Appendix F
Sheyenne River Hydrology Study

Kadrmas Lee & Jackson
Engineers Surveyors Planners

Technical Memorandum

Project Name:	Minnkota Power – Center to Grand Forks Transmissior Line
Client:	Stanley Consultants – Duane Phillips
Project Number:	50609146
Subject:	Sheyenne River Crossing – 100 yr Flood Elevation Determination
By:	Wade Frank, PE
Date:	January 25, 2011

Introduction

Minnkota Power's proposed Center to Grand Forks transmission line crosses the Sheyenne River near Cooperstown, ND. Stanley Consultants requested that Kadrmas Lee & Jackson (KL&J) perform a hydraulic analysis to determine the water surface elevation corresponding to the 100-year flood event at this location. The elevation data will be used to determine the top of foundation elevation for the transmission line structures.

Location

The crossing is located ten miles north and one mile east of Cooperstown, ND between Section 6 of Township 147 N and Section 31 of Township 148 N.

Design Hydrology

The Sheyenne River channel in this reach is narrow and meandering. The stream banks are covered with short grasses and dense trees and are relatively short with gradual slopes. The floodplain is a relatively undisturbed rolling prairie. The stream gradient was calculated at 1.0 ft/mi (0.000193 ft/ft) from the stream survey.

The USGS's (United States Geological Survey) *Water Resources Investigations Report 92-4020* was used to determine the flood frequency discharge values. The drainage area is in North Dakota's Hydrologic Region C.

Peak flow values were obtained from the Sheyenne River USGS gaging station #05057000 at Cooperstown, North Dakota. The gaging station has a contributing drainage area of 1,270 square miles (sq mi).

In addition to the gaging station information, a hydraulic report for a bridge on ND Highway 45 was used to determine the drainage area at the proposed crossing site. The bridge report states that the drainage area at the bridge

location, which is approximately 4 miles downstream of the transmission line crossing, is 96 sq mi less than at the gaging station. Using USGS topographic maps, it was then determined that the drainage area at the transmission line crossing is 21 sq mi less than the drainage area at the bridge. Therefore, the drainage area at the proposed crossing was found to be 117 sq mi less than the drainage area at the gaging station, which resulted in an area of 1,153 square miles.

Transfer equations from USGS Report 92-4020 were used in calculating the 100-year flow at this site. The 100-year flow was found to be 8,273 cfs (cubic feet per second). ***See Appendix A for detailed calculations.***

Hydraulic Analysis

The US Army Corps of Engineer's computer program HEC-RAS Version 4.1.0 was used to model the potential hydraulic conditions of the open channel for the 100-year flow event.

The 100-year stage was determined by a trial and error procedure using the Mannings equation and a typical river section located at the proposed crossing. Site surveys along with aerial mapping data was used in developing the typical section. The typical section was then propagated 1000 feet upstream and downstream and adjusted to match the local stream gradient.

After analysis, the approximate elevation for the 100-year frequency was found to be 1315.2. ***See Appendix A for output data.***

Recommendations

We recommend that the top of the transmission line structure foundations be set above elevation 1315.2. It may also be prudent to provide freeboard above the 100-year elevation to reduce the potential for ice to impact the structures during large flood events.

Appendices

Appendix A Hydrologic Data & HEC-RAS Output

Appendix A

Hydrologic Data and HEC-RAS Results

Kadrmas Lee & Jackson
Engineers Surveyors Planners

PROJECT Griggs Hydraulics
SHEET NO. 1 OF 1
CALCULATED BY SMM DATE 1/17/11
CHECKED BY QPJ DATE 1/19/10

Flow Calculations

Contributing Area At Cooperstown Gage = 1270 sq mi (Report 92-4020)

Contributing Area At Hwy 45 = 1270 - 96 = 1174 sq mi

Contributing Area At Site = 1174 - 21 = 1153 sq mi

Check Drainage Area Ratio:

CA_u / CA_g = 1153/1270 = 0.91 ok ✓ (Between 0.75 & 1.50)

100 yr flow:

100yr flow At Cooperstown Gage = 8750 cfs (Report 92-4020)

100yr flow At Site:

$$Q_{100} = 8750 \text{ cfs } (1153/1270)^{0.58}$$

$$\boxed{Q_{100} = 8273 \text{ cfs}}$$

Station 05056950,
n = 15 years,
Q_{TS} = 98 ft^3/s,
CA = 0.08 mi^2, and
S = 300 ft/mi.

The gaging station is located in region A, and the 100-year regression equation from table 4 is

$$Q_{100} = 110\ CA^{0.640}\ S^{0.234};\ \text{thus,}$$

$$Q_{TR} = Q_{100} = 110\ (0.08)^{0.640}\ (300)^{0.234} = 83.$$

The equivalent years of record, en, for this station for the 100-year equation is 3.8 years. Using equation 1,

$$Q_{TW} = \frac{15(98) + 3.8(83)}{15 + 3.8} = 95\ ft^3/s.$$

Example for Determining Peak-Flow Frequency Data for an Ungaged Site Near a Gaging Station on the Same Stream

The following is an example of how to use the drainage-area ratio method (eq. 2) to determine peak flow for an ungaged site near a gaging station on the same stream. To estimate the 100-year peak flow for an ungaged site on Burnt Creek, locate the site in figure 1. The site is located downstream of a gaging station on the same stream (station 06342450, Burnt Creek near Bismarck, N.Dak.). Contributing drainage area (CA_u) for the ungaged site is 114 mi^2, and the contributing drainage area (CA_g) for the gaging station (table 2, map number 139) is 108 mi^2. Both the ungaged site and the gaging station are located in region B. Determine if the drainage-area ratio (CA_u/CA_g) is between 0.75 and 1.50:

$$CA_u/CA_g = 114/108 = 1.06,$$

which meets the drainage-area ratio requirement. Thus, the following relation is used:

$$Q_{100(u)} = Q_{100(g)}\ (CA_u/CA_g)^{0.58},$$

where

$Q_{100(g)}$ = 7,790 ft^3/s, the weighted peak flow for the gaging station (table 2);
CA_u = 114 mi^2; and
CA_g = 108 mi^2.

Therefore,

$$Q_{100(u)} = 7{,}790\ (114/108)^{0.58} = 8{,}040\ ft^3/s.$$

Table 3.--Drainage area and peak flow for selected recurrence intervals for gaging stations not used in the generalized skew coefficient and regression analyses--Continued

Map number	Station number	Station name	Period of record used (water year)	Drainage area (square miles)	Peak flow (cubic feet per second) for selected recurrence intervals (years)						
					2	5	10	25	50	100	500
8a	05056400	Big Coulee near Churchs Ferry, N.Dak.	1950-89 E,R	1,620 (1,460)	97	394	752	1,410	2,040	2,780	4,930
9a	05057000	Sheyenne River near Cooperstown, N.Dak.	1945-90 E,U	6,470 (1,270)	1,100	2,470	3,670	5,490	7,040	8,750	13,300
10a	05058000	Sheyenne River below Baldhill Dam, N.Dak.	1950-90 C,R	7,470 (1,910)	1,050	2,350	3,330	4,600	5,520	6,400	8.280
11a	05058500	Sheyenne River at Valley City, N.Dak.	1919, 1938-49 U 1950-75, 1981-90 R	7,810 (2,110)	1,170 1,200	2,350 2,230	3,280 2,940	4,580 3,830	5,620 4,460	6,710 5,070	9,380 6,360
12a	05058700	Sheyenne River at Lisbon, N.Dak.	1957-90 E,R	8,190 (2,490)	1,300	2,610	3,680	5,220	6,480	7,830	11,300
13a	05059000	Sheyenne River near Kindred, N.Dak.	1950-90 C,R	8,800 (3,020)	1,200	2,300	3,170	4,420	5,430	6,510	9,270
14a	05059500	Sheyenne River at West Fargo, N.Dak.	1903-06, 1919, 1930-49 U 1950-90 C,R	8,870 (3,090)	1,040 1,210	1,820 2,240	2,390 2,990	3,130 3,950	3,690 4,660	4,260 5,370	5,600 6,940
15a	05060000	Maple River near Mapleton, N.Dak.	1944-76 E,U	1,450 (1,380)	1,140	2,980	4,740	7,560	10,100	12,900	20,700
16a	05064500	Red River of the North at Halstad, Minn.	1942-90 C,R	21,800 (18,000)	10,800	20,100	27,200	36,900	44,500	52,400	71,500

Project S-323(14)
CFS/ 8-6-63

Bridge No. 45-1
Sheyenne River

045-011.152

STREAM FLOW DATA:

Sheyenne River Drainage Area At the USGS Stream Gage Located East of Cooperstown:

Total Drainage Area = 6,750 square miles
Non-contributing = 5,490 square miles

Contributing Area = 1,260 square miles at the gage QR&

Then, the drainage area at the crossing will be:

Contributing area between gage and the crossing as estimated from county maps = 96 square miles approximately

Contributing area at the crossing = 1,260 - 96 = 1,164 square miles

Hydrologic Area A-2

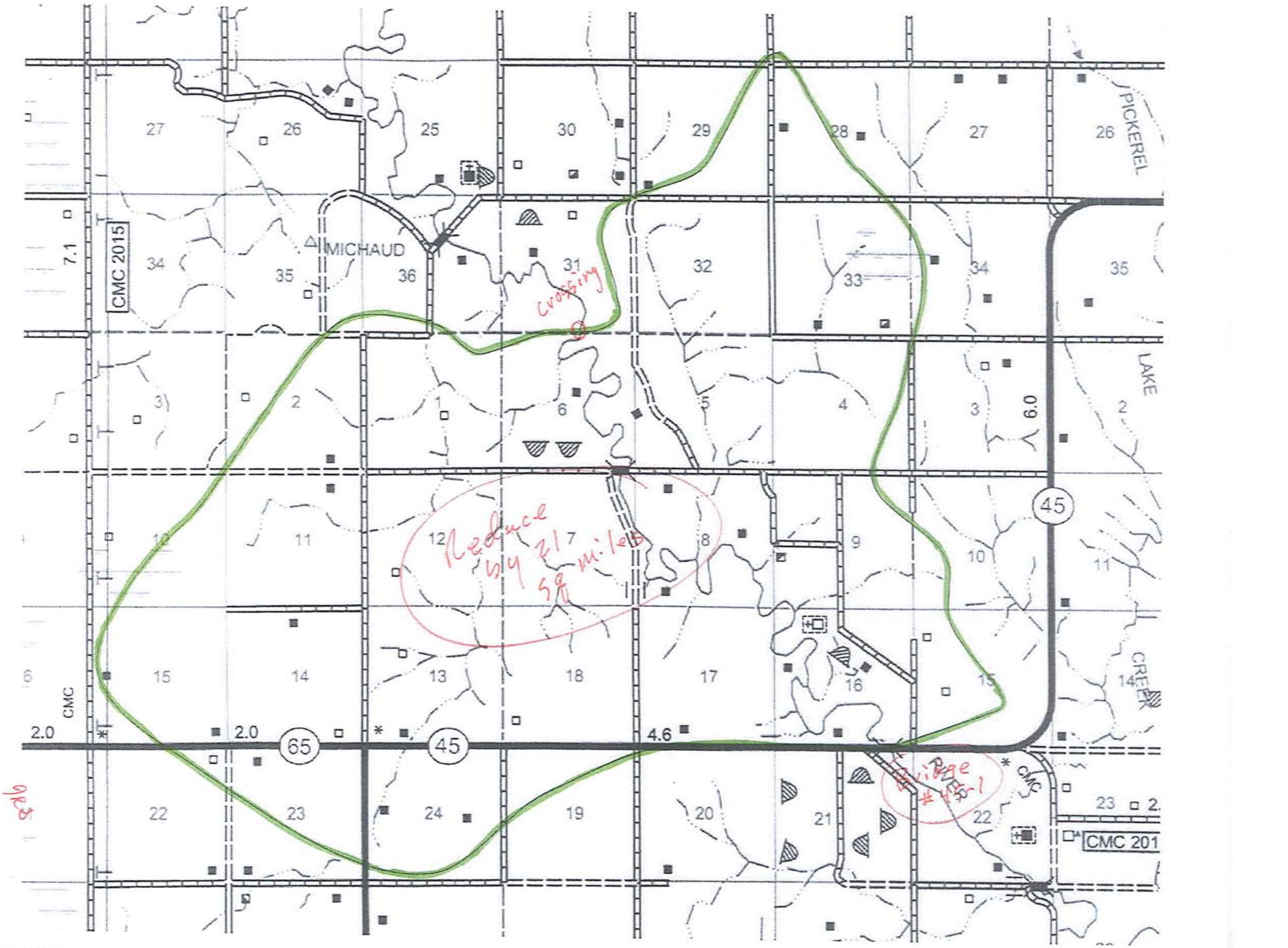
Design Frequency 25 years

USGS Chart Value For Q_{25}=3950 cfs

From USGS Topographic maps, the average gradient for the Sheyenne River in this vicinity is:

$S = 10'/33,400' = 0.000299$ ft./ft.

Then, $s^{\frac{1}{2}} = 0.0173$



MICHAUD
CMC 2015
CMC 201
CMC
PICKEREL
LAKE
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RIVER
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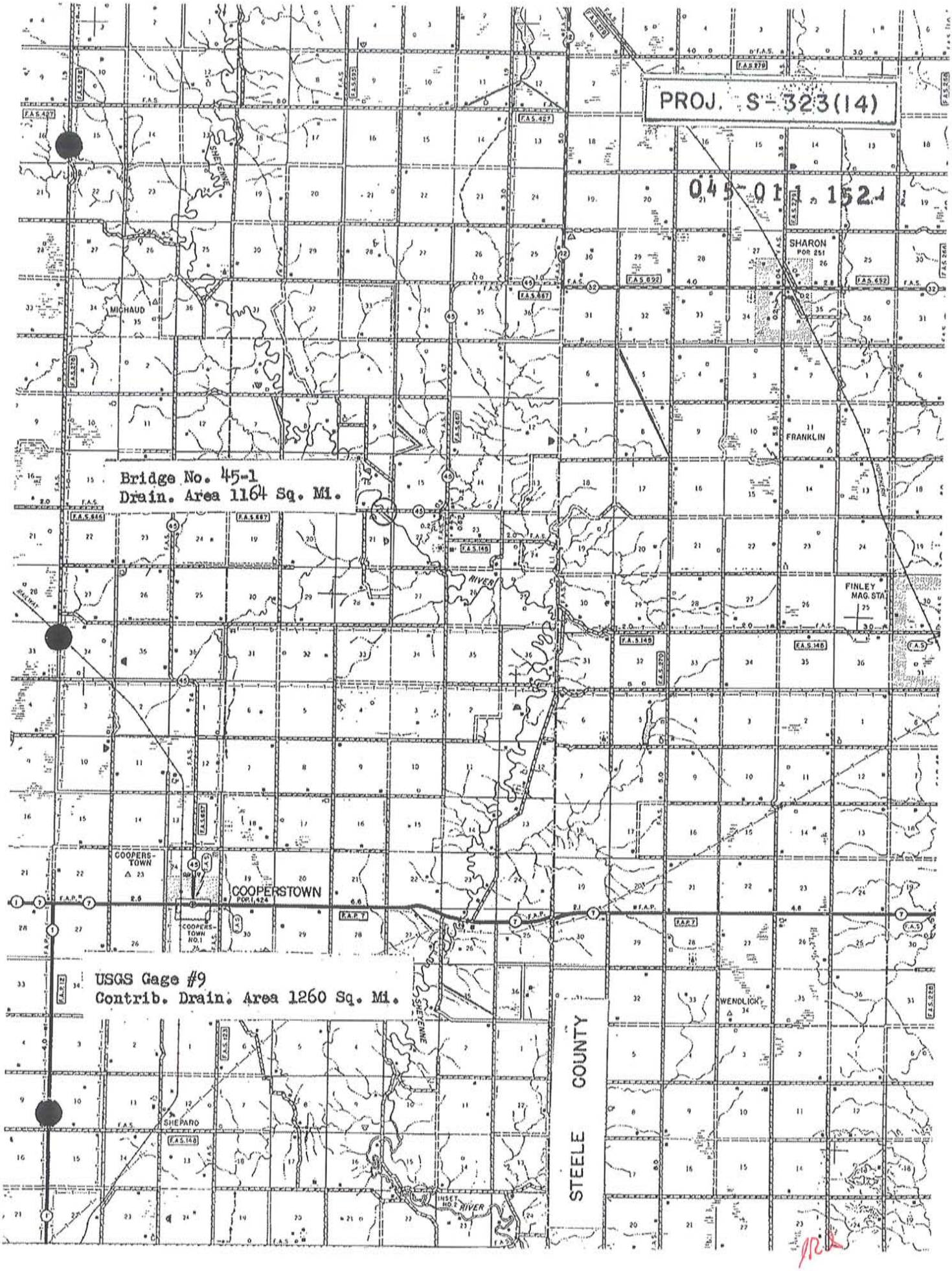
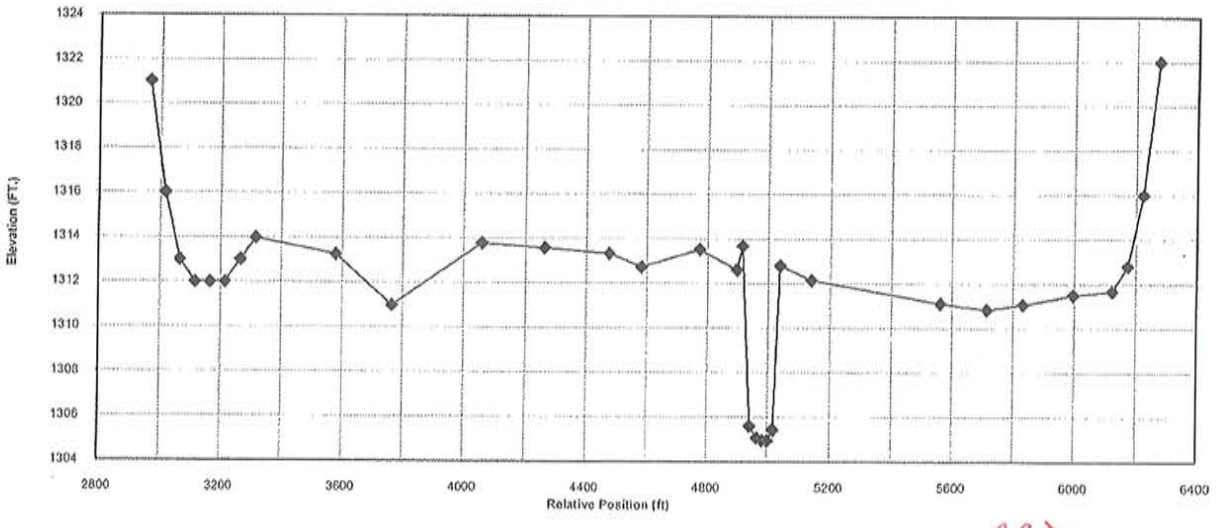
crossing
Reduce by 21 sq miles
Bridge


PROJ. S-323(14)
045-011-152
Bridge No. 45-1
Drain. Area 1164 Sq. Mi.
USGS Gage #9
Contrib. Drain. Area 1260 Sq. Mi.
SHARON
POP. 251
FRANKLIN
MICHAUD
FINLEY
MAG. STA.
COOPERS-
TOWN
COOPERSTOWN
POP. 424
COOPERS-
TOWN NO. 1
WENDLICK
SHEPARD
INSET
NO. 2
RIVER
STEELE COUNTY
SHEYENNE
RIVER
F.A.S. 427
F.A.S. 692
F.A.S. 667
F.A.S. 148
F.A.S. 279
F.A.P. 7

Typical Cross Section

Point #	Northing	Easting	Distance	Cummulative Distance	Relative Position	Elevation
GIS			0.00	0.00	2966.31	1321.00
GIS			50.00	50.00	3016.31	1316.00
GIS			50.00	100.00	3066.31	1313.00
GIS			50.00	150.00	3116.31	1312.00
GIS			50.00	200.00	3166.31	1312.00
GIS			50.00	250.00	3216.31	1312.00
GIS			50.00	300.00	3266.31	1313.00
6670	709442.9	2561805.9	50.00	350.00	3316.31	1313.97
6620	709413.9	2561545.8	261.79	611.79	3578.10	1313.26
6633	709337.8	2561375.0	186.95	798.75	3765.06	1310.97
6596	709365.3	2561082.2	294.05	1092.79	4059.10	1313.78
6591	709281.5	2560895.0	205.13	1297.93	4264.24	1313.57
6585	709273.1	2560683.1	212.03	1509.95	4476.26	1313.32
6582	709266.7	2560577.0	106.36	1616.31	4582.62	1312.72
6579	709255.1	2560386.0	191.31	1807.62	4773.93	1313.52
11674	709333.5	2560290.9	123.30	1930.92	4897.23	1312.62
11673	709338.5	2560274.0	17.64	1948.56	4914.87	1313.69
6577	709359.2	2560256.0	27.38	1975.93	4942.25	1305.60
6576	709352.9	2560233.5	23.42	1999.35	4965.66	1305.07
6575	709354.7	2560214.9	18.72	2018.07	4984.38	1304.95
6574	709356.0	2560199.3	15.62	2033.69	5000.00	1304.94
6573	709357.3	2560181.1	18.21	2051.90	5018.21	1305.43
6572	709356.8	2560161.2	19.95	2071.85	5038.17	1312.82
6564	709401.2	2560069.3	102.02	2173.87	5140.18	1312.16
6549	709433.0	2559649.4	421.15	2595.02	5561.34	1311.11
6543	709544.3	2559544.8	152.70	2747.73	5714.04	1310.84
6530	709538.7	2559426.0	118.95	2866.68	5832.99	1311.07
6526	709638.8	2559296.8	163.43	3030.11	5996.43	1311.50
6509	709637.4	2559168.6	128.26	3158.38	6124.69	1311.67
GIS			50.00	3208.38	6174.69	1312.80
GIS			50.00	3258.38	6224.69	1316.00
GIS			50.00	3308.38	6274.69	1322.00

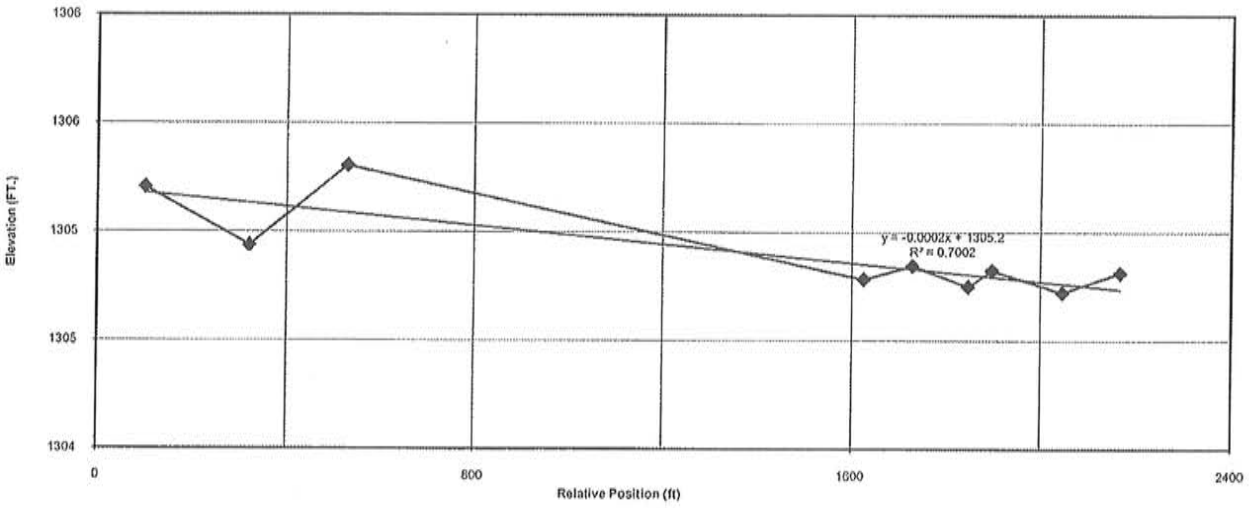
CL Transmission



1/18/2011

Channel Profile

Point #	Northing	Easting	Distance	Cummulative Distance	Relative Position	Elevation
11705	709561.67	2560277.84	0	0	1+00.00	1305.21
6574	709355.96	2560199.29	220.20	220.20	3+20.20	1304.94
11704	709166.73	2560106.98	210.54	430.74	5+30.74	1305.30
6661	709189.41	2561201.39	1094.64	1525.38	16+25.38	1304.78
6659	709222.38	2561298.28	102.35	1627.73	17+27.73	1304.85
6656	709251.99	2561413.57	119.04	1746.77	18+46.77	1304.75
6655	709243.26	2561463.10	50.29	1797.06	18+97.06	1304.82
6651	709120.07	2561546.63	148.83	1945.89	20+45.89	1304.72
6648	709001.10	2561528.49	120.34	2066.24	21+66.24	1304.81



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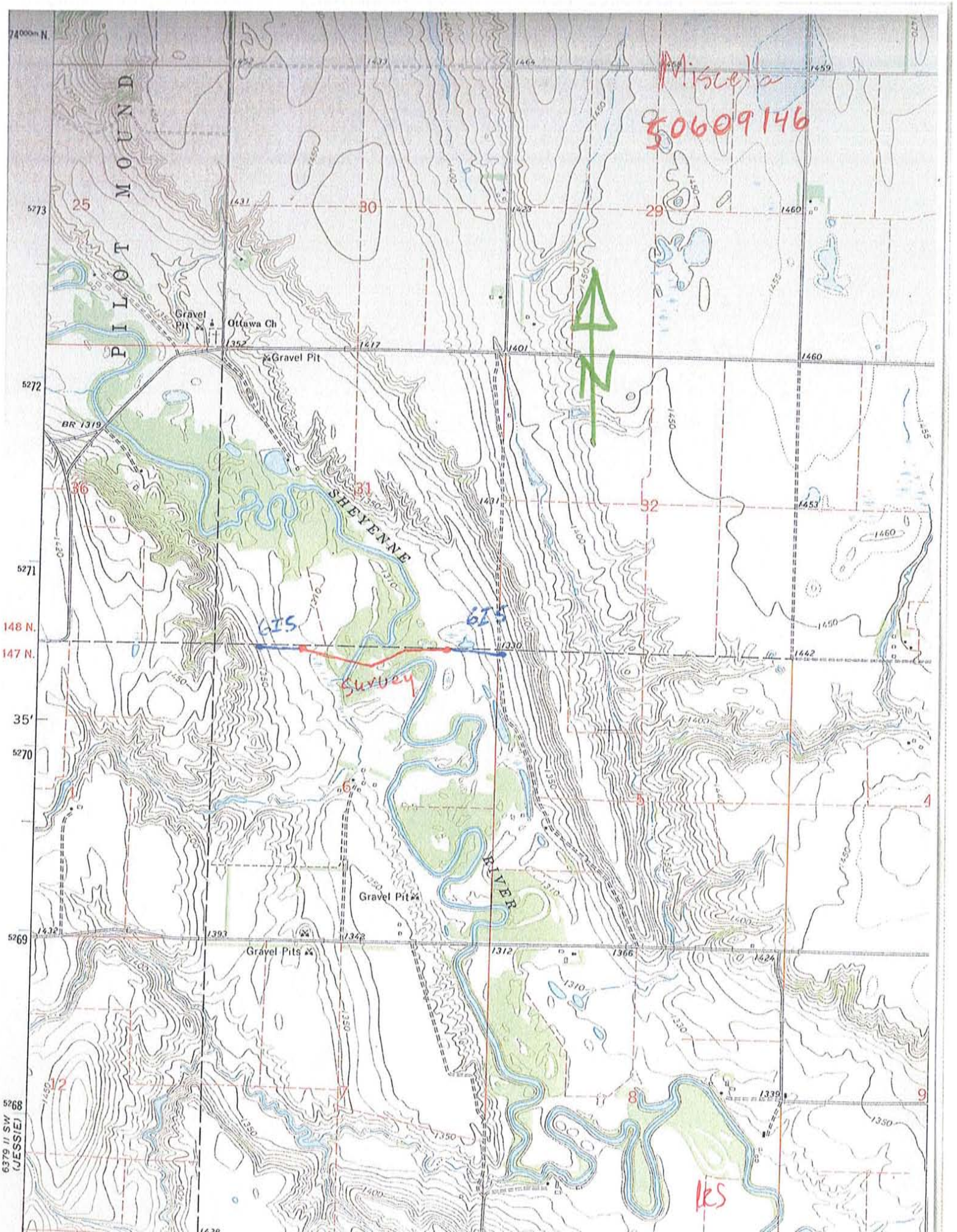
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50609146
PILOT MOUND
Gravel Pit
Ottawa Ch
Gravel Pit
BR 1319
SHEYENNE
GIS
GIS
Survey
148 N.
147 N.
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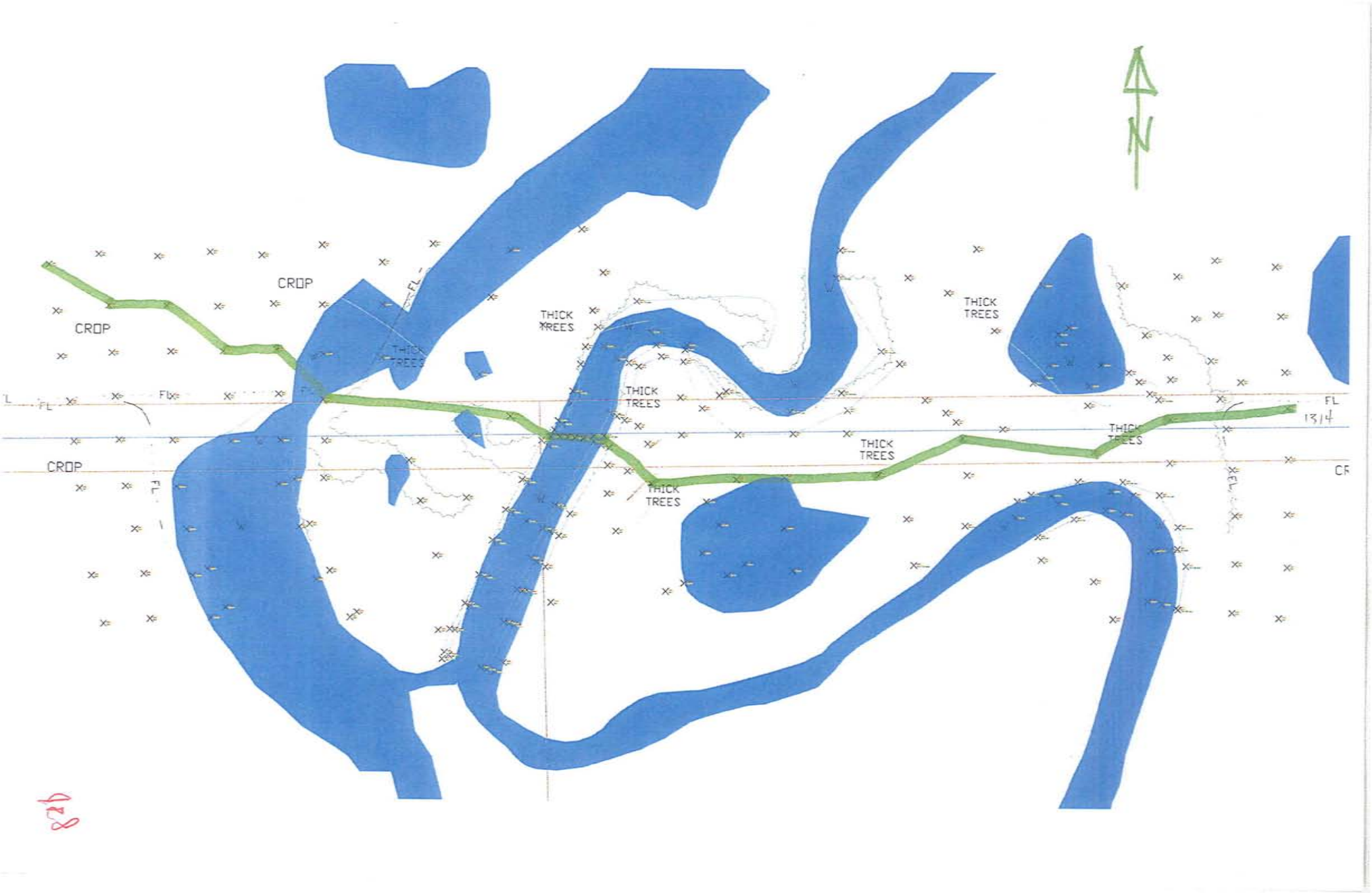
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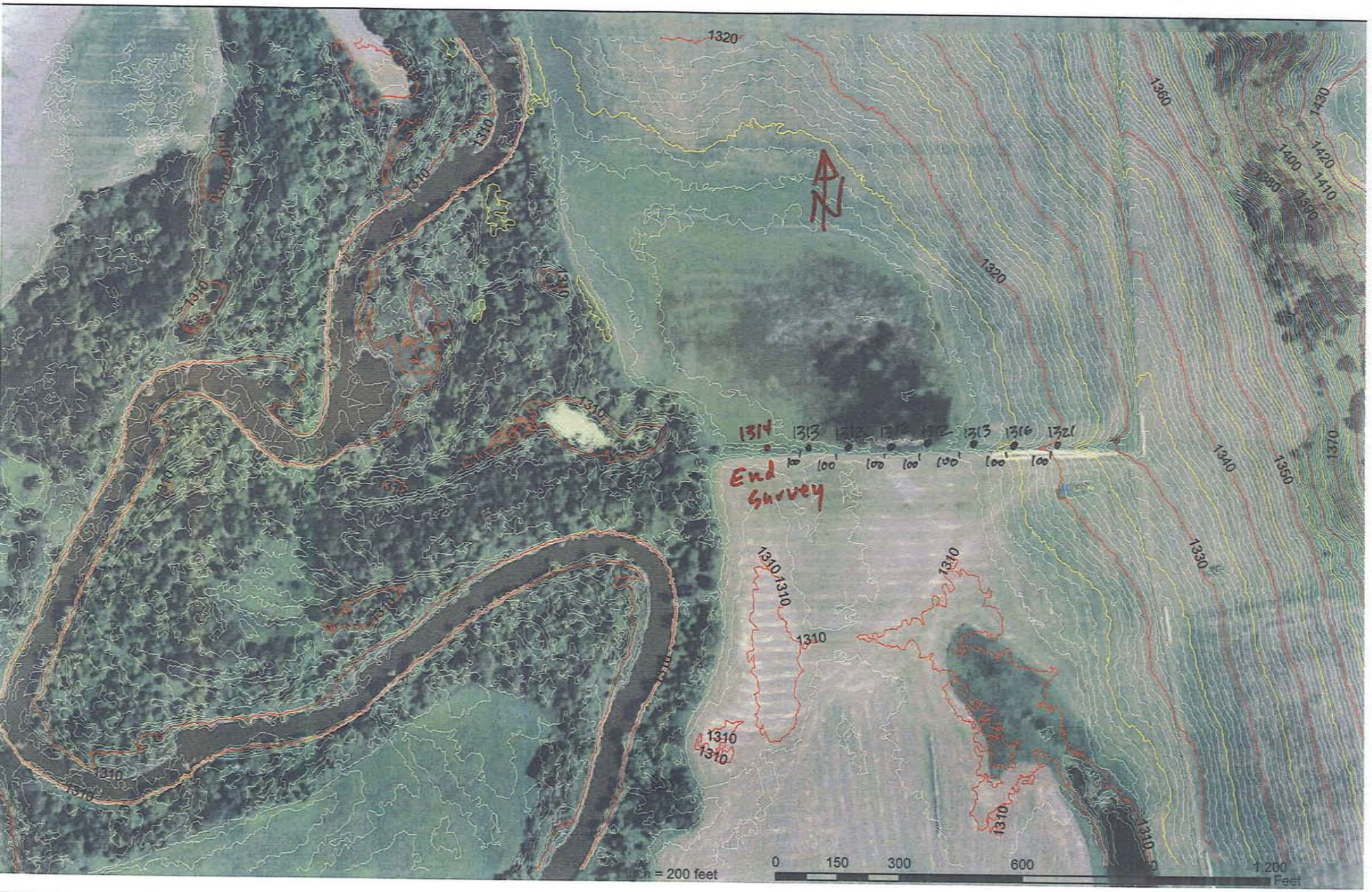
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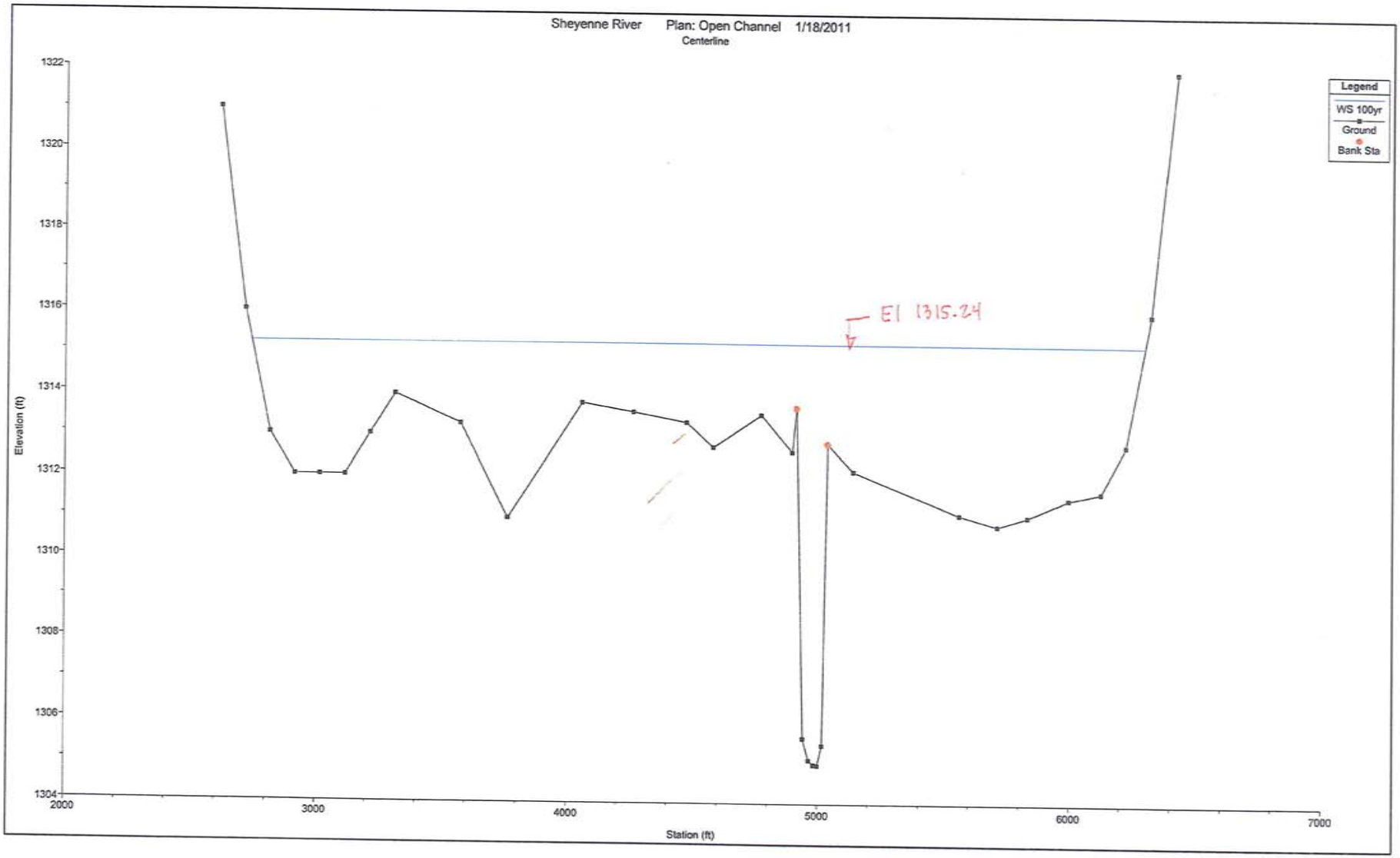
Sheyenne River Plan: Open Channel 1/18/2011
Centerline
Legend
WS 100yr
Ground
Bank Sta
EI 1315.24
Elevation (ft)
Station (ft)
1322
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2000
3000
4000
5000
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7000

Q28 1/24/10