SECTION 205 FEASIBILITY REPORT

ADA, MINNESOTA

WILD RICE AND MARSH RIVERS, MINNESOTA

APPENDIX A

HYDROLOGIC ANALYSIS

Appendix A. Hydrology

APPENDIX A. TABLE OF CONTENTS

List of Tables

List of Figures

Study Area

Location

The Wild Rice River Basin lies in the northwestern portion of Minnesota. The basin is located principally in Mahnomen and Norman Counties but includes a portion of Clearwater, Becker, and Clay Counties. The City of Ada is located in central Norman County, approximately 32 miles northeast of Moorhead, Minnesota. Ada lies approximately 2 miles north of the Wild Rice River, near the headwaters of the Marsh River, both of which are tributaries of the Red River of the North. Judicial Ditch 51 (JD 51) flows around the northern limits of the city, and provides an outlet for the city and agricultural lands north of the city, as well as occasional overflows from the Wild Rice River. JD 51 flows into the Marsh River 3 miles northwest of Ada. **Figure 1** shows the location of Ada, Minnesota.

The population of the community in 2000 was estimated at 1657. The community is principally engaged in agricultural-related business. The city is located very close to the 100-year floodplain.

Drainage Areas

Drainage basin divides in some places are indefinite because of the relatively flat land, numerous small lakes, and swamps with no channel or drainage courses shown on the maps. As a result, precise drainage area values are not available. Runoff from the upper one-third of the Wild Rice River Basin may be delayed because of the numerous small lakes and swamps in that area. During times of high flow, the discharges below the diversion do not represent flows originating on the drainage areas shown because of the diversion of part of the flow from the Wild Rice River to the Marsh River.

Drainage areas at pertinent locations are shown in **Table 1**. The drainage area upstream of the Wild Rice River at Ada is approximately 1050 square miles. The Marsh River drains an area of about 300 square miles and the Wild Rice River drainage area is about 1,650 square miles. At the point of diversion (42.8 river miles above the mouth of the Wild Rice River) the Wild Rice River drains an area of 1,090 square miles.

Table 1. Drainage Ares on Wild Rice and Marsh Rivers

Location	Drainage Area Square Miles
Wild Rice River @ Twin Valley	934
Wild Rice River @ diversion above Ada	1,090
Wild Rice River south of Ada	1,100
Wild Rice River @ Hendrum	1,560
Wild Rice River @ mouth	1,650
Marsh River near Shelly	220
Marsh River @ mouth	300

Topography

The topography of the Wild Rice River Basin above mile 55 and of the upper portion of the Marsh River Basin along Spring Creek is gently undulating to rugged. West of a north-south line crossing the Wild Rice River at about mile 43 lays an extremely flat plain. Between those two areas exists a transition composed of a series of sandy ridges. Elevations range from more than 1,500 (msl 1929 adj.) feet near the source of the Wild Rice River to 818 feet at the mouth of the Marsh River. Riverward slopes throughout the entire area above the plain are sufficient for adequate drainage but those in the lower reaches of the watershed are very flat and drainage is sluggish. About 94 percent of the area lying below the transition is under cultivation. The remainder includes municipalities, farmsteads, small wood lots, and roadways. The transition ridge area and the valleys in the upper portion of the basin contain substantial timber cover, and the upland area includes cultivation, scattered wood lots, and numerous small lakes. Nearly 60 percent of the upland area is under cultivation. **Figure 2** shows a map of the land use/land cover of the watershed.

The entire Wild Rice-Marsh River Basin has been modified by glacial action. The upper one third of the basin is covered by glacial drift containing numerous deposits of sand and gravel. Loam or silty loams comprise the generally light soils of the glacial drift area. Immediately downstream from the glacial drift area and covering the transitional area described above, exists a series of beach ridges formed by the old glacial Lake Agassiz during successively lower recessional stages. Throughout these ridges the soils contain much fine sand, classified generally as silty sand. The remainder of the watershed downstream form the ridges is a nearly flat lacustrine plain which was the bed of the glacial lake. Lacustrine deposits extend to great depths over this plain, particularly in the vicinity of the Red River of the North.

Streams

The Wild Rice River starts at Upper Rice Lake in Clearwater County. The normal elevation of this lake is 1,503 feet above mean sea level. About 20 miles downstream the Wild Rice River flows through Lower Rice Lake. The river then flows generally in a westerly direction until it joins the Red River of the North about 30 miles north of Moorhead, Minnesota. The total length of the river is about 185 miles. In the lower 50-mile reach, the river crosses the flat floor of the Red River Valley. The normal low water elevation of the Red River of the North at the junction with the Wild Rice River is 832 feet.

In the latter part of the 19th century, a 10-mile long ditch was constructed by local interests to divert a part of the Wild Rice River flood flows into the Marsh River. Before the diversion channel was constructed, the source of the Marsh River was in the low, flat terrain just south of Ada. That stream now heads about 3 miles east of Ada at the flow diversion structure on Marsh River Ditch. The ditch trends just north of Ada and generally westerly for about 10 miles to its junction with the Old Marsh River channel.

From this point the Marsh River flows northwesterly about 35 miles to its confluence with the Red River of the North about 15 miles north of the mouth of the Wild Rice River. **Figure 3** shows the stream and ditch network within the Wild Rice River Basin.

The principal tributaries of the Wild Rice River are the White Earth River (mile 99), Marsh Creek (mile 72), South branch Wild Rice River (mile 29.5), and Felton Ditch (mile 20.5) with drainage areas of 202, 154, 253, and 144 square miles, respectively. The principal tributary of the Marsh River is Spring Creek which has a drainage area of 135 square miles.

Climatology

Weather observations are currently being obtained by the National Weather Service (NWS) at three stations within the Wild Rice and Marsh River Basin, Mahnomen 1W, Twin Valley 3 SW, and Ada. At Mahnomen, daily precipitation records are available since August 1924 except for several months of no records in the early years. Temperature records are available since 1959. Hourly precipitation records have been obtained at or near Twin Valley since December 1940. At Ada, daily precipitation records are available for most of that period. Daily precipitation and temperatures are available at Beaulieu from 1900 until 1912, when the station was discontinued. Records of Beaulieu have been combined by the National Weather Service with records at Mahnomen, eight miles west of Beaulieu, in order to extend the period of Mahnomen records. Temperature and precipitation records obtained at Halstad, outside of the basin on the Red River of the North, from 1905, to 1916 have been combined with Ada records (14 miles southeast) by the National Weather Service in order to extend the length of the Ada records. Halstad was resumed as a precipitation station in 1956 (**reference 1 & 2).**

Temperature

The Wild Rice-Marsh River Basin has a continental climate which is characterized by extreme variations in temperature and moderate precipitation. Normal mean temperature for the basin is 40 degrees F and normal mean monthly temperatures vary from 70 degrees F in July to 5 degrees F in January. National Weather Service records show temperature extremes of 111 degrees at Ada on 6 July 1936 and -53 degrees F at Ada on 15 February 1936. **Table 2** summarizes temperature values for the National Weather Service station 220018 at Ada

The growing season between the last frost in the spring and the first frost in the fall averages 137 days at Ada. **Table 3** lists the length of the growing seasons.

Precipitation

Normal annual precipitation for the Wild Rice-Marsh River Basin averages about 24 inches, with greater precipitation in the eastern portion of the basin and slightly less in the western portion. The greatest annual precipitation observed was 33.39 inches at Ada in 1941, and the least observed was 10.25 inches at Mahnomen in 1936. Normal monthly precipitation for the basin ranges from a maximum of 4.3 inches in June to a minimum of 0.6 inch in February. Approximately 67 percent of the annual precipitation occurs during the 5-month growing season, May through September.

Up until the renowned June 2002 storm, the maximum 1-day rain was 5.83 inches on 07 August 1941. The maximum monthly rain was also in August of 1941 with 10.72 inches. The highest monthly rain may have been exceeded in June of 2002 based on unofficial estimates. As much as 10 inches fell during the 3-day storm of 9 to 11 June. According to the NWS, six or more inches of rain fell in less than twelve hours in northeastern Clay, southeastern Norman, and western Mahnomen counties. More than nine inches of rain was reported near Twin Valley in Norman County.

Less than two weeks later on 22 and 23 June rains exceeding four inches fell in an arc from already hard-hit Norman and Mahnomen counties, east to St. Louis County. Portions of Norman, Mahnomen, Becker, Clearwater, Itasca, and St. Louis counties reported more than six inches of rain in the two-day event. Rainfall amounts topping eight inches were observed in small areas of Mahnomen and St. Louis County. **Table 4** summarizes precipitation values for the NWS station 220018 at Ada.

Snowfall, which amounts to about 16 percent of the total annual precipitations, averages about 40 inches per year. The most snowfall occurred in the winter of 1996 – 1997 with 104 inches. **Table 5** lists snowfall averages and extremes for the period-of-record.

Table 2. Temperature Extremes and Summary, Ada, MN

	Temperature Summary NCDC Normals POR: 1971-2000			Temperature Extremes Period of Record: 1892-2001							
				High		Low		1-Day		1-Day	
Month	Max °F	Min °F	Mean °F	Mean°F	Year	Mean°F	Year	Max°F	Date	Min°F	Date
JAN	14.3	-5.4	4.5	20.9	1990	-8.3	1937	53	1/24/1981	-43	1/18/1994
FEB	21.4	2.3	11.9	27.3	1987	-12.4	1936	65	2/25/1958	-53	2/15/1936
MAR	34	16.3	25.2	38.4	1973	8.2	1893	78	3/30/1967	-39	3/10/1948
APR	53.1	31.3	42.2	52.1	1987	29	1893	100	4/21/1980	-12	04-02-1899
MAY	68.5	44.7	56.6	67.4	1977	45.5	1924	107	5/30/1939	12	5/12/1918
JUN	76.3	55	65.7	73.3	1988	56.9	1969	104	6/18/1933	26	6/1/1917
JUL	80.7	58.9	69.8	80	1936	65.1	1992	111	7/6/1936	37	7/3/1967
AUG	80.1	56.7	68.4	76.8	1983	62.2	1946	104	8/18/1976	31	08-31-1895
SEP	69.2	45.5	57.4	65.2	1897	49.6	1965	101	9/22/1936	17	09-30-1895
OCT	55.4	33.3	44.4	54.5	1953	32.8	1917	95	10/3/1922	-6	10/26/1919
NOV	34.2	17.8	26	39.5	2001	9.8	1896	74	11/17/1953	-35	11-30-1896
DEC	20	2.7	11.4	25.5	1939	-2.6	1927	60	12/6/1939	-42	12/13/1901
Annual	50.6	29.9	40.3	47.4	1931	31.3	1893	111	7/6/1936	-53	2/15/1936

Table 3. Length of Growing Season, Ada, MN

Length of Growing Season (Days) Derived from 1971-2000 Averages					
Base Temp °F	Median	Shortest	10%	90%	Longest
32	137	120	122	151	170
30	143	121	128	166	171
28	157	129	137	180	186
24	177	150	151	200	224
20	205	150	168	222	233
16	216	176	191	232	242

Table 4. Precipitation Extremes and Summary, Ada, MN

Month	Precipitation NCDC Normals POR: 1971-2000 (in)	Precipitation Extremes Period of Record: 1892-2001 High (in)	Year	Low (in)	Year	1-Day Max (in)	Date
JAN	0.83	2.21	1969	0	1952	1.05	1/1/1921
FEB	0.59	1.56	1948	0	1952	1.1	2/6/1946
MAR	1.03	2.95	1966	0	1918	1.24	3/3/1970
APR	1.69	6.01	1986	0	1949	2.41	4/21/1964
MAY	3.05	9.19	1985	0.22	1901	4.51	5/22/1981
JUN	4.32	8.22	1925	0.54	1929	3.6	6/4/1902
JUL	3.4	8.49	1962	0.18	1930	3.8	7/20/1952
AUG	2.84	10.72	1941	0.23	1949	5.83	8/7/1941
SEP	2.37	8.06	1973	0.04	1974	2.98	9/24/1973
OCT	2.03	7.49	1971	0.03	1992	2.65	10/17/1971
NOV	1.08	4.87	1977	0	1916	1.58	11/1/1974
DEC	0.7	1.87	1921	0.03	1944	1.36	12/2/1982
Annual	23.93	33.39	1941	12.25	1936	5.83	8/7/1941
Winter		5.02	1969	0.18	1931	1.36	12/2/1982
Spring		13.16	1985	1.06	1980	4.51	5/22/1981
Summer		19.58	1944	2.23	1929	5.83	8/7/1941
Fall		12.42	1977	0.71	1963	2.98	9/24/1973

Table 5. Snowfall Extremes and Summary, Ada, MN

Month	Snowfall Summary 1971-2000 Averages Snow (in)	Snowfall Extremes Period of Record: 1892-2001 High (in)	Year	1-Day Max	Date
JAN	11.4	29	1989	10	1/22/1982
FEB	5.7	15.8	1955	8	2/20/1955
MAR	6.9	26	1966	12	3/3/1966
APR	1	12.5	1970	9	4/19/1970
MAY	0	2.5	1954	2.5	5/2/1954
JUN	0	0	-	-	-
JUL	0	0	-	-	-
AUG	0	0	-	-	-
SEP	0	0	-	-	-
OCT	0.6	6.5	2001	6	10/30/1972
NOV	5.8	21	1985	10	11/28/1960
DEC	8.5	23.1	1996	12	12/30/1972
Season (Jul-Jun)	39.9	103.9	1996-1997	12	12/30/1972

Notable Storms.

July 1897

A storm during 18-22 July 1897 (UMV 1-2) was among the most severe storms which extended over the basin. The center was at Lambert, Minnesota, 27 miles north of Mahnomen, Minnesota. The total rainfall depth at the center was 8.2 inches of which 6.5 inches fell in the maximum 24-hour period. At Ada the total rainfall was 4.87 inches with 3.28 inches measured in 1 day.

July 1901

Another large storm in the vicinity (UMV 1-8)) occurred during 1-6 July 1901 and centered at Newfolden, Minnesota, located 75 miles north of twin Valley. Rainfall at the center totaled 10.1 inches in 4 days, of which 7.6 inches fell within 24 ours. During this storm 3.89 inches of rainfall were measured at Ada and 1.90 inches at Beaulieu.

July 1909

The greatest known storm in the basin (UMV 1-11(a)) occurred during 18-23 July 1909 and centered at Beaulieu, Minnesota, in the eastern part of the basin. This storm was one of the greatest storms in Minnesota for 6 hours duration over a few hundred square miles. At the storm center 10.75 inches of rainfall were measured on 20 July 1909 over a 24-hour period. Studies indicate that 10.5 inches of this rainfall occurred in the maximum 6 hours. Rainfall at Beaulieu totaled 12.07 inches in 4 days.

July 1972

More recently, on 21 and 22 July 1972, a very intense storm occurred on the central part of Minnesota. This storm had the greatest 24-hour official rainfall amount ever recorded in Minnesota. The 24-hour rainfall was 10.84 inches at Fort Ripley, which is located about 120 miles southeast of Twin Valley. Total storm rainfall at Fort Ripley was 12.10 inches. Several unofficial measurement exceeding 13 inches for the storm were obtained in Morrison and Todd Counties. The heavy rain covered a large area; the eight inch or greater rainfall extended 90 miles with an average width of 16 miles for an area of nearly 1,500 square miles. During this storm about 1 inch to 2 ½ inches of rain fell on the Wild Rice Basin.

June 1975

The rainfall of 28-29 June1975 produced one of the most significant rain events in Southeastern North Dakota and Northwestern Minnesota. **Figure 4** shows an isohytal map of the portion of rain that covered the Wild Rice Basin.

July 1993

Two major rain events occurred within 1 week of each other in July of 1993. The first storm was on 15-16 July and the second occurred on 24-25 July. **Figure 5** and **6** shows isohyetal maps for these events.

June 2000

Again in June of 2000 an event with more than 4 inches of rain occurred on 19 and 20 June. An isohyetal map of this event is shown in **Figure 7**.

June 2002

Flooding during June 2002, however, was not caused by factors usually associated with major flooding in the Red River Basin. In fact, precipitation had been below normal since late summer 2001 and as of 01 June 2002, the flooded area was in a moderate drought based on the Palmer Drought severity Index. The June 2002 floods were the result of heavy rainfall that swept across the region on 9-10 June and again on 22-24 June 2002.

During the early morning of 09 June 2002, a strong low-pressure system was located in southwestern South Dakota with a warm front extending northeastward across southeastern North Dakota and into Minnesota. Very warm and unstable air transported by a southerly low-level jet stream was located south of the warm front. A low-level jet stream located about 5,000 feet above ground surface with southerly wind speeds of 60 miles per hour is a common feature in the Great Plains during the summer. Very moist and unstable air located south of the warm front was pushed north by the jet stream. As the air was lifted over the front, moisture condensed and helped fuel the continuous thunderstorm development during the early morning of 09 June. The almost stationary low-pressure system produced a second round of storms on 10-11 June. Precipitation totals from the 3-day storm were greater than 5 inches in many areas, and the maximum storm total was about 10 inches.

Similar meteorological conditions occurred on 22-24 June, when warm and unstable air transported by the southerly low-level jet was pushed up and over a warm front that was draped across west-central Minnesota. Two waves of thunderstorms occurred. The first wave began during the evening on Saturday, 22 June and ended during the day on Sunday, 23 June. The second wave developed during the evening on Sunday and tapered off on Monday, 24 June. The largest rainfall totals in the first wave occurred in the northern two-thirds of the Red River Valley and northern Minnesota, and the largest rainfall totals in the second wave in the Red River basin occurred in the Wild Rice River basin and in the headwaters of the Clearwater River basin.

June 2002 rainfall totals exceeded historical averages by more than six inches in many areas, and by more than 10 inches in some locations. In the study area, the June 2002 rainfall exceeded one-half of the normal annual precipitation. When compared against all other historical June data, June 2002 precipitation totals ranked at or above the 99th percentile for nearly all of northwestern Minnesota, large areas of north central Minnesota, and some sections of northeastern, central and southeastern Minnesota. Almost 20-percent of al surface area in Minnesota was at or above the 99th percentile for June rainfall. **Figures 8 and 9** show isohyetal lines of the June 2002 storm for selected durations.

Hydrology

Stream Flow Records

Streamflow data are being obtained by the U.S. Geological Survey at four regular gaging stations in the Wild Rice and Marsh River Basins. Three other gaging stations have been maintained in the past and have been discontinued. **Table 6** shows the stream gages within the Wild Rice and Marsh River Basin. **Table 7** compares the year 2002 peaks with previous peaks at selected gaging stations. The source for **Table 7** is a USGS publication (**reference 3**) which gives pertinent data on the stations and shows maximum and minimum observed flow. During high stages a portion of the flow of the Wild Rice River is diverted into the Marsh River at a point 3 ½ miles east of Ada and has affected the flow at downstream gaging stations since they were established. A breakout formed 1 ½ miles southeast of Ada in 1947 and diverted some of the flow from the Wild Rice River at all stages into the Marsh River. Until the breakout was closed in November 1951 it also affected flows at downstream gaging stations.

Runoff Characteristics

Stream flow is small during the winter season. The Marsh River usually has no flow for long periods in the winter months. Streamflow usually rises in late March or in April, often reaching the highest flow of the year in April. Often the streamflow remains relatively high through June but usually recedes slowly in the summer, except after heavy rains. In the fall months the stream flow is rather low. The numerous lakes in the upper portion of the Wild Rice Basin tend to sustain the low flow on the main stem during the dryer seasons of the year.

Average annual runoff for 85 years of record at Twin Valley amounts to 150,600 acre-feet or 3.02 inches depth of runoff on the 934 square-miles drainage area. This runoff may have been reduced slightly by evaporation from the numerous lakes in the basin. The maximum annual runoff occurred in 2002 at 475,300 acre-ft. Minimum runoff occurred in 1997 at 16,430 acre-ft.

Runoff depths on the basin above the Hendrum and Shelly gages cannot be determined individually because of the diversion of flows above those stations. Approximately 62 percent of the annual flow at Twin Valley occurs in the 3 months of April through June.

The diversion ditch and weir, which were built in the latter part of the 19th century, result in a portion of the flows being diverted from the Wild Rice River into the Marsh River when the river stage is high. This diversion has been in existence during the entire period of downstream gaging stations and, at times of high flows, has reduced the discharge of the Wild Rice River at Hendrum and has increased the flow of the Marsh River near Shelly. During the period 1966-1970 local interests improved the Wild Rice channel below the diversion. Following this silt deposited in the Marsh River ditch to a depth of about 2 feet above the concrete crest of the weir. Consequently, considerably less flow is now diverted into the Marsh River at high stages than occurred before 1966.
The Hydraulics Appendix shows the main stem – diversion flow relationships used for this study.

Table 6. Stream Gauges within Wild Rice and Marsh River Basin

Agency	Site Number	Site Name	Period of Record		
			Begin Date	End Date	Peaks
USGS	05062280	MOSQUITO CREEK NEAR BAGLEY, MN	1961-04-18	1985-03-24	25
USGS	05062470	MARSH CREEK TRIBUTARY NEAR MAHNOMEN, MN	1961-03-17	1985-05-12	25
USGS	05062500	WILD RICE RIVER AT TWIN VALLEY, MN	1909-07-22	2006-03-31	85
USGS	05062700	WILD RICE RIVER TRIBUTARY NEAR TWIN VALLEY, MN	1961-05-14	1985-05-12	25
USGS	05062800	COON CREEK NEAR TWIN VALLEY, MN	1962-06-08	1984-06-09	23
USGS	05062850	COON CREEK TRIBUTARY NEAR TWIN VALLEY, MN	2000-06-20	2001-04-08	2
USGS	05062900	WILD RICE RIVER ABOVE ADA, MN	1985-05-14	1990-04-01	6
USGS	05063000	WILD RICE RIVER NEAR ADA, MN	1948-04-09	1953-07-04	6
USGS	05063200	SPRING CREEK TRIBUTARY NEAR OGEMA, MN	1963-06-02	1989-04-03	27
USGS	05063398	S. BR. WILD RICE RIVER AT CO. RD. 27 NR FELTON, MN	2004-10-30	2006-03-31	2
USGS	05063500	SOUTH BRANCH WILD RICE RIVER NEAR BORUP, MN	1944-07-12	1984-06-11	19
USGS	05063850	STATE DITCH 45 TRIBUTARY NEAR ULEN, MN	2002-06-09	2007-06-17	6
USGS	05064000	WILD RICE RIVER AT HENDRUM, MN	1944-07-15	2006-04-03	63
USGS	05067000	MARSH RIVER BELOW ADA, MN	1948-04-16	1973-03-05	6
USGS	05067050	MARSH RIVER DITCH NR ADA MN	1985-05-13	2007-03-22	23
USGS	05067500	MARSH RIVER NEAR SHELLY, MN	1944-07-11	2006-04-03	63

Table 7. Historical Peak Discharges and Stages[1]

Station Name and Number	Drainage Area (square miles)	Period of previously known peaks	Maximum peaks previously known From period of record				Maximum peaks during June 2002				
			Date	Stage (feet)	Date	Discharge (ft^3/s)	Date	Stage (feet)	Date	Discharge (ft^3/s)	Recurrence Interval (years)
Wild Rice River at Twin Valley, MN 05062500	934	1909-1917 1931-2001	07-22-1909 04-06-1997 04-07-2001	16.00 15.91 12.63[b]	07-22-1909 04-06-1997 04-08-2001	9,200 10,000 5,250	06-09-2002 06-24-2002	17.40[c] 18.00	06-09-2002 06-24-2002	14,000 19,000[a]	100-200 500
Wild Rice River at Hendrum, MN 0506400	1,560	1944-2001	-- 04-21-1979 04-18-1997 04-14-2001	-- 32.30 33.85[d] 31.62[d]	04-10-1978 -- 04-18-1997 04-10-2001	9,350 -- 10,600 9,720	06-13-2002 06-28-2002	28.02[b] 26.48	06-13-2002 06-28-2002	8,520 8,770[e]	10-25 10-25
Red River of the North at Halstad, MN 05064500	21,800	1936-1937 1942-2001	04-22-1979 04-19-1997 04-15-2001	39.00 40.74 38.44	04-22-1979 04-19-1997 04-14-2001	42,000 71,500 37,900	06-14-2002	20.46	06-13-2002	12,300	2-5
Marsh River Ditch near Ada, MN 05067050	--	1985-2001	04-06-1989	16.74	04-06-1989	1,070	06-10-2002	19.02	06-10-2002	1,700	ND
Marsh River near Shelly, MN 05067500	220	1944-2001	04-19-1979 04-18-1997 04-10-2001	23.36[c] 25.45[c] 19.24	04-19-1979 04-18-1997 04-10-2001	4,880 4,300[d] 2,380	06-12-2002 06-26-2002	24.92[b] 24.34	06-12-2002 06-26-2002	4,750 5,520	10-25 10-25

1. From USGS listed in Reference 3.
a. Flood peak later revised by USGS to 20,300 cfs.
b. Backwater from aquatic vegetation, ice debris, or other water source.
c. From floodmark/high watermark.
d. Backwater from Red River of the North.
e. Flood peak later revised by USGS to 8,690 cfs.

Flood Characteristics

Floods on the Wild Rice and Marsh River usually occur in the months of April through June, although floods have occurred in all months from March through July. Most of the floods result from snowmelt runoff which is often increased by spring rains. During the early stages of snowmelt runoff the river channel may be clogged by hard-packed snow and ice which increases river stages. During some years, ice or ice jams may increase the stages several feet. When conditions are favorable to runoff, spring rains following snowmelt may either extend the duration of high flows or result in additional high peak flows. Floods during the summer season can follow heavy widespread storms although high-river stages rarely occur after July.

Flood Problems

The City of Ada is subject to flooding from high stages on the Marsh and Wild Rice Rivers and on JD 51. Flooding occurs from both snowmelt and excessive summer rains. During the early stages of snowmelt, rivers and ditches are often clogged by ice and snow. Ice jams have been known to increase river stage by several feet. The primary source of flooding is from the Wild Rice River overflow to JD 51 and the Marsh River. While there are some levees along the Wild Rice River, high stages will occasionally break out, and overland flow will lead to flooding in Ada. JD 51 is a 9.8 mile diversion ditch that begins at a point on the Wild Rice River, 3-1/2 miles upstream of Ada. JD 51 runs along the northern edge of Ada and eventually connects to the Marsh River, west of Ada. In addition to carrying local runoff, under certain conditions, this ditch will divert a portion of the flow from the Wild Rice River. High flows in JD 51 and the Old Marsh River will cause flooding in Ada. The Marsh River lies directly to the south of Ada, between the city and the Wild Rice River. The location of JD 51, the Marsh River and the Wild Rice River is shown on **Figure 3.**

Historic Floods

March 1882

In March of 1882, 4 feet of snow fell in about 2 weeks. This snow melted so rapidly that the Wild Rice River was reported to have risen 12 to 20 feet in 1 day near Hendrum. Much damage occurred but no data are available on stages reached or area flooded. The Red River of the North at this time was at the highest stages known to pioneer settlers. At Hendrum the unfortunate persons lacking two-story homes were obliged to seek refuge in a nearby log church.

Spring and Summer 1896-1897

Several severe blizzards during the winter of 1896-97 produced heavy snowfall as evidenced by drifts as deep as 20 to 30 feet which nearly covered many houses. Warm weather came suddenly the following spring, ice jammed in the rivers, and water rushed into the rivers. The early spring flood was followed by another major flood during July of the same year. Many farms were vacated following the floods of 1897 and remained unoccupied for a number of years thereafter. As few graded roads traversed the basin at

that time, the floodwaters flowed unimpeded over the land. If a flood of similar magnitude to the 1897 flood were to occur under present conditions, much greater damage would result.

July 1909

Until years 1997 and 2002, the greatest known flood caused by rainfall was that of July 1909. This flood was caused by the storm of 18-23 July 1909, which centered at Beaulieu, Minnesota, in the eastern part of the Wild Rice River Basin. This was the greatest storm recorded until recently in the Red River Basin and also one of the most intense storms ever to occur within the State. The estimated maximum 24-hour rainfall at Beaulieu was 11.5 inches while the storm totaled 12.07 inches in 72 hours. In the lower part of the basin much less rainfall occurred, as evidenced by the total precipitation of 2.14 inches recorded at Halstad. The Wild Rice River rose rapidly following the heavy rain. At Twin Valley, the river rose more than 12 feet in 24 hours on 19-20 July, with a further rise of 2 feet in the next 48 hours. The computed peak flow on 22 July was 9,200 cfs which is almost twice any discharge observed since that time until 1997 and 2002. During the slow flood recession overbank stages persisted for about a month. This flood inundated much of the lower basins of the Wild Rice and Marsh Rivers, including the entire community of Ada.

April 1943

Two periods of high flow occurred during 1943. The first, resulting from the rapid melting of snow, produced a maximum flow of 2,030 cfs at Twin Valley on 1 April. High stages, which delayed seeding and other normal spring activities, prevailed in the vicinity of Ada for about 3 weeks. The second and larger flood occurred in June and produced a maximum discharge of 4,120 cfs on 4 June at Twin Valley. This flood resulted from the cumulative effect of heavy rains of about 1 inch on 15 and 16 May and a total of 4 to 5 inches from 23 May to 3 June. At that time ground conditions were favorable for a high rate of runoff as the spring was cooler and wetter than usual. The flood made many acres which had been flooded earlier in the season unfit for cultivation during the remainder of the year in addition to destroying a large acreage already in crop. Minor damage to roads and bridge approaches was experienced in this flood.

April 1947

The flood of April 1947 resulted from the melting of a heavy snow cover combined with rainfall. During the period 3-6 April precipitation, largely in the form of snow, was heavy throughout the basin, particularly in the eastern part of the basin. Mahnomen reported 1.97 inches of precipitation during that time. Subsequent near – freezing temperatures occurred which averaged about 0.75 inch over the basin. The rain was accompanied by rising temperatures. The combination of snowmelt and rainfall runoff produced overbank flow in many places. At Twin Valley the Wild Rice River peaked at 2,510 cfs on 15 April. Maximum flows at downstream gaging stations were 4,410 cfs on 15 and 16 April at Hendrum and 4,150 cfs on 14 April on the Marsh River near Shelly. The flows at the two latter locations were probably affected by the breakout 1 1/2 miles southeast of Ada which diverted flow from the areas of cropland from which the water receded slowly. Thus, the normal spring crop planting was delayed appreciably in the

area. Other damages sustained included washouts of road grades and damages from erosion.

Spring 1950

Three floods occurred in 1950 with peaks in April, May and June. A snow survey near the middle of March indicated water contents ranging between 2 and 3 inches over the basin. Additional precipitation, mostly snow, in the latter half of March and early April totaled about 1 1/2 inches. Limited melting of snow occurred early in April but the major runoff from snowmelt started on 14 April.

A peak flow occurred on 18 April along much of the river with peak flows of 2,940 cfs at Twin Valley, 990 cfs near Ada below diversion, 2,940 cfs at Hendrum, and 3,680 cfs near Shelly. The water spread overbank downstream from Ada to flood farmlands more than a mile from the channel. Some basements in Ada were flooded by overflow water when the Wild Rice Rive overtopped its banks east of town and moved across country, uniting with the Marsh River. The crest receded slowly and traffic in the area was hampered for more than a week.

During the last 7 days of April, rainfall averaged approximately 1 inch over the basin. Approximately 3 inches of additional rain fell from 2 to 9 May. Although this rainfall was distributed over several days, conditions were favorable for high runoff and flood conditions resulted. Peak flows at Twin Valley on 9 May, at Ada below the diversion on 9 May, at Hendrum on 10 May, and near Shelly on 11 May were 3,530 cfs, 1,180 cfs, 3,150 cfs, and 4,660 cfs, respectively.

The peak flow at Shelly is the largest recorded during the entire record of over 20 years. The Hendrum discharge was the highest of the year. During this flood a peak mean daily flow of 1,750 cfs was observed on the Marsh River below Ada, and most of this flow was diverted from the Wild Rice to the Marsh River at the breakout of 1 1/2 miles southeast of Ada. Additional flow was diverted into the Marsh River ditch, 3 1/2 miles east of Ada. This flood contributed to the May 1950 flood on the Red River of the North which was the greatest since 1897 and until 1966 at Grand Forks and downstream. Flows receded well below bankfull stage early June and remained at moderate flows until the last week of June.

Heavy rains and severe thunderstorms occurred on 24-25 June, with the greatest rainfall in the northwestern portion of the basin. Mahnomen reported 4.10 inches of rain in 24 hours, Twin Valley recorded 4.05 inches in 30 hours, and Ada had 3.10 inches in 24 hours. Near Leonard, 20 miles outside the northeast corner of the basin, 7.60 inches of rain was measured in 4 days, with 6.50 inches in 1 day. Flood flows resulted with instantaneous peaks of 4,380 cfs at Twin Valley on 26 June, 1,720 cfs near Ada below the diversions on 26 June, 2,040 cfs at Hendrum on 28 June, and 4,060 cfs on the Marsh River near Shelly on 29 June. This flood was the greatest of the year at Twin Valley and at Ada but was exceeded by spring peak flows at locations farther downstream.

Spring 1965

The fall and winter of 1964-65 were considerably colder than normal, resulting in deep frost penetration. Snowfall was above normal during the winter months. A snow survey in the latter part of March indicted an average of about 2 inches of water content, with the greatest amount in the upper portion of the basin. Temperatures remained generally below freezing throughout March. Beginning on 4 April temperatures above freezing prevailed as a rule. A series of rains from 3 to 11 April added from 2 more than 3 inches of water added to the snowmelt runoff. Flood flows resulted with peak flows of 3,160 cfs at Twin Valley on 12 April, 6,800 cfs at Hendrum on 14 April, and 3,120 cfs on the Marsh River at Shelly on 13 April.

Spring 1969

The flood of April 1969 followed a severe winter with heavy snow cover. Rainfall in September and October 1968 was considerably above normal on the basin. Snowfall in December and January was 2 to 3 times the normal amount for those months. February snowfall was well above normal on the basin, although there was not much snowfall in March. Temperatures averaged colder than normal in December, January, and March. Snow surveys in March showed water content of the snow cover averaging nearly 4 inches on the basin with greater depths in the upper portion. After the first few days of April, the temperature rose well above the melting point in the daytime. Then more than an inch of rainfall occurred on 8 and 9 April, which added to the snowmelt runoff, and caused severe flooding.

The peak flow at Twin Valley was 4,850 cfs on 10 April 1969. This was the largest discharge in the period of record, except for that of July 1909. Downstream at Hendrum the peak flow was 8,300 cfs on 15 April and was the largest flow during the period of record there. The Marsh River near Shelly had a maximum flow of 3,910 cfs on April 12. This flow at Shelly was exceeded by the flood of May 1950, when flow from the breakout near Ada added substantially to the Marsh River flow.

April 1997

Significant flooding occurred in Ada in April 1997. The spring 1997 flood was a snowmelt runoff event. The flooding on the Wild Rice River was exacerbated by 2-3 inches of rainfall on top of the melting snow. Heavy autumn precipitation contributed to spring flooding conditions. Snow depths for the area in January were ranked in the 99th percentile relative to the historical record. (Minnesota State Climatology Office). Due to cool temperatures in March and April 1997, there was a relatively late runoff period.

The flooding on the Wild Rice River in the spring of 1997 occurred in two waves. The first wave was caused by ice jams that developed on the Wild Rice River. Ice jams formed at the junction of Judicial Ditch 51, at the junction with the Old Marsh River channel and at Highway 9, just south of Ada. Ice jams increased stages on the Wild Rice River resulting in failure of the Wild Rice River dike systems and sent additional flow overland toward Ada, Minnesota. The ice jams sent massive flows up Judicial Ditch 51. The peak stage on the Wild Rice River during the first wave of flooding was 13.5 feet at the gage located near Ada, which fell short of the record stage by only 0.1 feet.

The Wild Rice River was nearing a peak condition when a powerful storm combined 2 to 3 inches of rainfall with freezing rain and snow. The rainfall quickly melted the remaining snowpack. This caused a second wave of flooding which overtopped levees in many locations in Ada. Road crossings downstream of the Heiberg Dam were overtopped. Highway 200 and Highway 9 were overtopped. The South Branch of the Wild Rice River overflowed its banks. The railroad track which had been acting as a levee between the eastern and western portions of Ada was overtopped by about six inches. The City of Ada was evacuated. Some streets in Ada were under more than 5 feet of water. The peak stage on the Wild Ricer River for the second wave of flooding was 16.5 feet at the gage located near Ada, which surpassed the flood of record by 2.9 feet.

Once water spilled over the levees it flowed overland through Ada and continued overland downstream. Culverts between the sections were not large enough to pass the overland flows. Sections filled like reservoirs until the water overtopped or breached roadways, spilling into the next section. Almost all of Hegne Township was flooded. Water submersed fields in bands from 5 to 10 miles wide.

There are two USGS gages currently in use on the Wild Rice River. The first is USGS gage, number 05062500, is located at Twin Valley, Minnesota. The second USGS gage, number 05064000, is located at Hendrum, Minnesota. Ada, Minnesota lies along the Wild Rice River between these gage locations. At the gage at Twin Valley, the instantaneous peak discharge was recorded at 10,000 cfs on 06 April. This discharge has a recurrence interval of approximately 70 years. It is estimated that the 1997 flood had a recurrence interval of 500 years, with extreme plugging conditions and ice jams.

June 2002

Flooding during June 2002, however, was not caused by factors usually associated with major flooding in the Red River Basin. In fact, precipitation had been below normal since late summer 2001 and as of 01 June 2002, the flooded area was in a moderate drought based on the Palmer Drought severity Index. The June 2002 floods were the result of heavy rainfall that swept across the region on 9-10 June and again on 22-24 June 2002.

Several streamflow gaging stations recorded peak stages and peak discharges during the June 2002 floods on the Wild Rice. A peak discharge of 14, 000 cfs occurred 09 June on the Wild Rice River at Twin Valley, Minnesota. The peak discharge exceeded the previous peak that occurred in 1997 by 40-percent and had a recurrence interval of about 200 years. Flooding was extensive in the City of Ada, Minnesota, just downstream of Twin Valley; however, flood fighting efforts prevented most damage. Flood discharges attenuated downstream of Twin Valley, but a significant peak discharge of 8,520 cfs occurred on 13 June on the Wild Rice River at Hendrum, Minnesota.

A peak discharge of 20,300 cfs occurred 24 June on the Wild Ricer River at Twin Valley, Minnesota. The peak discharge exceeded the peak on 09 June by 36-percent and had a recurrence interval of about 1,000 years. The peak discharge of 8,690 cfs that occurred

28 June on the Wild Rice River at Hendrum was slightly greater than the peak discharge that occurred 13 June.

Other Floods

Numerous other floods have occurred in the basin. It should be noted that eight out of the highest nine flood peaks occurred at Twin Valley in the last 18 years. Other notable floods were: 1989, 1978, 1979, 2000, 2001, and 2006. Their magnitude and corresponding rank is shown in **Table 8**. Documentation for some of them is described in **reference 2.**

Wild Rice River Discharge-Frequency

Twin Valley

An annual, instantaneous, peak, discharge-frequency relationship was developed at the USGS gage (05062500) at Twin Valley, MN. At this location the contributing drainage area is 934 square miles. This gage has 84 years of broken record (1909 to 1917, 1931 to 2006). **Table 8** lists the instantaneous, peak discharge values, corresponding dates, and rank of each event based on Water Year. The 1979 event was tagged by the USGS as being the largest event known to occur since 1909. Therefore, the top 4 events (2002, 1997, 1909 and 1978,as part of the 85 years of systematic record, are treated as high outliers resulting in a historic period length of 98 years.

The frequency curve was developed in accordance with the US Water Resource Council, Bulletin 17B **(reference 4)**. Computed probability was selected for the discharge frequencies to facilitate risk and uncertainty analysis. Events were plotted with the analytical curve for comparison of fit with the Log Pearson Type III distribution using the Median plotting positions. Median plotting positions are known to fit computed probability curves better than Weibull plotting positions which better fit expected probability curves. **Figure 10** shows the discharge-frequency plot.

The adopted skew was determined by weighting the computed station skew with the regional skew value of -0.37. The regional skew was obtained from the USGS publication for generalized skew coefficients for Minnesota dated 1997 **(reference 5)** with a mean square error of 0.182**. Table 9** lists the three moments of the frequency curve distribution; mean logarithm, standard deviation, and skew along with the computed probability values.

Comparison with Previous Studies

Two recent studies for the Ada flood control project were developed in 1999 and 2001 **(reference 6 & 7**). The primary differences in the resulting discharge-frequency values from these studies was due to the addition of years to the period of record and more specifically the significant events that occurred during the later part of the period of record. The Wild Rice River basin received two record-setting rainfall events in June of 2002. On 9 and 10 June, rainfall accumulations topped eight inches in portions of Norman and Mahnomen County. More than nine inches of rain was reported near Twin Valley. Later on 22 and 23 June torrential rain exceeding four inches and up to 5.5 inches fell in Mahnomen County. These rains generated a peak discharge at the Twin Valley gage of 20,300 cfs. Based on the most recent discharge-frequency curve, this event has a return period of approximately 1,000 years.

Table 10 lists the discharge-frequency estimates that were made in the past. The 100-yr discharge value increased by 3,870 cfs from 7,730 to 11,600 cfs. **Figure 11** shows the discharge-frequency curve based on a period-of-record up to 1997. **Figure 12** shows a comparison of the discharge-frequency curves. **Table 11** lists the corresponding frequency values and statistics.

Table 8. Annual Peak Discharges, Rank, & Plotting Positions

WILD RICE RIVER-TWIN VALLEY, MN-FLOW-ANNUAL PEAK

Events Analyzed			Ordered Events			
Day	Mon	Year	FLOW CFS	Rank	Water Year	FLOW CFS	Median Plot Pos
22	Jul	1909	9,200	1	2002	20,300*	0.71
26	Apr	1910	1,610	2	1997	10,000*	1.73
22	Apr	1911	473	3	1909	9,200*	2.74
12	May	1912	758	4	1978	6,470*	3.76
02	Apr	1913	1,610	5	1979	6,010	4.86
10	Jun	1914	1,120	6	2006	5,400	6.04
29	Jun	1915	2,340	7	2000	5,340	7.22
01	Jun	1916	1,670	8	1989	5,260	8.40
03	Apr	1917	719	9	2001	5,250	9.58
21	May	1931	112	10	1969	4,850	10.75
09	Apr	1932	358	11	1950	4,380	11.93
23	May	1933	450	12	1943	4,120	13.11
12	Apr	1934	266	13	1985	4,100	14.29
14	Jul	1935	216	14	1993	3,980	15.47
14	Apr	1936	2,490	15	1974	3,890	16.65
03	May	1937	301	16	1996	3,700	17.83
12	May	1938	836	17	1975	3,660	19.01
30	Mar	1939	459	18	1965	3,160	20.19
09	Apr	1940	1,100	19	2005	3,140	21.37
03	Apr	1941	828	20	1998	3,020	22.55
03	May	1942	1,550	21	1962	2,760	23.73
04	Jun	1943	4,120	22	1947	2,510	24.91
08	Jul	1944	1,560	23	2004	2,500	26.09
02	Apr	1945	1,520	24	1995	2,500	27.27
24	Mar	1946	1,490	25	1936	2,490	28.45
15	Apr	1947	2,510	26	1999	2,480	29.62
09	Apr	1948	916	27	1915	2,340	30.80
08	Jul	1949	1,610	28	1972	2,220	31.98
26	Jun	1950	4,380	29	1966	2,120	33.16
09	Apr	1951	1,820	30	1986	1,960	34.34
08	Apr	1952	1,810	31	1951	1,820	35.52
04	Jul	1953	1,170	32	1994	1,810	36.70
10	Apr	1954	1,390	33	1952	1,810	37.88
04	Apr	1955	927	34	1970	1,740	39.06
12	Apr	1956	1,380	35	1967	1,710	40.24
21	Apr	1957	814	36	1963	1,680	41.42
07	Jul	1958	294	37	1973	1,670	42.60
06	May	1959	451	38	1916	1,670	43.78
15	Apr	1960	716	39	1964	1,640	44.96
17	May	1961	847	40	1949	1,610	46.14
09	Jun	1962	2,760	41	1913	1,610	47.32
30	May	1963	1,680	42	1910	1,610	48.49
17	Apr	1964	1,640	43	1944	1,560	49.67
12	Apr	1965	3,160	44	1942	1,550	50.85

TABLE 8. (continued)

02 Apr 1966	2,120	45	1945	1,520	52.03
01 Apr 1967	1,710	46	1946	1,490	53.21
30 Mar 1968	594	47	2003	1,400	54.39
10 Apr 1969	4,850	48	1954	1,390	55.57
30 Apr 1970	1,740	49	1956	1,380	56.75
10 Apr 1971	1,060	50	1984	1,370	57.93
21 Mar 1972	2,220	51	1987	1,280	59.11
04 Sep 1973	1,670	52	1976	1,250	60.29
12 Apr 1974	3,890	53	1982	1,200	61.47
01 Jul 1975	3,660	54	1953	1,170	62.65
29 Mar 1976	1,250	55	1914	1,120	63.83
21 Apr 1977	146	56	1940	1,100	65.01
07 Apr 1978	6,470	57	1990	1,090	66.18
18 Apr 1979	6,010	58	1980	1,080	67.36
03 Apr 1980	1,080	59	1971	1,060	68.54
06 Sep 1981	295	60	1955	927	69.72
19 Apr 1982	1,200	61	1948	916	70.90
07 Mar 1983	635	62	1961	847	72.08
11 Jun 1984	1,370	63	1938	836	73.26
13 May 1985	4,100	64	1941	828	74.44
13 May 1986	1,960	65	1957	814	75.62
24 Jul 1987	1,280	66	1992	791	76.80
05 Apr 1988	711	67	1912	758	77.98
05 Apr 1989	5,260	68	1917	719	79.16
03 Apr 1990	1,090	69	1960	716	80.34
06 May 1991	682	70	1988	711	81.52
25 Aug 1992	791	71	1991	682	82.70
28 Jul 1993	3,980	72	1983	635	83.88
21 Jun 1994	1,810	73	1968	594	85.05
15 Mar 1995	2,500	74	1911	473	86.23
14 Apr 1996	3,700	75	1939	459	87.41
06 Apr 1997	10,000	76	1959	451	88.59
21 Jun 1998	3,020	77	1933	450	89.77
14 May 1999	2,480	78	1932	358	90.95
22 Jun 2000	5,340	79	1937	301	92.13
08 Apr 2001	5,250	80	1981	295	93.31
24 Jun 2002	20,300	81	1958	294	94.49
26 Jun 2003	1,400	82	1934	266	95.67
28 Mar 2004	2,500	83	1935	216	96.85
01 Nov 2004	3,140	84	1977	146	98.03
31 Mar 2006	5,400	85	1931	112	99.21

Note: Plotting positions based on historic period (H) = 98
Number of historic events plus high outliers (Z) = 4
Weighting factor for systematic events (W) = 1.1605

* Outlier

Ada

The discharge-frequency relationship for the Wild Rice River upstream of Judicial Ditch 51 was estimated by transferring the frequency estimate for Twin Valley by using a drainage area ratio to the 0.6 power. This exponent has been used in all previous studies and was originally adopted based on the guidance provided in the USGS regional regression equations for ungaged drainage basins **(reference 8).** One deviation from previous estimates is the adopted drainage area for the gage at Twin Valley. Previous studies used 888 square miles; however, recently the USGS has modified this estimate to be 934 square miles. Estimates for the discharge-frequency curve at Ada are presented in **Table 10.**

Table 9. Discharge-Frequency Values, Wild Rice R. @ Twin Valley, MN; 1909-2006

Frequency Curve for: WILD RICE RIVER-TWIN VALLEY, MN-FLOW-ANNUAL PEAK				
Percent Chance Exceedance	Computed Curve Flow in cfs	Expected Prob. Flow in cfs	Confidence Limits Flow in cfs	
			0.05	0.95
0.2	17,943	0	26,962	12,964
0.5	14,160	0	20,637	10,467
1.0	11,600	0	16,485	8,736
2.0	9,289	0	12,845	7,138
5.0	6,602	0	8,769	5,221
10.0	4,832	0	6,206	3,913
20.0	3,276	0	4,057	2,717
50.0	1,506	0	1,788	1,270
80.0	662	0	798	535
90.0	423	0	524	328
95.0	289	0	369	215
99.0	139	0	189	94

System Statistics	
Log Transform: Flow,	
Statistic	Value
Mean	3.1641
Standard Dev	0.4133
Station Skew	-0.1915
Regional Skew	-0.37
Weighted Skew	-0.2377
Adopted Skew	-0.2

Number of Events	
Event	Number
Historic Events	0
High Outliers	4
Low Outliers	0
Zero Or Missing	0
Systematic Events	85
Historic Period	98

Table 10. Comparison of Discharge-Frequencies with Prior Studies

		COE July 1999, IA Historic Period 1909 - 1996 Q cfs	COE 2001 Interim Report Historic Period 1909 - 1999 Q cfs	Houston Eng. Study, 2002 Historic Period 1909 - 2002 Q cfs no high outliers	COE 2002 Ada Study Historic Period 1909 - 2002 Q cfs 5 high outliers	COE, 2006 Update Historic Period 1909 - 2005 Q cfs 4 high outliers	COE July 2007 Ada, Interim Report Historic Period 1909 - 2006 Q cfs 4 high outliers
	Exceedence Frequency in%						
	Wild Rice River at Twin Valley						
	0.2	10,800	12,900	18,500		17,900	17,943
	0.5		10,500	14,500		14,100	14,160
	1	7,730	8,860	11,900		11,500	11,600
	2	6,500	7,300	9,460		9,240	9,289
	4						
	5		5,400	6,680		6,560	6,602
	10	3,800	4,080	4,860		4,800	4,832
	20		2,860	3,270		3,260	3,276
	Wild Rice River upstream of JD51	Transfer by DA ratio 1,3	Transfer by DA ratio 1,3	Transfer by Hec-Ras unsteady 1,3	Transfer by DA ratio (Adopted) 1,3	Transfer by DA ratio (n = 0.6) 1,3	Transfer by DA ratio 2,3
	0.2	12,200	14,600		19,800	19,153	19,685
	0.5		11,865		15,600	15,087	15,535
	1	8,740	10,000	11,331	12,800	12,305	12,726
	2	7,350	8,250		10,200	9,887	10,191
	4			8,094			
	5		6,102		7,240	7,019	7,243
	10	4,300	4,610	5,875	5,290	5,136	5,301
	20		3,232		3,580	3,488	3,594
1	DA at Twin Valley =	888	sq. mi.				
2	DA at Twin Valley =	934	sq. mi.				
3	DA at Ada =	1,090	sq. mi.				
	Adopted for current study						

Table 11. Discharge-Frequency Values, Pre-1997; Wild Rice R. @ Twin Valley, MN

Frequency Curve for: WILD RICE RIVER-TWIN VALLEY, MN-FLOW-ANNUAL PEAK2				
Percent Chance Exceedance	Computed Curve Flow in cfs	Expected Prob. Flow in cfs	Confidence Limits Flow in cfs	
			0.05	0.95
0.2	10,707	11,401	15,643	7,934
0.5	8,975	9,435	12,801	6,768
1.0	7,706	8,029	10,770	5,897
2.0	6,476	6,689	8,848	5,037
5.0	4,917	5,026	6,491	3,917
10.0	3,792	3,847	4,858	3,083
20.0	2,715	2,736	3,363	2,254
50.0	1,347	1,347	1,599	1,137
80.0	615	608	739	498
90.0	394	386	488	305
95.0	268	259	342	198
99.0	124	115	171	83

System Statistics	
Log Transform: Flow,	
Statistic	Value
Mean	3.1037
Standard Dev	0.3859
Station Skew	-0.3688
Regional Skew	-0.37
Weighted Skew	-0.3692
Adopted Skew	-0.4

Number of Events	
Event	Number
Historic Events	0
High Outliers	2
Low Outliers	0
Zero Or Missing	0
Systematic Events	75
Historic Period	88

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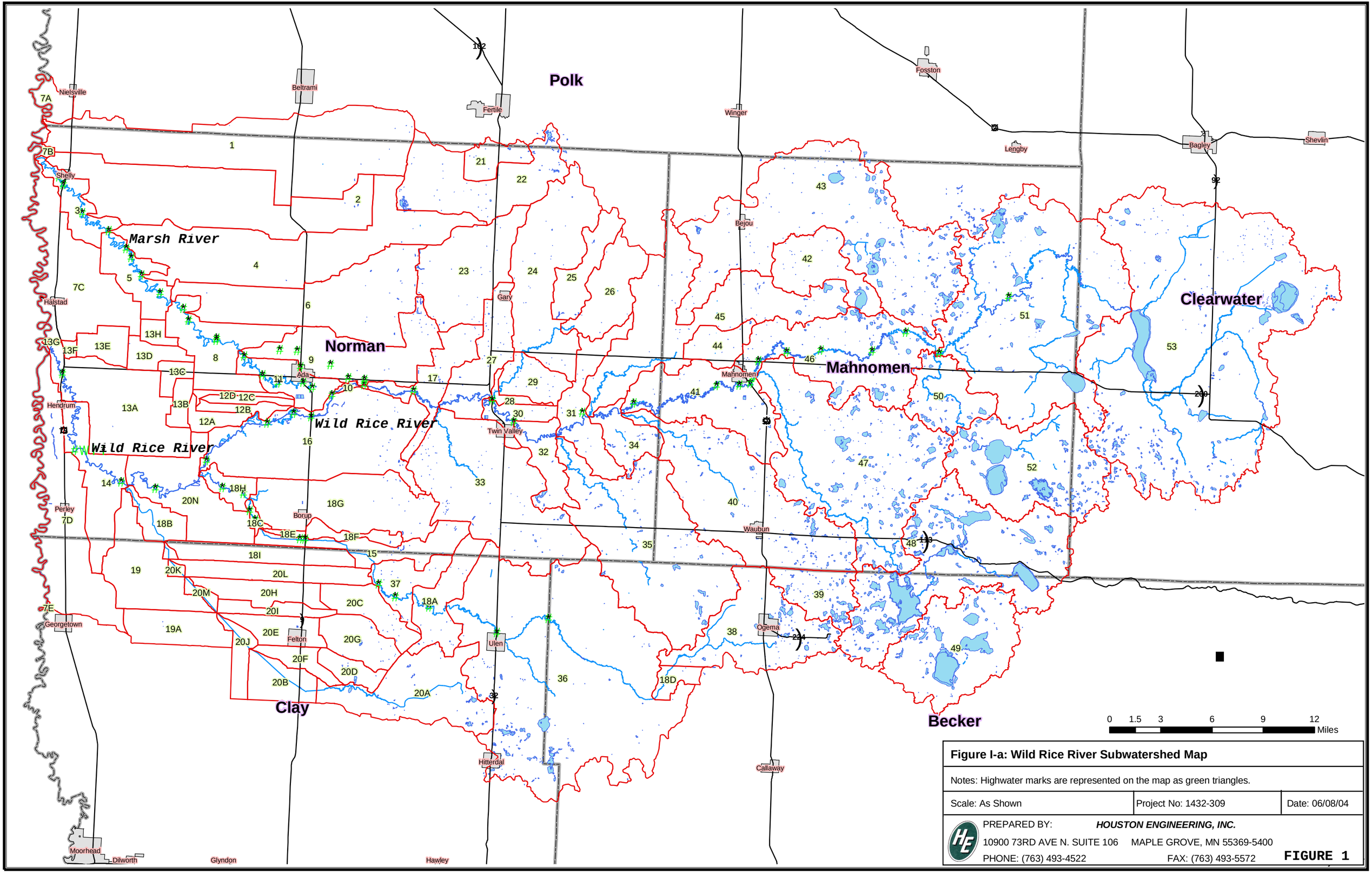

Figure I-a: Wild Rice River Subwatershed Map

Notes: Highwater marks are represented on the map as green triangles.

Scale: As Shown	Project No: 1432-309	Date: 06/08/04

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FIGURE 1

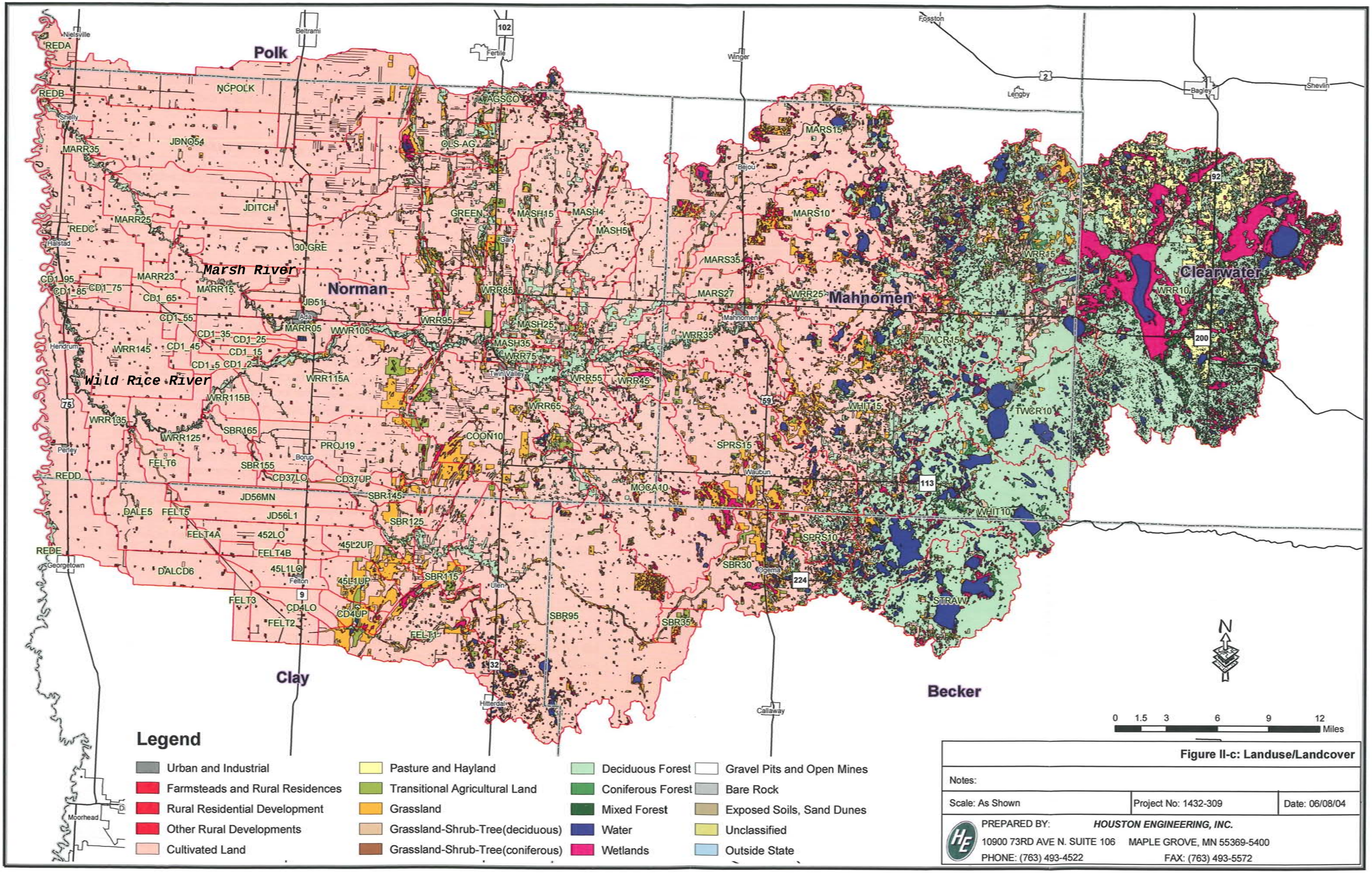

Figure II-c: Landuse/Landcover

Notes:

Scale: As Shown | Project No: 1432-309 | Date: 06/08/04

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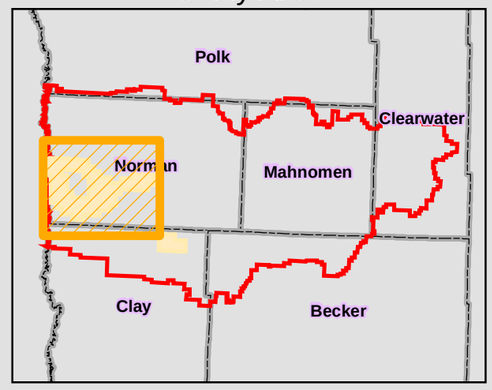
FIGURE 2

Wild Rice River

Legend

- Extent of LIDAR Coverage
- Waterbody
- Watercourse
- HE Subwatersheds
- Municipal Boundary
- County Boundary
- Interstates (MnDOT)
- US Hwys (MnDOT)
- State Hwys (MnDOT)
- County Roads (MnDOT)
- Rail Roads (MnDOT)

Study Area



0 0.5 1 2 3 4 Miles

Disclaimer: Houston Engineering, Inc. does not guarantee this data to be free from errors or inaccuracies, and disclaims any responsibility or liability for interpretations or decisions based on this data. Any errors found should be reported to the original data source provider.

Figure I-a: Wild Rice River - Hydraulic Model Location Map

Notes:

Scale: As Shown	Project No: 1432-310	Date: 06/28/04

PREPARED BY: ***HOUSTON ENGINEERING, INC.***
10900 73RD AVE N. SUITE 106 MAPLE GROVE, MN 55369-5400
PHONE: (763) 493-4522 FAX: (763) 493-5572

FIGURE 3

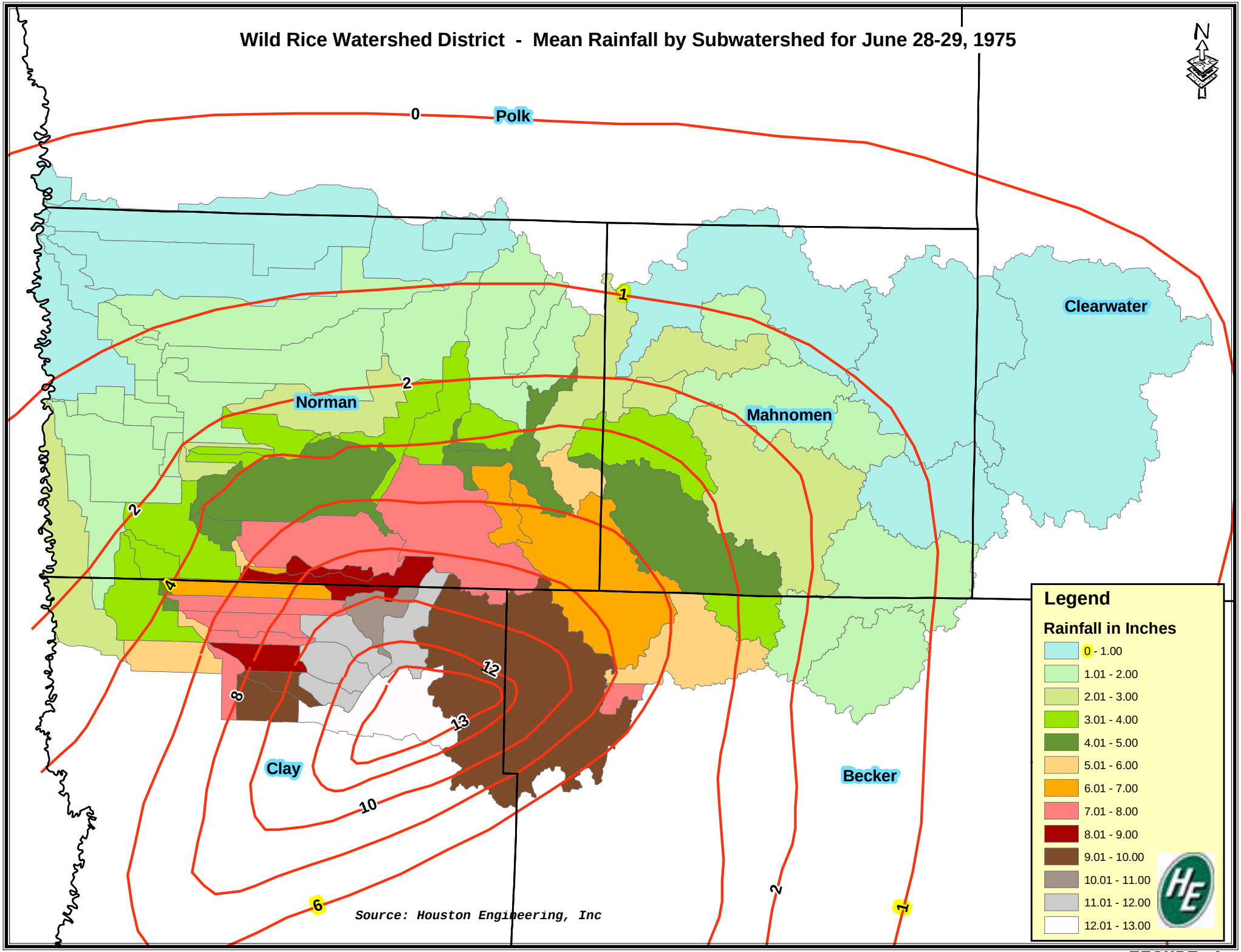

Wild Rice Watershed District - Mean Rainfall by Subwatershed for June 28-29, 1975
N
Polk
Norman
Mahnomen
Clearwater
Clay
Becker
0
1
2
4
6
8
10
12
13
2
2
1
Source: Houston Engineering, Inc
Legend
Rainfall in Inches
0 - 1.00
1.01 - 2.00
2.01 - 3.00
3.01 - 4.00
4.01 - 5.00
5.01 - 6.00
6.01 - 7.00
7.01 - 8.00
8.01 - 9.00
9.01 - 10.00
10.01 - 11.00
11.01 - 12.00
12.01 - 13.00

FIGURE 4

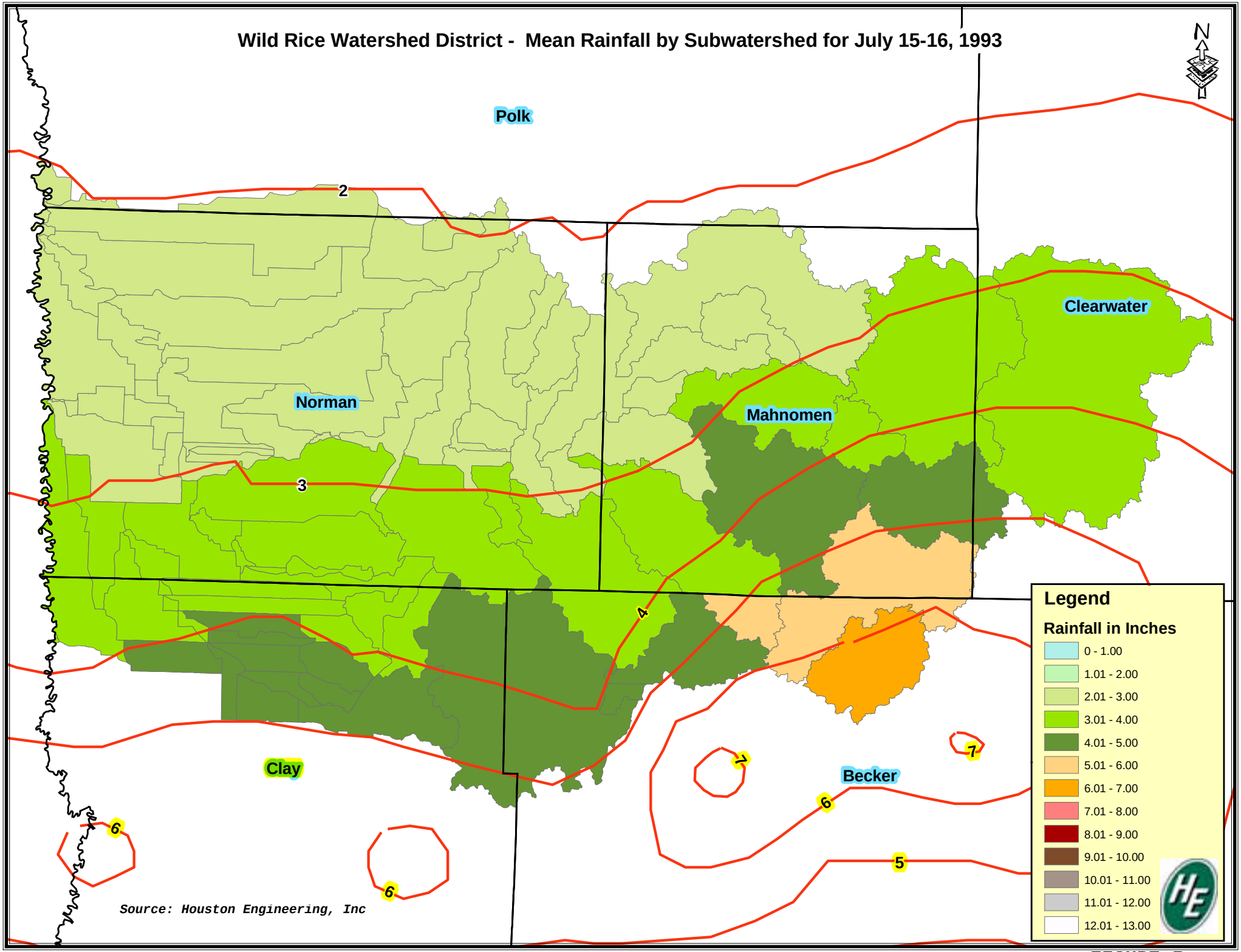

Wild Rice Watershed District - Mean Rainfall by Subwatershed for July 15-16, 1993
N
Polk
Norman
Mahnomen
Clearwater
Clay
Becker
2
3
4
5
6
7
Source: Houston Engineering, Inc
Legend
Rainfall in Inches
0 - 1.00
1.01 - 2.00
2.01 - 3.00
3.01 - 4.00
4.01 - 5.00
5.01 - 6.00
6.01 - 7.00
7.01 - 8.00
8.01 - 9.00
9.01 - 10.00
10.01 - 11.00
11.01 - 12.00
12.01 - 13.00

FIGURE 5

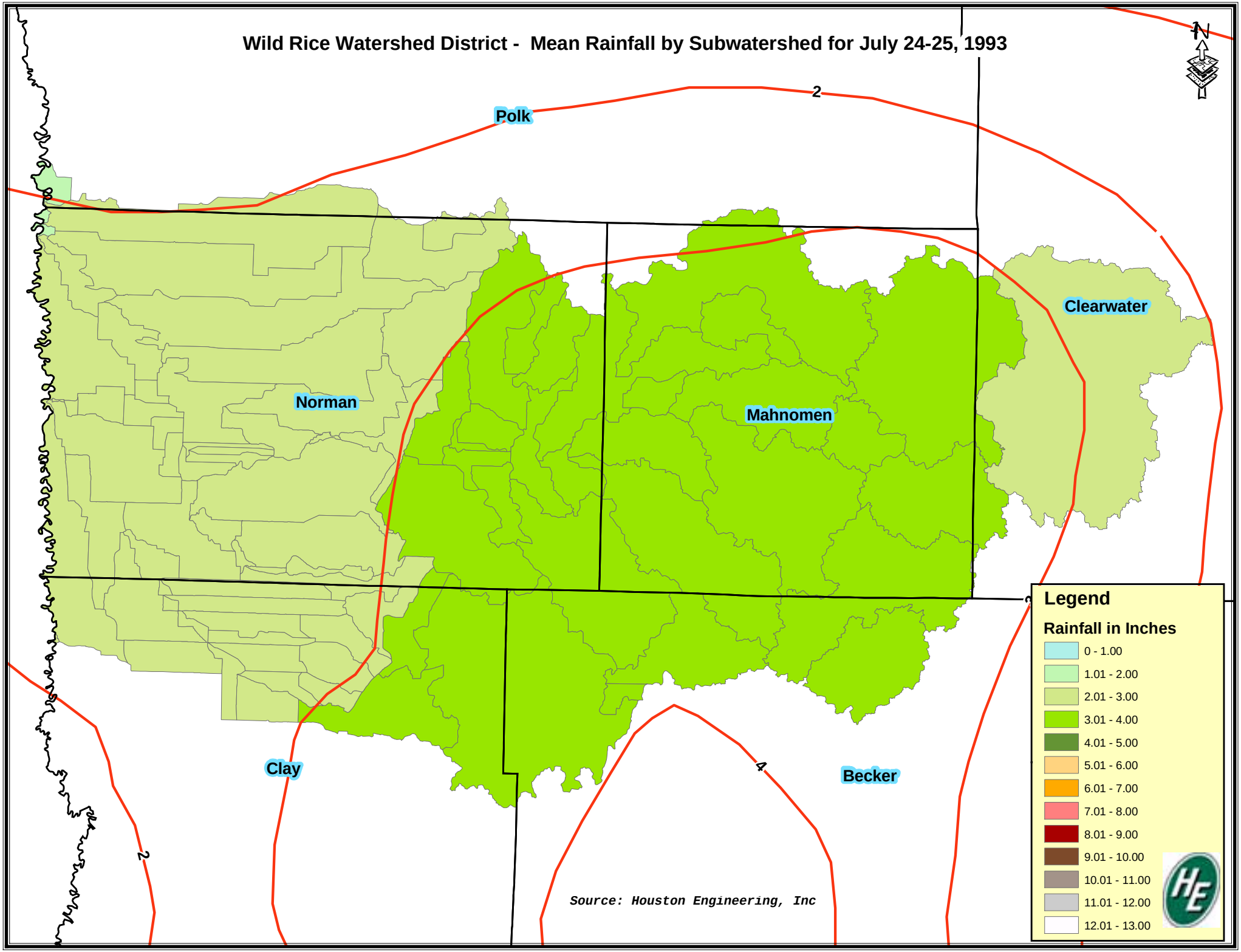

Wild Rice Watershed District - Mean Rainfall by Subwatershed for July 24-25, 1993
N
Polk
Norman
Mahnomen
Clearwater
Clay
Becker
2
2
4
Source: Houston Engineering, Inc
Legend
Rainfall in Inches
0 - 1.00
1.01 - 2.00
2.01 - 3.00
3.01 - 4.00
4.01 - 5.00
5.01 - 6.00
6.01 - 7.00
7.01 - 8.00
8.01 - 9.00
9.01 - 10.00
10.01 - 11.00
11.01 - 12.00
12.01 - 13.00

FIGURE 6

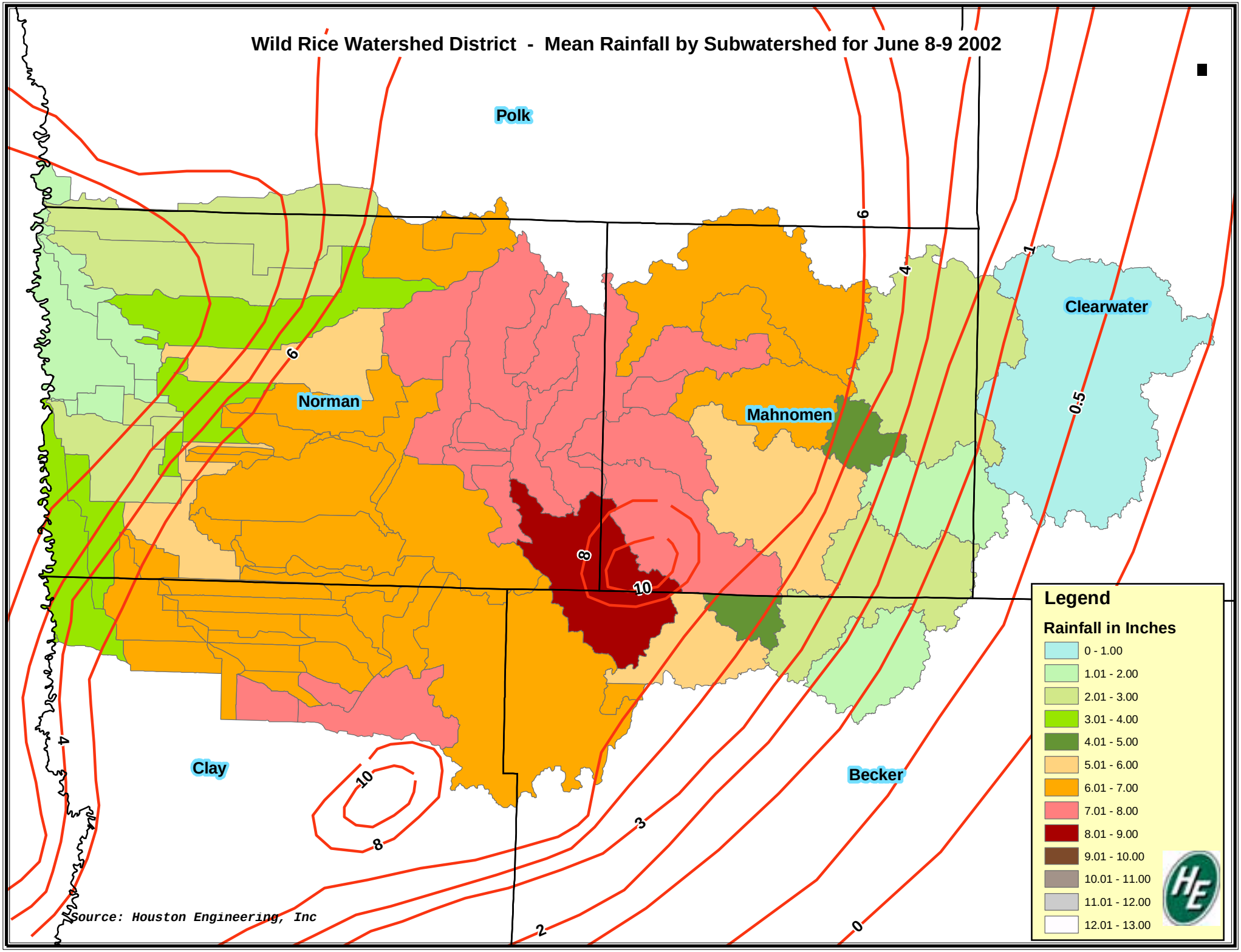

Wild Rice Watershed District - Mean Rainfall by Subwatershed for June 8-9 2002
Polk
Norman
Mahnomen
Clearwater
Clay
Becker
Source: Houston Engineering, Inc
Legend
Rainfall in Inches
0 - 1.00
1.01 - 2.00
2.01 - 3.00
3.01 - 4.00
4.01 - 5.00
5.01 - 6.00
6.01 - 7.00
7.01 - 8.00
8.01 - 9.00
9.01 - 10.00
10.01 - 11.00
11.01 - 12.00
12.01 - 13.00

FIGURE 7

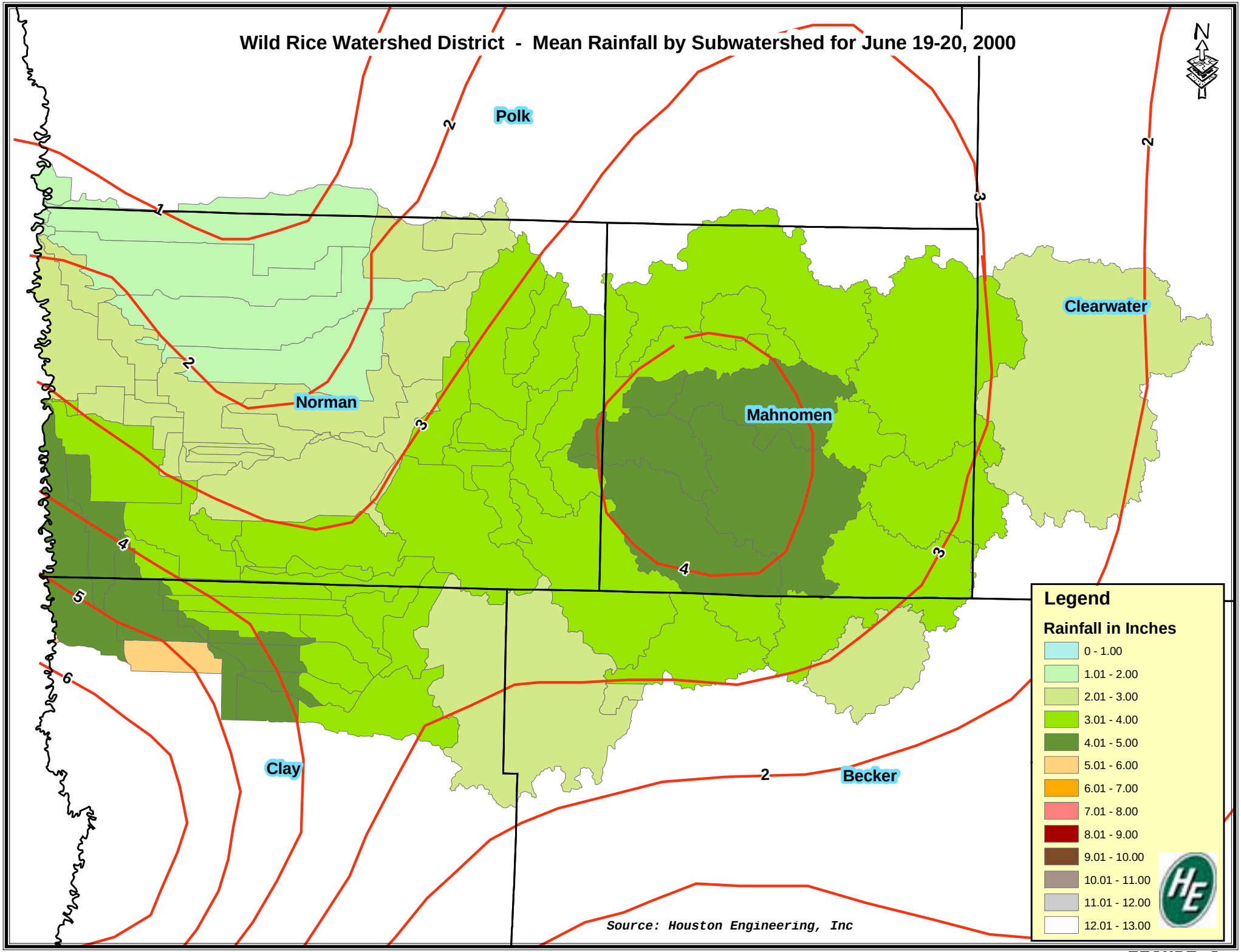

Wild Rice Watershed District - Mean Rainfall by Subwatershed for June 19-20, 2000
N
Polk
Norman
Mahnomen
Clearwater
Clay
Becker
1
2
3
4
5
6
Legend
Rainfall in Inches
0 - 1.00
1.01 - 2.00
2.01 - 3.00
3.01 - 4.00
4.01 - 5.00
5.01 - 6.00
6.01 - 7.00
7.01 - 8.00
8.01 - 9.00
9.01 - 10.00
10.01 - 11.00
11.01 - 12.00
12.01 - 13.00
Source: Houston Engineering, Inc

FIGURE 8

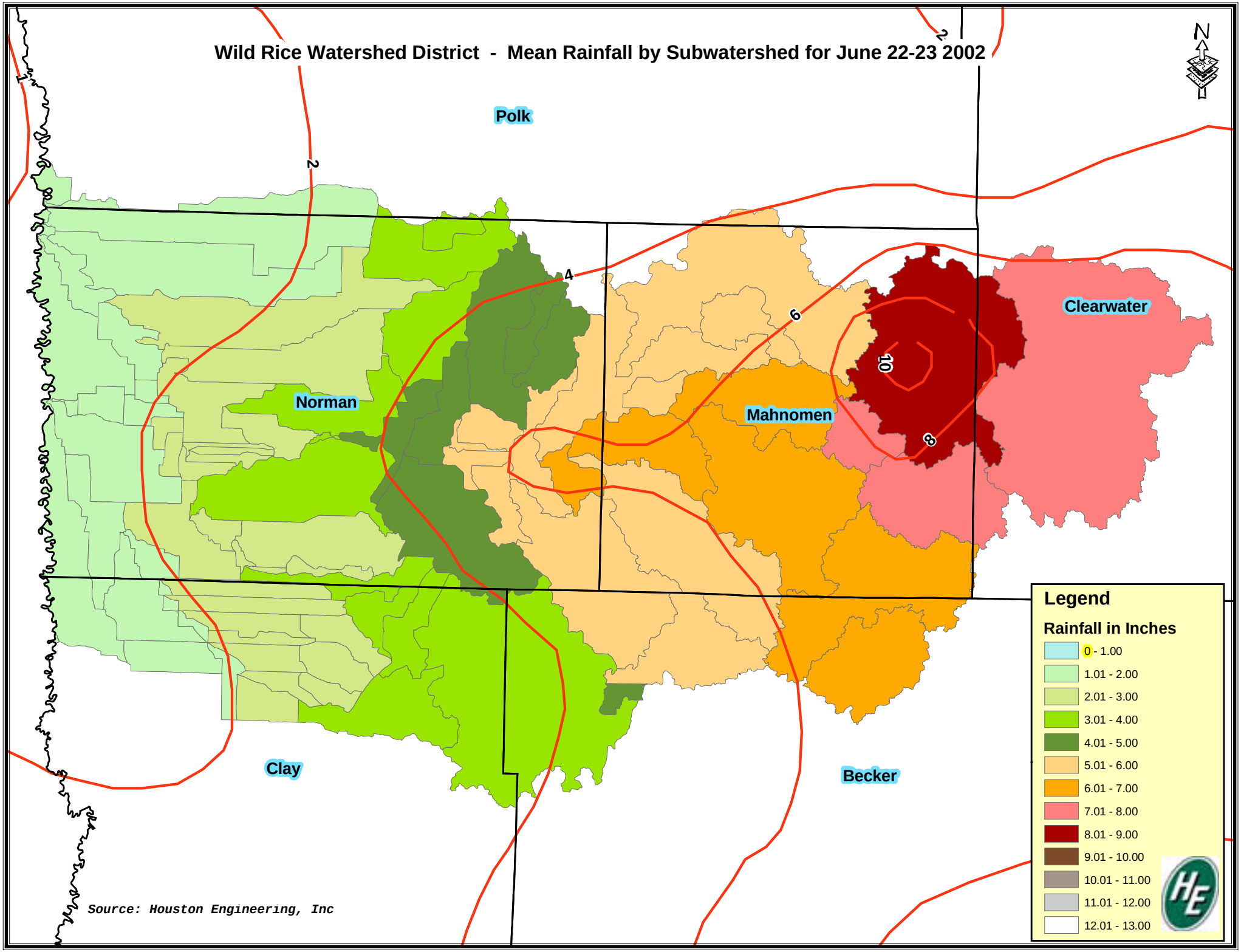
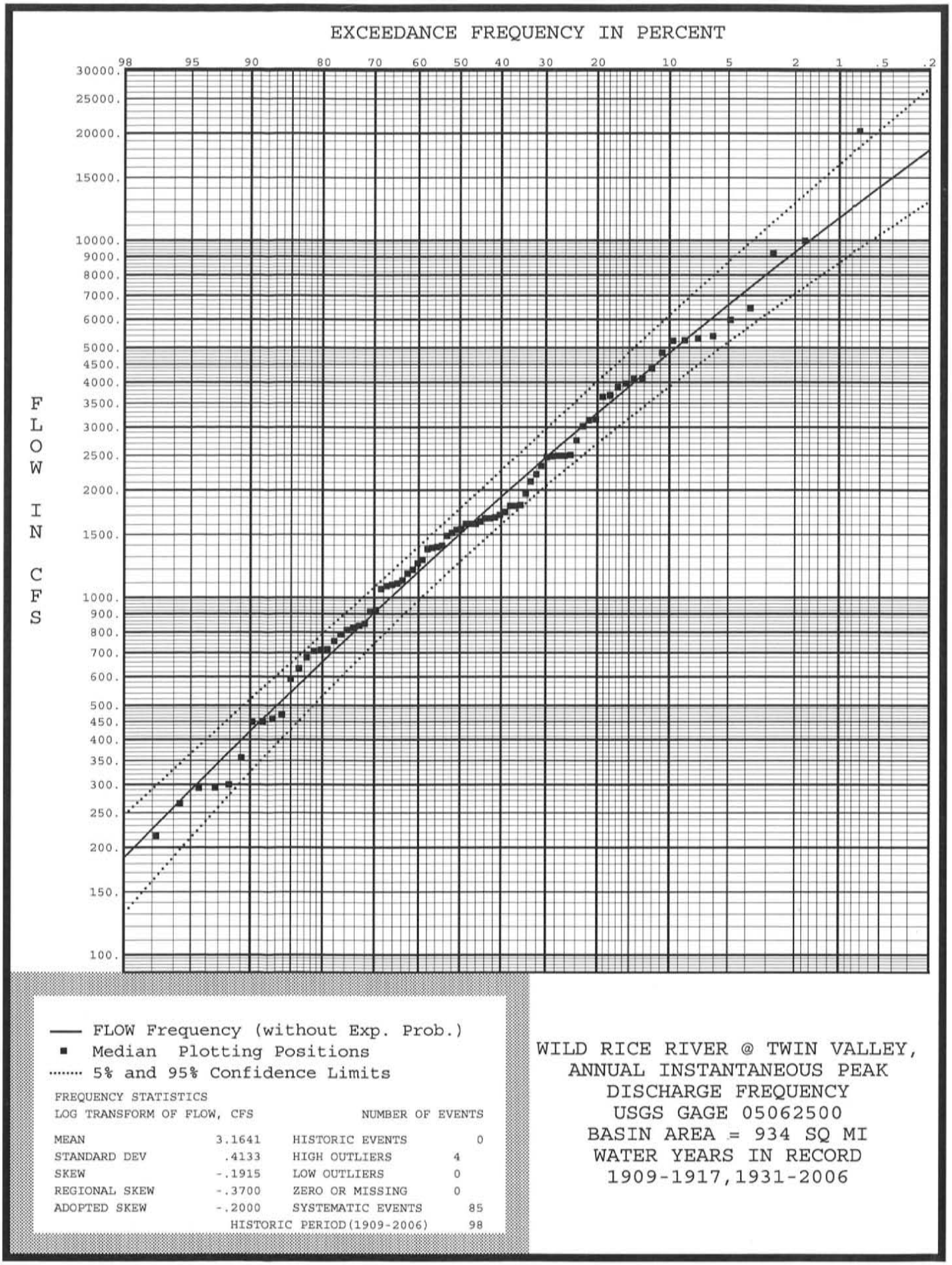

Wild Rice Watershed District - Mean Rainfall by Subwatershed for June 22-23 2002
N
Polk
Norman
Mahnomen
Clearwater
Clay
Becker
1
2
2
4
6
8
10
Source: Houston Engineering, Inc
Legend
Rainfall in Inches
0 - 1.00
1.01 - 2.00
2.01 - 3.00
3.01 - 4.00
4.01 - 5.00
5.01 - 6.00
6.01 - 7.00
7.01 - 8.00
8.01 - 9.00
9.01 - 10.00
10.01 - 11.00
11.01 - 12.00
12.01 - 13.00

FIGURE 9



—— FLOW Frequency (without Exp. Prob.)
▪ Median Plotting Positions
····· 5% and 95% Confidence Limits

FREQUENCY STATISTICS
LOG TRANSFORM OF FLOW, CFS

MEAN	3.1641	NUMBER OF EVENTS	
STANDARD DEV	.4133	HISTORIC EVENTS	0
SKEW	-.1915	HIGH OUTLIERS	4
REGIONAL SKEW	-.3700	LOW OUTLIERS	0
ADOPTED SKEW	-.2000	ZERO OR MISSING	0
		SYSTEMATIC EVENTS	85
		HISTORIC PERIOD(1909-2006)	98

WILD RICE RIVER @ TWIN VALLEY,
ANNUAL INSTANTANEOUS PEAK
DISCHARGE FREQUENCY
USGS GAGE 05062500
BASIN AREA = 934 SQ MI
WATER YEARS IN RECORD
1909-1917,1931-2006

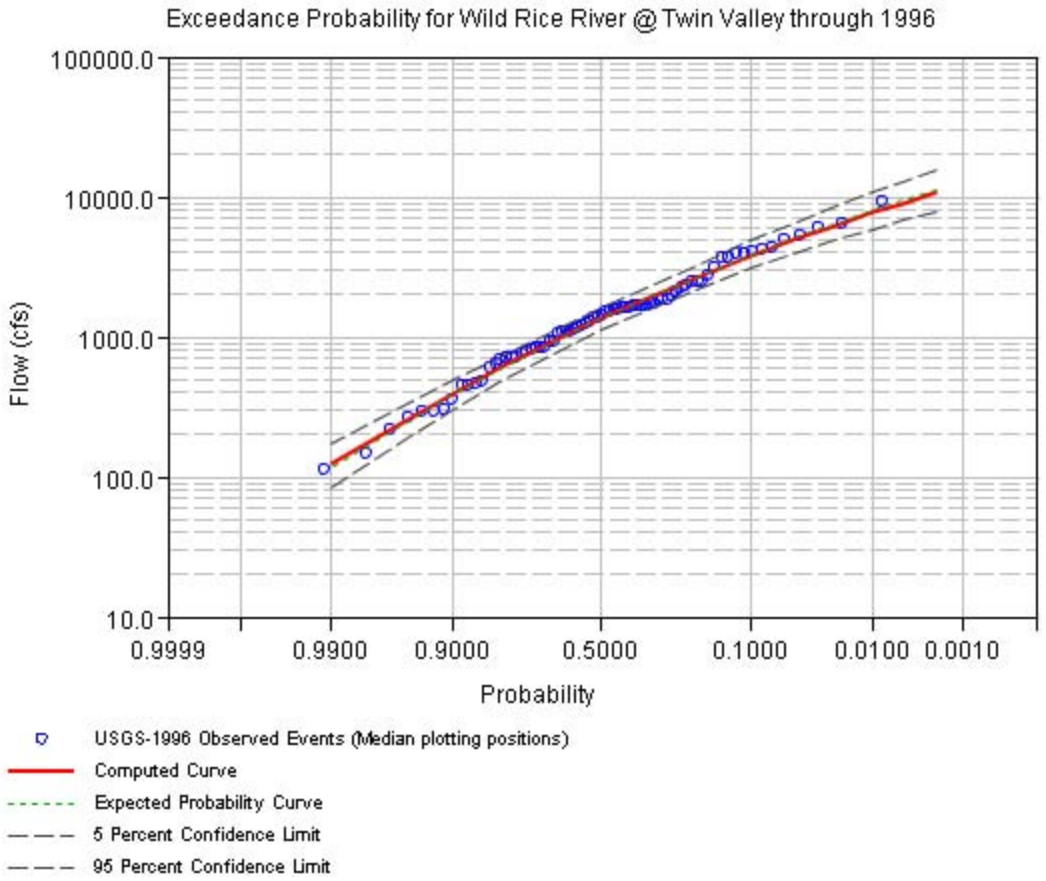


Figure 11. Twin Valley Discharge-Frequency; Pre-1997 Event

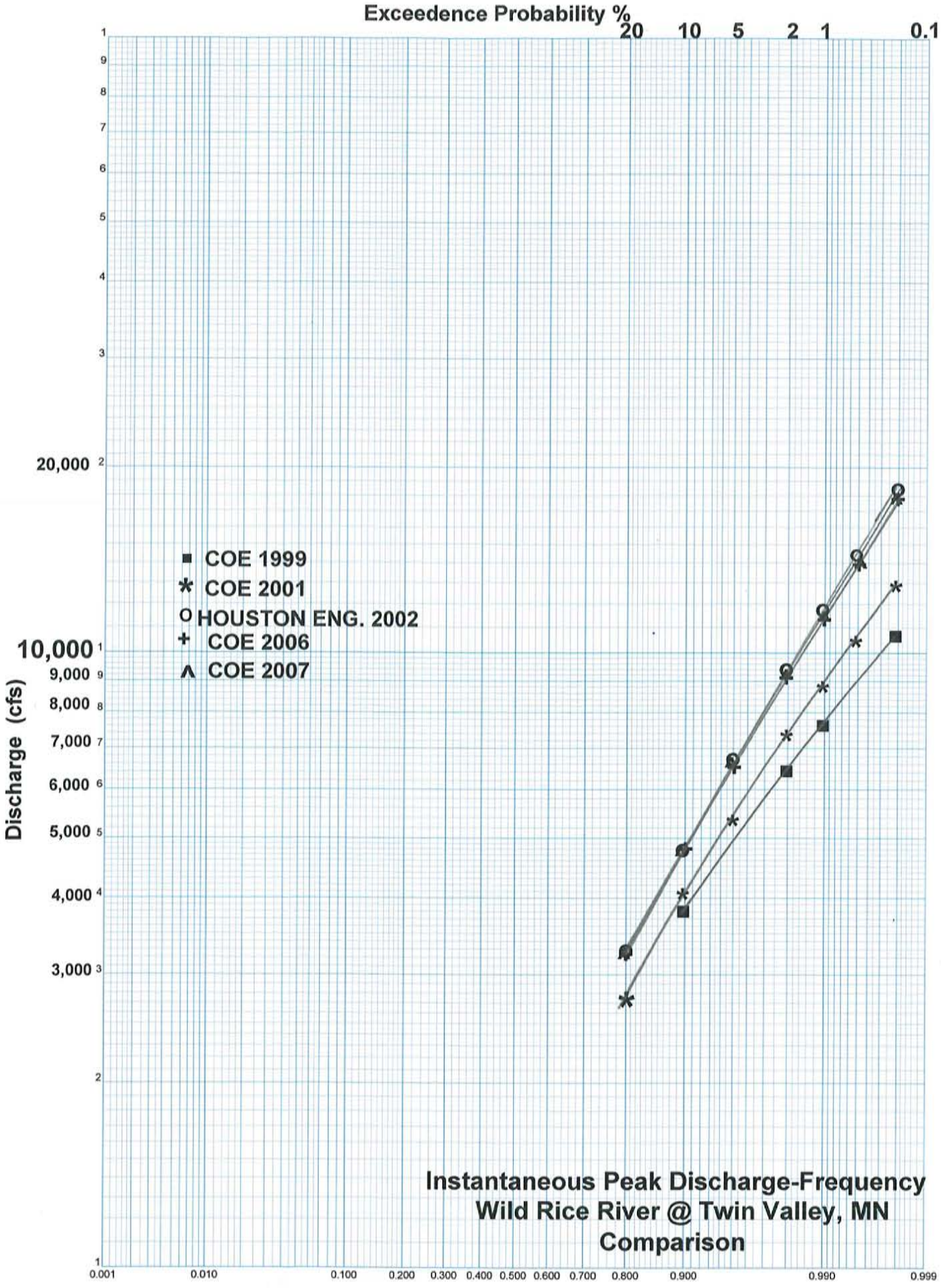

Exceedence Probability %
20
10
5
2
1
0.1
20,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
Discharge (cfs)
COE 1999
COE 2001
HOUSTON ENG. 2002
COE 2006
COE 2007
0.001
0.010
0.100
0.200
0.300
0.400
0.500
0.600
0.700
0.800
0.900
0.990
0.999
Instantaneous Peak Discharge-Frequency
Wild Rice River @ Twin Valley, MN
Comparison

Figure 12