HYDROLOGY AND
HYDRAULIC ANALYSIS
FOR
PENSTEMON DETENTION RESERVOIR
IN
TALL GRASS GOLF COURSE

SECTION I

INTRODUCTION

A. **Purpose:** The purpose of this report is to outline the design parameters used in the development of Penstemon Detention Reservoir in the Tall Grass Golf Course. Penstemon Detention Reservoir is one of seven reservoirs that will be used to control runoff such that there will be no net increase of stormwater runoff from development of the basin. The basin was considered to be that portion of the drainage area above 21st Street.

In order to develop the necessary design parameters for Penstemon Detention Reservoir, it is first necessary to develop a preliminary plan for Reservoir No. 1 north of 29th Street. It was assumed in the design of the Penstemon Detention Reservoir that Reservoir No. 1 would be built at some future date.

The purpose of this report is also to insure that any reservoir construction meets dam safety requirements. The calculations for the National Dam Safety Requirements will be required only when the storage volume between the top of the structure and the existing channel flowline exceeds 30 acre feet. The Division of Water Resources (DWR) does not review reservoir plans when the volume is less than 30 acre feet and does not require consideration of the Probable Maximum Precipitation (PMP) events. After initial studies, the volume of the Penstemon Detention Structure was set at less than 30 acre feet. Required storage in Lake #1 exceeds 30 acre-feet. Therefore, in final studies the PMP event must be considered, dam safety requirements met, and the reservoir reviewed by DWR.

B. **Scope:** The scope of the study involves the following major tasks:

1. Develop existing and future runoff hydrographs for the 100 year 6 hour storm event.
2. Through the use of reservoir routing, determine the maximum water surface elevations in the detention reservoirs for the 100 year 6 hour storm.
3. Develop a proposed grading plan and spillway design for each detention reservoir.

SECTION II

DESIGN METHODOLOGY

A. **Design Criteria:** The following criteria were utilized in the development of the detention reservoir:

1. The net increase in peak runoff due to development for the 100 year 6 hour storm event would be zero for the total basin above 21st Street.
2. The detention structure would be able to pass the 100 year 6 hour storm.

B. **Hydrology Computation Methods:** Runoff volumes and peak flows were calculated through the use of SCS (Soil Conservation Service) procedures.

Runoff volumes were determined through the use of SCS Hydrologic Soil Groupings and appropriate runoff curve numbers (CN) for the drainage basin under consideration. Runoff volume was also distributed over the storm duration in accordance with SCS recommendations.

Time of concentration (Tc) was determined by basin characteristics and through the use of the Kirpich Nomograph

$$Tc = \left(\frac{11.9L^3}{H}\right)^{.385}$$

L = Length of Basin (miles)
H = Elevation Difference in Basin (feet)

Unit hydrographs were developed and summed for the 100 year storm. Computer calculations utilizing SCS Soil Group Numbers, CN, Tc, drainage basin areas, etc. were performed to develop hydrographs and to provide the inflow hydrographs for routing purposes. The following formula was utilized in the computations:

$$Qp = \frac{484\ AR}{Tp}$$

where A = Area in square miles
R = Total runoff in inches (1 inch for unit hydrograph)
Tp = Time in hours from start of rise to peak rate

SECTION III

COMPUTATIONS

A. **Drainage Areas:** The total drainage area into the Penstemon Detention Reservoir is 381 acres. The drainage area into Lake #1 is 234 acres.

B. **Soil Complex Number (CN):** Discussion with the local SCS office in Wichita indicated the basin to contain 25% soil type B and 75% soil type D. From Ref. 5, p. 19 the existing condition of "Meadow: good condition" would produce a CN value of:

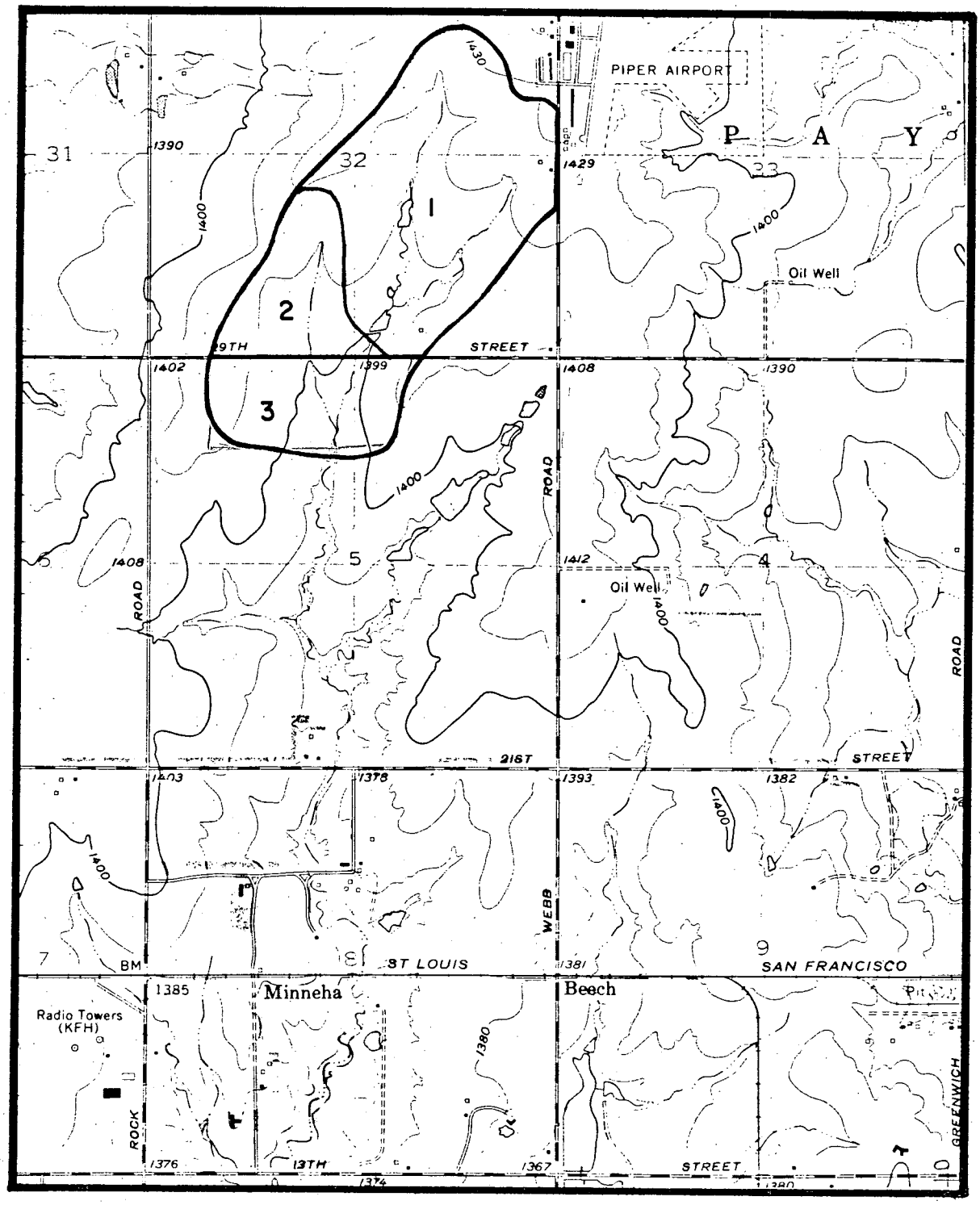
$$CN = 0.25(58) + 0.75(78) = 73$$

Development of the future CN values was done by dividing the basin into 3 sub-basins according to future planned development. These are shown on Figure 1. These areas were then used to develop a composite CN value. The calculations for this are shown in the following table.

DEVELOPMENT OF SOIL COMPLEX NUMBER

Area		% Area	Future Development	CN*	Combined CN (% Area x CN)
Lake #1					
Area 1	235 acres	100	Light Industrial	92	92
Penstemon Lake					
Area 2	76 acres	52	Light Industrial	92	48
Area 3	70 acres	48	Residential 1/4 Acre Lots	84	40
			Total CN		88
Total Basin					
Lake #1	235 acres	61.7	as above	92	56.8
Penstemon	146 acres	38.3	as above	88	33.7
			Total CN		90.5

*From Ref. 5 (Ave. 25% soil type B and 75% soil type D).



DRAINAGE AREA LAND USE

FIGURE 1

C. **Hydrographs and Detention Reservoir:** To produce the required detention, each of the reservoirs was designed to serve a dual purpose of flood control and to serve as a recreational lake. The lakes as designed would maintain a normal pool and would attenuate the 100 year 6-hour design storm to compensate for the additional development. The general shape of the lakes varies considerably from that of the existing contours to meet landscaping and storage requirements.

In order to develop an inflow hydrograph for Penstemon Lake, it was necessary to develop preliminary plans for the future lake to be located north of 29th Street. For these purposes, an orifice was provided to maintain a normal water pool elevation and a notch in the top of the structure to handle the 100 year 6 hour event. The PMP event will have to be considered and dam safety requirements met in final plans for Lake #1 because the planned storage capacity exceeds 30 acre-feet.

To produce the inflow hydrograph for Penstemon Lake, the outflow hydrograph for Lake #1 was added to the hydrograph developed for the remainder of the basin draining into Penstemon. A small orifice in the concrete dam will be provided to maintain the normal water pool elevation in Penstemon reservoir. The top of the dam will serve as the emergency spillway.

The following computations and parameters were utilized in the development of the design hydrographs, routing, and dam design.

General Procedure from Ref. 2, p. 76-83

Drainage Area - Lake #1 = 235 acres = .367 sq.mi.

Penstemon = 235 + 146 = 381 acres = .595 sq.mi.

From Ref. 3, Fig. 2-3

100 Yr, 6-hr. rainfall for 10 square miles

P = 5.9"

6 Hr. Rainfall Distributed by the Hour

(See Graph C, Fig. 2-6, Ref. 3)

Hour	%	100 yr. -6 hr. Accum. Rainfall	Inc. Rainfall
1	.08	0.5	0.5
2	.22	1.3	0.8
3	.70	4.1	2.8
4	.84	5.0	0.9
5	.93	5.5	0.5
6	1.00	5.9	0.4

Lake #1

Storage and Outflow Vs. Elevation

Elev. Ft.	Accumulated Storage Ac.Ft.	Outflow CFS	
211.00	0.00	0.00	Normal Pool
212.00	4.90	4.30	
212.50	7.40	7.30	
213.00	9.80	7.70	
214.00	16.40	13.30	
215.00	23.00	17.20	
216.00	31.90	20.30	
216.50	36.30	33.40	
217.00	40.70	55.70	
218.00	52.10	115.90	
218.50	57.80	151.90	Top of Structure
219.00	63.50	190.40	
220.00	68.30	274.90	

Penstemon Lake

Storage and Outflow Vs. Elevation

Elev. Ft.	Accumulated Storage Ac.Ft.	Outflow CFS	
203.00	0.00	0.00	Normal Pool
204.00	1.87	4.33	
204.50	2.92	7.34	
205.00	3.97	7.69	
206.00	6.56	13.31	Top of Structure
206.10	6.91	23.96	
206.20	7.27	43.06	
206.30	7.62	68.75	
206.40	7.97	98.38	
206.50	8.33	131.93	
206.60	8.68	172.06	
206.70	9.03	213.09	
206.80	9.38	261.90	
206.90	9.74	309.69	
207.00	10.09	366.84	
207.50	12.50	673.41	
208.00	14.91	1084.65	

Hydrograph and Elevation Information

	Lake #1	Penstemon
Existing 100 yr. (cfs)	402	594
Future Routed 100 yr. (cfs)	177	456
Future 100 yr. Elevation	218.82	207.14
Normal Pool Elevation	211.0	203.0
Top of Structure	218.5	206.0

Miscellaneous Information

		Lake #1	Penstemon
Spillway	Opening	1.5' x 1.5' Orifice 10' x 2.5' Notch	1.5' x 1.5' Orifice
Spillway (Upper Segment)	Width	200	112
	Side Slopes		4:1
Flood Storage (100 yr.-6 hr.)	Ac. Ft.	61.46	10.78
Storage to Top of Structure	Ac.Ft.	57.80	6.56

Individual hydrographs were developed by computer and the printout data are shown in Appendix A. The existing inflow hydrographs are based on the present undeveloped state of the drainage basin. The design inflow hydrographs are based on the future development of the entire basin. The routed outflow hydrograph from Penstemon indicates the effect of the proposed detention reservoir on the design inflow hydrographs. The 100 year 6 hour design peak inflow of cfs for the total basin was reduced via storage to a cfs peak on the reservoir outflow hydrograph. This is less than the calculated existing undeveloped peak inflow of cfs, therefore, the detention reservoirs will function to prevent any increase in peak runoff rates from the basin due to development.

REFERENCES

1. Determination of Peak Discharge From Rainfall Data for Urbanized Basins, Wichita, Kansas, U.S.G.S. Open File Report 78-974.

2. Design of Small Dams - 1974, Bureau of Reclamation.

3. Earth Dams and Reservoirs, TR 60 U.S. Dept. of Agriculture, S.C.S.

4. SCS National Engineering Handbook, Section 4.

HYDROGRAPH FROM RAINFALL AND WATERSHED DATA

GOLF COURSE LAKE NO 1 100 YEAR STORM EXISTING CONDITIONS

WATERSHED DATA

AREA (SQ.MI.)= 0.37
LENGTH (MI.) = 0.79
HEIGHT (FT.) = 32.00
CURVE NUMBER = 73.00
TIME OF CONCENTRATION(COMPUTED IF NOT GIVEN)= 0.520 HR.

RAINFALL DATA

TIME (HRS.)	TOTAL ACCUM. RAINFALL (IN.)
1.00	0.50
2.00	1.30
3.00	4.10
4.00	5.00
5.00	5.50
6.00	5.90

OUTPUT HYDROGRAPH--PLOTTING INTERVAL 0.25 HRS.

TIME (HRS.)	DISCHARGE Q CFS
0.25	0.0
0.50	0.0
0.75	0.0
1.00	0.0
1.25	0.0
1.50	1.0
1.75	8.6
2.00	22.8
2.25	81.6
2.50	203.2
2.75	320.4
3.00	401.7
3.25	370.3
3.50	249.7
3.75	177.2
4.00	163.6
4.25	147.5
4.50	116.1
4.75	98.5
5.00	95.3
5.25	91.1
5.50	83.2
5.75	78.8
6.00	77.7
6.25	57.3
6.50	22.6
6.75	3.5

HYDROGRAPH FROM RAINFALL AND WATERSHED DATA

LAKE 1, 100 YR STORM DEVELOPED L200 NP211 OR1.5X1.5 N10 AT 216 TOP218.5

WATERSHED DATA

AREA (SQ.MI.)= 0.37
LENGTH (MI.) = 0.79
HEIGHT (FT.) = 32.00
CURVE NUMBER = 92.00
TIME OF CONCENTRATION(COMPUTED IF NOT GIVEN)= 0.520 HR.

RAINFALL DATA

TIME (HRS.)	TOTAL ACCUM. RAINFALL (IN.)
1.00	0.50
2.00	1.30
3.00	4.10
4.00	5.00
5.00	5.50
6.00	5.90

OUTPUT HYDROGRAPH--PLOTTING INTERVAL 0.25 HRS.

TIME (HRS.)	DISCHARGE Q CFS
0.25	5.2
0.50	7.2
0.75	13.0
1.00	27.5
1.25	56.1
1.50	92.7
1.75	120.9
2.00	138.6
2.25	252.8
2.50	457.0
2.75	585.9
3.00	627.6 ←
3.25	529.7
3.50	338.6
3.75	230.8
4.00	208.9
4.25	186.0
4.50	144.6
4.75	121.5
5.00	116.8
5.25	111.0
5.50	100.6
5.75	94.9
6.00	93.4
6.25	69.4
6.50	27.5
6.75	4.4

OUTFLOW HYDROGRAPH FROM STORAGE AND OUTLET DATA

LAKE 1, 100 YR STORM DEVELOPED L200 NP211 OR1.5X1.5 N10 AT 216 TOP218.5

STORAGE AND OUTFLOW VS. ELEVATION

ELEV. FT.	STORAGE AC.FT.	OUTFLOW CFS
211.00	0.00	0.00
212.00	4.90	4.30
212.50	7.40	7.30
213.00	9.80	7.70
214.00	16.40	13.30
215.00	23.00	17.20
216.00	31.90	20.30
216.50	36.30	33.40
217.00	40.70	55.70
218.00	52.10	115.90
219.00	63.50	190.40
220.00	68.30	274.90

DISCHARGE, STORAGE, AND ELEVATION VS TIME

TIME HRS.	Q-IN CFS	Q-OUT CFS	STORAGE AC.FT.	ELEV. FT.
0.00	0.00	0.00	0.00	211.00
0.25	5.22	0.09	0.10	211.02
0.50	7.20	0.22	0.25	211.05
0.75	13.06	0.45	0.51	211.10
1.00	27.50	0.93	1.06	211.21
1.25	56.19	1.93	2.20	211.44
1.50	92.74	3.56	4.06	211.82
1.75	120.99	6.17	6.46	212.31
2.00	138.66	7.59	9.17	212.86
2.25	252.83	11.44	14.20	213.66
2.50	457.01	17.32	23.34	215.03
2.75	585.95	29.68	35.05	216.35
3.00	627.62	87.99	46.81	217.53
3.25	529.76	137.63	55.42	218.29
3.50	338.62	162.79	59.27	218.62
3.75	230.81	171.24	60.56	218.74
4.00	208.98	175.94	61.28	218.80
4.25	186.05	177.11 ←	61.46	218.82
4.50	144.65	172.92	60.82	218.76
4.75	121.51	166.37	59.82	218.67
5.00	116.81	160.08	58.86	218.59
5.25	111.05	153.86	57.91	218.50
5.50	100.69	147.14	56.88	218.41
5.75	94.90	140.55	55.87	218.33
6.00	93.47	134.63	54.96	218.25
6.25	69.44	126.40	53.70	218.14
6.50	27.57	114.31	51.80	217.97
6.75	4.49	103.47	49.74	217.79

HYDROGRAPH FROM RAINFALL AND WATERSHED DATA

PENSTEMON LAKE ENTIRE DRAINAGE BASIN EXISTING CONDITIONS 100 YR STORM

WATERSHED DATA

AREA (SQ.MI.)= 0.60
LENGTH (MI.) = 1.02
HEIGHT (FT.) = 33.00
CURVE NUMBER = 73.00
TIME OF CONCENTRATION(COMPUTED IF NOT GIVEN)= 0.690 HR.

RAINFALL DATA

TIME (HRS.)	TOTAL ACCUM. RAINFALL (IN.)
1.00	0.50
2.00	1.30
3.00	4.10
4.00	5.00
5.00	5.50
6.00	5.90

OUTPUT HYDROGRAPH--PLOTTING INTERVAL 0.25 HRS.

TIME (HRS.)	DISCHARGE Q CFS
0.25	0.0
0.50	0.0
0.75	0.0
1.00	0.0
1.25	0.0
1.50	1.3
1.75	9.7
2.00	27.6
2.25	98.4
2.50	242.2
2.75	416.4
3.00	570.2
3.25	594.0 ←
3.50	484.5
3.75	367.1
4.00	289.0
4.25	247.8
4.50	211.0
4.75	179.5
5.00	160.2
5.25	150.1
5.50	140.7
5.75	132.8
6.00	126.2
6.25	101.7
6.50	58.4
6.75	24.6
7.00	4.9
7.25	0.0

HYDROGRAPH FROM RAINFALL AND WATERSHED DATA

PENSTEMON LAKE Inflow Hydrograph 100 YEAR STORM ~~DRAINAGE AREA IN ADITION TO FUTURE LAKE BASIN DEVELOPED~~

WATERSHED DATA

AREA (SQ.MI.)=	0.23
LENGTH (MI.) =	0.68
HEIGHT (FT.) =	29.00
CURVE NUMBER =	88.00

TIME OF CONCENTRATION(COMPUTED IF NOT GIVEN)= 0.454 HR.

RAINFALL DATA

TIME (HRS.)	TOTAL ACCUM. RAINFALL (IN.)
1.00	0.50
2.00	1.30
3.00	4.10
4.00	5.00
5.00	5.50
6.00	5.90

OUTPUT HYDROGRAPH--PLOTTING INTERVAL 0.25 HRS.

TIME (HRS.)	DISCHARGE Q CFS Basin	+	Q-OUT CFS Future Lake	=	Qin Penstemon
0.25	10.7		0.00		0.00
0.50	9.6		0.09		10.80
0.75	4.2		0.22		9.80
1.00	6.9		0.45		4.70
1.25	21.2		0.93		7.80
1.50	40.8		1.93		23.10
1.75	57.3		3.56		44.40
2.00	72.4		6.17		63.50
2.25	151.5		7.59		80.00
2.50	273.8		11.44		162.90
2.75	346.2		17.32		291.10
3.00	364.6		29.68		375.90
3.25	294.7		87.99		452.60
3.50	180.4		137.63		432.30
3.75	129.6		162.79		343.20
4.00	125.0		171.24		300.80
4.25	108.2		175.94		300.90
4.50	82.7		177.11		285.30
4.75	71.5		172.92		255.60
5.00	70.6		166.37		237.90
5.25	66.4		160.08		230.70
5.50	59.9		153.86		220.30
5.75	57.1		147.14		207.00
6.00	52.2		140.55		197.70
6.25	25.2		134.63		186.80
6.50	5.2		126.40		151.60
6.75	0.0		114.31		119.50
			103.47		103.5

HYDROGRAPH FROM RAINFALL AND WATERSHED DATA

PENSTEMON LAKE 100 YEAR STORM DEVELOPED, INPUT HYD, NP203 TOP206 1.5X1.5

WATERSHED DATA

AREA (SQ.MI.)= 0.60
LENGTH (MI.) = 1.02
HEIGHT (FT.) = 33.00
CURVE NUMBER = 90.50
TIME OF CONCENTRATION(COMPUTED IF NOT GIVEN)= 0.690 HR.

RAINFALL DATA

TIME (HRS.)	TOTAL ACCUM. RAINFALL (IN.)
1.00	0.50
2.00	1.30
3.00	4.10
4.00	5.00
5.00	5.50
6.00	5.90

OUTPUT HYDROGRAPH--PLOTTING INTERVAL 0.25 HRS.

TIME (HRS.)	DISCHARGE Q CFS
0.25	10.8
0.50	9.8
0.75	4.7
1.00	7.8
1.25	23.1
1.50	44.4
1.75	63.5
2.00	80.0
2.25	162.9
2.50	291.1
2.75	375.9
3.00	452.6
3.25	432.3
3.50	343.2
3.75	300.8
4.00	300.9
4.25	285.3
4.50	255.6
4.75	237.9
5.00	230.7
5.25	220.3
5.50	207.0
5.75	197.7
6.00	186.8
6.25	151.6
6.50	119.5
6.75	103.5
7.00	0.0

OUTFLOW HYDROGRAPH FROM STORAGE AND OUTLET DATA

PENSTEMON LAKE 100 YEAR STORM DEVELOPED, INPUT HYD, NP203 TOP206 1.5X1.5

STORAGE AND OUTFLOW VS. ELEVATION

ELEV. FT.	STORAGE AC.FT.	OUTFLOW CFS
203.00	0.00	0.00
204.00	1.87	4.33
204.50	2.92	7.34
205.00	3.97	7.69
206.00	6.56	13.31
206.10	6.91	23.96
206.20	7.27	43.06
206.30	7.62	68.75
206.40	7.97	98.38
206.50	8.33	131.93
206.60	8.68	172.06
206.70	9.03	213.09
206.80	9.38	261.90
206.90	9.74	309.69
207.00	10.09	366.84
207.50	12.50	673.41
208.00	14.91	1084.65

DISCHARGE, STORAGE, AND ELEVATION VS TIME

TIME HRS.	Q-IN CFS	Q-OUT CFS	STORAGE AC.FT.	ELEV. FT.
0.00	0.00	0.00	0.00	203.00
0.25	10.80	0.50	0.21	203.11
0.50	9.80	0.93	0.40	203.21
0.75	4.70	1.11	0.48	203.25
1.00	7.80	1.42	0.61	203.32
1.25	23.10	2.43	1.05	203.56
1.50	44.40	4.41	1.90	204.01
1.75	63.50	7.39	3.08	204.57
2.00	80.00	9.01	4.58	205.23
2.25	162.90	74.70	7.69	206.32
2.50	291.10	331.08	9.87	206.93
2.75	375.90	378.06	10.17	207.01
3.00	452.60	455.61	10.78	207.14
3.25	432.30	416.34	10.47	207.08
3.50	343.20	314.50	9.76	206.90
3.75	300.80	293.95	9.62	206.86
4.00	300.90	299.24	9.66	206.87
4.25	285.30	284.51	9.55	206.84
4.50	255.60	254.46	9.32	206.78
4.75	237.90	241.20	9.23	206.75
5.00	230.70	237.48	9.20	206.74
5.25	220.30	227.75	9.13	206.73
5.50	207.00	215.19	9.04	206.70
5.75	197.70	208.26	8.98	206.68
6.00	186.80	199.30	8.91	206.66
6.25	151.60	162.97	8.60	206.57
6.50	119.50	132.57	8.33	206.50

Why build this lake at all ?