)	Mar-Jun 5388 2112/10030/5261/4148	Jul-Feb 1354 3112/1449/1293/1360 /1196/962/840/618	Mar-Jun 6558 2080/12231/7212/4709	Jul-Feb 1492 3555/1615/1401/1442/127 6/981/846/816	Mar-Jun 7589 1867/13398/9615/5475	Jul-Feb 1588 3909/1763/1513/15 09 /1377/1007/836/792
Tennant Method: Flushing Flow (200% AMF)	5397		6361		7177	
Optimum Range (60-100% AMF)	1619-2698		1908-3180		2153-3589	
Outstanding (60/40% AMF)	1619	1079	1908	1272	2153	1435
Excellent (50/30% AMF)	1349	810	1590	954	1794	1077
Good (40/20% AMF)	1080	540	1272	636	1435	718
Fair (30/10% AMF)	810	270	954	318	1077	359
Poor (10/10% AMF)	270	270	318	318	359	359
25% AMF Method	675		795		897	
Dry Water Year [Mean (Avg)]	Mar-Jun 175 5877/3280/1661/1201	Jul-Feb 473 1012/491/432/461 /419/336/361/269	Mar-Jun 1990 919/3789/1791/1460	Jul-Feb 544 1087/562/515/574 /499/387/358/367	Mar-Jun 2326 1150/4555/2121/1478	Jul-Feb 607 1154/605/569/707 /587/449/394/387
Average Water Year [Mean (Avg)]	Mar-Jun 4663 2739/7970/3995/3946	Jul-Feb 1562 2934/1635/1812/1711 /1541/1193/981/692	Mar-Jun 5724 2966/10553/4979/4399	Jul-Feb 1673 3545/1822/1984/1611 /1412/1071/984/959	Mar-Jun 6785 2452/13346/5917/5424	Jul-Feb 1866 3989/1978/2076/19 32 /1797/1253/969/937
Wet Water Year [Mean (Avg)]	Mar-Jun 10563 2833/20494/11039/7888	Jul-Feb 2152 5816/2368/1698/2010 /1711/1430/1243/943	Mar-Jun 13023 2427/24213/16393/9060	Jul-Feb 2346 6566/2661/1796/2095 /1772/1455/1258/1168	Mar-Jun 15327 1996/24667/24040/10606	Jul-Feb 2462 7293/2944/1960/19 59 /1818/1386/1219/11 13
Wetted Perimeter vs. Flow Method	Mar-Jun 3539 1396/6575/3455/2728	Jul-Feb 900 2050/963/860/904 /797/644/564/419	Mar-Jun 4304 1375/8014/4731/3095	Jul-Feb 990 2340/1071/931/958 /849/657/568/549	Mar-Jun 4978 1236/8777/6303/3595	Jul-Feb 1054 2572/1168/1005/10 02 /915/674/562/533

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APPENDIX C

HYDRAULIC RATING METHOD

(WETTED PERIMETER TECHNIQUE)

RED RIVER VALLEY WATER NEEDS ASSESSMENT

PHASE 1B

INSTREAM FLOW NEEDS ASSESSMENT

HYDRAULIC RATING METHOD
(WETTED PERIMETER TECHNIQUE)
AQUATIC LIFE MAINTENANCE ASSESSMENT

The Hydraulic Rating Method [(wetted perimeter technique) (Nelson 1980)] is frequently used with some success in instream flow studies, especially in Montana. Wetted perimeter is the distance along the bottom and sides of a cross-section of a stream in contact with water. It is roughly equal to the width plus two times the mean depth. In this hydraulic approach, a desired low-flow value is chosen from a habitat index that incorporates stream channel characteristics (Trihey and Stalnaker 1985). The wetted perimeter technique selects the narrowest wetted bottom of the stream cross section that is estimated to protect the minimum habitat needs (which frequently defines a limiting characteristic on the stream such as a riffle area). The relationship of wetted perimeter to cross section is shown in Figure C-1 below.

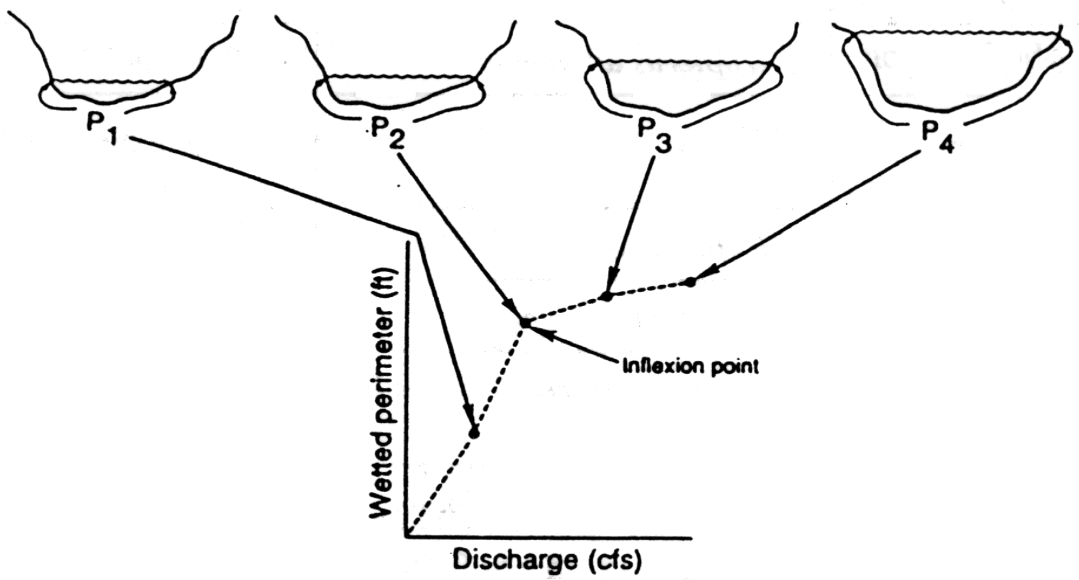

Figure C-1. Use of the wetted perimeter technique to estimate instream flows; from Stalnaker et al. (1994).

The analyst selects a critical area (typically a riffle) as an index of habitat for the rest of the stream. When a riffle is used as the indicator area, the assumption is that minimum flow satisfies the needs for food production, fish passage, and spawning. The usual procedure is to choose the break or "inflection point" in the stream's wetted perimeter versus discharge relation as a surrogate for minimally acceptable habitat. The inflection point represents that flow above which the rate of wetted perimeter gain begins to slow. Once this level of flow is estimated, other habitat areas, such as pools and runs, are also assumed to be satisfactorily protected. Because the shape of the channel can influence the results of the analysis, this technique is usually applied to streams with cross sections that are wide, shallow, and relatively rectangular.

Table C-1 (Table 3 of the Phase I, Part B Instream Flow Needs Assessment) displays results obtained from field data collections and model runs at both Reclamation sites (identified as Raines) and Houston Engineering, Inc. sites (Houston Engineering, Inc. 1997). Tables C-2 contains additional information on the results of the site specific wetted perimeter technique application. Warwick Study Site data would not calibrate using the HEC-RAS Model and, therefore, Lisbon Study Site data were used in the analysis. The Lisbon Study Site was very similar to the Warwick Site in associated channel habitat, vegetation, and channel geometry (see Appendix E for information comparing Warwick and Lisbon Study Site channel geometry)], however, ultimately, Houston Engineering, Inc. (1997) study site data were used in quantifying the relationship between available fishery habitat and flow.

Results

Recommended flows ranged from 12 to 17 cfs at Warwick, North Dakota, from 25 to 130 cfs near Horace, North Dakota, on the Sheyenne River and from 75 to 125 cfs at Fargo, North Dakota, on the Red River of the North. Houston Engineering, Inc. (December 1997) reported flows ranging from 50 to 100 cfs at Warwick, North Dakota, from 75 to 100 cfs near Horace, North Dakota, on the Sheyenne River, and from 150 to 225 cfs at Fargo, North Dakota, on the Red River of the North. As noted in Table C-1, habitat types other than riffle habitat were also presented in the analysis (run habitats for the Kindred Study Site and pool habitats for the Red River Study Site) for both Reclamation and Houston study sites.

In a true application of the wetted perimeter technique, comparisons should only be made for site-specific cross sections where riffle habitat is encountered, as previously explained in this report. As Houston Engineering, Inc. (December 1997) reported, recommendations derived using the wetted perimeter technique could be improved by evaluating the relationship between wetted perimeter and discharge for a greater number of cross sections taken specifically from riffle habitat. This was done by O'Shea (1995) for streams in Minnesota as reported for the wetted perimeter versus flow methodology application. The instream flow recommendations should be evaluated within the context of whether they are similar in magnitude to the recommendations derived from the Tennant Method and the Modified Habitat Preference Method. From analyzing these data, it appears that the flows reported for the wetted perimeter technique are similar to those reported for the Tennant Method, low flow period, good habitat range, as well as the 25% AMF results for each gaging station, and comparable to the reported Modified Habitat Preference Method maintenance flows.

Assuming the relatively few cross sections used in both analyses are representative of riffle habitat for a much larger portion of the Sheyenne River and/or Red River of the North is tenuous. The wetted perimeter technique resulted in a wide range of flows. It is anticipated that this wide range resulted from using multiple cross sections from many differing sites with differing geometric channel conditions. The sites identified as Reclamation, reported a consistently lower flow than those site reports for Houston. One explanation for the difference may be that several Reclamation sites were narrow and deep while more of the Houston sites were wide and shallow. The Reclamation sites would have exhibited greater velocities at lower discharges (flows), and resulted in the wetted perimeter technique results as displayed in Table C-1. This geometric channel configuration could account for the reported disparities between the Reclamation and Houston sites. However, if enough additional cross sections could be analyzed, it would be expected that a relatively good minimum flow could be calculated using this technique.

Literature Cited

Houston Engineering, Inc. December 1997. Instream flow needed for aquatic life. White Paper. Prepared for the Garrison Diversion Conservancy District. Houston Engineering, Inc., Fargo, North Dakota and Minneapolis, Minnesota. 17 pp. plus appendices.

Nelson, F.A. 1980. Evaluation of selected instream flow methods in Montana. Proceedings of the Annual Conference of the Western Association of Fish and Wildlife Agencies: 412-432.

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Trihey, E.W. and C.B Stalnaker. 1985. Evolution and application of instream flow methodologies to small hydropower development: An overview of the issues. Pages 176-183 in F.W. Olson, R.G White, and R.H. Hamre, editors. Proceedings of the symposium on small hydropower and fisheries. The American Fisheries Society. 119:1035-1047.

Table C-1
Sheyenne River and the Red River of the North
Hydraulic Rating Method (Wetted Perimeter Technique) Results

	05056000 Sheyenne River near Warwick, ND		05058500 Sheyenne River near Ft. Ransom, ND		05058700 Sheyenne River near Lisbon, ND	
Wetted Perimeter Technique	[1]Reclamation Range - 12-17 Mean - 15 n=1 (riffle)	Houston Range - 50-100 Mean - 75 n=4 (riffle/run)	Reclamation Range - 25 Mean - 25 n=1 (riffle/run)	Houston: N/A	Reclamation Range - 12-17 Mean - 15 n=1 (riffle/run)	Houston Range - 50-150 Mean - 94 n=3 (riffles)

	05059000 Sheyenne River near Kindred, ND		05059300 Sheyenne River near Horace, ND		05059500 Sheyenne River at West Fargo, ND	
Wetted Perimeter Technique	Reclamation Range - 25-130 Mean - 58 n=5 (runs)	Houston Range - 100-200 Mean - 142 n=4 (runs)	Reclamation Range - 25-130 Mean - 78 n=2 (riffles)	Houston Range - 100-200 Mean - 142 n=4 (riffle/run)	Reclamation Range - 25-130 Mean - 78 n=2 (riffles)	Houston Range - 100-200 Mean - 142 n=4 (riffle/run)

	05051522 Red River at Fargo, ND	
Wetted Perimeter Technique	Reclamation Range - 75 -125 Mean - 82 n=7 (pools)	Houston Range - 150-225 Mean - 181 n=4 (runs)

[1]Lisbon Study Site data used for both Warwick and Lisbon due to similarities between sites.

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APPENDIX D

A COMMUNITY ORIENTED APPROACH

FOR RECOMMENDING

AQUATIC LIFE MAINTENANCE FLOWS

RED RIVER VALLEY WATER NEEDS ASSESSMENT

PHASE 1B

INSTREAM FLOW NEEDS ASSESSMENT

A COMMUNITY ORIENTED APPROACH FOR RECOMMENDING AQUATIC LIFE MAINTENANCE FLOWS

Most instream flow studies utilizing the Instream Flow Incremental Methodology (IFIM) (Stalnaker et al. 1994) have simulated relationships between flow regime and weighted usable area (WUA) for a single species or for a few species of special interest. Although this approach may be appropriate for certain coldwater streams with low species diversities, it is not really adequate for warmwater streams (e.g., Sheyenne River and Red River of the North). The energetics of warmwater streams are very complex and an over-simplified approach (single or few target species) to complex fisheries management tends to somewhat overlook vital components of the stream system.

Frequently, the species of special interest in IFIM studies are game fish. Game fish are almost always predatory and often piscivorous (feeding on fishes). Predatory fish spend only a small fraction of their time feeding; most of their time is spent resting and digesting meals. This disproportion in activity causes habitat preference curves to be biased towards the resting phase of a piscivore's behavior. For instance, habitat preference data for smallmouth bass collected in Minnesota suggested that smallmouth bass are basically a pool species throughout their lifetime, yet, food habits studies found that about 50 percent of the fishes identified in their stomachs were riffle species and 75 percent of the prey species had their highest densities in riffle areas. Smallmouth bass were frequently observed chasing schools of stonerollers and shiners in riffle areas so shallow that smallmouth bass backs were out of the water. On several occasions this feeding behavior was so voracious that fleeing baitfish beached themselves. These incidents happened very quickly, and thus, the probability of actually sampling smallmouth bass in the act of feeding was relatively low. If habitat simulations and flow recommendations were based only on smallmouth bass habitat preference data, the simulations and recommendations might indicate that dewatering riffle areas to produce low velocity water, or flooding out riffle areas to produce deep water, would produce more smallmouth bass habitat. Either of these flow regime scenarios could be detrimental to smallmouth bass by reducing food production areas, therefore biasing instream flow recommendations in a negative manner (Aadland et al. 1991).

Relationships between WUA and standing stock of a fish species are likely to be greatest for fishes which use similar habitat for all aspects of their behavior and are least dependent on other areas. For example, a study evaluating IFIM in Oklahoma showed no correlation between WUA and standing stock of adult and juvenile smallmouth bass during any season of the year, but did show a significant correlation for freckled madtom, central stoneroller, and orangebelly darter, all non-piscivorous species (Orth and Maughan 1982).

Based on the above, a community based approach for developing an aquatic life maintenance seasonal instream flow regime was selected for use in this instream flow study. All species-life stages of fish known for both the Sheyenne River and the Red River of the North were assigned to one of the following six habitat preference guilds (Aadland et al. 1991).

Preference Guilds By Habitat Type

Shallow pool	[less than 2 ft (60 cm) deep, less than 1 ft/sec (30 cm/sec) velocity]
Medium pool	[2-5 ft (60-149 cm) deep, less than 1ft/sec (30 cm/sec) velocity]
Deep pool	[Greater than or equal to 5 ft (150 cm) deep]
Raceway	[2-5 ft (60-149 cm) deep, greater than or equal to 1 ft/sec (30 cm/sec) velocity]
Slow riffle	[less than 2 ft (60 cm) deep, 1-2 ft/sec (30-59 cm/sec) velocity]
Fast riffle	[less than 2 ft (60 cm) deep, greater than or equal to 2 ft/sec (60 cm/sec) velocity]

Shallow pool guild - This guild is largely made up of shiners, young-of-the-year suckers, and sunfishes. Habitat used by these fishes is usually found along the channel margin.

Medium pool guild - This guild consists of sunfishes, adult cyprinids and many of the predatory fishes. Many of the members of this guild are relatively ubiquitous (widespread), and are found in many different habitat types in different river systems.

Deep pool guild - This guild includes several shiners, sunfishes, suckers, and the channel catfish. These fish use the deepest water available. Many of the deep pool guild members are species which do not typically occur in streams without lake influence or are ubiquitous in their habitat use, however, channel catfish is the exception, consistently utilizing deep pools.

Raceway guild - This guild consists of juvenile and adult suckers and juvenile and adult smallmouth bass. These fish use areas which have moderate velocity and depth, large substrates and boulder or no cover. This habitat type has low species diversity but it usually possesses the highest fish biomass (due to presence of large fishes).

Slow riffle guild - This guild is preferred by more species-life stages than any other habitat type. Adult and young-of-the-year darters, adult and juvenile stonerollers, adult and spawning shiners, and adult and spawning suckers typify riffle assemblages with moderate to high velocities, gravel, cobble, or rubble substrate and vegetation or boulder cover.

Fast riffle guild - This guild consists of juvenile and adult longnose dace, adult, young-of-the-year and spawning darters, and spawning shorthead redhorse. These species-life stages are found in the highest velocity areas of a stream, are shallow water areas, have cobble or rubble substrates, and boulder or vegetation cover.

Fish species and their respective preference guild are displayed in Table D-1 (Aadland et al. 1991; North Dakota Game and Fish Department 1986; and, Peterka and Koel 1996).

Table D-1.
Sheyenne River and Red River of the North
Fish Species/Preference Guild Assemblage

Species	Preference Guild(s) by Life-Stage[1]	Upper Sheyenne River[2]	Middle Sheyenne River[3]	Lower Sheyenne River[4] and Red River	Spawning Timeframe (months)
Northern pike		X	X	X	Mar-May
Carp	shallow pool (Y), medium pool (A,J), raceway (A), slow riffle (Y)		X	X	Mar-May
Golden shiner	shallow pool (A,Y)	X	X		May-July
Common shiner	shallow pool (J), medium pool (A,J), deep pool (Y), slow riffle (A,S)	X	X		May-Jul
Spottail shiner	shallow pool (A,Y)	X	X		May-Jul
Spotfin shiner	shallow pool (A,Y), medium pool (S), deep pool (A), slow riffle (A,Y,S)		X		May-Aug
Sand shiner	shallow pool (A,Y), medium pool (A), slow riffle (A,S)	X	X		May-Aug
Bluntnose minnow	shallow pool (Y), medium pool (A), slow riffle (A)		X		May-Jul
Fathead minnow		X	X	X	May-Aug
Blacknose dace		X			May-Jun

Longnose dace	shallow pool (Y), slow riffle (A,S), fast riffle (A,Y)	X	X		May-Jun
Creek chub	shallow pool (A,J), slow riffle (Y)	X	X		Apr-Jul
White sucker	deep pool (A), slow riffle (J,Y)	X	X	X	Apr-Jun
Shorthead redhorse	raceway (A,J), slow riffle (Y), fast riffle (A,S)		X	X	Apr-Jun
Black bullhead	medium pool (A,Y)	X	X	X	May-Jul
Channel catfish	medium pool (J,Y), deep pool (A)			X	May-Jul
Stonecat	raceway (A), slow riffle (J), fast riffle (J,Y)			X	Jun-Aug
Tadpole madtom		X	X		Jun-Jul
Trout-perch		X	X		May-Aug
Brook stickleback		X			Apr-Jun
White bass	medium pool (J,Y)		X		May-Jun
Rock bass	shallow pool (A), medium pool (A,J,Y)		X		May-Jun
Pumpkinseed			X		May-Jul
Orangespotted sunfish	shallow pool (A)	X	X		May-Aug
Bluegill	deep pool (J)	X	X		May-Jul

Smallmouth bass	shallow pool (FR), medium pool (J,S,FI), deep pool (A), raceway (A,J), slow riffle (J), fast riffle (FI)		X		May-Jul
White crappie	medium pool (A)		X		May-Jul
Black crappie	medium pool (A,J), deep pool (A,J)	X			May-Jul
Iowa darter		X			Mar-May
Johnny darter	shallow pool (A), deep pool (Y), slow riffle (Y)	X	X		Apr-May
Yellow perch	medium pool (A,J), deep pool (A)	X	X		May-Jun
Blackside darter	slow riffle (A,Y), fast riffle (A)	X	X		Mar-May
Sauger				X	Apr-Jun
Walleye	medium pool (J,Y)		X	X	Mar-May
Freshwater drum			X	X	Jun-Sep

[1]Life-Stage Abbreviations Used: (A)=Adult, ((J)=Juvenile, (Y)=Young-of-the-year, (FI)=Fingerling, (FR)=Fry, (S)=Spawning

[2]Upper Sheyenne River - above Lake Ashtabula and Baldhill Dam

[3]Middle Sheyenne River - below Lake Ashtabula and Baldhill Dam to Pigeon Point Wildlife Area

[4]Lower Sheyenne River and Red River - below Pigeon Point Wildlife Area to confluence with Red River and mainstem Red River

Fish Species/Life-Stage by Preference Guild
Sheyenne River

Species	Shallow Pool	Medium Pool	Deep Pool	Raceway	Slow Riffle	Fast Riffle
Northern pike						
Carp	X (Y)	X (A,J)		X (A)	X (Y)	
Golden shiner	X (A,Y)					
Common shiner	X (J)	X (A,J)	X (Y)		X (A,S)	
Spottail shiner	X (A,Y)					
Spotfin shiner	X (A,Y)	X (S)	X (A)		X (A,Y,S)	
Sand shiner	X (A,Y)					
Fathead minnow						
Blacknose dace						
Longnose dace	X (Y)				X (A,S)	X (A,Y)
Creek chub	X (A,J)				X (Y)	
White sucker			X (A)		X (J,Y)	
Shorthead redhorse				X (A,J)	X (Y)	X (A,S)
Black bullhead		X (A,Y)				
Channel catfish		X (J,Y)	X (A)			
Stonecat				X (A)	X (J)	X (J,Y)
Tadpole madtom						
Trout-perch						
Brook stickleback						
White bass		X (J,Y)				
Rock bass	X (A)	X (A,J,Y)				
Pumpkinseed	X (A)		X (J)			
Orangespotted sunfish						
Smallmouth bass	X (FR)	X (J,S,FI)	X (A)	X (A,J)	X (J)	X (FI)
White crappie		X (A)				

Black crappie		X (A,J)	X (A,J)			
Iowa darter						
Johnny darter	X (A)		X (Y)		X (Y)	
Yellow perch		X (A,J)	X (A)			
Blackside darter	X (A,Y)		X (A)			
Sauger						
Walleye		X (J,Y)				
Freshwater drum						

Fish Species/Life-Stage by Preference Guild
Red River of the North

Species	Shallow Pool	Medium Pool	Deep Pool	Raceway	Slow Riffle	Fast Riffle
Chestnut lamprey						
Goldeye						
Mooneye						
Central minnow						
Northern pike						
River shiner	X (Y)					
Quillback						
White sucker			X (A)		X (J,Y)	
Bigmouth buffalo						
Silver redhorse		X (A,J)			X (Y)	
Channel catfish		X (J,Y)	X (A)			
Stonecat				X (A)	X (J)	X (J,Y)
Yellow perch		X (A,J)	X (A)			
River darter						
Walleye		X (J,Y)				
Freshwater drum						

Guild Representatives Used for Performing Instream Flow Needs Assessment
Sheyenne River and Red River of the North

Common Name	Scientific Name	Guild(s)
Spawning and Initial Growth Period (March-June)		
Smallmouth bass fry (SBFR)	*Micropterus dolomieui*	Shallow pool
Smallmouth bass fingerling (SBFI)	*Micropterus dolomieui*	Medium pool, fast riffle
Sand shiner young (SSY)	*Notropis stramineus*	Shallow pool
Walleye spawning (WS)	*Stizostedion vitreum*	Medium pool
Shorthead redhorse spawning (SRS)	*Moxostoma macrolepidotum*	Fast riffle
Shorthead redhorse young (SRY)	*Moxostoma macrolepidotum*	Slow riffle
White sucker young (WSY)	*Catastomus commersoni*	Slow riffle
Slenderhead darter spawning (SDS)	*Percina phoxocephala*	Fast riffle
Channel catfish young (CCY)	*Ictalurus punctatus*	Medium pool
Maintenance Period (July-February)		
Smallmouth bass juvenile (SBJ)	*Micropterus dolomieui*	Medium pool, raceway, slow riffle
Smallmouth bass adult (SBA)	*Micropterus dolomieui*	Deep pool, raceway
Sand shiner adult (SSA)	*Notropis stramineus*	Shallow pool
Shorthead redhorse juvenile (SRJ)	*Moxostoma macrolepidotum*	Raceway
Shorthead redhorse adult (SRA)	*Moxostoma macrolepidotum*	Raceway, fast riffle
White sucker juvenile (WSJ)	*Catastomus commersoni*	Slow riffle
Slenderhead darter adult (SDA)	*Percina phoxocephala*	Fast riffle
Channel catfish juvenile (CCJ)	*Ictalurus punctatus*	Medium pool
Channel catfish adult (CCA)	*Ictalurus punctatus*	Medium pool

These six habitat preference guilds describe the relationships between types of habitat (represented by velocity, depth, substrate, and cover), and the presence or absence of fish species. Habitat-flow relationships were simulated for the selected guild representatives (see Figures 2 through 5 of the Instream Flow Needs Assessment and Appendix F for habitat-flow relationships). The habitat-flow relationships differed for each member of the guild, thereby requiring some interpretation of the results. Using the Multiplicative Technique (Bovee 1982), an interpretative methodology, generally the species and life-stage with the lowest normalized WUA at each modeled discharge were identified as the indicator for instream flow regime discharge. By generally using this type of methodology, no assumptions are made about how much one life stage requires relative to another in the stream. Instead, the species-life stage(s) whose habitat is most restricted at a given flow are those on which the aquatic life maintenance seasonal instream flow regime is based. This approach results in the protection of the most important habitat type(s) within a stream, thereby, resulting in the protection of necessary community based interactions within the fishery community. Tables 6 through 10 of the Instream Flow Needs Assessment consider several other flow regime options which do make judgements regarding species and/or life stage.

In addition to utilizing the Modified Preference Method, a Goal Oriented Methodology was explored to help develop the seasonal instream flow regime as well as to provide an example for resource managers and for consideration in utilizing the seasonal instream flow regime for future planning and management purposes. For the Sheyenne River, the Goal Oriented Methodology was to maintain 50 percent of the WUA for all species during the maintenance period and maintain 50 percent of the WUA for all and/or select (target) species during the spawning period of the year (for the spawning period, selecting the flow which maintains the greatest amount of habitat for either all or target species, whichever was deemed to be reasonable based on professional judgement).

For the Red River of the North, the Goal Oriented Methodology was developed to consider two goals in developing the seasonal instream flow regime: (1) maintain 50 percent of the WUA in the stream during the maintenance and spawning periods of the year for all species, and (2) maintain 50 percent of the WUA in the stream during the spawning period of the year for all species (three options) plus maximize spawning WUA for channel catfish young (CCY) at 80 percent of available WUA (for the spawning period, selecting the flow which maintains the greatest amount of habitat for either all or select (target) species, whichever was deemed to be reasonable based on professional judgement).

Results

Results (instream flows) reported for the Modified Habitat Preference Method upstream and downstream of Lake Ashtabula are generally greater than those reported for Houston (see Table 3 of the Instream Flow Needs Assessment). In an attempt to determine what caused the differences in results, Houston Engineering, Inc. (Houston Engineering, Inc. 1999), completed an analysis of hydraulic calculations used in both studies and reviewed the preference curves associated with the fish species used in the analyses.

The selection of fish species for use in community-based instream flow estimation techniques, such as the Modified Habitat Preference Method, is critical to the instream flow recommendation. The objective of the Modified Habitat Preference Method is to determine the minimum stream flow at which weighted usable habitat area (WUA) is maximized for the fish species with the least amount of habitat. The stream flow at which this occurs is the instream flow recommendation. Weighted usable habitat area (WUA) is determined in accordance with the depth and velocity preferences of each fish species. It is therefore essential to select fish species that utilize habitat throughout the anticipated range of depths and velocities present within a particular stream. Instream flow studies utilizing different fish species will result in different instream flow regimes.

Figures D-1 through D-4 show the velocity and depth preference curves for the Garrison Diversion Conservancy District study. Figures D-5 through D-8 show the velocity and depth preference curves for the Bureau of Reclamation (Reclamation) study. Velocity and depth preference curves for both the spawning period and the nonspawning period of the selected fish species were used. Because the velocity and depth preference curves for a particular fish species changes according to the spawning and nonspawning periods, different fish species have been selected to cover the possible range of habitats for these periods. The velocity and depth, relative frequency and cumulative frequency distributions obtained from the GDCD study and the Reclamation study show considerable similarity. Although some differences are present between the relative frequency distributions, the cumulative frequency distributions "average out" the differences over the range of stream velocities and depths. When considering that the transects analyzed in each study represented different river reaches, the "averaged" results show that overall, the hydraulic analyses are quite similar.

Figures D-2 and D-4 show that there is a gap in the maintenance period, velocity and depth preference curves for the species used in the Garrison Diversion Conservancy District study. Since the hydraulic calculations of each study were shown to be similar, it is expected that this gap is responsible for the differences in instream flow results, and ultimately, instream flow regimes (see Appendices E and F for details associated with these analyses).

Appendix F, Table F-1 (Table 1, Phase I, Part B, Instream Flow Needs Assessment) displays the developed aquatic life maintenance seasonal instream flow regime for various study sites (Raines and Houston Engineering, Inc.) for the Modified Habitat Preference Method application (both Multiplicative Technique and Goal Oriented Methodology flows are presented). Appendix F should be consulted for additional information.

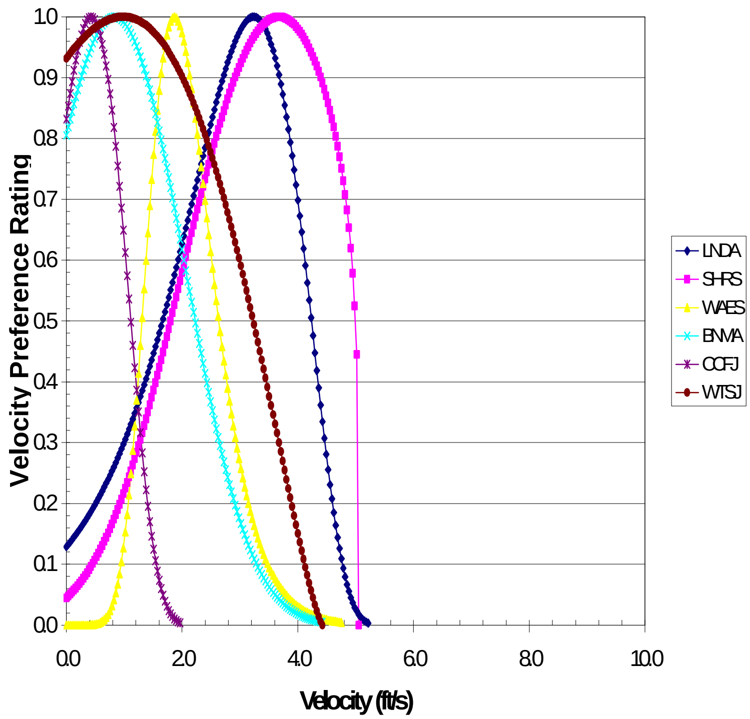

Figure D-1. Spawning period, velocity preference curves for the guild representatives of the GDCD study.

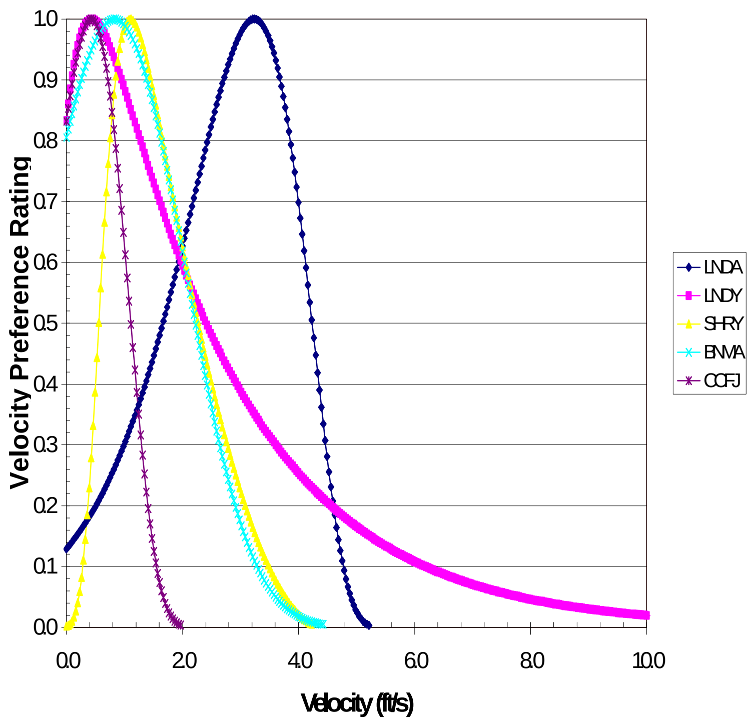

Figure D-2. Maintenance period, velocity preference curves for the guild representatives of the GDCD study.

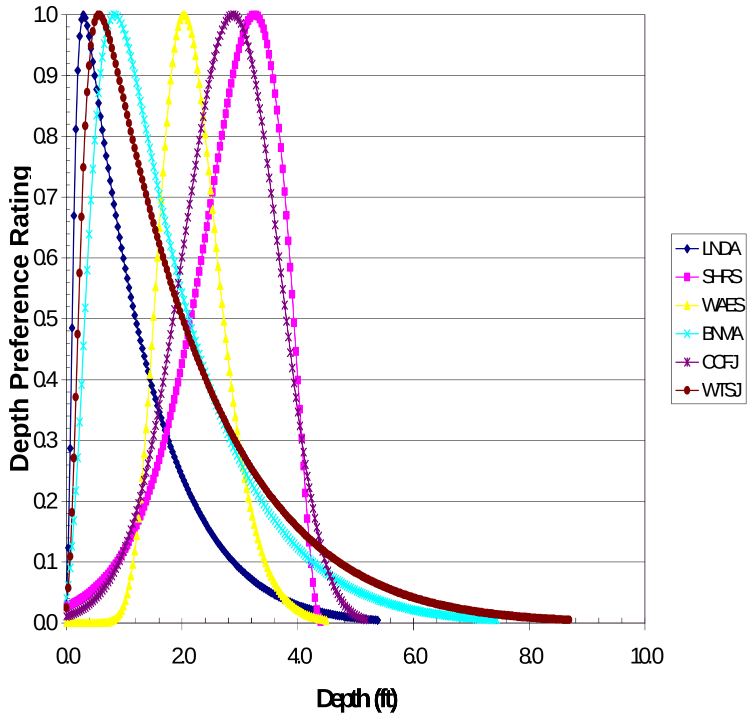

Figure D-3. Spawning period, depth preference curves for the guild representatives of the GDCD study.

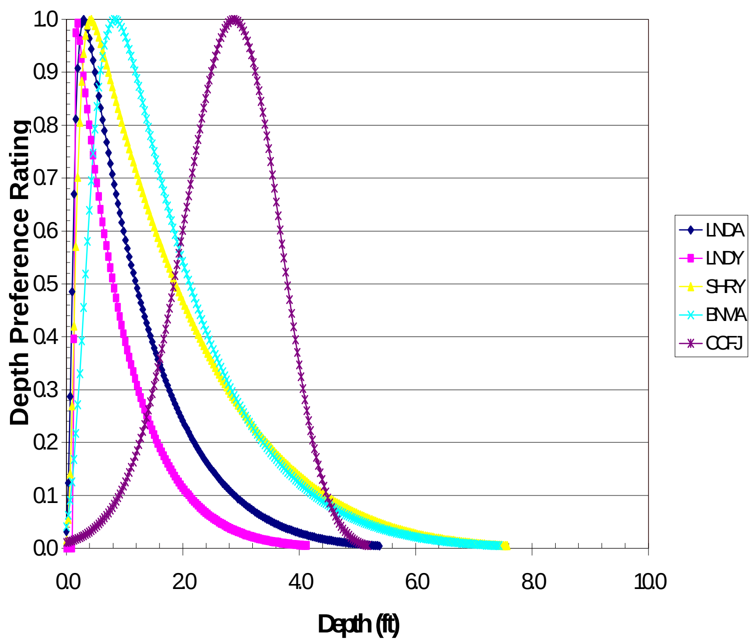

Figure D-4. Maintenance period, depth preference curves for the guild representatives of the GDCD study.

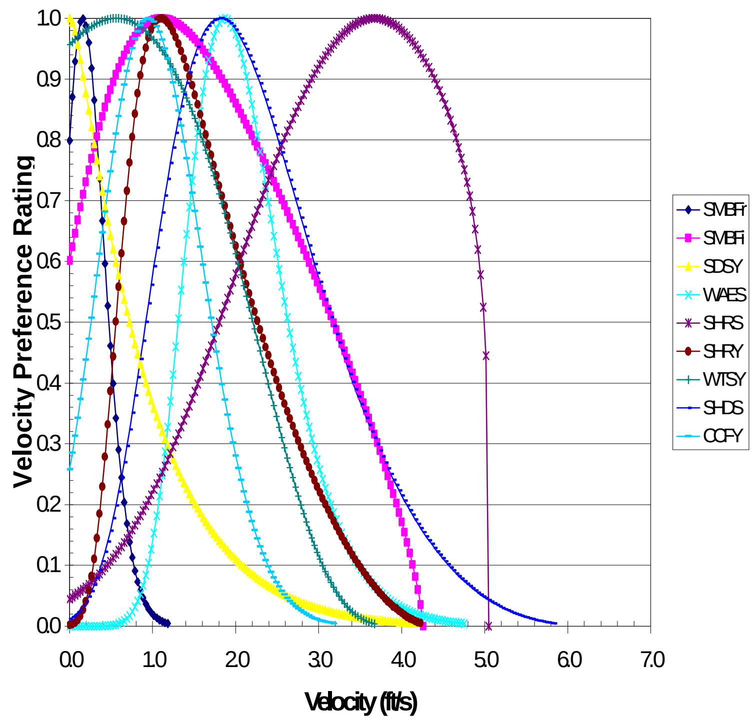

Figure D-5. Spawning period, velocity preference curves for the guild representatives of the Reclamation study.

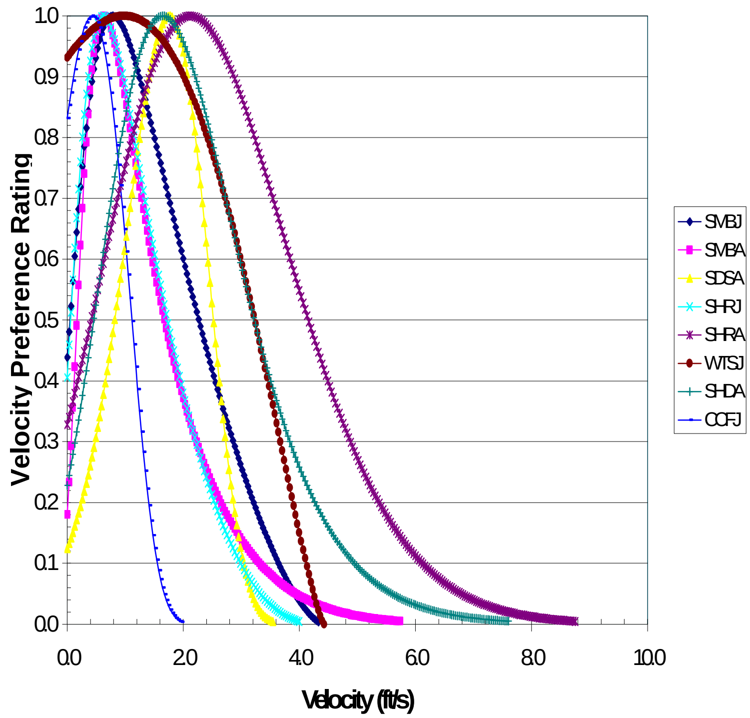

Figure D-6. Maintenance period, velocity preference curves for the guild representative of the Reclamation study.

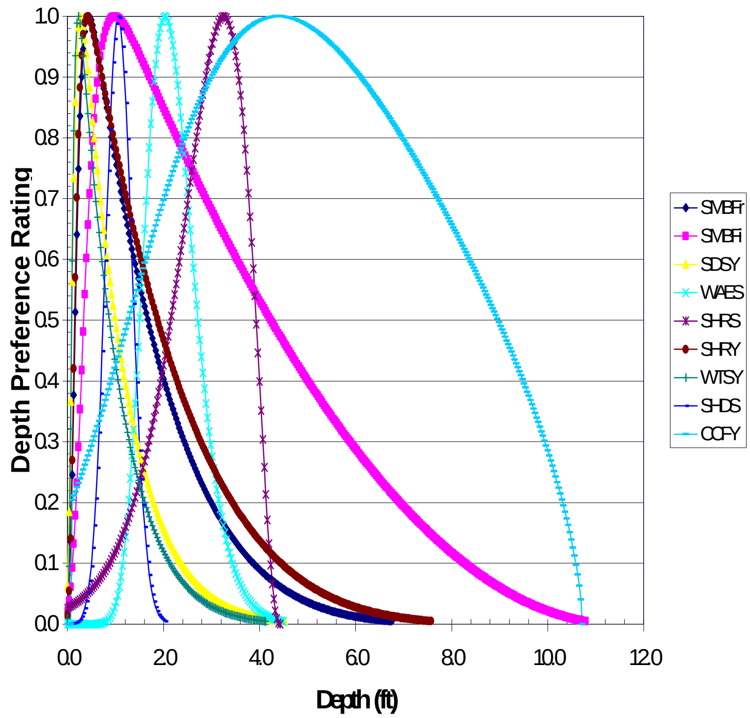

Figure D-7. Spawning period, depth preference curves for the guild representatives of the Reclamation study.

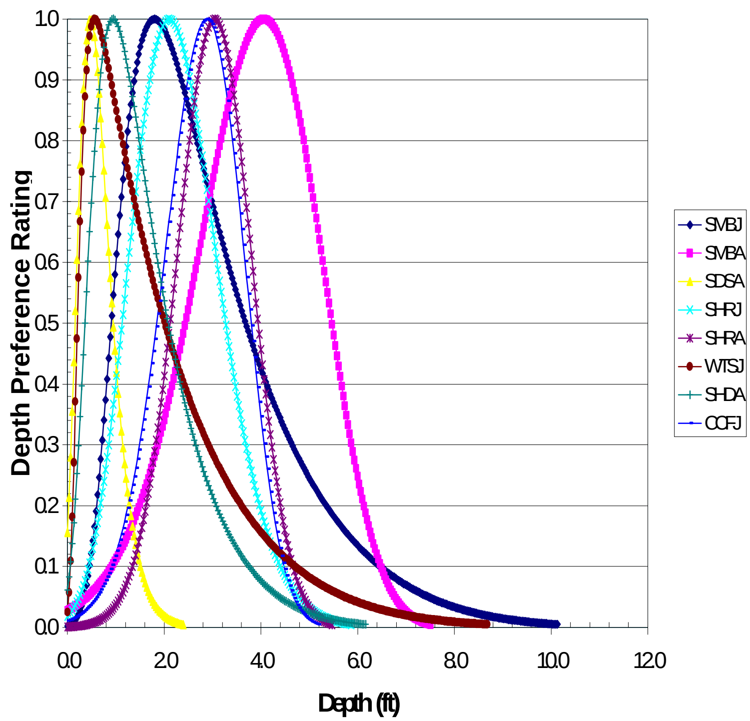

Figure D-8. Maintenance period, depth preference curves for the guild representatives of the Reclamation study.

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APPENDIX E

HYDRAULIC PROPERTIES STUDY

RED RIVER VALLEY WATER NEEDS ASSESSMENT

PHASE 1B

INSTREAM FLOW NEEDS ASSESSMENT

Comparison of Channel Geography

Warwick and Lisbon Study Sites

Comparison of Channel Geometry - Warwick and Lisbon Study Sites

Although data were twice collected at this site, the HEC-RAS Model was unable to be calibrated utilizing the data collected. Lisbon Study Site data were used in the Warwick Study Site analysis. Lisbon Study Site was very similar to the Warwick Study Site in associated instream habitat, vegetation, and channel geometry. The following five pages displays a side-by-side comparison of the channel geometries of the two sites. Ultimately, however, Houston Engineering, Inc. (1997) study site data were used in quantifying the relationship between available fishery habitat and flow.

Investigation of Hydraulic Calculations

Lisbon Study Sites

Reclamation and Houston Engineering, Inc.

Investigation of Hydraulic Calculations

Results (instream flow results) reported for the Modified Habitat Preference Method upstream and downstream of Lake Ashtabula are generally greater than those reported for Houston. In an attempt to determine what caused the differences in results, Houston Engineering, Inc. (Houston Engineering, Inc. 1999), completed an analysis of hydraulic calculations used in both studies and reviewed the preference curves associated with the fish species used in the analyses.

The differences between the instream flow recommendations made by the Modified Habitat Preference Method in the Garrison Diversion Conservancy District study and the Bureau of Reclamation (Reclamation) study was investigated by comparing the results of hydraulic calculations made at the Lisbon, North Dakota study site for the Sheyenne River. In the Garrison Diversion Conservancy District study, 12 transects, covering an x-mile reach, were utilized for hydraulic analysis; in the Reclamation study, five transects, covering an x-mile reach, were utilized for hydraulic analysis. Both studies utilized a calibrated HEC-RAS model for the determination of hydraulic depth and velocity within each cell composing a transect. The five transects used in the Reclamation study each consisted of 25 cells; the 12 transects used in the Garrison Diversion Conservancy District study consisted of 23 to 25 cells. Each study consisted of different river reaches.

A general comparison of the hydraulic depth and velocity results obtained at the Lisbon, North Dakota, study site for the Garrison Diversion Conservancy District and the Reclamation study was made with the use of relative frequency and cumulative frequency distributions. Because the number of transects and, therefore, the total number of cells in the Garrison Diversion Conservancy District study was much greater than in the Reclamation study, hydraulic depth and velocity, relative frequency distributions were utilized to provide a common (normalized) base for comparison. Cumulative depth and velocity frequency distributions were utilized to heighten the comparison. Figures E-1 through E-4 show relative frequency and cumulative frequency distributions developed for each parameter at flow rates of 50 cfs and 200 cfs. Each figure provides a side-by-side comparison of each study for hydraulic depth and velocity.

The velocity and depth, relative frequency and cumulative frequency distributions obtained from the Garrison Diversion Conservancy District study and the Reclamation study show considerable similarity (Figures E-1 through E-4). Although some differences are present between the relative frequency distributions, the cumulative frequency distributions “average” out the differences over the range of stream velocities and depths. When considering that the transects analyzed in each study represented different river reaches, the “averaged” results show that overall, the hydraulic analyses are quite similar. As a result, the differences between the instream flow recommendations made in the Garrison Diversion Conservancy District study and the Reclamation study are not likely to be associated with the hydraulic calculations, but rather the selected fish species.

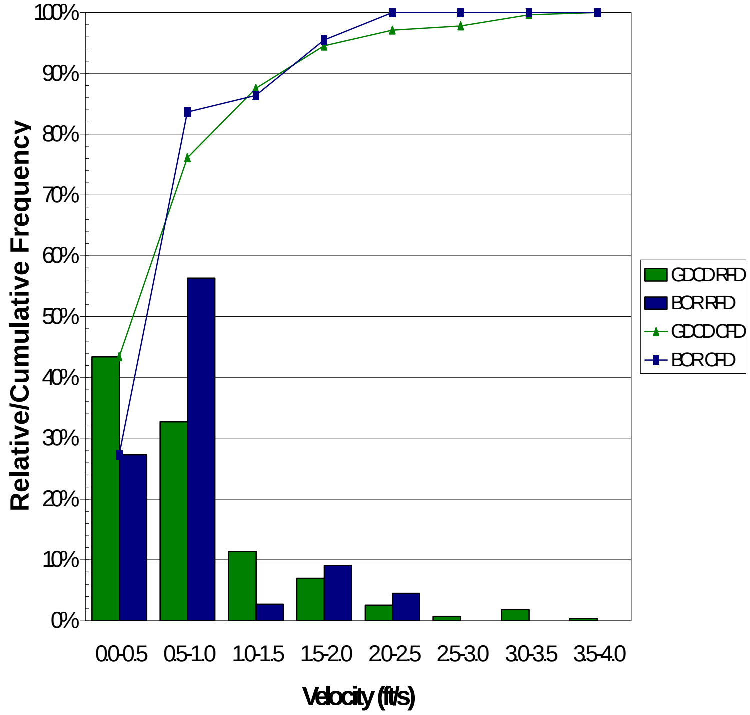

Figure E-1. Relative/cumulative frequency velocity distributions for the Garrison Diversion Conservancy District and Reclamation studies at 50 cfs.

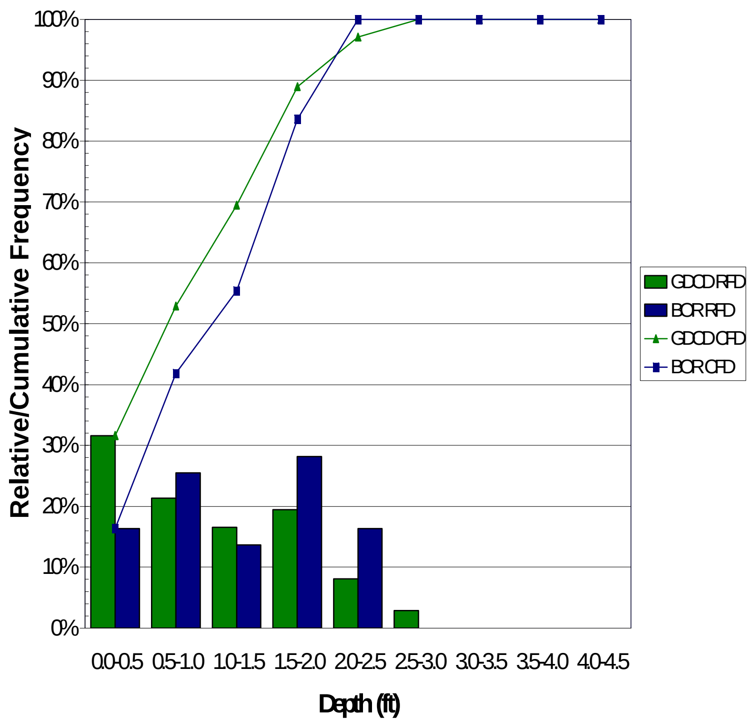

Figure E-2. Relative/cumulative frequency depth distributions for the Garrison Diversion Conservancy District and Reclamation studies at 50 cfs.

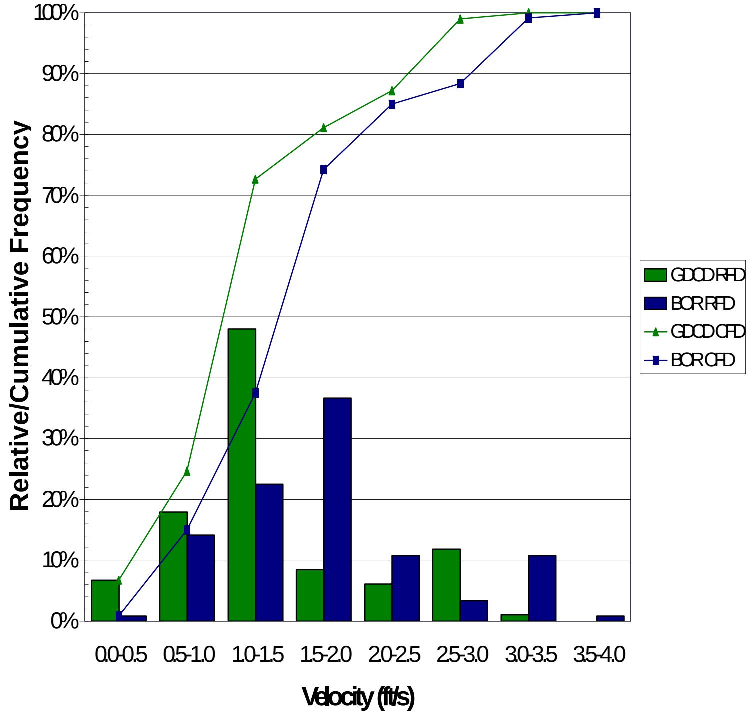

Figure E-3. Relative/cumulative frequency velocity distributions for the Garrison Diversion Conservancy District and Reclamation studies at 200 cfs.

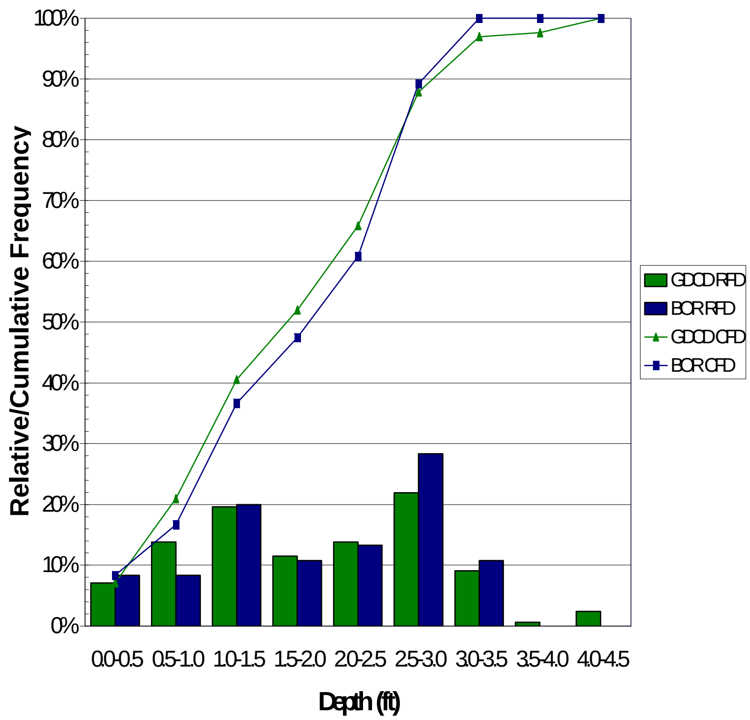

Figure E-4. Relative/cumulative frequency depth distributions for the Garrison Diversion Conservancy District and Reclamation studies at 200 cfs.

Literature Cited

Houston Engineering, Inc. February 1999. Investigation of hydraulic calculations used in the Instream Flow Needs Assessment. Prepared for use by the Bureau of Reclamation in Phase 1, Part B, of the Instream Flow Needs Assessment. Minneapolis, MN.

APPENDIX F

MODIFIED HABITAT PREFERENCE METHOD

RESULTS/DISCUSSION AND SUMMARY SHEETS

RED RIVER VALLEY WATER NEEDS ASSESSMENT

PHASE 1B

INSTREAM FLOW NEEDS ASSESSMENT

MODIFIED HABITAT PREFERENCE METHOD
RESULTS/DISCUSSION AND SUMMARY SHEETS
USED IN THE AQUATIC LIFE MAINTENANCE FLOW ASSESSMENT

Modified Habitat Preference Method

Methods available for assessing instream flows vary greatly in the issues they address, the uses for which they are intended, the assumptions underlying their application, and the intensity (and cost) of the effort required for the application. Considerable analysis and planning are required to tailor an instream flow analysis to meet the unique requirements of the resource, as well as applicable law and administrative procedures.

There are numerous instream flow methodologies which could have been used for the aquatic life maintenance flow needs assessment. Methodologies were grouped into "office" and "field/office" methods. Target species, planning schedules, and the amount of information deemed necessary to quantify the relationship between available fishery habitat and flow and to develop the seasonal instream flow regime were considered in ultimate method selection. The "field/office" approach which was utilized relied upon hydraulic simulation of flow at each study site transect (cross section) for each representative stream reach, with relationships developed between flows and certain hydraulic variables. Hydraulic variables, in turn, were related to fish habitat criteria.

Descriptive data were needed to display the effects of different flow regimes on resource values. Evaluative information was also needed to determine which set of conditions (e.g., instream fishery values and/or riverine riparian maintenance flows) were better or more desirable to evaluate resource conditions in terms of values (e.g., to decide what range of flows creates minimally acceptable, incremental, or optimal conditions). Once resource uses were established (e.g., fishery maintenance and spawning flows, riverine riparian corridor maintenance flows), the needed or desired resource conditions for providing those uses could be established. This required a study approach that recognized and thoroughly delineated resource values, while using appropriate methods to describe how flows related to resource conditions, and which applied evaluative standards to identify needed flows. Ultimately, study results will translate into the identification of the water costs where resource benefits would start to accrue, and the incremental levels of resource improvements for instream and riparian resources, for additional water costs (Phase II of the Red River Valley MR&I Water Needs Assessment).

The value-based process, which was utilized in this aquatic life maintenance flow needs assessment, consisted of five basic steps: (1) preliminary assessment and study design, (2) description of flow-dependent values, (3) description and quantification of hydrology and geomorphology, (4) description of the effects of flows on resource values, and (5) identification of instream flows to protect values. The value-based process is further discussed in Appendices A-F.

The quantification between available fishery habitat and flow and the development of the aquatic life maintenance seasonal instream flow regime were ultimately formulated to satisfy two distinct life stage periods of the fisheries year: the spawning and initial growth period (encompassing select species reproduction times), and the maintenance period (to satisfy fry survival and sustenance of juvenile and adult fish for the remainder of the year). The most critical period of the year for regulated and unregulated streams is the maintenance period (which corresponds to the low flow period) since flows are most susceptible to depletion due to drought and consumption during naturally dryer portions of the year and at times when off stream demands may be greatest (Brunson 1981).

Developing Representative Stream Reaches and Selection of Study Sites are addressed in Appendix A and this information will not be repeated here.

Selection of guild representatives for performing the Modified Habitat Preference Method assessment is discussed in Appendix D and this information will not be repeated here.

Performing hydraulic modeling of representative stream reaches is discussed in Appendix E and this information will not be repeated here.

Calculation of weighted usable area and quantification of the relationship between available fishery habitat and flow

Weighted usable area (WUA) within each representative stream reach and study site and each cross-sectional transect were calculated for each discharge of interest (see Appendix E for list of discharges used in the assessment) for each guild species. The WUA for each species within the guild was computed by integrating the products of depth and the preference curve value for depth and the mean column velocity and the preference curve value for velocity, across the representative cross section in a Lotus (Release 5) software spreadsheet. Combined habitat suitability was then multiplied by the amount of representative stream reach area which was measured at the specific study site and integrated over the representative reach to compute WUA. Available fishery habitat, expressed as percent of maximum WUA for all fish species versus flow was determined. This appendix contains summary sheets for each study site and species specific WUA by discharge and other quantitative relationship information.

Establishing an aquatic life maintenance seasonal instream flow regime utilizing the modified habitat preference method

As previously stated, a variation of the computational methods used by PHABSIM of the IFIM was developed and used to evaluate instream flow needs for the Modified Habitat Preference Method. The variation consisted of selecting representative stream reaches (and establishing and collecting representative cross-sectional data) on the Sheyenne River and the Red River of the North, performing hydraulic modeling (using the U.S. Army Corps of Engineers HEC-RAS

Model) to approximate velocity and depth distribution for site-specific data collected, and using habitat preference curves for fish species (developed for similar watersheds in Minnesota) from a variety of guilds as developed by Aadland et al. (1991), to calculate WUA for each representative stream reach in a Lotus (Release 5) software spreadsheet format. The Modified Habitat Preference Method was used to develop the seasonal instream flow regime by applying the technique of Bovee (1982) to WUA calculated by the multiplicative technique. Application of this technique to maintenance and spawning periods required identifying the minimum amount of habitat for all species over a range of discharges. This method consisted of optimizing the WUA for each species/life stage by the maximum WUA value.

Developing an aquatic life maintenance seasonal instream flow regime

In addition to utilizing the Modified Preference Method, a Goal Oriented Methodology was explored to help develop the seasonal instream flow regime as well as to provide an example for resource managers and for consideration in utilizing the seasonal instream flow regime for future planning and management purposes. For the Sheyenne River, the Goal Oriented Methodology was to maintain 50 percent of the WUA for all species during the maintenance period and maintain 50 percent of the WUA for all and/or select (target) species during the spawning period of the year (for the spawning period, selecting the flow which maintains the greatest amount of habitat for either all or target species, whichever was deemed to be reasonable based on professional judgement).

For the Red River of the North, the Goal Oriented Methodology was developed to consider two goals in developing the seasonal instream flow regime: (1) maintain 50 percent of the WUA in the stream during the maintenance and spawning periods of the year for all species, and (2) maintain 50 percent of the WUA in the stream during the spawning period of the year for all species (three options) plus maximize spawning WUA for channel catfish young (CCY) at 80 percent of available WUA (for the spawning period, selecting the flow which maintains the greatest amount of habitat for either all or select (target) species, whichever was deemed to be reasonable based on professional judgement).

Results and Discussion

Table F-1 displays both results af the Modified Habitat Preference Method (Multiplicative Technique) and the Goal Oriented Methodology. Tables F-2 contain site specific summary sheets used in the analysis. These summary sheets should be reviewed for additional information.

Results (instream flows) reported for the Modified Habitat Preference Method upstream and downstream of Lake Ashtabula are generally greater than those reported for Houston. In an attempt to determine what caused the differences in results, Houston Engineering, Inc., completed an analysis of hydraulic calculations used in both studies and reviewed the preference curves associated with the fish species used in the analyses.

First, Houston Engineering, Inc., compared the results of hydraulic calculations made at the Lisbon, North Dakota, study site (see Appendix E for details associated with this analysis). The velocity and depth, relative frequency and cumulative frequency distributions obtained from the GDCD study and the Reclamation study show considerable similarity. Although some differences are present between the relative frequency distributions, the cumulative frequency distributions “average out” the differences over the range of stream velocities and depths. When considering that the transects analyzed in each study represented different river reaches, the “averaged” results show that overall, the hydraulic analyses are quite similar.

As a result, the differences between the instream flow recommendations made in the GDCD study and the Reclamation aquatic life seasonal instream flow regime were deduced to not likely be associated with the hydraulic calculations, but rather the fish species selected for evaluation. Velocity and depth preference curves for both the spawning period and the non-spawning period (or maintenance period) of selected fish species were evaluated. Because the velocity and depth preference curves for a particular fish species changes according to the spawning and non-spawning periods, different fish species were selected to cover the possible range of habitats for these periods. The analysis showed that there was a gap in the non-spawning period, velocity and depth preference curves, for the species evaluated in the GDCD study. Since the hydraulic calculations of each study were shown to be similar, it is expected that this gap is responsible for the differences in instream flow results, and ultimately, instream flow regimes (see Appendix E).

Multiplicative technique flows generally result in more water and habitat (expressed as WUA) being maintained in the stream than most flows derived by applying the Goal Oriented Methodology (see Summary Tables which appear later).

As an example, at the Lisbon Study Site, Sheyenne River, multiplicative technique flows for all species would maintain 777135 WUA compared to 585300 WUA for the Goal Oriented Methodology (59 percent of the maximum available WUA versus 49 percent for the maintenance period and 59 versus 43 percent respectively, during the spawning period). For target species (or life stages), e.g., smallmouth bass fingerlings, walleye spawning, shorthead redhorse spawning, and channel catfish young, multiplicative technique flows would maintain 799612 WUA compared to 621028 WUA for the Goal Oriented Methodology (64 percent of the maximum available WUA versus 58 percent for the maintenance period and 68 versus 58 percent, respectively, during the spawning period).

The average depth and velocity of the stream at the Lisbon Study Site during the maintenance period (70 cfs flow for the multiplicative technique) was calculated to be 1.50 feet at 0.98 cfs. For spawning period flows (75 cfs for all species and 225 cfs for target species for the multiplicative technique), average depth and velocity was calculated to be 1.53 feet at 1.02 cfs and 2.13 feet at 1.90 cfs, respectively. Goal Oriented Methodology maintenance and spawning flows would result in less average depth and velocity at the site.

Table F-1. Summary of the Multiplicative Technique and Goal Oriented Methodology Results.

STUDY SITE	MULTIPLICATIVE TECHNIQUE					AQUATIC LIFE MAINTENANCE GOAL				
	Maintenance All Species	Spawning All Species	Spawning Select Species			Maintenance All Species	Spawning All Species	Spawning Select Species		
Warwick[1]	25	100	-			-	-	-		
Lisbon	70	75	225			25	35	70		
Ft. Ransom	70	125	340			55	340	125		
Pigeon Point	50	70	155			50	50	100		
Norman	130	100	150			50	100	100		
	Maintenance All Species	Spawning All Species	Spawning - All except WS, CCY	Spawning - Select except WS	Spawning - CCY	Maintenance All Species	Spawning All Species	Spawning - All except WS, CCY	Spawning - Select except WS	Spawning - CCY
Red River	100	125	133	125	75	50	375	450	450	450

[1]Results displayed for Houston Engineering Inc., Study (1997)

The surface area of the study reach increases from 7,892 ft^2 (wetted perimeter surface area of 7,980 ft^2) during maintenance flows to 7,927 ft^2 for all species and 8,728 ft^2 for target species, respectively, during spawning flows (see Summary Tables).

For the Red River of the North at Fargo, North Dakota, multiplicative technique flows for all species would maintain 117800980 WUA compared to 76960536 WUA for the Goal Oriented Methodology (51 percent of the maximum available WUA versus 47 (Goal # 1) or 49 percent (Goal # 2) for the maintenance period and 48 versus 65 (Goal # 1) and 70 (Goal # 2) percent, respectively, during the spawning period). For target species (or life stages), e.g., channel catfish young, multiplicative technique flows would maintain 117800980 WUA compared to 76960536 WUA for the Goal Oriented Methodology (35 percent of the maximum available WUA versus 80 percent for the maintenance period and 48 versus 70 percent, respectively, during the spawning period)(see Summary Tables).

The average depth and velocity of the stream at the Red River (Fargo) Study Site during the maintenance period (100 cfs flow for the multiplicative technique) was calculated to be 3.59 feet at 0.39 cfs. For spawning period flows (125 to 133 cfs for all species or variations of target species for the multiplicative technique), average depth and velocity was calculated to be 4.02 to 4.17 feet at 0.38 cfs, respectively. Goal Oriented Methodology maintenance flows (50 cfs) would result in less average depth but greater velocity at the site (2.47 feet at 0.41 cfs). Goal Oriented Methodology spawning flows (375 to 450 cfs) would result in greater average depth (7.17 to 7.87 feet) and velocity (0.43 cfs) at the site.

The surface area of the study reach increases from 55,356 ft^2 (wetted perimeter surface area of 56,358 ft^2) during maintenance flows to 62,548 ft^2 for all species and 63,758 ft^2 for variations of target species, respectively, during spawning flows (see Summary Tables).

See Summary Tables for more comparative information related to the other study sites and results of applying the multiplicative technique and the Goal Oriented Methodology.

Aquatic Life Maintenance Seasonal Instream Flow Regime

The aquatic life maintenance seasonal instream flow regime was developed to provide an instream flow foundation for the current Red River Valley MR&I Water Needs Assessment. The rational in completing this study was to provide sufficient analyses for the development of defensible recommendations for immediate planning purposes and to lay the foundation for additional future refinement. Reclamation believes that the aquatic life maintenance seasonal instream flow regime represents a flow regime which is capable of maintaining an acceptable level of instream values in the Sheyenne River and Red River of the North systems. An acceptable level of instream values was previously defined as those which would maintain the ecological integrity of the riverine ecosystem (maintaining the existing community structure at a defined level based on the application of hydrologic, hydraulic, and habitat based methodologies).

The data presented in Table 3 (Instream Flow Needs Assessment) demonstrate that the application of different methodologies will result in differing instream flow recommendations for any given location on the Sheyenne River and/or the Red River of the North. Use of the Modified Habitat Preference Method, both the multiplicative technique and the Goal Oriented Methodology (plus consideration of historic flows and hydrologic and hydraulic method results) resulted in the most defensible approach to developing an aquatic life maintenance seasonal instream flow regime for the study area for this appraisal level of analysis. Again, the aquatic life maintenance seasonal instream flow regime is presented in Table 3 and displayed in the "Reclamation" Aquatic Life Maintenance Seasonal Instream Flow Regime row of the table and also displayed in Table F-2 below.

Summary tables display comparisons between mean monthly flow rates and WUA for all species (and/or species life stages) and the developed aquatic life maintenance seasonal instream flow regime flow WUA for all species (and/or species life stages), for selected sites on the Sheyenne River and the Red River of the North. For the both the Sheyenne River and the Red River of the North, aquatic life maintenance seasonal instream flow regime flows would generally result in similar amounts of habitat being maintained for all sites considered (mean historic flows versus seasonal instream flows) but require less water (instream water) to produce the results.

For the Sheyenne River, an average of 61 percent of the maximum WUA for all species would be maintained during the maintenance period of the year and 66 percent of the maximum WUA for all species would be maintained during the spawning period of the year. For the Red River of the North, an average of 50 percent of the maximum WUA for all species would be maintained during the maintenance period of the year and 70 percent of the maximum WUA for all species would be maintained during the spawning period of the year.

On the Platte River in Nebraska, the U.S. Fish and Wildlife Service has developed a flow regime for fisheries which provided approximately 72 percent of the optimum physical habitat for all groups of fish analyzed [Biological Opinion for Kingsley Dam (FERC Project No. 1417) and North Platte/Keystone Diversion Dam (FERC Project No. 1835) Projects, Nebraska]. The aquatic life maintenance seasonal instream flow regime developed for this study compares favorably with the Platte River study (Sheyenne River - maintaining an average of 61 percent of the maximum WUA available for all species during the maintenance period of the year and 66 percent of the maximum WUA available for all species during the spawning period of the year; Red River of the North - an average of 70 percent of the maximum WUA available for all species would be maintained during the maintenance period of the year and 70 percent of the maximum WUA available for all species would be maintained for the spawning period of the year).

Table F-2
Sheyenne River and Red River of the North
Seasonal Instream Flow Regime for Aquatic Life Maintenance

Location	Flows in Cubic Feet Per Second (cfs)											
	Jan[1]	**Feb**	**Mar[1]**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Sheyenne River												
Harvey, ND	15	15	25	25	25	25	15	15	15	15	15	15
Warwick, ND[2]	25	25	100	100	100	100	25	25	25	25	25	25
Cooperstown, ND	50	50	125	125	125	125	50	50	50	50	50	50
Baldhill Dam, ND	50	50	125	125	125	125	50	50	50	50	50	50
Valley City, ND	50	50	125	125	125	125	50	50	50	50	50	50
Lisbon, ND[2]	70	70	225	225	225	225	70	70	70	70	70	70
Kindred, ND[2]	50	50	155	155	155	155	50	50	50	50	50	50
West Fargo, ND[2]	50	50	100	100	100	100	50	50	50	50	50	50
Harwood, ND	50	50	100	100	100	100	50	50	50	50	50	50
Red River of the North												
Wahpeton, ND	100	100	450	450	450	450	100	100	100	100	100	100
Hickson, ND	100	100	450	450	450	450	100	100	100	100	100	100
Fargo, ND[2]	100	100	450	450	450	450	100	100	100	100	100	100
Halstad, MN	200	200	1125	1125	1125	1125	200	200	200	200	200	200
Grand Forks, ND	440	440	2160	2160	2160	2160	440	440	440	440	440	440
Drayton, ND	480	480	2610	2610	2610	2610	480	480	480	480	480	480
Emerson, Manitoba, Canada	520	520	3060	3060	3060	3060	520	520	520	520	520	520

[1]Maintenance flows provided for the months of July-February; Spawning flows provided for the months of March-June.
[2]Actual data collection resulted in flow regime (either Reclamation or Houston Engineering, Inc. sites; all other site flow regimes based on estimated needs).

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Bovee, K. 1982. A guide to stream habitat analysis using the instream flow incremental methodology. Instream Flow Information Paper No. 12. FWS/OBS-82/26. U.S. Fish and Wildlife Service, Office of Biological Services, Fort Collins, CO.

Stalnaker, C. B., B. Lamb, J. Henriksen, K. Bovee, and J. Bartholow. 1994. The Instream Flow Incremental Methodology: A Primer for IFIM. National Ecology Research Center, Internal Publication. National Biological Survey. Fort Collins, CO. 99 pp.

SUMMARY TABLES

Tables F-2

Specific Study Site Summary Sheets

Sheyenne River at Warwick Aquatic Life Maintenance Seasonal Instream Flow Regime.

														Houston Eng
	Mean Monthly	Multiplicative	Multiplicative	Goal	Goal	O'Shea Method	Houston Eng		Multiplicative	Multiplicative	Goal	Goal	O'Shea	Mod Hab Pref
	Period of	Technique	Technique	Methodology	Methodology	Recomm-	Mod Hab Pref	Mean Monthly	Technique	Technique	Methodology	Methodology	Method	Method
	Record	All Species	Target Species	All Species	Target Species	endations	Method Recomm	All Species	All Species	Target Species	All Species	Target Species	All Species	All Species
Month	Flow (cfs)	Flow (cfs)	Flow (cfs)	Flow (cfs)	Flow (cfs)	Flow (cfs)	Flow (cfs)	Flow WUA	Flow WUA	Flow WUA	Flow WUA	Flow WUA	Flow WUA	Flow WUA
January	4	70	70	25	25	36	25	66715	79494	79494	60292	60292	66715	60292
February	27	70	70	25	25	43	25	69881	79494	79494	60292	60292	69881	60292
March	86	75	225	35	70	148	100	41327	35296	40915	25741	34673	40719	38413
April	266	75	225	35	70	413	100	32431	35296	40915	25741	34673	37648	38413
May	93	75	225	35	70	210	100	39564	35296	40915	25741	34673	41209	38413
June	51	75	225	35	70	129	100	41075	35296	40915	25741	34673	40468	38413
July	29	70	70	25	25	84	25	86084	79494	79494	60292	60292	82057	60292
August	12	70	70	25	25	36	25	66715	79494	79494	60292	60292	66715	60292
September	9	70	70	25	25	33	25	65069	79494	79494	60292	60292	65069	60292
October	10	70	70	25	25	36	25	66715	79494	79494	60292	60292	66715	60292
November	10	70	70	25	25	46	25	72142	79494	79494	60292	60292	71237	60292
December	6	70	70	25	25	40	25	68524	79494	79494	60292	60292	68524	60292
TOTALS								716242	777136	799612	585300	621028	716957	635988
AVERAGES	50	72	122	28	40	105	50							
									Multiplicative	Multiplicative	Goal	Goal		Houston Eng
								Mean Monthly	Technique	Technique	Methodology	Methodology	O'Shea Method	Mod Hab Pref
								% WUA Avg	% WUA Avg	% WUA Avg	% WUA Avg	% WUA Avg	% WUA Avg	% WUA Avg
								and % Max WUA	and % Max WUA	and % Max WUA	and % Max WUA	and % Max WUA	and % Max WUA	and % Max WUA
								for All Species	All Species	Target Species	All Species	Target Species	All Species	All Species
								Maint/Spawn	Maint/Spawn	Maint/Spawn	Maint/Spawn	Maint/Spawn	Maint/Spawn	Maint/Spawn
								Period	Period	Period	Period	Period	Period	Period
								43/60	79/59	79/64	55/49	55/58	67/63	55/63
								40/61	62/59	62/68	47/43	47/58	55/67	47/64

Sheyenne River at Lisbon Aquatic Life Maintenance Seasonal Instream Flow Regime.

Month	Mean Monthly Period of Record Flow(cfs)	Multiplicative Technique All Flow (cfs)	Multiplicative Technique Target Species Flow (cfs)	Goal Methodology All Species Flow (cfs)	Goal Methodology Target Species Flow (cfs)	O'Shea Method Recomm-endations Flow (cfs)	Mean Monthly All Species Flow WUA	Multiplicative Technique All Species Flow WUA	Multiplicative Technique Target Species Flow WUA	Goal Methodology All Species Flow WUA	Goal Methodology Target Species Flow WUA	O'Shea Method All Species Flow WUA
January	36	70	70	25	25	36	66715	79494	79494	60292	60292	66715
February	43	70	70	25	25	43	69881	79494	79494	60292	60292	69881
March	204	75	225	35	70	148	41327	35296	40915	25741	34673	40719
April	609	75	225	35	70	413	32431	35296	40915	25741	34673	37648
May	298	75	225	35	70	210	39564	35296	40915	25741	34673	41209
June	175	75	225	35	70	129	41075	35296	40915	25741	34673	40468
July	106	70	70	25	25	84	86084	79494	79494	60292	60292	82057
August	36	70	70	25	25	36	66715	79494	79494	60292	60292	66715
September	33	70	70	25	25	33	65069	79494	79494	60292	60292	65069
October	36	70	70	25	25	36	66715	79494	79494	60292	60292	66715
November	48	70	70	25	25	46	72142	79494	79494	60292	60292	71237
December	40	70	70	25	25	40	68524	79494	79494	60292	60292	68524
TOTALS							716242	777136	799612	585300	621028	716957
AVERAGES	139	72	122	28	40	105						
							Mean Monthly % WUA Avg and for Maint / Spawn Period	Multiplicative Technique % WUA Avg and % Max WUA All Species Maint / Spawn Period	Multiplicative Technique % WUA Avg and % Max WUA Target Species Maint / Spawn Period	Goal Methodology % WUA Avg and % Max WUA All Species Maint / Spawn Period	Goal Methodology % WUA Avg and % Max WUA Target Species Maint / Spawn Period	O'Shea Method % WUA Avg and % Max WUA All Species Maint / Spawn Period
							67 / 61	79 / 59	79 / 64	55 / 49	55 / 58	67 / 63
							55 / 65	62 / 59	62 / 68	47 / 43	47 / 58	55 / 67

Sheyenne River at Kindred Aquatic Life Maintenance Seasonal Instream Flow Regime.

Month	Mean Monthly Period of Record Flow (cfs)	Multiplicative Technique All Flow (cfs)	Multiplicative Technique Target Species Flow (cfs)	Goal Methodology All Species Flow (cfs)	Goal Methodology Target Species Flow (cfs)	O'Shea Method Recomm-endations Flow (cfs)	Mean Monthly All Species Flow WUA	Multiplicative Technique All Species Flow WUA	Multiplicative Technique Target Species Flow WUA	Methodology All Species Flow WUA	Methodology Target Species Flow WUA	Method All Species Flow WUA
January	48	50	50	50	50	47	73953	75781	75781	75781	75781	72953
February	55	50	50	50	50	51	79569	75781	75781	75781	75781	76539
March	206	70	155	50	100	150	57014	31115	56510	33239	47303	55736
April	658	70	155	50	100	445	40125	31115	56510	33239	47303	50651
May	392	70	155	50	100	272	54256	31115	56510	33239	47303	57854
June	241	70	155	50	100	172	57394	31115	56510	33239	47303	56734
July	171	50	50	50	50	127	83312	75781	75781	75781	75781	75836
August	73	50	50	50	50	63	87420	75781	75781	75781	75781	82781
September	57	50	50	50	50	52	80781	75781	75781	75781	75781	78781
October	57	50	50	50	50	52	80781	75781	75781	75781	75781	78781
November	68	50	50	50	50	60	88933	75781	75781	75781	75781	82000
December	55	50	50	50	50	51	78781	75781	75781	75781	75781	76781
TOTALS							862319	730708	832288	739204	795460	845427
AVERAGES	173	57	85	50	67	129						
							Mean Monthly % WUA Avg and for Maint / Spawn Period	Multiplicative Technique % WUA Avg and % Max WUA All Species Maint / Spawn Period	Multiplicative Technique % WUA Avg and % Max WUA Target Species Maint / Spawn Period	Goal Methodology % WUA Avg and % Max WUA All Species Maint / Spawn Period	Goal Methodology % WUA Avg and % Max WUA Target Species Maint / Spawn Period	O'Shea Method % WUA Avg and % Max WUA All Species Maint / Spawn Period
							60 / 50	55 / 53	55 / 53	55 / 53	55 / 53	60 / 55
							61 / 63	57 / 37	57 / 57	57 / 40	57 / 57	59 / 66

Sheyenne River at West Fargo Aquatic Life Maintenance Seasonal Instream Flow Regime.

Month	Mean Monthly Period of Record Flow(cfs)	Multiplicative Technique All Flow (cfs)	Multiplicative Technique Target Species Flow (cfs)	Goal Methodology All Species Flow (cfs)	Goal Methodology Target Species Flow (cfs)	O'Shea Method Recomm-endations Flow (cfs)	Mean Monthly All Species Flow WUA	Multiplicative Technique All Species Flow WUA	Multiplicative Technique Target Species Flow WUA	Goal Methodology All Species Flow WUA	Goal Methodology Target Species Flow WUA	O'Shea Method All Species Flow WUA
January	48	130	130	50	50	46	182932	116210	116210	202745	202745	163114
February	55	130	130	50	50	51	171135	116210	116210	202745	202745	196423
March	191	100	150	100	100	140	53891	47984	51716	47984	47984	50725
April	671	100	150	100	100	454	57933	47984	51716	47984	47984	57631
May	401	100	150	100	100	277	58018	47984	51716	47984	47984	56280
June	253	100	150	100	100	180	55433	47984	51716	47984	47984	53091
July	181	130	130	50	50	134	133618	116210	116210	202745	202745	121210
August	78	130	130	50	50	66	121017	116210	116210	202745	202745	76315
September	57	130	130	50	50	52	170135	116210	116210	202745	202745	194423
October	58	130	130	50	50	53	169135	116210	116210	202745	202745	196423
November	70	130	130	50	50	61	76315	116210	116210	202745	202745	139315
December	56	130	130	50	50	52	169135	116210	116210	202745	202745	194423
TOTALS							1418697	1121616	1136544	1813896	1813896	1499373
AVERAGES	177	120	137	67	67	131						
							Mean Monthly % WUA Avg and for Maint / Spawn Period	Multiplicative Technique % WUA Avg and % Max WUA All Species Maint / Spawn Period	Multiplicative Technique % WUA Avg and % Max WUA Target Species Maint / Spawn Period	Goal Methodology % WUA Avg and % Max WUA All Species Maint / Spawn Period	Goal Methodology % WUA Avg and % Max WUA Target Species Maint / Spawn Period	O'Shea Method % WUA Avg and % Max WUA All Species Maint / Spawn Period
							50 / 72	56 / 65	56 / 74	54 / 65	54 / 65	46 / 73
							58 / 89	45 / 76	45 / 82	79 / 76	79 / 76	66 / 87

Red River of the North at Fargo Aquatic Life Maintenance Seasonal Instream Flow Regime.

Month	Mean Monthly Period Record Flow	Multiplicative Technique All Flow (cfs)	Multiplicative Technique All Species Flow (cfs)	Multiplicative Technique All Sp - WS Flow (cfs)	Multiplicative Technique CCY Flow (cfs)	Goal # 1 Methodology All Species Flow (cfs)	Goal # 2 Methodology All Species Flow (cfs)	Goal Methodology All Species - WS, CCY Flow (cfs)	Goal Methodology All Sp - WS Flow (cfs)	Goal Methodology CCY Flow (cfs)	Combination Methodology All Species & CCY Max Flow (cfs)	O'Shea Method Recomm-endations Flow (cfs)	Mean Monthly All Species Flow WUA	Multiplicative Technique All Species Flow WUA	Multiplicative Technique All Species - WS, CCY Flow WUA	Multiplicative Technique All Sp - WS Flow WUA	Multiplicative Technique CCY Flow WUA	Goal # 1 Methodology All Species Flow WUA	Goal # 2 Methodology All Species Flow WUA	Goal Methodology All Species - WS, CCY Flow WUA	Goal Methodology All Sp - WS Flow WUA	Goal Methodology CCY Flow WUA	Combination Methodology All Species & CCY Max Flow WUA	O'Shea Method All Species Flow WUA
January	198	100	100	100	100	50	50	50	50	50	100	135	1475233	14622892	14622892	14622892	14622892	9472609	9472609	9472609	9472609	9472609	14622892	1213372
February	202	100	100	100	100	50	50	50	50	50	100	137	1491625	14622892	14622892	14622892	14622892	9472609	9472609	9472609	9472609	9472609	14622892	1223372
March	598	125	125	133	125	375	450	450	450	450	450	407	327508	204461	204461	216884	204461	273714	294916	294916	294916	294916	294916	280781
April	1810	125	125	133	125	375	450	450	450	450	450	1202	388906	204461	204461	216884	204461	273714	294916	294916	294916	294916	294916	388906
May	1014	125	125	133	125	375	450	450	450	450	450	680	388906	204461	204461	216884	204461	273714	294916	294916	294916	294916	294916	341877
June	1059	125	125	133	125	375	450	450	450	450	450	709	388906	204461	204461	216884	204461	273714	294916	294916	294916	294916	294916	346566
July	814	100	100	100	100	50	50	50	50	50	100	509	25300566	14622892	14622892	14622892	14622892	9472609	9472609	9472609	9472609	9472609	14622892	24772560
August	339	100	100	100	100	50	50	50	50	50	100	220	2033756	14622892	14622892	14622892	14622892	9472609	9472609	9472609	9472609	9472609	14622892	1523598
September	227	100	100	100	100	50	50	50	50	50	100	152	1583938	14622892	14622892	14622892	14622892	9472609	9472609	9472609	9472609	9472609	14622892	1294474
October	240	100	100	100	100	50	50	50	50	50	100	160	1664278	14622892	14622892	14622892	14622892	9472609	9472609	9472609	9472609	9472609	14622892	1324474
November	233	100	100	100	100	50	50	50	50	50	100	155	1603938	14622892	14622892	14622892	14622892	9472609	9472609	9472609	9472609	9472609	14622892	1304474
December	204	100	100	100	100	50	50	50	50	50	100	138	1483598	14622892	14622892	14622892	14622892	9472609	9472609	9472609	9472609	9472609	14622892	1233372
TOTALS													38131158	117800980	117800980	117850672	117800980	76875728	76960536	76960536	76960536	76960536	118162800	35247826
AVERAGES	578	108	108	111	108	158	183	183	183	183	217	384												
																							Combination	
														Multiplicative	Multiplicative	Multiplicative	Multiplicative	Goal # 1	Goal # 2	Goal	Goal	Goal	Methodology	
													Mean	Technique	Technique	Technique	Technique	Methodology	Methodology	Methodology	Methodology	Methodology	All Sp & CCY Max	O'Shea Method
													% WUA Avg	% WUA Avg	% WUA Avg	% WUA Avg	% WUA Avg	% WUA Avg	% WUA Avg	% WUA Avg	% WUA Avg	% WUA Avg	% WUA Avg	% WUA Avg
													and	and % Max WUA	and % Max WUA	and % Max WUA	and % Max WUA	and % Max WUA	and % Max WUA	and % Max WUA	and % Max WUA	and % Max WUA	and % Max WUA	and % Max WUA
													for	AllSpecies	AllSp - WS, CCY	All Sp - WS	CCY	All Species	All Species	All Sp - WS, CCY	All Sp - WS	CCY	CCY	All Species
													Maint / Spawn	Maint / Spawn	Maint / Spawn	Maint / Spawn	Maint / Spawn	Maint / Spawn	Maint / Spawn	Maint / Spawn	Maint / Spawn	Maint / Spawn	Maint / Spawn	Maint / Spawn
													Period	Period	Period	Period	Period	Period	Period	Period	Period	Period	Period	Period
													58 / 61	62 / 51	62 / 61	62 / 73	62 / 35	54 / 47	54 / 49	54 / 52	54 / 71	54 / 80	62 / 80	59 / 58
													16 / 87	50 / 48	50 / 48	50 / 51	50 / 48	32 / 65	32 / 70	32 / 70	32 / 70	32 / 70	50 / 70	5 / 81

Sheyenne River and Red River of the North Modified Habitat Preference Method and Aquatic Life Maintenance Seasonal Instream Flow Regime.

		05054500 Sheyenne River above Harvey, ND 1931-1984		05056000 Sheyenne River near Warwick, ND 1931-1984		05057000 Sheyenne River near Cooperstown, ND 1931-1984	
Modified Habitat Preference Method	Reclamation	Mar-Jun -* 25**	Jul-Feb -* 15**	Mar-Jun 75 (all sp), 225(target sp)* 35 (all sp), 70 (target sp)**	Jul-Feb 70 (all sp)* 25 (all sp)**	Mar-Jun 75 (all sp), 225(target sp)* 35 (all sp), 70 (target sp)**	Jul-Feb 70 (all sp)* 25 (all sp)**
	Houston	Mar-Apr 100	May-Feb 25	Mar-Apr 100	May-Feb 25	Mar-Apr 100	May-Feb 25
Aquatic Life Maintenance Seasonal Instream Flow Regime	Reclamation	Mar-Jun 25	Jul-Feb 15	Mar-Jun 100	Jul-Feb 25	Mar-Jun 125	Jul-Feb 50
	Houston	Mar-Apr 6	May-Feb 2	Mar-Apr 50	May-Feb 25	Mar-Apr 71	May-Feb 25

		05058000 Sheyenne River below Baldhill Dam, ND 1931-1984		05058500 Sheyenne River at Valley City, ND 1931-1984		05058700 Sheyenne River at Lisbon, ND 1931-1984	
Modified Habitat Preference Method	Reclamation	Mar-Jun 340 (all sp), 125 (target sp)* 125 (all sp), 340 (target sp)**	Jul-Feb 70 (all sp)* 55 (all sp)**	Mar-Jun 340 (all sp), 125 (target sp)* 125 (all sp), 340 (target sp)**	Jul-Feb 70 (all sp)* 55 (all sp)**	Mar-Jun 75 (all sp), 225 (target sp)* 35 (all sp), 70 (target sp)**	Jul-Feb 70 (all sp)* 25 (all sp)**
	Houston	Mar-Apr 250	May-Feb 75	Mar-Apr 250	May-Feb 75	Mar-Apr 250	May-Feb 75
Aquatic Life Maintenance Seasonal Instream Flow Regime	Reclamation	Mar-Jun 125	Jul-Feb 50	Mar-Jun 125	Jul-Feb 50	Mar-Jun 225	Jul-Feb 70
	Houston	Mar-Apr 74	May-Feb 25	Mar-Apr 74	May-Feb 25	Mar-Apr 185	May-Feb 55

Sheyenne River and Red River of the North Modified Habitat Preference Method and Aquatic Life Maintenance Seasonal Instream Flow Regime (Cont').

		05059000 Sheyenne River near Kindred, ND 1931-1984		05059500 Sheyenne River at West Fargo, ND 1931-1984		05060400 Sheyenne River at Harwood, ND 1931-1984	
Modified Habitat Preference Method	Reclamation	Mar-Jun 70 (all sp), 155 (target sp)* 50 (all sp), 100 (target sp)**	Jul-Feb 50 (all sp)* 50 (all sp)**	Mar-Jun 100 (all sp), 150 (target sp)* 100 (all sp), 100 (target sp)*	Jul-Feb 130 (all sp)* 50 (all sp)**	Mar-Jun 100 (all sp), 150 (target sp)* 100 (all sp), 100 (target sp)*	Jul-Feb 130 (all sp)* 50 (all sp)**
	Houston	Mar-Apr 38	May-Feb 15	Mar-Apr 50	May-Feb 25	Mar-Apr 50	May-Feb 25
Aquatic Life Maintenance Seasonal Instream Flow Regime	Reclamation	Mar-Jun 155	Jul-Feb 50	Mar-Jun 100	Jul-Feb 50	Mar-Jun 100	Jul-Feb 50
	Houston	Mar-Apr 135	May-Feb 45	Mar-Apr 135	May-Feb 45	Mar-Apr 135	May-Feb 45

		05051500 Red River of the North at Wahpeton, ND 1942-1984		05051522 Red River of the North at Hickson, ND 1976-1984	
Modified Habitat Preference Method	Reclamation	Mar-Jun -* 450**	Jul-Feb -* 100***	Mar-Jun -* 450**	Jul-Feb -* 100***
	Houston	None	None	None	None
Aquatic Life Maintenance Seasonal Instream Flow Regime	Reclamation	Mar-Jun 450	Jul-Feb 100	Mar-Jun 450	Jul-Feb 100
	Houston	None	None	None	None

Sheyenne River and Red River of the North Modified Habitat Preference Method and Aquatic Life Maintenance Seasonal Instream Flow Regime (Cont').

		05054000 Red River of the North at Fargo, ND 1931-1984		05064500 Red River of the North at Halstad, MN 1931-1984	
Modified Habitat Preference Method	Reclamation	Mar-Jun 75-133 (various sp)** 450 (various sp)***	Jul-Feb 100 (all sp)* 50 (all sp)**	Mar-Jun -* 1125**	Jul-Feb -* 200***
	Houston	Mar-Apr 200	May-Feb 200	None	None
Aquatic Life Maintenance Seasonal Instream Flow Regime	Reclamation	Mar-Jun 450	Jul-Feb 100	Mar-Jun 1125	Jul-Feb 200
	Houston	Mar-Apr 200	May-Feb 200	None	None

		05082500 Red River of the North at Grand Forks, ND 1931-1984		05092000 Red River of the North at Drayton, ND 1931-1984		05102500 Red River of the North at Emerson, Manitoba, Canada 1931-1984	
Modified Habitat Preference Method	Reclamation	Mar-Jun -* 2160**	Jul-Feb -* 440***	Mar-Jun -* 2610**	Jul-Feb -* 480***	Mar-Jun -* 3060**	Jul-Feb -* 520***
	Houston	None	None	None	None	None	None
Aquatic Life Maintenance Seasonal Instream Flow Regime	Reclamation	Mar-Jun 2160	Jul-Feb 440	Mar-Jun 2610	Jul-Feb 480	Mar-Jun 3060	Jul-Feb 520
	Houston	None	None	None	None	None	None

*Multiplicative Technique Results for all species (all sp) and target species (target sp).
**Maintaining approximately 50% of the Weighted Usable Area (WUA) available in the stream for both all species (all sp) and target species (target sp).
***Maintaining approximately 50% of the Weighted Usable Area (WUA) available in the stream for various target species and approximately 80% of the available habitat for channel catfish young (CCY).

APPENDIX G

RIVERINE RIPARIAN CORRIDOR MAINTENANCE NEEDS ASSESSMENT

RED RIVER VALLEY WATER NEEDS ASSESSMENT

PHASE 1B

INSTREAM FLOW NEEDS ASSESSMENT

RIVERINE RIPARIAN CORRIDOR MAINTENANCE NEEDS ASSESSMENT
INSTREAM FLOW NEEDS ASSESSMENT

The seasonal instream flow regime for maintaining the Sheyenne River riparian corridor and the Red River of the North riparian corridor was developed by first evaluating the relationships between streamflow and riparian water table elevations along these rivers. The relationships between existing streamflow and riparian water table elevations along both rivers were evaluated using methodology developed for the San Pedro River, Arizona, study (Jackson et al. 1987). Secondly, the seasonal instream flow regime for aquatic life maintenance was reviewed and items were added which would maintain the existing long-term river-specific riparian corridors. Maintenance of the existing forest community was assumed to be applicable to all associated vegetational communities to include associated wetlands along the Sheyenne River and the Red River of the North.

The natural values of the Sheyenne River and Red River of the North are inextricably linked to water resources. Riparian vegetation, wildlife, fisheries, recreation, and other water-related natural values depend on instream flows (including floods and related groundwater conditions). Baseflows and riparian zone water tables are maintained almost entirely by surface water inflows except for the Sheyenne River reach between Lisbon, North Dakota, and the Kindred, North Dakota, area. This stream reach is a gaining reach. It receives inflows from groundwater from the Sheyenne aquifer. Between Lake Ashtabula (Baldhill Dam) near Valley City, North Dakota, and the Fargo, North Dakota, area, riverflow is maintained by both surface runoff and flow releases from Baldhill Dam. Depending on where you are on the river system, regional groundwater depletions or localized (near stream) drawdowns in the flood plain aquifer can reduce instream flows and concurrently lower riparian zone water tables. The existing woody riparian community (oak-elm-ash complex) along the Sheyenne River and Red River of the North is somewhat sensitive to water table declines. Periodic floodflows are required for vegetation reproduction, flood plain development, and channel maintenance and evolution.

The viability of any mechanism (legal, administrative, or technical) which serves to protect the water-dependent natural resources of the Sheyenne River and the Red River of the North needs to rely on a thorough scientific analysis of the relationships between natural characteristics of the area and water availability.

Riparian Vegetation

The riparian corridor is dominated by a variety of trees. These include bur oak, hackberry, box elder, American elm, basswood, and green ash with occasional peachleaf willow along the riverbanks. Ordinarily a well developed understory, usually present, is composed of small trees and tall shrubs including hop-hornbeam and prickly ash. All of the these species are tolerant or very tolerant to flooding. The herbaceous vegetation of the riparian floor is especially luxuriant and is composed of a variety of species. The more common plants are nodding fescue, Virginia wild rye, nodding muhly, charming sedge, Sprengel's sedge, jack-in-the-pulpit, wood leek, large bellwort, false Soloman's seal, Soloman's seal, nodding trillium, carrion flower, wood nettle, wild ginger, columbine, kidneyleaf buttercup, tall meadowrue, bloodroot, yellow wood violet, pink wood violet, wild sarsaparilla, honewort, and waterleaf (Stewart 1975 and field data collections). As for the forest community, these herbaceous species are all tolerant to flooding and moist soil conditions.

The oak-elm-ash complex provides the primary structure of the riparian gallery forest. Pioneer species such as peachtree willow establish a foothold for other species to begin the stream terrace building process. These pioneer species are confined to very shallow groundwater sites and require sustained flow for seedling establishment. Oak-elm-ash colonization occurs after pioneer species establishment. Seed drop and moderately high streamflows must coincide for oak-elm-ash reproduction. Seedlings require moist sites such as streambanks and overflow channels. Moist soil conditions must prevail until roots grow to depths where moisture is continuously available (roughly the water table). The oak-elm-ash complex draws its water from the immediate stream recharge zone/shallow stream aquifer. Therefore, maintaining the stream recharge zone/shallow stream aquifer is very important. Moist soil conditions will maintain the herbaceous vegetation of the riparian floor. Most of the existing riparian species will also tolerate moderate drought conditions.

On both the Sheyenne River and Red River of the North flood plains, three forest types can be distinguished. On the lowest and most frequently flooded area, pioneering tree species such as peachtree willow and cottonwood are very sparse. More mature cottonwoods are sparsely scattered throughout the flood plain. The forest community consists of older cottonwoods, bur oak, box elder, and green ash. At the highest elevations, flood plain forests are dominated by green ash, box elder, American elm, and bur oak. Canopies are relatively closed and lack the tall shrub and sapling layer characteristic of cottonwood forests.

Both the Sheyenne River and Red River of the North no longer contain many stream bars, abandoned meanders, or many areas where overflow flooding occurs. Peachtree willow and cottonwood colonization is absent on most stream bars and streambanks (e.g., overflow channels or abandoned meanders). In the absence of rejuvenation by flooding, cottonwoods and peachtree willows have and will continue to disappear since seedbed requirements for regeneration appear to be lacking and/or overflow flooding occurs at the wrong time of the year (not corresponding to seed drop). Aggradation of alluvium subsequent to bar building during flooding requires that root depth accommodate depth of aggradation for roots to obtain moist soil near the groundwater or for tap roots to tap the groundwater. Sediment aggradation must continue to provide a seedbed for cottonwoods and willows. The rate of river stage drawdown has most recently occurred abruptly instead of gradually, and has negatively affected seedling survival rates. Rainfall alone is usually not sufficient to support seed germination and reestablishment of pioneering species on alluvial bars (Segelquist et al. 1993). Lack of pioneering species rejuvenations has changed the plant dominance from a cottonwood-willow complex in the lower flood plain to higher species diversity but lower landscape diversity.

Evaluation of Streamflow and Riparian Water Table Elevations

The relationships between existing streamflow and riparian water table elevations along both rivers were evaluated using methodology developed for the San Pedro River, Arizona, study (Jackson et al. 1987). Baseflows and riparian zone water tables are maintained almost entirely by inflows from the regional groundwater aquifer. Riparian stands along both rivers are therefore sensitive to water table fluctuations.

Annual flows during both the high (March-June) and low flow (July-February) periods of record have increased within the last 10 years of historical record (the historical record used for this study - 1931-1984; see Appendix B - Tables B-2). Groundwater well levels have remained fairly constant over time. There does not appear to be an indication that groundwater levels in the flood plain aquifer have or are declining with the existing hydrograph.

Riparian Corridor Flow Analysis

The annual flow regime for both the Sheyenne River and the Red River of the North was stratified into two distinct seasons to facilitate the riverine corridor flow analyses (same seasonal distribution as used for the aquatic life maintenance flow analyses) - spawning period, March-June (high flow), and maintenance period, July-February (low flow).

High Flow Period (March-June)

Annual flows during the high flow period have actually increased within the last 10 years of record (the historical record used for this study - 1931-1984; see Appendix B - Tables B-2). These flows normally would beneficially influence riparian vegetation seedling establishment by increasing the availability of required continuously moist surface soil conditions, however, it appears that the flows do not correspond to pioneering species seed drop (late May-early July). Large overbank flows usually occur during March and early April. This period is also a critical period for fish spawning and juvenile fish survival and growth, and is an important bird migration period. It is also an important recreational use period on both rivers. Flows are also required to prevent further loss of open water habitat for fish and wildlife.

Managing the rivers to meet the aquatic life maintenance seasonal instream flow regime would maintain a perennial stream throughout each representative river reach, however, the magnitude of the flows would be less than the mean seasonal flows of record (approximately one-half the magnitude of the historic flows - see Tables 3, 6 through 10, and 11, Instream Flow Needs Assessment, and Table G-1). The existing hydrograph would be somewhat flattened. It is expected, however, that managing the rivers to meet the aquatic life maintenance seasonal instream flow regime should stabilize groundwater levels at their present levels, and, at the same time, provide adequate moist soil conditions for the riparian forest community. The aquatic life maintenance seasonal instream flow regime is anticipated to maintain the existing flood plain forest community in its present status.

Table G-1
Sheyenne River and Red River of the North
Seasonal Instream Flow Regime for Riverine Riparian Corridor Maintenance and Improvement

	Mean Seasonal Flows[1] and Seasonal Spawning Flows[2] March-June (cfs)		Mean Seasonal Flows[1] and Seasonal Maintenance Flows[2] July-February (cfs)		Maximum Out-of-Channel Flows[3] Late May-Early July (cfs)
<u>Sheyenne River</u>					
Harvey, ND (05054500)[4]	21[1]	25[2]	2[1]	15[2]	None
Warwick, ND (05056000)	124	100	11	25	<600
Cooperstown, ND (05057000)	226	125	22	50	<800
Baldhill Dam, ND (05058000)	250	125	39	50	<4,000
Valley City, ND (05058500)	273	125	41	50	<2,500
Lisbon, ND (05058700)	321	225	47	70	<2,250
Kindred, ND (05059000)	374	155	73	50	<2,800
West Fargo, ND (05059500)	379	100	75	50	None
Harwood, ND (05060400)	566	100	94	50	None
<u>Red River of the North</u>					
Wahpeton, ND (05051500)	927	450	328	100	None
Hickson, ND (05051522)	966	450	284	100	None
Fargo, ND (05054000)	1120	450	307	100	<3,000
Below Fargo, ND	1120	450	307	100	<3,000
Halstad, MN (05064500)	2760	1125	610	200	<15,000
Grand Forks, ND (05082500)	5388	2160	1354	440	<21,000
Drayton, ND (05092000)	6558	2610	1492	480	<14,000
Emerson, Manitoba, Canada (05102500)	7589	3060	1588	520	<26,000

[1]Mean Monthly Seasonal Flows for period of record used in the Phase I, Parts A and B, analysis (1931-1984); from Table 3.
[2]Aquatic Life Maintenance Seasonal Instream Flow Regime; Table 3 and Table 5. Riparian corridor maintenance flows would be met by the aquatic life maintenance seasonal instream flow regime and the natural riverine flow regime.
[3]Incorporating riverine riparian corridor improvement flows would require allowing non-damaging flood flows (U.S. Army Corps of Engineers, St. Paul District) to occur on an annual or semi-annual basis along both rivers. It is recommended that flows in excess of channel capacities (but less than maximum non-damaging flood flows above) be allowed between late May and early July to assist in pioneering species germination and growth. Flows which are out of channel (non-damaging channel capacity flows) should occur for a 2-week period between late May and early July preceding cottonwood and willow seed disbursal by approximately 1 week. This flow scheme should produce adequate moist soil conditions to benefit seed germination and growth and improve the existing flood plain forest community.
[4]USGS and/or International Gaging Station identification number.

If a goal of the management of the riverine riparian corridor is to improve the corridor for pioneering species (cottonwood-willow) seed germination and growth, large out-of-channel flows would be required (see Table G-1). Non-damaging overbank flows in excess of channel capacities (but less than maximum non-damaging flood flows displayed in Table G-1) should be allowed to assist in pioneering species germination and growth (e.g., Red River of the North at Fargo channel capacities are about 1,000 cfs, maximum non-damaging flood flows are 3,000 cfs, and, therefore, flows between 1,000 and 3,000 cfs would help improve the riparian community). The non-damaging out of channel flows along the Sheyenne River and the Red River of the North reported in Table G-1 were determined by the U.S. Army Corps of Engineers (Daniel Reinartz, U.S. Army Corps of Engineers, St. Paul District, Personal Communication). Non-damaging flows which are out of channel should occur for a 2-week period during late May through early July and precede cottonwood and willow seed disbursal by approximately 1 week. In absence of these out-of-channel flows, the existing flood plain forest community would be continued.

Low Flow Period (July-February)

The low flow period is critical to the maintenance and evolution of geomorphic features along the river corridor - especially flood plains, stream bars, and nursery bars for fish.

Managing the rivers to meet the aquatic life maintenance seasonal instream flow regime would maintain a perennial stream throughout each representative river reach, however, the magnitude of the flows would vary between the upper and lower watersheds on the Sheyenne River (being greater in the upper watershed and less in the lower watershed) and generally be less than historic flows on the Red River of the North (see Table G-1). The existing hydrograph would be somewhat flattened as well, but not as much as during the high flow period. It is expected, however, that the aquatic life maintenance seasonal instream flow regime should stabilize groundwater levels at their present levels, and, at the same time, provide adequate moist soil conditions for the riparian forest community. The aquatic life maintenance seasonal instream flow regime is anticipated to maintain the existing flood plain forest community in its present status.

Providing high flows during the summer months (after early July) in excess of the present 10-year return period flood favor channel incision and may cause excessive riparian zone physical adjustments. Therefore, high flows are not recommended for the low flow period for riverine riparian corridor improvement.

Recommendations

The conditions which were determined to be necessary to maintain the existing flood plain forest community in its present status are:

1. Maintain perennial streamflow at the aquatic life maintenance seasonal instream flow regime level (Table 5 of the Instream Flow Needs Assessment and Table G-1). This

should ensure the availability of shallow groundwater for the roots of existing riparian vegetation. Historical perennial streamflows are as follows (percent of time that water year type is DRY-AVERAGE-WET for the 1931-1984 period of record, by river): Sheyenne River = 41:31:28 and Red River of the North = 36:35:29.

2. Maintain a moist seedbed and shallow groundwater for rooted seedlings to help ensure adequate moisture is available for the establishment of pioneering species. This moisture is generally supplied by spring runoff and flooding (natural riverine flow regime). Stream diversions, excessive groundwater pumping, or streamflow regulation (provided by dams) can prevent the spring runoff moisture needed for seed sprouting and rooting within the flood plain. Stream diversions should be managed in a way so as not to lessen spring runoff conditions along the Sheyenne River and the Red River of the North.

3. Implement measures to allow for natural tree/shrub revegetation to occur on both the Sheyenne River and the Red River of the North. This would assist in maintaining the riparian corridors. Removal of tree seedlings by livestock grazing and trampling is probably one of the greatest threats to the riparian community.

4. Maintaining natural successional change appears to be the most prudent management option for riparian corridor maintenance even though there are areas where the riparian zone is fairly narrow to nonexistent. Artificial wholesale planting of riparian vegetation is not being recommended for the Sheyenne River and Red River of the North at this time. If riparian area encroachment should become more of a problem in the future, consideration should be given to riparian protection and reestablishment in problem areas.

The conditions which were determined to be necessary to **improve** the existing flood plain forest community by improving the pioneering species community (cottonwood-willow complex) and changing the plant dominance are:

1. Changing the hydrograph to lessen the number of DRY water year types on both the Sheyenne River and the Red River of the North would not appreciably, in and by itself, improve the riverine riparian corridor and species diversity. Water alone cannot maintain the system. Alluvial bar formation and lowering the rate of stage drawdown on the river after flood events might provide some positive benefits for improving the riverine riparian corridor; higher landscape diversity would result (i.e., reestablishment of the cottonwood-willow complex in a lower flood plain position). Alluvial bar formation would provide a seedbed for cottonwood-willow germination [(natural or manmade - e.g., mechanically formed or river training devices constructed - jetties, gabbions, etc.)]. Gradually lessening the rate of river stage drawdown after flood events would allow better seedling survival rates. In lieu of these items being implemented, areas of the existing riparian corridor could be selectively manipulated to improve species diversification and improve the riparian area vegetational complex (e.g., mechanically removing existing vegetation and establishing new and different vegetation).

2. Allowing non-damaging out-of-bank flows on an annual or semi-annual basis along both rivers would help improve the riparian flood plain forest community. If available, non-damaging overbank flows in excess of channel capacities (but less than maximum non-damaging flood flows) should be provided to assist in pioneering species germination and growth (e.g., Red River of the North at Fargo channel capacities are about 1,000 cfs, maximum non-damaging flood flows are estimated to be 3,000 cfs, and, therefore, flows between 1,000 and 3,000 cfs would help improve the riparian community). Non-damaging out of channel flows along the Sheyenne River and the Red River of the North have been determined by the U.S. Army Corps of Engineers (Daniel Reinartz, U.S. Army Corps of Engineers, St. Paul District, Personal Communication). Non-damaging flows which are out of channel should occur for a 2-week period during late May through early July and precede cottonwood and willow seed disbursal by approximately 1 week.

   This flow scheme should produce adequate moist soil conditions to benefit pioneering species seed germination and growth. This improvement recommendation is just that, a recommendation to improve the existing riparian corridors. In its absence, the aquatic life maintenance flows are expected to be sufficient to maintain the existing flood plain forest community.

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APPENDIX H

WATER QUALITY IMPROVEMENT

OPPORTUNITIES AND NEEDS ASSESSMENT

RED RIVER VALLEY WATER NEEDS ASSESSMENT

PHASE 1B

INSTREAM FLOW NEEDS ASSESSMENT

WATER QUALITY IMPROVEMENT
OPPORTUNITIES AND NEEDS ASSESSMENT
FOR THE INSTREAM FLOW NEEDS ASSESSMENT

Red River of the North Flow Augmentation to Meet Water Quality Standards

Introduction

The Red River of the North (Red River), located near the geographic center of the North American continent, flows northward into Canada and drains an area that is largely a glacial lake plain. It forms the boundary between the states of Minnesota and North Dakota northward from where it is formed at the confluence of the Boise de Sioux and the Otter Tail Rivers near Wahpeton, North Dakota. The Red River leaves the United States at the Canadian Border near Emerson, Manitoba, Canada. A major North Dakota tributary to the Red River is the Sheyenne River that drains a part of central North Dakota.

The water quality of a river system is a function of the environmental conditions created by climate, topography, geology, soils and land use and cover. The U.S. Geological Survey (USGS) (Stoner et al. 1998) identified the following land uses in the Red River valley: 81 percent agricultural, 8 percent forest, 6 percent wetland, 3 percent water, 2 percent rangeland, and 1 percent urban. Crop land amounts to 64 percent of the total area with wheat, barley, corn, and soybeans as the principal crops. Secondary crops include oats, sugar beets, sunflowers, potatoes, and forage grasses. Most nonagricultural land is along the eastern edge of the basin in Minnesota. The urban centers are adjacent to the Red River at Fargo and Grand Forks, North Dakota, and Moorhead, Minnesota.

In 1990, about 36 percent of the withdrawal from the surface water was for public supplies (Stoner et al. 1993). Most of these withdrawals were by Fargo and Grand Forks, North Dakota, and Moorhead, Minnesota. All public drinking water should meet standards to protect the health of users and preferably have no objectionable taste and odor. Water use can affect water quality. Examples are domestic and irrigation uses. Wastewater treatment plants can discharge objectionable materials into receiving waters if treatment is inadequate, and irrigation can increase leaching of salts and agricultural chemicals into shallow ground water and streams through surface runoff and shallow drainage. Irrigation and livestock uses account for about 47 percent of the total water used in the valley. About 33 percent of the water use is derived from surface sources.

Stream Water Quality Standards

The State of North Dakota has established water quality standards for surface water based on water use and hydrologic conditions. The Red and Sheyenne rivers are Class 1 and Class 1A streams, respectively. Class 1 waters are to have a quality capable of supporting aquatic life and be suitable for boating, swimming, and other water recreation. Class 1 waters must also be able to meet the bacteriological, physical, and chemical requirements for municipal use after treatment consisting of coagulation, settling, filtration, and chlorination, or equivalent processes. The quality will also be such as to permit its use for irrigation, stock watering, and wildlife use without injurious effects (North Dakota State Department of Health 1991). Class 1A waters must be suitable for the same uses as Class 1 waters, except that treatment for municipal use may also include water softening to meet chemical requirements of the North Dakota State Department of Health (NDSDH). Since the Red River forms the boundary between North Dakota and Minnesota, Minnesota has also established standards for the Red River. Table 1 contains a summary of the established standards.

Each of the identified water uses has criteria established for supporting and not supporting the identified use. Some of the uses also have partially supporting criteria such as for the conventional parameters described below. These criteria are used in Clean Water Act Section 305(b) reports to assess the status of stream reaches. Toxic substance criteria violations typically produce non-supporting status.

Toxic substances are important to the health of surface water aquatic life and domestic drinking water supplies. North Dakota has applied these criteria in their Section 305(b) "North Dakota, Water Quality Assessment, 1992-1993" report to the U.S. Environmental Protection Agency (EPA) (North Dakota State Department of Health 1994). Stream segments were listed as not supporting their designated uses if one or more violations of a standard for a toxic substance were identified in the available data during a 3-year period. These toxic substances include chlorine residual, ammonia, toxic trace elements, and toxic organic materials. The Fargo-Moorhead reach of the Red River was identified as being impacted by ammonia discharges from their combined treated effluent discharges (North Dakota State Department of Health 1994). The Red River also had 291 stream miles listed for fish consumption advisory due to mercury levels in fish tissue.

Conventional, as opposed to toxic, parameters include dissolved oxygen, temperature, pH, and most of the others listed in Table 1. The stream is fully supporting the identified uses if all conventional parameter criteria are below the standard in 90 percent of the measurements in a specific 3-year period. It is partially supported if one criterion is exceeded in 11 to 25 percent of the measurements and not supporting if any one criterion is exceeded in more than 25 percent of the measurements. For North Dakota's criteria, phosphorus and nitrate are listed as interim guideline limits and are not considered the same as the other conventional criteria. However, North Dakota may establish specific standards on a stream-by-stream or reach-by-reach basis.

Water Quality in the Red River Basin

The USGS under the National Water Quality Assessment (NAWQA) Program has published several reports on water quality in the Red River of the North Basin. These reports have evaluated various pollutants and their sources. A summary of the findings, mostly taken from Stoner et al. (1998), follows.

Table 1. Stream Standards for the Sheyenne and Red Rivers.			
	Sheyenne River	Red River	
Parameter	Class 1A Streams[1]	Class 1 Streams[1]	Minnesota Standard[1]
Boron (mg/L)[2]	0.75	0.75	None
Chlorine Residual (mg/L)	0.019 (Acute) 0.011 (Chronic)	0.019 (Acute) 0.011 (Chronic)	0.019 (max) 0.006 (Chronic)
Chloride (mg/L)	175	100	230
Dissolved Oxygen (mg/L)	5	5	5
Sodium (percent)	60	50	60
Dissolved Nitrate (mg/L-N)[3,4]	1.0	1.0	10
Total Phosphorus (mg/L-P)[4]	0.1	0.1	None
Sulfate (mg/L)	450	250	250
Fecal Coliforms[5] (No./100 mL)	200	200	200
pH (standard units)	7 - 9	7 - 9	6.5 - 9
Temperature (° F)	85	85	86
Ammonia[6] (un-ionized mg/L-N)	Function of temperature and pH	Function of temperature and pH	0.040
Toxic Substances[7]	See State Tables	See State Tables	See State Tables

[1] The listed standard is based on the most critical value for the listed uses of the water.
[2] The boron standard is for irrigation water use.
[3] The Minnesota standard is based on drinking water requirements.
[4] Nitrate and phosphorus are interim guidelines for North Dakota.
[5] This standard is for full body contact water recreation. North Dakota season is from May 1 to September 30 and Minnesota is from March 1 to October 31.
[6] North Dakota has a formula to calculate the allowable concentration of un-ionized NH_3.
[7] Each State provides tables in their standards maximum contaminant concentration to prevent adverse impacts to water users and aquatic life.

Streams draining areas containing the largest percentage of crop land (central and southern parts of the Red River drainage basin) had the highest concentrations of nutrients (dissolved phosphorus, nitrate, and organic nitrogen). Agricultural activity has increased the concentration and load of nutrients potentially degrading stream quality and increasing eutrophication of lakes and reservoirs. Ground water used for domestic and public water supplies in the basin were safe to drink according to EPA standards for nitrate and pesticides.

Treated effluent from urban areas along the Red and Sheyenne rivers has some effect on the rivers' water quality. The median concentration of ammonia and total phosphorus were slightly higher in the Red River downstream from the Fargo, North Dakota-Moorhead, Minnesota area (Stoner et al. 1998). Compared to historic data for the river downstream of Fargo, North Dakota-Moorhead, Minnesota (Tornes and Brigham 1994), concentrations of ammonia-nitrogen have decreased slightly and nitrate-nitrogen have increased slightly. These trends likely reflect improved aeration of treated effluent over time. The Fargo, North Dakota-Moorhead, Minnesota area represents the largest urban area in the basin, and it moderately affects the Red River water quality during flow conditions observed by the USGS from 1993 to 1995. Ammonia-nitrogen concentrations were elevated at the point of discharge, but were diluted by the river and tributary flows, based on measurements 78 miles downstream at Halstad, Minnesota. The USGS also concluded that ammonia-nitrogen was variable at several monitoring sites suggesting that the stream was being affected by the discharge of treated effluent or ammonia-nitrogen was generated under reducing (low oxygen) conditions (Tornes et al. 1997).

Median total phosphorus concentrations in North Dakota streams were typically above the 0.1 mg/L interim guideline limit in the USGS data for the 1993 - 1995 period (Tornes et al. 1997). Other studies found that total phosphorus had positive correlations with stream flow (Houston Engineering, Inc. 1997) which means that as flows increase, the phosphorus concentration also increases. Reclamation also found that phosphorus concentrations frequently increased as flow increased as shown in the attached water quality graphs (Attachment I)(Bureau of Reclamation 1998). These plots show that total phosphorus concentrations were higher at low flows where urban areas could influence the concentrations. The rural monitoring location concentrations generally increased with flow rate.

Above normal flows were experienced during the referenced USGS period with 1993 and 1994 having spring runoff peaks near the 75th percentile flow and 1995 being greater than the 75th percentile of the long-term flow record in the basin. Summer flows each year exceeded the 75th percentile. These high flows could cause agriculture area pollutants to have elevated concentrations. However, flows for dilution of the urban and industrial discharges were provided at the discharge points to the river. This may not have been the case, if observed flows had been near or below the 25th percentile. Most of the water quality data was collected from the late 1960's to the present which generally represent median to high flow conditions. Only five years between 1965 and 1984 were ranked as low flow years by Reclamation (Bureau of Reclamation 1999). In the period of record from 1931 to 1984, Reclamation identified 20 years with low flow conditions. All five of the above referenced low flow years were in the top half of Reclamation's low flow rankings. Tables 2 and 3 show the period of record when data was collected for each water quality parameter. In the cases where data was collected prior to the late 1960's, only a few samples were collected.

The water quality data summarized in Tables 2 and 3 were obtained from the EPA's STORET data base. Most of the data were collected by the USGS and the NDSDH. Existing reports were also used in the evaluation of the potential effects of increased flows on water quality.

Plots of concentrations of water quality measures and stream standards *versus* instantaneous flow rate were developed. The individual plots at each gaging station are contained in Attachment I to this appendix.   Tables 2 and 3 present selected information that is illustrated by the plots in Attachment I. For each water quality standard and equivalent data set, each line of the tables contain the listed parameter, number of observations for each parameter, the percent of values exceeding the standard, and the period of record, the flow range when the standard was exceeded, the flow range for the period of record, and the most recent month and year that the standard was exceeded.   The data indicate that most of the standards are met most of the time. These data do indicate that there are nitrate, phosphorus, and fecal coliform concentrations exceeding the standard, most by phosphorus. Fecal coliform data are confined to less than half of the sites.

As can be seen by the data in Tables 2 and 3, there is a great deal of variation in the number of observations between sites and among the various measures against the water quality standards.

In some cases samples have not been collected in recent years for certain parameters at some stations, as indicated by the ending dates for the period of record. In these circumstances, more recent data would be necessary to define a need or effect. In still other instances the water quality standards have not been exceeded in recent years. In such a case it should be assumed that additional flow would not help meet water quality standards, but there may still be an effect on water quality. The following discussion addresses background information on water quality standards and relates each to the water quality data in the Sheyenne and Red River basins.

Boron is an essential plant nutrient (U.S. Environmental Protection Agency 1987]. Boron will be taken up by plants to the extent of their needs. However, excessive boron can be harmful to plants. The water quality standard for boron (Table 1) is an irrigation water standard for the protection of sensitive crops (U.S. Environmental Protection Agency   1987). Boron is also extremely soluble, and is usually present as the borate ion (U.S. Environmental Protection Agency 1987). Decreases in boron would be expected to be primarily due to plant uptake and dilution, primarily by the latter.

Table 2: Water Quality of the Sheyenne River - Comparison to Standards

Standard	Site	Number of Obs.	Percent > Std.	Period of Record From:	Period of Record To:	During Exceedences Min. Flow	During Exceedences Max. Flow	Period of Record Min. Flow	Period of Record Max. Flow	Last Exceeded
Boron	ABOVE HARVEY	162	42.0	11/06/72	11/21/96	0.2	12	0.2	500	Nov-96
	NEAR WARWICK	106	0.0	03/27/51	08/03/94	NA	NA	0.1	2,230	NA
	NEAR COOPERSTOWN	246	0.5	10/11/59	03/27/94	1,130	1,130	0.02	4,900	May-71
	BELOW BALDHILL DAM	101	0.0	06/05/59	03/26/94	NA	NA	1	4,730	NA
	AT VALLEY CITY	17	0.0	05/15/74	03/26/94	NA	NA	11	1,960	NA
	AT LISBON	200	0.0	08/02/56	08/04/92	NA	NA	1	2,110	NA
	NEAR KINDRED	39	5.1	05/04/72	09/27/79	1,170	1,850	28	4,100	NA
	AT WEST FARGO	51	3.9	09/16/69	09/16/93	1,010	1,560	5	3,050	Mar-78
	AT HARWOOD	0								
Chloride	ABOVE HARVEY	168	0.0	11/06/72	11/21/96	NA	NA	0.2	500	NA
	NEAR WARWICK	156	0.0	03/27/51	08/27/96	NA	NA	0.1	2,230	NA
	NEAR COOPERSTOWN	257	0.0	10/11/59	08/23/96	NA	NA	0.02	4,900	NA
	BELOW BALDHILL DAM	113	0.0	06/05/59	08/21/96	NA	NA	0.7	4,730	NA
	AT VALLEY CITY	274	0.0	06/13/68	05/01/96	NA	NA	0.8	3,910	NA
	AT LISBON	235	0.0	08/02/56	09/04/96	NA	NA	1.0	4,270	NA
	NEAR KINDRED	196	0.0	05/04/72	09/05/96	NA	NA	19.0	4,060	NA
	AT WEST FARGO	54	0.0	09/16/69	08/27/96	NA	NA	5.0	3,050	NA
	AT HARWOOD	209	2.4	05/14/74	11/18/92	12	120	12	2,680	Feb-81
Fecal Coliforms	ABOVE HARVEY	0	----	-----	-----	-----	-----	-----	-----	-----
	NEAR WARWICK	0	----	-----	-----	-----	-----	-----	-----	-----
	NEAR COOPERSTOWN	0	----	-----	-----	-----	-----	-----	-----	-----
	BELOW BALDHILL DAM	0	----	-----	-----	-----	-----	-----	-----	-----
	AT VALLEY CITY	211	24.2	09/29/71	09/02/92	9.5	879	0.8	2,300	Sep-92
	AT LISBON	0	----	-----	-----	-----	-----	-----	-----	-----
	NEAR KINDRED	3	0.0	07/27/76	09/29/76	NA	NA	39	40	NA
	AT WEST FARGO	0	----	-----	-----	-----	-----	-----	-----	-----
	AT HARWOOD	184	16.8	05/14/74	11/18/92	22	649	12	2,680	Jul-92
Dissolved Oxygen	ABOVE HARVEY	71	18.3	11/15/82	09/01/95	1	165	0.2	165	Feb-92
	NEAR WARWICK	3	0.0	10/16/86	08/21/95	NA	NA	15	27	NA
	NEAR COOPERSTOWN	77	11.7	05/09/71	08/07/95	6	150	6	3,210	Jun-95
	BELOW BALDHILL DAM	39	0.0	03/21/79	08/08/95	NA	NA	3	3,950	NA
	AT VALLEY CITY	194	5.2	11/15/67	08/04/92	11	184	4.9	3,910	Jul-91
	AT LISBON	39	0.0	07/29/73	09/04/96	NA	NA	23	3,985	NA
	NEAR KINDRED	291	1.0	07/27/76	09/05/96	40	68	19	4,100	Feb-80

Table 2 (continued)

Last Standard	Site	Number of Obs.	Percent > Std.	Period of Record From:	To:	During Exceedences Min. Flow	Max. Flow	Period of Record Min. Flow	Max. Flow	Last Exceeded
Percent Sodium	ABOVE HARVEY	167	76.0	11/06/72	11/21/96	0.2	32	0.2	500	Nov-96
	NEAR WARWICK	156	1.3	03/27/51	08/27/96	22	70	0.1	2,230	Aug-96
	NEAR COOPERSTOWN	251	0.0	10/11/59	08/23/96	NA	NA	0.02	4,900	NA
	BELOW BALDHILL DAM	103	0.0	06/05/59	08/21/96	NA	NA	0.7	4,730	NA
	AT VALLEY CITY	21	0.0	05/15/74	05/01/96	NA	NA	825	1,850	NA
	AT LISBON	236	0.4	08/02/56	09/04/96	1.0	2,110	1	4,270	Dec-82
	NEAR KINDRED	196	0.0	05/04/72	09/05/96	NA	NA	0	4,060	NA
	AT WEST FARGO	54	0.0	09/16/69	08/27/96	NA	NA	845	1,925	NA
	AT HARWOOD	202	2.0	05/14/74	11/18/92	12	40	12	2,680	Nov-76
Unionized Ammonia	ABOVE HARVEY	40	0.0	07/16/81	11/21/96	NA	NA	0.5	224	NA
	NEAR WARWICK	0	----	-----	-----	-----	-----	-----	-----	-----
	NEAR COOPERSTOWN	68	1.5	03/06/79	09/16/81	53	76	5	3,210	May-81
	BELOW BALDHILL DAM	30	33.3	03/21/79	09/17/81	9	90	3	4,730	Sep-81
	AT VALLEY CITY	110	0.9	06/15/76	09/02/92	24	24	5	2,300	Jul-78
	AT LISBON	4	0.0	06/08/95	09/04/96	NA	NA	46	473	NA
	NEAR KINDRED	169	1.2	07/27/76	08/10/95	29	38	19	4,100	Sep-78
	AT WEST FARGO	1	0.0	03/12/91	03/12/91	NA	NA	36	36	NA
	AT HARWOOD	110	4.5	06/10/76	11/18/92	29	130	15	1,800	Jun-92
Nitrate	ABOVE HARVEY	14	0.0	11/06/72	07/15/81	NA	NA	1	170	NA
	NEAR WARWICK	42	11.9	04/08/64	03/30/83	20	1,940	1	1,940	Jul-71
	NEAR COOPERSTOWN	96	4.2	10/11/59	03/31/83	7	3,210	2	3,210	May-79
	BELOW BALDHILL DAM	46	4.3	10/03/60	03/14/83	33	1180	3	4,730	May-75
	AT VALLEY CITY	113	5.3	05/15/74	11/21/88	5.3	913	1	2,300	Apr-84
	AT LISBON	29	13.8	10/15/66	01/31/75	28	3,510	9	4,270	Mar-72
	NEAR KINDRED	88	1.1	05/04/72	12/17/81	1,850	1,850	23	4,100	Apr-75
	AT WEST FARGO	12	16.7	07/06/72	03/21/83	101	1,990	42	1,990	Mar-76
	AT HARWOOD	102	5.9	03/11/80	11/12/88	101	1,800	20	1,800	Mar-88
Total Phosphorus	ABOVE HARVEY	0	----	-----	-----	-----	-----	-----	-----	-----
	NEAR WARWICK	0	----	-----	-----	-----	-----	-----	-----	-----
	NEAR COOPERSTOWN	77	92.2	05/09/71	08/07/95	5	3,210	5	3,210	Aug-95
	BELOW BALDHILL DAM	40	87.5	03/21/79	08/08/95	3	4,730	3	4,730	Aug-95
	AT VALLEY CITY	184	94.6	02/04/76	10/07/92	1	2,300	1	2,300	Oct-92
	AT LISBON	7	71.4	11/15/94	09/04/96	126	3,985	46	3,985	Aug-95
	NEAR KINDRED	188	84.6	07/27/76	09/05/96	19	4,100	19	4,100	Aug-95

Table 2 (continued)

Standard	Site	Number of Obs.	Percent > Std.	Period of Record From:	Period of Record To:	During Exceedences Min. Flow	During Exceedences Max. Flow	Period of Record Min. Flow	Period of Record Max. Flow	Last Exceeded
pH	ABOVE HARVEY	169	0.6	11/06/72	11/21/96	0.5	0.5	0.2	500	Aug-74
	NEAR WARWICK	166	1.8	03/27/51	08/27/96	4	440	0.1	2,230	Nov-77
	NEAR COOPERSTOWN	258	1.6	10/11/59	08/23/96	9	400	0.02	4,900	Mar-95
	BELOW BALDHILL DAM	113	1.8	06/05/59	08/21/96	9	76	0.7	4,730	Oct-78
	AT VALLEY CITY	295	2.4	06/13/68	05/01/96	11	1,040	0.8	3,910	Sep-87
	AT LISBON	232	0.0	08/02/56	09/04/96	NA	NA	1	4,650	NA
	NEAR KINDRED	212	0.0	05/04/72	09/05/96	NA	NA	19	4,100	NA
	AT WEST FARGO	56	1.8	09/16/69	08/27/96	2,890	2,890	5	3,690	Mar-87
	AT HARWOOD	207	0.5	05/14/74	11/18/92	212	212	15	2,680	Aug-75
Sulfate	ABOVE HARVEY	168	1.8	11/06/72	11/21/96	1	12	0.2	500	Dec-94
	NEAR WARWICK	157	0.0	03/27/51	08/27/96	NA	NA	0.1	2,230	NA
	NEAR COOPERSTOWN	250	0.0	10/11/59	08/23/96	NA	NA	0.02	4,900	NA
	BELOW BALDHILL DAM	103	0.0	06/05/59	08/21/96	NA	NA	0.7	4,730	NA
	AT VALLEY CITY	273	0.0	06/13/68	05/01/96	NA	NA	0.8	3,910	NA
	AT LISBON	234	0.0	08/02/56	09/04/96	NA	NA	1	4,270	NA
	NEAR KINDRED	196	0.0	05/04/72	09/05/96	NA	NA	19	4,060	NA
	AT WEST FARGO	54	0.0	09/16/69	08/27/96	NA	NA	5	3,050	NA
	AT HARWOOD	209	1.4	05/14/74	11/18/92	20	96	12	2,680	Feb-82
Temperature	ABOVE HARVEY	252	0.0	10/04/71	11/21/96	NA	NA	0.2	500	NA
	NEAR WARWICK	290	0.3	01/25/63	08/27/96	3	3	0.1	3,160	Aug-88
	NEAR COOPERSTOWN	390	0.0	10/11/59	08/23/96	NA	NA	0.02	4,900	NA
	BELOW BALDHILL DAM	278	0.0	10/02/64	08/28/96	NA	NA	0.05	5,510	NA
	AT VALLEY CITY	334	0.0	06/13/68	07/11/96	NA	NA	4.4	5,200	NA
	AT LISBON	341	0.0	03/19/64	09/04/96	NA	NA	1	5,210	NA
	NEAR KINDRED	383	0.0	10/13/71	09/05/96	NA	NA	18	4,960	NA
	AT WEST FARGO	300	0.0	09/16/69	08/27/96	NA	NA	5	3,840	NA
	AT HARWOOD	177	0.0	05/14/74	11/18/92	NA	NA	15	2,680	NA

Table 3: Water Quality of the Red River of the North - Comparison to Standards

	Site	Number of Obs.	Percent > Std.	Period of Record From:	Period of Record To:	During Exceedences Min. Flow	During Exceedences Max. Flow	Period of Record Min. Flow	Period of Record Max. Flow	Std.Last Exceeded
Boron	At WAHPETON	42	2.4	06/04/74	08/18/94	1,190	1,190	72	8,310	Jun-74
	At HICKSON	79	0.0	11/03/75	08/16/94	NA	NA	7	14,100	NA
	At FARGO	139	0.0	05/16/49	04/01/94	NA	NA	14	24,300	NA
	Below FARGO	84	0.0	06/03/70	09/16/86	NA	NA	16	17,300	NA
	At HALSTAD, MN	22	0.0	07/08/61	03/12/91	NA	NA	109	24,500	NA
	At GRAND FORKS	142	0.7	06/22/49	09/30/92	305	305	175	79,700	Jul-61
Chloride	At WAHPETON	94	1.1	06/04/74	08/14/96	230	230	31	8,310	Jan-83
	At HICKSON	86	0.0	11/03/75	08/15/96	NA	NA	7	14,100	NA
	At FARGO	380	0.0	05/16/49	05/01/96	NA	NA	12	24,300	NA
	Below FARGO	130	0.0	08/05/70	09/16/86	NA	NA	9	17,300	NA
	At HALSTAD, MN	133	0.0	07/08/61	09/03/96	NA	NA	109	24,500	NA
	At GRAND FORKS	433	1.6	12/27/29	08/29/96	190	4,210	159	79,700	Feb-86
Fecal Coliforms	At WAHPETON	50	10.0	10/04/82	09/01/92	265	1,530	31.0	3,210	Sep-91
	At HICKSON	0	----	-----	-----	---	-----	-----	-----	-----
	At FARGO	169	36.7	08/19/71	11/18/92	35	10,600	32	10,600	Sep-92
	Below FARGO	38	39.5	09/10/70	09/28/76	23	4,150	10	4,150	May-76
	At HALSTAD, MN	0	----	-----	-----	---	-----	-----	-----	-----
	At GRAND FORKS	215	13.0	12/27/29	11/18/92	306	20,900	159	39,500	Jul-91
Dissolved Oxygen	At WAHPETON	35	0.0	04/21/86	05/05/92	NA	NA	31	3,210	NA
	At HICKSON	60	5.0	12/17/75	03/11/91	7	295	7	8,580	Mar-79
	At FARGO	149	1.3	07/17/68	05/13/92	33	1,320	12	8,200	Jun-70
	Below FARGO	80	6.3	07/16/69	09/16/86	23	262	9	6,560	May-76
	At HALSTAD, MN	253	2.1	01/27/78	06/15/95	160	3,330	124	19,200	Jul-83
	At GRAND FORKS	200	1.5	07/17/68	06/22/95	215	1,450	159	39,500	Feb-89
Percent Sodium	At WAHPETON	49	0.0	06/04/74	08/14/96	NA	NA	35	8,310	NA
	At HICKSON	85	0.0	11/03/75	08/15/96	NA	NA	7	14,100	NA
	At FARGO	140	0.0	08/11/56	05/01/96	NA	NA	14	24,300	NA
	Below FARGO	117	0.0	06/03/70	09/16/86	NA	NA	9	17,300	NA
	At HALSTAD, MN	133	0.0	07/08/61	09/03/96	NA	NA	0	24,500	NA
	At GRAND FORKS	152	0.0	06/22/49	08/29/96	NA	NA	175	79,700	NA
Unionized Ammonia	At WAHPETON	42	0.0	04/15/85	09/01/92	NA	NA	31	3,210	NA
	At HICKSON	65	0.0	11/03/75	08/01/86	NA	NA	7	8,580	NA
	At FARGO	112	19.6	03/08/78	11/18/92	44	833	32	8,200	May-92

Table 3 (continued)

	Site	Number of Obs.	Percent > Std.	Period of Record From:	Period of Record To:	During Exceedences Min. Flow	During Exceedences Max. Flow	Period of Record Min. Flow	Period of Record Max. Flow	Std.Last Exceeded
Nitrate	At WAHPETON	43	7.0	06/04/74	10/13/88	1,600	3,210	31	3,210	Apr-86
	At HICKSON	0	---	-----	-----	-----	-----	---	-----	-----
	At FARGO	172	8.3	05/16/49	12/08/88	140	24,300	14	24,300	Feb-88
	Below FARGO	14	7.1	01/07/70	08/29/72	107	2,130	107	2,130	Aug-72
	At HALSTAD, MN	8	0.0	07/05/72	08/11/76	NA	NA	109	24,500	NA
	At GRAND FORKS	165	9.1	06/22/49	12/06/88	2,030	40,800	2,030	40,800	Mar-88
Total Phosphorus	At WAHPETON	52	63.5	10/04/82	09/01/92	31	3,210	31	3,210	Sep-92
	At HICKSON	65	73.8	11/03/75	08/01/86	7	8,580	7	8,580	Aug-86
	At FARGO	174	91.4	11/23/77	11/18/92	32	10,600	32	10,600	Nov-92
	Below FARGO	59	100.0	11/14/69	12/21/77	9	3,150	9	3,150	Dec-77
	At HALSTAD, MN	107	NA	01/27/78	06/15/95	NA	NA	119	19,200	NA
	At GRAND FORKS	192	92.7	09/24/70	06/22/95	159	39,500	159	39,500	Jun-95
pH	At WAHPETON	103	1.0	06/04/74	08/14/96	3,550	3,550	31	8,310	Apr-96
	At HICKSON	89	2.2	11/03/75	08/15/96	196	6,200	7	14,100	Apr-96
	At FARGO	403	0.0	05/16/49	05/01/96	NA	NA	12	24,300	NA
	Below FARGO	160	0.0	07/16/69	09/16/86	NA	NA	9	17,300	NA
	At HALSTAD, MN	161	3.7	07/08/61	09/03/96	164	2,360	34	24,800	Jun-93
	At GRAND FORKS	433	0.7	12/27/29	08/29/96	2,220	9,800	159	79,700	Apr-87
Sulfate	At WAHPETON	95	7.4	06/04/74	08/14/96	31	2,510	31	8,310	Apr-88
	At HICKSON	86	2.3	11/03/75	08/15/96	7	9	7	14,100	Feb-77
	At FARGO	387	0.8	05/16/49	05/01/96	174	833	12	24,300	Nov-87
	Below FARGO	137	0.7	11/14/69	09/16/86	11	2,640	9	17,300	Sep-78
	At HALSTAD, MN	133	0.0	07/08/61	09/03/96	NA	NA	109	24,500	NA
	At GRAND FORKS	192	7.8	04/22/63	06/22/95	190	2,550	159	79,700	Feb-86
Temperature	At WAHPETON	311	0.3	10/05/71	08/14/96	59	59	2	8,310	Jul-77
	At HICKSON	218	0.5	11/03/75	08/15/96	74	74	7	14,100	Jul-87
	At FARGO	549	0.3	08/25/60	09/05/96	57	57	9	24,300	Jul-87
	Below FARGO	167	0.0	07/16/69	09/16/86	NA	NA	9	17,300	NA
	At HALSTAD, MN	451	0.0	04/12/65	09/03/96	NA	NA	23	39,900	NA
	At GRAND FORKS	745	0.0	12/27/29	08/29/96	NA	NA	2	80,900	NA

Boron only exceeds its standard at one site with any frequency. At the Sheyenne River gage above Harvey, 42 percent of the boron samples are greater than the standard (Table 2). The NDSDH may use the natural background level as a standard for a particular parameter. This appears to be the situation with boron in the Sheyenne River above the Harvey gage. At the other sites in the basin, the standard has not been exceeded since the 1970's (Table 2). The same is true of boron at the sites on the Red River (Table 3). Consequently, only the site at Harvey could be considered to have a possible problem with boron, where the standard was most recently exceeded in November 1996 (Table 2), when the most recent sample available was collected. It is noteworthy that the flow in the Sheyenne River has been in the lower part (less than or equal to 12 ft^3/s) of the range of flow at the site (maximum of 500 ft^3/s) when the standard was exceeded. This type of relationship between flow and water quality will be further discussed later, but based on this indication, additional flow at the site would be expected to reduce (dilute) the boron content if the added water were lower in concentration than the water that historically has flowed by the site.

The chloride standard is related to EPA secondary maximum contaminant levels (SMCL's). SMCL's are based on aesthetic considerations, which in the case of chloride is based on the taste of the water. Both the North Dakota and the Minnesota instream standards (Table 1) are lower than the chloride SMCL of 250 mg/L (U.S. Environmental Protection Agency 1996). Chloride, like borate, is extremely soluble and virtually impossible to economically remove once it is dissolved in water, and the lower standard leaves additional room before the impairment level is reached.

Chlorides very seldom exceeded the water quality standard in either the Sheyenne or Red river basins (Tables 2 and 3). Chloride only exceeded its standard in the Sheyenne River basin at the Harwood site (Table 2), the farthest downstream site; and at two sites on the Red River mainstem (Table 3). The exceedences included one each over the period of record at Harwood and Wahpeton. There were seven occasions on which the standard was exceeded at Grand Forks, but the last one was over 10 years ago. At all three sites, the exceedences of the chloride standard occurred at the lower end of the flow range (Tables 2 and 3; Figures I-15 through I-29).

Fecal coliform bacteria are used as an indicator of the presence of potential pathogens (disease-causing micro-organisms) in waters used for body-contact recreation. The standard is the same in both North Dakota and Minnesota (Table 1). Fecal coliform bacteria are also an indicator of the bacterial content of water and an indicator of the amount of disinfection that the water would require for drinking purposes. There are a large number of fecal coliform bacteria samples at sites monitored by the NDSDH, including the Sheyenne River at Valley City and Harwood (Table 2), and the Red River at Fargo and Grand Forks (Table 3). There is a relatively high frequency of samples exceeding the standard, particularly in the vicinity of Fargo (Table 3). The river flow at the time of the exceedences was in the lower half of the total range of flow at the monitoring sites (Tables 2 and 3). This would indicate that there may be a relationship to flow. This is generally shown in several of the figures in Attachment I (Figures I-43 through I-48). [The fecal coliform bacteria concentration in Figures I-43 through I-48 are in MPN CFU/100 mL, which is Most Probable Number (a statistical estimation technique) of Colony Forming Units (presumably a cell, but some colonies that have grown may actually represent an initial aggregation of cells)].

Dissolved oxygen (D.O.) represents a gas dissolved in water. The concentration in water is the result of the amount of oxygen consumed by the oxygen demand due to the decomposition of organic matter (BOD or biochemical oxygen demand, mostly due to bacterial respiration). Water is oxygenated by the atmosphere and the amount of dissolved oxygen in the water is the reflection of the rate of atmospheric (and sometimes photosynthetic) oxygenation, less the BOD. The D.O. has been less than the standard (the reverse of the other standards) at a majority of the monitoring sites (five of nine in the Sheyenne River basin (Table 2) and four of five in the Red River basin (Table 3), but at relatively low frequencies. In the Sheyenne River basin, the D.O. concentration is below the standard (oxygen deficient) in over 18 percent of the measurements (Table 2), but the frequency of exceedence of the standard fall to less than 1 percent near the mouth of the river at Harwood. In the Red River, there is a greater frequency that the standard is not met in the central part of the study area than either upstream or downstream (Table 3). Even in the central part of the area, there are fluctuations in the frequency. The data in Tables 2 and 3 and Figures I-30 through I-42 indicate that there may be a relation to flow.

Percent sodium is the percentage of the total cations (calcium, magnesium, sodium, and potassium, in milliequivalents) made up by sodium (Skougstad et al. 1979). The USGS data in STORET for percent sodium only extend to 1983. Data subsequent to that were calculated from retrieved cation data, which extends the record in most instances to 1996 (Tables 2 and 3). The State data for percent sodium extend to 1992. To evaluate the percent sodium the change in the composition of the cations must be evaluated. The actual cation data are necessary to do this. The State data in STORET do not include the cations. Further evaluation of percent sodium will be based solely on the USGS data.

The percent sodium is a measure of the potential sodium hazard for irrigation water. In addition to contributing to osmotic pressure, sodium is toxic to certain plants and frequently causes problems in soil structure, infiltration, and permeability rates (U.S. Environmental Protection Agency 1987). The percent sodium standards are 60 percent in the Sheyenne River basin and 50 percent in the Red River basin, except for the Minnesota site at Halstad, which is also 60 percent (Table 1).

There are no instances in which the percent sodium is greater than the standard in the Red River basin (Table 3). In the Sheyenne River, the percent sodium is frequently greater than the standard above Harvey (Table 2), but exceeded the standard on only one or at most two occasions at the other monitoring sites (Table 2). The exceedences at the sites lower in the basin are from data in the 1970's and earlier 1980's (Table 2). Because the high percent sodium occurs only at the one site, by supplemental water deliveries, nothing could be done to affect the composition of the water at the monitoring site.

Ammonia can exhibit both lethal and sub-lethal toxicity to aquatic life (U.S. Environmental Protection Agency 1987). Sub-lethal effects on fish include reduced hatching success, reduced growth rate and morphological development, and pathologic changes in tissues of gills, livers, and kidneys (U.S. Environmental Protection Agency 1987). The site on the Sheyenne River below Baldhill Dam exceeded the ammonia-nitrogen standard about one third of the time, but all of the data are from a two year period that ended in 1981. Whether this is still a problem is unknown. Except for the monitoring sites at Harwood, the ammonia-nitrogen standard has not been exceeded at the other sites on the Sheyenne River since 1981. All of the times that the ammonia standard was exceeded were at lower flows (Table 2; Figures I-69 through I-75). The standard has been exceeded almost 20 percent of the time in the vicinity of Fargo (Table 3), which shows that the standard was exceeded in the most recent data collected by the State in 1992. The frequency of exceeding the ammonia standard decreases with increasing distance downstream from Fargo (Table 3).

The North Dakota nitrate standard (Table 1) is considered an interim guideline limit (NDSDH 1991), like the total phosphorus interim guideline limit. The nitrate interim guideline limit is 10 mg/L, which is also the drinking water standard in the Minnesota reach of the Red River (Table 1). The much lower North Dakota interim guideline limit is related to the role of nitrate as a nutrient (North Dakota State Department of Health 1991); the drinking water standard for nitrate still applies as an absolute upper limit. The most recent nitrate data are at least 10 years old and may or may not reflect current conditions (Tables 2 and 3).

Nitrate-nitrogen has exceeded the North Dakota interim guideline limit with some frequency in both the Sheyenne and Red river basins (Tables 2 and 3). At three of the sites on the Sheyenne River (near Warwick, at Lisbon, and at West Fargo), the interim guideline limit was exceeded between 10 and 20 percent of the time (Table 2). At the stations farther downstream, 6 percent or less of the samples exceeded the interim guideline limit. In the Red River, between 7 and 10 percent of the samples exceeded the North Dakota interim guideline limit (Table 3). The drinking water standard was not exceeded in either basin.

There is no total phosphorus standard for the Red River in Minnesota (Table 1). North Dakota has an interim guideline limit like that for nitrate, which been developed for the control of nuisance or excessive plant growth (North Dakota State Department of Health 1991). Total phosphorus has exceeded the North Dakota interim guideline limit in most of the samples collected at all sites in both the Sheyenne and Red rivers (Tables 2 and 3). There does not appear to be any relationship to flow; the standard is exceeded across the entire range of flow at most sites (Tables 2 and 3; Figures I-105 through I-116). This will be discussed in more detail later. Figures I-105 through I-116 also show that the interim guideline limit can be greatly exceeded at times.

The pH standard encompasses a range of values in both Minnesota and North Dakota (Table 1). The upper limit in both sets of State standards is 9, but the lower limits differ slightly, with a lower limit of 7 in North Dakota and 6.5 in Minnesota. The standards can therefore be exceeded by values that are both too high or too low. This is best illustrated in Figures I-90 through I-104, which show the pH range as a band across each plot. The summary data in Tables 2 and 3 show the percent of samples outside the range of the pH standard along with the associated range of flows, but the direction in which the standard is not met is not shown. This is shown in the figures. There are both high and low pH values shown. The direction varies from site to site, but overall, the number of high and low values outside of the range of the standards is about equal, and the percent of samples that are not within the range of the standards is relatively small, at most 2 percent (Tables 2 and 3).

Sulfate is another very soluble dissolved solid. The SMCL for sulfate is 250 mg/L, the same as the water quality standard for the Red River (Table 1). Most of the SMCL's are developed for taste or odor considerations in drinking water. The primary concerns when sulfate is considered are scale formation in hot water tanks and its laxative effect at very high concentrations, *circa* 1,000 mg/L (Faust and Aly 1998). The sulfate standard in the Sheyenne River is higher than that in the Red River at 450 mg/L. It should be noted that the EPA has proposed a sulfate SMCL of 500 mg/L (Faust and Aly 1998), which would be greater than the higher ambient standard in the Sheyenne River.

The frequency with which the sulfate standard is exceeded in the Sheyenne River is very low and only occurred at the farthest upstream station above Harvey and the farthest downstream station at Harwood (Table 2).   The only recent exceedence was observed above the study area above Harvey. All exceedences were at low flows (Table 2; Figures I-117 and I-125).

In the Red River at least one sample exceeded the sulfate standard at each of the monitoring sites except for Halstad (Table 3). The greatest frequency of exceedence was at Grand Forks (Table 3), where the standard was exceeded 15 times over the period of record. With one exception, the standard was exceeded during the months of November through March, most often in March. The standard was exceeded when the flows were somewhat low, but not at the lowest (Table 3; Figure I-131).

The temperature standard was only exceeded once in the Sheyenne River at all of the sites combined. That was at the site near Warwick in August 1988 (Table 2) or 10 years ago. The exceedence did occur at a comparatively low flow. The effect of flow on water temperature concerns the resistance to atmospheric warming by a larger mass of water and a similar effect on warm water loadings to a receiving stream. There were more exceedences of the temperature standard in the Red River (Table 3), but these also amounted to only one per site. None of the exceedences in the Red River has been recent (Table 3), and all were at lower, but not the low flow.

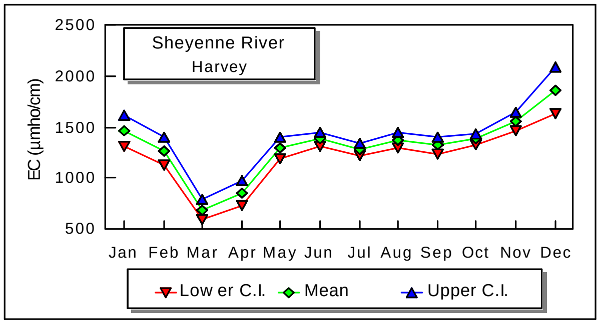
Toxic substances have been sampled by the USGS as part of the Red River NAWQA study (Stoner et al. 1998). The USGS indicated the following from data collected during the 3-year intense data collection period between 1993 and 1995. Pesticides detected in streams and shallow ground water did not exceed drinking water standards and, except for a single concentration of the herbicide triallate, were not acutely toxic to aquatic life based on current standards. The pesticide concentrations were greatest during periods of runoff close to the time of pesticide application (Tornes et al. 1997).

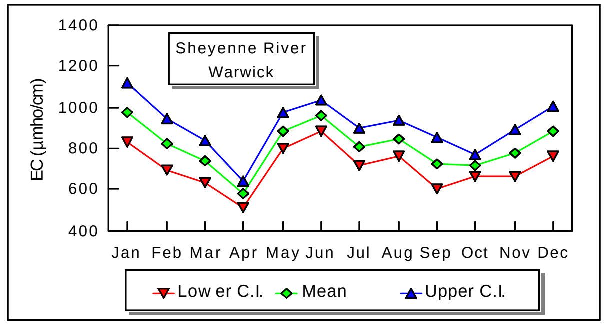
Polychlorinated biphenyl (PCB's) concentrations in fish tissue were below Federal standards for fish consumption. Polycyclic aromatic hydrocarbons (PAH's) were detected in stream sediments at some locations at levels thought to adversely affect aquatic life. Volatile organic compounds (VOC's), which can enter water from petroleum products and industrial solvents, were rarely detected in ground water beneath agricultural areas or in the Red River.

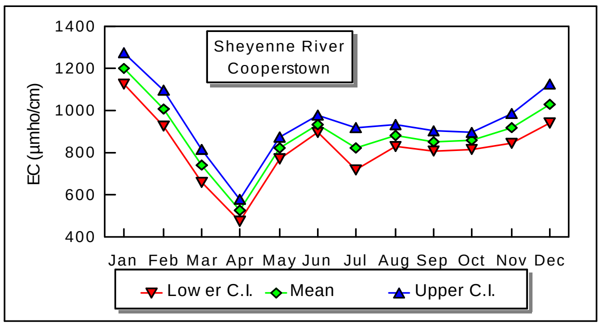
Relationships between Water Quality and Flow

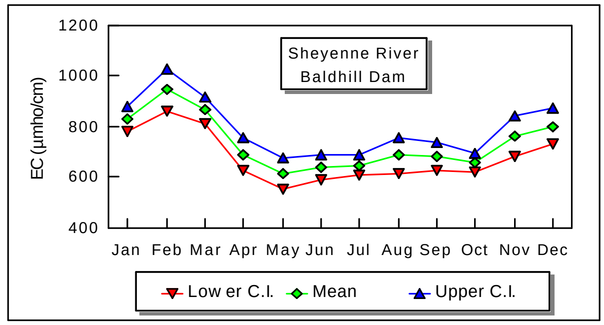
The most common water quality measurement made is electrical conductivity (EC), also known as specific conductance, because it is both inexpensive and easy to measure. EC is a measure of the electrolytes (ions) in the water and is therefore a measure of the electrical activity of the total dissolved solids (TDS). There is usually an inverse correlation between flow and EC (or TDS). The relationship reflects the fact that peak flows tend to result from snowmelt or rainfall runoff, which are both dilute (low in dissolved solids). The dilute runoff mixes with the more concentrated water in the river, reducing the EC and increasing the flow. Low flows in the river usually consist of baseflow or ground water discharge, which is higher in EC because it dissolves minerals as it passes through an aquifer. The inverse correlation is an indicator of a dilution predominated system.

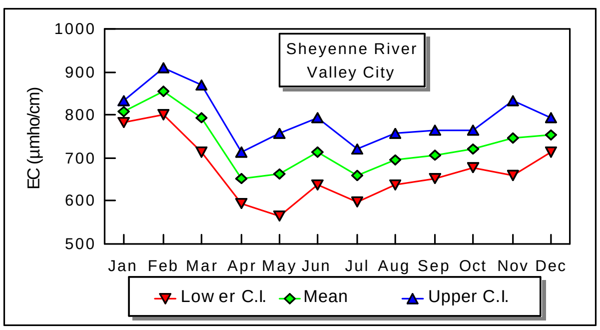
The monthly distribution of EC at each of the sites in the Sheyenne River basin is shown on Figure 1. Each of the plots on Figure 1 shows the average EC and its 95 percent confidence interval ($\pm 2 \times$ standard error of the mean). At the uppermost site above Harvey, the minimum EC for an average year occurs in March and the maximum in December. At the next two sites the minimum occurs in April and the maximum in December and January. Once the river reaches Baldhill Dam the EC does not show as much difference between the minimum and maximum. The minimum is in May, but it is little different from what is shown for June, particularly at the upper confidence limit (Figure 1). At Valley City the confidence limits begin to diverge quite a bit. The minimum average is in April, but the minimum upper confidence limit is in July. In other words the distribution through the year becomes somewhat more complex. The pattern at Lisbon resembles one from farther upstream, particularly in regard to the very tight confidence interval, except during December, when the greatest EC for the year is observed. The monthly distribution of EC near Kindred is very much like that at Cooperstown. The minimum EC in April does not form quite as deep a trough as the Cooperstown plot, but June peak followed by a summer plateau is just as pronounced (Figure 1). At West Fargo the lowest average monthly EC is once again in April, as is the case at Harwood. The maximum EC at West Fargo is during January, while at Harwood it is during February.

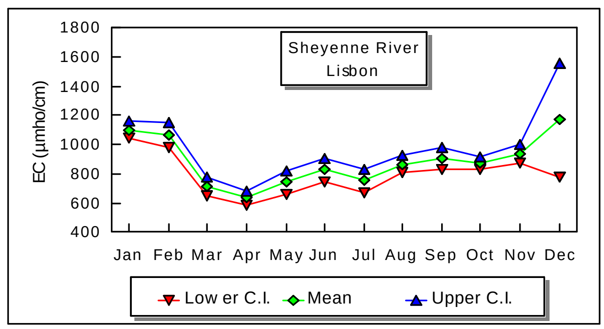


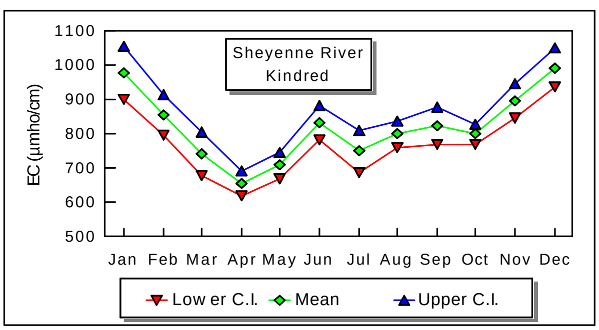


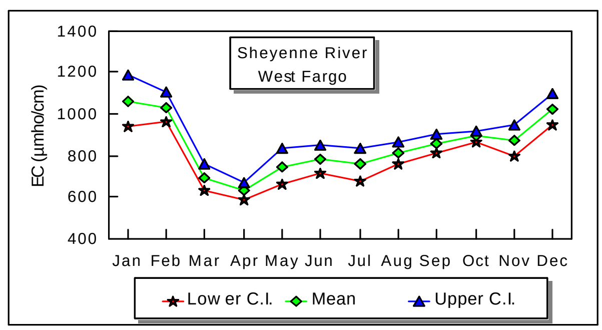












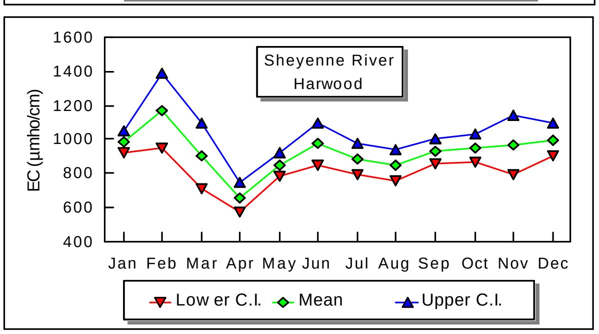


Figure 1: Monthly Distribution of EC at Nine Sites in the Sheyenne River Basin

The EC data shown in Figure 1 indicate that the seasonal pattern in EC is somewhat variable from site to site in the Sheyenne Basin. There is no consistent upstream to downstream pattern apparent in the data. Much of the difference in EC among the sites may be due to the differences in the years of data that went into the calculation of the averages and the confidence intervals. The periods of record for the EC data are similar to those for chloride in Table 2, although there are about 100 more EC measurements at each site than there are chloride determinations.

Figure 2 shows the relationship between EC and flow at each of the nine sites in the Sheyenne River basin. It should be noted that all of the regressions of EC on flow are statistically significant and all are inverse (Figure 2). However, the r^2 values, a measure of the percent of the variation in the dependent variable that is explained by the independent variable, are all rather small. Five of the nine have an r^2 between 0.41 and 0.48. This means that at best, only 48 percent of the variation in EC can be explained on the basis of flow. Two of the regressions have an r^2 of 0.03, indicating that only 3 percent of the variation in EC can be explained by flow. It should be noted that sites below water control structures, such as dams, can have a great effect on the EC-flow relationship. Dams control the flow, but the EC is controlled by the flow above the dam, which may not be reflected in the flow that bypasses a dam. In general, the flow in the river is a significant factor, but not the only factor, controlling EC.

Figure 3 shows the seasonal distribution of EC at the sites in the Red River basin. At the site near Wahpeton, the lowest average monthly EC occurs in March; it shifts to April at the site at Hickson. The minimum monthly EC occurs in April at each of the remaining sites, except for the one below Fargo, where it occurs in June. The sites below Fargo has the shortest record of any of the sites on the Red River in the study area. The maximum EC occurs during the winter months at all of the sites; most commonly the peak monthly average occurs in December or January (Figure 3). The differences in the periods of record probably account for much of the difference in the monthly distribution of EC in the Red River. As was the case in the Sheyenne River basin, the periods of record most closely resemble those for chloride (Table 3), but for the most part there are 200 to 300 more EC observations than chloride observations.

Figure 4 shows plots of the EC - flow relationships in the Red River basin. As was the case in the Sheyenne River basin, all of the regressions are statistically significant with a probability of less than 0.01 that the relationship reflects one due to random chance. All of the relationships are inverse, indicated a system dominated by dilution. The r^2 values associated with the regressions indicate that other factors than flow are important in controlling EC in the basin. In general the r^2 's increase with decreasing elevation in the basin. At the two stations highest in the basin, both of the r^2 's are 0.07, the two middle sites are between 0.2 and 0.3, increasing to 0.45 at Halstad. There is a decrease to 0.35 at the Grand Forks site. Once again the noteworthy fact is that the best r^2 shows that flow explains at most 45 percent of the variation in EC.

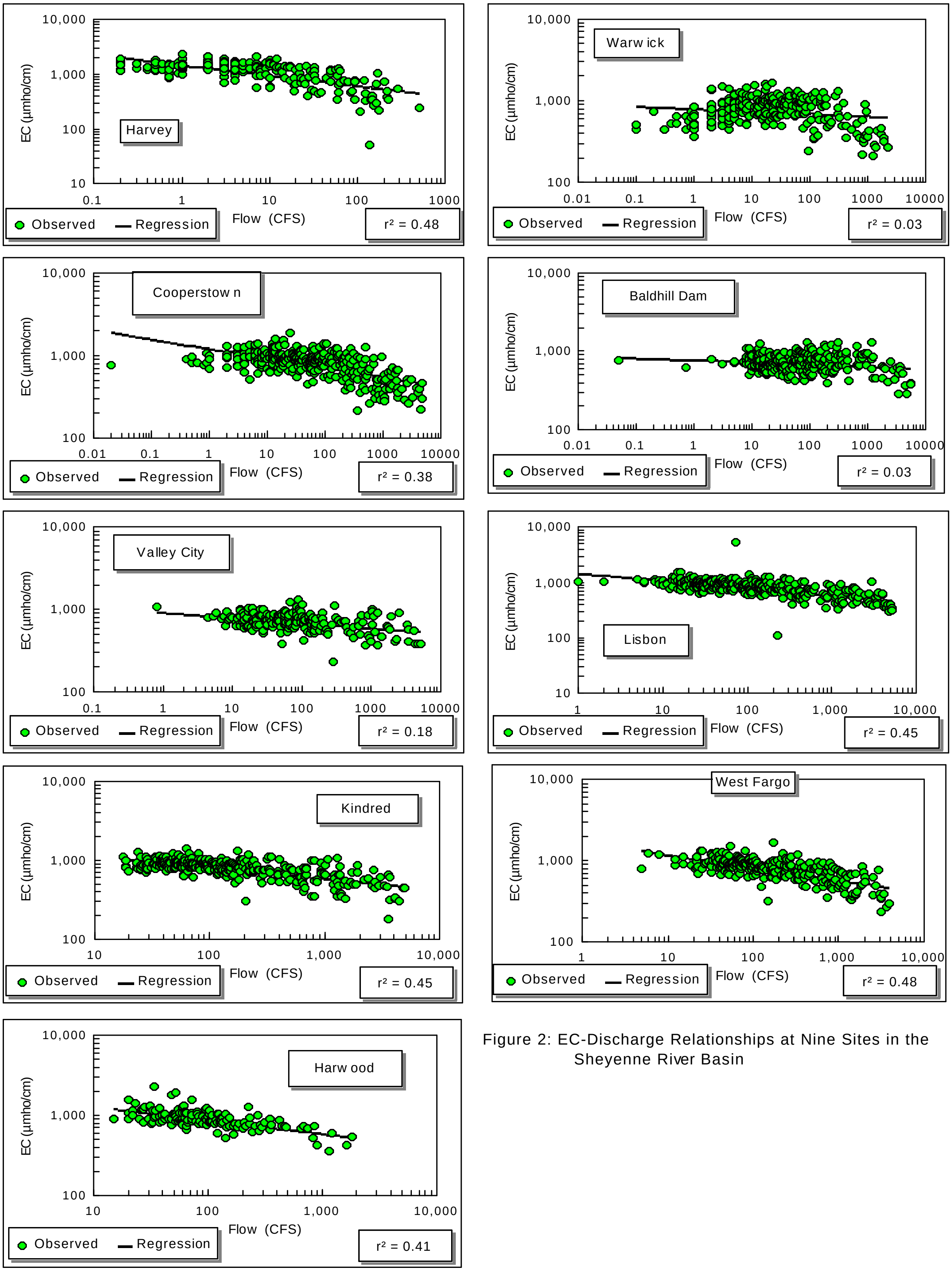


Figure 2: EC-Discharge Relationships at Nine Sites in the Sheyenne River Basin

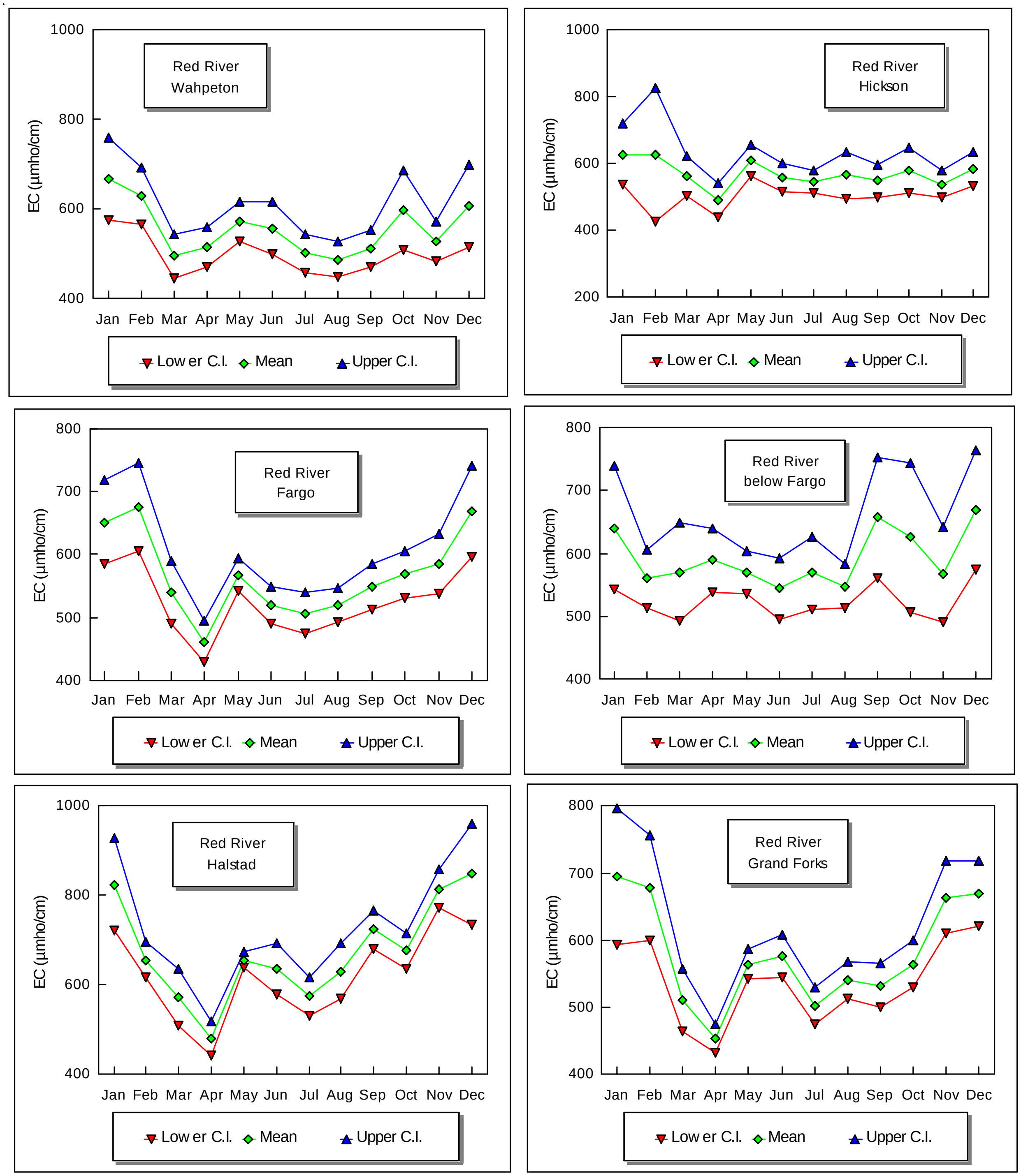


Figure 3: Monthly Distribution of EC at Six Sites in the Red River Basin

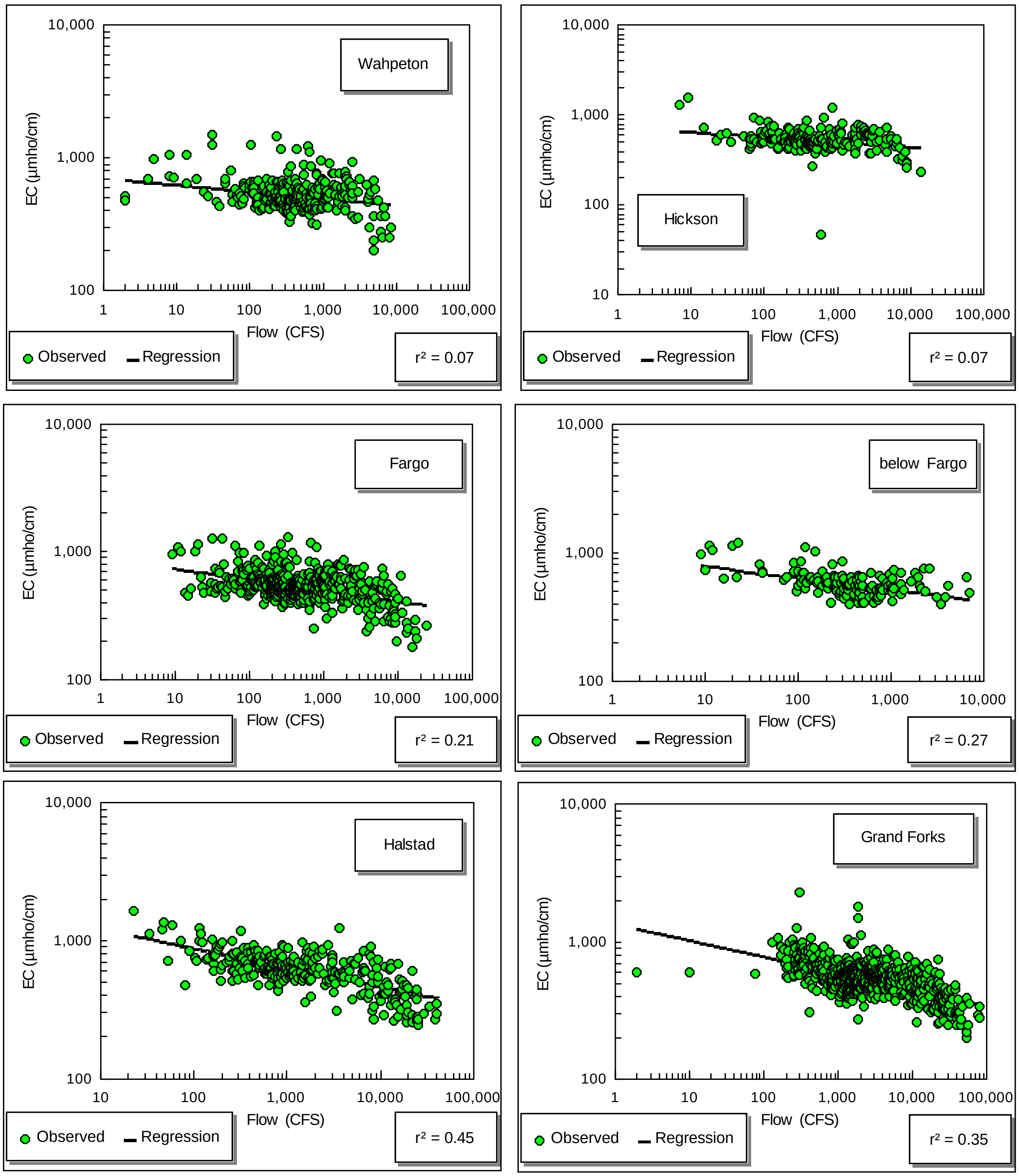


Figure 4: EC-Discharge Relationships at Six Water Quality Monitoring Sites in the Red River of the North Basin

The water quality standard that is exceeded most often in both the Sheyenne and Red river basins is the total phosphorus interim guideline limit. An interim guideline limit that may be changed if it is determined that the background is higher. As noted above, the interim guideline limit is exceeded in the vast majority of the samples at all sites in both basins. The farthest upstream site with any total phosphorus data is the one near Cooperstown (Table 2). The distribution of samples is heavily weighted to the spring (March through June - Figure 5). There are no samples that exceeded the interim guideline limit during November through January, but there were very few samples collected. Beginning with the site at Valley City, most of the samples in all months of the year exceed the total phosphorus interim guideline limit (Figure 5). At Valley City all of the samples exceeded the interim guideline limit during June through August and in January and all but one or two samples exceeded the interim guideline limit in the other months of the year. Near Kindred, the interim guideline limit was met about ½ the time during October through December, but was rarely met in the other months of the year. At Harwood the phosphorus interim guideline limit was met in about ¼ of the samples during November through January, but rarely during the remaining months (Figure 5).

Total phosphorus data for the upstream station at Wahpeton in the Red River basin are somewhat sparse (Figure 6). There are no samples in five of the months; the interim guideline limit was exceeded most of the time in five of the remaining months that have data (April through September). At Hickson the interim guideline limit was met most of the time during October through December, but was not met at all during April through August (Figure 6. At the other four sites the interim guideline limit was rarely met in all months of the year, and it was never met in any sample at the site below Fargo (Figure 6).

Total phosphorus includes several different forms, but most importantly for this discussion, they include dissolved and suspended. If the dissolved fraction predominates, the relationship to flow should be inverse like that for EC. If the suspended fraction predominates, then the correlation to flow should be positive. The positive relationship would reflect the higher concentrations in runoff and an erosive source for the phosphorus. However, if the suspended phosphorus flow should be positive. The positive relationship would reflect the higher concentrations in runoff and an erosive source for the phosphorus. However, if the suspended phosphorus predominates in a municipal or industrial point source that provides a constant (or near constant) loading, then dilution may be a predominant factor and the relationship could be inverse. Alternatively if there are a variety of sources and neither dilution nor erosion dominates, there will be no relationship to flow. All of these conditions are exhibited in the Sheyenne and Red river basins as illustrated by the regression relations shown in Table 4.

APPENDIX I

FLOW-RELATED RECREATIONAL OPPORTUNITIES AND NEEDS ASSESSMENT

RED RIVER VALLEY WATER NEEDS ASSESSMENT

PHASE 1B

INSTREAM FLOW NEEDS ASSESSMENT

FLOW-RELATED RECREATIONAL
OPPORTUNITIES AND NEEDS ASSESSMENT
INSTREAM FLOW NEEDS ASSESSMENT

INTRODUCTION

The recreation information used in the flow-related recreational opportunities and needs assessment analysis was readily available from applicable studies and reports dealing with recreation activities on streams and rivers in North Dakota and from reports on river recreation trends/preferences in the United States. No new information has been generated for this assessment.

Initially, river-based recreational activities were divided into three categories: (1) fishing, (2) water contact, and (3) boating. These categories were further subdivided into specific recreational activities. Information on these specific river-based recreation activities was limited, with the exception of canoeing. The North Dakota Parks and Recreation Department (NDPRD) has collected and analyzed some data relating to canoeing experiences on the two rivers; therefore, this is the only recreation activity that is discussed in detail. Land-based recreation activities that are river-dependent were subsequently added for consideration. Data are more readily available for these activities than the river-based activities. Following is a list of river-based activities:

Fishing	Water Contact	Boating
Wading	Swimming	Sailing
Boat, power	Wading	Low power
Boat, non-power	Water skiing	High power
		Canoeing-kayaking
		Rowing-canoeing-drifting
		Tubing-floating

Following is a list of land-based recreational activities that occur in proximity to the two river corridors:

Sightseeing	Hunting	Picnicking
Walking/jogging	Bicycling	
Camping	Snowmobiling	

EXISTING CONDITION

River-based and associated land-based recreation activities on the Red River of the North and the Sheyenne River continue to be very important to the people of North Dakota. Statewide during 1996, fishing, sightseeing, walking/jogging, camping, boating/water skiing, picnicking, hunting, and bicycle riding were the river-related recreation activities most often participated in by the residents of North Dakota (North Dakota Parks and Recreation Department 1997). Fishing continues to be the number one river recreation activity for the State.

To identify a trend in river recreation for the rivers of North Dakota, the NDPRD compared its 1987 rivers survey with one completed in 1996. One activity that occurs on many rivers in North Dakota that was not surveyed in 1987 is canoeing; therefore, the State was unable to establish a trend in this activity because of the lack of information in 1987. However, nationwide, Americans purchased about 90,000 canoes in 1988, which was about a 14 percent increase from 1985 (Ingrassia 1989). In 1996, about 19,000 adults, or 4.1 percent of the adult population of North Dakota, participated in canoeing activities. The James, Little Missouri, and Sheyenne rivers had the largest mean canoe activity-days per river user.

According to the NDPRD 1997 report, the Missouri, Red River of the North, Little Missouri, Sheyenne, Souris, and James rivers are the six most popular recreation rivers in the State, ranked by priority use. Statewide over the last 10 years, the Sheyenne River has gone from sixth place to fourth in terms of recreation use. The Red River of the North continues to receive the second most recreation activity-days of any river in the State.

Red River of the North recreation activities include sightseeing (21.8 percent), walking/jogging (20 percent), bicycling (13.3 percent), fishing (10.7 percent) snowmobiling (8.5 percent) and picnicking (5.0 percent)(North Dakota Parks and Recreation Department 1997). Fishing has declined over the past few years on the Red River of the North, but continues to be ranked among the top six river activities in the State. The decrease in fishing on some North Dakota rivers and streams is likely due to the decline in the State's riverine fisheries resources (North Dakota Game and Fish Department 1997). Most of the decline is a result of degraded habitat (U.S. Environmental Protection Agency 1997; Kelsch and DeKrey 1997; and, Peterka and Koel 1997). The index of watershed indicators, which is based on 15 cumulative indicators (U.S. Environmental Protection Agency 1997), ranked the upper Red River of the North as having serious water quality problems.

Sheyenne River recreation activities include walking/jogging (20.1 percent), fishing (13 percent), sightseeing (10.5 percent), hunting (10.4 percent), hiking (8.3 percent), photography (8.3 percent), and picnicking (6.3 percent)(North Dakota Parks and Recreation Department 1997).

Overall, outdoor recreation respondents to the 1995 State Comprehensive Outdoor Recreation Plan (SCORP)(North Dakota Parks and Recreation Department 1995) household survey reported that playground/picnic areas, developed campgrounds, and paved bicycle trails were the three most needed facility improvements.

Respondents in 1987 reported that increased or improved river access, followed by increased picnic and camping areas, riverfront park areas, and public swimming areas were the types of river recreation improvements most desired (North Dakota Parks and Recreation Department

1987). In 1996, river recreation respondents were asked which two facility improvements would provide them with a better recreation experience along or on North Dakota rivers, and they reported that "clean rivers" (42.3 percent) and "shoreline access" (35.9 percent) were the two most important. Other facility improvements that were important to river recreation users were modern restrooms (33.9 percent), trails (20.9 percent), picnic/playgrounds (20.3 percent), and watercraft landings (19.5 percent)(North Dakota Parks and Recreation Department 1997).

Statewide, North Dakota river recreation participants reported they participated in recreation activities most often during summer months, with 80 percent of participants using river associated recreation in July. About 34 to 39 percent of the statewide river recreation users participated in the different activities in the months of May and September. The month of March had the lowest recreation use, statewide. Red River of the North recreation users participated in river associated recreation during the months of June (69.9 percent), July (75.0 percent), and August (58.8 percent) (North Dakota Parks and Recreation Department 1997). Except for fishing and some other activities listed above, most of the recreation activities that people participated in during these months were land-based activities that are river-dependent. The optimum time for certain river-based activities such as canoeing and rafting are earlier in the year (April and May), when flows are historically higher. Other river-based activities such a fishing, sailing, swimming, and tubing, etc., would occur during June, July, and August, when the weather is typically better and existing flows allow for easy access to the river and associated beach and fishing areas.

As stated earlier, most of the people who responded to questionnaires which were distributed during the preparation of the 1996 NDPRD Survey (North Dakota Parks and Recreation Department 1997), listed clean rivers, facility development, river access, and increased opportunities as their primary concerns for rivers in North Dakota. Following are some of the main concerns raised by the respondents to the survey:

? Advertising and brochures are needed to increase public awareness of the recreation opportunities that are available in the local areas.

? More opportunities are needed in urban areas.

? Winter recreation opportunities, such as snowmobiling and cross country skiing, should be provided and trails should be maintained.

? More public land should be obtained to help access problems.

? Raw sewage and farm chemicals should be prevented from entering the river system.

? Beach areas, camping, restrooms, launch sites, and picnic areas (day use) should be provided.

? Care should be taken not to increase facility development in sensitive areas because overuse could negatively impact sensitive resources.

? Rivers are dirty and should be cleaned up.

Respondents to the survey did not mention that flows should be adjusted to accommodate recreation use during the peak recreation season (June, July, and August). Comments on user dissatisfaction focused on the lack of infrastructure development, access, and opportunities rather than a lack of sufficient instream flows to benefit recreation.

Some of the comments received directly relate to capacity limits being reached for many segments of the river systems. The suggestion that more beach areas, restrooms, launch sites, etc., are needed indicate that user capacities of existing facilities and sites may have already been reached. If the above-mentioned types of improvements were provided, they could increase recreation use and thereby increase the effect of river associated recreation on the local and State economies (North Dakota Parks and Recreation Department 1997). The clean rivers aspect is particularly important in light of a President's Commission poll on American Outdoors, which found that natural beauty was the most important criteria for tourists in selecting a site for outdoor recreation (National Park Service 1995).

The NDPRD is in the process of collecting information through a consulting firm to assist it in making management decisions and in producing detailed brochures. The brochures will discuss canoeing opportunities and recreation facilities available for public use on the rivers in North Dakota, including the Red River of the North and the Sheyenne River (BlueStem Incorporated 1998).

Flow Evaluation and Effects on Existing Recreational Uses

To evaluate the potential effects of changes in flows on one form of river recreation, canoeing, North Dakota Parks and Recreation Department canoeing rating tables were utilized. Canoeing ratings of poor, fair, good, and excellent were defined by the State in terms of water depth, in feet. This reflects a users capability of achieving a certain level of canoeing experience. A canoeing rating system based on discharge, in cubic feet per second (cfs), was then created. An asterisk (*) denotes uncertain information.

Two selected sites on the Sheyenne River that were surveyed by the State included portions of the river near Cooperstown, at U.S. Geological Survey (USGS) gaging station 05057000, and at Lisbon, at USGS gaging station 05058700. Following were their findings:

Sheyenne River near Cooperstown- USGS gaging station 05057000

Rating	**Depth (feet)**	**Discharge (cfs)**
Poor	0-1.5	0* - 399
Fair	1.5-2.5	399 - 814*
Good	2.5-3.5	814*- 1260
Excellent	3.5-4.5	1260-1710

Sheyenne River at Lisbon - USGS gaging station 05058700

Rating	**Depth (feet)**	**Discharge (cfs)**
Poor	0-1.5	0* - 186*
Fair	1.5-2.5	186* - 380*
Good	2.5-3.5	380* -598
Excellent	3.5-4.5	598 -845

Three sites on the Red River of the North that were surveyed are Wahpeton, at USGS gaging station 05051500, Fargo, at USGS gaging station 05054000, and Grand Forks, at USGS gaging station 05082500. Following are their findings:

Red River of the North at Wahpeton - USGS gaging station 05051500

Rating	**Depth (feet)**	**Discharge (cfs)**
Poor	0-1.5	0 - 26*
Fair	1.5-2.5	26* - 108*
Good	2.5-3.5	108* - 294
Excellent	3.5-4.5	294-620

Red River of the North at Fargo - USGS gaging station 05054000

Rating	Depth (feet)	Discharge (cfs)
Poor	0-1.5	0 - 759*
Fair	1.5-2.5	759* - 1680*
Good	2.5-3.5	1680* -2760*
Excellent	3.5-4.5	2760* -3640*

Red River of the North at Grand Forks - USGS gaging station 05082500

Rating	Depth (feet)	Discharge (cfs)
Poor	0-1.5	Not available
Fair	1.5-2.5	Not available
Good	2.5-3.5	Not available
Excellent	3.5-4.5	1300* -3150*

In the evaluation, Reclamation compared average monthly flow (depths and velocities) at the different USGS gaging stations on the Red River of the North and the Sheyenne River, extending over the 54-year period from 1931 thru 1984 (Appendix B), with calculated aquatic life maintenance seasonal instream flow regime flows (depths and velocities). The comparison was made for both the spawning period - March-June (high flow period), and the maintenance period - July-February (low flow period).

While the aquatic life maintenance seasonal instream flow regime might maintain aquatic life, the flows do not necessarily maintain or optimize recreational opportunities. There would be certain gains in recreation benefits when the historic flows are less than the aquatic life maintenance seasonal instream flow regime. The aquatic life maintenance seasonal instream flow regime would tend to extend the recreation canoeing season for certain segments of the river when flows are historically low (i.e., July through February) and during most dry water years.

The frequency of obtaining a certain level of canoeing experience would vary depending on whether it was a dry water year, average water year, or a wet water year. As an example, the quality of the canoeing experience and the months available to the users to achieve that experience in a wet water year may be greater for the entire recreation season, depending on the type of experience the user is seeking (i.e., a white water experience or a leisurely float trip). If aquatic life maintenance seasonal instream flow regime flows are greater than historic flows, the opportunities for achieving a favorable canoeing experience may be enhanced. However, as flows increase (i.e., velocity), there is also an increased concern for public health and safety.

The evaluation indicated that there should not be a significant impact on the recreational use of either the Sheyenne River or the Red River of the North if the rivers are managed to meet the aquatic life maintenance seasonal instream flow regime. As previously mentioned, recreationists would be benefitted the most during low flow years when historic flows are normally less than aquatic life maintenance seasonal instream regime flows. The effects on canoeing range from poor to excellent, depending on the river, river segment, and site location of the canoeing experience. The specific effects that the aquatic life maintenance seasonal instream flow regime would have on other recreation activities were not analyzed.

FUTURE CONDITION

There are certain assumptions and findings that can be made that should assist river mangers in formulating future recreation management strategies. Some assumptions would indicate that certain actions could be initiated without compromising other non-recreation river uses. A general discussion of carrying capacity limits associated with river systems can help provide some insight for future management strategies. An understanding of carrying capacity limits is essential for managers and their future planning efforts and in setting long-term goals and objectives for the management of recreation resources. Monitoring of recreation use and establishing carrying capacity limits would assist decision makers in determining the impacts that future use may have on existing resources.

Assumptions:

There is a point at which increased recreation use will cause reductions or losses to outputs associated with nonrecreational purposes and benefits (Cordell et al. 1993).

There is a belief that, with increasing dialogue among water users, a broader societal perspective among decision makers, and more flexible and creative lake/reservoir operations, “major improvements can be accomplished without abandoning” (LaGrassa 1991) any water resource purpose or benefit.

There is a water level that may be too high, at which point it begins to negatively affect recreational fishing, shoreline stability, turbidity, facilities, public safety, beaches, habitat, and visitation. This would produce an associated decrease in recreation values.

There is a water level that may be too low, at which point it begins to negatively affect river access, fisheries habitat, aesthetics, backwater areas, wildlife, boating, safety of recreationists, and visitation. This would produce an associated decrease in recreation values.

There is a point in river operations that the level of recreation satisfaction declines and recreationists are displaced to other areas or to other recreation or nonrecreation activities.

Increased reservoir-based recreation could, at some point, compete with downstream recreation and the minimum instream flows needed to accommodate a variety of river-based and dependent land-based recreation uses. Holding water for longer periods of time in reservoirs for the benefit of flat-water recreationists during the recreation season (June, July, and August) may decrease the opportunities available to river recreationist during certain times of the year.

Recreation activities may affect fish and wildlife in numerous ways. For example, recreation may disrupt nesting and feeding areas, alter flight patterns, cause mortality, increase unnatural energy consumption, displace species temporally or permanently, destroy aquatic vegetation, have both visual and auditory effects, increase unnatural wildlife dependency (e.g., feeding by humans), increase pollution from boat motors and human litter and waste, cause shoreline erosion and habitat losses, increase water turbulence and turbidity, decrease aquatic growth, and decrease fishery populations directly through recreational fishing and indirectly through other human activities. Conversely, the protected and conserved land use status associated with public recreation areas is often a benefit to waterfowl, terrestrial wildlife such as deer, and numerous nongame species. While there is consensus that humans do affect fish and wildlife, the type and amounts of change and the associated benefits and costs vary widely because of local conditions (Mississippi River Marina Cumulative Impacts Task Force 1990; York 1994).

There is a trend in protecting agricultural land in and around urban areas for open space and parklands. The addition of recreation values to agricultural lands (i.e., fee hunting), irrigation ditches, and reservoirs, etc., is helping to justify protective farmland easements and other land and water conservation methods.

Nationwide, recreation use of available sites would continue to increase over time. This is a reflection of the "baby boomer" generation, increased leisure time, new recreation technologies, and increased public information about recreation opportunities in rural communities. It has been estimated that there would be a 50-100 percent increase in public demand for water-based recreation opportunities at state and Federal facilities over the next 20 years. Without major changes in infrastructure and management programs, the health and safety of the visiting public and the integrity of the natural environment may be compromised (National Recreation Lakes Study Commission 1998).

Carrying Capacity:

Carrying capacity is the ability of a recreational resource to support a user population at a measurable threshold, based on specific goals and objectives (Phister and Frenkel 1974). Carrying capacity will vary with the amount of instream flow in a river at any one time. The volume and velocity of flows are important in sustaining a quality recreation experience over an extended period of time. The amounts, timing, and duration of flows in the river needed to conduct a certain type of river recreation activity differs among the many users of the river. Optimum flows for a quality experience for one river recreation activity is not necessarily optimum for another (i.e., optimum flows for river canoeing are not necessarily optimum for swimming or fishing). Ideally, instream flows could be established that benefit the greatest number of river recreation users at any one time, while not negatively impacting other environmental resources. Except for the discussion on canoeing presented above, which was supported by information provided by the State, the impacts, if any, that the aquatic life maintenance flow recommendations would have on other recreational activities within the river corridors are not known at this time.

Carrying capacity is assumed to be different for individual river segments and depends on available access points, types of use, and physiography of the river system, as well as available flows. Recreationists seeking solitude and a wilderness experience will not tolerate encounters with other users, while recreationists seeking thrills and excitement have a higher tolerance of other users.

Carrying capacity can be subdivided into four categories: (1) physical, (2) ecological, (3) facility, and, (4) social. Subdividing allows for more detailed analysis of the recreation carrying capacity of any given resource (Aukerman and Storck 1995).

***Physical Carrying Capacity*:** Physical carrying capacity can be described as the area that is available to a recreational user for participating in a specific recreation activity. Physical carrying capacity of a river system can be increased or decreased by regulating the flows which pass through the system. Currently, however, the ability to regulate flows in the Sheyenne River and the Red River of the North are limited.

***Ecological Carrying Capacity*:** Ecological carrying capacity can be described as the impacts that a level of recreation use will have on plants, animals, soils, water, air, etc. These are the environmental effects that a use will have on other resources in the area. Waterflow may have some effect on the capacity of a resource to support an activity, especially when it is combined with a high impact recreational use such as stream fishing.

***Facility Carrying Capacity*:** Facility carrying capacity can be described as the ability of an existing facility to accommodate the current level of recreation use. User conflicts can occur if a facility has reached its carrying capacity. For example, user conflicts could occur if too many users were attempting to use the same number of limited boat ramps or access points along a river course. Riverflows can affect facility carrying capacity in that the flows may increase or decrease the user demand for the use of the river and, therefore, increase or decrease the use of existing support facilities.

***Social Carrying Capacity*:** Social carrying capacity can be described as the impacts that resource users have on one another. The number, type, and location of recreation users encountered by other resource users sometimes affects the recreation experience one is seeking to enjoy. The social carrying capacity differs among users and depends on the type of experience being sought and the tolerance level of the individuals or groups using the resource. Existing flows in the river system may affect the social carrying capacity of a river. If the usable surface acres of a river increase, the ability of the recreationists to tolerate the presence of another user also increases. Likewise, if usable surface acres are small, the river system will not socially accommodate as many recreation users. If use increases over time and the river acres remain constant, the river will eventually reach its social carrying capacity limit (i.e., recreationists will not tolerate the sights and sounds of other users).

Comments made by the public concerning the need for more access points and accompanying facilities are assumed to be tied to overcrowding at existing access sites and developed areas along river corridors and, in particular, within the urban areas such as Fargo, Grand Forks, and Valley City. This is an indication that carrying capacity limits, especially facility capacity limits, may have been reached for some infrastructure developments on both the Sheyenne River and the Red River of the North.

There is no indication from the public comments that social carrying capacities have been reached on any segments of either river. Most of the comments suggest increasing the opportunities within the urban segments (i.e., promoting activities, establish trails and parks, increasing jet and water skiing opportunities, etc). The river segments within urban areas would have the capacity to accept higher concentrations of individuals because these individuals would more willingly tolerate the sights, sounds, and actions of other recreation users. The capacity limits for remote segments of the river system would be lower because individuals using these areas are seeking a type of experience different from the urban user.

Public comments regarding facility development in sensitive areas and the disposal of raw sewage and farm chemicals into the river system indicate that the public is somewhat aware of the factors that may contribute to the ecological carrying capacity of a river system. The cumulative impacts that additional recreation development and use may have on the river's ecological system have not been determined. The impact may be significant and depends on the type, size, location, and number of facilities developed and the types of recreational use those facilities attract.

The fact that most recreation users participate in recreation activities during the summer months presents a common problem which occurs throughout the western United States. The peak season for water-based and associated land-based river recreation often occurs at the same time that water is in great demand for other purposes (i.e., agriculture, flood control, municipal and industrial, and fish and wildlife).

CONCLUSIONS

North Dakota's river recreation is important to the residents of the State, with 42 percent of adults participating in some type of river recreation in 1996. There may be some opportunities for river managers to minimally increase recreation use without significantly altering existing flows. Immediate benefits might be achieved without significant changes in river operations by: (1) increasing public access, (2) providing public information on the available recreation opportunities, (3) providing a limited number of support facilities such as boat launch sites, trails, and swim beaches, and (4) cleaning up rivers. Managers would have to monitor the carrying capacities of different river segments and determine when carrying capacities have been reached so that negative impacts to other resources and other users can be avoided. There should not be a significant impact on the recreational use of either the Sheyenne River or the Red River of the North if management of the instream flows are adjusted to the aquatic life maintenance seasonal instream flow regime. Recreationists would be benefited the most during low flow years when historic flows are normally less than the aquatic life maintenance flows. The effects that the flows would have on canoeing were previously discussed and ranged from poor to excellent, depending on the location of the canoeing experience on each of the rivers. The effects that the flows would have on other recreation activities have not been fully discussed or analyzed.

It is important that both rivers are managed by river segments according to river access points, types of use, and physiography of the river. Strategies applied to the management of one river segment are most likely not applicable to other segments of the river. Portions of each of the rivers that flow through urban areas should be managed as high density use areas, while remote sections should be managed as low density use areas with little development.

Increased river-based recreation may at some point compete with reservoir-based (flat-water) recreation and instream flows which may be established for other uses, such as water quality and fish and wildlife, as well as other priority uses such as agriculture and municipal and industrial. The interaction effect will be important for managers of both river and reservoir systems to consider in the future. A systematic approach for coordinated river management by a variety of water users will be necessary to assure a diversity of quality outdoor recreation experiences. A public information program which effectively monitors existing recreation use and future demand will be required. At some point in the water drawdown process, the level of recreation satisfaction declines and recreationists are displaced to other substitute areas or to other recreation or non-recreation activities. This happens when the physical, social, facility, and/or ecological carrying capacity limits have been reached.

By providing additional access points, either through acquisition of lands in fee title or through acquisition of rights-of-way or lease of existing lands over the entire length of both river corridors, dispersal of users to other areas may be possible. This may help alleviate the feeling of overcrowding which has been expressed by the public.

As the demand for recreation use increases, it may compete with other uses of the limited water supplies within the Sheyenne River basin and the Red River of the North basin. If future recreation demands are to be met, changes in infrastructure and management programs may be needed. Without these changes, public health and safety, as well as the character of the natural environment could be compromised.   Decisionmakers should continue to communicate and address the impacts that future demand will have on the limited water supplies and other resources within the basin. They should strive to look for creative solutions to accommodate future demand.

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APPENDIX J

RECREATIONAL ECONOMICS ASSESSMENT

RED RIVER VALLEY WATER NEEDS ASSESSMENT

PHASE 1B

INSTREAM FLOW NEEDS ASSESSMENT

CHANGES IN RECREATIONAL ACTIVITIES ON THE RED RIVER OF THE NORTH AND THE SHEYENNE RIVER DUE TO CHANGES IN INSTREAM FLOWS: CHANGES IN USE, REGIONAL ECONOMIC IMPACTS, AND ECONOMIC BENEFITS

The recreational economics assessment addresses changes in recreational activities due to recommended changes in instream flows: changes in use, Regional economic impacts, and economic benefits).

Methodology

Modifying instream flows for fish species and aquatic habitat can have a significant effect on water based recreational use. Changes in river flow rates and depths influence the types of recreation that can be supported and the quality of the recreation experience. The most difficult part of estimating the recreational impacts from changes in instream flows is estimating changes in visitation that are likely to occur as a result of changing water velocities and depths. This analysis relied heavily on an analysis of recreation activities associated with instream flows published by the U.S. Fish and Wildlife Service (1978) to evaluate the effect of varying instream flows on river recreation activity.

Changes in recreational use associated with changes in instream flows do have an impact on the local economy and do influence the benefits of river based recreation. The regional economic impacts from recreation expenditures are fundamentally different than the benefits from recreation. Benefits represent the value of recreation activities to participants while regional impacts represent the influence of recreation activities on sales, income, and employment in the region. Both the regional impacts and recreational benefits from changes in instream flows in the Red River of the North and the Sheyenne River are estimated in this analysis. Regional impacts were estimated using the U.S. Forest Service IMPLAN (IMpact analysis for PLANning) model (1993) and recreational expenditure data collected by the North Dakota Parks and Recreation Department (NDPRD). The economic benefits from changes in river recreation are based on a recreation travel cost model for six North Dakota rivers, which included the Red River of the North and the Sheyenne River (Piper 1998).

Current levels of recreation use were estimated for the Red River of the North and the Sheyenne River using NDPRD survey data (1997). Use was separated by type of activity and location of use along the rivers. The estimated changes in use due to changes in river flows were based on the probabilities of recreating at various water depths and velocities for different types of activities. The changes in probabilities were converted into changes in river recreation trips. Using average recreation expenditure data from the NDPRD survey, the increase in recreation related expenditures resulting from instream flow changes were estimated. These expenditure data were then used to estimate regional impacts. Last, the benefits from increased river recreation visits as a result of potential instream flow changes were estimated. The evaluation compared not only the management of the rivers to the aquatic life maintenance seasonal instream flow regime flows but also the Modified Habitat Preference Method instream flow regime (see Table 3, Instream Flow Needs Assessment).

Water Based Recreational Activities

The NDPRD collected information on river-related recreation activities by river location and type of activity, river recreation-related expenditures, the importance of river recreation compared to other types of recreation and public services, and the benefits of North Dakota river recreation. Recreation use was separated in the survey by river and type of use. As a result, the NDPRD survey provides sufficient data for estimating the total number of recreation activity days[1] and trips for individual North Dakota rivers.

The survey sample was designed to be representative of the entire North Dakota adult population, including both river recreators and nonrecreators. Therefore, the sample data can be used to estimate total North Dakota river recreation use and use by river. Based on the survey results and an estimated 1996 North Dakota population of 643,500 people, about 265,800 North Dakota residents (including adults and children) participated in North Dakota river recreation in 1996, and there were approximately 3.5 million North Dakota river recreation visits in 1996 by North Dakota residents. About 20.2 percent of all river recreation visits were to Red River of the North sites and 5.6 percent were to Sheyenne River sites, representing 711,400 recreation visits to the Red River of the North and 197,200 visits to the Sheyenne River.

Many different types of recreation were included in the recreation survey, including: sightseeing, hiking, canoeing, fishing, picnicking, camping, hunting, walking, and others. Table J-1 displays the distribution of recreation activities on the Red River of the North and the Sheyenne River.

A wide variety of recreation activities were included in the survey. However, not all activities may be affected by changes in river flows. Only water contact types of recreation are included in this analysis of recreation impacts from changes in river flows. It is assumed that recommended changes in flows will not be severe enough to affect activities such as hiking, camping, hunting, and other non-water contact activities. The types of recreation included in this analysis are: canoeing, fishing, boating (which includes jetskiing), and swimming. It is assumed that one-half of the fishing is from the shore and the other half is from a boat. It is also assumed that one-half of the boating is low-power boating and one-half is nonmotorized boating. Using the percentages presented in Table J-1, the level of water-based river recreation use in the study area is presented in Table J-2.

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[1] An activity day represents any period of time spent participating in an activity during any part of a day. An activity day could be represented by a short 30 minute hike or a full day 8 hour hike. Activity days and number of trips are not necessarily equivalent.

Table J-1. Recreation activities on the Red River of the North and Sheyenne River.

Activity	Red River of the North	Sheyenne River
Biking	17.34%	0.13%
Boating	1.25%	1.57%
Camping	0.81%	4.85%
Canoeing	0.76%	3.15%
Fishing	14.11%	14.02%
Hiking	3.81%	9.17%
Historical	1.03%	1.18%
Hunting	0.67%	11.14%
Ice fishing	1.16%	3.93%
Jet Skiing	0.31%	0%
Nature viewing	2.20%	7.08%
Off-road vehicles	0.31%	1.97%
Photography	3.00%	8.91%
Picnicking	4.84%	7.08%
Sightseeing	10.48%	12.32%
Sledding	2.20%	0.79%
Snowmobiling	9.95%	0.66%
Snow skiing	5.47%	1.83%
Swimming	0.18%	0.92%
Walking	16.76%	4.98%
Other	3.36%	4.33%

Table J-2. Current water-based recreation use on the Red River of the North and Sheyenne River.

Activity	Red River of the North Percentage of Recreation	Red River of the North Visits	Sheyenne River Percentage of Recreation	Sheyenne River Visits
Boating	1.56	11,100	1.57	3,100
Canoeing	0.76	5,400	3.15	6,200
Fishing	14.11	100,400	14.02	27,600
Swimming	0.18	1,300	0.92	1,800

Changes in Recreation Use

The visitation estimates presented in Table J-2 represent a base flow level of use. In order to evaluate the effect of changes in instream flows on recreation activity, recreation visitation at the Modified Habitat Preference Method and the aquatic life maintenance seasonal instream flow regime level must be estimated and compared to the base flow use (see Table 3, Instream Flow

Needs Assessment for Modified Habitat Preference Method and aquatic life maintenance seasonal instream flow regime flows).

The effect of changes in stream flows on recreational activities can vary a great deal depending on the type of activity under consideration. For example, flows associated with good canoeing conditions are likely to be much different than flows associated with good swimming conditions. The relationship between water depth, velocity, and recreation use must be estimated for each type of activity in order to estimate recreation use under different water flow scenarios.

The Aquatic Life Maintenance Flow Assessment provides base and aquatic life maintenance seasonal instream flow regime flows at nine different points along the Sheyenne River and seven points along the Red River of the North. The recreation use estimates presented in Table J-2 must be further dissaggregated into use that can be represented by each of the 16 separate points along the two rivers because the flow levels vary widely at each point. Recreation data from the NDPRD survey were used to determine the percentage of recreation attributable to each of the 16 points along the two rivers. Visitation was attributed to the river flow point closest to the origin of the recreator. For example, Red River of the North recreation participants who originated in Fargo were assumed to recreate at flow levels measured at the Red River of the North sample site near Fargo. This was done for both rivers and for all four activities. Table J-3 displays the percentage of use attributed to each site and Table J-4 displays visitation attributed to each site. It needs to be emphasized that a zero (0) does not mean that a specific type of recreation does not take place at a particular site. The percentages are used to determine what flows are used to estimate changes in recreation based on the best available data from the NDPRD survey.

Visitation estimates represent a base flow level of use. In order to evaluate the effect of changes in instream flows on recreation activity, recreation visitation at the Modified Habitat Preference Method flow level, and the aquatic life maintenance seasonal instream flow regime level were estimated and compared to the base flow use (Tables J-5 and J-6). The effect of changes in streamflows on recreational activities can vary a great deal depending on the type of activity under consideration. Using the base conditions and the U.S. Fish and Wildlife Service's report (1978), the probabilities at each stream measurement location (instream flow study sites) were calculated and current levels of use at each measurement location were correlated with the calculated probabilities. The probabilities were then calculated at each measurement location for flow regime stream depths and velocities (generated through the Aquatic Life Maintenance Flow Needs Assessment: see Appendix F - Summary Sheets). The change in probabilities were then used to estimate a proportional change in recreational use.

It should be recognized that the U.S. Fish and Wildlife Service study is a generalization of the response of recreation participants to changes in stream conditions. Different streams have different characteristics which could have a more important impact on recreation use than water depth and velocity. However, without site specific recreation data covering a variety of instream flow conditions, a more site specific analysis cannot be completed.

Table J-3. The percentage of recreation attributed to each aquatic life maintenance seasonal instream flow regime flow analysis site.

Sample point	Fishing	Canoeing	Boating	Swimming
Red River of the North				
Wahpeton	3.8%	0%	0%	0%
Fargo	45.2%	94.1%	5.5%	50%
Halstad, MN	2.1%	5.9%	11.1%	0%
Grand Forks	43.0%	0%	66.7%	50%
Drayton	1.6%	0%	16.7%	0%
Emerson, Manitoba	4.3%	0%	0%	0%
Sheyenne River				
Harvey	12.3%	0%	0%	0%
Warwick	6.2%	41.7%	11.1%	0%
Cooperstown	1.3%	4.2%	0%	0%
Baldhill Dam	0%	0%	33.3%	0%
Valley City	0%	12.5%	22.2%	100%
Lisbon	2.5%	8.3%	11.2%	0%
Kindred	0%	4.2%	0%	0%
Horace	12.3%	20.8%	22.2%	0%
West Fargo	65.4%	8.3%	0%	0%

Table J-4. Recreation use attributed to each aquatic life maintenance seasonal instream flow regime analysis site.

Sample point	Fishing	Canoeing	Boating	Swimming
Red River of the North				
Wahpeton	3,800	0	0	0
Fargo	45,400	5,100	600	650
Halstad, MN	2,100	300	1,200	0
Grand Forks	43,200	0	7,400	650
Drayton	1,600	0	1,900	0
Emerson, Manitoba	4,300	0	0	0
Sheyenne River	3,400	0	0	0
Harvey	1,700	2,600	350	0
Warwick	400	250	0	0
Cooperstown	0	0	1,000	0
Baldhill Dam	0	800	700	1,800
Valley City	700	500	350	0
Lisbon	0	250	0	0
Kindred	3,400	1,300	700	0
Horace	18,000	500	0	0
West Fargo				

Estimated visitation under the base condition (Average Flow Visitation), Modified Habitat Preference Method (Modified Habitat Preference Method Flow Visitation), and Aquatic Life Maintenance Seasonal Instream Flow Regime flows (Aquatic Life Maintenance Seasonal Instream flow Regime Flow Visitation) are presented in Tables J-5 and J-6.

This analysis indicates that the aquatic life maintenance seasonal instream flow regime would have essentially no impact on river recreation (an increase of 320 visits annually) and would result in no river recreation related regional economic impacts and no recreation benefits. The Modified Habitat Preference Method flow regime would increase river recreation by about 2,640 visits annually on the Red River of the North and by about 2,940 visits annually on the Sheyenne River. This amounts to a 2.23 percent increase in visitation for the Red River of the North, a 7.60 percent increase for the Sheyenne River, and a 3.56 percent increase overall.

Although the projected percentage increase in total visitation resulting from the Modified Habitat Preference Method flows analyzed is relatively small, the impact on the local economy could be significant.

Regional Economic Impacts and Benefits from Changes in River Recreation

As previously stated, this analysis indicates that the aquatic life maintenance seasonal instream flow regime would have essentially no impact on river recreation (an increase of 320 visits annually) and would result in no river recreation related regional economic impacts and no recreation benefits.

The regional impacts from changes in recreation with the Modified Habitat Preference Method flows were estimated using the projected change in recreation visitation presented above, expenditure data from the NDPRD (1997), and the U. S. Forest Service IMPLAN model (1993). The NDPRD survey provided estimates of expenditures per activity day. These expenditures were converted into expenditures per trip and multiplied by the change in visitation to estimate the total change in recreation expenditures resulting from changing instream flows. The estimated changes in expenditures by type of spending are presented in Table J-7.

The recreation expenditures per activity day and per trip presented in Table J-7 are representative of all types of river-related recreation (such as the activities presented in Table J-1) rather than just for water contact types of recreation. As a result, actual recreation expenditures may be higher or lower than the expenditures estimated in Table J-7, but more detailed estimates are not available.

The change in expenditures were input by category into the IMPLAN model. The regional economic impacts presented in this analysis from changes in recreation spending are limited to the Sheyenne River-Red River of the North study area. The geographic area represented by the model includes the following North Dakota counties: Barnes, Cass, Cavalier, Grand Forks, Griggs, Nelson, Pembina, Ransom, Richland, Sargent, Steele, Traill, and Walsh. Based on the

Table J-5. Average Flow, Modified Habitat Preference Method Flow, and Aquatic Life Maintenance Seasonal Instream Flow Regime Visitation Estimates for the Red River of the North.

Location/Activity	Average Flow Visitation	Modified Habitat Preference Method Flow Visitation	Aquatic Life Maintenance Seasonal Instream Flow Regime Flow Visitation
Red River of the North			
Near Wahpeton, ND			
Fishing	3,800	3,800	3,420
Total	**3,800**	**3,800**	**3,420**
Near Fargo, ND			
Fishing	45,400	48,500	45,400
Canoeing	5,100	5,100	5,100
Boating	600	590	600
Swimming	650	650	650
Total	**51,750**	**54,840**	**51,750**
Near Halstad, MN			
Fishing	2,100	2,100	2,100
Canoeing	300	300	300
Boating	1,200	1,200	1,200
Total	**3,600**	**3,600**	**3,600**
Near Grand Forks, ND			
Fishing	43,200	43,200	43,200
Boating	7,400	6,950	6,950
Swimming	650	650	650
Total	**51,250**	**50,800**	**50,800**
Near Drayton, ND			
Fishing	1,600	1,600	1,600
Boating	1,900	1,900	1,900
Total	**3,500**	**3,500**	**3,500**
Near Emerson, Manitoba, Canada			
Fishing	4,300	4,300	4,300
Total	**4,300**	**4,300**	**4,300**
TOTALS	**118,200**	**120,840**	**117,370**

Table J-6. Average Flow, Modified Habitat Preference Method Flow, and Aquatic Life Maintenance Seasonal Instream Flow Regime Visitation Estimates for the Sheyenne River.

Location/Activity	Average Flow Visitation	Modified Habitat Preference Method Flow Visitation	Aquatic Life Maintenance Seasonal Instream Flow Regime Flow Visitation
Sheyenne River			
Near Harvey/Warwick, ND			
Fishing	5,100	5,050	5,200
Canoeing	2,600	3,250	2,600
Boating	350	650	350
Total	**8,050**	**8,950**	**8,150**
Near Cooperstown, ND			
Fishing	400	380	400
Canoeing	250	240	230
Total	**650**	**620**	**630**
Near Baldhill Dam, ND			
Boating	1,000	1,950	980
Total	**1,000**	**1,950**	**980**
Near Valley City, ND			
Canoeing	800	1,050	800
Boating	700	800	700
Swimming	1,800	1,800	1,800
Total	**3,300**	**3,650**	**3,300**
Near Lisbon, ND			
Fishing	700	700	710
Canoeing	500	560	490
Boating	350	350	330
Total	**1,550**	**1,610**	**1,530**
Near Kindred, ND			
Canoeing	250	250	250
Total	**250**	**250**	**250**
Near Horace, ND			
Fishing	3,400	3,800	3,650
Canoeing	1,300	1,300	1,300
Boating	700	710	810
Total	**5,400**	**5,810**	**5,760**
Near West Fargo, ND			
Fishing	18,000	18,300	18,100
Canoeing	500	500	500
Total	**18,500**	**18,800**	**18,600**
TOTALS	**38,050**	**41,640**	**39,200**

Table J-7. Estimated annual change in recreation spending with the modified habitat preference method flows.

Expenditure Category	Expenditure per Activity Day	Expenditure per Visit	Change in Visitation	Change in Recreation Spending
Food and beverages	$7.35	$7.75	5,580	$43,200
Lodging	$1.74	$1.83	5,580	$10,200
Transportation	$7.67	$8.08	5,580	$45,100
Camera, film, developing	$1.27	$1.34	5,580	$7,500
Boat launching fees	$0.27	$0.28	5,580	$1,560
Bait	$1.11	$1.17	5,580	$6,500
Campsite fees	$1.47	$1.55	5,580	$8,650
Equipment rental	$0.20	$0.21	5,580	$1,170
Other	$3.30	$3.48	5,580	$19,400
Total	**$24.38**	**$25.69**	**5,580**	**$143,280**

expenditure information presented in Table J-7, the value of the change in total output in the study region due to changes with the modified habitat preference method flows would amount to about $167,300 annually. The impact on income would be valued at $92,400 annually and employment impacts are estimated to be four jobs.

Economic Benefits from Changes in River Recreation

The benefits from river recreation represent the value of recreation activities to participants. Benefits can result from increased recreation opportunities through new facilities or improved access or benefits can result from improved resource conditions that enhance the recreation experience. In this analysis, improved conditions resulting from changes in instream flows would translate into increased visitation. Therefore, benefits can be measured by multiplying the estimated increase in visitation times the value of a recreation visit.

Estimates of the benefits from river recreation for all of North Dakota have been estimated in a previous analysis using the NDPRD data (Piper, 1998). The benefits were estimated in the analysis using a regional travel cost model, where distance traveled combined with the time and out-of-pocket costs of travel are used as a proxy for the variable cost of river recreation. Although the benefits represent the average benefit for a river recreation trip in North Dakota and are not specific to the Red River of the North and the Sheyenne River, more site and activity specific recreation benefit estimates are not available.

The average benefit for river recreation in North Dakota was estimated to be $32.50 per visit (Piper 1998). The number of river recreation visits with the modified habitat preference method flows were estimated to increase by 5,580 visits. As a result, the recreational benefits from modified habitat preference method flows are estimated to be $181,350 annually.

Summary

This analysis has presented estimates of the change in recreation visits on the Red River of the North and the Sheyenne River resulting from the implementation of Modified Habitat Preference Method flows and Aquatic Life Maintenance Seasonal Instream Flow Regime flows, the regional economic impacts that could be expected from the change in visitation, and the benefits from increased river recreation. Estimates of current water contact recreation use are 118,200 visits on the Red River of the North and 38,700 visits on the Sheyenne River. Visitation is estimated to increase by 5,580 visits annually with the Modified Habitat Preference Method flows in both rivers, resulting in increased recreation expenditures of $143,280 annually. The increase in recreational spending would increase the value of total output in the Red River Valley by about $167,300 annually and would generate about $92,400 in additional income each year. The benefits from increased recreation are estimated to be $181,350 annually. The Aquatic Life Maintenance Seasonal Instream Flow Regime flows would have no significant impact on recreation visitation or expenditures.

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APPENDIX K

LEGAL AND INSTITUTIONAL ANALYSIS OF STATE WATER LAW

RED RIVER VALLEY WATER NEEDS ASSESSMENT

PHASE 1B

INSTREAM FLOW NEEDS ASSESSMENT

LEGAL AND INSTITUTIONAL ANALYSIS OF STATE WATER LAW

FOR THE

INSTREAM FLOW NEEDS ASSESSMENT

A legal and institutional analysis of State Water Law was conducted to identify legal and institutional instream flow related opportunities and needs for the Sheyenne River and the Red River of the North, North Dakota and Minnesota. The analysis emphasized North Dakota Water Law. The analysis is an update to Nelson et al. (1978). In Nelson et al. (1978), the U.S. Fish and Wildlife Service's Biological Services Program identified and evaluated the most promising institutional methods for reserving instream flows to benefit fish and wildlife in North Dakota. The text dealing with legal issues associated with the protection of North Dakota instream flows was taken from several sources, but primarily from Krenz (1998), Delmore (1997), Sagsveen (1977), and supplemented by other information provided by staff of the North Dakota State Water Commission as well as information posted on the North Dakota Water Law web site.

In a 1986 survey of the United States and Canadian provinces, Reiser et al. (1989) identified legislation protecting instream flow in 16 States, 12 of which were west of or along the 100th meridian. Instream flow regulations in the Western States have more recently been reviewed by McKinney and Taylor (1988) and MacDonnell et al. (1989). Thirteen of the States have specifically designated recreation as a legitimate reason for protecting instream flows (i.e., beneficial use). Only six (6) of the States allow for protection of instream flows for aesthetic or scenic reasons. However, several of the States allow instream flow rights to protect water quality as a way of protecting aesthetic quality. In several states, natural resource department personnel consider water quality protection to be the means for preserving aesthetic quality of riverine areas (Shelby et al. 1982). Aquatic life, water quality, and recreation are directly benefitted by the designation of other uses as a "beneficial use." In California, the State's granting and regulation of permits and licenses, water quality management, and application of the public trust doctrine all offer opportunities that sometimes have the effect of protecting instream flows (Gray 1989).

The traditional requirements for a valid water claim in the West include: (1) intent to apply the water to a beneficial use, (2) actual diversion of water from a naturally occurring water body, and (3) application of the water to a beneficial use within a reasonable time. The designation of "beneficial use" water rights for preserving fish and wildlife habitat, water quality, or for maintaining riverine resources for recreational use has not been the primary impediment to instream flow regulations (Shelby et al. 1982). The difficultly most often encountered is the traditional requirement that water be diverted from natural water courses in order to establish a water right under the Prior Appropriation doctrine (Tarlock 1978, 1979). The appropriation doctrine emphasizes diversion under the principles of beneficial use and "first in time" being "first in right."

North Dakota Water Law

Section 3 of Article XI of the North Dakota Constitution states, “All flowing streams and natural water courses shall forever remain the property of the state for mining, irrigating and manufacturing purposes.” The appropriation of water in the State of North Dakota is by statute the responsibility of the State Engineer. Chapter 61-04 of the North Dakota Century Code (N.D.C.C.) addresses the appropriation of water in the State. The State Engineer has adopted rules contained in Chapters 89-03-01, 89-03-02, and 89-03-03 of the North Dakota Administrative Code. The manner in which hearings are conducted by the State Engineer pursuant to the provisions of Chapter 61-04 are bound by Chapter 28-32 of the N.D.C.C., more commonly known as the Administrative Agencies Practice Act.

N.D.C.C. § 61-28-02(11) defines waters of the state as: “all waters within the jurisdiction of this state including all streams, lakes, ponds, impounding reservoirs, marshes, watercourses, waterways, and all other bodies or accumulations of water on or under the surface of the earth, natural or artificial, public or private, situated wholly or partly within or bordering upon the state, except those private waters that do not combine or effect a junction with natural surface or underground waters just defined.”

N.D.C.C. § 61-04-01.1 defines beneficial use as: “a use of water for a purpose consistent with the best interests of the people of the state.”

N.D.C.C. § 61-04-01.1 defines fish, wildlife, and recreation use as: “the use of water for the purposes of propagating and sustaining fish and wildlife resources and for the development and maintenance of water areas necessary for outdoor recreation activities.”

Chapter 61-04-01.2 requires that a right to appropriate water can be acquired for beneficial use only as provided in Chapter 61-04 (Appropriation of Water). Beneficial use shall be the basis, the measure, and the limit of the right to the use of water.

Chapter 61-04 requires that an appropriation of water involve an actual diversion and works before a water permit may be issued. The legislature has not provided a mechanism for the issuance of water permits specifically for the preservation of a naturally occurring instream flow. However, under existing state law, a water permit can be issued for a project to divert or store water and release it to maintain an instream flow. The existing water permit issued for the Garrison Diversion Project allows project water to be delivered to satisfy instream flow needs and the water is protected from downstream diversion under existing state law.

N.D.C.C § 61-04-06 (emphasis added below) lists the factors the State Engineer must consider in making a determination about whether to issue a water permit. That section provides, in part:

The State Engineer shall issue a permit if the state engineer finds all of the following:

1. The rights of a prior appropriator will not be unduly affected.
2. The proposed means of diversion or construction are adequate.
3. The proposed use of water is beneficial.
4. The proposed appropriation is in the public interest. In determining the public interest, the State Engineer shall consider all of the following:
    a. The benefit to the applicant resulting from the proposed appropriation.
    b. The effect of the economic activity resulting from the proposed appropriation.
    c. The effect on fish and game resources and public recreational opportunities.
    d. The effect of loss of alternate uses of water that might be made within a reasonable time if not precluded or hindered by the proposed appropriation.
    e. Harm to other persons resulting from the proposed appropriation.
    f. The intent and ability of the applicant to complete the appropriation.

There are six factors the State Engineer must consider when determining whether a proposed appropriation is in the public interest (4.a.-f. above). The six factors are considered and the determination of public interest is a judgment decision made by the State Engineer. One of the six factors the State Engineer must consider is the effect on fish and game resources and public recreational opportunities (4.c.). This is the avenue through which impacts to aquatic resources are considered in the existing appropriation process.

Chapter 28-32 specifies that the decision must be based on information introduced into the hearing record. Section 89-03-01-06.3 identifies a list of data commonly used in evaluating permit applications which, unless specifically excluded by the hearing officer, are automatically included in the hearing record, and all parties attending the hearing are informed that this information has been taken into the record. Section 89-03-01-06.1 outlines the procedure to be used by the State Engineer to consider additional information not made a part of the record during the hearing process.

When there are competing applications for water from the same source, and the source is insufficient to supply all applicants, the State Engineer shall adhere to the following order of priority (N.D.C.C. § 61-04-06.1 Preference in granting permits):

1. Domestic use.
2. Municipal use.
3. Livestock use.
4. Irrigation use.
5. Industrial use.
6. Fish, wildlife, and other outdoor recreational uses.

In determining whether the proposed appropriation is in the public interest, the State Engineer must evaluate each of the items listed above in N.D.C.C. § 61-04-06.2 (4.a.-f.). If, when evaluated and balanced with the other factors, the State Engineer determines that the potential effect on fish and game resources or public recreational opportunities would be detrimental, and on a whole that the public interest would not be served by issuance of a water permit, the State Engineer could deny the permit, or could issue the permit with conditions to protect fish and game resources or public recreational opportunities. Such a condition could require, if supported by the evidence, the requirement that water may be diverted from a stream or lake only when flows exceed a certain level. If an applicant requests a permit to impound water, a condition could be added to require releases to be made to augment flows. The determination of what elements of the public interest are impacted, and what the public interest requires is committed to the sound discretion of the State Engineers. Shokal v. Dunn, 707 p. 2d 441 (1985).

Reservations of Water

N.D.C.C. § 61-04-31 contains a procedure where, through the adoption of rules, the State Engineer may establish a moratorium on the withdrawal of water, thereby in effect protecting existing instream flows. This section provides:

1. Whenever it appears necessary to the State Engineer, or when so directed by the State Water Commission, the State Engineer may by regulation:
    a. Reserve and set aside waters for beneficial utilization in the future; and
    b. When sufficient information and data are lacking to allow for the making of sound decisions, withdraw various waters of the state from additional appropriations until such data and information are available.
2. Prior to the adoption of a regulation under this section, the State Engineer shall conduct a public hearing in each county in which waters relating to the regulation are located. The public hearing shall be preceded by a notice placed in a newspaper of general circulation published within each of the counties.
3. Regulations adopted hereunder shall be subject to Chapter 28-32.

The legislative history to N.D.C.C. § 61-04-31 provides "[t]he recent drought has emphasized that certain streams may not have unappropriated water available for further beneficial use. It is the State Engineer's opinion that he should be authorized to place a moratorium on further appropriations in streams having limited or no unappropriated water available." Hearing on S. 2062 Before the Senate Comm. on Natural Resources, 45th N.D. Leg. (January 13, 1977) (Testimony of Murray Sagsveen, Counsel, State Water Commission).

This section may not provide much protection if a reservation can only be made where little or no unappropriated water exists. Reservations cannot affect senior rights, and if little or no water is available for appropriation at the time the reservation is made, there may not be sufficient water to support fish and wildlife. In addition, reservations do not create vested property rights and are subject to administrative decisions to lift or remove the reservation and allow unappropriated water to be appropriated.

There are five streams in North Dakota for which conditional water permit applications are not accepted. The North Dakota State Water Commission voted in 1960 to place a moratorium on the issuance of additional water permits on the mainstems of Apple and Cedar Creeks and the Green, Cannonball, and Grand rivers. A review of State Water Commission meeting minutes reveals that the moratoriums resulted from concerns with low flows being experienced at the time. This occurred during a drought period, and it appears from the minutes that no analysis was conducted to assess the level of appropriation. These moratoriums are still in effect today.

These five streams are the only bodies of water for which a moratorium has been placed on the issuance of new conditional water permits. There have been other instances where applications have been denied because there would have been sufficient water available only on an infrequent basis. In these instances, the State Engineer judged that, due to the inadequacy of the water supply during most years, it was not in the public interest to issue a permit. This does not mean that new applications are not accepted for these streams; applications are accepted and evaluated on their specific merits.

Applications for water from ground water sources are processed and evaluated in the same manner as those for surface water sources. In instances where a ground water appropriation may impact a surface water supply, the evaluation process takes the potential interaction into account. In some instances, if a ground water withdrawal would have a significant adverse impact on a senior appropriator on a surface water source, the application could be denied. In some instances, however, the ground water contribution to a stream is regarded as an inefficient capture system. In such cases, permits for the withdrawal of water from a stream to which aquifer discharges have been conditioned so that their right to withdraw water from the stream shall not restrict development of the ground water source. In these instances, the benefit of developing the greater resources of the ground water system is determined to be superior to the benefit derived from the maintenance of the ground water discharge to the surface water system.

The authority of the State Engineer to enforce the water appropriation laws are explained in Section 61-04-29. This section provides that the State Engineer has the authority to enjoin the unauthorized use of water or issue orders as necessary to administer the provisions of Chapter 61-04. Section 61-04-30 provides that any person who uses a significant quantity of water without a permit or violates the terms of their permit or an order of the State Engineer is guilty of a Class A misdemeanor. Section 61-04-32 provides that a water permit holder who has their water supply illegally diminished is entitled to damages sufficient to cover the cost of alternatives necessary to ensure the delivery of the permitted quantity and quality of water.

Water Permits for Instream Flows Associated with the Construction of Works

The use of water for fish, wildlife, and recreation is considered a beneficial use of water. The State Engineer can issue water permits for such uses provided there is a diversion of the water. An applicant for a water right could specifically receive the right to impound water in a reservoir or dam for the purpose of making releases of the water impounded to augment stream flows. The water released would be protected from appropriation by others.

Attorney General Opinions/Judicial Opinions

The authority to establish or protect instream or minimum flows is authority granted by the legislature to a specific entity such as a state agency. The Attorney General cannot establish or protect instream or minimum flows through the issuance of an opinion but could issue an opinion on whether the authority exists for an agency of the state to establish or protect instream flows. The Attorney General has not issued an opinion on this issue.

A requirement for an instream flow can be established judicially. There are decisions in other jurisdictions that impose the public trust doctrine in the area of water rights to protect instream flows. Beck, Waters and Water Rights § 14-03 (c) (4) (C). The North Dakota Supreme Court has applied the public trust to water rights, but the ruling is extremely limited. See United Plainsmen v. North Dakota State Water Conservation Comm., 247 N.W. 2d 457 (N.D. 1976). The decision only requires study and planning in the allocation of water resources to determine the effects of allocation on present water supplies and future water needs.

In the early 1980's, the State Water Commission and State Engineer brought a lawsuit to stop the draining of Rush Lake, a meandered non-navigable body of water. The state claimed that the construction of drains and dikes built by a landowner substantially diminished the lake and threatened to totally destroy it. The North Dakota Supreme Court held that protecting the integrity of the waters of the State is a valid exercise of the State Water Commission’s duties pursuant to N.D.C.C. § 61-02-14, as well as being part of the state’s affirmative duty under the “public trust” doctrine. North Dakota State Water Com’n v. Board of Managers, 332 N.W. 2d 254, (N.D. 1983). The court allowed the draining to take place, however, because the state had tacitly approved the draining by being involved in resolving the disputes over the draining. This case provides authority for the State Water Commission to establish levels necessary to protect the integrity of the state’s waters. That authority may be limited to instances where permits have not already been issued.

Instream Flow and Water Quality

Where instream flows affect water quality and are impacted by man-induced activity, the North Dakota Health Department appears to have some authority over the flow itself. N.D.C.C. § 61-28-02(7) defines pollution as: “the manmade or man-induced alteration of the physical, chemical, biological, or radiological integrity of any waters of the state.” Where human activity directly impacts stream flows such as to change dissolved oxygen levels for water temperature in a manner which could affect aquatic life the Department has authority and has exercised such authority in the past. In a letter to the U.S. Army Corps of Engineers on February 22, 1995, the Department indicated that Federal activity which could change the temperature of the thermocline and result in the reduction of water quality may come within Department enforcement authority.

Legislation

A number of states have enacted laws allowing the acquisition of instream rights. The right of appropriation for preservation of instream flows is generally a public right. Waters at § 14.03 (c) (4) (C). Legislation can be introduced by either a state agency or a legislator.

Another method to protect instream flows is by the adoption of legislation that preserves natural flows in certain named bodies of water. The legislative assembly enacted N.D.C.C. ch. 61-29, which is known as Little Missouri State Scenic River Act. Its purpose is to preserve the Little Missouri River in a free-flowing natural condition. N.D.C.C. § 61-29-06 prohibits channelization, reservoir construction, or diversion, other than for agricultural or recreational purposes, and dredging within the confines of the river and tributary streams of the river. Riparian landowners are not prohibited from using the river for domestic or livestock water purposes.

State Water Commission Internal Policies

The information presented below was derived from the North Dakota Water Law web site. This material was obtained from a working draft of internal State Water Commission policies dated October 1, 1998.

The 1999 State Water Management Plan is a comprehensive vision for water management for the 21st Century. It provides a vision in which water is used efficiently and is allocated through laws that conform to the prior appropriation doctrine. State Water Plan recommendations are directed toward the improved management and utilization of the State's water resources. The State Water Commission has produced a working draft of policy input from the public involvement process as of August 11, 1998, which includes the following recommendation pertaining to instream flows:

"It is recommended that the State Water Commission determine if it is in the public interest to seek appropriate waters in the state for instream flow purposes, insofar as those waters do not impede on prior appropriations".

The following comment accompanies the above recommendation: "Instream flows protect many non-consumptive uses such as fish and wildlife habitat, aquatic life, recreation, aesthetic beauty, transportation, navigation, hydropower and water quality. Many of these uses have direct effects on the economy while others represent intangible values, and the public interest. The state engineer has no authority to directly establish minimum stream flows through the appropriation process due to the necessity of works or construction of works required by the North Dakota Administrative Code 89-03-01-07. For future interest, a requirement for an instream flow, however, could be established judicially. The state engineer could establish a base line stream flow to protect the integrity of the state's water pursuant to NDCC 61-02-14, and under the public trust doctrine. However, due the implied references to prior appropriations in such cases, the authority for such action may be limited".

"The State Water Commission could support efforts to obtain storage and natural flow rights to improve and maintain instream flows when in the public interest. The NDCC could be expanded to enable the State Water Commission to transfer acquired water rights to instream flow water rights. By law similar provisions are made to protect other water users and the agricultural base of an area. The state does, to a very limited extent, preserve natural flow levels on the Little Missouri River, NDCC 61-29 and 61-29-06 as part of the Little Missouri State Scenic River Act".

Federal Authority

There are several Federal laws that may create requirements for instream flows. The following identified Federal laws are not intended to be exclusive. There may be other Federal laws and authorities, such as laws requiring Federal permits or licenses or laws governing public land management decisions, that provide opportunities to protect instream flows.

(1) The Endangered Species Act: The designation of streams or lakes as critical habitat for endangered species often results in protection of stream flows or minimum flows because there must be a sufficient quantity of water available to maintain water quality standards needed for the habitat to survive.

(2) The Clean Water Act: The Clean Water Act has been construed by the United States Supreme Court to allow the imposition of a minimum flow requirement in § 401 certifications. Section 401 requires states to provide a certification that state water quality requirements will be met if a federal license or permit is issued for any activity resulting in a discharge into navigable waters. The United States Supreme Court held that the Clean Water Act is not just concerned with water quality, but also issues of quantity that may affect quality. PUD No. 1 of Jefferson County v. Washington Dep't of Ecology, 114 S. Ct. 1900 (1994). Section 401 certifications are required when Section 404 permits are issued.

(3) Federal Reserved Water Rights: When the United States withdraws land from the public domain and reserves it for a Federal purpose, appurtenant water then unappropriated is implicitly reserved to the extent necessary to accomplish the purposes of the reservation. United States v. New Mexico 426 U.S. 696, 699-700 (1978). Courts have recognized implied federal reserved water rights for varied federal reservations, including national forests, monuments, parks, recreation areas, wildlife refuges, and Indian reservations. United States v. Jesse, 744 P.2d 491, 494 (Co. 1987). The status of reserved rights for wilderness areas is unsettled. The reserved water rights doctrine is construed narrowly

and the right includes "only that amount of water necessary to fulfill the purpose of the reservation, [and] not more." Cappaert v. United States 426 U.S. 128, 141 (1976). For example, the United States' claims for reserved water rights in national forests for recreational, scenic, or wildlife values and stock watering have been denied because the purposes of the reservation of national forests were to secure favorable conditions of water flows and to furnish a continuous supply of timber for the use and necessities of the people. United States v. New Mexico, 426 U.S. 696.

(4) National Wild and Scenic Rivers Act: The National Wild and Scenic Rivers Act seeks to preserve unique stream in free-flowing conditions. It establishes a procedure by which rivers may be recommended for inclusion, studies, and eventually listed under the wild and scenic rivers system. The Wild and Scenic Rivers Act specifically provides that the designation of any stream or portion of a stream as a national wild, scenic or recreational river "shall not be construed as a reservation of the waters of such stream for purposes other than those specified in this chapter, or in quantities greater than necessary to accomplish these purposes". 16 USCA 1284 (c).

Arguably, although stated in the negative, this language establishes a reserved right to water in a river corridor to meet its specific flow needs and the purposes of the Act, which are to maintain the inherent values of river flows and allow rivers to flow freely for the benefit and enjoyment of the public. 16 USCA § 1271. This is a non-consumptive reservation of water. Generally, reserved water rights have a priority date based on the date Congress reserves land. With a river designation, no land is being reserved, however, if a reserved right is created, the priority date would likely be the date Congress makes the designation. Vested rights prior to the date of creation generally would not be affected. The Act does contain language indicating that vested water rights may be condemned. 16 USCA § 1284(b) provides that "any taking by the United States of a water right which is vested under either State of Federal law at the time such river is included in the national wild and scenic rivers system shall entitle the owner thereof to just compensation."

(5) The Fish and Wildlife Coordination Act: Although we are not aware of this Act being used to establish instream flows, it does require that wildlife conservation be given equal consideration with other objectives of water resources development.

Minnesota Water Law

Minnesota Statute 103G.265 requires the Minnesota Department of Water Resources to manage water resources to ensure an adequate supply to meet long-range seasonal requirements for domestic, agricultural, fish and wildlife, recreational, power, navigation, and quality control purposes. The Water Appropriation Permit Program exists to balance competing management objectives that include both development and protection of Minnesota's water resources.

Water law in Minnesota is governed by riparian rights. Riparian water rights, or eastern water law, state that the owner of land containing a natural stream or abutting a stream is entitled to receive the natural flow of the stream limited only by the equal rights of the other riparian owners. The riparian owner is protected against the diversion of water except for domestic purposes upstream from his property and from the diversion of excess floodflows toward his property.

The Minnesota Department of Natural Resources has established minimum instream flows using a hydrologic method (i.e., 90 % exceedance flow) as a guideline. Using this method, the Minnesota Department of Natural Resources established a minimum instream flow for the Red River of the North of 38 cfs at Fargo, North Dakota.

State Treatments of a Previous Instream Flow Recommendation

The following was extracted from the Garrison Diversion Conservancy District, Instream Flow Needed for Aquatic Life White Paper prepared by Houston Engineering, Inc. (Houston Engineering, Inc. December 1997) and is presented here for informational purposes.

The Souris-Red-Rainy River Basin Commission (1972) recommended a *minimum* instream flow of 7 cubic feet per second (cfs) at Fargo, North Dakota, to provide a factor of safety for water needs and ensure that some minimal riverflow is maintained below each withdrawal point. The basic flow needs at each withdrawal point consist of the minimum base flow and the allocated withdrawals. The Souris-Red-Rainy River Basin Commission (1972) also suggested a target flow of 100 cfs at Fargo, North Dakota, to protect the fishery value of the river and to aid in waste assimilation.

Because the Red River of the North is a resource shared by the States of North Dakota and Minnesota, each State has been involved in recommending instream flows. As previously stated, the Minnesota Department of Natural Resources, which follows eastern water law, established a minimum instream flow for the Red River of the North of 38 cfs at Fargo, North Dakota.

As previously stated, the North Dakota State Water Commission, which follows western water law, considers instream flow needs during the issuance of water appropriation permits. The State Water Commission presently has no *legal* requirement for maintaining minimum instream flows. One proposal, using the Tennant Method (Tennant 1976), put forward by the North Dakota Game and Fish Department to the State Water Commission for instream flows within the Red River of the North at Wahpeton, North Dakota, during discussions of the ProGold appropriations permit (ProGold is a “value added” high fructose corn syrup processing plant, which began operations in 1997), consisted of the following:

- April - May — 551 cfs (100% of mean annual discharge)
- June - September — 220 cfs (40% of mean annual discharge)
- October - March — 110 cfs (20% of mean annual discharge)

Legal and Institutional Analysis Summary

It does appear that there are means and measures available in North Dakota Water Law to protect instream flows, whether it be by appropriations, judicially, acquisition and transfer, water quality enforcement mechanisms, or in the planning process. These means and measures should be further investigated in Phase II of the Red River Valley MR&I Water Needs Assessment. Minnesota appears to have a mechanism in place by which they can establish minimum instream flows. Minnesota Water Law should be further investigated in Phase II of the Red River Valley MR&I Water Needs Assessment.

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