Availability and Quality of Surface and Groundwater Resources in West-Central and Southwest North Dakota

Dodge Water Depot, Dunn County - Photo Courtesy of Mike Hove

By
Robert Shaver

ND Water Resource Investigation No. 53
North Dakota State Water Commission

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INTRODUCTION

The Tyler Formation is a regionally extensive, organically rich, Pennsylvanian unit comprised of sandstone, marine limestone and shale (Nordeng and Nesheim, 2011). Limited data suggests the Tyler Formation is sufficiently mature to generate oil (Nordeng and Nesheim, 2011) Potential exists for oil development in the E1/2 of McKenzie County, the NW1/4 of Dunn County, the W1/2 of Hettinger County, the E1/2 of Slope County, the S1/2 of Billings County, and the W1/2 of Stark County (verbal communication, Steve Nordeng) (fig.1).

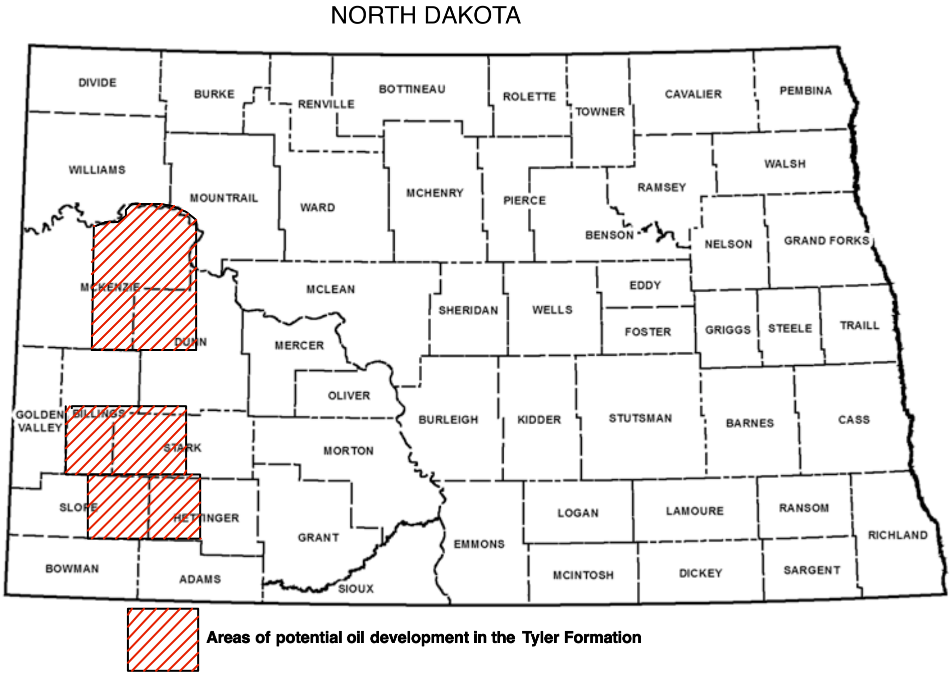


Figure 1 – Locations of potential oil development in the Tyler Formation

Preliminary estimates of oil development provided by the Oil and Gas Division of the North Dakota Industrial Commission, indicate between 2,500 to 7,000 oil wells could be completed in the Tyler Formation over a 7 to 10 year period. Activity is expected to increase significantly within 2 to 5 years with 250 to 500 oil wells being constructed each year. It is estimated that 1.5 to 2 million gallons of water will be needed to complete each oil well. This amounts to an annual water demand of between 1,680 acre-feet (350 oil wells) and 2,240 acre-feet (500 oil wells).

The purpose of this report is to provide an assessment of the availability of both surface and ground-water sources in west-central and southwest North Dakota. For each water source, water quality data is presented to provide the potential water user with a basis for determining if limitations exist for the proposed use. **It is very important for the potential water user to contact staff hydrologists at the Water Appropriations Division of the North Dakota State Water Commission for more detailed assessment of water availability and quality at a specific site.**

ACKNOWLEDGEMENTS

Thanks are extended to the following North Dakota State Water Commission personnel: Darin Schepp for preparing stream flow exceedence tables, Chris Bader for providing water quality summary tables for selected ground water sources, Alan Wanek for providing general hydrogeological information in western North Dakota, Andrew Nygren for preparation of precipitation and median daily stream discharge figures, Jon Patch, Bill Schuh, and Jennifer Morin for editing and report review. Thanks are extended to Pete Wax, Environmental Scientist, North Dakota Department of Health, Division of Water Quality for providing water chemistry data from Bowman-Haley, Dickinson, and Heart Butte Reservoirs. Recognition is also due to Joel Galloway, Hydrologic Studies Section Chief, U.S. Geological Survey, Water Resources Division, Bismarck, ND, for providing water chemistry data from Dickinson and Heart Butte Reservoirs. Thanks are also extended to Steven Nordeng, Geologist, ND State Geological Survey for providing information on potential for oil development from the Tyler Formation and to Gregory Gere, Assistant Area Manager, Dakotas Office, U.S. Bureau of Reclamation, for providing information relative to water-related contract and repayment principles and requirements. Finally, thanks are extended to Scott Schnieder, Engineer, Apex Engineering, Bismarck, ND, for providing information on the proposed wastewater treatment facility for the City of Dickinson, ND.

CLIMATE

West-central and southwest North Dakota are characterized by a semi-arid climate with precipitation averaging about 14 to 16 inches per year. Approximately 50 to 60 percent of the annual precipitation falls in the four-month period from April through July, while nearly 75 percent occurs in the six-month period from April through September (Jensen, no date). Mean annual temperature is about 43 degrees F ranging from about -50 degrees F. to about 110 degrees F (Jensen, no date).

A summary of precipitation data measured at a weather station in Dickinson, North Dakota is shown in Figure 2. Over the period of record from 1905 through 2011, total annual water year (October through September) precipitation ranges from 6.33 inches in 1936 to 32.29 inches in 1941 with a mean value of 16.24 inches. Backward five-year moving averages of water year, April through September, and October through March precipitation are also shown in Figure 2 to more readily identify wet and dry periods. The wettest period occurred during the early 1940’s and the driest period occurred during the 1930’s.

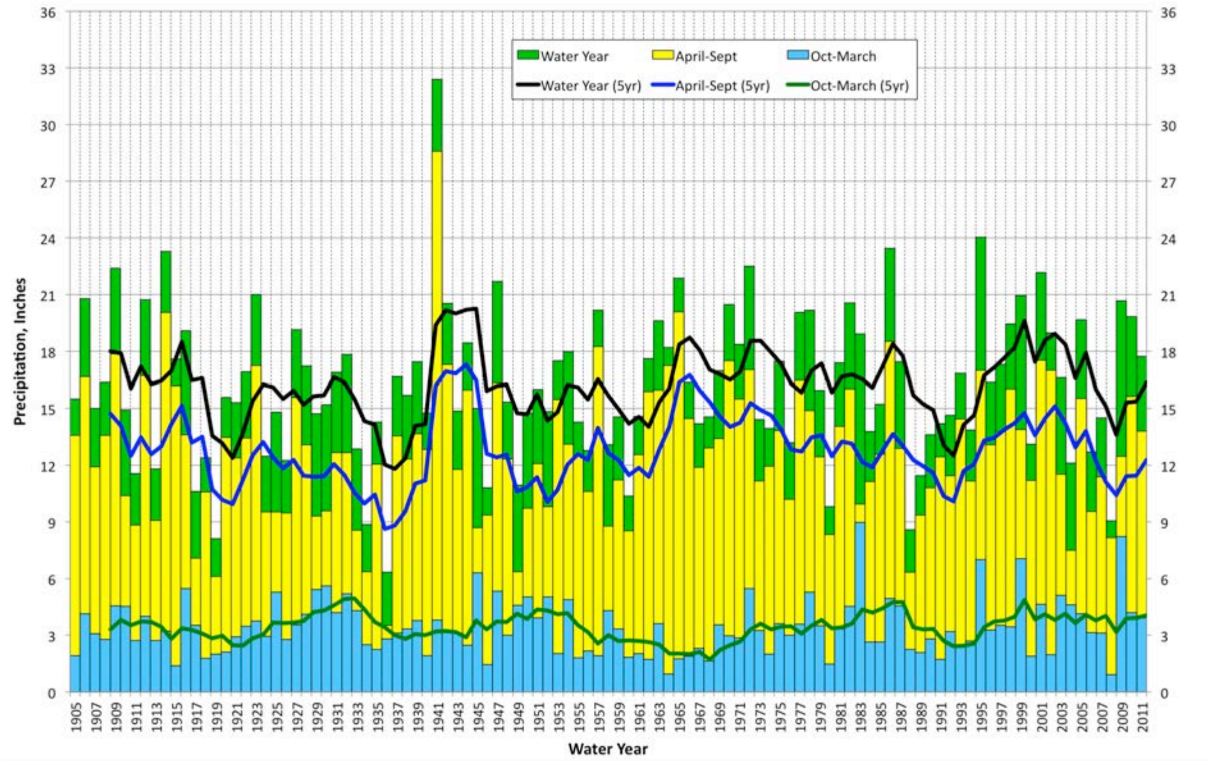


Figure 2 – Precipitation summary at Dickinson, North Dakota

POTENTIAL WATER SOURCES

Water resources in west central and southwest North Dakota are limited. Streams are characterized by highly variable flows, and with the exception of the Missouri River, cannot provide reliable water supplies throughout the year. Reliable surface water supplies are available primarily from dams and reservoirs. These include Bowman-Haley, Dickinson (Patterson Lake) and Heart Butte (Lake Tschida) Reservoirs.

The City of Dickinson is served by the Southwest Water Authority, which diverts water from the Missouri River. Reuse of Dickinson’s waste stream is another potential source of water for industrial use.

The landscape of most of southwest North Dakota is non-glaciated and as a result, lacks glaciofluvial aquifers of Pleistocene age that are major sources of freshwater throughout other areas of North Dakota. Some glaciofluvial aquifers occur in both McKenzie and Dunn Counties that are potential sources of fresh water for oil field industrial use. These include the Bennie Peer, Little Missouri River, Charbonneau, Tobacco Garden, Killdeer, Goodman Creek, and Horse Nose Butte aquifers (fig.3). The Fox Hills, Tongue River, and other Tertiary-age bedrock aquifers are also potential sources of fresh water for oil field industrial use.

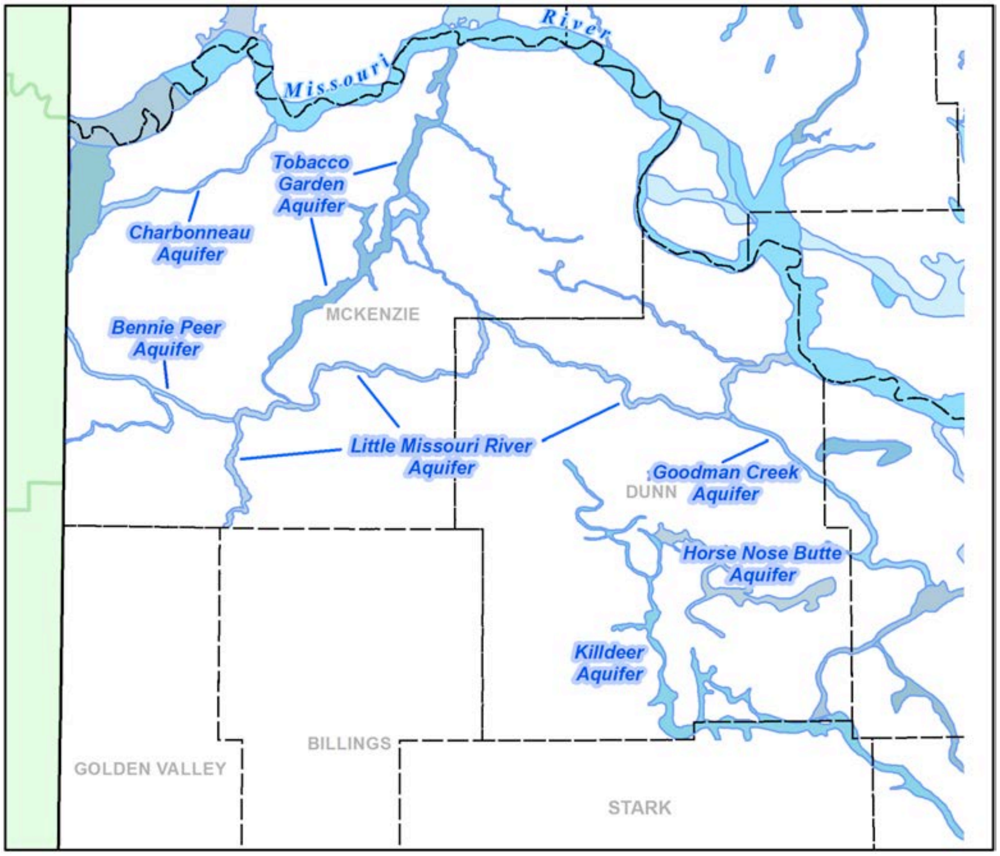


Figure 3. – Location of major glaciofluvial aquifers in McKenzie and Dunn Counties

Rivers and Streams

The U.S. Geological Survey measures continuous stream discharge at selected sites throughout North Dakota (fig. 4).

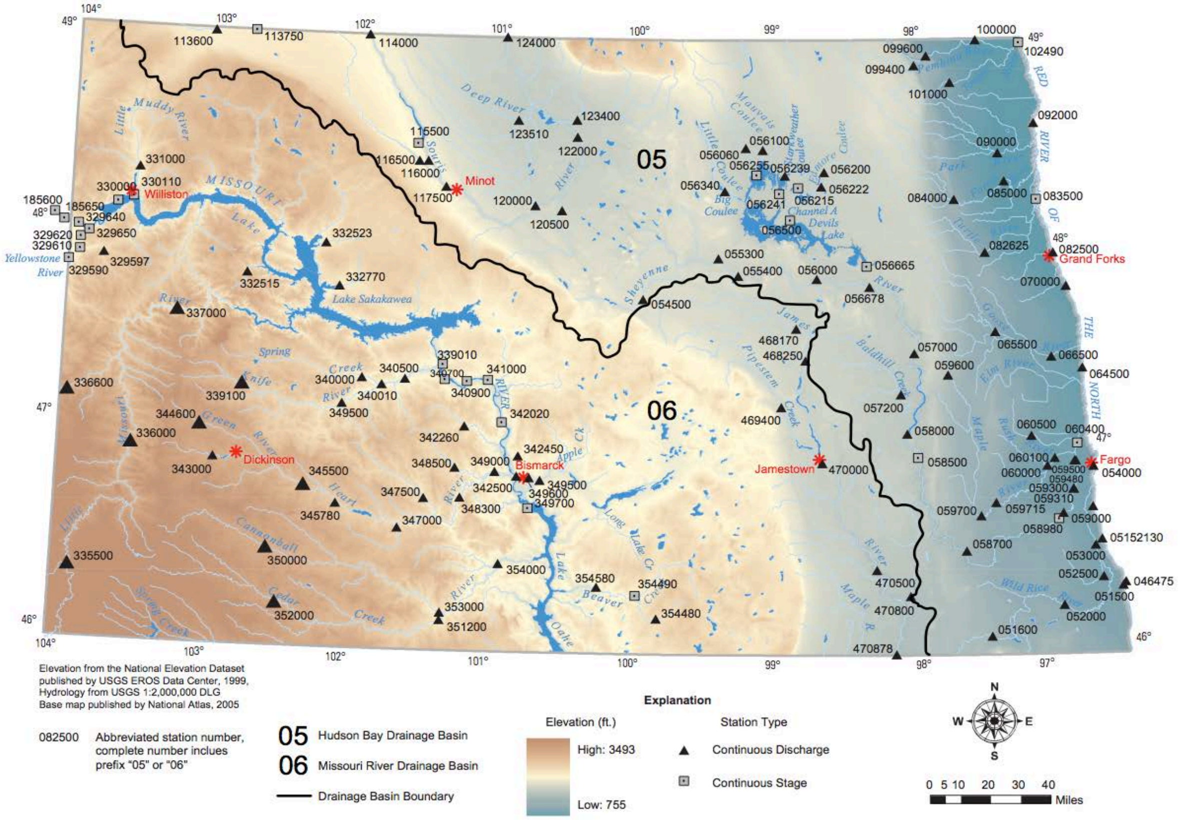


Figure 4 – Location of continuous discharge and continuous stage stream gaging sites in North Dakota (Map prepared by U.S. Geological Survey, July, 2012)

In the study area, these sites include:

1) Little Missouri River at Marmarth – Site #335500
2) Little Missouri River at Medora – Site #336000
3) Beaver Creek near Trotters – Site #336600
4) Little Missouri River near Watford City – Site #337000
5) Knife River at Manning – Site #339100
6) Green River at New Hradec – Site #344600
7) Heart River at Richardton – Site # 345500
8) Cannonball River at Regent – Site#350000
9) Cedar Creek near Haynes – Site #352000

Probabilities of exceeding monthly flows at the above gaging stations are shown in Tables 1 through 9. Median daily discharge for the above gaging stations are shown graphically in figures 5 through 11.

Table 1 – Probabilities of exceeding monthly flows from the Little Missouri River at Marmarth, ND

Site #335500 Little Missouri River at Marmarth, ND

January		February		March		April		May		June	
% Exceedance	**cfs**	**% Exceedance**	**cfs**	**% Exceedance**	**cfs**	**% Exceedance**	**cfs**	**% Exceedance**	**cfs**	**% Exceedance**	**cfs**
95	0.00	95	0.00	95	0.50	95	24.50	95	12.00	95	7.92
90	0.02	90	0.00	90	10.90	90	34.70	90	17.90	90	20.60
85	0.03	85	0.00	85	22.20	85	44.00	85	25.00	85	32.60
80	0.04	80	0.00	80	35.20	80	54.60	80	34.50	80	44.30
75	0.05	75	0.48	75	48.30	75	66.20	75	44.70	75	56.80
70	0.35	70	1.18	70	65.80	70	79.10	70	54.60	70	75.00
65	0.85	65	1.85	65	88.50	65	100.90	65	67.40	65	95.40
60	1.17	60	3.00	60	110.00	60	124.10	60	83.50	60	118.50
55	1.86	55	4.39	55	142.60	55	149.60	55	105.60	55	148.50
50	2.53	50	6.57	50	185.30	50	184.40	50	132.20	50	181.90
45	3.35	45	10.40	45	241.00	45	230.50	45	165.70	45	231.60
40	4.48	40	15.80	40	317.80	40	291.20	40	208.70	40	287.40
35	5.86	35	23.60	35	431.40	35	375.70	35	262.10	35	372.20
30	9.06	30	34.20	30	578.10	30	492.50	30	337.60	30	494.40
25	12.20	25	50.60	25	797.10	25	640.00	25	470.60	25	670.60
20	15.90	20	83.30	20	1146.50	20	882.40	20	695.00	20	899.40
15	21.30	15	140.50	15	1761.60	15	1247.20	15	959.80	15	1286.80
10	31.00	10	303.80	10	2753.90	10	1816.70	10	1568.20	10	1939.40
5	61.40	5	821.10	5	4504.80	5	3258.10	5	3193.20	5	3364.50

July		August		September		October		November		December	
% Exceedance	**cfs**	**% Exceedance**	**cfs**	**% Exceedance**	**cfs**	**% Exceedance**	**cfs**	**% Exceedance**	**cfs**	**% Exceedance**	**cfs**
95	0.62	95	0.06	95	0.04	95	2.37	95	3.64	95	0.07
90	6.84	90	1.76	90	1.59	90	4.60	90	6.29	90	0.58
85	14.80	85	4.00	85	2.88	85	6.80	85	8.21	85	1.02
80	20.90	80	7.01	80	3.98	80	8.67	80	10.50	80	2.05
75	27.70	75	11.60	75	5.67	75	10.30	75	12.80	75	2.82
70	35.00	70	15.00	70	8.47	70	12.30	70	14.70	70	4.31
65	42.90	65	18.30	65	11.60	65	14.60	65	16.70	65	5.06
60	52.30	60	22.20	60	14.50	60	16.80	60	19.10	60	6.26
55	62.70	55	26.20	55	17.30	55	19.60	55	21.40	55	7.72
50	76.50	50	31.70	50	20.80	50	22.40	50	23.30	50	9.55
45	93.50	45	37.20	45	25.40	45	25.40	45	25.30	45	12.00
40	115.90	40	46.10	40	30.80	40	29.80	40	27.20	40	13.90
35	143.80	35	55.70	35	36.70	35	34.10	35	30.10	35	16.30
30	180.40	30	66.20	30	43.80	30	39.70	30	33.60	30	19.30
25	221.40	25	76.80	25	52.30	25	47.60	25	37.10	25	22.20
20	279.30	20	97.90	20	64.40	20	56.50	20	43.90	20	25.30
15	340.40	15	130.00	15	83.70	15	79.30	15	53.20	15	29.70
10	501.40	10	192.90	10	121.30	10	157.40	10	73.60	10	36.10
5	919.20	5	334.70	5	252.50	5	493.20	5	115.50	5	53.50

Table 2 – Probabilities of exceeding monthly flows for the Little Missouri River at Medora, ND

Site #336000 Little Missouri River at Medora

January		February		March		April		May		June	
% Exceedance	cfs	% Exceedance	cfs	% Exceedance	cfs	% Exceedance	cfs	% Exceedance	cfs	% Exceedance	cfs
95	0.00	95	0.01	95	0.59	95	34.50	95	15.30	95	20.20
90	0.00	90	0.02	90	10.50	90	56.90	90	27.90	90	48.20
85	0.01	85	0.03	85	30.80	85	75.20	85	39.40	85	69.40
80	0.02	80	0.05	80	54.40	80	93.00	80	52.10	80	101.10
75	0.40	75	0.29	75	80.00	75	111.20	75	67.80	75	132.00
70	0.58	70	0.82	70	107.50	70	134.30	70	88.40	70	164.70
65	1.09	65	1.11	65	134.50	65	160.50	65	110.90	65	199.40
60	1.33	60	1.80	60	175.90	60	193.30	60	137.40	60	264.70
55	1.98	55	2.80	55	233.20	55	245.80	55	169.10	55	336.80
50	2.38	50	5.01	50	306.50	50	321.60	50	207.70	50	406.70
45	3.17	45	9.39	45	417.70	45	425.50	45	271.90	45	508.30
40	4.41	40	20.00	40	537.70	40	556.60	40	347.90	40	631.60
35	5.77	35	27.30	35	660.00	35	710.00	35	446.20	35	807.40
30	7.74	30	43.90	30	861.70	30	905.00	30	577.20	30	1026.20
25	10.90	25	53.70	25	1152.90	25	1170.50	25	730.70	25	1268.30
20	14.40	20	93.40	20	1593.50	20	1455.10	20	946.70	20	1543.30
15	20.50	15	152.70	15	2106.00	15	1892.40	15	1263.20	15	1983.30
10	28.30	10	238.30	10	3581.00	10	2734.90	10	1961.30	10	2770.10
5	63.60	5	583.10	5	5964.00	5	5866.20	5	3584.90	5	4661.00

July		August		September		October		November		December	
% Exceedance	cfs	% Exceedance	cfs	% Exceedance	cfs	% Exceedance	cfs	% Exceedance	cfs	% Exceedance	cfs
95	8.74	95	1.94	95	1.23	95	1.95	95	3.64	95	0.12
90	20.60	90	5.24	90	3.90	90	4.83	90	7.37	90	1.09
85	33.80	85	10.20	85	7.03	85	8.66	85	9.30	85	1.74
80	50.60	80	15.10	80	10.80	80	11.50	80	11.30	80	2.05
75	64.70	75	20.00	75	13.90	75	13.90	75	13.40	75	3.29
70	81.10	70	25.90	70	17.10	70	16.20	70	15.50	70	4.66
65	98.70	65	32.70	65	20.60	65	19.60	65	17.60	65	6.42
60	118.60	60	39.40	60	25.20	60	23.20	60	19.90	60	7.90
55	140.30	55	46.20	55	30.40	55	27.00	55	22.40	55	9.38
50	168.20	50	56.80	50	36.20	50	30.90	50	25.00	50	10.90
45	199.50	45	67.90	45	44.20	45	37.00	45	27.90	45	12.30
40	242.70	40	81.90	40	54.10	40	44.10	40	30.90	40	14.40
35	292.40	35	95.90	35	67.00	35	54.20	35	35.80	35	16.70
30	350.50	30	121.90	30	82.60	30	65.90	30	42.30	30	18.80
25	426.00	25	156.70	25	100.90	25	79.10	25	51.10	25	21.00
20	515.30	20	210.00	20	124.40	20	99.80	20	61.50	20	27.70
15	696.20	15	305.40	15	170.10	15	133.50	15	76.80	15	36.50
10	970.70	10	518.40	10	287.40	10	206.80	10	109.50	10	52.90
5	1553.80	5	992.30	5	581.40	5	537.60	5	185.40	5	74.60

Table 3 – Probabilities of exceeding monthly flows from Beaver Creek near Trotters, ND

Site #336600 Beaver Creek Near Trotters, ND

January		February		March		April		May		June	
% Exceedance	cfs	% Exceedance	cfs	% Exceedance	cfs	% Exceedance	cfs	% Exceedance	cfs	% Exceedance	cfs
95	0.15	95	0.00	95	1.71	95	2.10	95	1.09	95	0.11
90	0.30	90	0.00	90	2.69	90	3.22	90	1.74	90	0.59
85	0.45	85	0.00	85	3.92	85	4.26	85	2.31	85	0.88
80	1.07	80	0.00	80	4.95	80	5.40	80	3.54	80	1.51
75	1.34	75	0.01	75	5.96	75	6.87	75	4.47	75	2.48
70	1.81	70	0.08	70	7.28	70	8.84	70	5.73	70	3.32
65	1.93	65	0.94	65	9.00	65	11.00	65	6.83	65	4.23
60	2.05	60	1.33	60	12.10	60	13.00	60	7.78	60	5.24
55	2.45	55	1.76	55	15.10	55	15.00	55	8.78	55	6.36
50	2.74	50	2.18	50	18.90	50	16.60	50	9.79	50	7.48
45	3.09	45	2.69	45	24.00	45	18.30	45	11.50	45	8.83
40	3.34	40	3.36	40	30.80	40	19.90	40	13.50	40	10.20
35	3.53	35	4.57	35	39.40	35	23.60	35	15.80	35	12.30
30	3.74	30	5.66	30	49.90	30	27.30	30	18.30	30	15.60
25	4.07	25	7.30	25	66.10	25	36.00	25	21.40	25	19.40
20	4.61	20	10.60	20	98.70	20	50.70	20	25.80	20	25.10
15	5.20	15	18.90	15	149.20	15	75.80	15	33.50	15	35.00
10	7.20	10	33.60	10	267.70	10	119.80	10	47.70	10	59.00
5	18.50	5	103.40	5	665.30	5	223.50	5	77.90	5	119.30

July		August		September		October		November		December	
% Exceedance	cfs	% Exceedance	cfs	% Exceedance	cfs	% Exceedance	cfs	% Exceedance	cfs	% Exceedance	cfs
95	0.00	95	0.00	95	0.00	95	0.00	95	0.01	95	0.03
90	0.00	90	0.00	90	0.00	90	0.01	90	0.02	90	0.04
85	0.03	85	0.00	85	0.00	85	0.02	85	0.02	85	0.06
80	0.07	80	0.00	80	0.00	80	0.05	80	0.27	80	0.97
75	0.29	75	0.00	75	0.00	75	0.14	75	0.37	75	1.20
70	0.56	70	0.02	70	0.00	70	0.17	70	0.49	70	1.37
65	1.03	65	0.05	65	0.00	65	0.19	65	0.66	65	1.56
60	1.46	60	0.10	60	0.02	60	0.23	60	0.82	60	1.85
55	2.01	55	0.18	55	0.05	55	0.29	55	1.02	55	2.00
50	2.76	50	0.32	50	0.08	50	0.32	50	104.00	50	2.13
45	3.64	45	0.58	45	0.13	45	0.43	45	2.34	45	2.25
40	4.66	40	0.95	40	0.19	40	0.50	40	2.75	40	2.86
35	5.78	35	1.36	35	0.34	35	0.66	35	3.11	35	3.56
30	7.55	30	1.90	30	0.53	30	1.11	30	3.46	30	3.94
25	10.40	25	2.40	25	0.75	25	1.45	25	4.10	25	4.36
20	13.90	20	3.16	20	1.00	20	1.74	20	4.90	20	4.80
15	19.30	15	4.31	15	1.67	15	2.11	15	5.71	15	5.23
10	30.20	10	6.60	10	3.09	10	2.76	10	6.34	10	5.65
5	49.90	5	13.40	5	4.79	5	5.20	5	7.80	5	0.00

Table 4 – Probabilities of exceeding monthly flows from the Little Missouri River near Watford City, ND

Site #337000 Little Missouri River Near Watford City, ND

January		February		March		April		May		June	
% Exceedance	cfs	% Exceedance	cfs	% Exceedance	cfs	% Exceedance	cfs	% Exceedance	cfs	% Exceedance	cfs
95	0.00	95	0.00	95	0.08	95	59.20	95	35.00	95	30.60
90	0.00	90	0.00	90	3.76	90	93.80	90	52.90	90	63.50
85	0.00	85	0.00	85	20.90	85	118.40	85	70.10	85	92.30
80	0.00	80	0.00	80	49.70	80	148.60	80	87.80	80	123.10
75	0.00	75	0.00	75	83.30	75	193.50	75	106.90	75	156.50
70	0.00	70	0.00	70	121.60	70	233.90	70	129.60	70	194.70
65	0.00	65	0.00	65	177.70	65	277.00	65	158.00	65	241.70
60	0.43	60	0.27	60	241.00	60	322.50	60	189.90	60	301.10
55	0.99	55	0.77	55	308.80	55	370.70	55	226.00	55	371.10
50	1.23	50	1.36	50	383.00	50	443.80	50	269.00	50	447.40
45	1.99	45	2.52	45	493.50	45	567.10	45	326.40	45	533.00
40	2.37	40	5.76	40	647.40	40	699.00	40	395.40	40	640.10
35	3.16	35	9.97	35	866.70	35	850.50	35	484.00	35	778.40
30	4.92	30	17.70	30	1199.00	30	1042.40	30	616.70	30	957.70
25	7.00	25	37.60	25	1662.20	25	1306.30	25	783.50	25	1216.50
20	10.80	20	83.70	20	2292.40	20	1670.80	20	994.00	20	1596.50
15	17.30	15	190.00	15	3263.90	15	2229.90	15	1368.60	15	2120.90
10	31.50	10	417.40	10	5166.10	10	3365.30	10	2167.50	10	2940.60
5	65.90	5	1096.20	5	9076.10	5	6271.40	5	3777.50	5	4704.20

July		August		September		October		November		December	
% Exceedance	cfs	% Exceedance	cfs	% Exceedance	cfs	% Exceedance	cfs	% Exceedance	cfs	% Exceedance	cfs
95	20.50	95	8.29	95	3.00	95	1.76	95	1.68	95	0.01
90	42.80	90	17.00	90	7.79	90	4.19	90	4.44	90	0.33
85	65.90	85	24.30	85	12.80	85	7.26	85	7.62	85	0.95
80	86.90	80	31.90	80	17.00	80	12.20	80	11.70	80	1.47
75	106.70	75	42.00	75	21.00	75	16.60	75	15.20	75	1.99
70	128.30	70	52.40	70	25.40	70	20.30	70	18.20	70	3.32
65	150.00	65	62.40	65	30.70	65	23.80	65	21.10	65	4.36
60	174.20	60	72.90	60	39.40	60	27.70	60	23.90	60	6.30
55	198.50	55	83.60	55	48.60	55	32.60	55	27.00	55	8.02
50	228.70	50	96.20	50	58.30	50	38.30	50	31.50	50	9.53
45	269.10	45	110.30	45	70.70	45	45.70	45	36.10	45	11.20
40	312.80	40	126.20	40	84.80	40	53.90	40	41.10	40	13.30
35	374.00	35	147.40	35	102.40	35	64.20	35	46.10	35	15.70
30	439.10	30	170.90	30	122.70	30	75.50	30	53.30	30	19.20
25	540.30	25	209.80	25	145.60	25	92.80	25	61.80	25	23.40
20	666.10	20	261.20	20	184.80	20	119.00	20	74.70	20	29.80
15	841.40	15	334.20	15	241.90	15	173.30	15	92.10	15	38.30
10	1204.70	10	477.70	10	336.70	10	333.20	10	119.00	10	51.40
5	1953.80	5	772.00	5	600.80	5	796.10	5	218.10	5	69.00

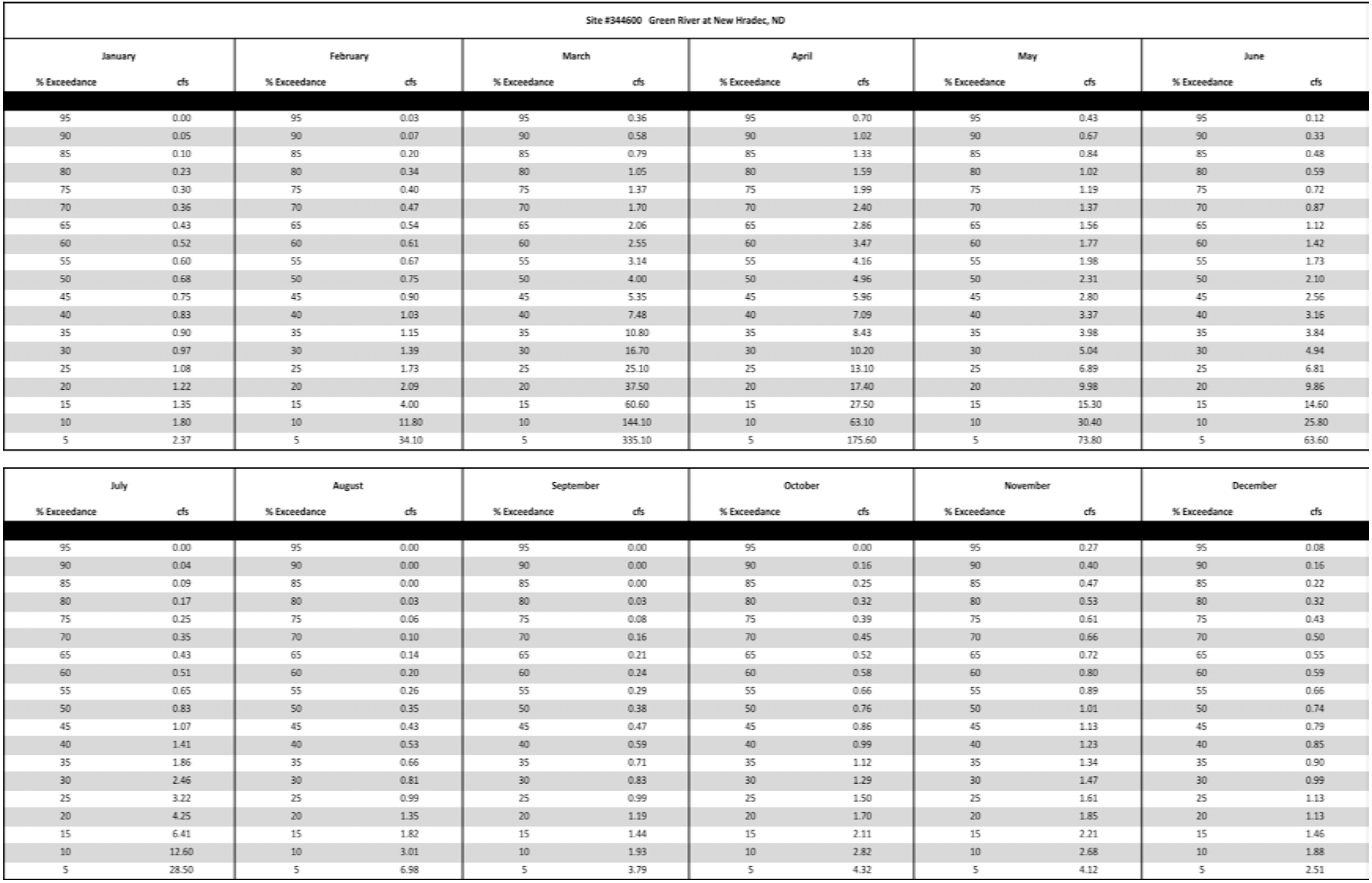
Table 5 – Probabilities of exceeding monthly flows in the Knife River at Manning, ND

Site #339100 Knife River at Manning, ND

January		February		March		April		May		June	
% Exceedance	cfs	% Exceedance	cfs	% Exceedance	cfs	% Exceedance	cfs	% Exceedance	cfs	% Exceedance	cfs
95	0.00	95	0.08	95	0.75	95	1.25	95	0.60	95	0.20
90	0.10	90	0.14	90	1.21	90	1.76	90	0.83	90	0.45
85	0.21	85	0.22	85	1.56	85	2.20	85	1.10	85	0.68
80	0.30	80	0.32	80	1.87	80	2.83	80	1.39	80	0.93
75	0.41	75	0.48	75	2.47	75	3.48	75	1.69	75	1.18
70	0.53	70	0.62	70	3.15	70	4.08	70	2.02	70	1.42
65	0.61	65	0.76	65	3.90	65	4.62	65	2.34	65	1.67
60	0.67	60	0.95	60	5.09	60	5.20	60	2.66	60	1.92
55	0.73	55	1.11	55	6.64	55	6.01	55	2.98	55	2.23
50	0.83	50	1.25	50	8.44	50	6.94	50	3.43	50	2.54
45	0.95	45	1.39	45	11.30	45	8.20	45	3.96	45	2.95
40	1.09	40	1.64	40	15.10	40	10.00	40	4.74	40	3.45
35	1.24	35	1.89	35	21.10	35	12.70	35	5.75	35	4.08
30	1.38	30	2.21	30	28.90	30	16.10	30	7.34	30	4.99
25	1.55	25	2.57	25	45.10	25	20.20	25	9.95	25	6.76
20	1.73	20	3.61	20	66.70	20	26.60	20	13.50	20	9.99
15	1.90	15	10.70	15	102.40	15	39.70	15	19.60	15	15.80
10	2.30	10	29.20	10	200.00	10	70.70	10	33.80	10	27.40
5	3.90	5	66.80	5	477.60	5	166.70	5	73.70	5	55.10

July		August		September		October		November		December	
% Exceedance	cfs	% Exceedance	cfs	% Exceedance	cfs	% Exceedance	cfs	% Exceedance	cfs	% Exceedance	cfs
95	0.03	95	0.00	95	0.00	95	0.00	95	0.31	95	0.21
90	0.06	90	0.00	90	0.00	90	0.05	90	0.49	90	0.33
85	0.12	85	0.02	85	0.03	85	0.17	85	0.59	85	0.41
80	0.24	80	0.04	80	0.04	80	0.31	80	0.70	80	0.52
75	0.35	75	0.08	75	0.07	75	0.43	75	0.81	75	0.59
70	0.49	70	0.13	70	0.11	70	0.55	70	0.92	70	0.66
65	0.64	65	0.19	65	0.15	65	0.65	65	1.03	65	0.73
60	0.81	60	0.29	60	0.21	60	0.74	60	1.14	60	0.81
55	1.03	55	0.36	55	0.29	55	0.89	55	1.25	55	0.89
50	1.32	50	0.43	50	0.37	50	1.09	50	1.35	50	0.99
45	1.60	45	0.53	45	0.46	45	1.26	45	1.47	45	1.10
40	1.89	40	0.66	40	0.55	40	1.42	40	1.61	40	1.24
35	2.35	35	0.86	35	0.67	35	1.61	35	1.74	35	1.38
30	2.92	30	1.10	30	0.81	30	1.81	30	1.91	30	1.54
25	3.76	25	1.33	25	1.03	25	2.04	25	2.10	25	1.73
20	5.80	20	1.66	20	1.29	20	2.50	20	2.29	20	1.93
15	9.58	15	2.32	15	1.60	15	3.10	15	2.79	15	2.18
10	18.20	10	3.87	10	2.28	10	3.94	10	3.39	10	2.48
5	38.50	5	7.93	5	3.70	5	6.11	5	4.40	5	2.98

Table 6 – Probabilities of exceeding monthly flows in the Green River at New Hradec, ND



Site #344600 Green River at New Hradec, ND

January		February		March		April		May		June	
% Exceedance	cfs	% Exceedance	cfs	% Exceedance	cfs	% Exceedance	cfs	% Exceedance	cfs	% Exceedance	cfs
95	0.00	95	0.03	95	0.36	95	0.70	95	0.43	95	0.12
90	0.05	90	0.07	90	0.58	90	1.02	90	0.67	90	0.33
85	0.10	85	0.20	85	0.79	85	1.33	85	0.84	85	0.48
80	0.23	80	0.34	80	1.05	80	1.59	80	1.02	80	0.59
75	0.30	75	0.40	75	1.37	75	1.99	75	1.19	75	0.72
70	0.36	70	0.47	70	1.70	70	2.40	70	1.37	70	0.87
65	0.43	65	0.54	65	2.06	65	2.86	65	1.56	65	1.12
60	0.52	60	0.61	60	2.55	60	3.47	60	1.77	60	1.42
55	0.60	55	0.67	55	3.14	55	4.16	55	1.98	55	1.73
50	0.68	50	0.75	50	4.00	50	4.96	50	2.31	50	2.10
45	0.75	45	0.90	45	5.35	45	5.96	45	2.80	45	2.56
40	0.83	40	1.03	40	7.48	40	7.09	40	3.37	40	3.16
35	0.90	35	1.15	35	10.80	35	8.43	35	3.98	35	3.84
30	0.97	30	1.39	30	16.70	30	10.20	30	5.04	30	4.94
25	1.08	25	1.73	25	25.10	25	13.10	25	6.89	25	6.81
20	1.22	20	2.09	20	37.50	20	17.40	20	9.98	20	9.86
15	1.35	15	4.00	15	60.60	15	27.50	15	15.30	15	14.60
10	1.80	10	11.80	10	144.10	10	63.10	10	30.40	10	25.80
5	2.37	5	34.10	5	335.10	5	175.60	5	73.80	5	63.60

July		August		September		October		November		December	
% Exceedance	cfs	% Exceedance	cfs	% Exceedance	cfs	% Exceedance	cfs	% Exceedance	cfs	% Exceedance	cfs
95	0.00	95	0.00	95	0.00	95	0.00	95	0.27	95	0.08
90	0.04	90	0.00	90	0.00	90	0.16	90	0.40	90	0.16
85	0.09	85	0.00	85	0.00	85	0.25	85	0.47	85	0.22
80	0.17	80	0.03	80	0.03	80	0.32	80	0.53	80	0.32
75	0.25	75	0.06	75	0.08	75	0.39	75	0.61	75	0.43
70	0.35	70	0.10	70	0.16	70	0.45	70	0.66	70	0.50
65	0.43	65	0.14	65	0.21	65	0.52	65	0.72	65	0.55
60	0.51	60	0.20	60	0.24	60	0.58	60	0.80	60	0.59
55	0.65	55	0.26	55	0.29	55	0.66	55	0.89	55	0.66
50	0.83	50	0.35	50	0.38	50	0.76	50	1.01	50	0.74
45	1.07	45	0.43	45	0.47	45	0.86	45	1.13	45	0.79
40	1.41	40	0.53	40	0.59	40	0.99	40	1.23	40	0.85
35	1.86	35	0.66	35	0.71	35	1.12	35	1.34	35	0.90
30	2.46	30	0.81	30	0.83	30	1.29	30	1.47	30	0.99
25	3.22	25	0.99	25	0.99	25	1.50	25	1.61	25	1.13
20	4.25	20	1.35	20	1.19	20	1.70	20	1.85	20	1.13
15	6.41	15	1.82	15	1.44	15	2.11	15	2.21	15	1.46
10	12.60	10	3.01	10	1.93	10	2.82	10	2.68	10	1.88
5	28.50	5	6.98	5	3.79	5	4.32	5	4.12	5	2.51

Table 7 – Probabilities of exceeding monthly flows in the Heart River at Richardton, ND

Site #345500 Heart River at Richardton, ND

January		February		March		April		May		June	
% Exceedance	cfs	% Exceedance	cfs	% Exceedance	cfs	% Exceedance	cfs	% Exceedance	cfs	% Exceedance	cfs
95	0.05	95	0.05	95	1.97	95	9.67	95	5.06	95	4.37
90	0.39	90	0.48	90	5.24	90	14.70	90	6.95	90	6.80
85	1.18	85	0.87	85	7.69	85	19.10	85	9.45	85	9.49
80	1.91	80	1.82	80	11.20	80	22.90	80	12.10	80	12.30
75	2.17	75	2.31	75	14.70	75	27.40	75	14.80	75	15.00
70	2.62	70	2.85	70	18.50	70	32.20	70	17.40	70	18.00
65	3.15	65	3.44	65	22.90	65	37.70	65	20.00	65	21.10
60	3.49	60	4.19	60	28.80	60	43.50	60	22.70	60	25.90
55	3.84	55	4.97	55	37.80	55	50.00	55	25.60	55	30.90
50	4.27	50	5.80	50	52.40	50	58.70	50	29.90	50	37.40
45	4.78	45	6.73	45	69.60	45	67.30	45	34.10	45	44.80
40	5.37	40	8.21	40	86.10	40	85.00	40	40.10	40	53.60
35	6.26	35	10.40	35	115.80	35	106.80	35	46.00	35	64.70
30	7.21	30	13.80	30	165.10	30	132.80	30	56.20	30	78.40
25	8.31	25	18.60	25	267.60	25	179.30	25	68.00	25	101.70
20	9.59	20	24.20	20	376.90	20	246.30	20	83.00	20	136.80
15	11.40	15	39.70	15	488.20	15	363.70	15	111.30	15	196.30
10	15.00	10	64.50	10	809.60	10	703.50	10	174.30	10	310.50
5	21.30	5	186.10	5	2093.30	5	1571.50	5	405.20	5	641.80

July		August		September		October		November		December	
% Exceedance	cfs	% Exceedance	cfs	% Exceedance	cfs	% Exceedance	cfs	% Exceedance	cfs	% Exceedance	cfs
95	1.54	95	0.09	95	0.09	95	0.00	95	2.22	95	1.12
90	2.91	90	0.45	90	0.58	90	1.72	90	3.94	90	2.08
85	4.30	85	0.96	85	1.15	85	2.61	85	4.47	85	2.89
80	5.98	80	1.78	80	1.95	80	3.83	80	5.88	80	3.39
75	8.01	75	2.60	75	2.78	75	4.68	75	7.02	75	4.03
70	9.97	70	3.79	70	3.85	70	5.94	70	7.76	70	4.74
65	12.10	65	5.13	65	4.85	65	7.05	65	8.53	65	5.36
60	14.30	60	6.24	60	5.73	60	8.01	60	9.36	60	5.96
55	16.50	55	7.37	55	6.64	55	8.99	55	10.30	55	6.52
50	19.80	50	8.49	50	7.59	50	10.20	50	11.40	50	7.09
45	23.30	45	9.93	45	8.62	45	11.30	45	12.60	45	8.03
40	27.70	40	11.70	40	9.73	40	12.70	40	13.60	40	8.97
35	32.90	35	14.00	35	11.30	35	14.30	35	14.70	35	981.00
30	39.00	30	16.40	30	13.10	30	16.00	30	15.90	30	10.70
25	48.60	25	19.90	25	15.20	25	18.10	25	17.00	25	11.80
20	60.70	20	24.50	20	17.70	20	20.30	20	18.40	20	13.10
15	77.50	15	31.60	15	21.10	15	23.40	15	21.00	15	15.00
10	116.10	10	45.40	10	26.20	10	30.20	10	24.70	10	18.70
5	250.80	5	78.70	5	35.80	5	47.20	5	34.60	5	24.10

Table 8 – Probabilities of exceeding monthly flows in the Cannonball River at Regent, ND

Site #350000 Cannonball River at Regent, ND

January		February		March		April		May		June	
% Exceedance	cfs	% Exceedance	cfs	% Exceedance	cfs	% Exceedance	cfs	% Exceedance	cfs	% Exceedance	cfs
95	0.10	95	0.07	95	0.82	95	4.35	95	2.85	95	2.27
90	0.47	90	0.42	90	2.41	90	5.20	90	3.39	90	3.15
85	0.84	85	0.77	85	3.44	85	6.64	85	3.95	85	3.87
80	1.07	80	1.07	80	4.29	80	7.59	80	4.59	80	4.59
75	1.24	75	1.56	75	4.97	75	8.81	75	5.45	75	5.34
70	1.51	70	1.80	70	5.68	70	10.90	70	6.25	70	6.15
65	1.83	65	2.01	65	7.03	65	13.20	65	7.03	65	7.05
60	2.03	60	2.37	60	8.82	60	15.30	60	8.09	60	8.15
55	2.20	55	2.83	55	10.90	55	17.60	55	9.24	55	9.56
50	2.37	50	3.37	50	13.20	50	205.00	50	11.00	50	11.50
45	2.73	45	3.94	45	16.60	45	24.00	45	13.10	45	13.80
40	3.12	40	4.38	40	22.40	40	28.30	40	15.90	40	16.60
35	3.49	35	4.81	35	31.70	35	33.20	35	19.50	35	20.50
30	3.88	30	5.24	30	45.80	30	41.30	30	23.00	30	25.70
25	4.29	25	6.04	25	66.70	25	52.50	25	28.20	25	32.50
20	4.71	20	7.08	20	92.70	20	71.00	20	36.50	20	42.80
15	5.36	15	10.70	15	135.10	15	109.60	15	52.10	15	64.50
10	6.12	10	22.10	10	253.30	10	204.20	10	90.20	10	116.80
5	7.74	5	57.60	5	752.90	5	525.50	5	218.80	5	298.30

July		August		September		October		November		December	
% Exceedance	cfs	% Exceedance	cfs	% Exceedance	cfs	% Exceedance	cfs	% Exceedance	cfs	% Exceedance	cfs
95	0.76	95	0.71	95	0.88	95	1.49	95	2.01	95	0.99
90	1.26	90	1.01	90	1.22	90	1.85	90	2.38	90	1.46
85	1.79	85	1.35	85	1.48	85	2.04	85	2.69	85	1.87
80	2.44	80	1.65	80	1.75	80	2.23	80	2.95	80	2.06
75	3.14	75	1.94	75	2.06	75	2.47	75	3.13	75	2.24
70	3.83	70	2.21	70	2.30	70	2.73	70	3.30	70	2.47
65	4.55	65	2.48	65	2.57	65	3.03	65	3.50	65	2.69
60	5.27	60	2.85	60	2.86	60	3.35	60	3.73	60	2.90
55	6.18	55	3.30	55	3.20	55	3.63	55	3.96	55	3.12
50	7.26	50	3.75	50	3.55	50	3.85	50	4.19	50	3.34
45	8.56	45	4.32	45	3.89	45	4.08	45	4.42	45	3.59
40	10.30	40	4.90	40	4.22	40	4.32	40	4.65	40	3.89
35	12.30	35	5.48	35	4.57	35	4.82	35	4.93	35	4.19
30	14.40	30	6.35	30	4.92	30	5.31	30	5.31	30	4.56
25	17.00	25	7.23	25	5.38	25	5.83	25	5.68	25	4.96
20	21.00	20	8.31	20	5.97	20	6.36	20	6.36	20	5.73
15	28.10	15	10.80	15	6.79	15	7.28	15	7.38	15	6.42
10	43.20	10	15.30	10	7.87	10	9.94	10	9.09	10	7.40
5	78.60	5	30.70	5	10.40	5	18.40	5	13.90	5	9.80

Table 9 – Probabilities of exceeding monthly flows in Cedar Creek near Haynes, ND

Site #352000 Cedar Creek Near Haynes, ND											
January		February		March		April		May		June	
% Exceedance	cfs	% Exceedance	cfs	% Exceedance	cfs	% Exceedance	cfs	% Exceedance	cfs	% Exceedance	cfs
95	0.01	95	0.00	95	0.89	95	2.20	95	1.46	95	0.66
90	0.26	90	0.47	90	1.61	90	3.14	90	1.92	90	1.30
85	0.53	85	0.66	85	2.42	85	3.85	85	2.37	85	1.76
80	0.79	80	0.87	80	3.55	80	4.66	80	2.91	80	2.19
75	0.98	75	1.10	75	4.32	75	5.59	75	3.52	75	2.66
70	1.13	70	1.34	70	4.91	70	7.10	70	4.10	70	3.29
65	1.27	65	1.63	65	5.50	65	8.51	65	4.88	65	4.24
60	1.50	60	1.92	60	6.68	60	10.60	60	5.90	60	5.57
55	1.75	55	2.22	55	8.05	55	14.00	55	7.01	55	7.06
50	1.96	50	2.52	50	10.40	50	17.40	50	8.30	50	9.13
45	2.18	45	2.88	45	14.70	45	20.60	45	9.74	45	12.10
40	2.58	40	3.90	40	20.20	40	25.10	40	12.40	40	15.00
35	3.00	35	4.54	35	29.40	35	30.50	35	15.70	35	18.20
30	3.43	30	5.13	30	42.10	30	37.00	30	21.50	30	22.10
25	3.86	25	5.77	25	57.60	25	50.80	25	28.50	25	30.20
20	4.38	20	7.26	20	84.80	20	81.60	20	39.00	20	42.00
15	4.92	15	10.00	15	140.70	15	130.70	15	56.10	15	64.50
10	5.69	10	16.90	10	284.60	10	231.50	10	88.20	10	106.80
5	6.71	5	52.10	5	619.10	5	532.60	5	215.50	5	229.20

July		August		September		October		November		December	
% Exceedance	cfs	% Exceedance	cfs	% Exceedance	cfs	% Exceedance	cfs	% Exceedance	cfs	% Exceedance	cfs
95	0.24	95	0.02	95	0.08	95	0.44	95	0.90	95	0.55
90	0.47	90	0.19	90	0.22	90	0.67	90	1.18	90	0.91
85	0.69	85	0.32	85	0.43	85	0.79	85	1.37	85	1.14
80	0.91	80	0.44	80	0.57	80	0.90	80	1.57	80	1.34
75	1.29	75	0.56	75	0.71	75	1.02	75	1.77	75	1.49
70	1.71	70	0.71	70	0.83	70	1.15	70	1.98	70	1.65
65	2.19	65	0.86	65	0.97	65	1.27	65	2.21	65	1.83
60	2.81	60	1.10	60	1.20	60	1.44	60	2.49	60	2.02
55	3.51	55	1.41	55	1.39	55	1.66	55	2.76	55	2.22
50	4.32	50	1.79	50	1.62	50	2.01	50	3.02	50	2.42
45	5.31	45	2.19	45	1.92	45	2.40	45	3.31	45	2.66
40	6.42	40	2.63	40	2.20	40	2.87	40	3.63	40	3.03
35	7.66	35	3.14	35	2.50	35	3.38	35	3.97	35	3.41
30	9.05	30	3.90	30	2.87	30	3.90	30	4.41	30	3.96
25	11.40	25	4.96	25	3.45	25	4.69	25	4.95	25	4.55
20	14.50	20	6.57	20	4.21	20	5.52	20	5.65	20	5.22
15	19.70	15	9.86	15	5.29	15	6.64	15	6.63	15	5.97
10	27.80	10	16.10	10	7.19	10	8.59	10	8.04	10	6.78
5	49.50	5	31.80	5	10.00	5	16.00	5	14.00	5	9.06

The data indicates a large degree of variability in stream flows within a single month and throughout the year. For example, at the gaging station on the Little Missouri River at Marmarth (Site #335500), during the month of April, twenty percent of the time stream-flow exceeds 882.4 cubic feet per second (cfs) and seventy-five percent of the time stream-flow exceeds 66.2 cfs. At the same gaging site, fifty percent of the time stream flow exceedences range from 2.53 cfs in January to 185.3 cfs in March.

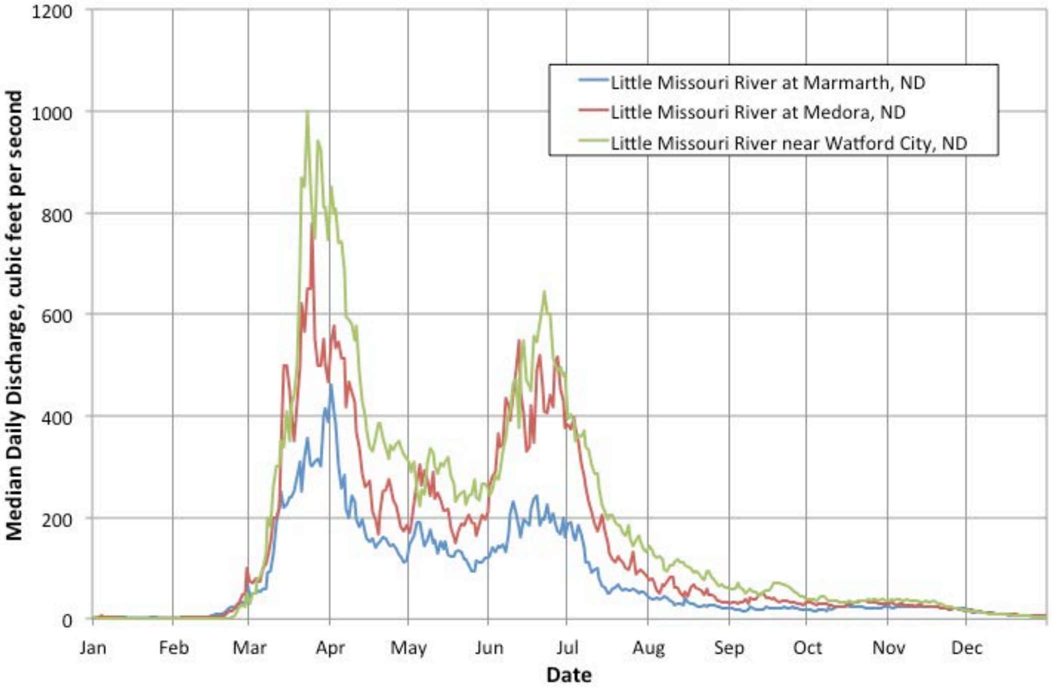


Figure 5 – Median daily discharge in the Little Missouri River at Marmarth, Medora, and Watford City, North Dakota

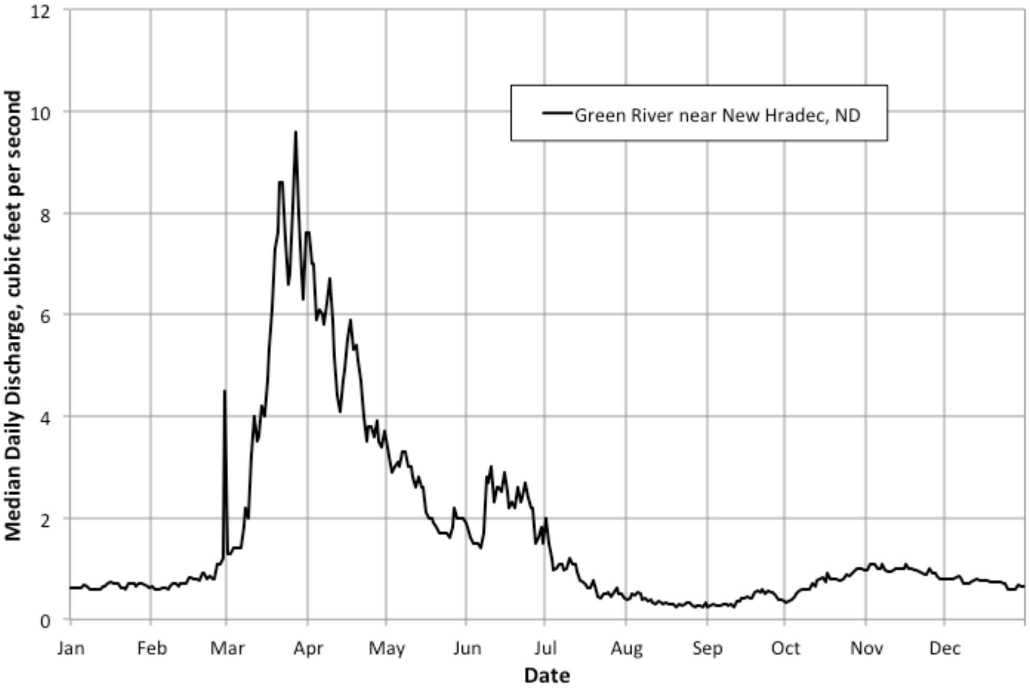


Figure 6 – Median daily discharge in the Green River at New Hradec, ND

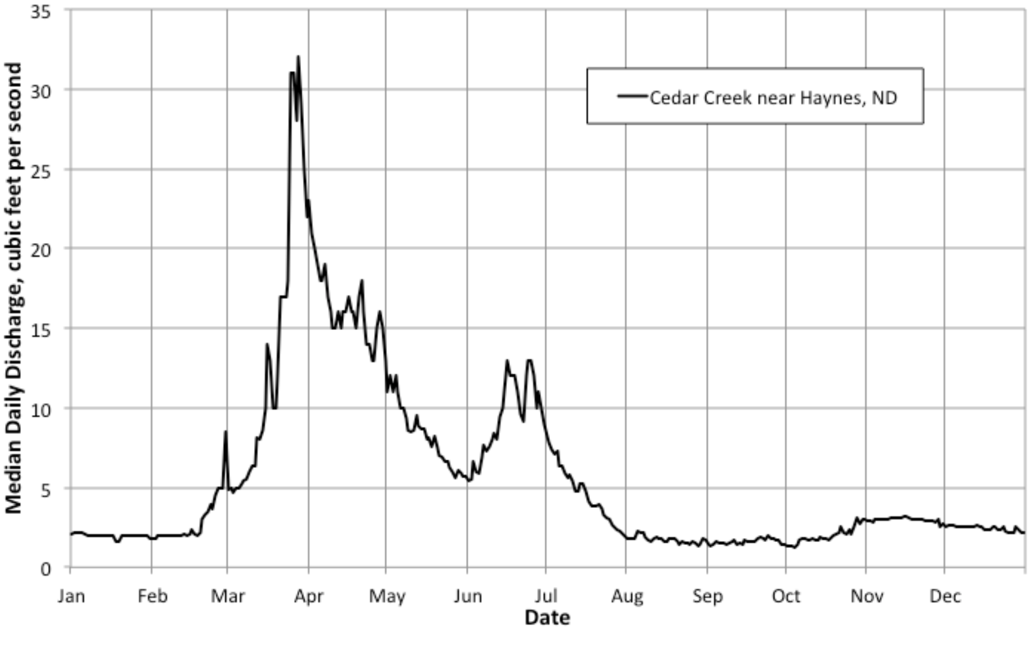


Figure 7 – Median daily discharge in Cedar Creek near Haynes, ND

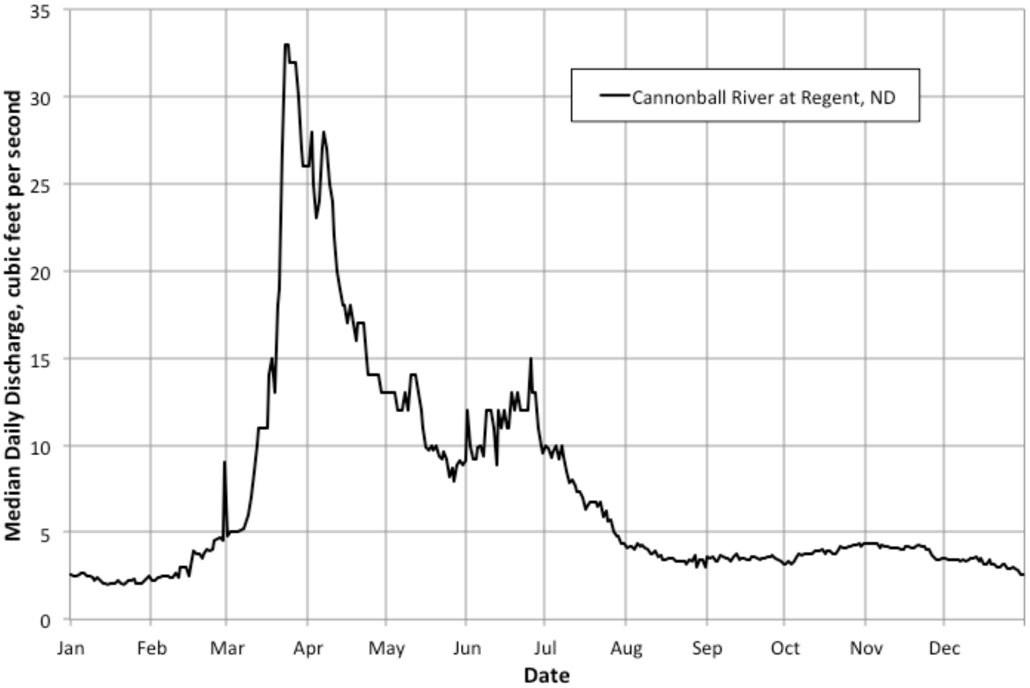


Figure 8 – Median daily discharge in the Cannonball River at Regent, ND

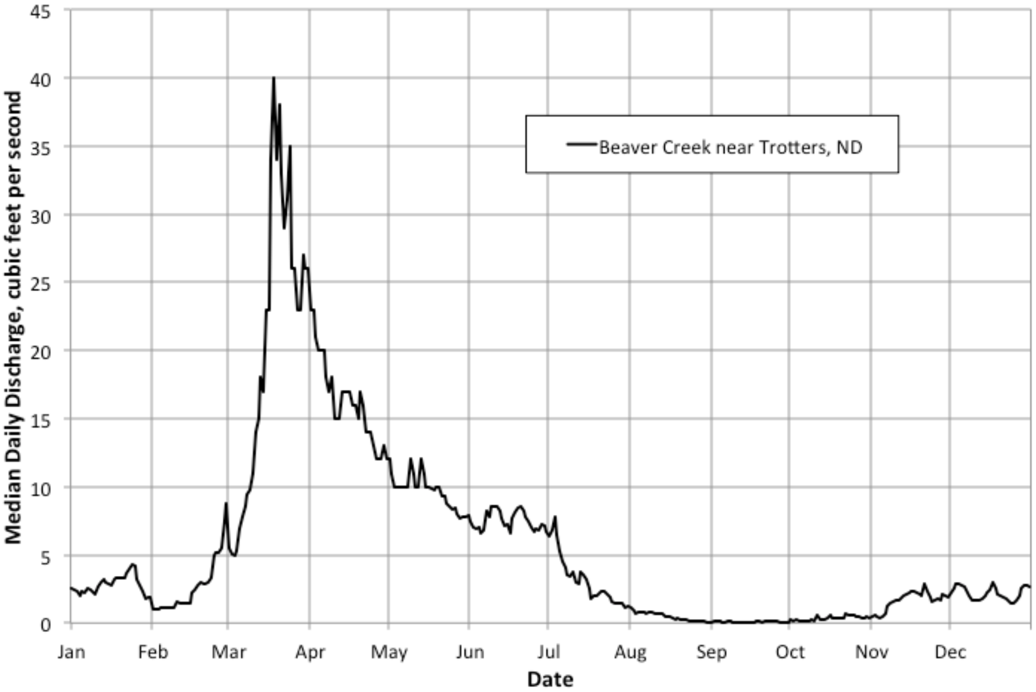


Figure 9 – Median daily discharge in Beaver Creek near Trotters, ND

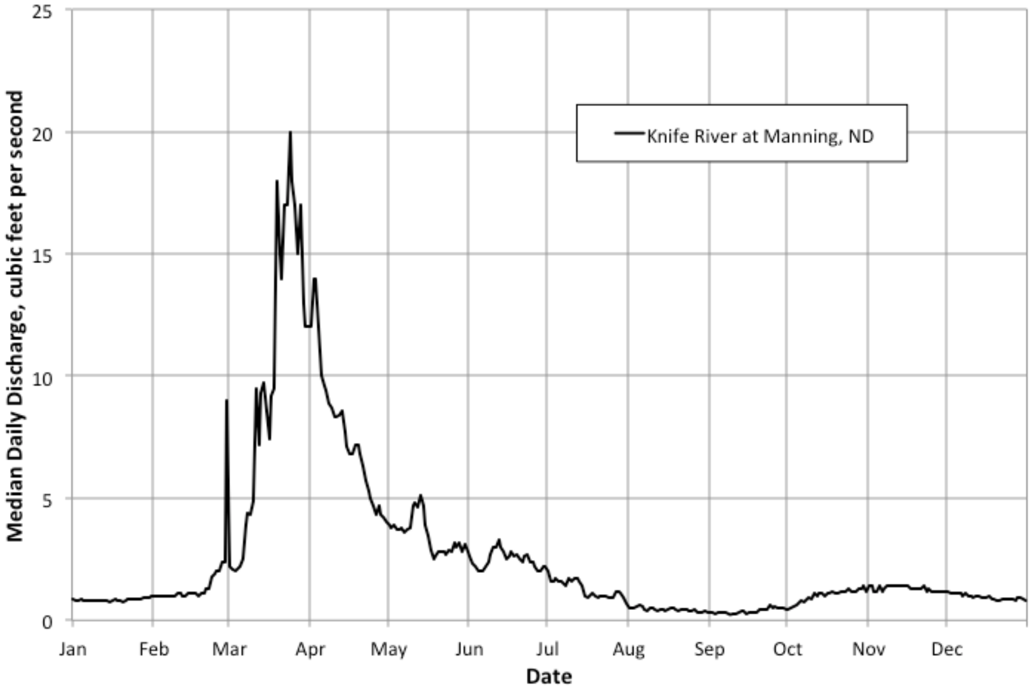


Figure 10 – Median daily discharge in the Knife River at Manning, ND

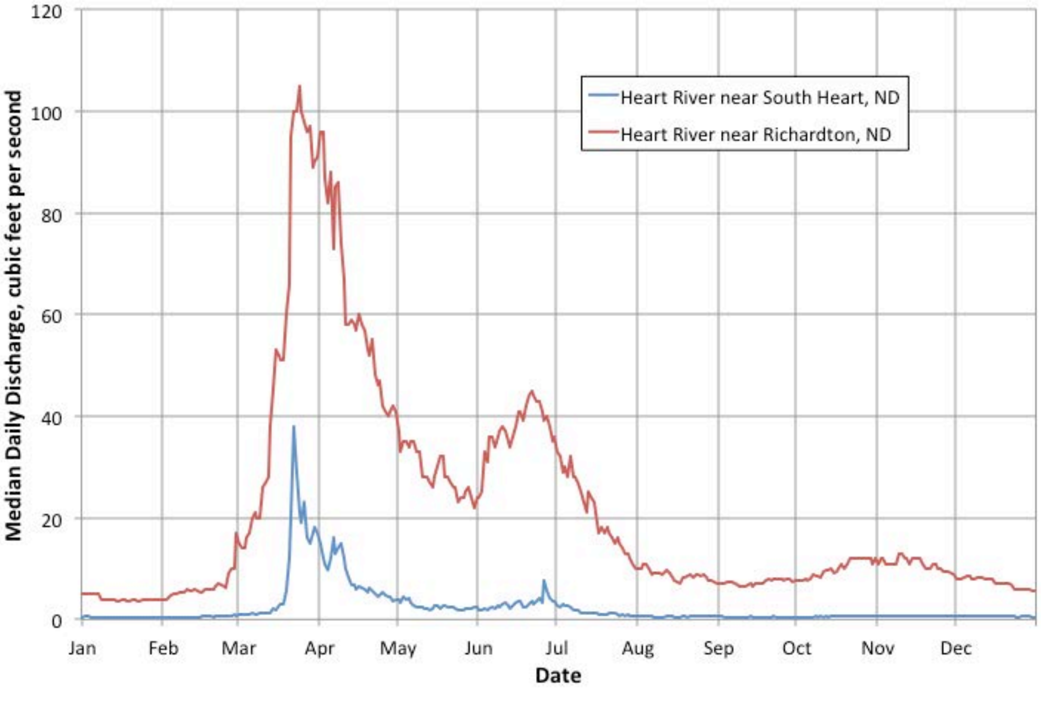


Figure 11 – Median daily discharge in the Heart River at South Heart and Richardton, ND

Given the large degree of variability in stream flows in southwestern North Dakota, these sources are not deemed reliable for large-scale oil field industrial supplies.

To increase surface water source reliability, off-stream storage can be used to provide water when stream flows are inadequate for large-scale industrial diversions. For example, during high flow spring runoff periods, Bully Pulpit golf course located south of Medora, N.D. diverts water from the Little Missouri River to retention ponds that provide irrigation water during the summer and fall.

Reservoirs

Bowman-Haley Reservoir

The following narrative in this paragraph is excerpted from “Lake Water Quality Assessment for Bowman-Haley Reservoir, Bowman County, North Dakota” prepared by the North Dakota Department of Health (Wax, 2005). Bowman-Haley Reservoir is a 1,732-acre impoundment at the confluence of the North Fork of the Grand River, Alkali Creek and Spring Creek (fig. 12). The reservoir has a multipurpose storage capacity of 18,765 acre-feet. The dam lies approximately 8 miles east and 14 miles south of the City of Bowman, in Bowman County, North Dakota. The dam was built and is maintained and operated by the U.S. Army Corps of Engineers (COE). Construction began in August 1966, and the reservoir was completed and filled by March of 1969. Discharge from the Bowman-Haley Reservoir forms the continuation of the North Fork of the Grand River. The North Fork of the Grand River, Alkali Creek and Spring Creek drainages combine to give Bowman-Haley Reservoir a watershed of approximately 475 square miles.

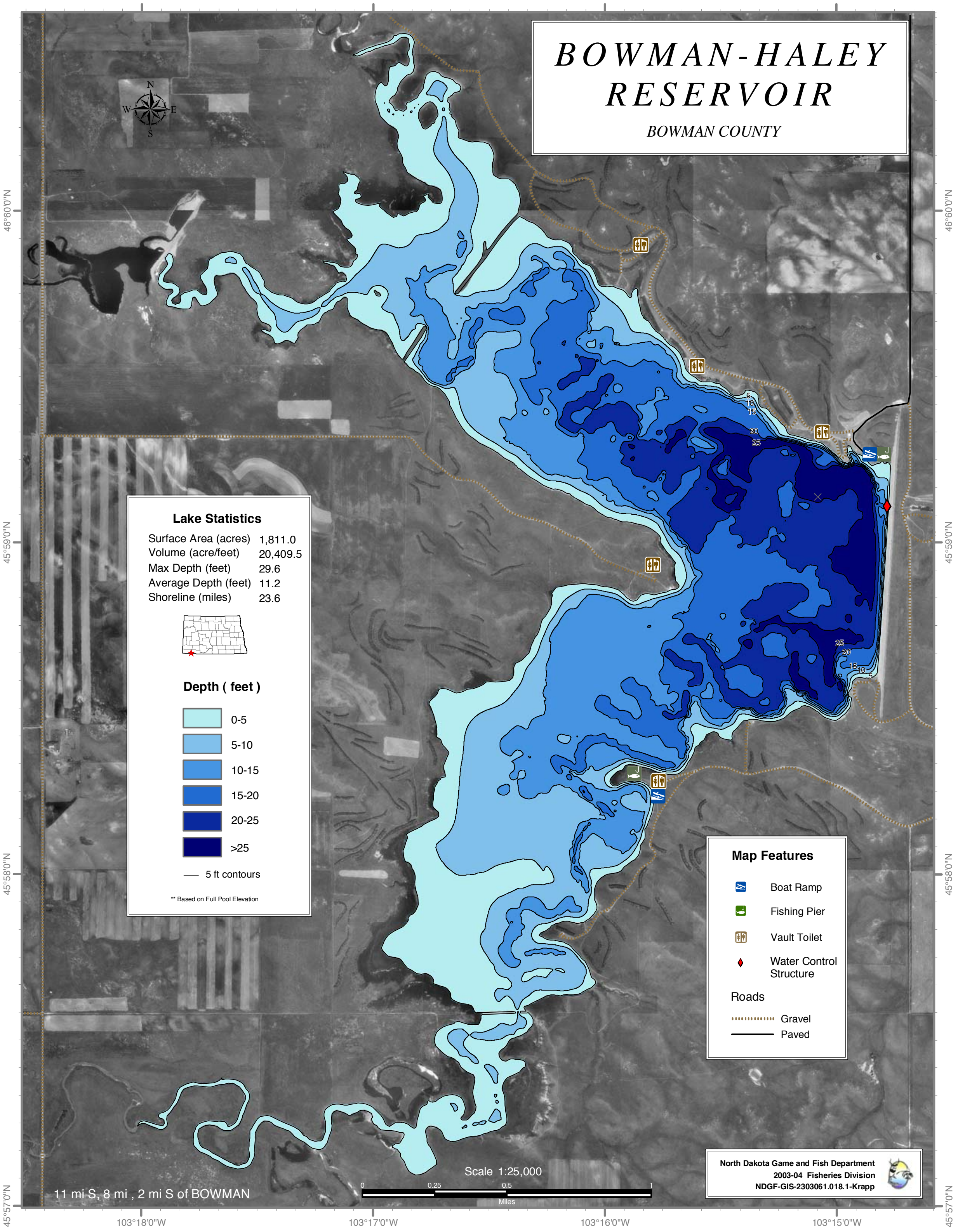


Figure 12 – Location of Bowman-Haley Reservoir

As part of a statewide Lake Water Quality Assessment (LWQA), the North Dakota Department of Health collected water samples for chemical analysis in Bowman-Haley Reservoir from March 5, 1993 through February 21, 1995 and from July 20, 2000 through January 31, 2001 (Wax, 2005). Samples generally were taken in a 6.6 feet long sample chamber fully submerged just below the water surface. At times discrete samples were taken from between 3.3 to 26.2 feet below the water surface.

The U.S. Geological Survey collected reservoir samples on July 11, 1969, August 6, 1970, October 12, 1970, February 24, 1971 and March 17, 1971 (U.S. Geological Survey, National Water Information System). For the above samplings, minimum, maximum and mean values for selected analytes are shown in Table 10.

Table 10 – Minimum, maximum and mean values of selected analytes from Bowman-Haley Reservoir

Analyte	Unit	Minimum Value	Maximum Value	Mean	Number of Samples
Iron	mg/L	0	1.17	0.28	39
Manganese	mg/L	0.008	0.219	0.029	37
Calcium	mg/L	28	84	44	38
Magnesium	mg/L	18	93.8	48	38
Sodium	mg/L	150	704	403	38
Potassium	mg/L	7.1	14.7	11.5	38
Bicarbonate	mg/L	228	527	354	38
Carbonate	mg/L	0	42	21	33
Sulfate	mg/L	290	1580	902	38
Chloride	mg/L	2.4	17.4	11.0	38
Phosphorus	mg/L	0.019	0.104	0.043	21
Nitrate + Nitrite (as N)	mg/L	0	0.47	0.10	33
Dissolved Solids	mg/L	639	2720	1617	38
Hardness (Ca, Mg)	mg/L	160	557	309	38
Percent Sodium	percent	65	76	75	38
SAR	unitless	5.2	13.1	9.9	38
Conductivity	umhos/cm	974	3670	2305	38
Alkalinity (as $CaCO_3$)	mg/L	278	432	331	33
pH	unitless	8.08	8.95	8.59	38

Probability plots of selected analytes measured from the above described State Health Department samples from Bowman-Haley Reservoir are presented in Figures 13 through 31. Probability plots provide the potential water user with an assessment of the chances of exceeding the concentration or value of a selected analyte. For example, in Figure 13, seventy percent of the time the calcium concentration of water samples from Bowman-Haley Reservoir is expected to be less than about 55 mg/L and thirty percent of the time the concentration of calcium is expected to be greater than 55 mg/L.

For the purpose of this report, all water chemistry sample data from both sources in the Bowman-Haley Reservoir and the U.S. Geological Survey data from various sampling depths in Dickinson and Heart Butte Reservoirs were combined to prepare summary statistics. The statistics are intended to be a gross summary of the range of data measured, without separation by stratification or selection method. Those intending to use the water sources should anticipate chemical stratification and investigate the data further as those effects may preclude application of the water for a specific industrial use or affect intake placement.

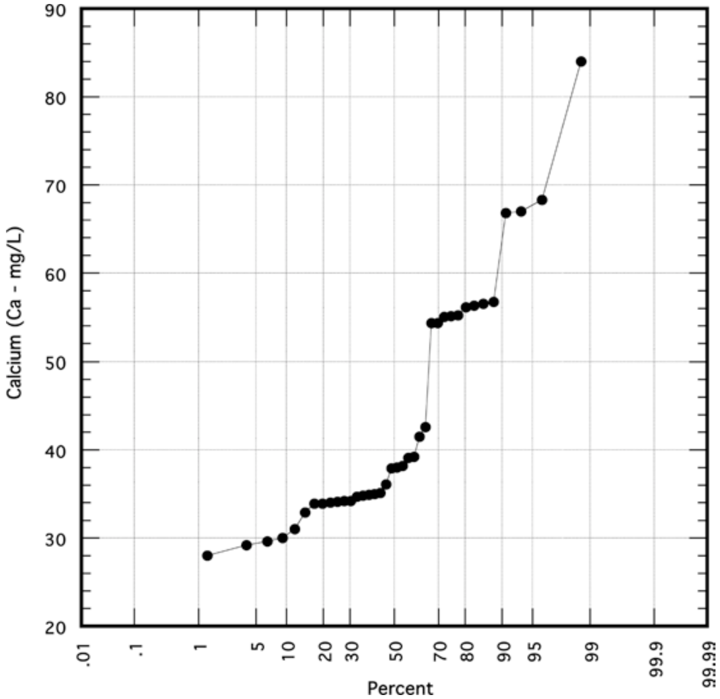


Figure 13 – Probability plot of calcium (Bowman-Haley Reservoir)

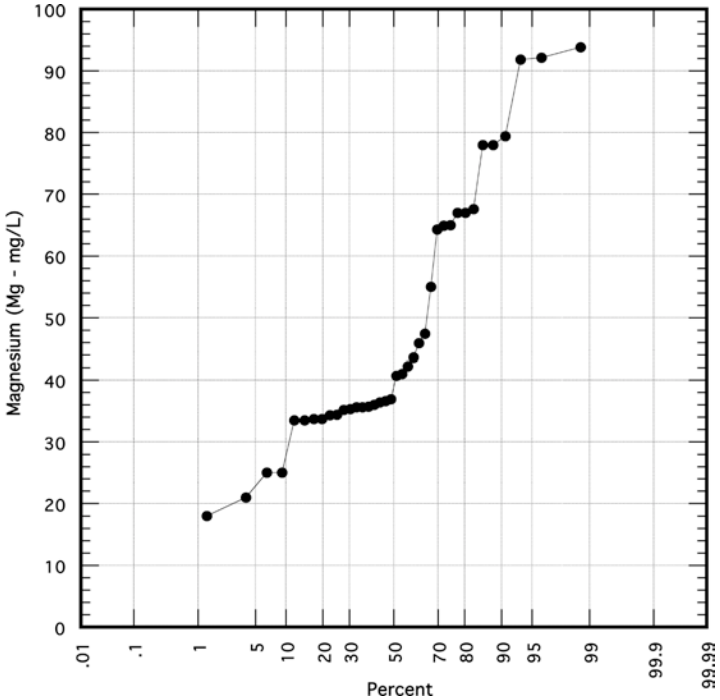


Figure 14 – Probability plot of magnesium (Bowman-Haley Reservoir)

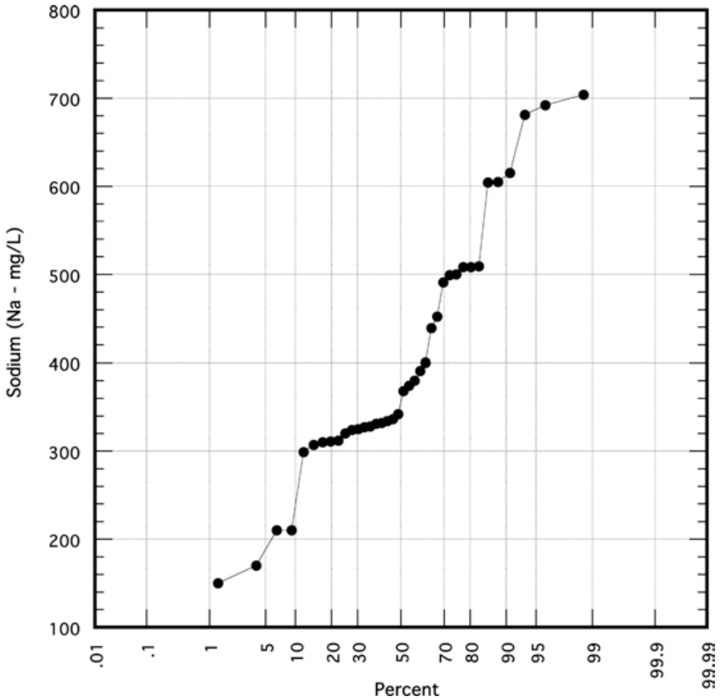


Figure 15 – Probability plot of sodium (Bowman-Haley Reservoir)

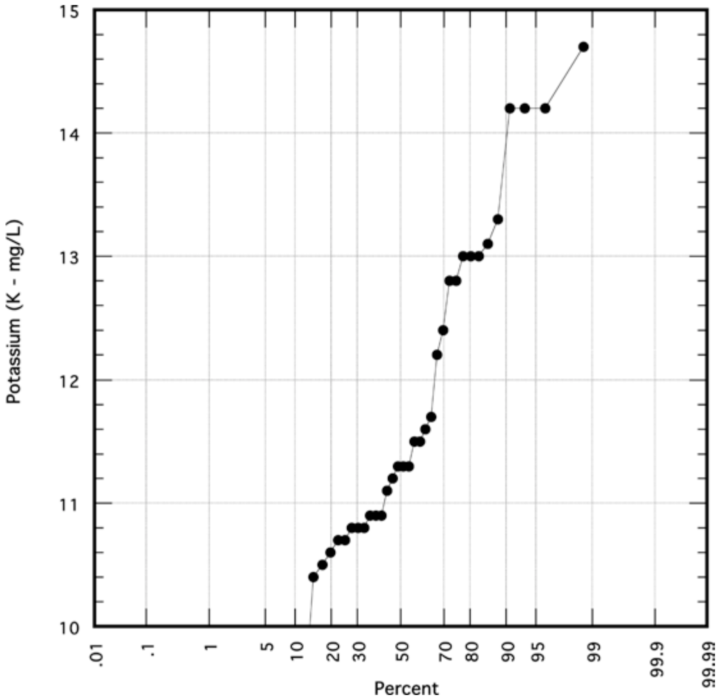


Figure 16 – Probability plot of potassium Bowman-Haley Reservoir)

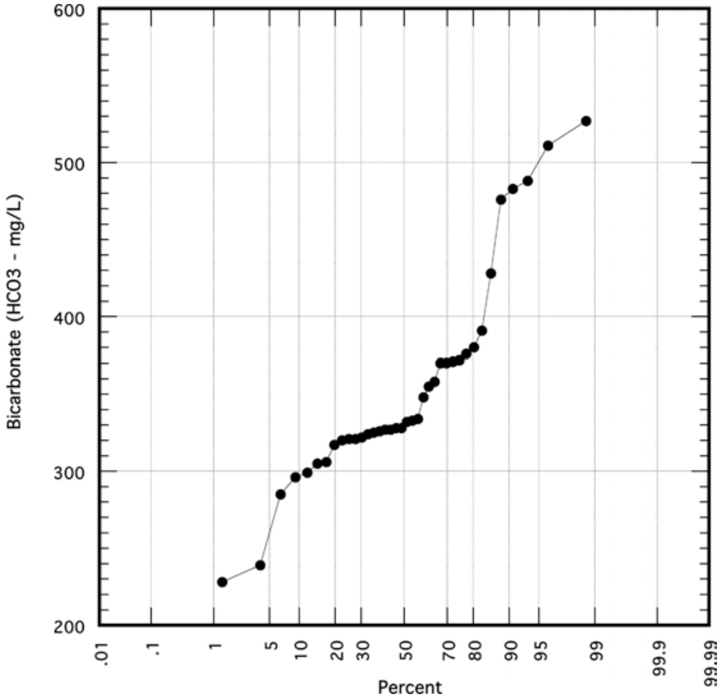


Figure 17 – Probability plot of bicarbonate (Bowman-Haley Reservoir)

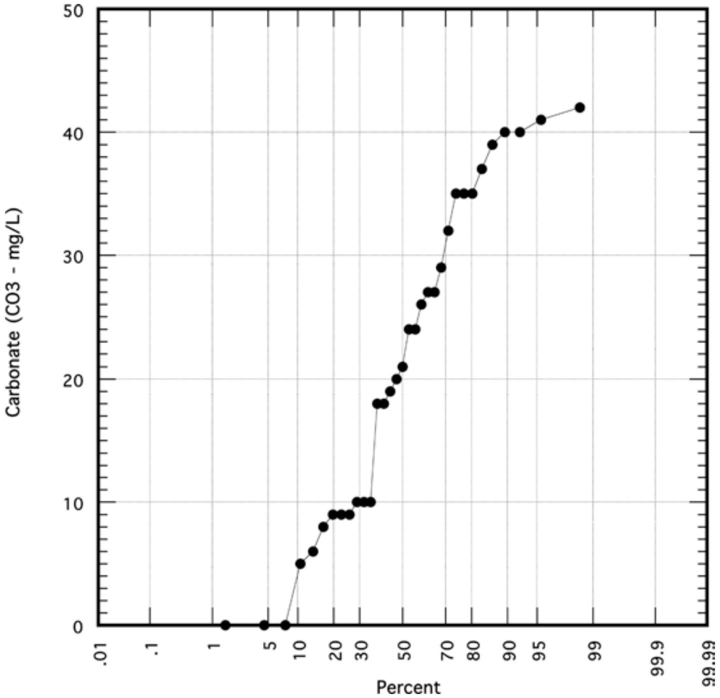


Figure 18 – Probability plot of carbonate (Bowman Haley Reservoir)

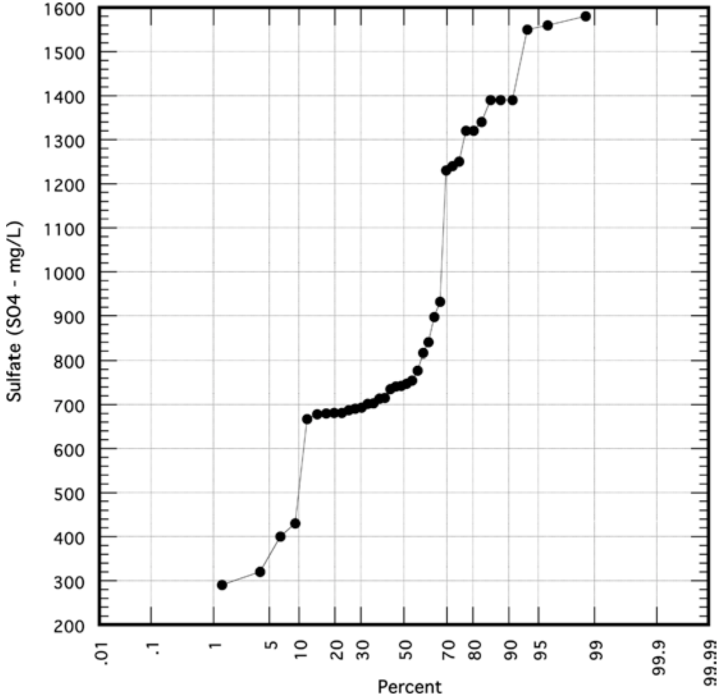


Figure 19 -- Probability plot of sulfate (Bowman-Haley Reservoir)

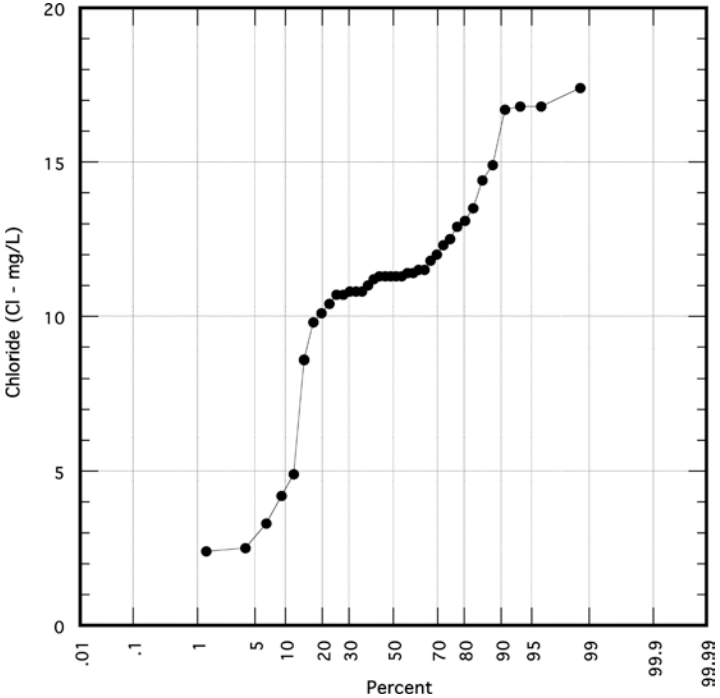


Figure 20 – Probability plot of chloride (Bowman-Haley Reservoir)

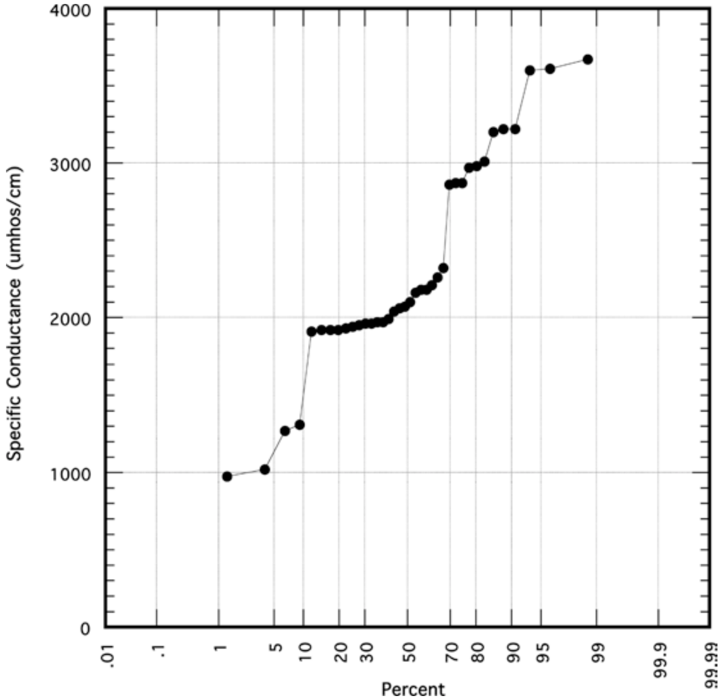


Figure 21 – Probability plot of conductivity (Bowman-Haley Reservoir)

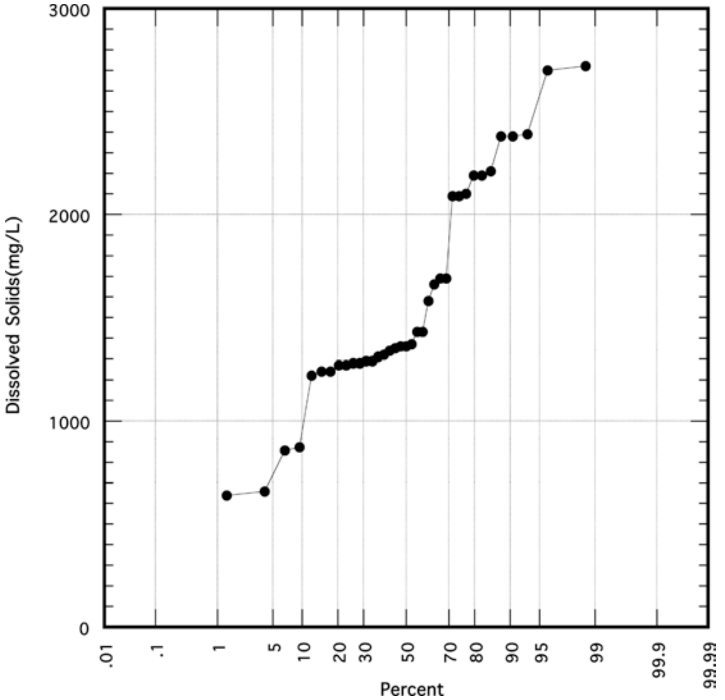


Figure 22 – Probability plot of dissolved solids Bowman-Haley Reservoir)

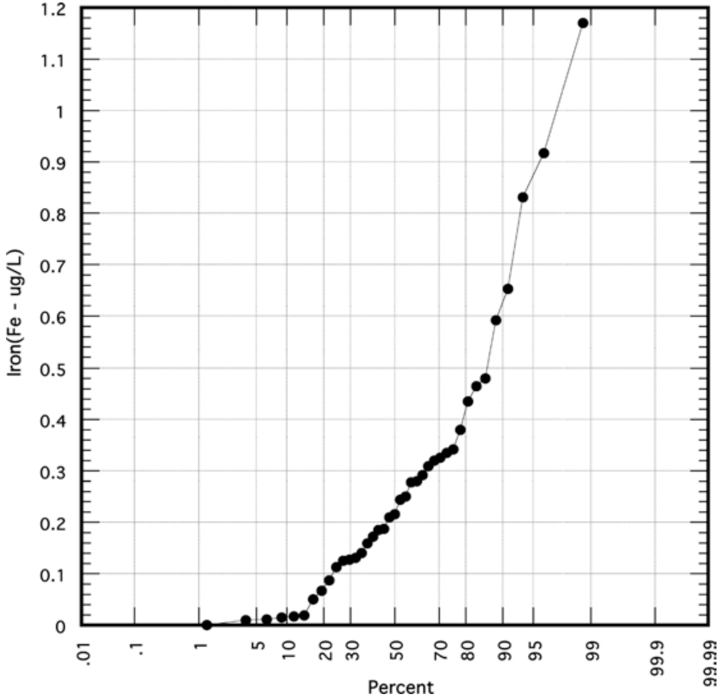


Figure 23 – Probability plot of iron (Bowman-Haley Reservoir)

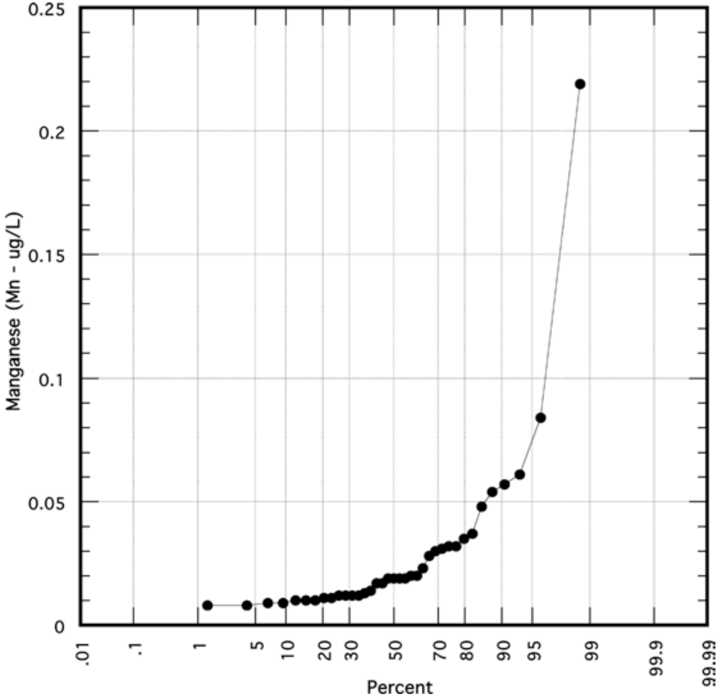


Figure 24 – Probability plot of manganese (Bowman-Haley Reservoir)

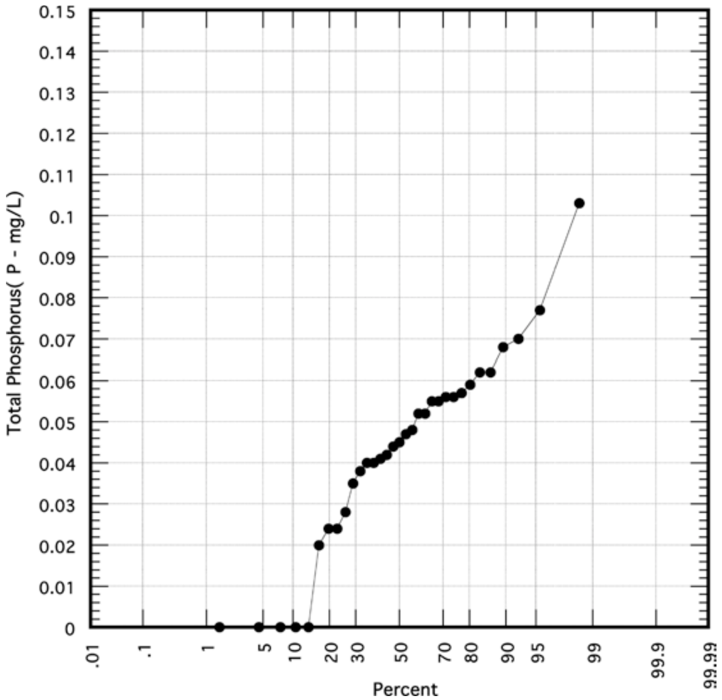


Figure 25 – Probability plot of phosphorous (Bowman-Haley Reservoir)

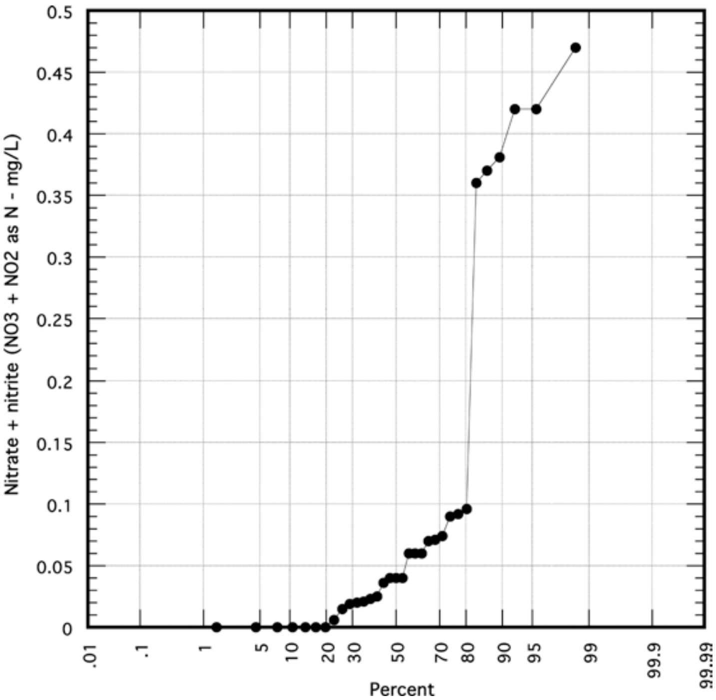


Figure 26 – Probability plot of NO3 + NO2 (Bowman-Haley Reservoir)

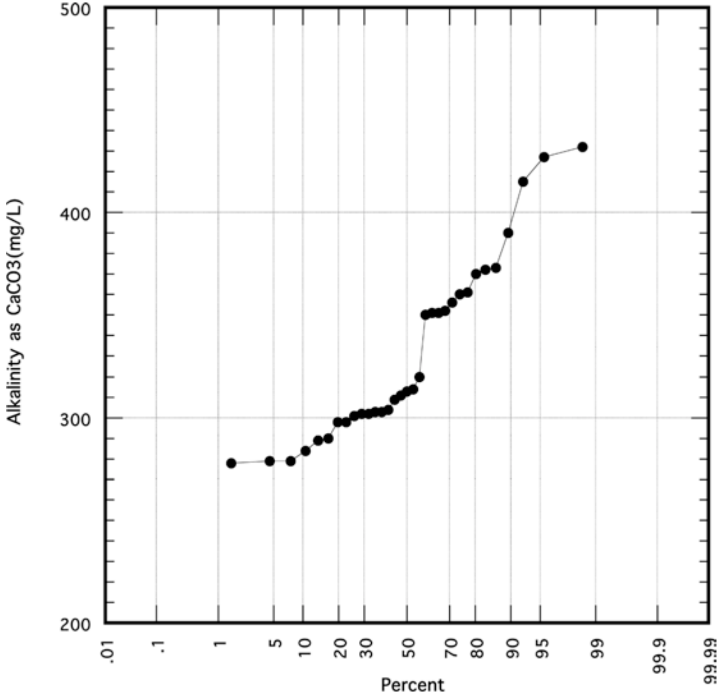


Figure 27 – Probability plot of alkalinity as CaCO3 (Bowman-Haley Reservoir)

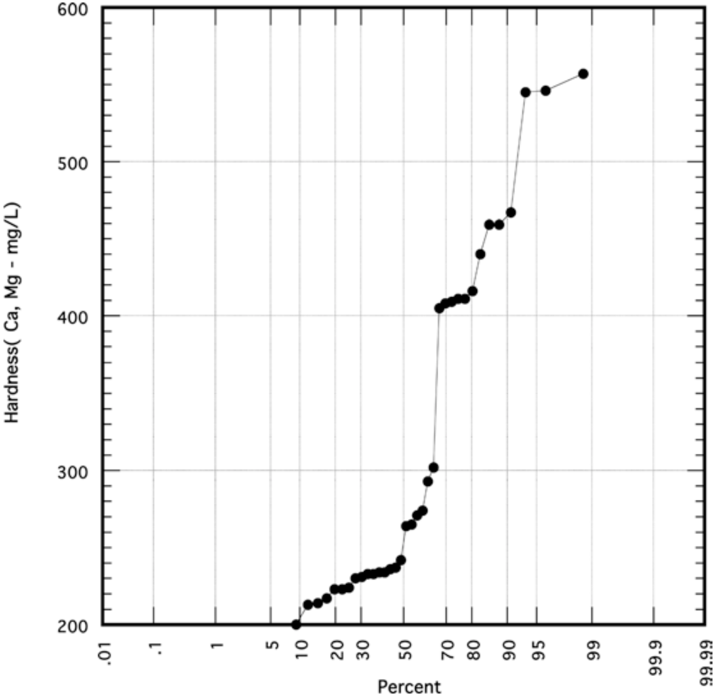


Figure 28 – Probability plot of hardness (Bowman-Haley Reservoir)

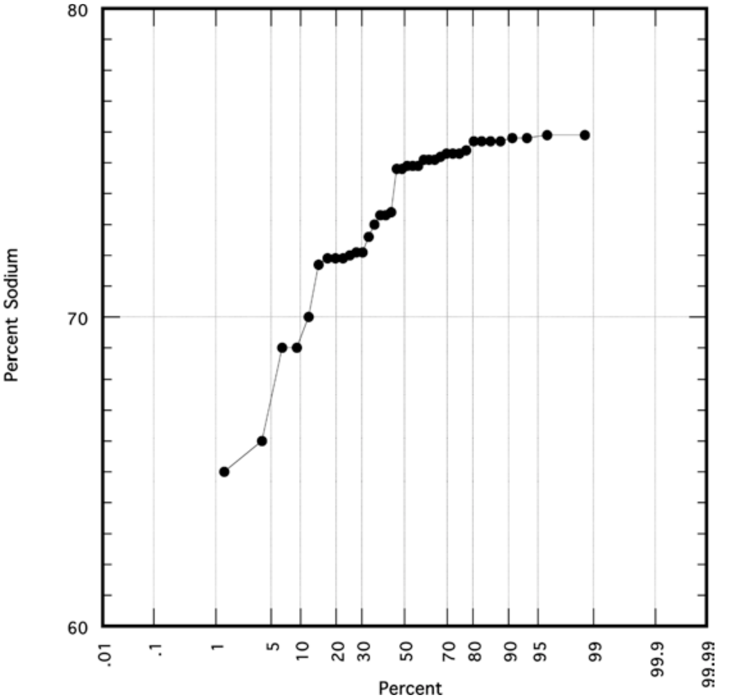


Figure 29 – Probability plot of percent sodium (Bowman-Haley Reservoir)

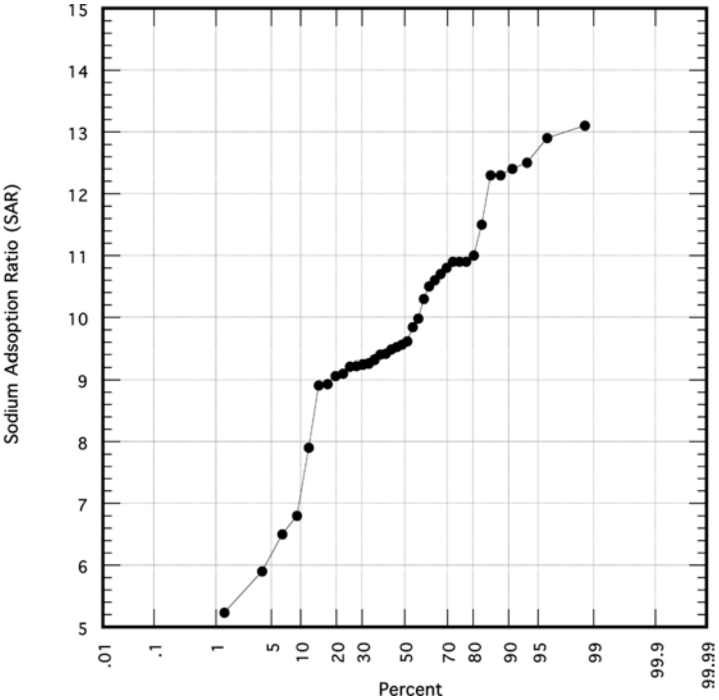


Figure 30 – Probability plot of sodium adsorption ratio (Bowman-Haley Reservoir)

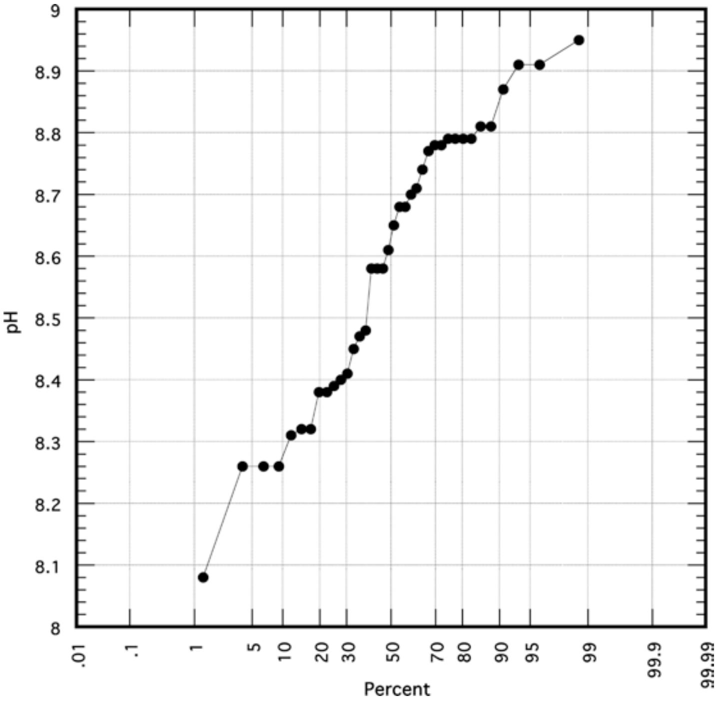


Figure 31 – Probability plot of field pH (Bowman-Haley Reservoir)

Temporal variations of concentrations and values of selected analytes measured from the above described State Health Department samples from Bowman-Haley Reservoir are presented in Figures 32 through 48. Although the data is somewhat sparse, the potential water user may find these graphs useful in assessing seasonal variability and longer-term trends.

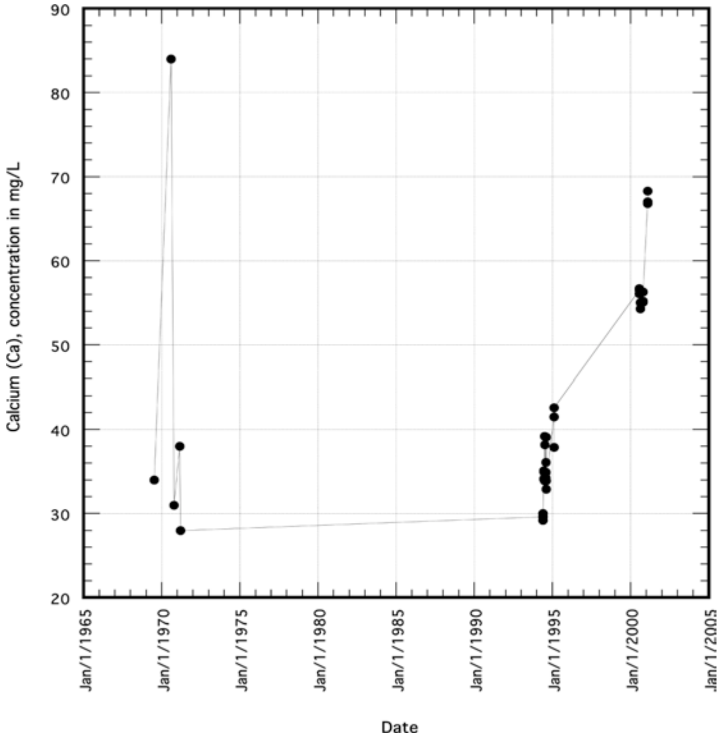


Figure 32 – Temporal variation of calcium (Bowman-Haley Reservoir)

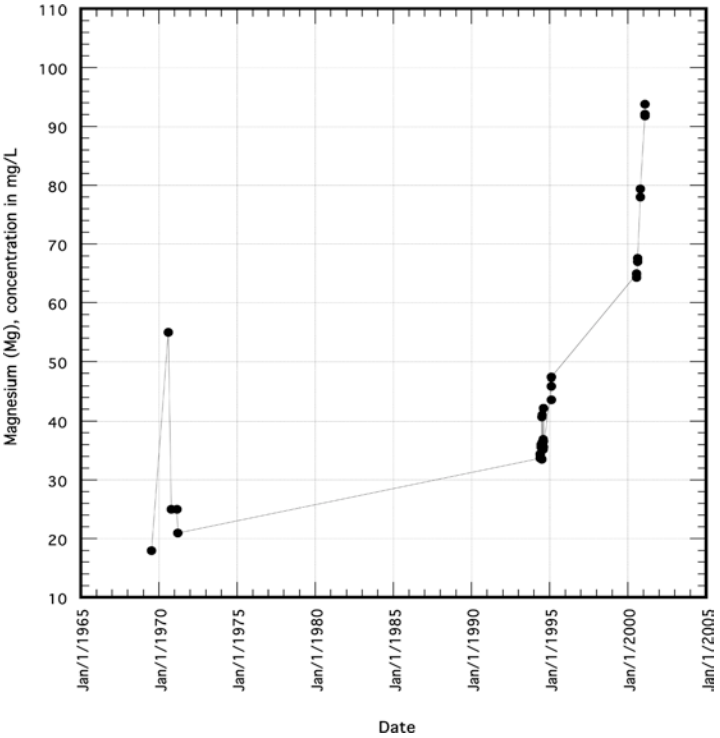


Figure 33 – Temporal variation of magnesium (Bowman-Haley Reservoir)

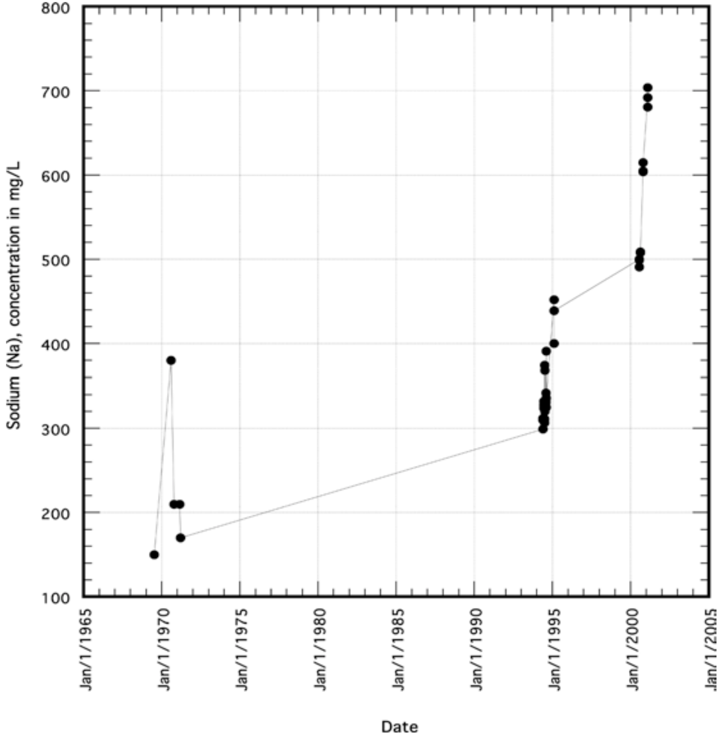


Figure 34 – Temporal variation of sodium (Bowman-Haley Reservoir)

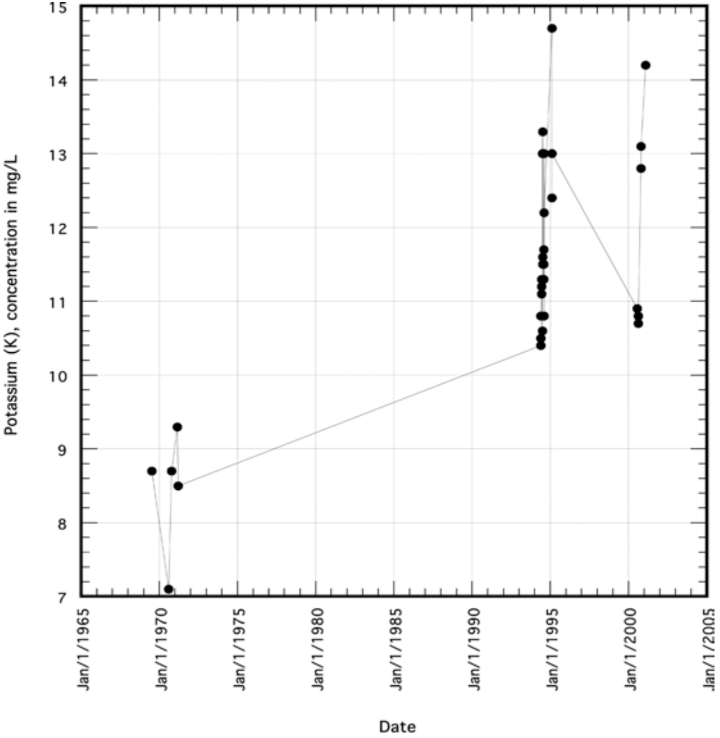


Figure 35 – Temporal variation of potassium (Bowman-Haley Reservoir)

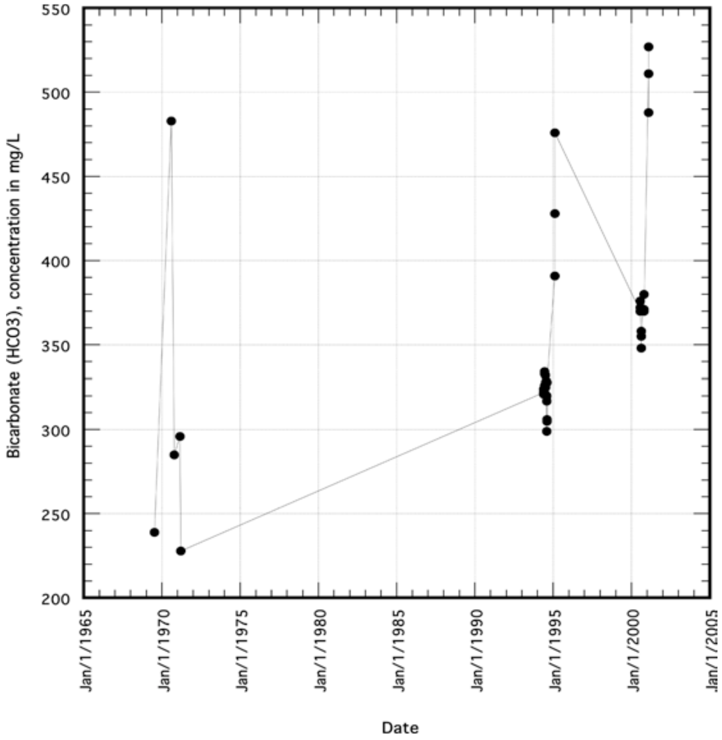


Figure 36 – Temporal variation of bicarbonate (Bowman-Haley Reservoir)

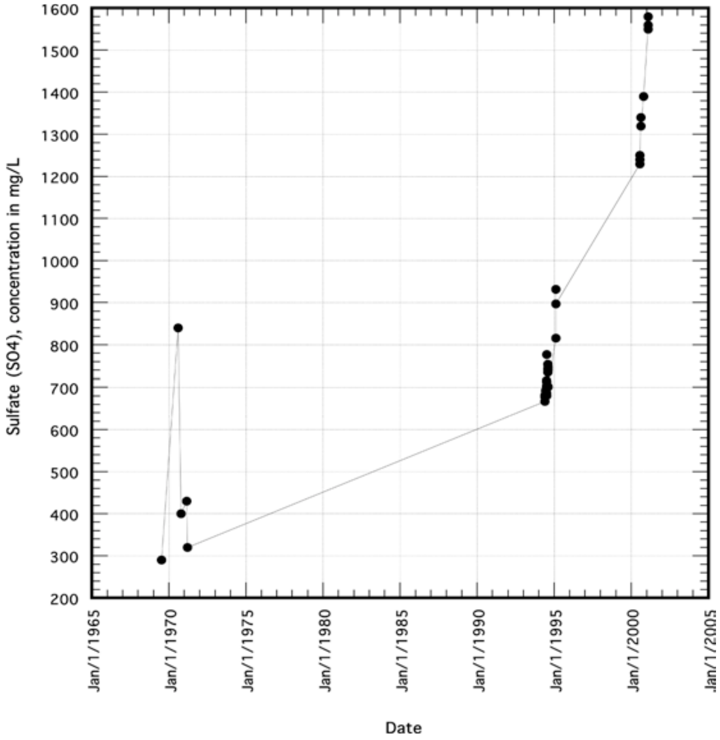


Figure 37 – Temporal variation of sulfate (Bowman-Haley Reservoir)

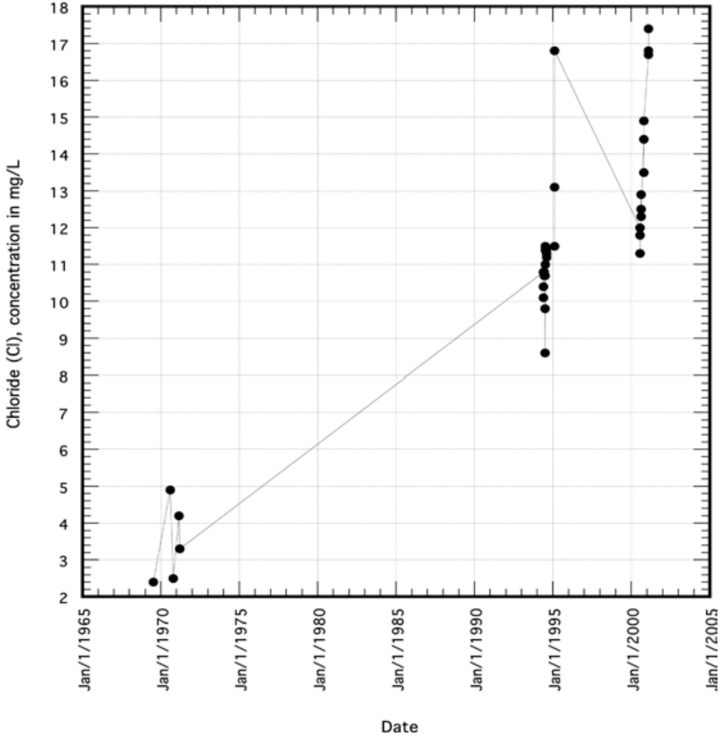


Figure 38 – Temporal variation of chloride (Bowman-Haley Reservoir)

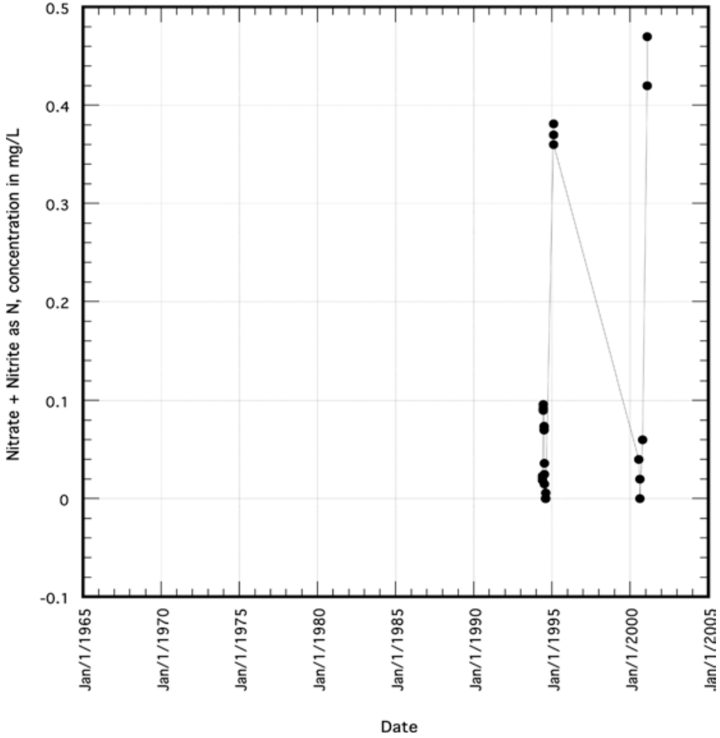


Figure 39 – Temporal variation of nitrate + nitrite (Bowman-Haley Reservoir)

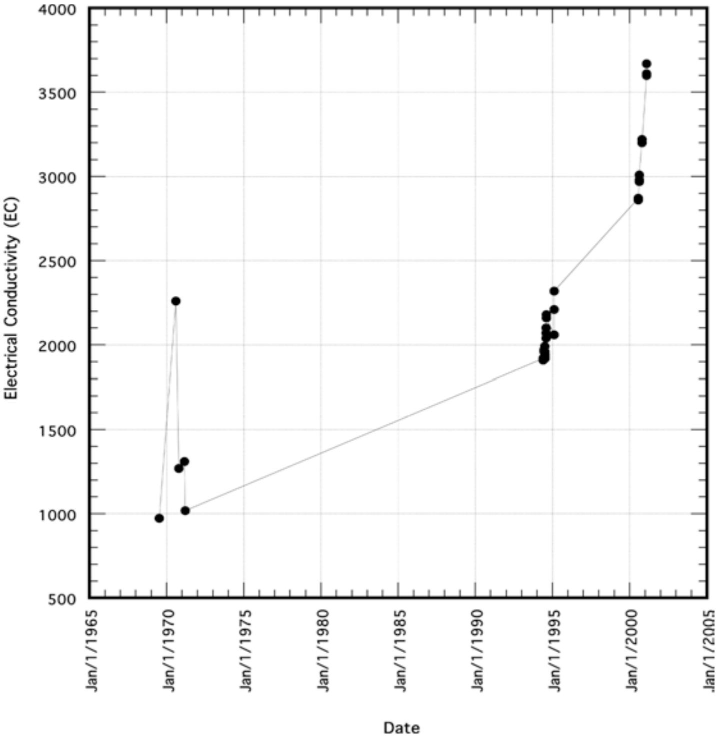


Figure 40 – Temporal variation of electrical conductivity (Bowman-Haley Reservoir)

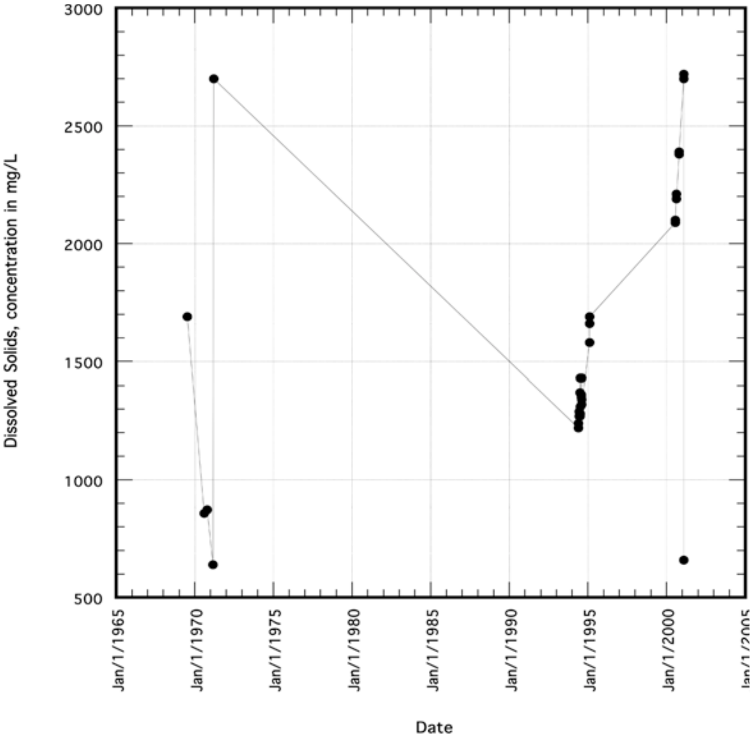


Figure 41 – Temporal variation of dissolved solids (Bowman-Haley Reservoir)

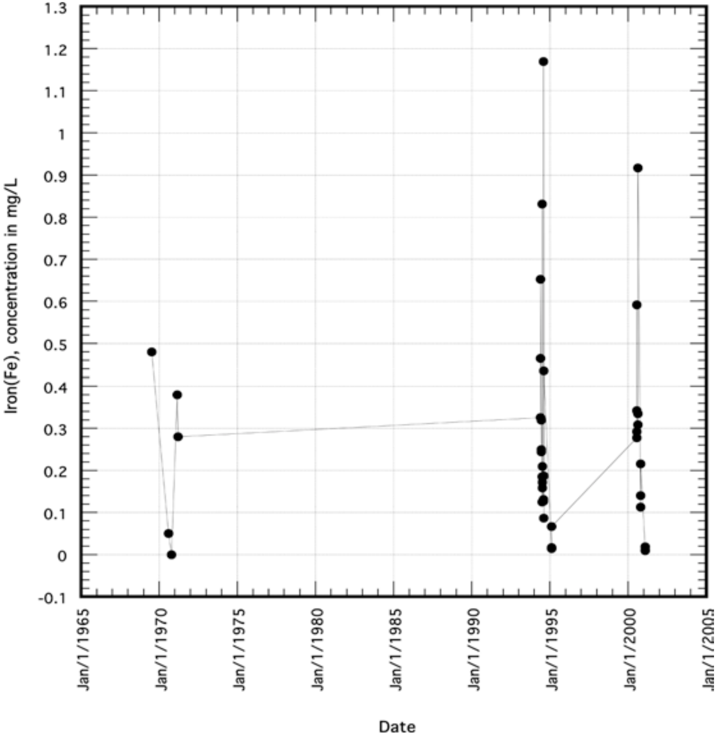


Figure 42 – Temporal variation of iron (Bowman-Haley Reservoir)

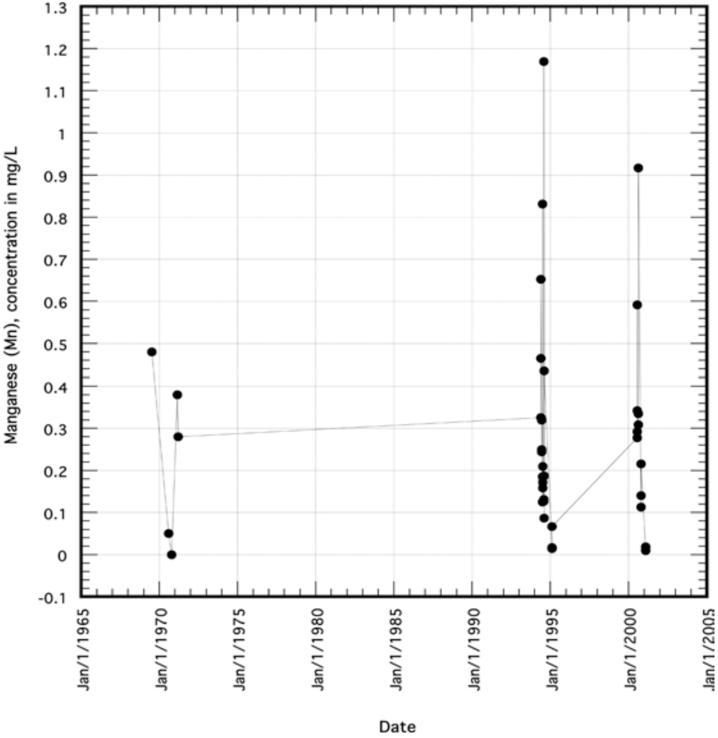


Figure 43 - Temporal variation of manganese (Bowman-Haley Reservoir)

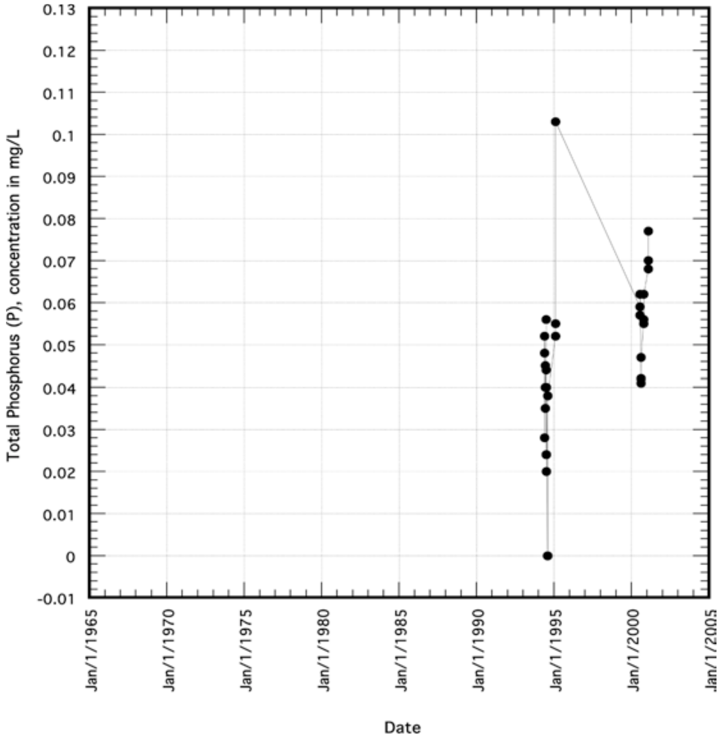


Figure 44 – Temporal variation of phosphorous (Bowman-Haley Reservoir)

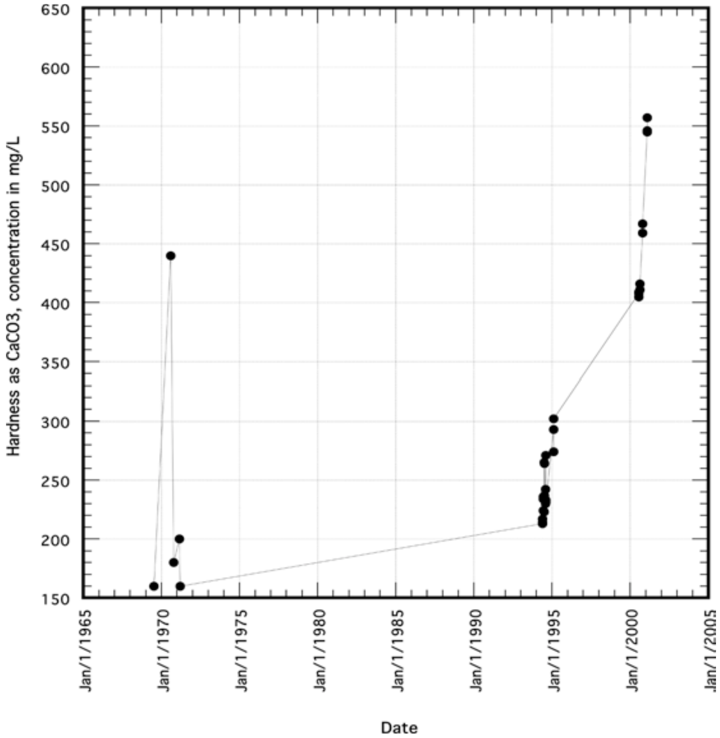


Figure 45 – Temporal variation of hardness (Bowman-Haley reservoir)

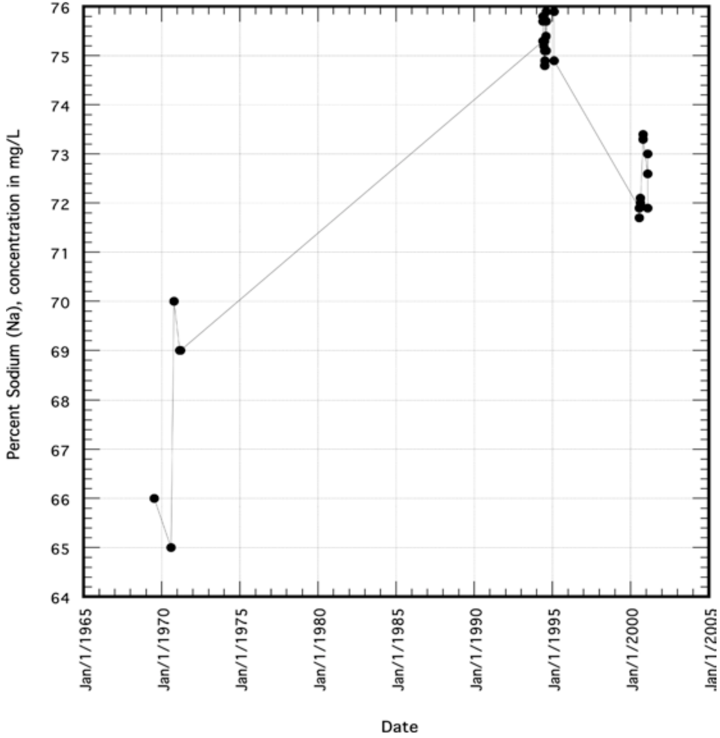


Figure 46 – Temporal variation of percent sodium (Bowman-Haley Reservoir)

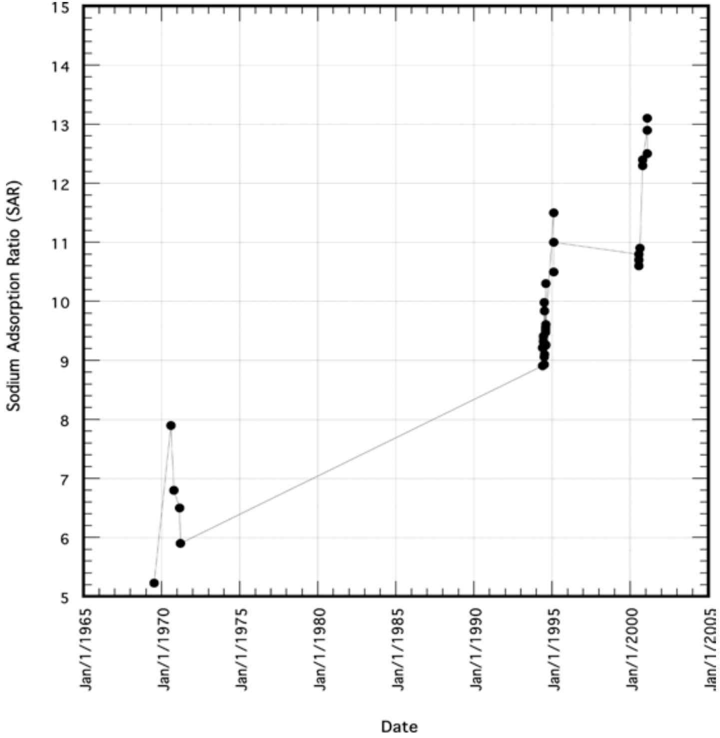


Figure 47 – Temporal variation of sodium adsorption ratio (Bowman-Haley Reservoir)

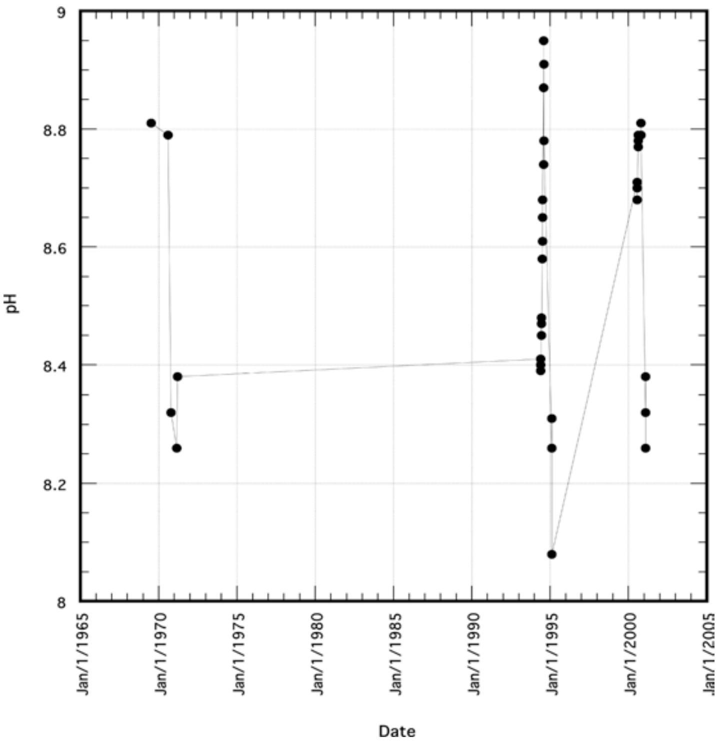


Figure 48 – Temporal variation of pH (Bowman- Haley Reservoir)

A history of poor water quality and massive algal blooms prompted the addition of a hypolimnetic drawdown in 1988 and a water quality improvement project in 1990 (Wax, 2005). The COE's hypolimnetic drawdown was designed to allow the discharge of inferior water below the metalimnion during periods of thermal stratification. The system has been relatively unsuccessful as Bowman-Haley Reservoir rarely thermally stratifies. The water quality improvement project implemented in 1990 was successful at reducing the amount of nutrients and suspended solids reaching Bowman-Haley Reservoir from the Alkali and Spring Creek drainages. Variable water quality coupled with the occurrence of "massive" algal blooms could preclude application of raw, untreated water from Bowman-Haley Reservoir for oil field industrial use.

Existing Water Permits – Bowman Haley Reservoir

The Bowman County Water Management District holds Perfected Water Permit No. 1220 allowing for an annual appropriation of 3,000 acre-feet from Bowman-Haley Reservoir for municipal and industrial use. The point of diversion is Section 24, Township 129 North, Range 101 West. To date, the district has not put any water to beneficial use under this perfected water permit. Thus, up to 3,000 acre-feet of water is available for industrial use. Potential industrial water users should contact Jerry Palczewski, Chairman, Bowman County Water Management District at (701)-275-8289(H) or (701) 275-8103(W) to determine water availability and access.

Dickinson Reservoir (Patterson Lake)

The following narrative in this paragraph is excerpted from, “Lake Water Quality Assessment for Edward Arthur Patterson Lake, Stark County, North Dakota”, (Wax, 2006). Patterson Lake is a Bureau of Reclamation project completed in 1950 to supply potable water for the city of Dickinson, irrigation, downstream flood protection and water-based recreation. The rolled earthen structure dams the Heart River approximately 1 mile southwest of Dickinson (fig. 49). The Dam impounds 956 surface acres with a maximum depth of 27 feet and an average depth of 9 feet.

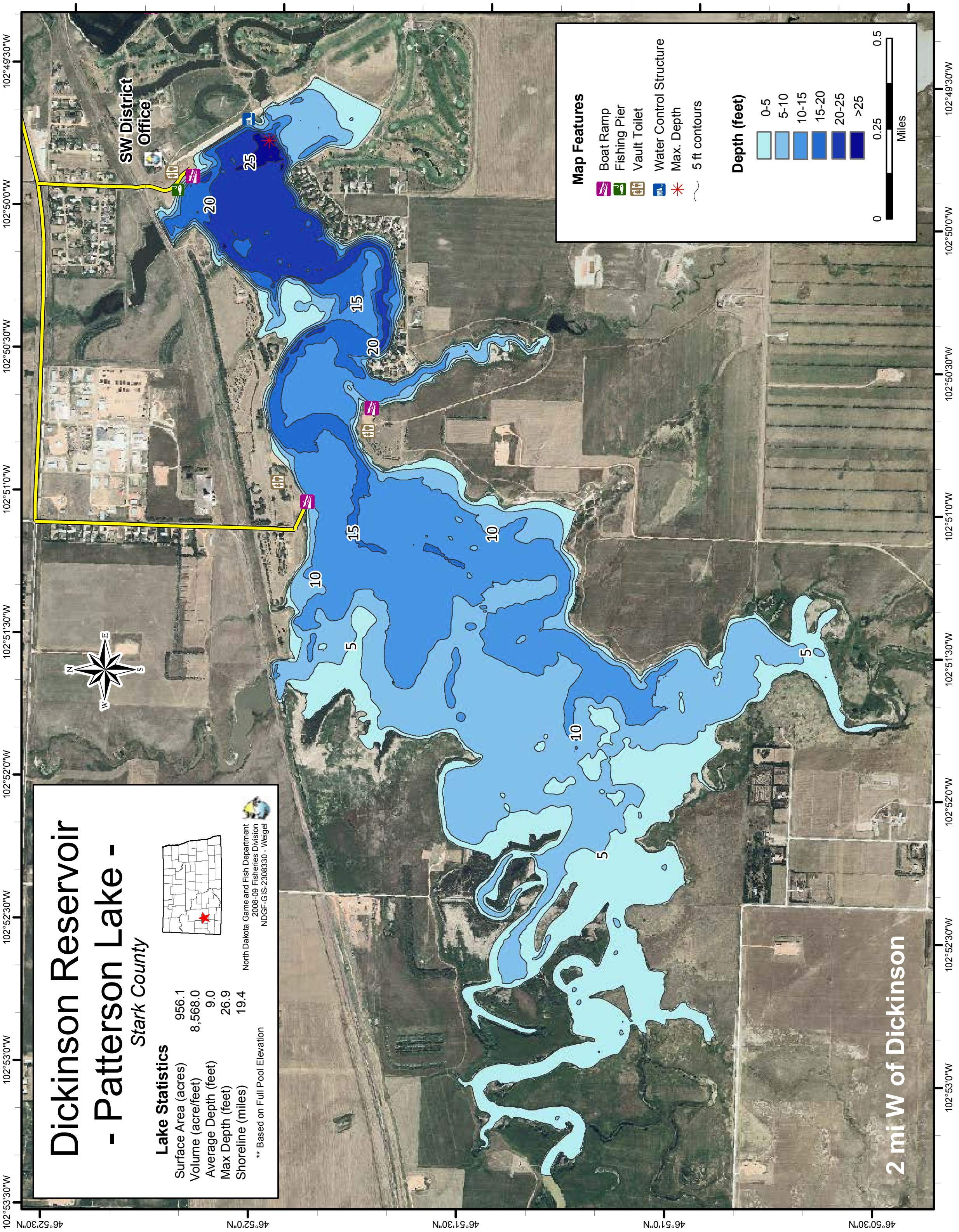


Figure 49 – Location of Dickinson Reservoir (Patterson Lake)

As part of a statewide Lake Water Quality assessment (LWQA), the North Dakota Department of Health collected water samples for chemical analysis from Dickinson Reservoir in 1992 and 1993, 1995 and 1996, and 2000 and 2001 (Wax, 2006). The U.S. Geological Survey began collecting water samples for chemical analysis from Dickinson Reservoir in October 1970 and continues this water-quality sampling program to the present (U.S. Geological Survey, National Water Information System). The U.S. Geological Survey data set is more comprehensive than that of the State Health Departments LWQA data set and therefore the U.S. Geological Survey data set from October 1970 to October 2011 is summarized in this report. On each sampling date, water samples for chemical analysis were collected at the water surface and at selected depths below water surface to a maximum depth of 24.6 feet. Sampling depths were not kept constant over the period of sampling record. For the purpose of this report, all U.S. Geological Survey samples were combined to prepare summary statistics. The minimum, maximum, and mean values for selected analytes of the U.S. Geological Survey data set are shown in Table 11.

Table 11 – Minimum, maximum and mean values of selected analytes from Dickinson Reservoir

Analyte	**Unit**	**Minimum Value**	**Maximum Value**	**Mean**	**Number of Samples**
Calcium	mg/L	20	90	50	129
Magnesium	mg/L	11	68	31	129
Sodium	mg/L	55	594	230	129
Potassium	mg/L	5.8	19	10.8	127
Sulfate	mg/L	120	1190	475	128
Chloride	mg/L	2.9	48	11.4	129
Iron	mg/L	0.004	0.52	0.05	26
Manganese	mg/L	0.001	0.663	0.10	26
Dissolved Solids	mg/L	274	2300	970	127
Hardness (as $CaCO_3$)	mg/L	95	489	251	129
Sodium Adsorption Ratio	unitless	2.45	13	6.2	129
Percent Sodium	percent	51	78	64	128
pH (field)		7.1	9.5	8.3	61
Dissolved Oxygen	mg/L	3.3	21	9.2	56
Water Temperature	degrees C	0	23	10.0	61

Probability plots of selected analytes measured from the above described U.S. Geological Survey samples from Dickinson Reservoir are presented in Figures 50 through 65.

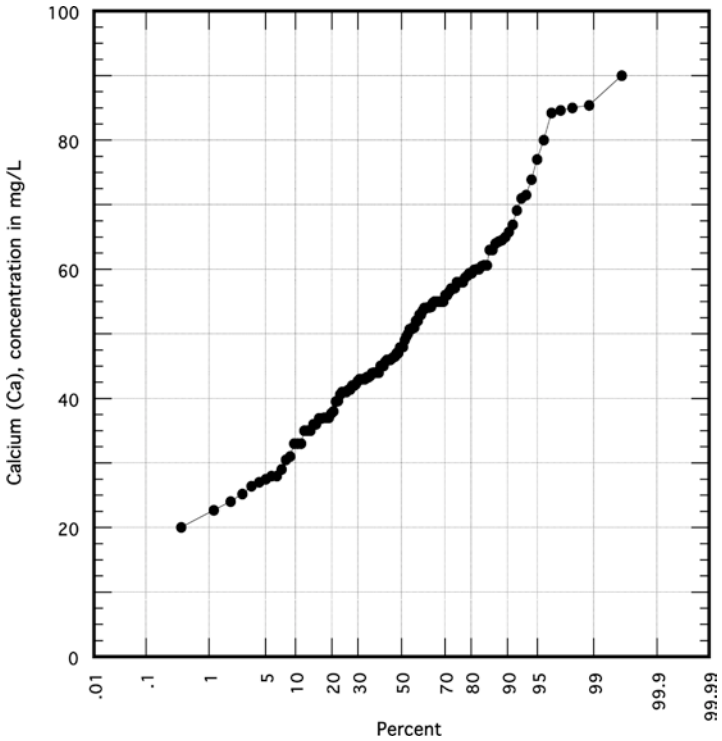


Figure 50 – Probability plot of calcium (Dickinson Reservoir)

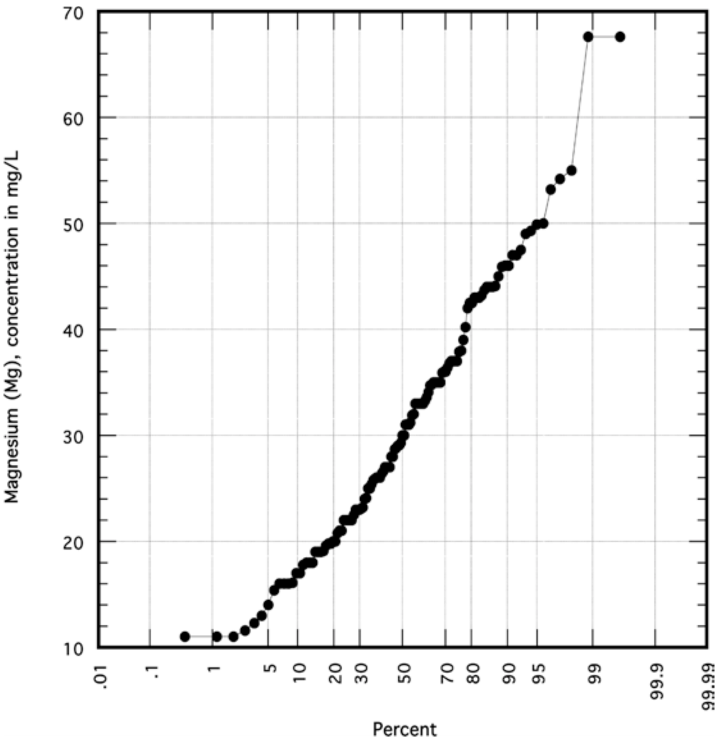


Figure 51 – Probability plot of magnesium (Dickinson Reservoir)

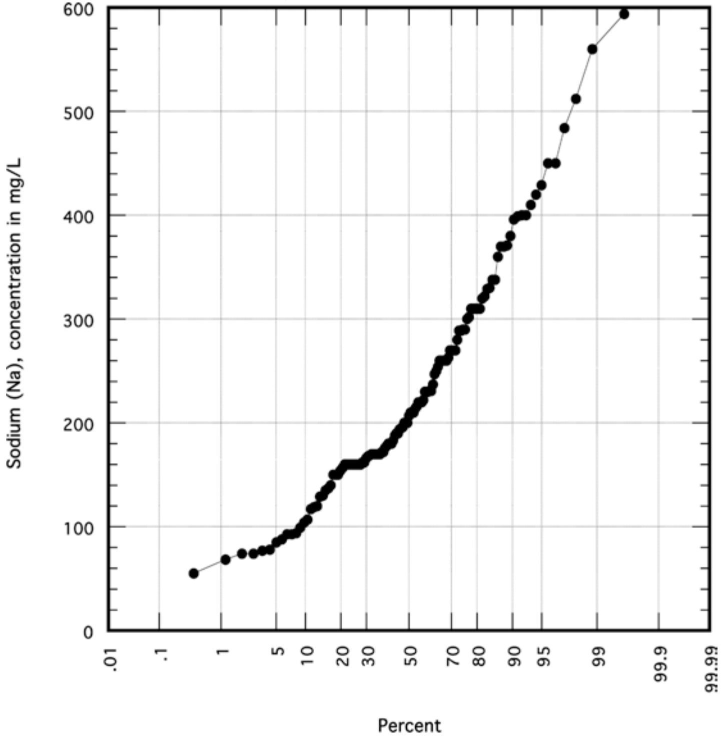


Figure 52 – Probability plot of sodium (Dickinson Reservoir)

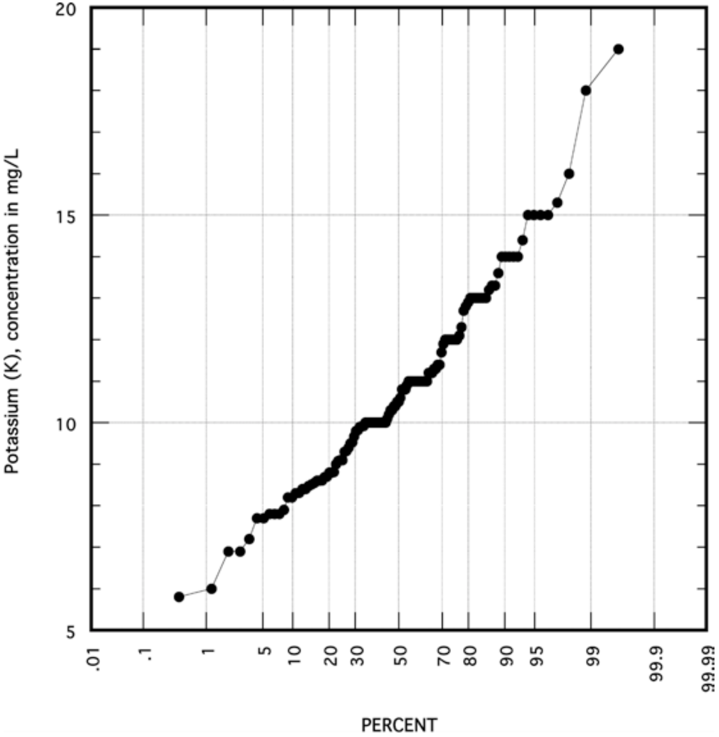


Figure 53 – Probability plot of potassium (Dickinson Reservoir)

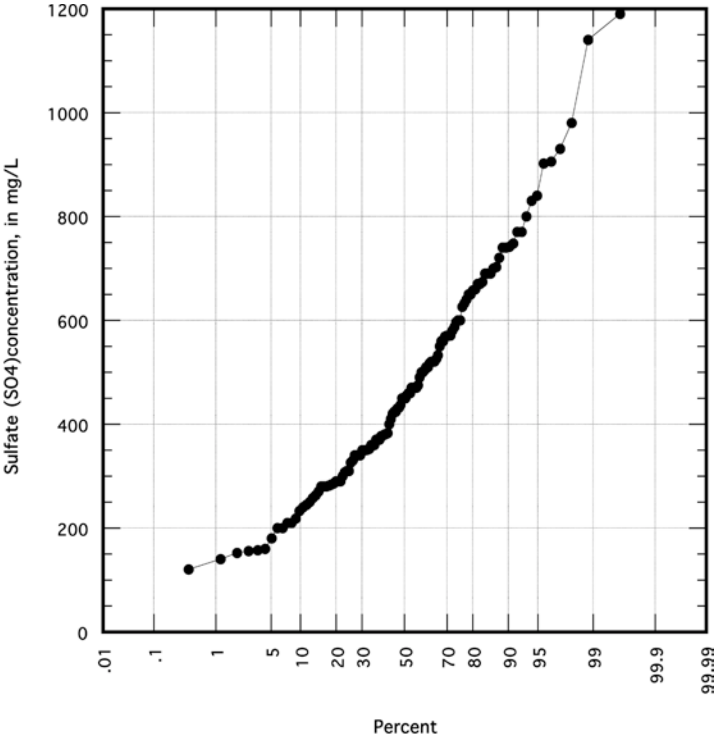


Figure 54 – Probability plot of sulfate (Dickinson Reservoir)

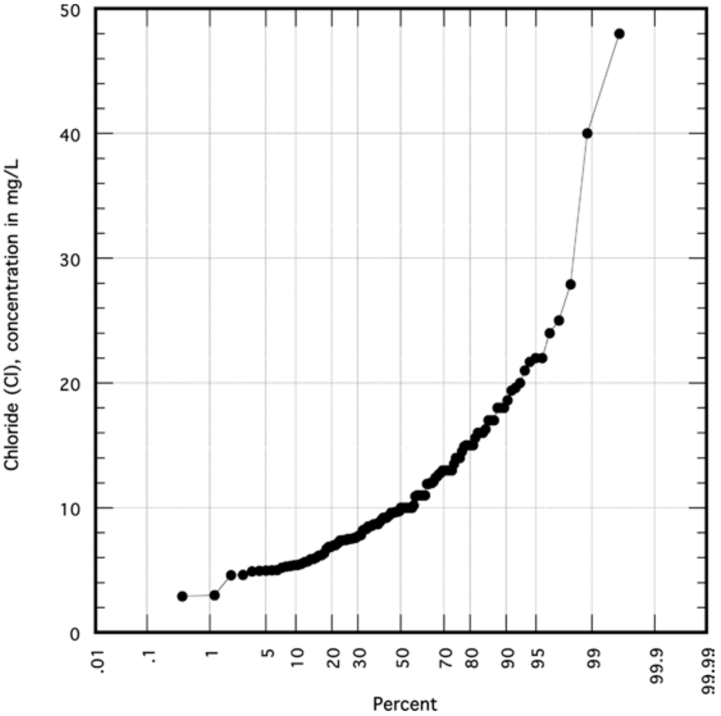


Figure 55 – Probability plot of chloride (Dickinson Reservoir)

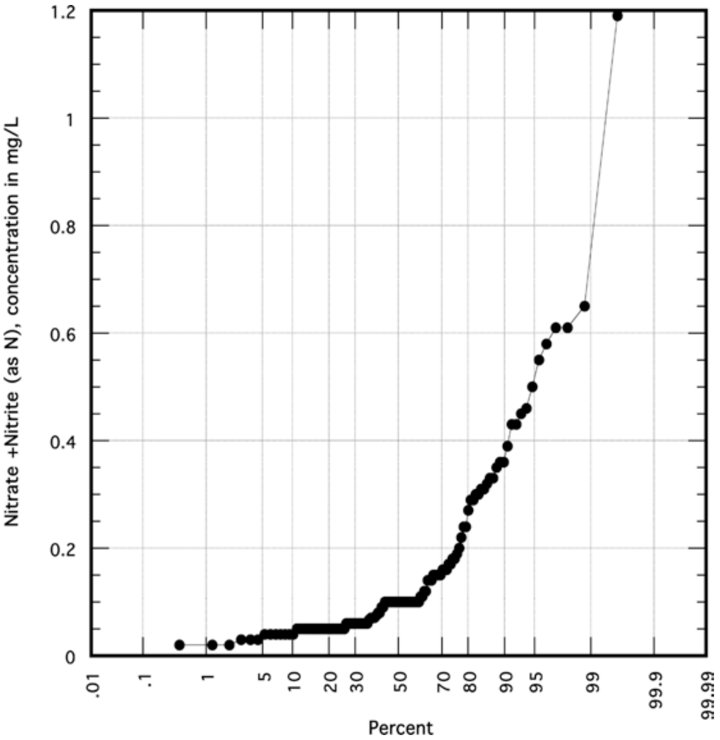


Figure 56 – Probability plot of nitrate + nitrite (Dickinson Reservoir)

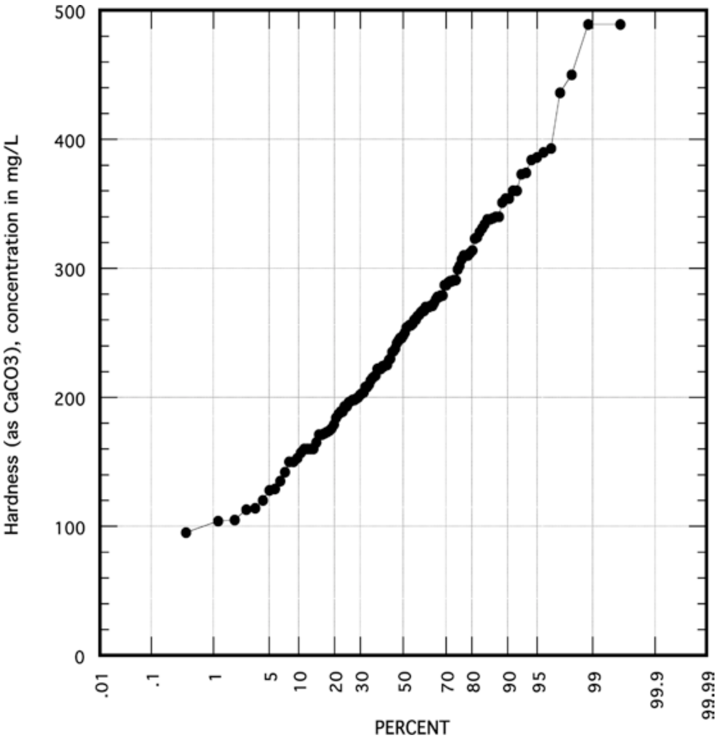


Figure 57 – Probability plot of hardness (Dickinson Reservoir)

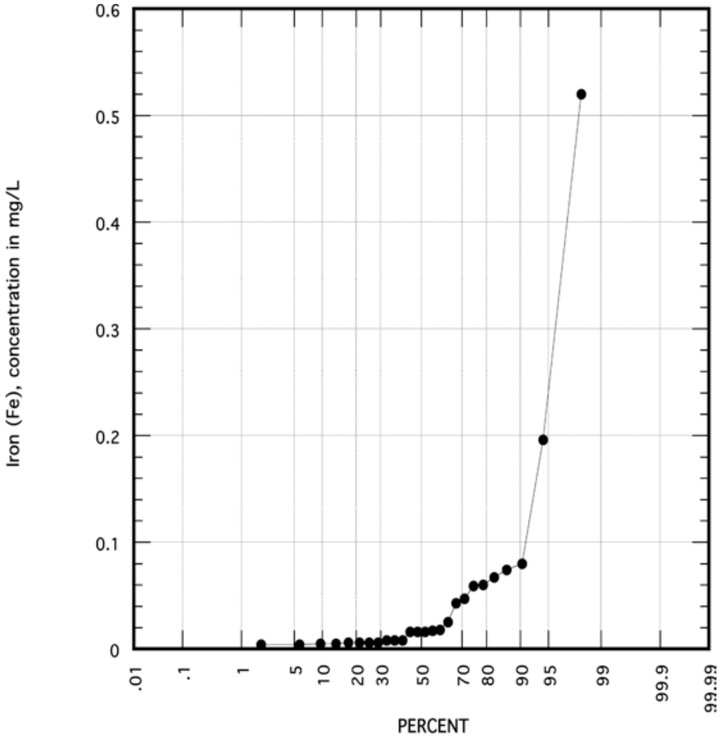


Figure 58 – Probability plot of iron (Dickinson Reservoir)

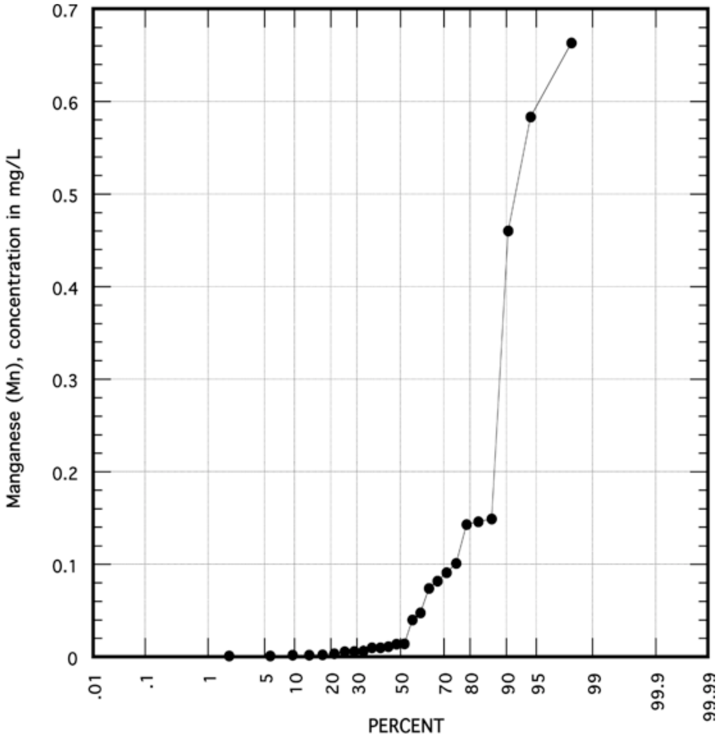


Figure 59 – Probability plot of manganese (Dickinson Reservoir)

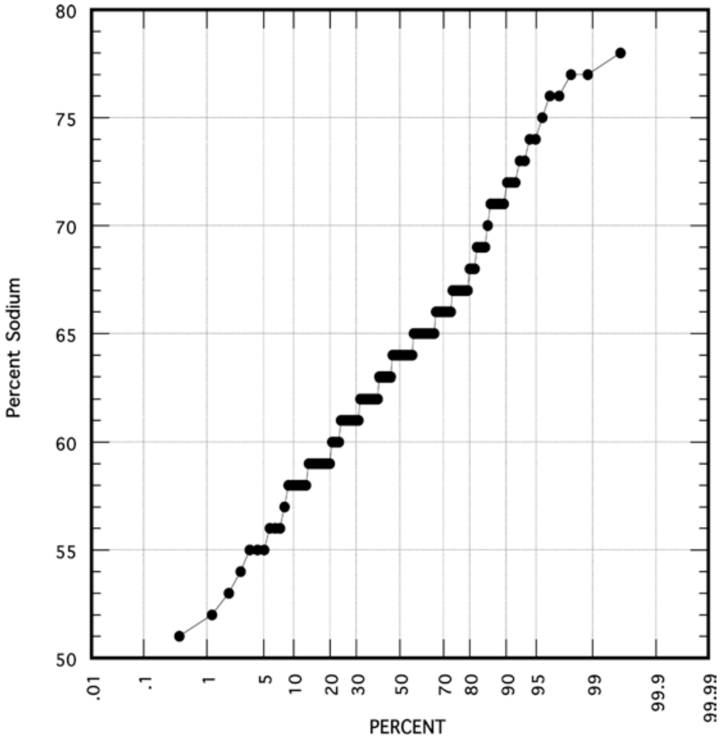


Figure 60 – Probability plot of percent sodium (Dickinson Reservoir)

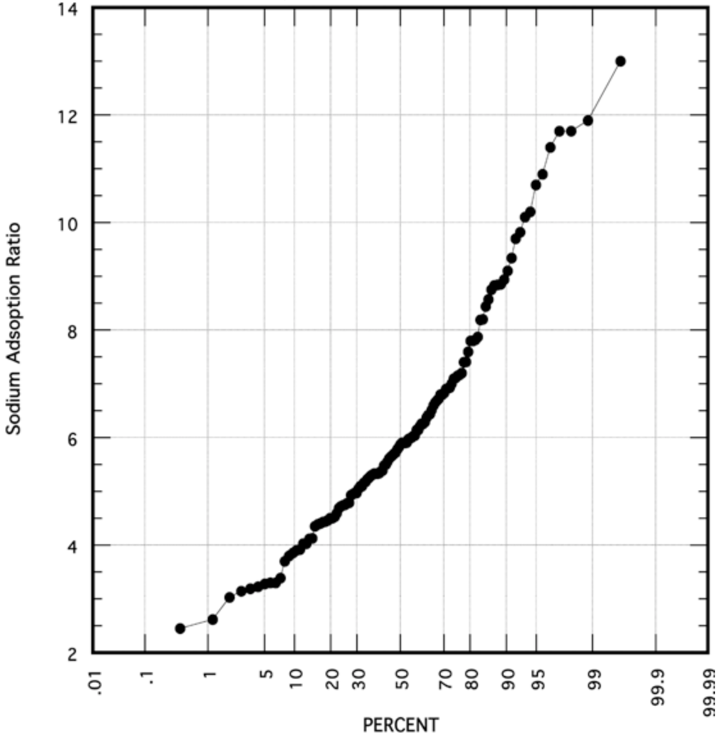


Figure 61 – Probability plot of sodium adsorption ratio (Dickinson Reservoir)

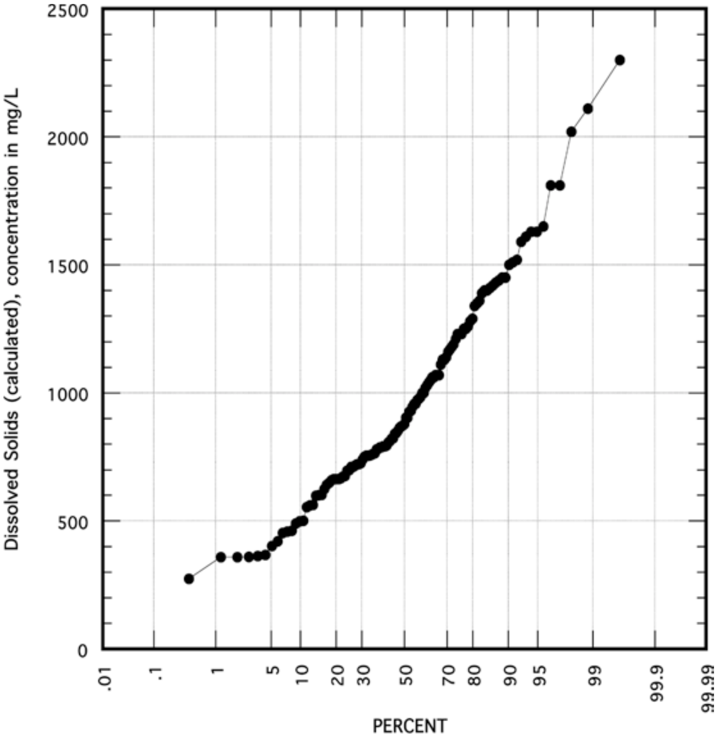


Figure 62 – Probability plot of dissolved solids (Dickinson Reservoir)

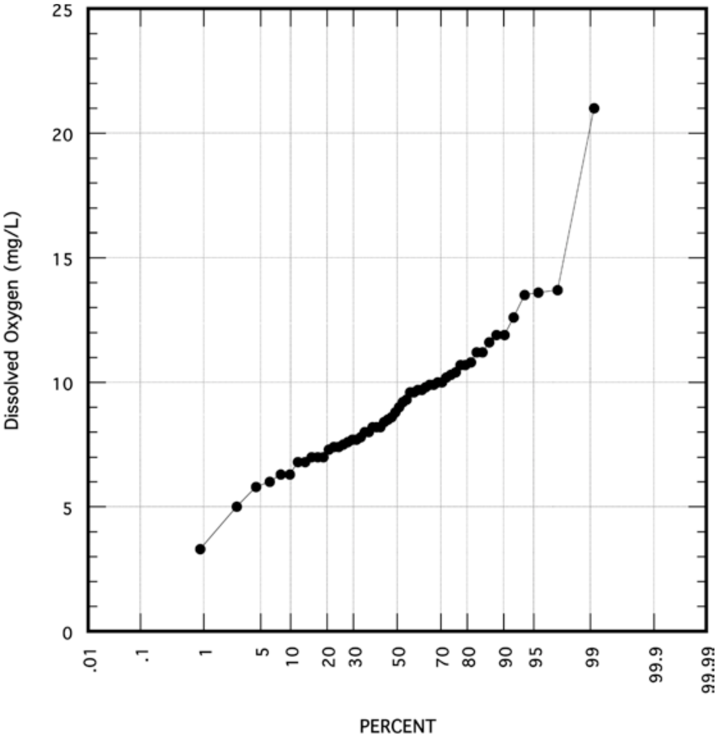


Figure 63 – Probability plot of dissolved oxygen (Dickinson Reservoir)

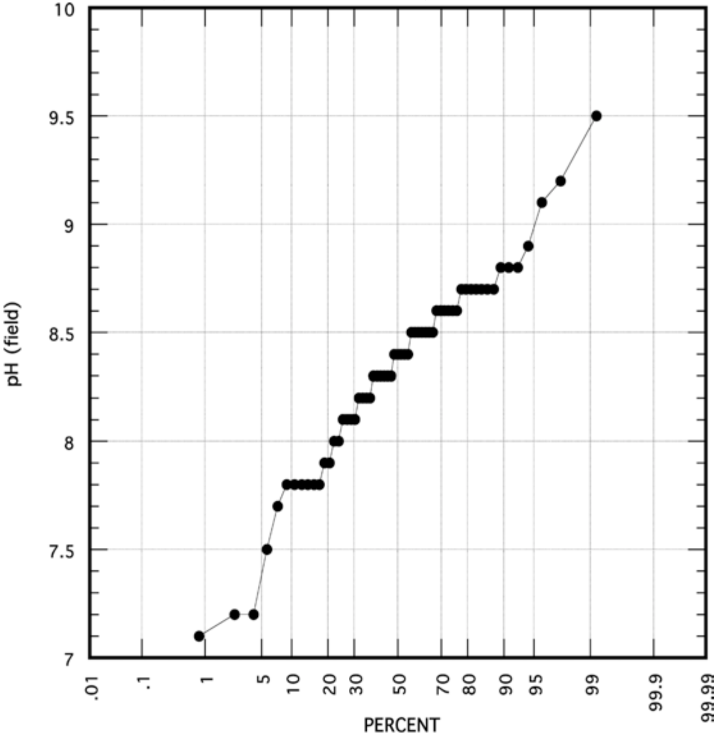


Figure 64 – Probability plot of field pH (Dickinson Reservoir)

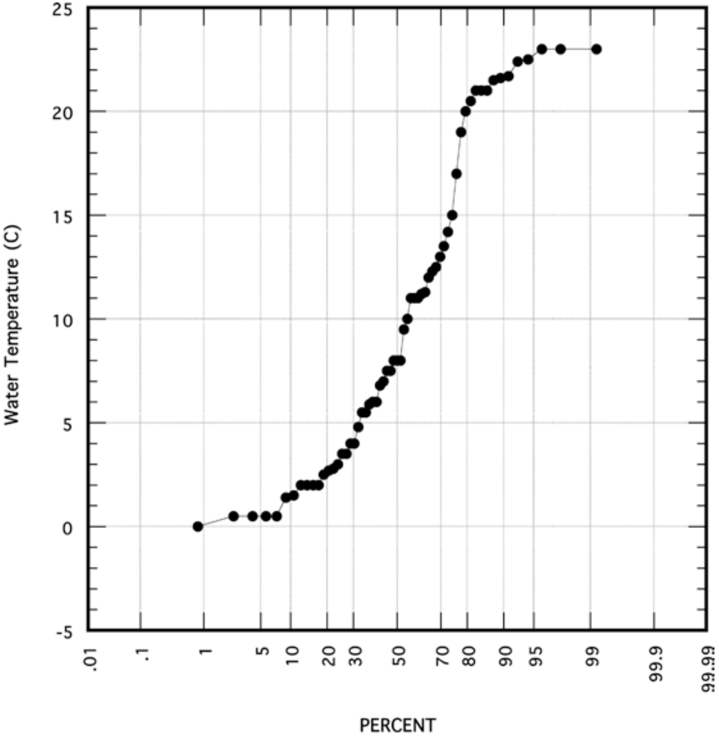


Figure 65 – Probability plot of water temperature (Dickinson Reservoir)

Temporal variations of concentrations and values of selected analytes measured from the above described U.S. Geological Survey samples from Dickinson Reservoir are presented in Figures 66 through 81. Unlike the water quality data from Bowman-Haley Reservoir, the U.S. Geological Survey data is much more comprehensive. Seasonal variability is evident and there appear to be no significant long-term trends in the concentrations and values of the selected analytes.

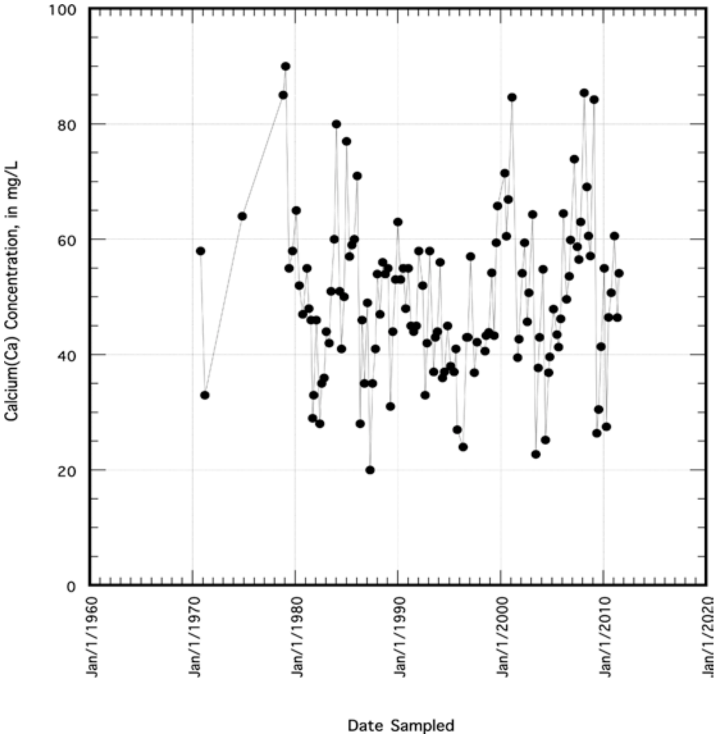


Figure 66 – Temporal variation of calcium (Dickinson Reservoir)

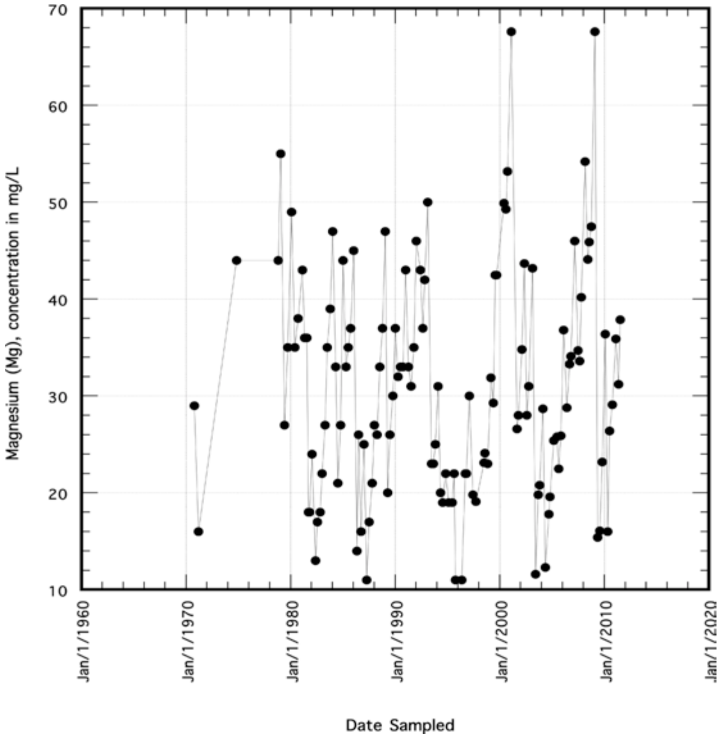


Figure 67 – Temporal variation of magnesium (Dickinsor Reservoir)

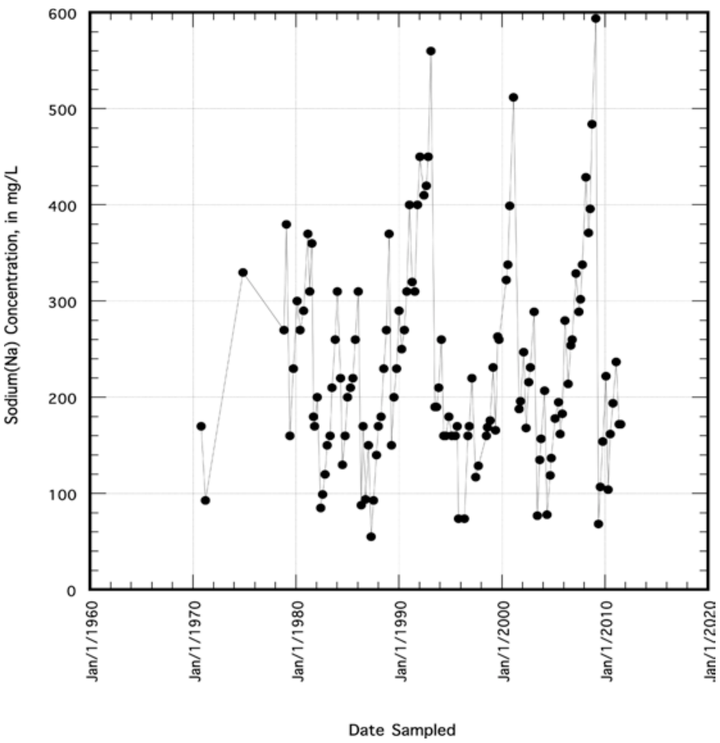


Figure 68 – Temporal variation of sodium (Dickinson Reservoir)

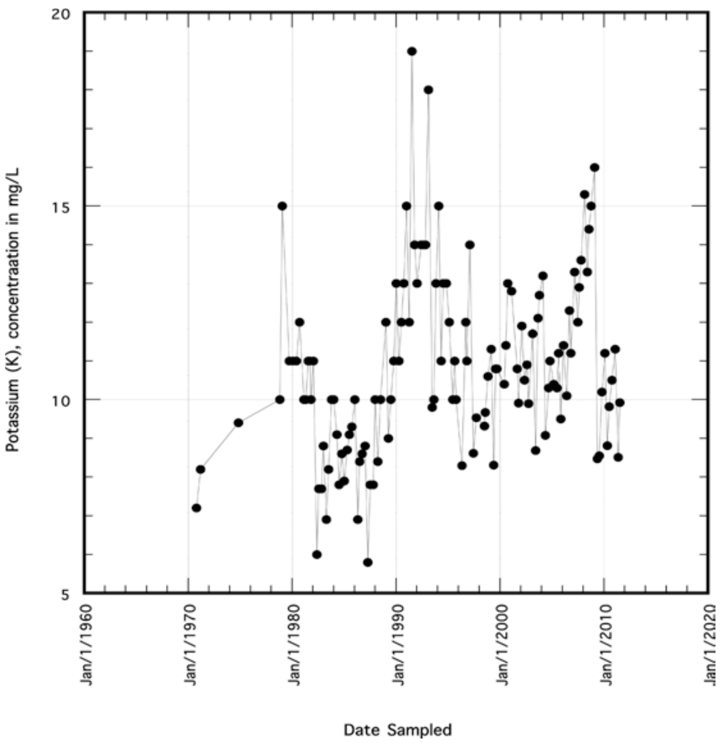


Figure 69 – Temporal variation of potassium (Dickinson Reservoir)

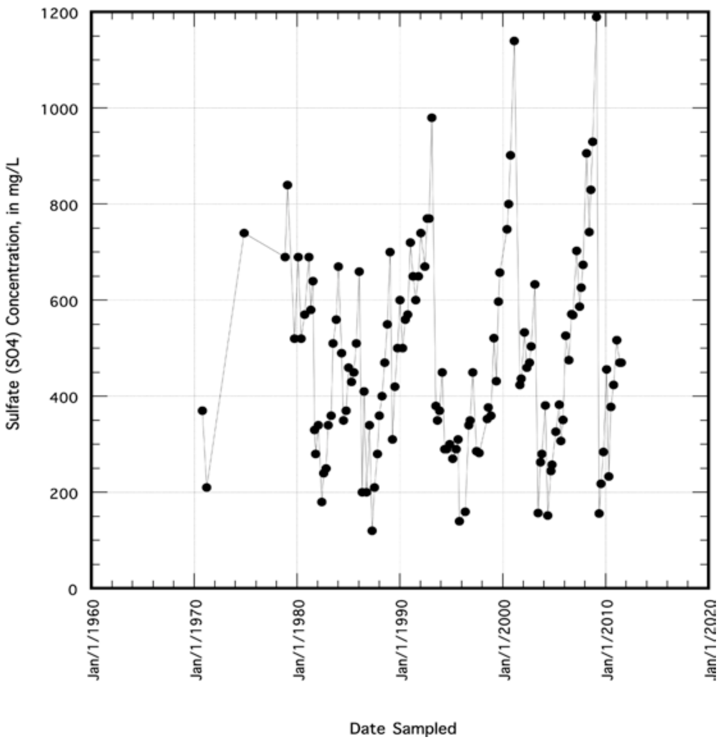


Figure 70 – Temporal variation of sulfate (Dickinson Reservoir)

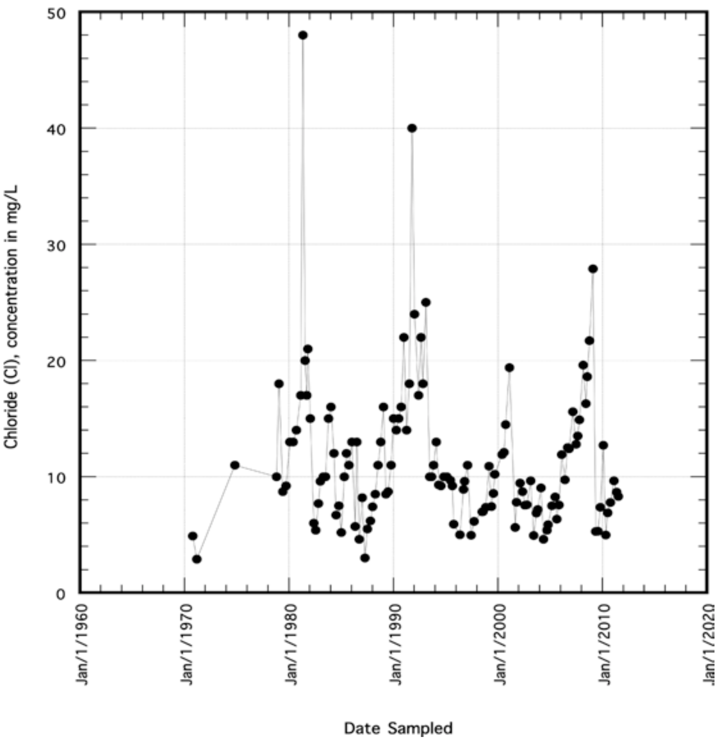


Figure 71 – Temporal variation of chloride (Dickinson Reservoir)

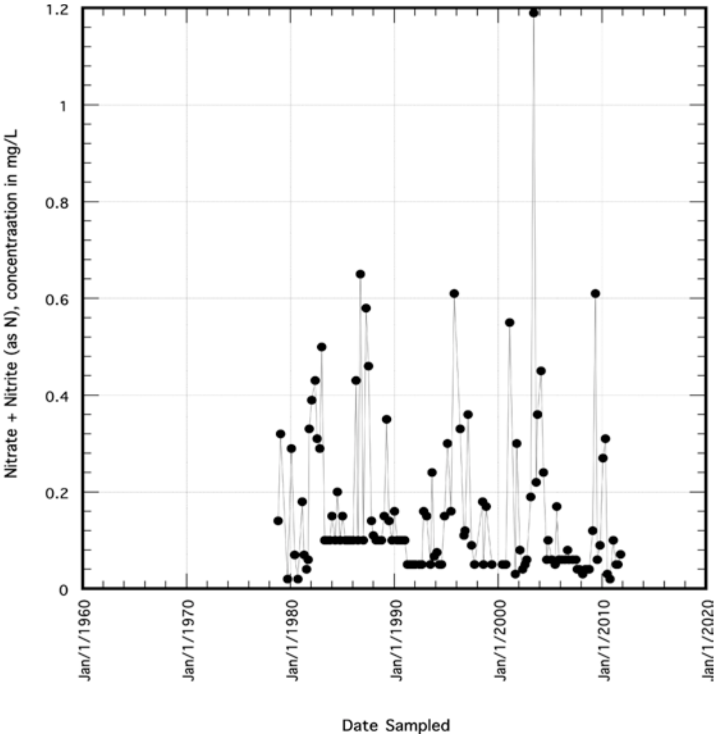


Figure 72 – Temporal variation of nitrate + nitrite (Dickinson Reservoir)

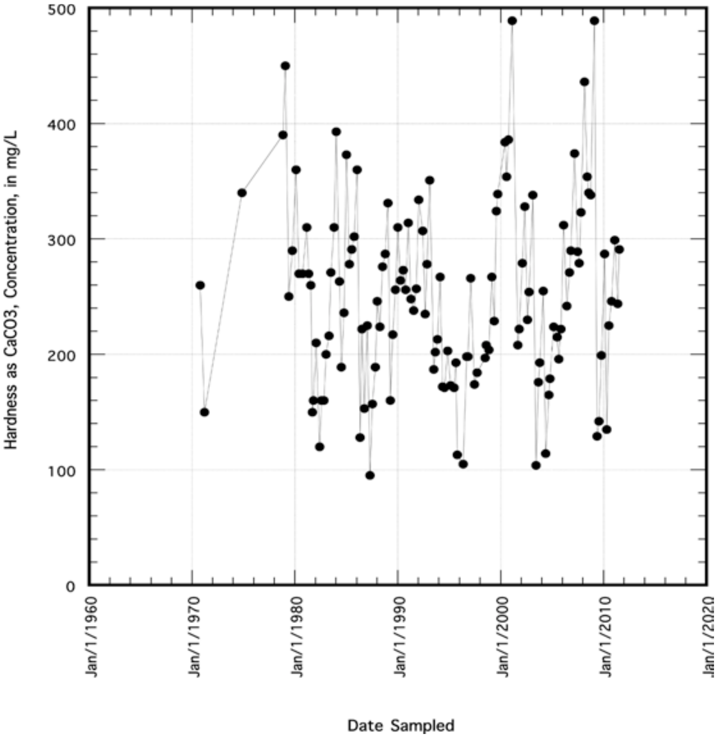


Figure 73 – Temporal variation of hardness (Dickinson Reservoir)

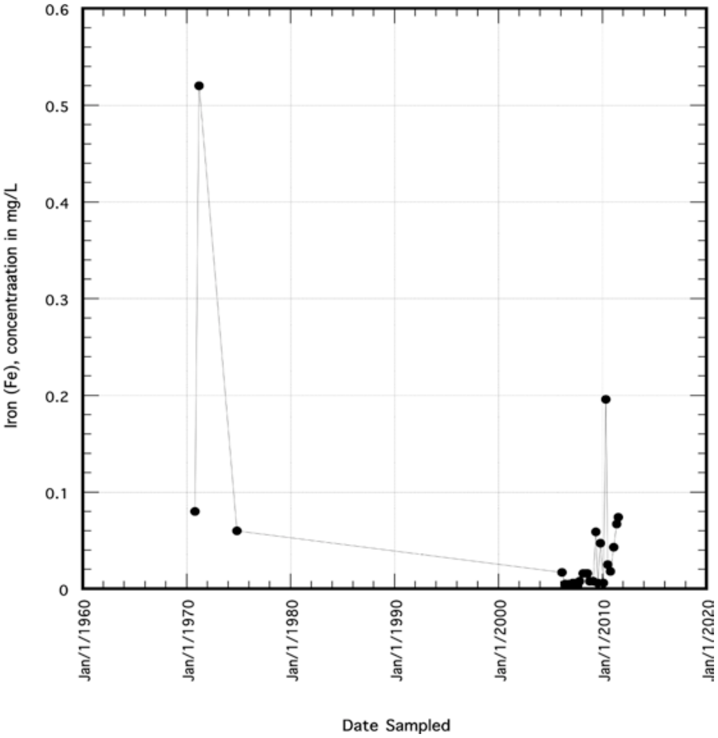


Figure 74 – Temporal variation of iron (Dickinson Reservoir)

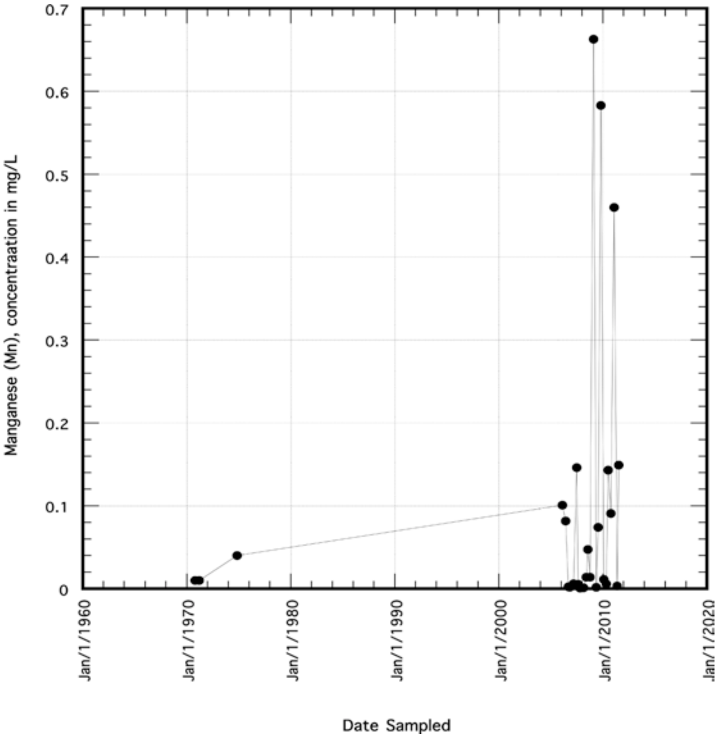


Figure 75 – Temporal variation of manganese (Dickinson Reservoir)

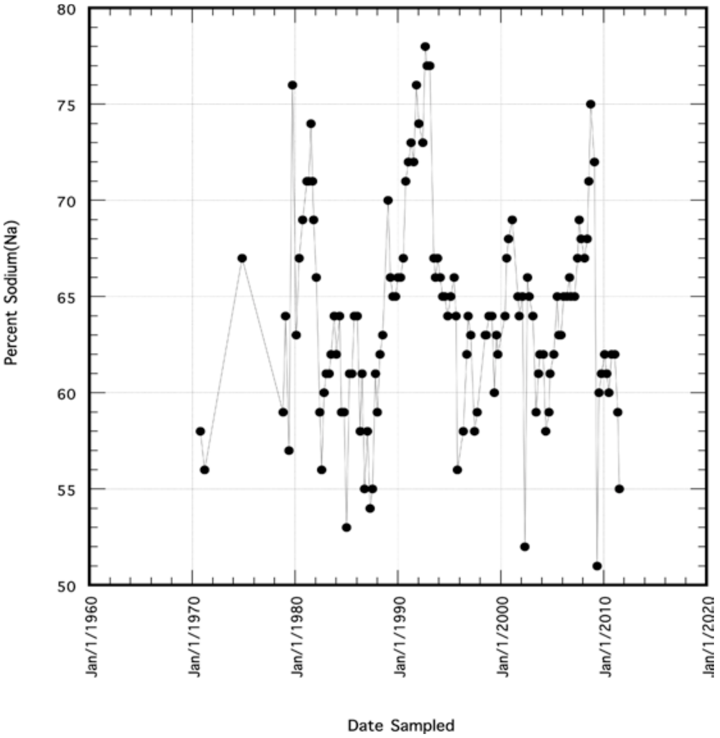


Figure 76 – Temporal variation of percent sodium (Dickinson Reservoir)

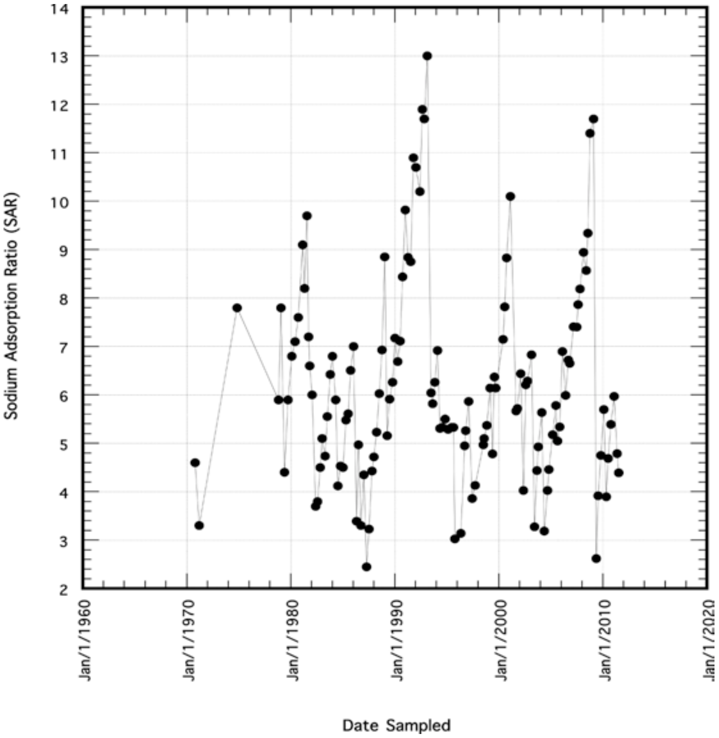


Figure 77 – Temporal variation of sodium adsorption ratio (Dickinson Reservoir)

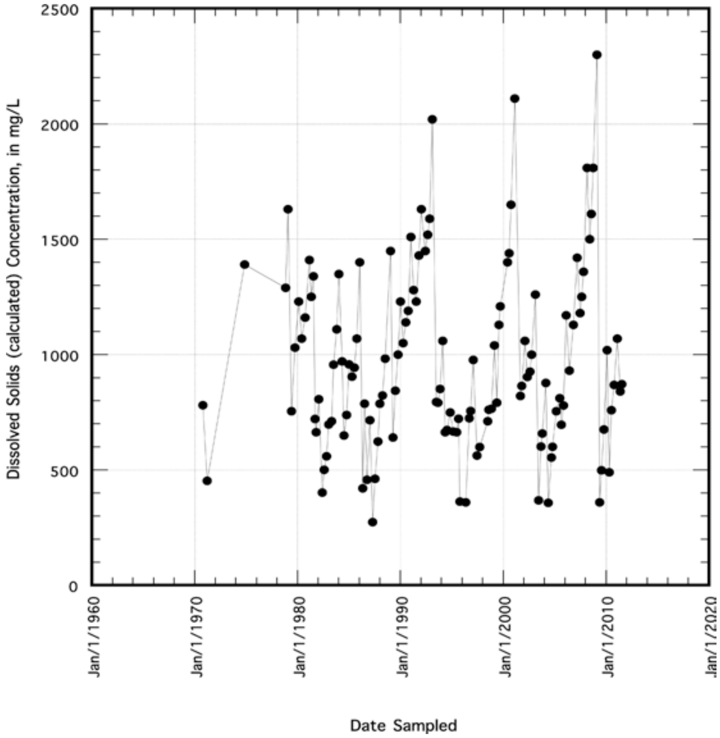


Figure 78 - Temporal variation of dissolved solids (Dickinson Reservoir)

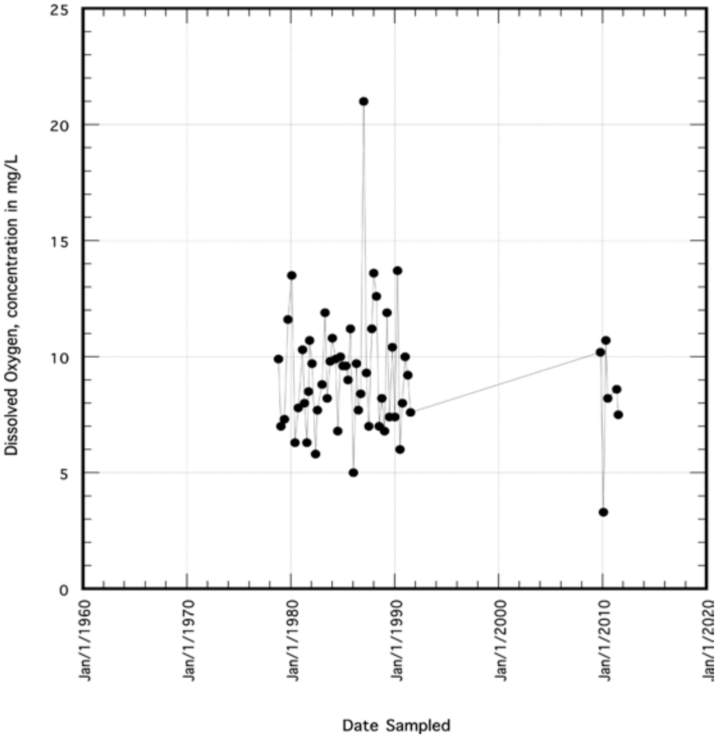


Figure 79 – Temporal variation of dissolved oxygen (Dickinson Reservoir)

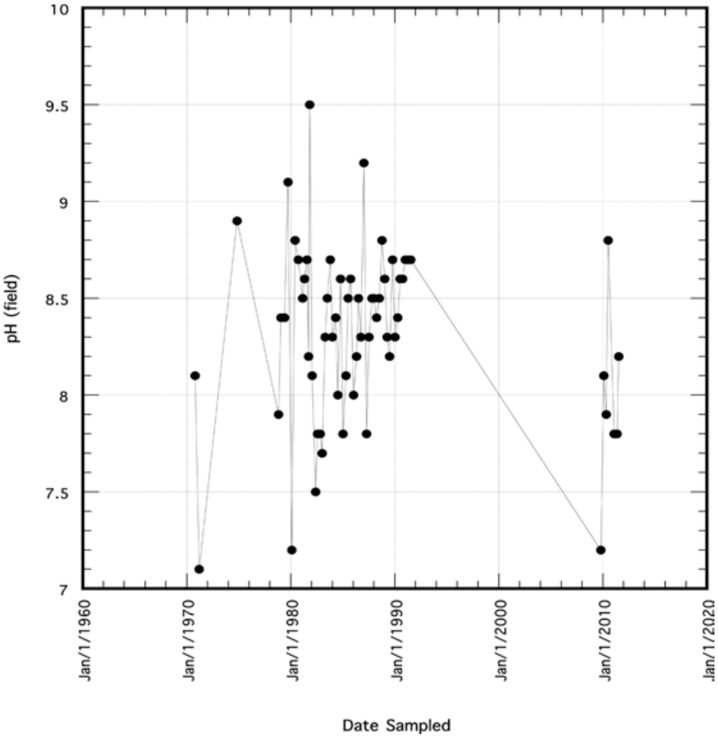


Figure 80 – Temporal variation of pH (Dickinson Reservoir)

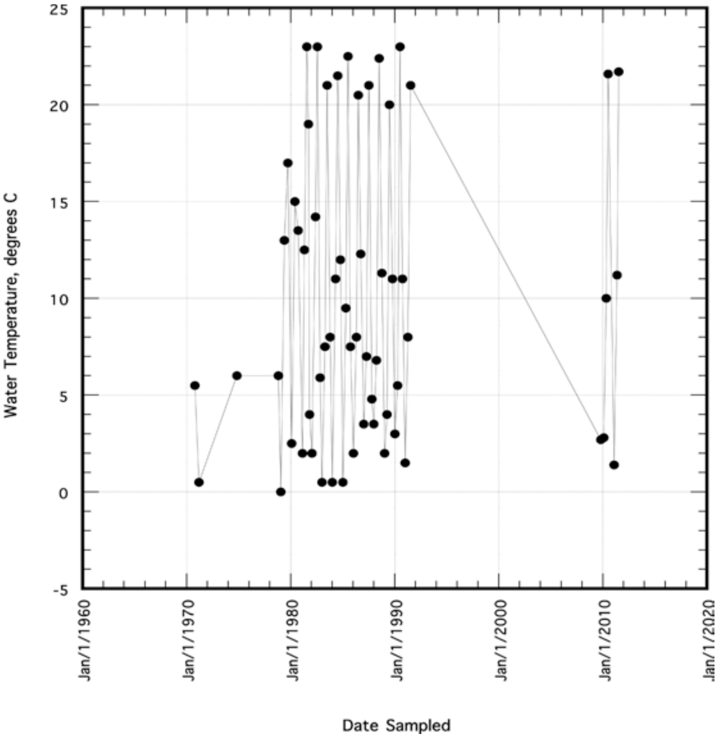


Figure 81 – Temporal variation of water temperature (Dickinson Reservoir)

Existing Water Permits – Dickinson Reservoir

The US Bureau of Reclamation holds Perfected Water Permit No. 250A, allowing for an annual diversion of 7,000 acre-feet of water from Dickinson Reservoir to irrigate 380.0 acres of land with the remainder of the water allocation for municipal use. The point of diversion is the NW1/4SW1/4 of Section 8, Township 139 North, Range 096 West.

During 1980 and 1981, Dickinson Dam was enlarged increasing the reservoir's conservation storage from 6,676 acre-feet to 10,169 acre-feet. This amounted to an additional storage of 3,493 acre-feet.

On February 11, 1980, the U.S. Bureau of Reclamation applied for Conditional Water Permit No. 3216 to divert 3,493.0 acre-feet of water annually from Dickinson Reservoir for municipal, industrial, recreation, fish and wildlife use. The point of diversion is the SW1/4 of Section 8, Township 139 N., Range 096 W. Conditional Water Permit No. 3216 was perfected on September 30, 1985.

The City of Dickinson began diverting the water from Dickinson Reservoir under Perfected Water Permit No. 250 in 1967. In October 1991, the city ceased pumping for municipal use from Dickinson Reservoir and obtained its municipal water supply from the Southwest Water Authority. The city continues to divert water from Dickinson Reservoir for golf course irrigation.

In addition, water is diverted from Dickinson Reservoir to irrigate lands owned by Dickinson Heart River Mutual Aid Corporation.

Given that the City of Dickinson no longer diverts water for municipal use from Dickinson Reservoir, there is a large volume of water available for municipal, industrial, recreation, fish and wildlife use under Perfected Water Permits 250A and 3216. This was confirmed in a February 15, 2012 telephone conversation with Mr. Gregory Gere, Assistant Area Manager, U.S. Bureau of Reclamation, Dakotas Office located in Bismarck. Parties interested in diverting water from Dickinson Reservoir for oil-field industrial use should contact Mr. Gere at (701) 221-1202. In order to divert water for industrial use under Perfected Water Permit No. 3216, the potential water user must enter into a "Water Service Contract" with the Bureau of Reclamation. As part of this process, the Bureau of Reclamation will require preparation of a "fair market analysis". A section of the Reclamation Manual describing water-related contract and repayment principles and requirements is found in Appendix I.

Heart Butte Reservoir (Lake Tschida)

Heart Butte Reservoir (Lake Tschida) is a U.S. Bureau of Reclamation (USBR) project to provide storage for irrigation. The reservoir is located approximately 17 miles south of Glen Ullin on the Heart River in northwestern Grant County (Fig.82). At full pool, Lake Tschida covers approximately 5,018 acres, with a maximum depth of 64 feet and an average depth of 27.9 feet (Wax, 2006).

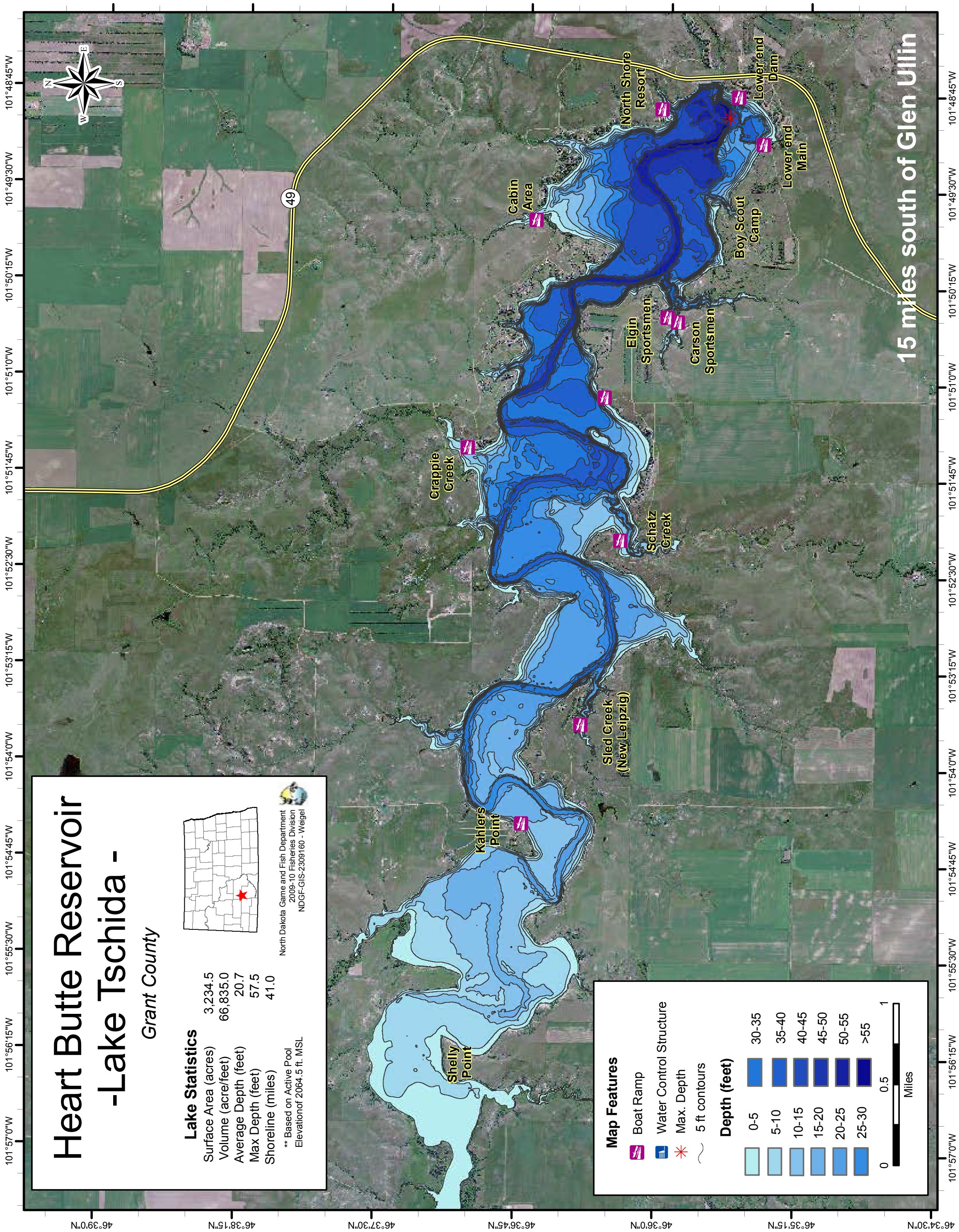


Figure 82 – Location of Heart Butte Reservoir (Lake Tschida)

A part of a state-wide Lake Water Quality Assessment (LQWA), the North Dakota Department of Health collected water samples for chemical analysis from Heart Butte Reservoir (Lake Tschida) in 1992 and 1993 and 2000 and 2001 (Wax, 2006). The U.S. Geological Survey began collecting water samples for chemical analysis from Heart Butte reservoir in October 1970 and continues this water-quality sampling program to the present (U.S. Geological Survey, National Water Information System). The U.S. Geological Survey data set is more comprehensive than that of the State Health Department's LWQA data set and therefore the U.S. Geological Survey data set from October to 1970 to July 2011 is summarized in this report.

For the most part, water samples for chemical analysis were collected at the water surface and at selected depths below water surface to a maximum depth of 27.9 feet. Sampling depths were not kept constant over the period of sampling record. For the purpose of this report, all U.S. Geological Survey samples were combined to prepare summary statistics. The minimum, maximum, and mean values for selected analytes of the U.S. Geological Survey data for Heart Butte Reservoir (Lake Tschida) are shown in Table 12.

Table 12 – Minimum, maximum and mean values of selected analytes from Heart Butte Reservoir (Lake Tschida).

Analyte	Unit	Minimum Value	Maximum Value	Mean	Number of Samples
Calcium	mg/L	20	77	53	95
Magnesium	mg/L	9	68	39	95
Sodium	mg/L	69	294	176	95
Potassium	mg/L	1.4	16	11	95
Sulfate	mg/L	138	747	415	95
Chloride	mg/L	3.6	24	11.1	95
Iron	mg/L	0.0003	0.17	0.03	26
Manganese	mg/L	0.0005	0.07	0.016	26
Dissolved Solids	mg/L	318	1400	860	94
Hardness (as $CaCO_3$)	mg/L	88	476	291	95
Sodium Adsorption Ratio	unitless	2.7	6.8	4.5	95
Percent Sodium	percent	44	64	55	95
pH (field)		7	9.2	8.2	950
Dissolved Oxygen	mg/L	0.2	18.8	8.8	930
Water Temperature	degrees C	0.5	24.9	12.1	950

Probability plots of selected analytes measured from the above described U.S. Geological Survey samples from Heart Butte Reservoir are presented in Figures 83 through 97.

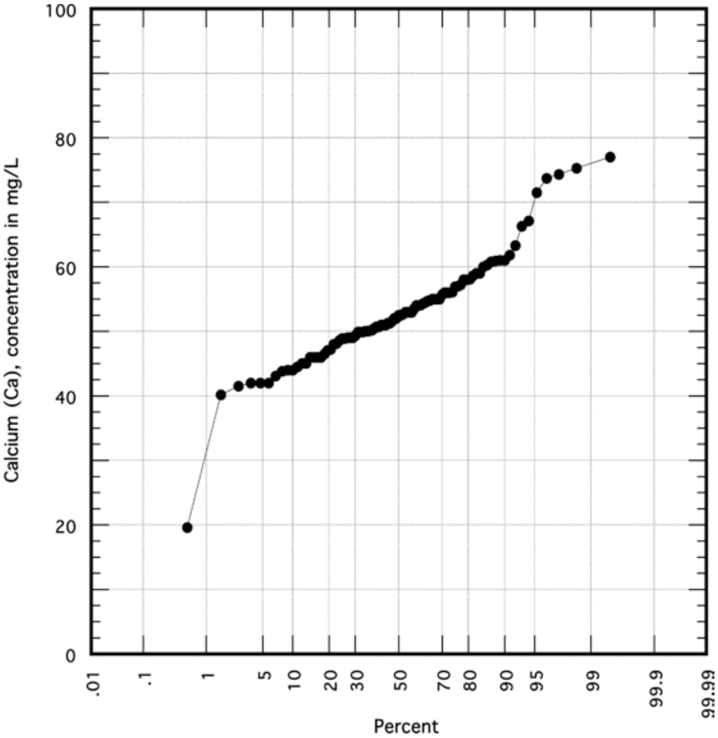


Figure 83 – Probability plot of calcium (Heart Butte Reservoir)

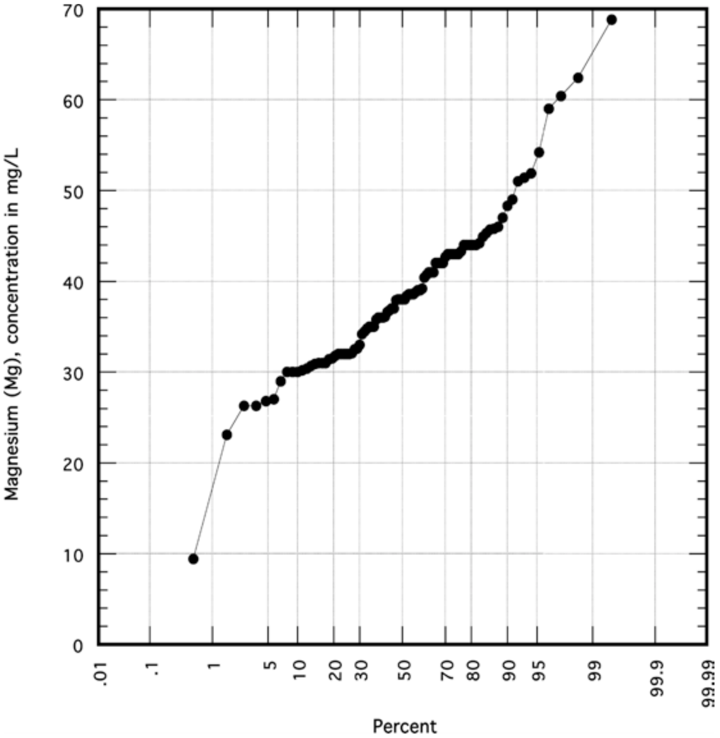


Figure 84 – Probability plot of magnesium (Heart Butte Reservoir)

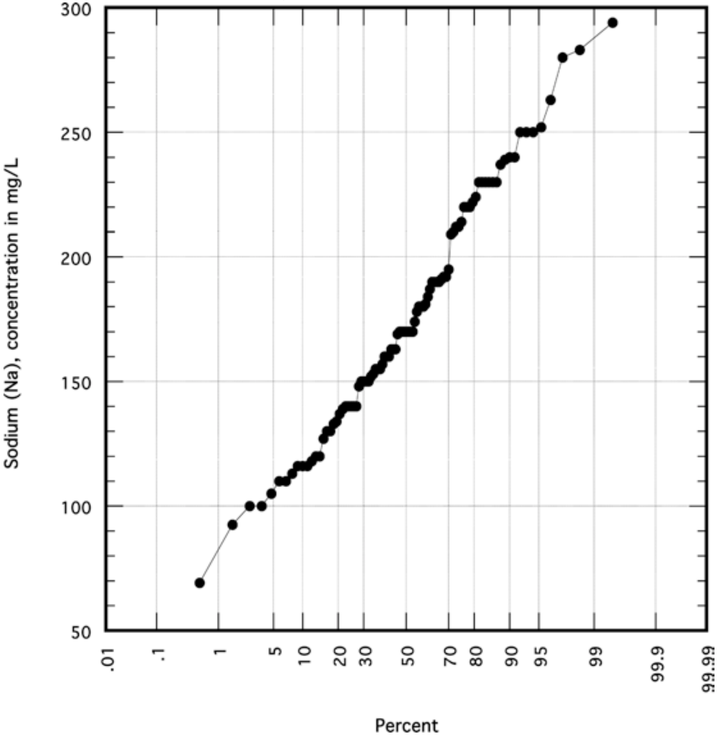


Figure 85 – Probability plot of sodium (Heart Butte Reservoir)

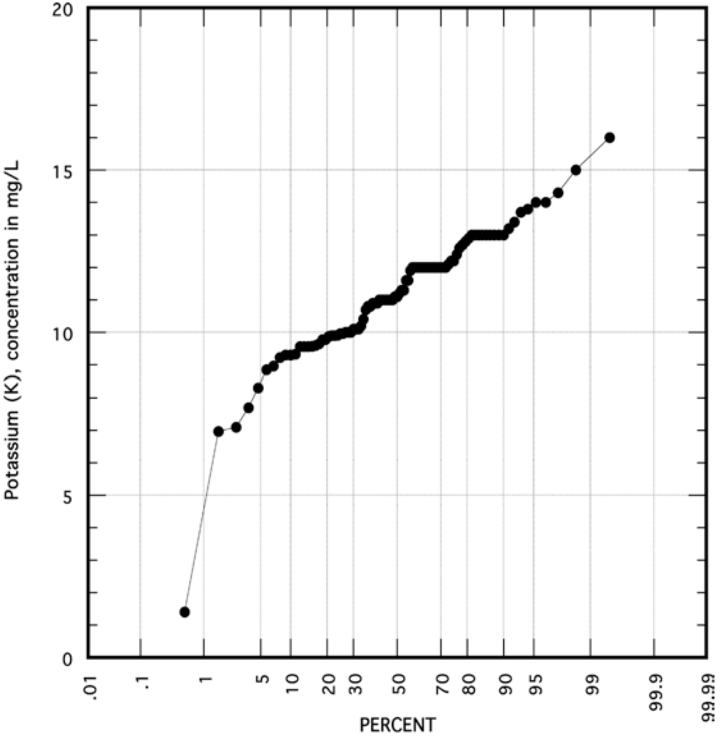


Figure 86 – Probability plot of potassium (Heart Butte Reservoir)

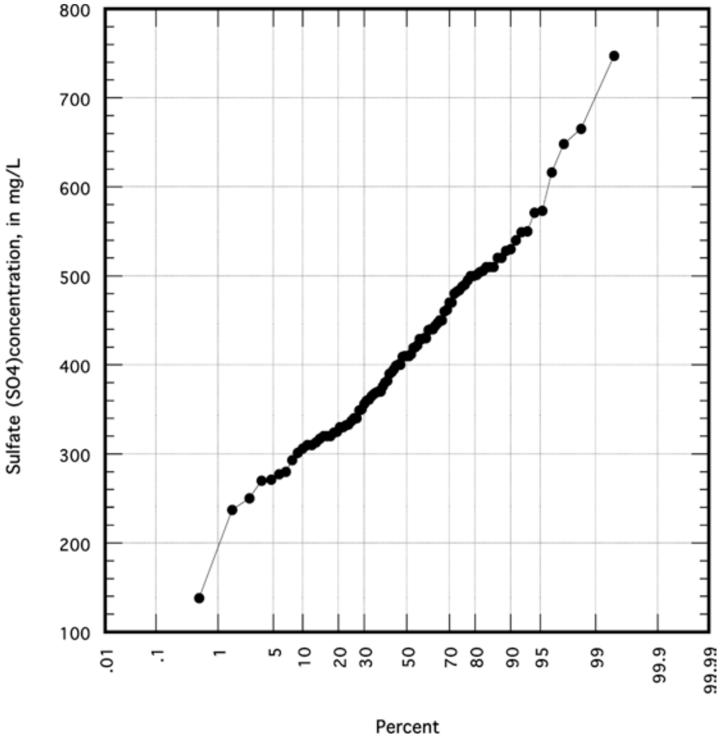


Figure 87 – Probability plot of sulfate (Heart Butte Reservoir)

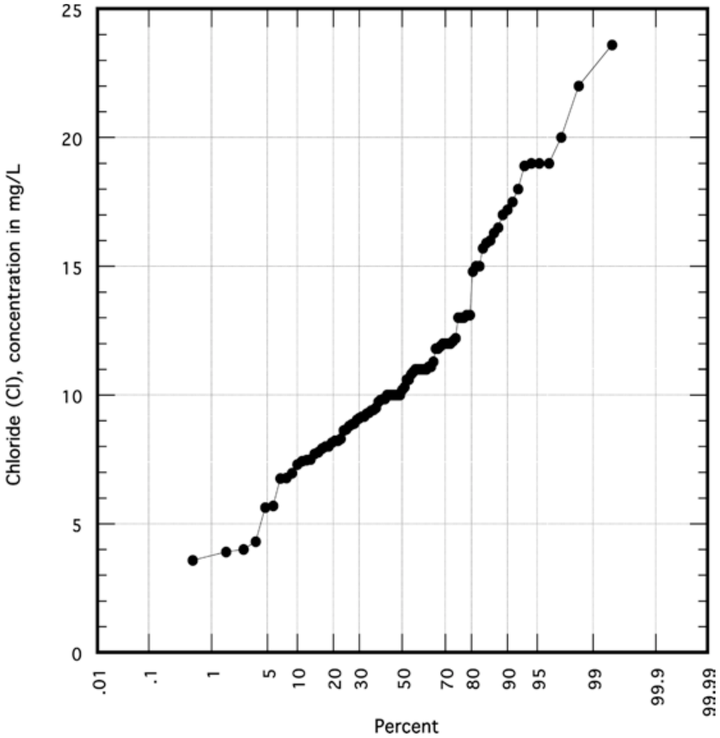


Figure 88 – Probability plot of chloride (Heart Butte Reservoir)

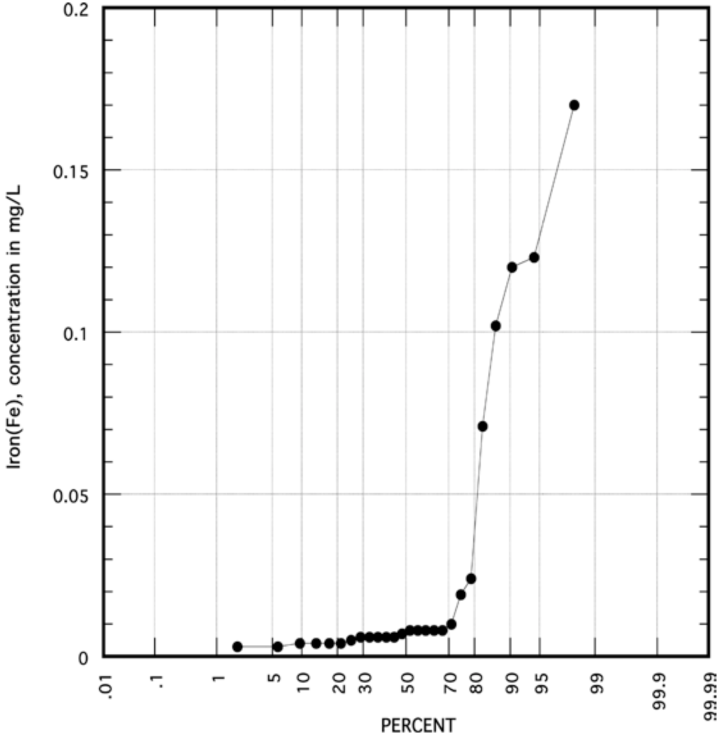


Figure 89 – Probability plot of iron (Heart Butte Reservoir)

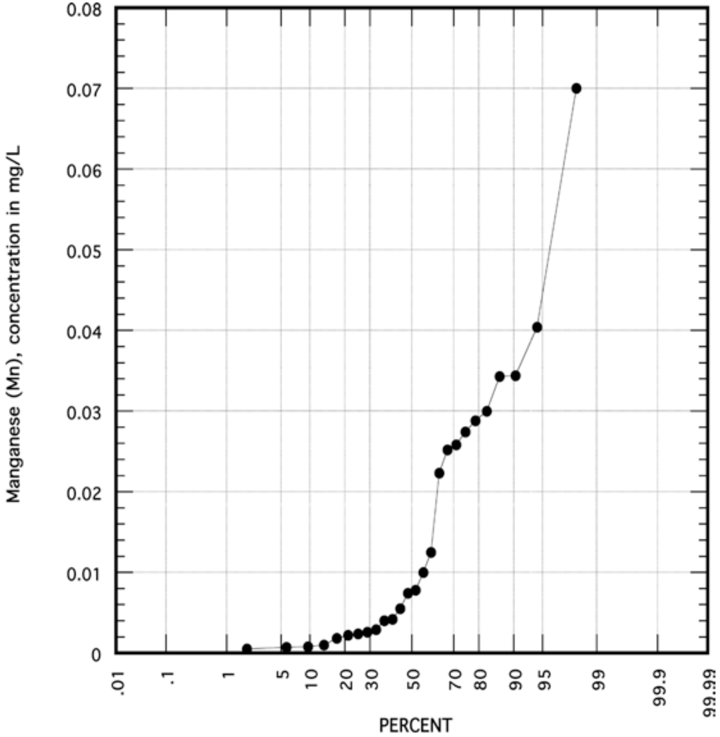


Figure 90 – Probability plot of manganese (Heart Butte Reservoir)

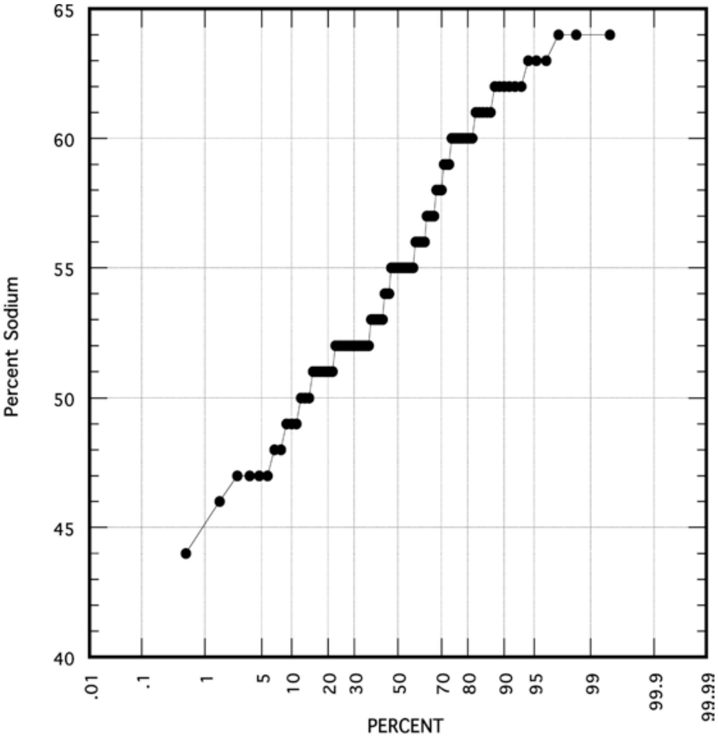


Figure 91 – Probability plot of percent sodium (Heart Butte Reservoir)

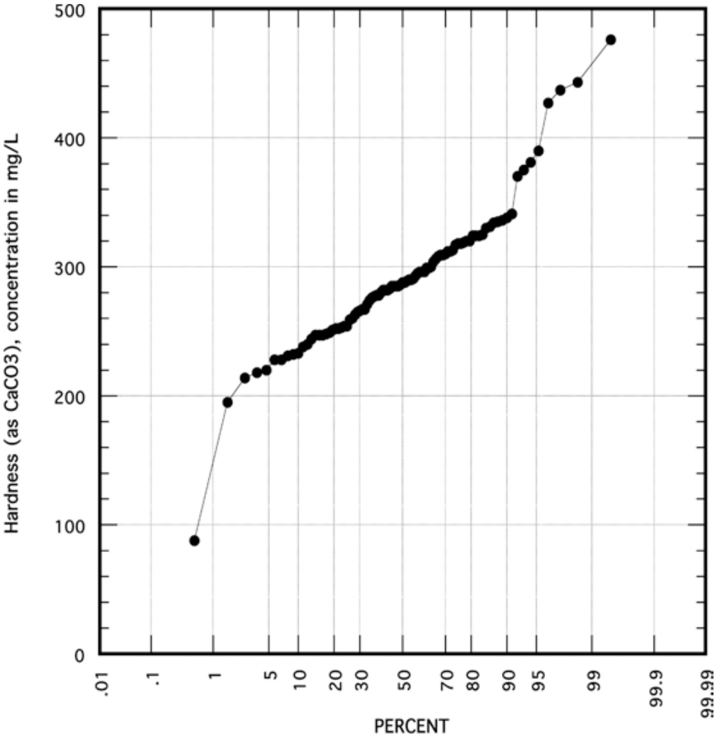


Figure 92 – Probability plot of hardness (Heart Butte Reservoir)

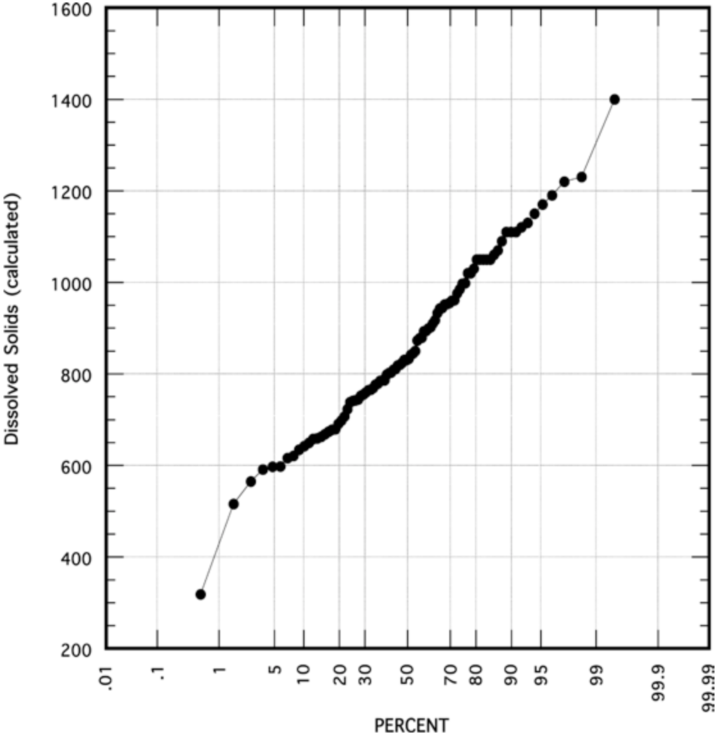


Figure 93 – Probability of dissolved solids (Heart Reservoir)

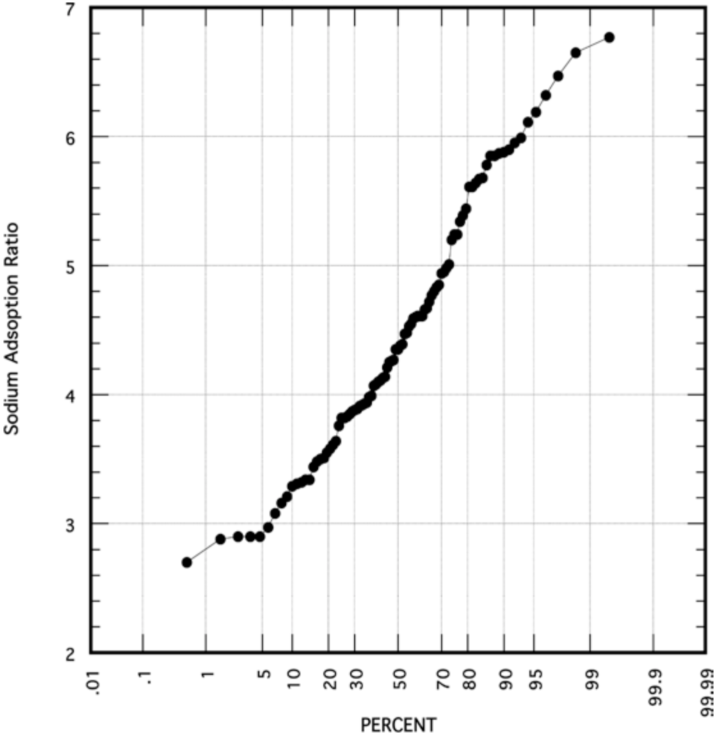


Figure 94 – Probability plot of sodium adsorption ratio (Heart Butte Reservoir)

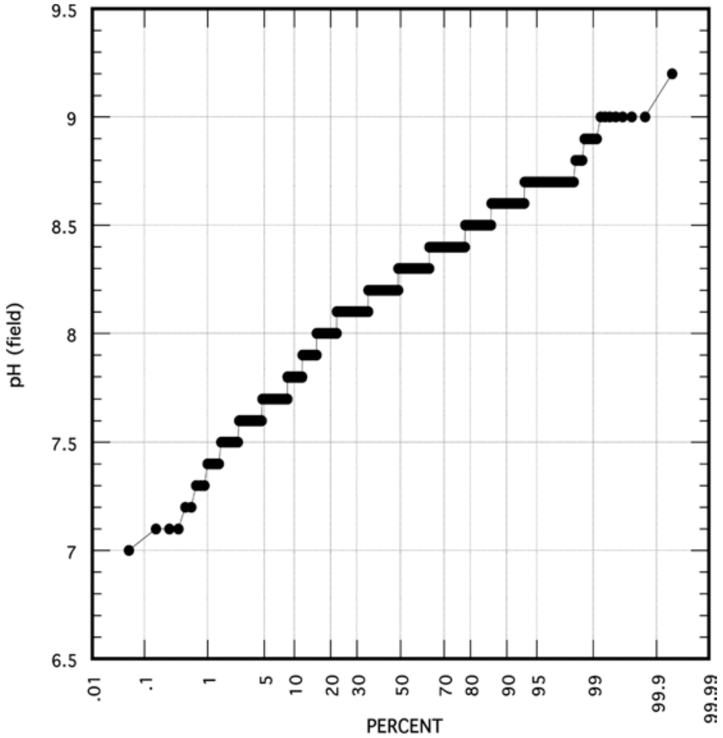


Figure 95 – Probability plot of field pH (Heart Butte Reservoir)

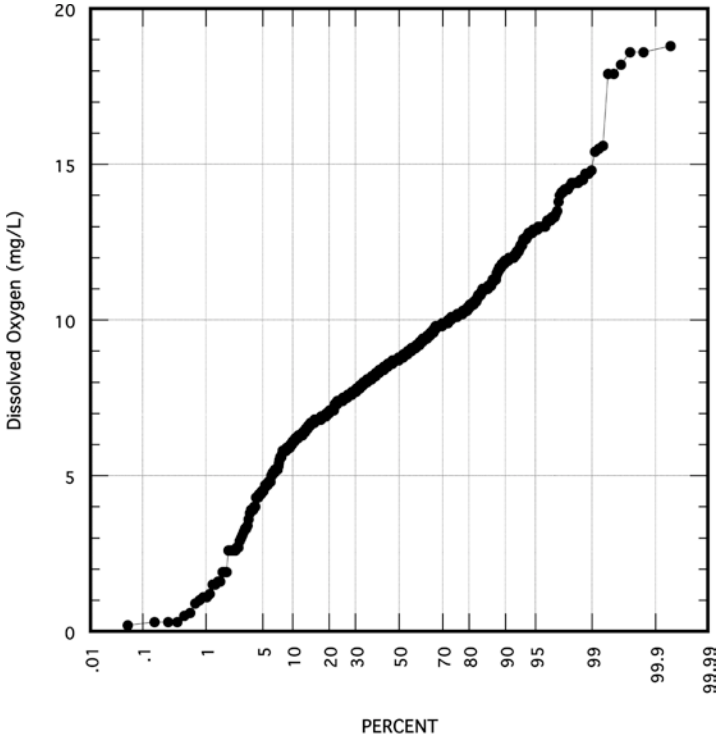


Figure 96 – Probability plot of dissolved oxygen (Heart Butte Reservoir)

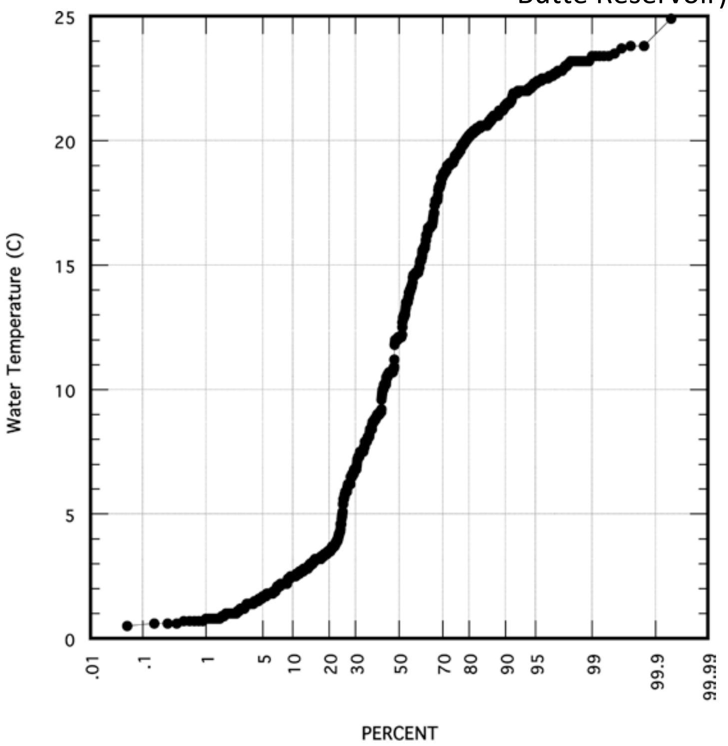


Figure 97 – Probability plot of water temperature (Heart Butte Reservoir)

Temporal variations of concentrations and values of selected analytes measured from the above described U.S. Geological Survey samples from Heart Butte Reservoir are presented in Figures 98 through 112. Unlike the water quality data from Bowman-Haley Reservoir, the U.S. Geological Survey data is much more comprehensive. Seasonal variability is evident and there appear to be no significant long-term trends in the concentrations and values of the selected analytes.

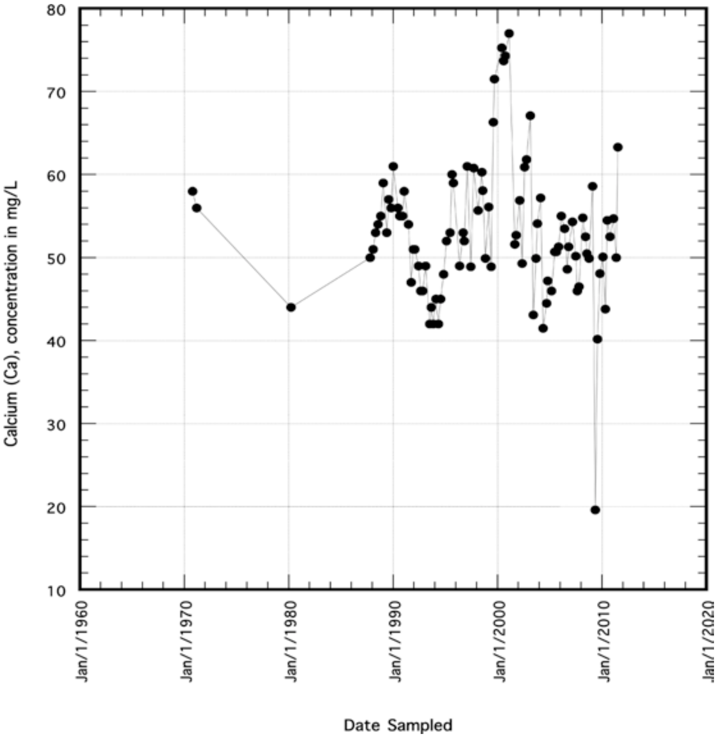


Figure 98 – Temporal variation of calcium (Heart Butte Reservoir)

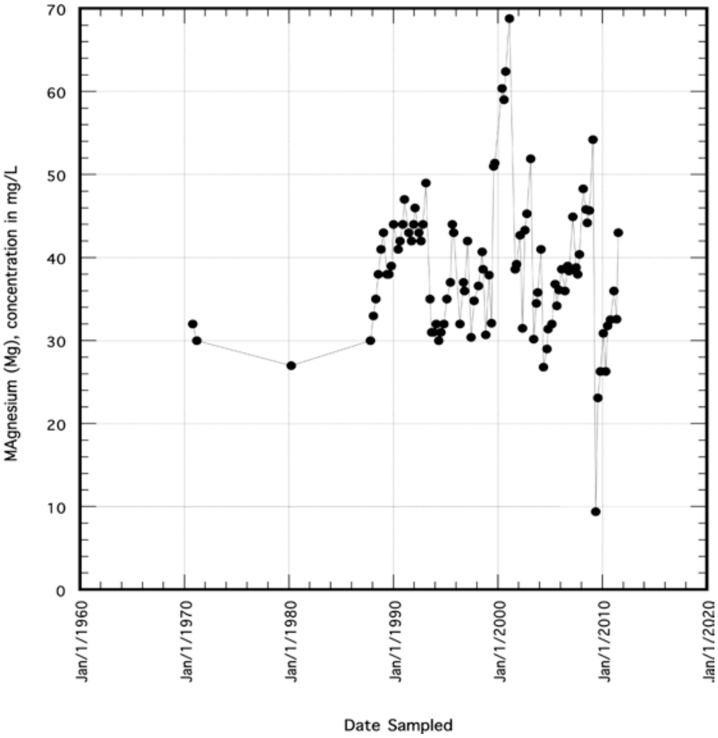


Figure 99 – Temporal variation of magnesium (Heart Butte Reservoir)

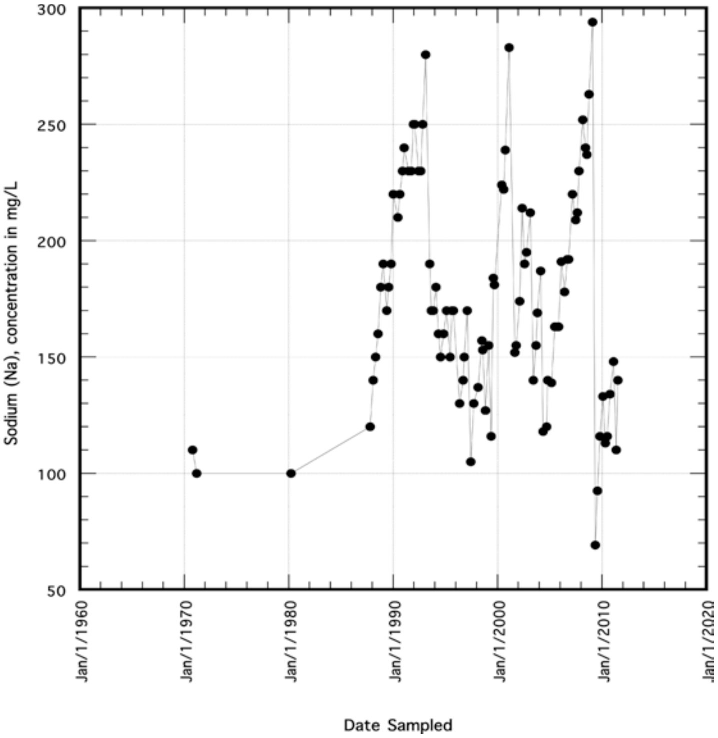


Figure 100 – Temporal variation of sodium (Heart Butte Reservoir)

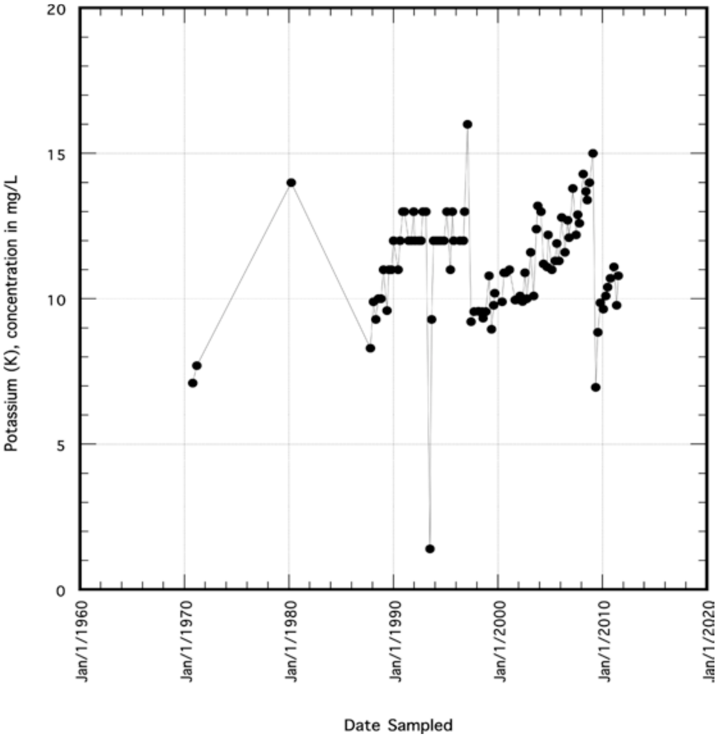


Figure 101 – Temporal variation of potassium (Heart Butte Reservoir)

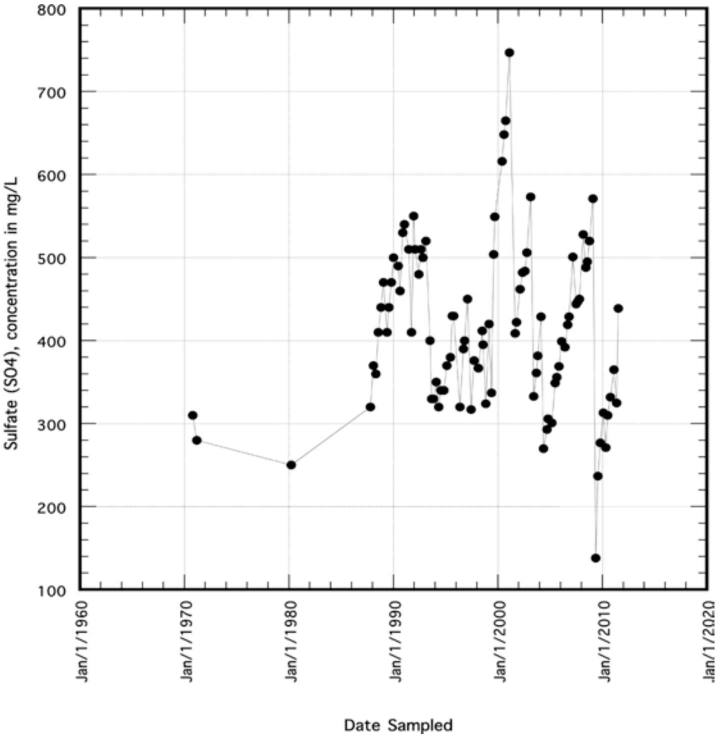


Figure 102 – Temporal variation of sulfate (Heart Butte Reservoir)

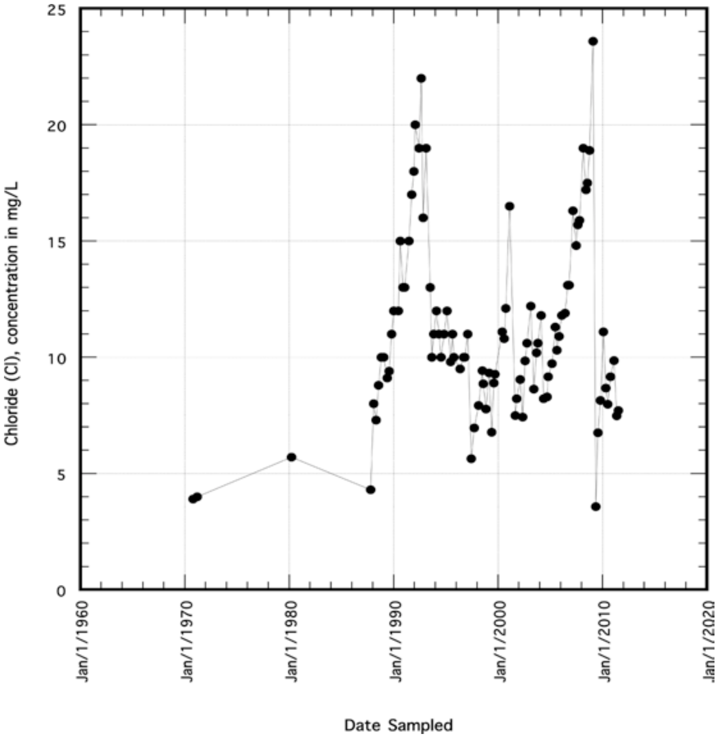


Figure 103 – Temporal variation of chloride (Heart Butte Reservoir)

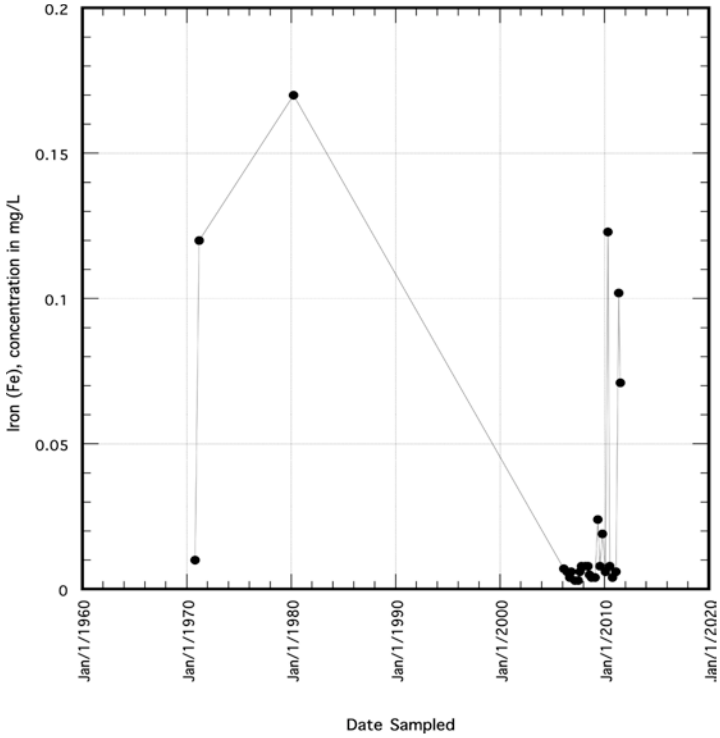


Figure 104 – Temporal variation of iron (Heart Butte Reservoir)

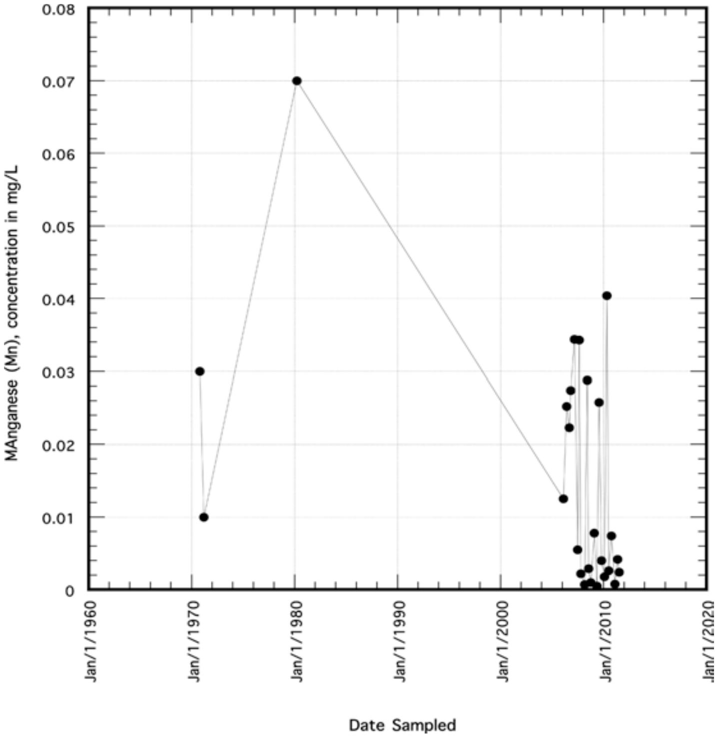


Figure 105 – Temporal variation of manganese (Heart Butte Reservoir)

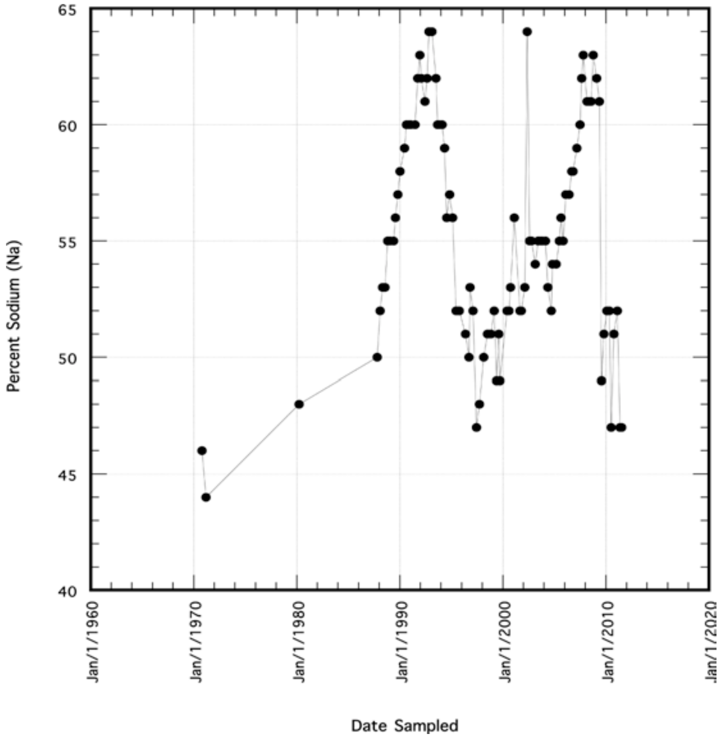


Figure 106 – Temporal variation of percent sodium (Heart Butte Reservoir)

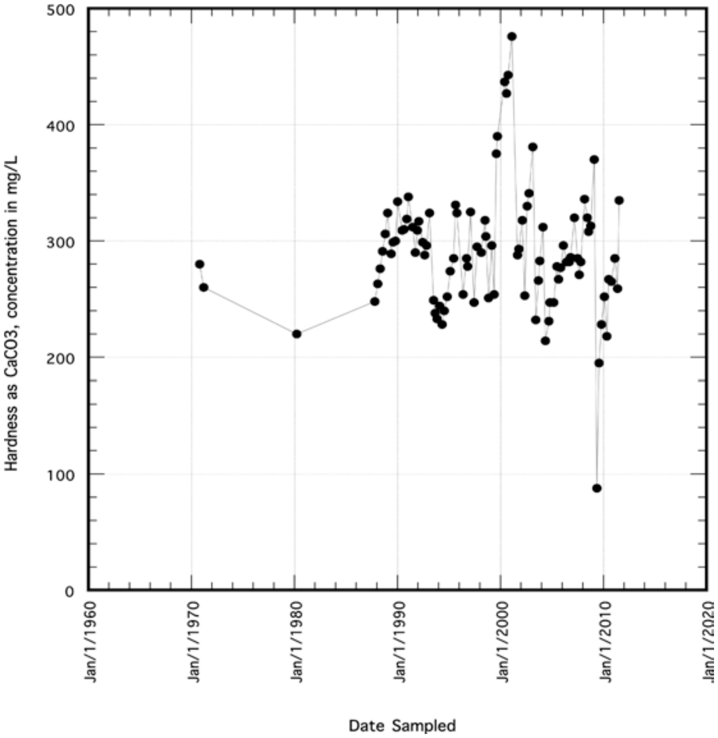


Figure 107 – Temporal variation of hardness (Heart Butte Reservoir)

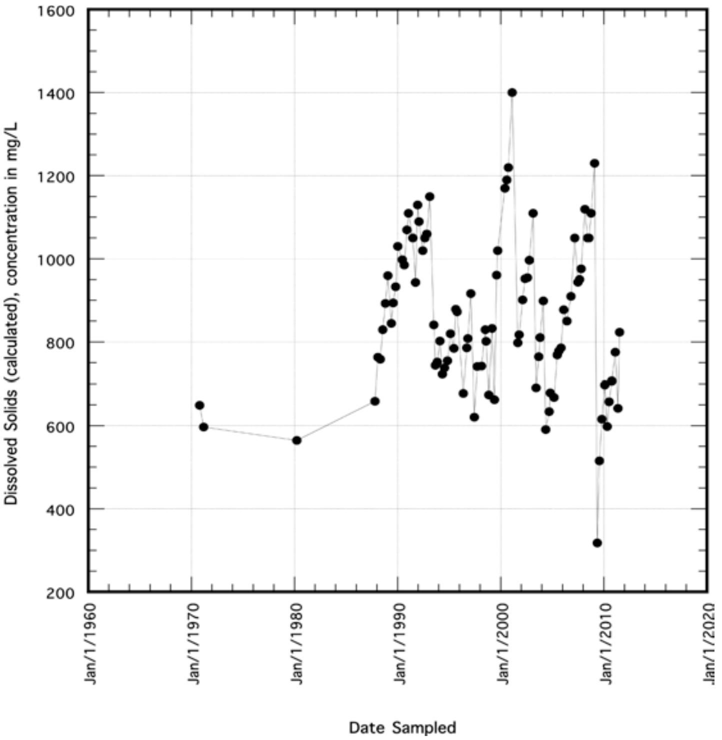


Figure 108 – Temporal variation of dissolved solids (Heart Butte Reservoir)

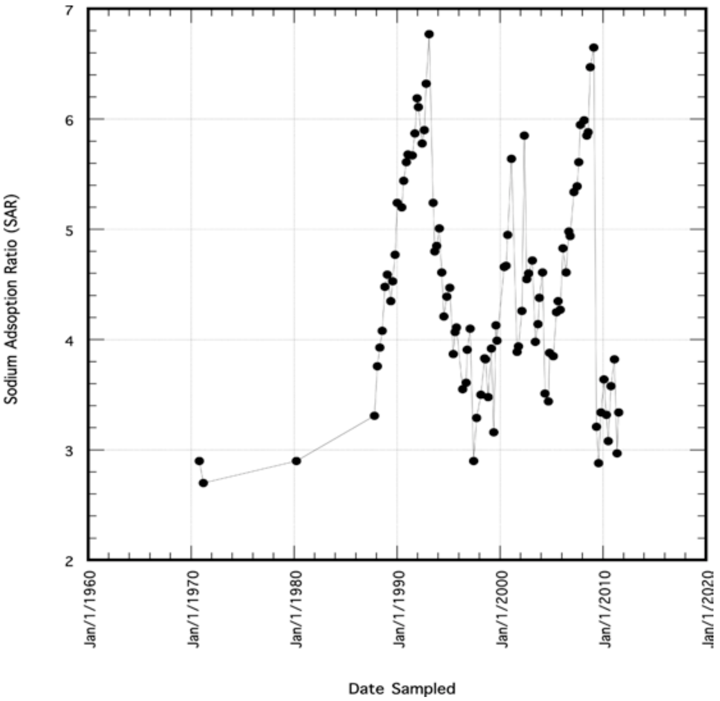


Figure 109 – Temporal variation of sodium adsorption ratio (Heart Butte Reservoir)

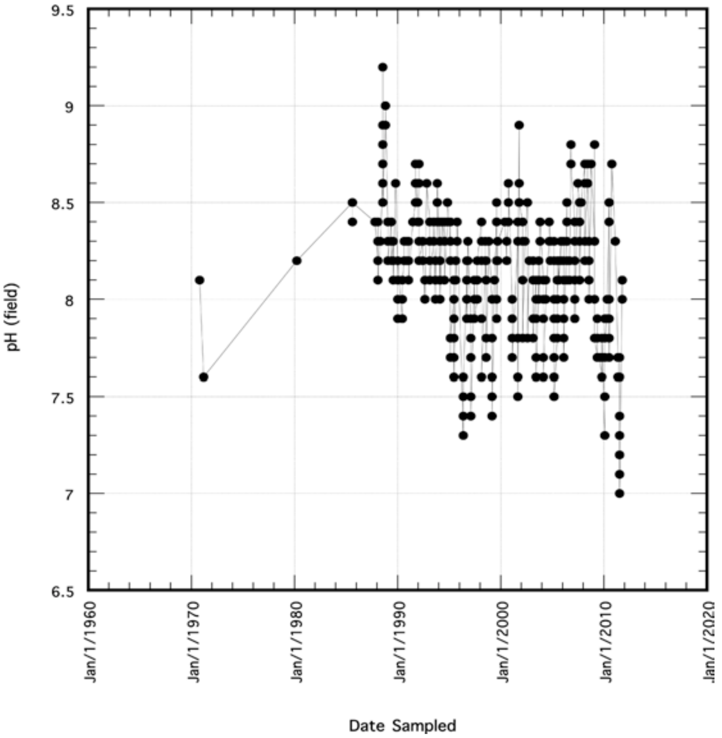


Figure 110 – Temporal variation of field pH (Heart Butte Reservoir)

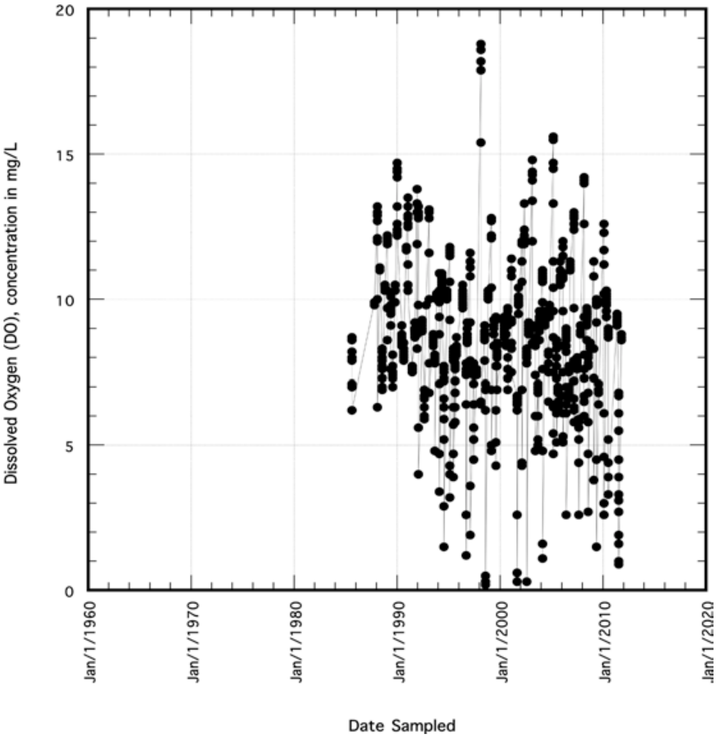


Figure 111 – Temporal variation of dissolved oxygen (Heart Butte Reservoir)

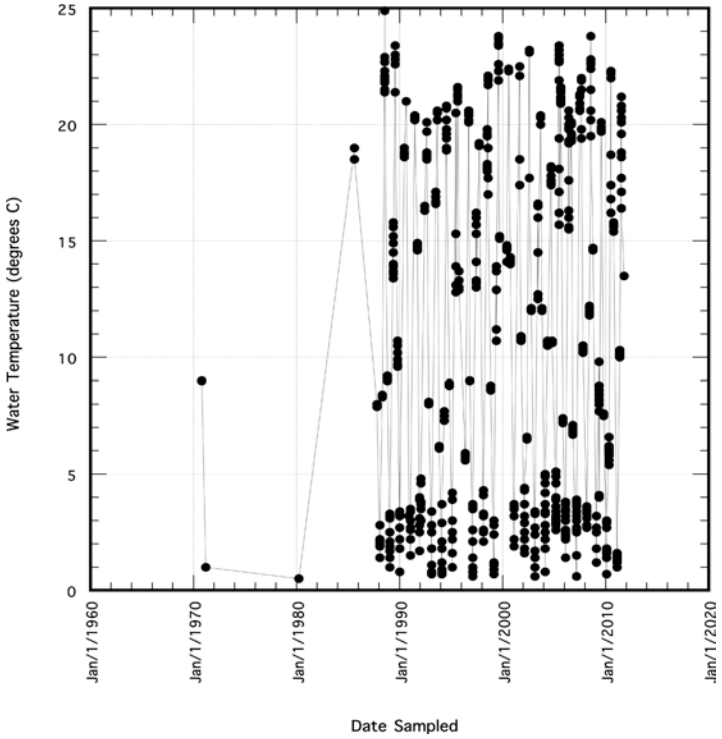


Figure 112 – Temporal variation of water temperature (Heart Butte Reservoir)

Existing Water Permits – Heart Butte Reservoir

The U.S. Bureau of Reclamation (USBR) holds Perfected Water Permit No. 250B for 75,785 acre-feet of storage in the Heart Butte Reservoir to irrigate 3,500 acres of land. An additional 8,500 acres of land also may be included to be irrigated under "extension" in Perfected Water Permit No. 250B. Beneficial use for this acreage was last extended to April 1, 1972. The USBR made additional requests for extension to develop the 8,500 acres in 1978, 1979, and 1986. No action by the State Engineer was taken.

In order to divert water for industrial use from Heart Butte Reservoir, the USBR would need to apply for an industrial use permit from the State Engineer. Issuance of an industrial conditional water permit would be based, in large part, on the level of impacts on downstream (Heart River) water users.

City of Dickinson – Reuse of Municipal Waste Stream

The City of Dickinson wastewater treatment facility is designed to treat up to a maximum daily discharge of 2.23 million gallons. Discharge has increased from 1.41 million gallons per day in 2006 to 2.15 millions gallons per day during the first six months of 2011 (Apex Engineering, 2011). The City of Dickinson has a Class III wastewater treatment plant and discharges its waste water to the Heart River, which is a class 1A stream. The city's treatment process consists of pretreatment, advanced aeration, and a four-cell lagoon system.

The city plans to upgrade its water treatment plant with construction to be completed in the Fall 2013. Once the new treatment facility becomes operational, plans exist to supply one million gallons of treated water per day (3.07 acre-feet per day) to a loading point(s) to be used primarily for oil field industrial use. This amounts to an annual industrial supply of up to 1120 acre-feet. The City of Dickinson is not required to return any portion of its municipal waste stream to the Heart River and can therefore beneficially use its waste stream to extinction.

Ground Water Sources

As previously mentioned there are basically two types of aquifers that occur in North Dakota. These are glaciofluvial aquifers and bedrock aquifers.

Glaciofluvial Aquifers

Glaciofluvial aquifers formed by glacial melt water that deposited sand and gravel during the Pleistocene Epoch when much of North Dakota was covered by large continental glaciers. However, the continental glaciers did not occupy the southwest part of the state including Billings, Golden Valley, Slope, Bowman, Hettinger, Adams, Stark, and Grant Counties, and the western part of Dunn County. As a result, these counties are devoid of glaciofluvial aquifers. Major glaciofluvial aquifers in McKenzie and Dunn Counties are the Bennie Peer, Little Missouri River, Charbonneau, Tobacco Garden, Killdeer, Goodman Creek, and Horse Nose Butte aquifers. These aquifers can provide some water for oil field industrial use. However, given the current level of appropriation from most of these aquifers and the fact that these aquifers are of limited areal extent, they are not capable of providing water for large-sale industrial use to meet full oil field demand as projected for development of the Tyler play. Good descriptions of these aquifers and associated hydrogeologic characteristics are found in county ground-water studies by Klausing (1979) and Croft (1985). Considerable test drilling, water level, water quality, and well yield information are presented in these county ground-water studies. These county ground-water studies are available on the North Dakota State Water Commission website (www.swc.nd.gov). Too access the county studies reports (click on "Reports and Publications" then click on "County Ground-Water Studies).

Bennie Peer Aquifer (McKenzie County)

The Bennie Peer aquifer is a long narrow glaciofluvial deposit in the valleys of Bennie Peer and West and East Hay Draw Creeks from the Montana state line near Sidney to the Little Missouri River (Croft, 1985, in Schuh, 2010)(fig.3). The aquifer consists of up to 70 feet of sand and gravel, mixed with finer sediments. Croft (1985) estimated transmissivities ranging from 3,000 to 13,000 ft^2/day and potential well yields greater than 100 gallons per minute from properly completed wells in the central part of the aquifer. Ground water in the Bennie Peer aquifer is characterized by relatively large dissolved solids concentrations ranging from 2,740 mg/L to 4,880 mg/L with a mean of 3,347 mg/L (Table 13). The water is mainly a sodium-sulfate type. There are no existing or pending water permit applications diverting or seeking to divert water from the Bennie Peer aquifer. Schuh (2010) estimates 500 to 1000 acre-feet of annual withdrawals may be sustainable from the Bennie Peer aquifer.

Table 13 – Minimum, maximum and mean values of selected analytes from the Bennie Peer aquifer (McKenzie County)

Analyte	Unit	Minimum Value	Maximum Value	Mean	Number of Samples
Iron	mg/L	0.11	2.6	0.77	6
Manganese	mg/L	0.02	0.24	0.1	6
Calcium	mg/L	44	150	94	6
Magnesium	mg/L	22	89	50	6
Sodium	mg/L	820	1400	1012	6
Potassium	mg/L	7.3	16	11	6
Bicarbonate	mg/L	955	1570	1328	6
Carbonate	mg/L	0	14	2.3	6
Sulfate	mg/L	910	2400	1485	6
Chloride	mg/L	6.5	18	10.2	6
Nitrate (NO3)	mg/L	1	8.1	2.2	6
Dissolved Solids	mg/L	2740	4880	3347	6
Hardness (Ca, Mg)	mg/L	200	740	442	6
SAR	unitless	15	29	22	6
Conductivity (field)	uS/cm	3400	6300	4400	6
pH (field)		7.6	8.75	7.99	5

Little Missouri River Aquifer (McKenzie and Dunn Counties)

The Little Missouri River aquifer is located in McKenzie and Dunn Counties (fig. 3). The aquifer is comprised of sand and gravel that was deposited in the Little Missouri River valley (Croft, 1985). The aquifer is about 40 miles long and about three-fourths of a mile wide with a maximum thickness of 176 feet (Croft, 1985). Individual well yields of about 100 gallons per minute are possible from properly completed wells. Dissolved solids concentrations range from 1590 mg/L to 4,370 mg/L with a mean value of 2,335 mg/L (Table 14). The ground water generally is a sodium-sulfate type. Additional appropriation is available from the Little Missouri River aquifer.

Table 14 – Minimum, maximum and mean values of selected analytes from the Little Missouri River aquifer (McKenzie and Dunn Counties)

Analyte	Unit	Minimum Value	Maximum Value	Mean	Number of Samples
Iron	mg/L	0.09	0.38	0.17	6
Manganese	mg/L	0.02	1.4	0.31	6
Calcium	mg/L	37	240	109	6
Magnesium	mg/L	16	97	44	6
Sodium	mg/L	450	1100	703	6
Potassium	mg/L	8.6	25	17	6
Bicarbonate	mg/L	836	1340	1060	6
Sulfate	mg/L	590	2200	1098	6
Chloride	mg/L	6	13	9.3	6
Dissolved Solids	mg/L	1590	4370	2535	6
Hardness (Ca, Mg)	mg/L	160	1000	455	6
SAR	unitless	11	21	15	6
pH (field)		7.7	8.3	7.95	6

Charbonneau Aquifer (McKenzie County)

The Charbonneau aquifer is a long, thin aquifer underlying parts of Charbonneau and Timber Creeks from the Yellowstone River bottom near Cartwright to Lake Sakakawea northeast of Alexander (fig.3). The aquifer consists of sand and gravel deposits interbedded with finer sediments. Croft (1985) estimated well yields in excess of 100 gallons per minute are possible from properly completed wells. Dissolved solids concentrations range from 860 mg/L to 2,720 mg/L with a mean of 1447 mg/L (Table 15). The ground water generally is a calcium-sodium-sulfate and sodium-sulfate type. Given the current level of appropriation in the Charbonneau aquifer, Schuh (2010) estimates that an additional appropriation of a few hundred acre-feet is possible.

Table 15 – Minimum, maximum and mean values of selected analytes from the Charbonneau aquifer (McKenzie County)

Analyte	Unit	Minimum Value	Maximum Value	Mean	Number of Samples
Iron	mg/L	0	3.93	1.03	10
Manganese	mg/L	0.01	0.53	0.2	10
Calcium	mg/L	8	190	95	11
Magnesium	mg/L	0	120	52	11
Sodium	mg/L	196	697	378	11
Potassium	mg/L	5.7	10.5	7.9	10
Bicarbonate	mg/L	669	1777	962	11
Carbonate	mg/L	0	26	3	11
Sulfate	mg/L	48	1200	423	11
Chloride	mg/L	2.6	120	17.2	11
Nitrate (NO3)	mg/L	0.09	110	11.25	10
Dissolved Solids	mg/L	860	2720	1447	10
Hardness (Ca, Mg)	mg/L	12	970	452	11
SAR	unitless	3.07	17	7.9	10
Conductivity (field)	uS/cm	1450	3300	1964	9
Alkalinity (as $CaCO_3$)	mg/L	592	1458	805	9
pH (field)		7.3	7.3	7.3	1

Tobacco Garden Aquifer (McKenzie County)

The Tobacco Garden aquifer is a long narrow aquifer extending from the Little Missouri River northeast of Bennie Peer Creek to Lake Sakakawea south of Lunds Landing (fig.3). The aquifer consists of up to 90 feet of sand and gravel interbedded with clay beds. Croft (1985) reported transmissivities ranging from 7,000 to 19,000 ft^2/day and a hydraulic conductivity exceeding 500 ft/day at one site. Individual well yields in excess of 500 gallons per minute are possible from properly completed wells. Ground water in the Tobacco Garden aquifer is mainly a sodium-bicarbonate type. Dissolved solids concentrations range from 490 to 3,330 mg/L with a mean of 1,389 mg/L (Table 16). Schuh (2010) estimates that an additional appropriation of a few hundred acre-feet is possible in less developed and undeveloped parts of the aquifer.

Table 16 – Minimum, maximum and mean values of selected analytes from the Tobacco Garden aquifer (McKenzie County)

Analyte	Unit	Minimum Value	Maximum Value	Mean	Number of Samples
Iron	mg/L	0.02	3.78	0.65	28
Manganese	mg/L	0.01	0.89	0.32	28
Calcium	mg/L	3	610	73	28
Magnesium	mg/L	1	190	36	28
Sodium	mg/L	110	755	387	28
Potassium	mg/L	2	20	7.8	28
Bicarbonate	mg/L	424	1220	809	28
Carbonate	mg/L	_	_	_	_
Sulfate	mg/L	71	2100	516	28
Chloride	mg/L	0	42	5.7	28
Nitrate (NO3)	mg/L	_	_	_	_
Dissolved Solids	mg/L	490	3330	1389	28
Hardness (Ca, Mg)	mg/L	12	2300	327	28
SAR	unitless	1	49	12	28
Conductivity (field)	uS/cm	700	3320	1904	28
Alkalinity (as $CaCO_3$)	mg/L	405	1000	703	11
pH (field)		7.4	8.65	7.94	9

Killdeer Aquifer (Dunn, Morton, and Stark Counties)

The Killdeer aquifer extends from a few miles north of the city of Killdeer in Dunn County southeast into northwestern Morton County where it joins the Elm Creek aquifer (Schuh, 2010)(fig.3). In Morton County the aquifer consists of up to 233 feet of fine to medium sand, with some gravel interbedded with silt and clay (Klausing 1979). The mean thickness is about 80 feet. A transmissivity of 10,000 ft^2/day and a storativity of 0.02 were calculated from an aquifer test conducted on a well completed in the Killdeer aquifer two miles west of the city of Killdeer. Individual well yields of about 300 gallons per minute are possible from properly completed wells. Outside of the Killdeer area, information on the Killdeer aquifer is sparse (Wanek 2009 in Schuh,2010). Ground water in much of the Killdeer aquifer is a sodium-bicarbonate to sodium-sulfate type (Schuh 2010). Dissolved solids concentrations range from 456 mg/L to 5,060 mg/L with a mean of 2,325 mg/L (Table 17). Up to about 1500 acre-feet of additional appropriation may be possible in the southeast part of the aquifer near Glen Ullin (Schuh 2010).

Table 17 – Minimum, maximum and mean values of selected analytes from the Killdeer aquifer (Dunn, Morton and Stark Counties)

Analyte	Unit	Minimum Value	Maximum Value	Mean	Number of Samples
Iron	mg/L	0	5.5	0.7	21
Manganese	mg/L	0.02	3.7	0.42	21
Calcium	mg/L	22	570	116	21
Magnesium	mg/L	7.8	160	57	21
Sodium	mg/L	50	1200	601	21
Potassium	mg/L	4.2	17	9.5	21
Bicarbonate	mg/L	343	1490	902	21
Carbonate	mg/L	0	23	3.1	21
Sulfate	mg/L	110	3000	1070	21
Chloride	mg/L	0	17	4.8	21
Nitrate (NO3)	mg/L	0	2.5	1.1	21
Dissolved Solids	mg/L	456	5060	2325	21
Hardness (Ca, Mg)	mg/L	87	2100	524	21
SAR	unitless	1.3	43	13.8	21
Conductivity (field)	uS/cm	670	5275	3064	18

Goodman Creek Aquifer (Dunn County)

The Goodman Creek aquifer underlies an area of about 6 square miles in northwestern Dunn County (Klausing, 1979) (fig.3). The aquifer consists of an upper and lower unit. The upper unit is comprised of or very fine to coarse gravelly sand and is separated from the lower unit by a silty, sandy clay bed that may be as much as 77 feet thick. The lower unit is comprised of interbedded sand, gravel and clayey gravel. The combined aquifer thickness ranges from 28 to 139 feet with a mean thickness of 66 feet (Klausing, 1979). The aquifer is overlain by silt and clay. Individual well yields of up to 1,000 gallons per minute are possible from properly completed wells in the Goodman Creek aquifer (Klausing, 1979). The ground water in the Goodman Creek aquifer generally is very hard and is predominately a sodium-bicarbonate type (Table 18). Dissolved solids concentrations range from 68 mg/L to 2,250 mg/L with a mean value of 882 mg/L. Over much of the area of the Goodman Creek aquifer, the potential for additional industrial development is good. Schuh (2010) estimates up to about 500 acre-feet of additional appropriation is available from the Goodman Creek aquifer.

Table 18 – Minimum, maximum and mean values of selected analytes from the Goodman Creek aquifer (Dunn County)

Analyte	Unit	Minimum Value	Maximum Value	Mean	Number of Samples
Iron	mg/L	0	9.6	1.0	38
Manganese	mg/L	0.01	1.2	0.24	38
Calcium	mg/L	4.7	180	76	38
Magnesium	mg/L	2.9	126	36	38
Sodium	mg/L	13.7	489	185	38
Potassium	mg/L	1	8.4	5.9	38
Bicarbonate	mg/L	62	717	540	38
Sulfate	mg/L	0.5	1190	285	38
Chloride	mg/L	0	78	6.4	38
Dissolved Solids	mg/L	68	2250	882	38
Hardness (Ca, Mg)	mg/L	24	968	340	38
Percent Sodium	percent	21	72	52	38
SAR	unitless	1	8.6	4.4	38
pH (field)	unitless	7	7.96	7.48	2

Horse Nose Butte Aquifer (Dunn County)

The Horse Nose Butte aquifer underlies an area of about 10 square miles in Dunn County (Klausing, 1979) (fig.3). The aquifer generally is comprised of very fine to very coarse sand with interbedded sand and gravel layers that occur locally. Aquifer thickness ranges from a few feet to 85 feet with a mean thickness of about 40 feet. Individual well yields from properly completed wells in the Horse Nose Butte aquifer are estimated to range from about 50 to 500 gallons per minute (Klausing, 1979). Ground water in the Horse Nose Butte aquifer is very hard and is predominantly a sodium-bicarbonate-sulfate type. Dissolved solids concentrations range from 298 to 2,200 mg/L (Table 19). The potential for development of large-scale industrial appropriations is poor given the current level of appropriation in the Horse Nose Butte aquifer (Schuh, 2010).

Table 19 – Minimum, maximum, and mean values of selected analytes from the Horse Nose Butte aquifer (Dunn County).

Analyte	Unit	Minimum Value	Maximum Value	Mean	Number of Samples
Iron	mg/L	0	3.05	0.90	21
Manganese	mg/L	0.01	0.96	0.35	21
Calcium	mg/L	23	180	83	21
Magnesium	mg/L	15	98	35	21
Sodium	mg/L	4.9	747	336	21
Potassium	mg/L	1.8	12	6.6	21
Bicarbonate	mg/L	275	894	662	21
Sulfate	mg/L	33	1390	550	21
Chloride	mg/L	1.1	30	6.2	21
Dissolved Solids (	mg/L	298	2200	1277	21
Hardness (Ca, Mg)	mg/L	120	830	352	21
Percent Sodium	percent	4	84	60	21
SAR	unitless	0.1	16	8.5	21

Bedrock Aquifers

The upper Cretaceous Fox Hills and Hell Creek Formations and sandier intervals of various Tertiary Formations, in particular, the Tongue River Formation are capable of providing individual well yields sufficient to accommodate water depot loading points. In some of the sandier Tertiary Age intervals, multiple wells would likely be required to provide an adequate discharge rate.

Fox Hills/Hell Creek Aquifers

The Hell Creek aquifer conformably overlies the Fox Hills aquifer and both aquifers are hydraulically connected. As a result, both aquifers are managed as a single hydrologic unit. The Fox Hills/Hell Creek aquifer underlies western North Dakota and is a major water source for domestic/stock use in rural areas. Individual well yields of up to about 200 gallons per minute are possible from properly completed wells in the Fox Hills/Hell Creek aquifer. In topographic low areas along the Little Missouri, Missouri, and Knife River Valleys, wells completed in the Fox Hills/Hell Creek aquifer flow above land surface and are important sources of water for stock use. Unfortunately, recharge rates for the Fox Hills/Hell Creek aquifer over much of North Dakota are low. Water level monitoring in the Fox Hills/Hell Creek aquifer over the past 30 years indicates consistent pressure head declines of between 1 to 2 feet per year. Should this trend continue, it is predicted that over the next 60 to 90 years, many of the flowing wells will cease to flow. The resulting economic impact will be significant because new, large diameter wells will need to be constructed to accommodate pumps and energy supplies will be needed to power the pumps. Given that many of these wells are located in remote areas, providing electrical service will be expensive. Based on the above, it is the policy of the State Engineer to direct larger-scale water users, including water depots for oil field industrial supply, to water sources other than the Fox Hills/Hell Creek aquifer.

The Water Appropriation Division is currently developing a computer model of the Fox Hills/Hell Creek aquifer in eastern Montana, northern South Dakota and the western one-half of North Dakota. A major goal of the model is to assess future water level declines resulting from the current level of appropriation in the aquifer. Based on the modeling results, additional appropriation for oil field industrial withdrawals may be considered in the future in some areas of the Fox Hills/Hell Creek aquifer.

Tertiary Aquifers

Sandier intervals of the Tertiary Fort Union Group, in particular, the basal Tongue River Formation are potential sources of water for oil field industrial use. Good descriptions of these aquifers and associated hydrogeologic characteristics are found in Trapp and Croft (1975), Croft (1978), Klausing (1979), Anna (1981), and Croft (1985). Considerable test drilling, water level, water quality, and well yield information are presented in these county ground-water studies. These county ground-water studies are available on the North Dakota State Water Commission website (www.swc.nd.gov). To access the county studies reports (click on "Reports and Publications" then click on "County Ground-Water Studies.

Cannonball – Ludlow Aquifer System

The Cannonball – Ludlow Aquifer system underlies most of west central and northwest North Dakota. In eastern Adams County, the Cannonball Ludlow aquifer is comprised of medium grained sandstone and siltstone (Croft, 1978). The sandstone beds are commonly interbedded with siltstones and claystones (Trapp and Croft, 1975, and Klausing, 1979). In Dunn County, Klausing (1979) indicates the Cannonball-Ludlow aquifer system consists of fine to very fine silty sandstone beds ranging in thickness from 10 to 125 feet thick. Croft (1978) reports a transmissivity, hydraulic conductivity and storativity of 20 ft^2/day, 1ft/day, and 0.0008, respectively, from pumping and recovery test data measured in a single well. Klausing (1979) reports a range in hydraulic conductivities from 0.06 to 0.45 ft/day based on data measured from sidewall cores. Individual well yields of up to about 50 gallons per minute are possible from properly completed wells in the sandstone beds (Klausing, 1979).

Maximum, minimum and mean values of selected analytes in ground water samples from the Cannonball-Ludlow aquifer are shown in Table 20.

Table 20 – Maximum, minimum, and mean values of selected analytes from the Cannonball-Ludlow aquifer.

Analyte	Unit	Minimum Value	Maximum Value	Mean	Number of Samples
Iron	mg/L	0.04	10	2.0	8
Manganese	mg/L	0.01	0.05	0.02	7
Calcium	mg/L	4	19	7	8
Magnesium	mg/L	0.7	16	4.1	8
Sodium	mg/L	226	786	437	8
Potassium	mg/L	1.9	4.2	2.6	8
Bicarbonate	mg/L	376	1880	891	8
Sulfate	mg/L	37	426	190	8
Chloride	mg/L	1.1	49	12.7	8
Dissolved Solids (	mg/L	610	1890	1136	8
Hardness (Ca, Mg)	mg/L	13	104	33	8
Percent Sodium	percent	90	99	96	8
SAR	unitless	18	76	40	8
pH (field)	unitless	_	_	_	_

Dissolved solids concentrations range from 610 mg/L to 1890 mg/L with a mean of 1136 mg/L. The ground water generally is a sodium-bicarbonate type.

Tongue River Aquifer

The Tongue River aquifer system consists of fine to medium grained sandstone, siltstone, claystone, and lignite (Croft, 1985). The coarsest, thickest sandstone beds occur near the bottom of the aquifer. Based on tests conducted on sidewall cores taken from these sandstone beds, hydraulic conductivity ranged from 0.03 to 58 ft/day with larger values possibly reflecting the occurrence of fractures. In Dunn County, Klausing (1979) reports hydraulic conductivity ranging from 0.01 to 0.95 ft/day based on side-wall core testing. Trapp and Croft (1975) report transmissivity ranging from 70 to 530 ft^2/day based on calculations using resistivity geophysical logs. Anna (1981) reports transmissivities ranging from 220 to 530 ft^2/day based on recovery well tests. Individual well yields of up to about 200 gallons per minute are possible from properly completed wells in the Tongue River aquifer.

Maximum, minimum, and mean values of selected analytes in ground water samples from the Tongue River aquifer are shown in Table 21.

Table 21 – Maximum, minimum, and mean values of selected analytes from the Tongue River aquifer.

Analyte	Unit	Minimum Value	Maximum Value	Mean	Number of Samples
Iron	mg/L	0	71	3.3	212
Manganese	mg/L	0	4.2	0.28	142
Calcium	mg/L	1.6	975	56	202
Magnesium	mg/L	0.2	740	46	202
Sodium	mg/L	17.9	1100	479	210
Potassium	mg/L	1.1	29	5.2	197
Bicarbonate	mg/L	38	2480	1017	215
Sulfate	mg/L	0	4500	472	211
Chloride	mg/L	0	460	18.9	213
Dissolved Solids	mg/L	295	6290	1634	193
Hardness (Ca, Mg)	mg/L	6	4400	318	215
Percent Sodium	percent	6	99.5	83	207
SAR	unitless	0.6	122	39	206
pH (field)	unitless	5.7	9	7.87	28

Dissolved solids concentrations range from 295 mg/L to 6,290 mg/L with a mean of 1634 mg/L. The ground water generally is a sodium-bicarbonate type with some sodium-sulfate type water occurring in Adams and Bowman Counties (Croft, 1978).

Sentinel Butte Aquifer

The Sentinel Butte aquifer system consists of yellowish-gray fine to medium sandstone, lignite, gray claystone and silty claystone (Anna, 1981). The aquifer units consist of poorly consolidated sandstone and lignite (commonly fractured). Trapp and Croft (1975) report transmissivities ranging from 440 to 1130 ft^2/day and storativities ranging from 0.0007 to 0.016, based on pumping test analyses. Klausing (1979) reports hydraulic conductivities ranging from 0.057 to 0.18 ft/day based on sidewall core tests and hydraulic conductivities ranging from 0.06 to 0.50 ft/day based on slug test analysis. Anna (1981) indicates individual well yields of up to 50 gallons per minute from properly completed wells in the sandstone beds and individual well yields of up to 200 gallons per minute in the lignite (fractured) beds.

Maximum, minimum and mean values of selected analytes in ground water samples from the Sentinel Butte aquifer are shown in Table 22.

Table 22 – Maximum, minimum, and mean values of selected analytes from the Sentinel Butte aquifer

Analyte	Unit	Minimum Value	Maximum Value	Mean	Number of Samples
Iron	mg/L	0	52	1.4	390
Manganese	mg/L	0	16	0.28	326
Calcium	mg/L	1	2370	82	364
Magnesium	mg/L	0.2	1160	54	364
Sodium	mg/L	0.1	7360	444	381
Potassium	mg/L	0.7	240	6.6	358
Bicarbonate	mg/L	0	2360	666	421
Sulfate	mg/L	0.3	7980	675	398
Chloride	mg/L	0	17500	81	396
Dissolved Solids	mg/L	82	27800	1698	362
Hardness (Ca, Mg)	mg/L	5	9200	420	420
Percent Sodium	percent	4	99.5	66	370
SAR	unitless	0.2	132	21	369
pH (field)	unitless	5.9	10.35	7.83	30

Dissolved solids concentrations range from 82 mg/L to 27,800 mg/L with a mean of 1698 mg/L. The ground water generally is a sodium-bicarbonate type but in shallow wells less than 100 feet deep, Anna (1981) reports the ground water is a calcium-magnesium-bicarbonate type.

City of New England

The City of New England holds Perfected Water Permit No. 4033 allowing for an annual appropriation of 124.0 acre-feet for municipal use. The maximum pumping rate is 205 gallons per minute.

Trapp (1971) documents eight municipal wells that have been used by the city. The New England municipal wells were all drilled to depths less than 105 feet below land surface. These wells probably were completed in sand intervals of the Tertiary, Sentinel Butte Formation of the Fort Union Group. Municipal well No. 7 had a reported yield of 130 gallons per minute (Trapp, 1971).

In 2001, the municipal ground water capture system was inspected by staff of the Water Appropriations Division. At the time of the inspection, city wells No. 6 and No. 7 located in the SE1/4NE1/4 of Section 4, Township 135 North, Range 097 West were being used to provide the municipal water supply. In 1998, the city obtained its municipal water supply from the Southwest Water Authority and the municipal wells were no longer used to any great extent.

In a February 21, 2012 memo, Mr. Alan Wanek, Hydrologist Manger, Water Appropriation Division, indicated the City of New England could temporarily sell up to 124 acre-feet of water annually for industrial use under Perfected Water Permit No. 4033 provided the city applies for a new industrial use permit. Approval of the annual volume of water requested in the industrial use water permit application will be based on requirements prescribed in North Dakota Century Code 61-04.

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APPENDIX I

U.S. Bureau of Reclamation Manual: Directives and Standards

Subject: Purpose:

Reclamation Manual

Directives and Standards

Water-Related Contract and Repayment Principles and Requirements

To lay out the defining principles and essential points of policy behind the Bureau of Reclamation's water-related contracting and repayment program. The benefits of this Directive and Standard (D&S) are that it helps ensure that Reclamation continues to fulfill its contracting responsibilities according to the basic objectives and principles arising from relevant law and policy, by orienting staff, contractors, and the public to the essential concepts, objectives, requirements, and methods that drive and define Reclamation's water-related contracting and repayment activities.

Reclamation Law, as applicable,1 beginning with the Reclamation Act of 1902 (ch. 1093, 32 Stat. 388)

Director, Office of Program and Policy Services Office of Program and Policy Services; Contract Services Office, 84-56000

Authority:

Approving Official: Contact:

PEC 05-01

1. **Introduction.** The overarching objective behind Reclamation's water-related contracting, as stated in Reclamation Manual Policy PEC P05, is to make the required deliveries of water under Reclamation contracts, according, in each instance, to applicable law and policy. To do this effectively, Reclamation must take into account each contractor's relevant needs and circumstances, the generally growing demand on the West's water supplies for municipal uses, demands on supplies for environmental needs, and Reclamation's obligation to Native American Tribes. This D&S sets out the defining principles and points of policy through which the contracting and repayment program accomplishes its overarching objective.

2. **Defining Principles.**

A. **Requirement to Contract.** To protect the interests of the United States, general Reclamation law requires contracts for the delivery and storage of project and non-project water, for the use of Federal facilities, and for the recovery of reimbursable project costs. Contracts are always required, unless a superseding Federal authority dictates otherwise, and must be executed pursuant to appropriate authority, whether found in general Reclamation law, project-specific legislation, or other congressional authorization. This is true whether the water is to be delivered for consumptive or non- consumptive use.

[1] As used here, the term "Reclamation law" refers inclusively to those laws, beginning with the Reclamation Act of 1902, that Congress enacts or has enacted to authorize Reclamation to perform its mission, whether these are original, amending, or supplementing laws.

B. **Agreement on Contract Terms.** To promote good customer relations and avoid disputes, both now and in the future, Reclamation must ensure that the parties to its contracts share its understanding of contract terms. Reclamation should work with the other party(ies) to resolve differences before entering into a contract, and should set out, with specificity, the meanings of the terms as they are to be used therein. Reclamation contracts must protect both the interests of the United States and those of its water users, while recognizing the relationship of its contracting activities to the numerous and complex issues facing the West (increasing urbanization, changing environmental issues, etc.). It best serves these ends, and is thus in the best interests of all concerned, for Reclamation to use clear language in contracts and related documents, and during negotiations, to ensure that the meaning and purpose of its contract terms are clear to all parties.

C. **Water Rates.** Reclamation's water-related contracts must protect the Federal investment and ensure that repayment of the reimbursable capital cost is made in accordance with Reclamation law. Subsections 9(c), (d), and (e) of the Reclamation Project Act of 1939 (1939 Act) require repayment of all reimbursable costs. Pub. L. 76-260; 43 U.S.C. § 485h(c), (d), and (e). The methods used in recovering these costs vary.

(1) **Irrigation Rates Generally.**

. (a) Contractors' obligations to repay capital project costs under contracts made pursuant to subsection 9(d) of the 1939 Act are generally based on their ability to pay. The cost of the irrigation component is paid without interest. Costs beyond an irrigation district's repayment ability are generally paid by either power users through "aid to irrigation" or by municipal and industrial (M&I) users, where these sources are available. The same points apply to water rates established in contracts under subsection 9(e) of the 1939 Act, except that these contracts are renewed until the contractor has paid its obligation, or at least until it has the ability to repay its remaining obligation under a converted repayment contract, and the costs beyond the contractor's ability to pay within the contract term are therefore not shifted to other project beneficiaries.

. (b) Note that, to ensure that irrigation water users are paying up to their ability throughout their repayment periods, it is Reclamation's policy that a contract provision calling for reviews of ability to pay every 5 years be placed in all new, renewed, or amended contracts. See Commissioner's Memorandum of July 7, 1999, "Ability-to-Pay Policy," as supplemented by memoranda of August 13, 1999, "Directives and Standards for Periodic Review of Irrigation Ability-to-Pay Analyses," and December 18, 2002, "Limitations Regarding the Ability-to-Pay Policy."

(2) **M&I Rates Generally.** M&I water rates are based on the costs allocated to M&I with an interest component added. See subsection 9(c) of the 1939 Act (cited above), as supplemented by the Water Supply Act of 1958 (Pub. L. 85-500, Title III; 43 USCA § 390b).

D. **Constraints on the Availability of Water (Water Shortages).** Understandings between Reclamation and its water users concerning the respective responsibilities and liabilities of the parties during times when the full amount of water under contract cannot be delivered are vital for protecting the interests of the United States, as well as those of the water users by allowing Reclamation to effectively and equitably deal with shortages.

3. **Points of Policy.** Reclamation will negotiate water-related contracts adhering to as many of the following points of policy as are applicable under the relevant circumstances.

A. Contract terms and repayment periods will be for the maximum duration provided by law (typically 40 years) unless (1) ability to pay justifies a lesser time, or (2) a contractor requests a shorter term. For those authorities that are silent regarding contract term (except those specifying instead a repayment period), such as the Warren Act (Pub. L. 61-406; 43 U.S.C. §§ 523 to 525), a 40-year maximum term will be used. Some project-specific authorizations may provide for a shorter term, such as the Central Valley Project Improvement Act (CVPIA), which limits contracts for irrigation water delivery to 25 years (Pub. L. 202-575, Title XXXIV § 3404[c]), and some may provide for a longer term, such as the Colorado River Storage Project authorization, which provides for a period of up to 50 years (Pub. L. 84-485; 43 U.S.C. § 620[c]). See Commissioner's Memorandum of October 23, 2001, "Policy for Terms of Contracts."

B. Following payout of a contractor's obligation pursuant to its repayment contract, no further costs will continue associated with that contract's construction obligation. However, operation and maintenance (O&M) costs and other provisions of the contract do continue.

C. Explanatory recitals will be written in a manner that communicates a clear understanding of the purpose of the contract. See Paragraph 2.B. above.

D. Contracts will ensure that (1) the Federal investment and (2) Reclamation's O&M costs for entering and administering contracts are recovered pursuant to law and policy. Costs for preparation of National Environmental Policy Act (NEPA) and Endangered Species Act (ESA) compliance documents are considered O&M costs for completed projects.

E. When entering new, renewed, supplemented, or amended contracts, appropriate environmental compliance will be performed. See Reclamation Manual Policy ENV P03 (NEPA) and ENV P04 (ESA); Departmental Manual 516 DM 14; and see

Pub. L. 91-190; 42 U.S.C. § 4321, et seq. (NEPA); Pub. L. 93-205; 16 U.S.C. § 1531, et seq. (ESA). Costs associated with NEPA, ESA, and other applicable regulations that are charged to the contractor as O&M costs should reflect only costs of those activities associated with the contract action. See Reclamation Manual Directive and Standard WTR 02-01.

F. Bases of Negotiation (BON) will provide information on the expected level of NEPA documentation and ESA consultation to be performed. Reclamation Manual Policy and Directives and Standards for BON requirements will be forthcoming. When use of a categorical exclusion is expected, the exclusion will be identified with a short discussion in support of its use. See 40 CFR 1508.4; 516 DM 14.5; and Reclamation Manual Policy ENV P03 and ENV P04.

G. Good water management will be encouraged and should be a goal for all contracts. Water conservation plans will be developed pursuant to the authority of section 210 of the Reclamation Reform Act of 1982 (Pub. L. 97-293, Title II; 43 U.S.C. § 390jj) and project-specific statutes such as the CVPIA (Pub. L. 102-575, Title XXXIV § 3405(e); 106 Stat. 4709). See Reclamation Manual Directive and Standard WTR 01-01; 43 CFR 427.1.

H. As a general matter, finding ways to make existing water supplies go further, whether through improved water conservation, investments in research and new technology, modernization of existing infrastructures, or other authorized means is encouraged.

I. Water banks should be used where available and authorized. Reclamation should promote water banking and similar concepts as means to help resolve water supply conflicts and shortages.

J. Transfers of O&M of project facilities will follow the guidance in the memorandum of June 25, 2001, “Guidelines for Negotiating and Executing Contracts for the Transfer of Operation, Maintenance, and Replacement of Project Facilities.”

K. Reclamation will work in partnership with interested contractors to develop, review, and understand O&M programs and related budgets. While Reclamation retains authority over final O&M program budget and management decisions, it is Reclamation policy to actively provide all contractors who share in project O&M costs the opportunity to fully participate in the development and formulation of the relevant O&M program. See Reclamation Manual Policy WTR P05 and Commissioner’s memorandum of March 18, 2004, “Guidance for Implementation of the Bureau of Reclamation Manual Policy WTR P05.”

L. Full payment of annual O&M costs is required in advance of water delivery, as mandated by section 46 of the Omnibus Adjustment Act of 1926 (Pub. L. 69-284; 43 U.S.C. § 423e), and section 6 of the 1939 Act (Pub. L. 76-260; 43 U.S.C. § 485e).

Advance payment of O&M costs will be adjusted to actual costs either during the year or at the year's end. See Reclamation Manual Policy and Directives and Standards WTR P01 and WTR 02-01.

M. Contract negotiations must be announced in advance, and an opportunity provided the public for review and comment of the draft contract. Associated public meetings are to be conducted in a manner that provides opportunities for the public to observe and provide meaningful input. See Reclamation Manual Policy and Directives and Standards CMP P03 and CMP 04-01; and see subsection 9(f) of the 1939 Act (Pub. L. 76-260, as amended by Pub. L. 97-293; 43 U.S.C. § 485h[f]).

N. Meetings held prior to the approval of the BON for the purpose of gathering and exchanging factual information will be clearly identified as such and conducted in a manner that will not prejudice the pending approval of the BON or the contract negotiations.

O. Subject to delegation of authority and approval of a BON, each Regional Director is responsible and accountable for conducting contract negotiations, for drafting proposed contracts, and for contract administration.