Report of

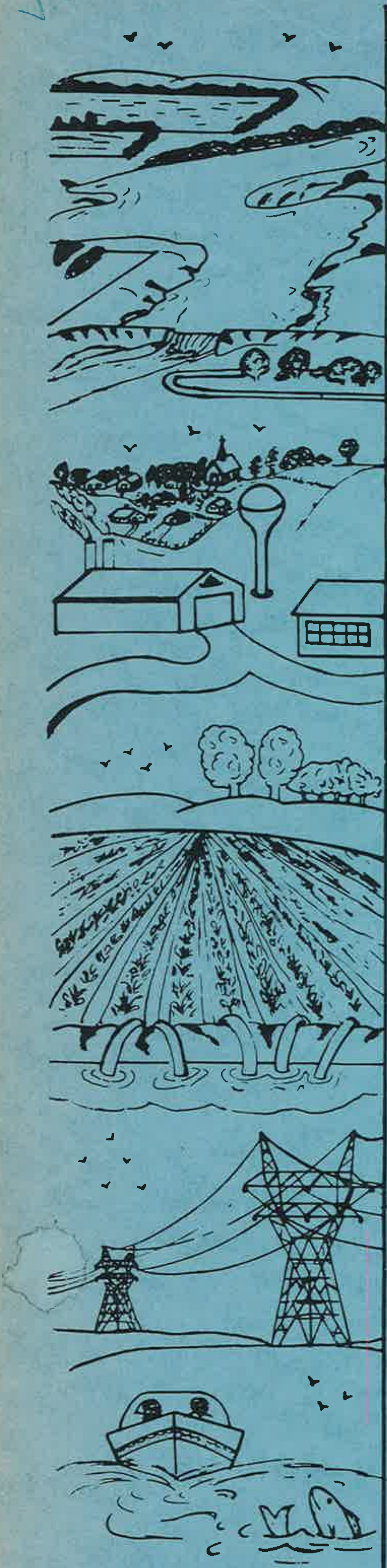
NORTH DAKOTA STATE WATER COMMISSION

State Office Building

BISMARCK, NORTH DAKOTA

58501

BEULAH DAM COMPLEX



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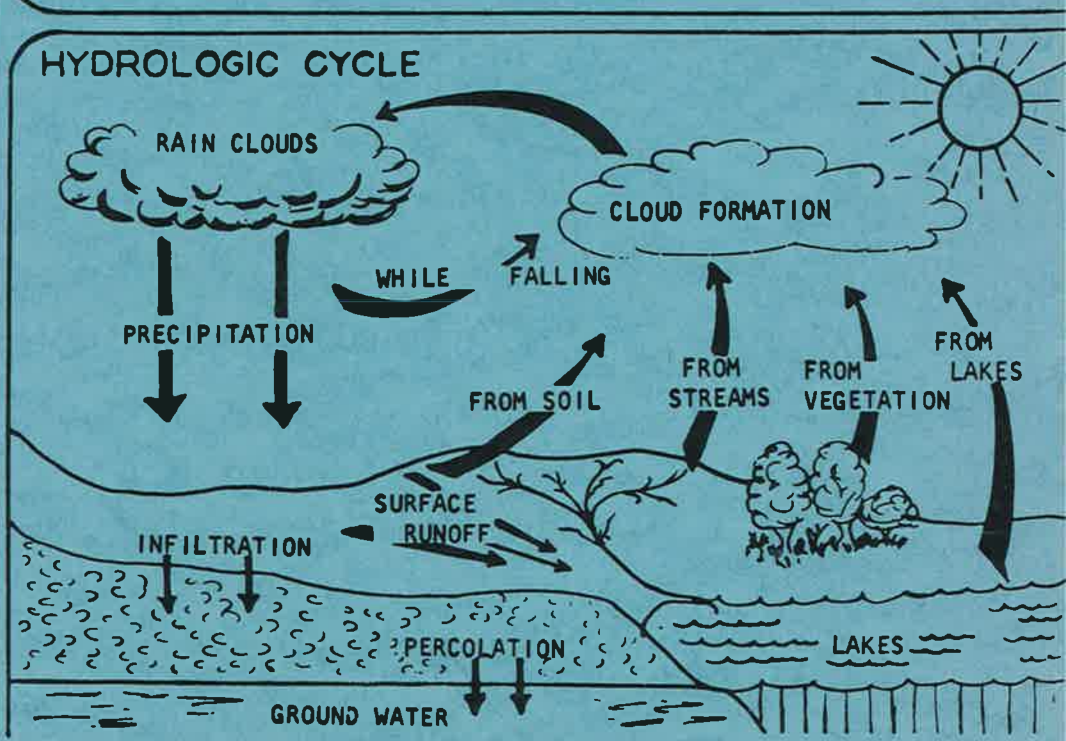

NORTH DAKOTA

STATE WATER COMMISSION

REPORT ON

BEULAH DAM COMPLEX

HYDROLOGY, DESIGN & CONSTRUCTION COST ESTIMATE

APPROVED BY: MILO W. HOISVEEN
CHIEF ENGINEER

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ASS'T. CHIEF ENGINEER

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OFFICE ENGINEER

MARCH 31, 1969

BEULAH DAM COMPLEX

SWC Project #1464

I. INTRODUCTION:

The Beulah Dam Complex is to consist of a large rolled earthfilled dam located in the SE$\frac{1}{4}$ of Section 9, Township 143 North, Range 88 West on Brush Creek and a lowhead reinforced concrete channel dam on the Knife River, located in the SW$\frac{1}{4}$ of Section 4, Township 143 North, Range 88 West.

The small drainage area above Brush Creek Dam necessitates pumping waters of the Knife River into the Brush Creek reservoir to maintain the water surface level at spillway control elevation. The dam on the Knife River will create the needed pumping pool.

Following are data relative to hydrology, design and estimated costs for construction of the complex.

II. HYDROLOGY:

A. BRUSH CREEK DAM - The drainage area of Brush Creek above the dam site is approximately 33 square miles. The average annual yield of the drainage basin, based on the yield of the Knife River above the Golden Valley gaging station, is 44 acre-feet per square mile. The total average annual inflow to the Brush Creek reservoir is 1,452 acre-feet.

The average annual yield of Brush Creek is of minor significance in consideration of filling the reservoir. Flows of the Knife River will have to be pumped into the reservoir for filling and maintaining the water surface level.

Hydrology developed for a rainfall of 50-year frequency on the area would approximate 3.0 inches falling in a 3.6 hour period. The computed design inflow hydrograph has a peak of 2,723 cubic feet per second and a total volume of 792 acre-feet which is equal to a runoff depth of 0.45 inches from the contributing drainage area of 33 square miles. Computations developed for maximum flows and a graphical presentation of the hydrograph are attached. Also shown are 25-year and 100-year maximum discharges and total volume of the respective storms.

The length of the Brush Creek channel is 17 miles and the total fall within this distance is 453 feet.

B. KNIFE RIVER CHANNEL DAM - The drainage area above the proposed location of the Lowhead Dam on the Knife River is 1,408 square miles. In considering the flows or yields of the Knife River, practically all flow at the dam site would be available for pumping into the Brush Creek reservoir. Spring Creek, with a drainage area of 581 square miles, enters the Knife River below the project and these flows would be available for use downstream and would be sufficient for all existing appropriators on the lower Knife River.

Following are duration tables of daily discharges, highest and lowest mean discharges, and high flow volume frequency duration curves from gaging stations in the immediate area.

In view of others having developed sustained yields of Knife River flows, this information is not included.

Drainage Area at Dam Site = 33 square miles

Length of Channel = 17 ± mi.

Total Fall - 453 feet (Elevation 2253 to Elevation 1800)

$$T_c = \frac{2.47\ L^{1.15}}{H^{0.385}} = \frac{2.47 \times 17^{1.15}}{453^{0.385}} = \frac{2.47 \times 26}{10.5} = 6.1 \text{ Hr. (Use 6 Hr.)}$$

$$C = \frac{0.25}{T_c^{0.284}} = \frac{0.25}{1.67} = 0.15 = 15\%$$

$\frac{P}{T_c}$ = 0.12 = 12%; P = .12 x T_c = 0.72 Hr.; Use 12% Model

Duration = 5P (say) = 5 x 0.72 Hr. = 3.6 Hr.

Rainfall, 50-year - 3.6 Hr. = 3.0 inches

$$M = \frac{DA}{T_c} = \frac{33}{6} = 5.5$$

R.O. = 3.0 x 0.15 = 0.45 inches

D = M x R.O. = 5.5 x .45 inches = 24.75 inches

Period	1st	2nd	3rd	4th	5th	Total
% Dist.	28	33	19	14	6	100%
D	0.69	0.82	0.47	0.35	0.15	2.48

Frequency	3.6 Hr. R.F.	Max. cfs	Total Vol., AF.
25-yr.	2.7 in.	2450	713
50-yr.	3.0 in.	2723	792
100-yr.	3.3 in.	2995	871

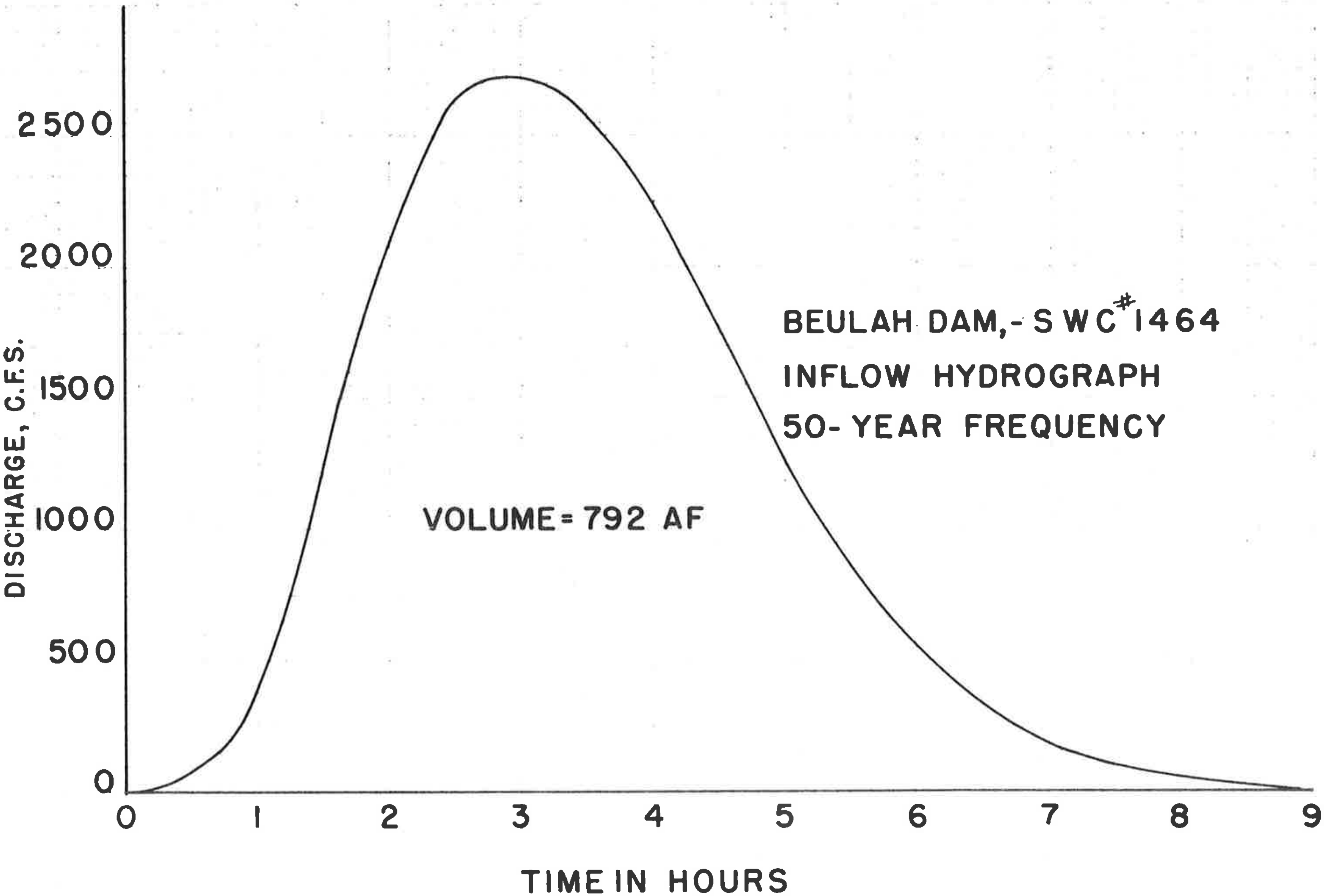
Time Hrs.	%T_c	1st Per. D = .69	2nd Per. D = .82	3rd Per. D = .47	4th Per. D = .35	5th Per. D = .15	Total Disch., cfs
.0	0	0	0 = 12%	0 = 24%	0 = 36%	0 = 48%	0
.3	5	32	3 = 15%	1 = 25%	4 = 40%	2 = 50%	32
.6	10	115					115
.9	15	278	15				293
1.2	20	615	89				704
1.5	25	1029	239	1			1269
1.8	30	1217	531	30			1778
2.1	35	1098	1050	95			2243
2.4	40	947	1400	222	11		2580
2.7	45	801	1378	484	47		2710
3.0	50	664	1196	742	120	1	2723*
3.3	55	536	1021	826	266	13	2662
3.6	60	419	853	727	487	37	2523
3.9	65	315	696	625	611	83	2330
4.2	70	226	552	527	573	174	2052
4.5	75	162	422	434	495	248	1761
4.8	80	128	309	348	421	259	1465
5.1	85	111	218	270	350	225	1174
5.4	90	91	165	201	284	193	934
5.7	95	67	140	143	224	162	736
6.0	100	39	118	104	170	133	564
6.3	105	13	92	84	123	106	418
6.6	110	1	60	73	87	82	303
6.9	115		27	59	67	60	213
7.2	120		5	42	58	43	148
7.5	125			22	48	32	102
7.8	130			7	37	26	70
8.1	135			0	23	22	45
8.4	140				9	18	27
8.7	145				1	12	13
9.0	150					6	6
9.3	155					2	2
9.6	160					0	0
							31,995

Maximum Discharge - 2,723 c.f.s.

Time Intervals, 5% x T_c = .05 x 6 = 0.30 Hr.

31,995 x 0.30 = 9,598 Hr.Sec.Ft. = 793 Acre-Feet

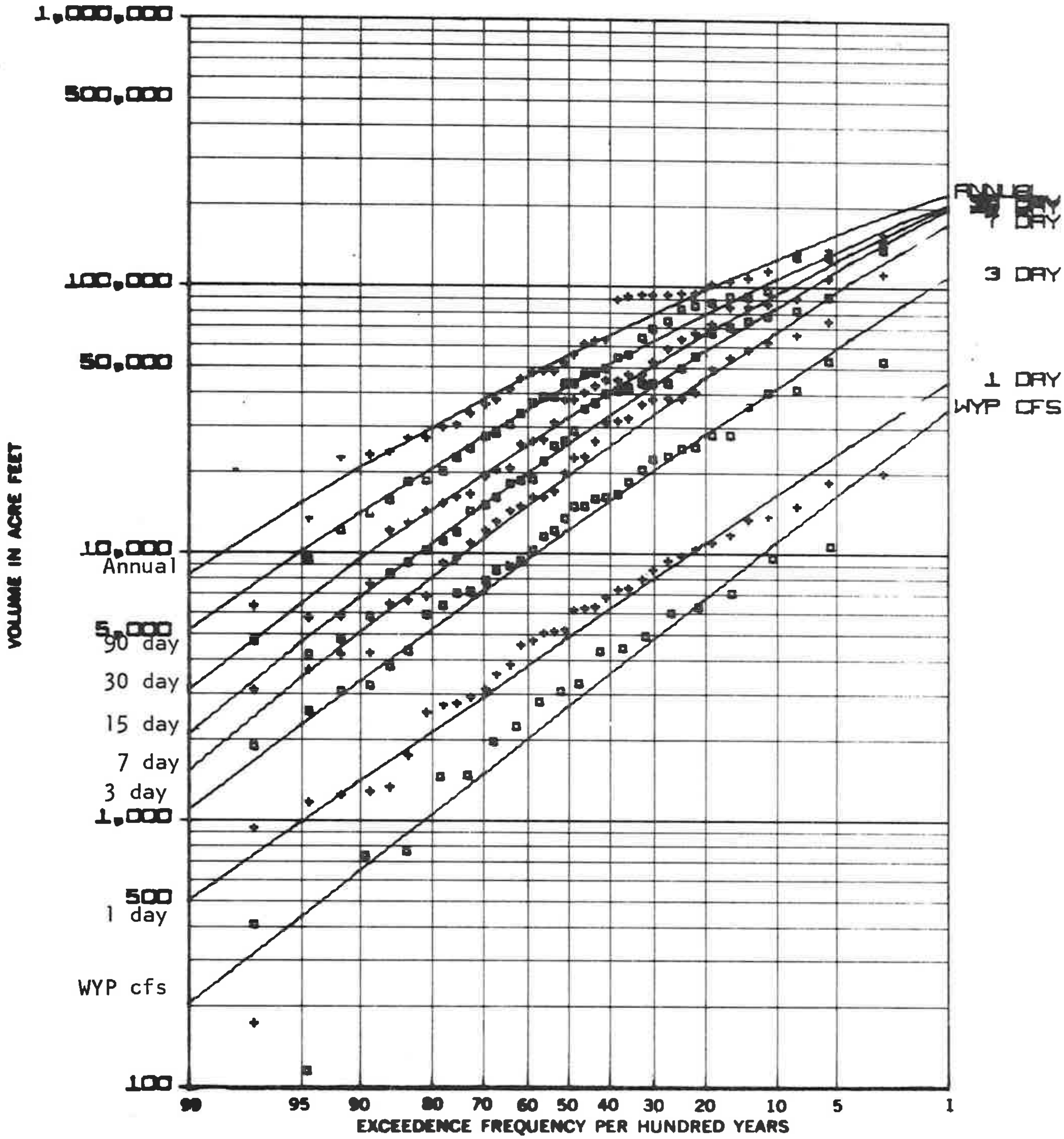
33 Square Miles x 53.33 AF/sq. mi. x 0.45 (in R.O.) = 792 Acre-Feet (Check)


BEULAH DAM, - SWC # 1464
INFLOW HYDROGRAPH
50- YEAR FREQUENCY
VOLUME = 792 AF
DISCHARGE, C.F.S.
2500
2000
1500
1000
500
0
0
1
2
3
4
5
6
7
8
9
TIME IN HOURS

DHG 5-22-68

Source: Missouri Basin Inter-Agency Committee

HIGH-FLOW VOLUME-FREQUENCY DURATION CURVES

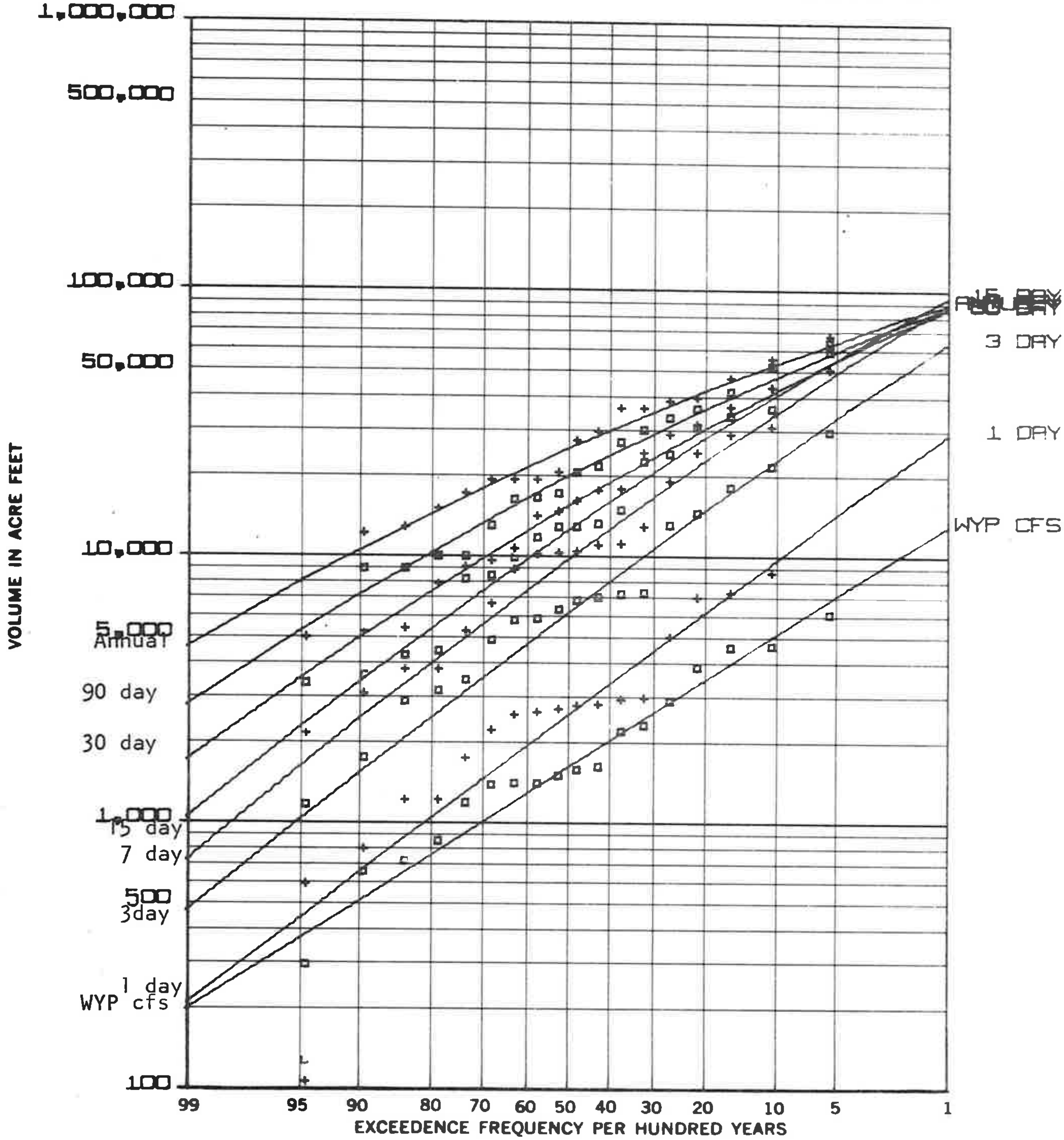


KNIFE RIVER NR. GOLDEN VALLEY (AT. NR. BRONCHO), N. DAK.

1905-06,08-24,44-63 06-3395.00

Source: Missouri Basin Inter-Agency Committee

HIGH-FLOW VOLUME-FREQUENCY DURATION CURVES



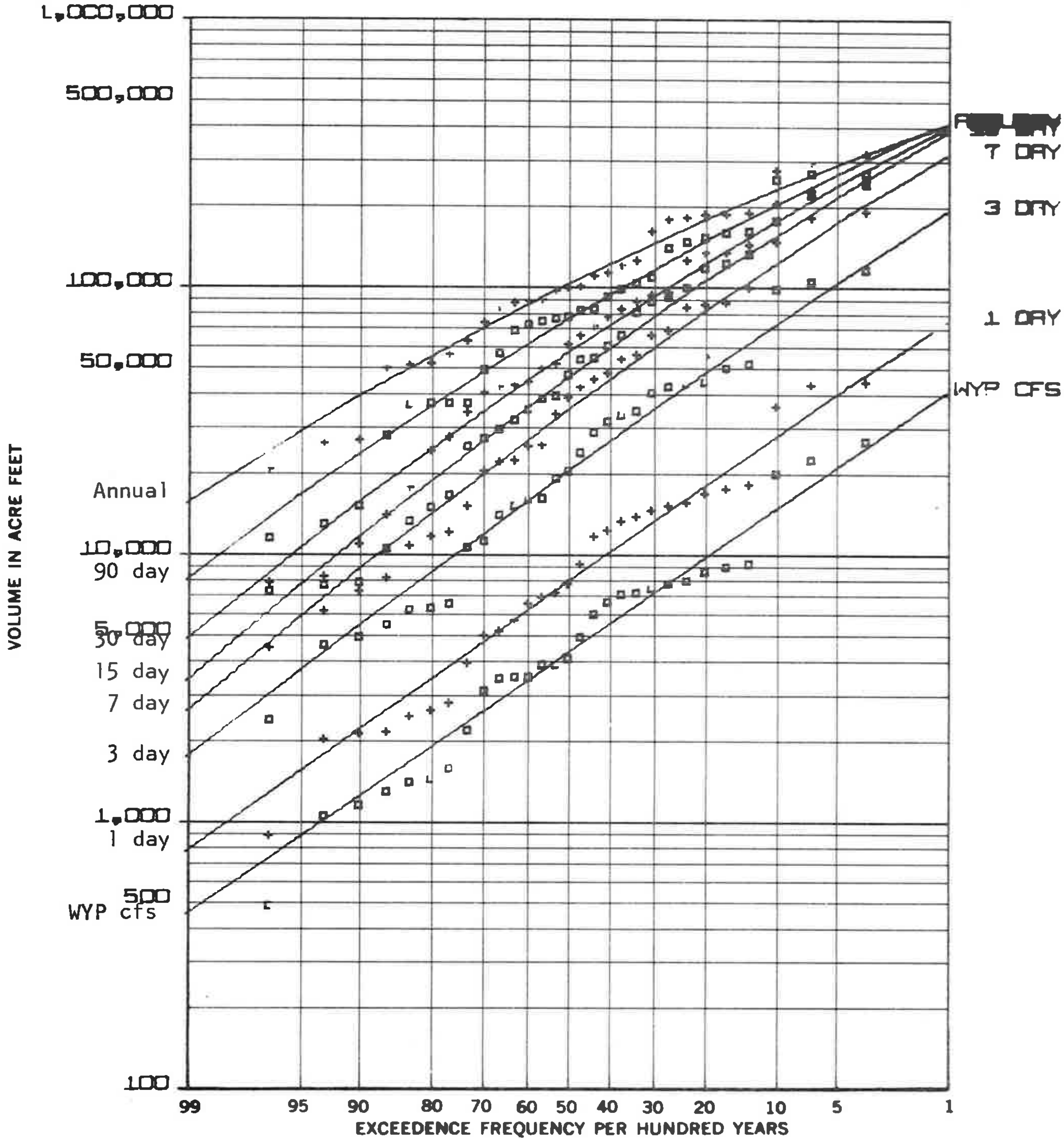
SPRING CREEK AT ZAP, N. DAK.

1946-1963

06-3400.00

Source: Missouri Basin Inter-Agency Committee

HIGH-FLOW VOLUME-FREQUENCY DURATION CURVES



KNIFE RIVER AT HAZEN, N. DAK.

1931-33,38-63 06-3405.00

Knife River near Golden Valley, N. Dak. (06-3395.00)

Location.--Lat 47°09', long 102°03', in SE¼ sec.34, T.143 N., R.90 W., on left bank 6 ft downstream from highway bridge, 4½ miles downstream from Elm Creek, and 9 miles south of Golden Valley.
Drainage area.--1,230 sq mi, approximately.
Average discharge.--36 years, 91.7 cfs.

DURATION TABLE OF DAILY DISCHARGE

NUMBER OF DAYS IN CLASS

YEAR \ CLASS	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	CFS-DAYS
1905	3				1		15	10	36	99	60	28	35	8	13	43	1	3	2	1	1	4	2													6985.1
1906									53	94	8	16	28	15	42	17	8	5	10	33	6	6	5	4	4	5	6									48018.0
1908	2						5		23	89	62	57	19	14	8	24	4	14	11	5	7	13	7	2												18652.0
1909										131		28	39	22	18	28	3	15	7	12	4	13	34	6	2	1	2									48236.0
1910										12	59	19	195	20	13	9	7	8	2	3	2	4		2	2	1	6	1								32044.0
1911									18	32	67	32	87	12	14	54	10	11	12	7	3	4	2													11777.0
1912										58	61	42	29	20	39	36	18	8	12	2	5	10	2	4	3	2	7	7	1							71512.0
1913										34	55	20	82	36	67	35	13	8	1	1	2	1	2	1	3		1	2	1							28906.0
1914										28	31	61	72	38	40	37	15	5	9	6	6	4	5		2		1	2	1	2						47101.0
1915												46	134	42	32	41	16	27	9	5	3	2	3	3	1		1									19376.0
1917										86	37	54	36	42	35	32	5	2	2	7	8	2	5	5	7											24851.0
1918										8	77	20	118	35	18	35	11	7	4	3	8	5	1	1	2	3	5	4								47871.0
1919									60	33		80	37	15	56	16	6	36	6	2	3	7	3		2	1	1	1								23178.0
1922										34	21	33	27	57	16	36	6	8	3	5	10	11	6	5	3	1		2								32997.9
1923							51		8	41	30	88	24	20	15	12	19	9	5	2	7	12	3	2	5	2	6	4								53617.0
1924										57		27	66	58	29	41	19	25	14	7	5	8	2	4	3	1										24670.5
1944										13	72	37	86	23	40	20	13	10	5	6	11	6	3	9	3	4	3	2								46015.8
1945										11	33	62	86	30	38	35	12	8	15	5	4	10	2	3	4	1	1	1	2	2						55511.1
1946						1	30	3	34	44	46	97	29	5	9	19	13	4	11	5	4	5	3		3											13867.8
1947									1	24	42	18	62	39	42	34	20	15	8	7	9	18	5	8	2	6	1	2	2							59202.0
1948										39	31	38	92	24	28	33	20	12	10	4	6	6	6	4	4	2	5	2								47641.0
1949									30	46	63	50	48	17	35	29	12	7	5	2	2	4	2	2	1		2	6	2							47696.2
1950							54		7	18	14	69	60	11	17	33	11	6	11	10	7	11	7	2	8	3	2	1		2	1					69412.9
1951											64	103	53	21	29	31	5	17	14	7	3	3	2	1	1	1	6	1	3							52652.0
1952									13	24	49	47	84	16	49	22	17	10	9	2	6	6	1		1		1	1	2	6						80817.5
1953									11	20	62	123	16	15	19	29	15	20	13	3	8	8	1	1	1											15732.6
1954									10	35	75	33	8	35	46	45	16	12	13	7	5	14	4	1	2	1	1	2								31423.5
1955							23	6	15	39	43	25	115	21	22	15	4	10	8	3	6	7	3													12090.1
1956				31	39	1	9	8	31	53	21	28	43	18	21	19	9	12	8	2	2	2	3	3	1	2										15211.5
1957						31	6	18	72	68	20	12	28	11	15	28	17	7	10	3	8	7	1	1	2											14032.9
1958				28	14	2	5	3	55	95	87	17	12	6	5	5	1	4	3	4	4	5	3	1	2	4										17204.2
1959	62	13	5	11	26	7	18	28	23	26	22	27	24	6	20	13	4	4	3	1	4	4	5	1	2	1	4	1								26565.7
1960		1	3	2	8	8	8	16	39	89	49	37	38	19	15	9	2	3	4	2	2	1		2	2	1	6									24466.0
1961	15	6	19	25	12	20	40	46	59	13	13	20	18	8	11	18	17	5																		3277.9
1962	70	22	4	5	1	6	28	9	26	24	15	20	13	8	21	21	12	9	18	5	12	7	4	3		1	1									21227.5
1963	10	3	3	4	4	7	12	2	20	76	28	18	11	14	35	34	34	23	13	3	6	3	2													12536.7

CLASS	CFS	TOTAL	ACCUM	PERCT	CLASS	CFS	TOTAL	ACCUM	PERCT	CLASS	CFS	TOTAL	ACCUM	PERCT	CLASS	CFS	TOTAL	ACCUM	PERCT
	.0	162	13148	100.0	09	3.0	1593	11516	87.6	18	100	290	1374	10.5	27	3000	42	69	.5
1	.1	45	12986	98.8	10	5.0	1398	9923	75.5	19	150	182	1084	8.2	28	5000	14	27	.2
2	.2	34	12941	98.4	11	7.0	1632	8525	64.8	20	200	189	902	6.9	29	7000	12	13	.1
3	.3	106	12907	98.2	12	10.0	1954	6893	52.4	21	300	233	713	5.4	30	10000	1	1	.0
4	.5	105	12801	97.4	13	15.0	801	4939	37.6	22	500	139	480	3.7	31				.0
5	.7	83	12696	96.6	14	20.0	972	4138	31.5	23	700	81	341	2.6	32				.0
6	1.0	304	12613	95.9	15	30.0	988	3166	24.1	24	1000	78	260	2.0	33				.0
7	1.5	149	12309	93.6	16	50.0	415	2178	16.6	25	1500	44	182	1.4	34				.0
8	2.0	644	12160	92.5	17	70.0	389	1763	13.4	26	2000	69	138	1.0	35				

Knife River near Golden Valley, N. Dak. (06-3395.00)

HIGHEST MEAN DISCHARGE, IN CFS, FOR THE FOLLOWING NUMBER OF CONSECUTIVE DAYS IN YEAR ENDING SEPTEMBER 30

YEAR	1	3	7	15	30	60	90	120	150	183	274	ANNUAL	PEAK
1905	597.0	442.0	270.0	144.0	100.0	75.1	54.4	42.4	40.0	35.0	24.4	19.1	
1906	2420.0	2300.0	1670.0	1250.0	1000.0	623.0	424.0	372.0	309.0	258.0	174.0	131	
1908	902.0	735.0	473.0	351.0	265.0	154.0	175.0	145.0	118.0	97.1	66.9	50.9	
1909	2580.0	2080.0	1250.0	762.0	640.0	376.0	320.0	313.0	282.0	258.0	174.0	131	
1910	3210.0	2760.0	2370.0	1690.0	891.0	460.0	312.0	247.0	200.0	165.0	114.0	87.7	
1911	641.0	550.0	308.0	164.0	97.8	63.5	69.3	59.0	52.1	54.5	39.8	32.3	
1912	5000.0	4260.0	3660.0	2420.0	1560.0	962.0	740.0	573.0	464.0	384.0	258.0	196	
1913	5990.0	4210.0	2740.0	1480.0	765.0	396.0	271.0	207.0	168.0	140.0	102.0	79.1	
1914	7700.0	7030.0	4540.0	2290.0	1240.0	655.0	471.0	366.0	299.0	249.0	168.0	129	a7700
1915	2320.0	1540.0	885.0	516.0	351.0	219.0	161.0	131.0	112.0	94.9	66.9	53.0	b2320
1917	1480.0	1340.0	1090.0	985.0	642.0	358.0	249.0	191.0	154.0	127.0	88.4	68.1	b1480
1918	4420.0	3970.0	2950.0	1490.0	765.0	401.0	270.0	206.0	183.0	251.0	172.0	132	
1919	3160.0	2570.0	1470.0	902.0	531.0	307.0	220.0	171.0	138.0	115.0	82.3	63.5	b3160
1922	3780.0	1970.0	1180.0	623.0	441.0	260.0	221.0	207.0	204.0	172.0	118.0	90.3	
1923	4780.0	3850.0	2780.0	1480.0	1150.0	781.0	523.0	394.0	330.0	275.0	191.0	147	
1924	1580.0	1210.0	674.0	409.0	277.0	162.0	157.0	142.0	132.0	111.0	77.2	67.4	
1944	3730.0	3180.0	1920.0	1190.0	690.0	391.0	398.0	362.0	294.0	243.0	164.0	126	4460
1945	7000.0	6830.0	4860.0	2560.0	1440.0	751.0	551.0	435.0	351.0	291.0	199.0	152	a7000
1946	1400.0	1230.0	798.0	491.0	284.0	156.0	107.0	82.0	84.9	70.7	49.0	38.0	a1400
1947	5630.0	4730.0	2660.0	1360.0	806.0	471.0	370.0	400.0	354.0	307.0	213.0	162	6020
1948	4100.0	3500.0	2810.0	1890.0	1100.0	635.0	484.0	371.0	303.0	252.0	171.0	130	4370
1949	5300.0	4770.0	3970.0	2660.0	1430.0	737.0	500.0	380.0	309.0	255.0	172.0	131	6400
1950	10300.0	9120.0	5470.0	3150.0	1850.0	1070.0	739.0	562.0	453.0	373.0	251.0	190	10900
1951	6800.0	6130.0	4240.0	2810.0	1480.0	772.0	529.0	408.0	328.0	280.0	189.0	144	7200
1952	9530.0	9080.0	8210.0	4750.0	2450.0	1250.0	844.0	647.0	520.0	431.0	291.0	221	9740
1953	1390.0	1010.0	508.0	314.0	248.0	178.0	130.0	114.0	94.3	79.3	55.4	43.1	1510
1954	3200.0	2850.0	1700.0	865.0	451.0	250.0	210.0	162.0	155.0	140.0	113.0	86.1	3320
1955	680.0	643.0	489.0	287.0	223.0	150.0	106.0	83.5	69.8	58.1	42.4	33.1	750
1956	1950.0	1480.0	1050.0	645.0	358.0	197.0	141.0	114.0	94.7	80.7	54.5	41.6	a2300
1957	1300.0	1090.0	705.0	378.0	208.0	114.0	89.6	98.3	89.5	73.9	50.3	38.4	1490
1958	1800.0	1600.0	1190.0	638.0	333.0	170.0	115.0	136.0	110.0	90.8	62.1	47.1	2000
1959	3500.0	2730.0	2300.0	1430.0	809.0	417.0	281.0	215.0	173.0	142.0	96.2	72.8	a5000
1960	2600.0	2550.0	2260.0	1400.0	723.0	366.0	249.0	192.0	156.0	129.0	87.5	66.8	2830
1961	89.0	70.0	67.9	64.7	53.1	32.5	27.1	20.7	17.9	16.6	11.6	8.98	117
1962	2660.0	1750.0	960.0	554.0	456.0	271.0	191.0	162.0	136.0	115.0	77.1	58.2	3080
1963	655.0	525.0	309.0	198.0	131.0	97.2	80.5	79.9	70.5	64.7	44.5	34.4	779

a About.
b Maximum daily.

Knife River near Golden Valley, N. Dak. (06-3395.00)

LOWEST MEAN DISCHARGE, IN CFS, FOR THE FOLLOWING NUMBER OF CONSECUTIVE DAYS IN YEAR BEGINNING APRIL 1

YEAR	1	3	7	14	30	60	90	120	150	183	274
1904	2.0	2.0	2.0	2.0	2.1	2.5	2.7	3.4	3.6	3.5	7.5
1905	.0	.0	.5	.8	1.3	1.9	2.3	2.6	2.7	2.6	18.4
1907	2.0	2.0	2.0	2.0	2.5	3.9	4.8	5.1	5.1	4.9	9.4
1908	.0	.3	.7	1.4	2.4	3.5	3.7	4.0	4.1	4.0	21.5
1909	5.0	5.0	5.0	5.0	5.0	5.6	7.0	8.7	9.7	10.0	62.6
1910	4.0	4.0	4.0	4.0	4.1	4.6	5.0	6.9	7.5	8.2	10.0
1911	2.0	2.0	2.0	2.0	3.4	4.1	4.1	4.5	5.2	6.3	17.2
1912	4.0	4.0	4.0	4.0	4.0	4.9	6.3	8.3	17.3	19.3	26.0
1913	4.0	4.0	4.0	4.0	4.1	4.6	5.7	7.0	8.4	8.5	10.1
1914	8.0	8.0	8.0	8.0	8.1	9.1	9.7	10.3	10.5	11.0	21.5
1916	4.0	4.0	4.0	4.0	4.0	4.3	4.9	6.1	7.7	8.9	20.8
1917	4.0	4.0	4.0	4.0	4.0	4.7	5.6	7.0	6.8	6.7	10.0
1918	5.0	5.0	5.0	5.7	6.2	7.6	8.4	11.3	13.7	17.4	98.1
1922	4.0	4.0	4.0	4.4	6.1	6.6	7.4	11.6	11.1	11.8	65.9
1923	1.0	1.0	1.0	1.0	1.0	1.2	6.5	7.9	12.4	30.4	31.7
1944	3.0	3.3	4.0	5.0	6.9	7.3	10.6	13.8	13.4	13.4	74.8
1945	1.0	1.0	1.0	1.0	2.0	2.8	3.8	4.8	5.1	5.6	31.1
1946	.9	1.1	1.3	1.6	4.0	4.2	6.5	8.1	7.7	7.2	17.4
1947	4.0	4.0	4.0	4.2	4.8	6.5	7.8	8.7	9.0	9.5	93.2
1948	2.0	2.0	2.0	2.0	2.0	2.6	3.4	4.6	5.3	5.2	10.5
1949	1.0	1.0	1.0	1.0	1.0	1.1	2.2	3.9	5.2	5.4	10.7
1950	5.0	5.0	5.0	5.0	5.4	5.9	7.1	7.4	7.6	8.1	10.4
1951	2.0	2.0	2.0	2.1	2.7	4.3	6.4	9.0	9.3	12.8	19.7
1952	5.1	5.1	5.2	5.4	6.0	6.7	7.1	7.4	7.2	7.4	15.6
1953	2.3	2.4	2.5	2.7	2.8	4.1	4.8	5.1	4.8	5.9	26.2
1954	4.0	4.0	4.0	4.0	4.4	5.1	6.7	8.1	8.9	18.4	46.2
1955	.3	.3	.3	.3	.3	.4	1.0	1.6	1.9	2.4	5.6
1956	.8	.8	.8	.8	.8	1.7	2.2	2.8	2.8	3.3	11.3
1957	.9	1.0	1.2	1.6	2.2	2.5	3.1	3.6	4.0	3.7	13.2
1958	.0	.0	.0	.0	.0	.3	.7	1.5	1.6	1.4	23.7
1959	.0	.0	.0	.0	.1	.3	3.7	4.1	4.3	5.6	6.6
1960	.1	.2	.2	.3	.4	.9	1.3	1.4	1.4	2.3	6.5
1961	.0	.0	.0	.0	.0	.0	.0	.3	.6	.7	2.6
1962	.0	.0	.0	.0	.3	1.6	2.8	3.0	3.2	4.9	21.1

Spring Creek at Zap, N. Dak. (06-3400.00)

Location.--Lat 47°17', long 101°55', in SW¼ sec.14, T.144 N., R.89 W., on right bank 250 ft downstream from Northern Pacific Railway bridge in Zap and 9 miles upstream from mouth.
Drainage area.--545 sq mi.
Average discharge.--18 years, 40.1 cfs.
Remarks.--Flow regulated by Ilo Lake (capacity, 7,130 acre-ft).

DURATION TABLE OF DAILY DISCHARGE

NUMBER OF DAYS IN CLASS

CLASS / YEAR	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	CFS-DAYS
1946	19						36	3	32	35	74	62	36	14	12	10	9	4	6	3	3	2	2		3											10471.8
1947									10	46	86	54	51	23	24	14	5	9	10	11	8	4	4	3	3											19726.6
1948							2		28	58	62	75	37	29	5	16	10	5	14	6	1	7	3	3	5											20223.3
1949	40						12		11	43	97	63	23	24	11	17	5	3	2	3	2	3		2	1	1	2									15042.5
1950	45						21		14	15	19	84	46	21	30	13	5	12	9	9	7	3	5	2	1		2	2								28579.6
1951										17	86	123	34	16	33	14	12	9	3	4	3	1	2	1	4		1	2								23697.1
1952										5	104	120	60	21	13	16	6	3	2	2	1	3	1		2	1	1	3	2							34703.2
1953										7	59	147	35	25	31	29	9	7	8	2	2	2		1	1											9927.0
1954									3	50	90	53	57	24	18	24	11	8	11		6	4	3	1	2											13688.4
1955							1	23	17	72	58	97	31	11	19	11	9	6	1	3	3	3														6253.7
1956					24	6	43	10	14	87	39	32	46	13	15	15	8	2	3	2	1	2		1	2	1										9703.9
1957							26		20	88	88	33	24	16	27	16	7	2	8	1	2	3	3	1												8762.1
1958						5	42	11	15	85	121	27	23	10	7	3	3	2	2		2	3	4													6469.0
1959	66				10	11	64	22	31	40	21	24	27	10	11	7	3	2	3		4	2	3	2	2											9695.4
1960						1		23	103	47	66	46	30	12	14	6	2	1	2	1	1	2	1		3	3	1	1								18180.9
1961					6	13	28	31	62	123	25	21	13	10	6	22	5																			2535.2
1962	88	7	1		1	1	3	5	36	27	10	40	28	16	23	27	12	4	9	6	6	5	4	2	4											18306.1
1963						8	2		9	39	39	103	28	36	42	35	12	3	4	2	1		2													7628.6

CLASS	CFS	TOTAL	ACCUM	PERCT	CLASS	CFS	TOTAL	ACCUM	PERCT	CLASS	CFS	TOTAL	ACCUM	PERCT	CLASS	CFS	TOTAL	ACCUM	PERCT
	.0	258	6574	100.0	09	3.0	884	5409	82.3	18	100	97	366	5.6	27	3000	8	10	.2
1	.1	7	6316	96.1	10	5.0	1144	4525	68.8	19	150	55	269	4.1	28	5000	2	2	.0
2	.2	1	6309	96.0	11	7.0	1204	3381	51.4	20	200	53	214	3.3	29				.0
3	.3	0	6308	96.0	12	10.0	629	2177	33.1	21	300	49	161	2.4	30				.0
4	.5	41	6308	96.0	13	15.0	331	1548	23.5	22	500	37	112	1.7	31				.0
5	.7	45	6267	95.3	14	20.0	341	1217	18.5	23	700	19	75	1.1	32				.0
6	1.0	280	6222	94.6	15	30.0	295	876	13.3	24	1000	33	56	.9	33				.0
7	1.5	128	5942	90.4	16	50.0	133	581	8.8	25	1500	6	23	.3	34				.0
8	2.0	405	5814	88.4	17	70.0	82	448	6.8	26	2000	7	17	.3	35				

Spring Creek at Zap, N. Dak. (06-3400.00)

HIGHEST MEAN DISCHARGE, IN CFS, FOR THE FOLLOWING NUMBER OF CONSECUTIVE DAYS IN YEAR ENDING SEPTEMBER 30

YEAR	1	3	7	15	30	60	90	120	150	183	274	ANNUAL	PEAK
1946	1400.0	1200.0	757.1	440.0	250.8	135.5	94.1	72.9	63.7	52.9	36.7	28.7	a1400
1947	1430.0	1234.0	742.7	397.7	303.4	164.2	123.6	137.8	116.7	100.6	69.8	54.0	1530
1948	1330.0	1169.7	940.7	818.9	487.9	281.3	203.2	155.5	127.2	105.2	71.7	55.3	1430
1949	2540.0	2206.7	1397.9	774.5	415.9	219.2	152.2	116.2	94.6	78.5	52.9	41.2	2890
1950	4400.0	3726.7	2235.7	1219.5	733.6	429.1	295.0	225.5	182.9	151.7	102.3	78.3	4580
1951	3600.0	3100.0	2080.0	1147.2	614.5	327.6	233.7	178.8	144.6	122.3	83.8	64.9	3900
1952	5640.0	5043.3	3664.3	2014.5	1044.3	535.3	361.4	273.8	221.1	182.6	124.0	94.8	6130
1953	1480.0	822.0	385.1	280.1	164.9	97.5	73.9	65.5	55.6	47.5	33.9	27.2	2360
1954	1140.0	986.3	653.1	335.9	183.4	125.7	116.8	90.7	79.7	66.3	47.8	37.5	1610
1955	408.0	300.0	224.3	121.7	89.9	70.8	51.3	41.2	34.0	28.6	21.5	17.1	664
1956	1500.0	1250.0	814.3	438.7	240.9	131.3	91.8	72.5	59.4	50.0	34.2	26.5	1650
1957	900.0	533.3	276.9	146.3	134.1	79.1	56.7	52.6	52.2	43.7	30.3	24.0	1200
1958	620.0	583.3	484.0	287.7	155.8	82.8	57.2	45.2	37.3	31.3	22.8	17.7	726
1959	1300.0	1000.0	800.0	505.9	275.1	143.3	98.1	76.0	61.1	50.3	34.6	26.6	1420
1960	3740.0	2463.3	1798.6	1038.1	535.3	274.4	186.5	142.0	115.1	95.2	65.0	49.7	4640
1961	55.0	50.0	42.9	40.3	37.4	23.9	19.5	15.6	13.0	11.2	8.7	6.9	130
1962	1380.0	1081.7	750.7	447.9	299.8	241.8	169.5	131.5	116.7	98.4	66.1	50.2	2230
1963	623.0	487.3	274.7	150.7	91.6	63.4	51.4	43.6	39.5	35.3	25.2	20.9	862

a Maximum daily.

LOWEST MEAN DISCHARGE, IN CFS, FOR THE FOLLOWING NUMBER OF CONSECUTIVE DAYS IN YEAR BEGINNING APRIL 1

YEAR	1	3	7	14	30	60	90	120	150	183	274
1946	1.3	1.3	1.5	1.8	2.7	4.0	5.0	5.6	5.5	5.3	8.7
1947	1.0	1.3	1.7	1.9	2.4	2.7	3.7	4.3	5.0	5.5	28.8
1948	.0	.0	.0	.0	.0	.5	1.3	2.2	3.2	3.7	5.5
1949	.0	.0	.0	.0	.0	.3	1.1	2.6	3.6	4.0	5.5
1950	3.6	3.8	4.2	4.5	5.2	5.8	6.3	6.3	6.6	7.2	8.9
1951	5.0	5.0	5.0	5.1	5.6	5.8	6.0	6.2	6.7	7.2	9.5
1952	3.5	3.7	4.0	4.4	5.2	6.3	6.6	6.8	6.6	6.7	8.0
1953	3.0	3.0	3.0	3.0	3.6	4.6	5.3	5.7	6.0	6.9	25.3
1954	2.8	2.8	3.0	3.0	3.4	3.7	4.8	5.6	6.1	6.9	10.9
1955	.5	.5	.5	.5	.6	.8	1.0	1.9	2.5	2.7	4.1
1956	1.0	1.0	1.0	1.0	1.2	2.0	2.9	3.6	4.0	4.3	6.2
1957	2.5	2.5	2.8	3.0	3.8	4.2	4.7	5.1	5.3	5.2	11.6
1958	.0	.0	.0	.0	.0	.0	.2	1.0	1.3	1.3	2.4
1959	.8	.8	.8	1.1	1.2	1.3	2.8	3.8	4.1	5.1	4.9
1960	.9	1.2	1.4	1.5	2.0	2.6	3.1	3.3	3.2	3.2	5.2
1961	.0	.0	.0	.0	.0	.0	.0	.5	1.0	1.4	1.5
1962	.7	.7	.7	1.1	2.2	3.0	4.5	5.5	6.1	6.5	29.8

Knife River at Hazen, N. Dak. (06-3405.00)

Location.--Lat 47°17', long 101°37', in SE¼ sec.18, T.144 N., R.86 W., on right bank at upstream side of highway bridge, half a mile south of Hazen and 2 miles upstream from Antelope Creek.
Drainage area.--2,350 sq mi, approximately.
Average discharge.--29 years, 168 cfs.
Remarks.--Small diversions above station. Slight regulation by Lake Ilo (capacity, 7,130 acre-ft).

DURATION TABLE OF DAILY DISCHARGE

NUMBER OF DAYS IN CLASS

YEAR / CLASS	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	CFS-DAYS
1931									7	7	23	128	82	33	24	21	20	6	7	3	2	1		1												13139.8
1932							1	14	11	32	71	40	25	50	37	17	11	10	14	10	13	4	2	4												25773.7
1933	16			30		25		1	7	21	36	44	26	32	37	18	16	6	2	6	7	6	7	14	8											51337.6
1938								13	19	16	30	23	37	35	76	20	19	23	11	8	11	9	1	2	5	4		2	1							64164.2
1939												82	60	55	41	54	21	29	6	3	4	1	1	2			2	1	3							61528.0
1940										24	70	55	72	62	39	17	12	5	2	1	2	3	1	1												13339.0
1941										39	36	76	28	35	42	23	18	13	13	13	14	6	1		2	4	2									44766.0
1942												83	26	68	38	34	38	17	11	12	16	3	8	6		5										50862.0
1943									9	30	21	25	19	47	16	26	53	29	20	13	20	5	8	5	7	2	3	2	1	1	1	2				161094.0
1944												8	36	52	115	46	24	18	4	15	7	9	8	10	3	4	3	2	2							95514.0
1945												18	23	63	99	43	36	25	8	12	16	5	2	4	1	3		2	5							92863.0
1946										4	28	47	39	104	62	12	14	9	11	6	10	6	7	2	1	2	1									37332.0
1947												18	47	23	98	40	34	28	9	9	13	12	8	12	4	3	5	2								94558.0
1948												28	15	91	95	28	31	12	13	13	8	6	3	2	8	4	7	2								90838.0
1949											34	47	23	74	69	28	34	16	10	6	5	2	2	3	1	1	4	3	3							82031.0
1950										31	19	23	11	15	76	53	28	34	8	10	18	6	9	4	8	6	1	1		2	1	1				139932.0
1951														53	166	14	53	21	11	17	7	5	3	3	1	1	3	3	4							96612.0
1952													33	52	130	41	39	26	10	6	10	3	2	2		2	1	1	2	4	2					148055.0
1953													12	109	113	20	32	20	8	19	14	10	1	2	4	1										42714.0
1954												12	32	109	24	45	34	32	13	22	23	3	6	5		3	2									57124.0
1955											26	14	24	102	101	30	24	9	4	11	9	5	3	3												26439.4
1956									43	9	30	61	40	26	49	29	18	13	13	15	9	1		3	3		3	1								44287.2
1957												118	70	32	38	25	18	12	10	14	15	4	4	5												31788.0
1958										39	14	57	141	49	23	6	4	4	5	5	6	1	3	3	1	4										28308.0
1959	28			1		5	6	10	21	66	37	33	15	32	57	14	8	4	3	2	4	2	5	3	2	1	6									45106.9
1960									6	19	46	60	67	45	57	23	13	7	3	3	4	1	1	1	1	2	4	3								55664.2
1961							1	6	40	36	81	78	21	29	29	13	4	8	11	3	5															10425.3
1962	59	2	2	1		4	2	23	18	18	35	6	12	39	30	14	20	14	11	12	14	13	6	4	1	4	1									49193.8
1963								4	22	10	7	20	58	64	23	41	39	41	16	10	6	1	2	1												25195.0

CLASS	CFS	TOTAL	ACCUM	PERCT	CLASS	CFS	TOTAL	ACCUM	PERCT	CLASS	CFS	TOTAL	ACCUM	PERCT	CLASS	CFS	TOTAL	ACCUM	PERCT
	.0	103	10592	100.0	09	5.0	401	10135	95.7	18	150	267	1407	13.3	27	5000	25	60	.6
1	.2	2	10489	99.0	10	7.0	644	9734	91.9	19	200	279	1140	10.8	28	7000	21	35	.3
2	.3	2	10487	99.0	11	10.0	1204	9090	85.8	20	300	292	861	8.1	29	10000	7	14	.1
3	.5	32	10485	99.0	12	15.0	1094	7886	74.5	21	500	133	569	5.4	30	15000	4	7	.1
4	.7	0	10453	98.7	13	20.0	1580	6792	64.1	22	700	104	436	4.1	31	20000	3	3	.0
5	1.0	34	10453	98.7	14	30.0	1804	5212	49.2	23	1000	107	332	3.1	32				.0
6	1.5	10	10419	98.4	15	50.0	795	3408	32.2	24	1500	61	225	2.1	33				.0
7	2.0	71	10409	98.3	16	70.0	715	2613	24.7	25	2000	56	164	1.5	34				.0
8	3.0	203	10338	97.6	17	100.0	491	1898	17.9	26	3000	48	108	1.0	35				

Knife River at Hazen, N. Dak. (06-3405.00)

HIGHEST MEAN DISCHARGE, IN CFS, FOR THE FOLLOWING NUMBER OF CONSECUTIVE DAYS IN YEAR ENDING SEPTEMBER 30

YEAR	1	3	7	15	30	60	90	120	150	183	274	ANNUAL	PEAK
1931	1320.0	770.3	442.7	259.8	133.5	89.6	73.2	69.5	59.0	55.2	43.6	36.8	1450
1932	1250.0	1049.3	846.9	447.7	300.7	219.0	205.2	186.9	154.9	130.0	89.8	70.4	1300
1933	1980.0	1896.7	1622.9	1319.7	1211.8	731.2	516.9	405.1	326.5	268.8	186.2	140.7	2200
1938	7420.0	6830.0	3861.6	2026.5	1121.7	669.4	468.7	442.1	390.5	336.0	229.1	175.8	a7540
1939	9180.0	8750.0	6032.9	3101.0	1616.2	850.8	586.2	466.9	382.5	318.2	216.8	168.6	a9300
1940	1090.0	826.7	524.6	265.9	139.7	85.3	64.9	76.1	69.0	58.7	44.5	36.4	a1150
1941	3920.0	3490.0	2792.9	1591.4	867.9	480.4	389.0	332.6	271.2	225.8	158.4	122.6	a4110
1942	2880.0	2566.7	1600.1	911.2	738.9	432.4	438.3	363.7	305.9	256.4	176.2	139.3	3120
1943	22400.0	19833.3	13257.1	7464.0	3887.5	2200.8	1504.8	1231.4	1027.1	858.7	582.4	441.4	26500
1944	7890.0	7166.7	4812.9	2734.0	1488.1	791.1	790.6	727.3	589.8	489.9	336.3	261.0	8010
1945	8520.0	8336.7	7188.6	3974.8	2263.7	1192.1	867.9	688.6	571.2	476.5	328.2	254.4	8690
1946	3300.0	2700.0	1842.9	1168.7	716.6	396.2	274.4	214.6	221.0	184.7	129.2	102.3	3500
1947	5910.0	5273.3	3271.7	1813.3	1404.5	786.4	617.6	626.8	548.2	480.7	336.0	259.1	6000
1948	6700.0	5600.0	4057.1	3377.3	2119.6	1205.0	899.3	694.6	567.9	472.3	322.1	248.2	7070
1949	7640.0	7346.7	6251.4	4154.0	2268.8	1193.0	827.9	634.6	518.3	429.9	290.9	224.7	7760
1950	21800.0	17633.3	10772.9	6026.7	3476.7	2063.8	1428.6	1098.3	892.5	741.0	501.2	383.4	22700
1951	8900.0	7433.3	6314.3	4502.7	2435.2	1305.5	912.4	706.0	573.1	496.8	340.3	264.7	9000
1952	18200.0	16633.3	13828.6	8193.2	4301.2	2214.9	1507.4	1159.7	938.0	777.9	527.8	404.5	20200
1953	2600.0	1793.3	1097.9	989.3	681.8	430.0	316.7	286.9	242.1	204.9	146.0	117.0	3440
1954	3630.0	3260.0	2411.4	1295.4	730.1	455.5	417.7	330.9	288.0	240.8	200.4	156.5	3880
1955	1100.0	1060.0	875.7	562.7	411.9	285.7	205.5	167.9	142.1	121.4	89.8	72.4	b1400
1956	6200.0	4800.0	3085.7	1827.3	1036.2	573.7	410.1	330.2	275.0	231.1	157.4	121.0	6630
1957	1400.0	1103.3	782.0	504.7	464.2	281.7	205.8	203.4	189.7	158.6	111.0	87.1	1590
1958	2500.0	2370.0	1870.0	1064.3	569.2	297.7	204.0	205.8	168.2	140.2	99.8	77.6	b3500
1959	4630.0	4053.3	3455.7	2248.9	1303.3	678.2	462.5	356.9	287.8	237.0	160.9	123.6	4930
1960	6990.0	5810.0	4980.0	3008.2	1578.5	810.8	553.2	429.6	347.8	290.0	196.8	152.1	7230
1961	450.0	406.7	324.3	246.3	183.7	109.5	85.6	67.2	56.0	48.5	35.5	28.6	488
1962	3510.0	2743.3	1479.9	855.0	837.2	597.5	433.6	356.8	313.1	264.4	177.6	134.8	3860
1963	1020.0	914.7	588.6	356.3	235.7	175.3	156.1	143.2	134.0	121.9	85.5	69.0	1050

a Maximum observed.
b About.

Knife River at Hazen, N. Dak. (06-3405.00)

LOWEST MEAN DISCHARGE, IN CFS, FOR THE FOLLOWING NUMBER OF CONSECUTIVE DAYS IN YEAR BEGINNING APRIL 1

YEAR	1	3	7	14	30	60	90	120	150	183	274
1930	6.2	7.2	8.2	9.1	10.0	10.0	10.0	10.6	11.4	12.0	16.6
1931	1.6	1.9	2.1	3.0	3.7	5.6	6.4	9.0	12.6	33.4	37.4
1932	.0	.0	.0	.0	3.4	6.9	9.0	13.8	15.1	14.6	39.6
1938	10.0	10.0	10.0	10.0	10.7	11.7	12.5	13.8	17.1	19.3	162.8
1939	6.0	6.0	6.1	6.5	6.9	8.5	11.6	14.7	15.5	15.8	27.3
1940	5.0	5.0	5.4	5.9	6.0	6.5	7.8	8.8	10.0	11.1	25.0
1941	10.0	10.0	10.0	10.2	10.7	11.4	12.1	14.2	19.7	27.3	46.5
1942	4.0	4.0	4.0	4.4	6.8	6.9	8.0	11.8	14.3	15.8	79.3
1943	13.0	13.0	13.4	14.2	16.7	18.0	19.3	25.7	31.1	31.1	58.1
1944	10.0	10.0	10.4	12.1	14.3	16.7	26.6	30.7	32.1	33.2	139.5
1945	6.0	6.3	6.4	7.4	9.6	11.5	12.8	17.2	19.3	20.6	58.9
1946	10.0	10.0	10.7	11.8	14.6	15.8	20.0	24.2	23.5	22.3	49.4
1947	11.0	11.0	11.1	11.6	12.6	15.9	19.6	22.7	24.8	26.5	134.9
1948	7.0	7.0	7.0	7.1	7.8	9.2	10.7	13.4	17.3	18.3	27.8
1949	5.0	5.0	5.0	5.0	5.5	7.0	10.1	15.4	19.2	20.8	32.3
1950	20.0	20.0	20.0	20.0	20.0	22.3	24.9	26.1	28.3	31.4	41.7
1951	15.0	15.0	15.0	15.0	16.4	19.1	24.2	26.2	28.2	31.4	51.6
1952	20.0	20.7	21.1	21.6	23.1	26.1	27.0	29.1	30.1	31.0	48.8
1953	12.0	12.0	12.6	13.5	16.6	20.9	22.2	22.6	21.9	24.5	84.7
1954	14.0	14.7	16.1	18.3	19.4	21.8	23.5	25.3	26.2	37.6	67.4
1955	4.0	4.0	4.0	4.0	4.0	4.7	6.2	8.4	9.4	10.6	19.5
1956	10.0	10.3	11.0	11.0	11.3	12.0	13.2	15.2	15.4	16.3	34.7
1957	10.0	10.0	10.0	10.4	11.3	13.9	15.1	16.0	16.9	16.4	37.2
1958	.0	.0	.0	.0	.1	1.2	2.6	5.9	7.4	7.2	30.6
1959	4.0	4.0	4.1	4.9	5.4	6.1	8.7	10.8	11.6	15.9	16.4
1960	3.0	3.3	3.6	3.8	4.8	7.5	8.6	9.6	9.5	11.6	21.1
1961	.0	.0	.0	.0	.0	.0	.5	2.0	2.9	3.7	5.8
1962	2.5	2.5	2.7	2.9	3.4	7.2	11.6	13.8	14.8	16.3	67.9

III. DESIGN:

A. BRUSH CREEK DAM - The base of the core trench for the earthfill embankment will be excavated into firm and compact clay along the valley walls, and into glacial till and bedrock along the valley floor. The bench on the right bank of the proposed earthfill is to be excavated in its entirety in view of its sandy composition. This coarse material will be utilized in construction of the toe drain for the embankment. Several small coal veins located beyond the bedrock are not anticipated to cause excessive seepage in view of the impervious material located above the coal bed. Should excessive seepage occur in the future, it could be controlled through grouting processes. The core of the embankment will extend to elevation 1900.

The crest of the embankment is to be established at elevation 1915 with a four-foot crown in the center of the fill to provide for settlement. The crest of the embankment will have an 80-foot width and 6 inches of crown upstream and downstream to provide for surface drainage. The embankment will be constructed with a 3:1 upstream slope and 2:1 downstream slope with 2 berms located on the downstream side. The upper berm on the downstream side will be 10 feet wide and located at elevation 1880.0. The lower berm will be 10 feet wide and will be located at elevation 1840.0. The creek bed elevation in this area is approximately 1795.

There are no drainage gutters provided on the downstream side of the earthfill abutments. It was decided that a calculated risk would be taken regarding erosion in this area, hoping that erosion would be minimal,provided a good grass cover ould be obtained in this area. In the event grass cover is not sufficient, drainage gutters can be installed at some later date.

Incorporated in the embankment will be a horizontal filter drain and a vertical chimney drain. The thickness of the horizontal filter drain will be 10 feet through the bottom area with a transition zone from 10 feet at elevation 1820 to 5 feet at elevation 1840. At elevation 1840,there will be another transition zone from 5 feet at elevation 1840 to 3 feet at elevation 1865 at which point the drain will be discontinued. The chimney drain located at the downstream edge of the core will be 6 feet in width and extend to elevation 1865. Gradation of the material for the chimney and horizontal filter drain will be the same. A collector toe drain 5 feet wide and 4 feet in depth will extend throughout that area of the horizontal filter drain with 2 points of escape each 50 feet on either side of the outlet structure. Further water pressure relief measures are incorporated in the structure with 8 relief wells. The wells will be 3 feet in diameter and of varying depth. They will be located along the base of the structure. It has been determined that the water pressure relief facilities incorporated in this structure are more than adequate to preclude sloughing.

The upstream side of the embankment is to be faced with rock riprap from elevation 1830.0 to elevation 1910.0. Computations developed for thickness of rock riprap required indicate a 6 inch gravel base and an 18-inch rock riprap will be sufficient from elevation 1830.0 to elevation 1860.0. From elevation 1860.0 to elevation 1880.0, a 6-inch gravel base is to be provided with a 24-inch layer of rock riprap. From elevation 1880.0 to elevation 1910.0, a 12-inch gravel base is to be provided on top of which a 30-inch layer of rock riprap is to be placed.

Slope stability analyses of this structure were developed with a minimum safety factor of 1.75. The circular arc analysis of the structure as proposed indicates that the structure has a minimum factor of safety of 1.92. The translatory analysis by the sliding block method provided a safety factor of 3.66.

The service spillway will consist of a reinforced concrete box drop inlet, a 48-inch reinforced concrete pipe extending laterally through the embankment and a reinforced concrete outlet structure. There are 3 anti-seep collars provided on the lateral pipe. One collar is located immediately upstream from the core and the other 2 collars will be located within the core. The crest of the box inlet is to be established at elevation 1900.0. The inside dimensions of the inlet structure are 8' x 8' with an 8-foot drop. Additional bearing will be provided by four 8-foot cast-in-place concrete piling 12 inches in diameter. The inside dimensions of the outlet structure are 13' 6" x 21'. This width is required in view of the service spillway and the drawdown pipe both discharging into the outlet structure. Cast-in-place concrete piling 12 inches in diameter will be provided on the upstream side of the outlet structure with a 4-foot cutoff wall on the downstream side. A special reinforced concrete pipe had to be designed, due to the fill over the pipe being in excess of 50 feet.

The drawdown pipe will consist of a 24-inch welded steel pipe with three-eighth inch wall thickness. The inlet of the drawdown pipe is to be established at elevation 1820 and an outlet at elevation 1792. There are 3 anti-seep collars provided on the drawdown pipe with 2 valves and manholes. The double valve system is provided as an added safety feature. Cathodic protection is provided on the steel drawdown pipe. The upstream manhole is to be constructed of corregated metal and will be approximately 100 feet in height. The valve stem will be extended to the top and the only reason anyone would have to descend this manhole would be if the valve became defective. Nylon nets will be provided at 20-foot intervals within the pipe as a safety feature to descend the pipe. The pipe will be waterproofed with an asphaltic material. The downstream manhole will be constructed of reinforced concrete pipe. Reinforced concrete bearing pads are provided at 10-foot intervals along the drawdown pipe. Dresser couplings will be utilized to allow for expansion and settlement. A dresser type coupling will be utilized at valve connections to allow for differential settlement and also to provide for removal of the valves if necessary.

The crest of the emergency spillway is set at elevation 1905.0. The minimum width of the spillway is 100-feet with 4:1 side slopes.

Flood routing a 50-year flood frequency storm through the reservoir indicates that the reservoir water surface level will raise 1.1 feet. Selection of the size spillway was to provide adequate safety features for storms of cloudburst intensity. The reservoir routing computations are as follows:

RESERVOIR FLOOD ROUTING

TIME HOURS	CHANGE IN HOURS	INFLOW CFS	INFLOW AC.-FT.	TRIAL RES. ELEV.	OUTFLOW Q-CFS	OUTFLOW AC.-FT.	CHANGE IN AC.-FT.	TOTAL STORAGE AC.-FT.	RESERVOIR ELEV.	REMARKS
0				1900.0				23,995		
0.9	0.9	293	22.0	1900.0	0	0	22.0	24,017.0	1900.0	OK
1.8	0.9	1778	133.0	1900.2	6.19	0.5	132.5	24,149.5	1900.2	OK
2.7	0.9	2710	203.0	1900.5	24.5	1.8	201.2	24,350.7	1900.5	OK
3.6	0.9	2523	190.0	1900.8	49.58	3.7	186.3	24,537.0	1900.8	OK
4.5	0.9	1761	132.0	1900.9	59.16	4.4	127.6	24,664.6	1900.9	OK
5.4	0.9	934	70.0	1901.0	69.3	5.2	64.8	24,729.4	1901.0	OK
6.3	0.9	418	31.4	1901.1	75.97	6.0	25.4	24,754.8	1901.1	High Point OK
7.2	0.9	148	11.1	1901.1	75.97	6.0	5.1	24,759.9	1901.1	OK
8.1	0.9	45	3.4	1901.1	75.97	6.0	- 2.6	24,757.3	1901.1	OK

Reservoir sedimentation was based on 50 years and found to be a total of 495 acre-feet.

Evaporation and seepage losses would vary considerably depending upon the water surface area, etc. Seepage losses will be minimal several years after the reservoir is filled as porous areas become plugged with silt and the water table of adjoining lands is adjusted. Annual evaporation will be in the vicinity of 2.5 times the amount of water surface area. Following are some physical features of the Brush Creek Dam:

a.	Maximum height of dam embankment:	115.0 feet
b.	Maximum depth of reservoir at control elevation 1900.0:	100.0 feet
c.	Reservoir water surface area control elevation 1900.0:	785.0 acres
d.	Reservoir capacity at control elevation 1900.0:	24,000 acre-feet
e.	Drainage area above the dam:	33 sq. mi.

Area capacity tabulations and curve for the reservoir are attached.

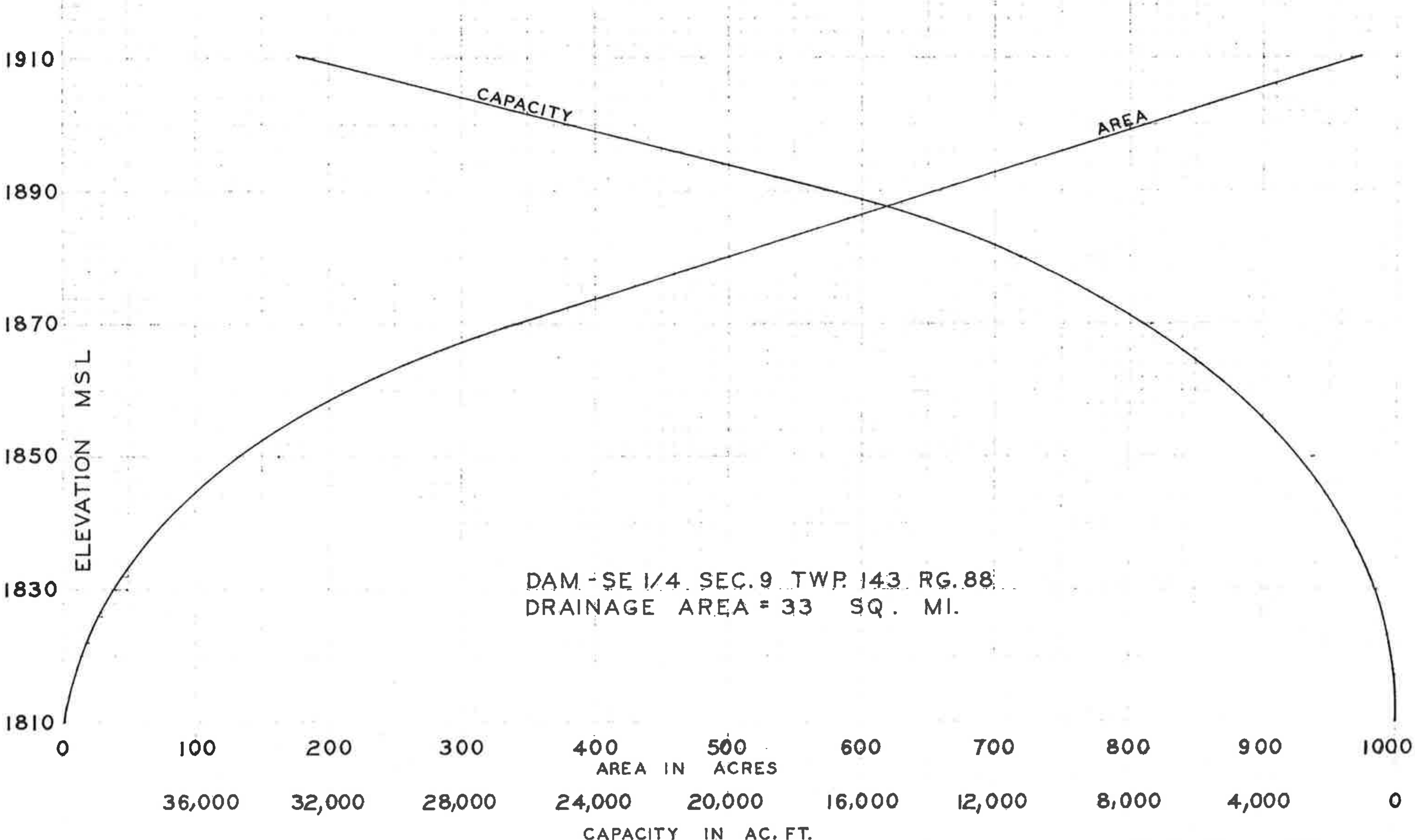
AREA CAPACITY TABULATION

ELEVATION	AREA	CAPACITY
1910	971.9	32,755.9
1905	873.6	28,142.1
1900	785.2	23,995.1
1895	695.7	20,292.8
1890	613.6	17,019.5
1885	552.2	14,105.0
1880	482.7	11,517.7
1875	416.2	9,270.4
1870	342.7	7,373.1
1865	294.5	5,780.1
1860	242.2	4,438.3
1855	199.8	3,333.3
1850	163.6	2,424.8
1845	138.9	1,668.5
1840	109.6	1,047.2
1835	73.5	589.4
1830	49.4	282.1
1825	23.5	99.8
1820	8.0	21.0
1815	.2	.5
1810	0	0

AREA CAPACITY CURVE

BEULAH DAM

SWC PROJECT NO. 1464



5 - 14 - 68 L E S

1. SOILS - The soils encountered in the borrow areas are predominantly lean to medium clays and fatty clays of the CL and CH soil group respectively. The upper 20 feet ± of the subsurface deposits are weathered brown to mottled gray-brown clays (CL) with lenticular or discontinuous fine-grained sand deposits. Maximum dry densities ranged from 105 to 115 pounds per cubic foot and optimum moistures from 14 to 19 percent. Below the depth of approximately 20 feet, the soil is a moist nonoxidized clay (CH) of the Tongue River Formation. The bedrock clay is easy to distinguish from the overlying deposits because of its gray to bluish gray color and the predominance of thinly interbedded lignite beds. The typical lignite bed is about 1 to 2 feet thick. A considerable decrease in maximum dry density occurs within the bedrock clay. This is due, no doubt, to carbonaceous deposits. Maximum dry densities ranged from 92 to 110 pounds per cubic foot and optimum moistures from 17 to 24 percent.

In order to evaluate the factor of safety of the downstream embankment slope, it was necessary to select representative samples of the borrow area for triaxial compression tests by the Highway Department testing laboratory.

Triaxial Compression Test:

The triaxial compression test Q_c is intended to provide a rapid procedure for determiming the relationship between stress and strain in a compressed soil sample under various constant lateral pressures. Six test specimens molded from disturbed borrow area samples were prepared for triaxial testing. The 6 test speciments were subject to lateral pressures of 5, 10 and 20 pounds per square inch in determining the triaxial compressive strength of the fill material. From the test results, Mohr's Stress Circles were plotted for determining the cohesion and angle of internal friction. Test values are listed below:

Test Hole No. 10:

Description of Sample: Brown Clay (CL)

Depth: 1.0 - 7.0 feet

Maximum Dry Density: 111 lbs per cu. ft.

Optimum Moisture: 16 percent

Liquid Limit: 38 percent

Plasticity Index: 19 percent

Specific Gravity: 2.58

Typical Angle of Internal Friction: Near 38°

Cohesion: 648 lbs. per sq. ft.

Test Hole No. 10:

Description of Sample: Brown Clay (CL)

Depth: 12.0 - 15.0 feet

Maximum Dry Density: 110 lbs. per cu. ft.

Optimum Moisture: 16 percent

Liquid Limit: 37 percent

Plasticity Index: 20 percent

Specific Gravity: 2.63

Typical Angle of Internal Friction: Near 27°

Cohesion: 2,261 lbs per sq. ft.

Slope Stability Analyses:

The object of such an analysis is to determine beforehand how steep or high a slope may be constructed in a given soil.

The preliminary embankment design proposed a 2:1 downstream slope with two 10-foot stability berms. The stability analysis was conducted in such a manner that the slope angle would satisfy the specified factor of safety. In selecting a numerical value as a factor of safety, the Soil Conservation Service was consulted as to their "Class of Structures" and associated factors of safety relative to slope angles. According to their engineering handbook for Work Unit Staffs, Beulah Dam would be classified as a class c structure.

> A class c structure is: Structures located where failure may cause loss of life, serious damage to homes, industrial and commercial buildings, important public utilities, main highways, or railroads.

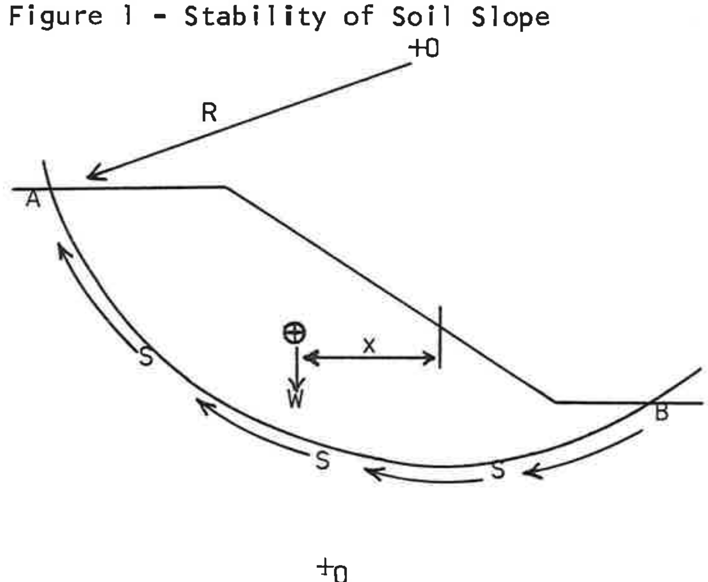
Factors of safety under this class ranged from approximately 1.25 to 1.75. A 1.75 factor of safety of the slope with respect to failure was chosen.

In many soils, particularly those possessing cohesion, failure in embankments generally take place along roughly circular arcs and consequently a method of analysis has been developed on that basis. Assuming that the soil is fairly homogeneous, our method of analysis was to draw a circle with center at point O in Figure 1 and cutting the slope in points A and B as shown in the figure. We consider that failure would most likely occur when the mass of soil to the right of and above the arc AB slides down the arc AB. From the area of the segment and its unit weight, the activating force W can be calculated through the center of gravity of the soil mass. Since motion will take place about the center of the circle 0, the weight W times the distance x of the center of gravity from the vertical through 0 gives an acting moment equal to Wx. The resisting moment is supplied by the shearing strength of the soil acting along the length of the arc AB. This moment is equal to the shearing strength s times the arc length $\overline{AB}$ times the radius of the circle R. Therefore, the factor of safety SF of the slope for the selected circle can be calculated from

$$SF = \frac{\text{resisting moment}}{\text{acting moment}} = \frac{s\overline{AB}R}{Wx}$$

Selecting a circle of differing radius or differing center or both, a new SF can be calculated by the same method. The minimum SF determined from a succession of such trials is approximately the factor of safety of the real slope.

Figure 1 - Stability of Soil Slope



The preceding method of slope analysis is essentially the same as the Highway Department used for their solution by computer programming. In Figure 2, the downstream embankment section of Beulah Dam is shown. It was necessary to establish for a given height and configuration whether or not a 2:1 downstream slope was stable for the measured values of soil cohesion, angle of internal friction and unit weight. The lower most cohesion value of 648 lbs per square foot was used to determine the factor of safety of the slope.

Slope stability calculations show a minimum value of 1.92 as the factor of safety of the real slope. As previously mentioned, the specified factor of safety of the slope with respect to failure of the 2:1 slope angle was 1.75.

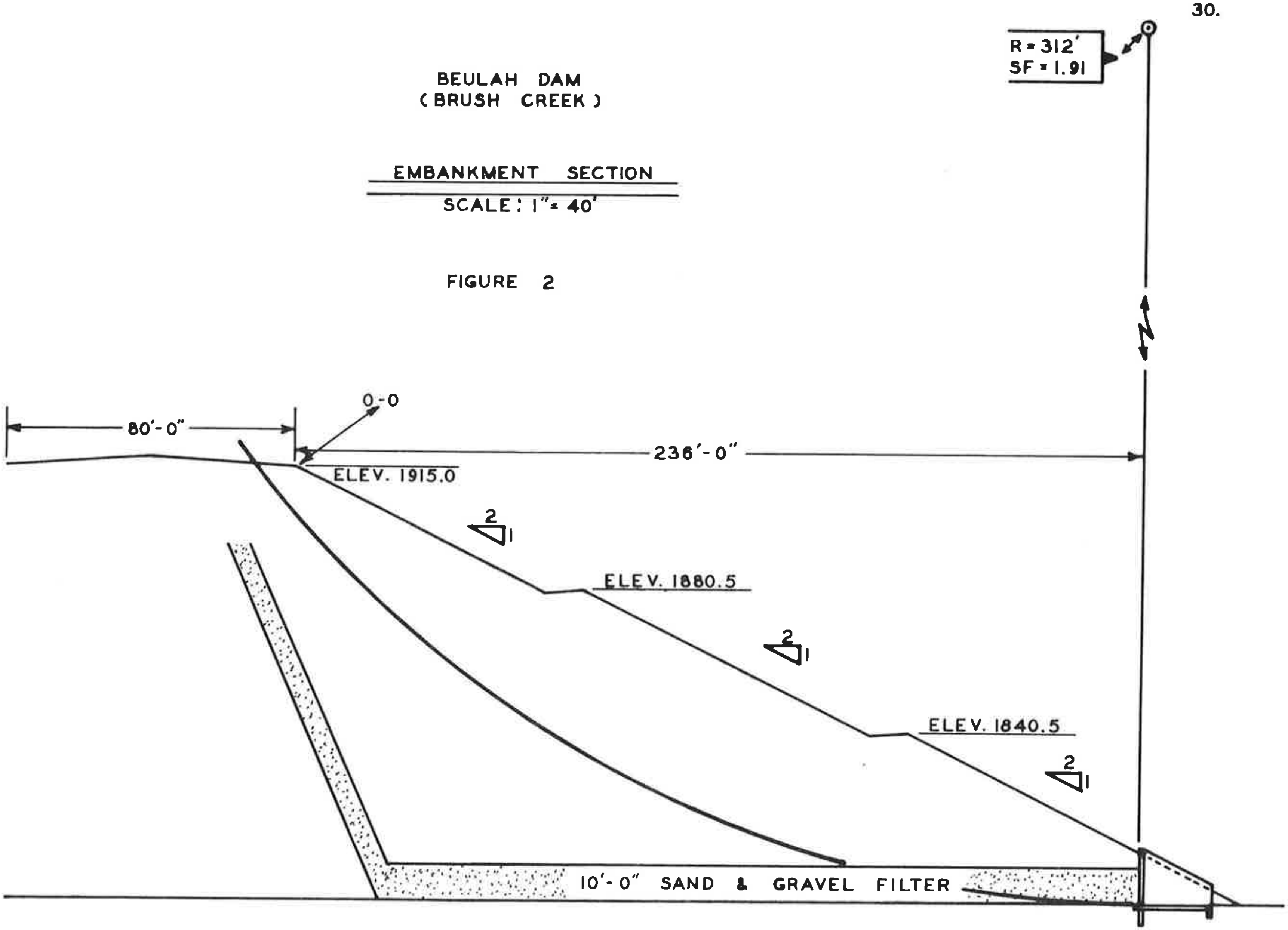
In addition to the computer programs for slope stability calculations, several stability analyses were made relative to translatory slides. It may be considered in this case that the horizontal filter, weakened by neutral stress, could cause a mass slide to occur where the initial movement is translatory or straight-line rather than rotational. Application of the translatory method of stability analysis is illustrated in Figures 3 and 4.

BEULAH DAM
(BRUSH CREEK)

EMBANKMENT SECTION

SCALE: 1" = 40'

FIGURE 2



Beulah Dam #1464
Brush Creek

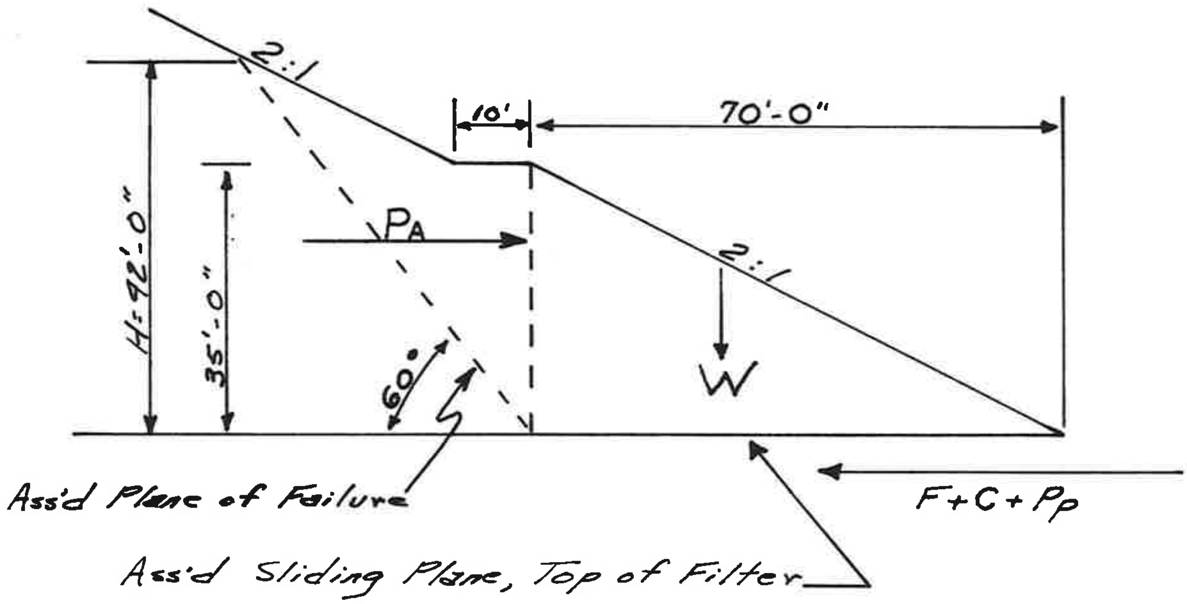


Figure 3, Translatory Analysis

$$P_a = \frac{\gamma H^2}{2}\left(\frac{1-\sin\phi}{1+\sin\phi}\right)$$

P_a = Active Pressure
γ = Unit Wt. of Soil, Use 110 lbs/cu. ft.
H = Vert. Height of Wedge, H = 42'
ϕ_1 = Angle of Internal Friction (Fill Material = 38°)
ϕ_2 " " " " (Filter Material = 35° Ass'd.)

$$P_a = \frac{(110)(42^2)}{2}\left(\frac{1-\sin 38°}{1+\sin 38°}\right)$$

$$= (55)(1764)\left(\frac{1-0.61566}{1+0.61566}\right)$$

$$= 97,020\left(\frac{0.38434}{1.61566}\right)$$

$$= 97,020(0.23788) = 23,079$$

P_a = 23,079 lbs./ft.

Weight of Sliding Block

½ x 70 x 35 x 110 = 134,750 lbs/ft.

Friction Force (F) = Normal Force (Wt. of Block) x tan ϕ_2

134,750 x tan 35°
134,750 x 0.70021 = 94,353
F = 94,353 lbs./ft.

$$SF = \frac{F+P_p+C}{P_a} =$$

$$= \frac{94,353+0+0}{23,079} = 4.09$$

SF = 4.09

Beulah Dam #1464
Brush Creek

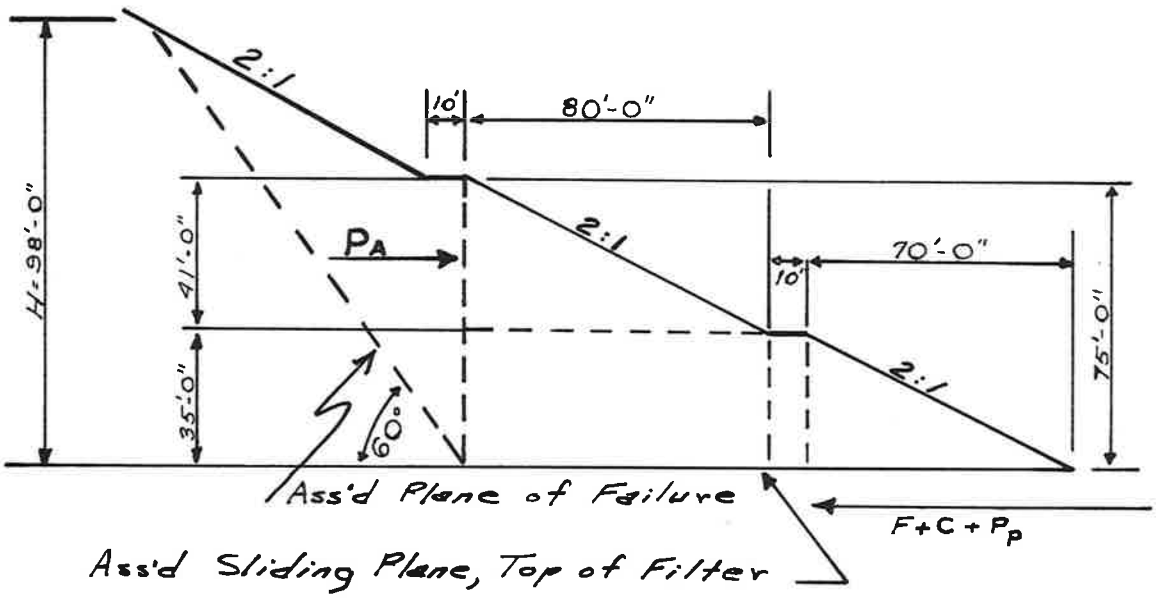


Figure 4. Translatory Analysis

$$P_a = \frac{\gamma H^2}{2}\left(\frac{1-\sin\phi}{1+\sin\phi}\right)$$

P_a = Ative Pressure
γ = Unit Wgt. of Soil, Use 110 lbs/cu. ft.
H = Vert. Height of Wedge, H = 98'
ϕ_1 = Angle of Internal Friction (Fill Material = 38°)
ϕ_2 = " " " (Filter Material = 35° Ass'd.)

$$P_a = \frac{(110)(98^2)}{2}\left(\frac{1-\sin 38°}{1+\sin 38°}\right)$$

$= (55)(9604)(0.23788)$

$= 528,220\ (0.23788)$

$P_a = 125,653$ lbs/ft.

Weight of Sliding Block

$(\tfrac{1}{2} \times 40 \times 80 + 35 \times 80 + 10 \times 35 + \tfrac{1}{2} \times 70 \times 35)(110)$
$(1600 + 2800 + 350 + 1225)(110)$
$5975 \times 110 = 657,250$
Wt. = 657,250

F = 657,250 × tan 35°
= 657,250 × 0.70021
F = 460,213 lbs/ft.

$$SF = \frac{F + P_p + C}{P_a} = \frac{460,213 + 0 + 0}{125,653}$$

SF = 3.66

B. KNIFE RIVER CHANNEL DAM - The Knife River Channel Dam is a lowhead reinforced concrete weir-type structure. The structure has a 50 foot flat section across the center and then slopes to the top of the river channel banks. Past experience on this type of structure has revealed exceptionally good hydraulic characteristics, which minimize erosion of adjoining land.

The structure has been designed for a capacity which will allow submergence of the structure with equal level of water upstream and downstream and thereby not induce flooding in the general area. The structure will be submerged as flows approach 12,000 cfs.

The control elevation is to be established at 1779.5 and the base of the apron is to be established at 1767.0, which is somewhat below the downstream channel elevation and should preclude erosion of that area immediately downstream from the dam. The over-all width of the structure is 170 feet. The total drop is 12.5 feet and the apron length 21 feet.

An 8-foot ten gage corrugated steel sheet piling cutoff wall is provided on the upstream side immediately beneath the weir of the structure. The sheet piling extends 10 feet beyond the structure at each end, which will allow for future extension should the need arise. Weep pipes are provided on the downstream cutoff wall to relieve water pressure beneath the slab. The upstream side of the weir will be coated with a waterproofing agent to preclude seepage through construction joints and/or any other pinholes which may occur in the concrete. Rock riprap will be provided 30 feet upstream from the structure, 10 feet beyond the ends of the structure and 50 feet beyond the downstream toe of the structure.

It is proposed that this structure be constructed in the dry and then the Knife River Channel diverted. After completion of the structure an approach channel and outlet channel will be constructed away from the structure. Earthfill from the approach and outlet channels will be utilized to construct an earthern plug in the Knife River in the vicinity of the structure. The balance of earth will be spread over that area of the oxbow immediately south of the structure.

The purpose of this structure is to provide a pumping pool which will be utilized in filling of the Brush Creek Dam reservoir.

The capacity of the channel dam reservoir will be in the vicinity of 200 acre-feet.

IV. COST ESTIMATE:

Following is a cost estimate for construction of the dam: (Project interests have requested that cost estimates be provided for Brush Creek Dam with a 35-foot top width and an 80-foot top width.)

A. BRUSH CREEK DAM:

1. Stripping:

   100,000 CY @$0.35 ----------------------$ 35,000.00

2. Earthfill Embankment

   2,050,000 CY @$0.40 -------------------- 820,000.00

3. Core Trench Excavation

   260,350 CY @$0.80 ---------------------- 208,280.00

4. Concrete

   112.0 CY @$150.00 -------------------------- 16,800.00

5. Reinforcing Steel

   8,000 lbs. @$0.20 ---------------------- 1,600.00

6. Reinforced Concrete Pipe

   (Service Spillway, 48" Diameter)

   370 L.F. @$80.00 ----------------------- 29,600.00

7. Drawdown Pipe

   a. Welded Steel Pipe, 24" diameter and 0.375" wall thickness, includes all couplings, cut off walls, bearing pads, etc.

      612 L.F. @$35.00 ------------------- 21,420.00

   b. Valves, 24" complete with stems and accessories

      2 valves @$3,000 ------------------- 6,000.00

c. Manhole, complete as shown on plans (Upstream side)

Lump Sum --------------------------------$ 15,000.00

d. Manhole, complete as shown on plans (Downstream side)

Lump Sum -------------------------------- 2,000.00

e. Cathodic Protection

Lump Sum -------------------------------- 1,000.00

8. Rock Riprap

65,000 Tons @$6.00 ------------------------------ 390,000.00

9. Gravel Bedding for Rock Riprap

14,000 Tons @$2.50 ------------------------------ 35,000.00

10. Filter Drain Material

(Includes excavating trenches, etc.)

160,000 Tons @$2.50 ------------------------- 400,000.00

11. Vertical Relief Wells

(Includes constructing wells and 100 Tons graded aggregate)

Lump Sum ------------------------------------ 4,000.00

12. Seeding and Placing Black Dirt

Lump Sum ------------------------------------- 10,000.00

13. Trash Rack -- 1,500.00

SUB TOTAL $1,997,200.00

B. KNIFE RIVER CHANNEL DAM:

Channel Dam:

1. Structural Excavation

Lump Sum ------------------------------------- 7,500.00

2. Concrete

   275 CY @$150.00 -----------------------------$ 41,250.00

3. Reinforcing Steel

   28,520 lbs. @$0.20 --------------------------- 5,704.00

4. Corrugated Steel Sheet Piling
   (10 gage)

   1,520 sq. ft. @$3.50 ------------------------- 5,320.00

5. Rock Riprap

   1,800 Tons @$6.00 ---------------------------- 10,800.00

6. Gravel Bedding

   600 Tons @$2.50 ------------------------------ 1,500.00

7. Earth Excavation
   Approach and Exit Channel (Includes
   construction of channel plug-4,000CY)

   55,000 CY @$0.40 ----------------------------- 22,000.00

8. Weep Pipe, Waterstop, Waterproofing
   and Miscellaneous Items

   Lump Sum ------------------------------------- 1,500.00

9. Black dirt, Fertilizing and Seeding

   Lump Sum ------------------------------------- 500.00

CHANNEL PLUG

10. Stripping

    250 CY @$0.35 -------------------------------- 87.50

11. Core Trench Excavation

    400 CY @$0.80 -------------------------------- 320.00

12. Rock Riprap

    900 Tons @$6.00 ------------------------------ 5,400.00

13. Gravel Bedding for Rock Riprap

300 Tons @ $2.50----------------------------	$ 750.00
SUBTOTAL---------	$ 102,631.50

ACCUMULATED SUBTOTALS:

BRUSH CREEK DAM-----------------------------	$1,997,200.00
KNIFE RIVER CHANNEL DAM---------------------	102,631.50
SUBTOTAL---------	$2,099,831.50
Contingencies	100,168.50
Construction Inspection	50,000.00
Contract Administration	75,000.00
TOTAL	$2,325,000.00

C. TOTAL COST FOR DAM CONSTRUCTION USING A 35-FOOT TOP WIDTH FOR BRUSH CREEK DAM:

Total Costs with 80-foot top width:		$2,325,000.00
Less		
1) Earthfill Embankment 294,540 CY @ 40 cents---------	$117,816.00	
2) Reinforced Concrete Pipe (Service Spillway, 48" Diameter) 45 L.F. @ $80------------------	3,600.00	
3) Drawdown Pipe (Welded Steel Pipe, 24" Diameter) 45 L.F. @ $35------------------	1,575.00	
SUBTOTAL		122,991.00
TOTAL COSTS WITH 35-FOOT TOP WIDTH ---------		$2,202,009.00

(Provisions will have to be incorporated in the bid proposal for utilizing material from right bank bench in the filter drains.)