Hydrology and Hydraulic Analysis for the Fantasea Lake and Fantasea Development in Wichita, Kansas

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Van Doren-Hazard-Stallings
Architects-Engineers-Planners
Wichita-Topeka-Minneapolis-Kansas City

Table of Contents

SECTION I

INTRODUCTION

A. **Purpose:** The purpose of this study is to evaluate the use of a detention reservoir for the Fantasea development such that there will be no net increase of stormwater runoff from development of the basin and to insure that any reservoir construction meets dam safety requirements.

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. Develop emergency spillway and freeboard hydrographs based on the PMP (Probable Maximum Precipitation) event for the area.
3. Through the use of reservoir routing, determine the maximum water surface elevations in the detention reservoir for the 100 year 6 hour storm and for the PMP emergency spillway and freeboard hydrographs.
4. Develop a proposed grading plan for the 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.
2. The detention structure would be able to pass the 100 year 6 hour storm and maintain a minimum freeboard of three feet under the condition in item 1 above.
3. The detention dam would be classified as "high hazard" and would meet requirements of the Division of Water Resources concerning the PMP (Probable Maximum Precipitation) storm event, i.e., contain the freeboard hydrograph and allow at least 3' freeboard for emergency spillway hydrograph.

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 was determined by basin characteristics and through the use of the Kirpich Nomograph

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

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

Unit hydrographs were developed and summed for the 100 year storm as well as the PMP storm event. 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

The relationship of Tp to storm duration and time of concentration was established through the relationship of Tp = D/2 + 0.6 Tc. Therefore the formula for peak flow took the form of;

$$Qp = \frac{484\ AR}{D/2 + 0.6\ Tc}$$

where D = Duration of storm event (or storm segment for unit hydrograph)
Tc = Time of concentration

The inflow hydrographs for the various conditions were routed through the detention reservoir by use of a computer model and checked with a graphical system. Within the computer program, an elevation-storage curve and elevation-discharge curve for the reservoir were developed and used to formulate a routing curve known as the "$\frac{2S}{t} + O$" curve. With this curve and the inflow hydrograph, an outflow hydrograph was developed.

In development of the discharge curve, the flow in the outlet pipe was omitted because of its relatively low capacity and the high possibility it could become partially or completely plugged by debris during high flows.

The following references were utilized for the computations:

1. Design of Small Dams - 1974, Bureau of Reclamation.
2. Probable Maximum Precipitation Estimates, U.S. East of 105th Meridian. HR No. 51, U.S. Dept. of Commerce.
3. Earth Dams and Reservoirs, TR 60 U.S. Dept. of Agriculture. SCS.
4. SCS National Engineering Handbook, Section 4.
5. Determination of Peak Discharge From Rainfall Data for Urbanized Basins, Wichita, Kansas, U.S.G.S. Open File Report 78-974.

SECTION III

COMPUTATIONS

A. **Drainage Areas:** The project drainage area consists of approximately 151 acres of presently undeveloped land. Drainage from this area will pass directly through the Fantasea site and the detention reservoir.

B. **Hydrographs and Detention Reservoir:** To produce the required detention, a reservoir was designed to serve a dual purpose of flood control and also to serve as a recreational lake for the Fantasea development. The lake as designed would maintain a normal pool and would attenuate the 100 year 6 hour design storm to compensate for the additional development.

In order to meet landscaping and storage requirements, the general shape of the structure varies considerably from that of existing contours. A small pipe (18 inches in diameter) would be provided to maintain the normal water pool elevation. In addition, an emergency spillway would be provided to pass the storm flows based on probable maximum precipitation events.

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

General Procedure from Ref. 1, p. 76-83

Drainage Area - 151 Acres - 0.236 $mi.^2$

Rainfall - Ref. 2

Fig. 18 All season PMP for 6 hr. 10 $m.^2$ = 27.7"

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)

		PMP - 6 hr.		100 yr. - 6 hr.	
Hour	%	Accum. Rainfall	Inc. Rainfall	Accum. Rainfall	Inc. Rainfall
1	.08	2.2	2.2	0.5	0.5
2	.22	6.1	3.9	1.3	0.8
3	.70	19.4	13.3	4.1	2.8
4	.84	23.3	3.9	5.0	0.9
5	.93	25.8	2.5	5.5	0.5
6	1.00	27.7	1.9	5.9	0.4

Soil Complex Number (CN)

100 Yr. Storm

25% Soil Type B, 75% Soil Type D

From Local SCS Office in Wichita

From Ref. 5, p. 19

Existing Condition:

Meadow: good condition

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

Future Condition:

1/4 Acre residential lot, 38% impervious

CN = 0.25 (75) + (0.75) 87 = 84

PMP

From Ref. 1, Table A-7, p. 543

Assume above condition is II

From table:

CN = 73 becomes CN = 87

CN = 84 becomes CN = 93

Dam Design

Assume we are in a high hazard area. Therefore design for following precipitation conditions:

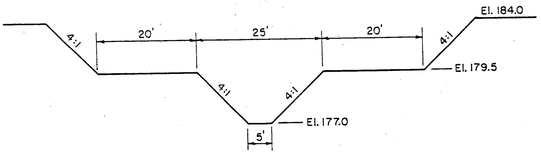
Freeboard Hydrograph - Use PMP

Emergency Spillway Hydrograph - Use $P_{100} + 0.26\ (PMP - P_{100})$

Emergency Spillway - Rainfall

Hour	PMP	P_{100}	PMP-P_{100}	$P_{100} + 0.26\ (PMP-P_{100})$
1	2.2	0.5	1.7	0.9
2	6.1	1.3	4.8	2.5
6	19.4	4.1	15.3	8.1
4	23.3	5.0	18.3	9.8
5	25.8	5.5	20.3	10.8
6	27.7	5.9	21.8	11.6

Emergency Spillway Design



Detention Reservoir Information

Elevation (ft.)	Accum. Storage (Ac. ft.)	Discharge (cfs)	
175	0	-	(Normal Pool)
176	4.0	-	
177	8.0	0	
178	13.0	12	
179	19.0	92	
180	25.0	261	
181	31.0	734	
182	39.0	1573	
183	48.0	2653	

Table 2 indicates the pertinent flows and elevations for the design of the reservoir.

Table 2

	Inflow (cfs)	Outflow (cfs)	Max. Elevations
Existing 100 yr.	213	-	-
Future 100 yr.	293	198	179.62
Emergency Spillway	724	699	180.92
Freeboard	1743	1743	182.16
Top of Dam	-	-	184.0
Spillway (Upper Segment)	-	-	179.5
Spillway (Main Channel)	-	-	177.0
Normal Pool	-	-	175.0

Spillway (Main Channel)	Width	5 feet
	Side Slopes	4:1
	Top Width	25 feet
Spillway (Upper Segment)	Width	65 feet
	Side Slopes	4:1
	Top Width	101 feet

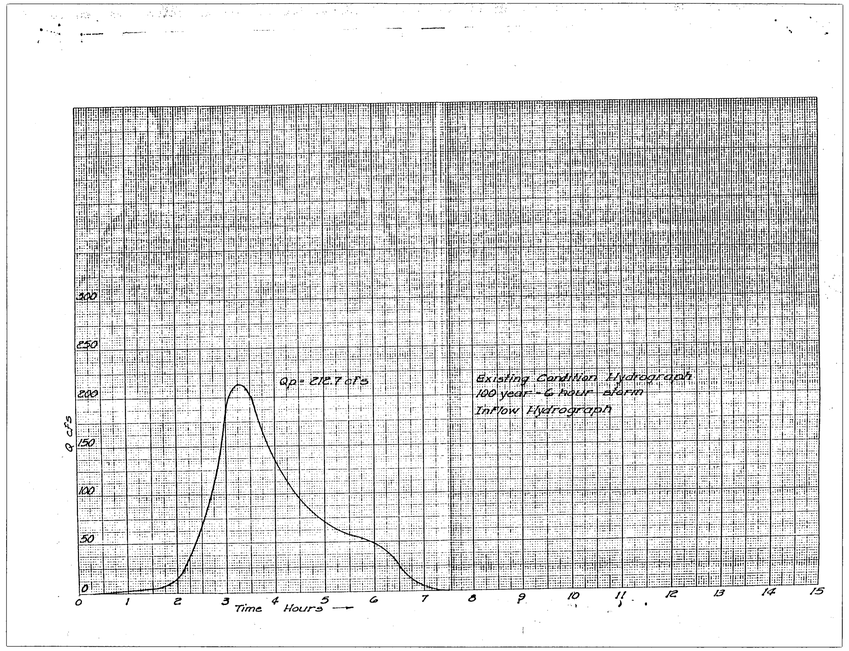
Flood Storage (100 yr-6 hr)	22.7 AFT
Outlet Pipe (Normal Pool)	18 inches

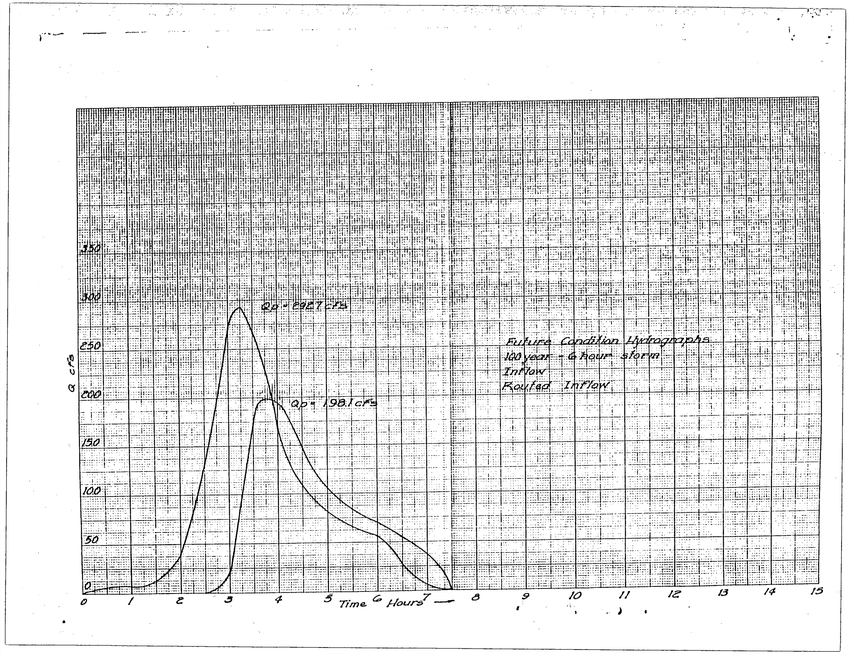
Individual hydrographs were developed and are shown in Appendix A. The existing inflow hydrograph is based on the present undeveloped state of the drainage basin. The design inflow hydrograph is based on the future development of the entire basin. The routed outflow hydrograph indicates the effect of the proposed detention reservoir on the design inflow hydrograph. The hydrographs of the PMP storm event also indicate the effect of the detention reservoir.

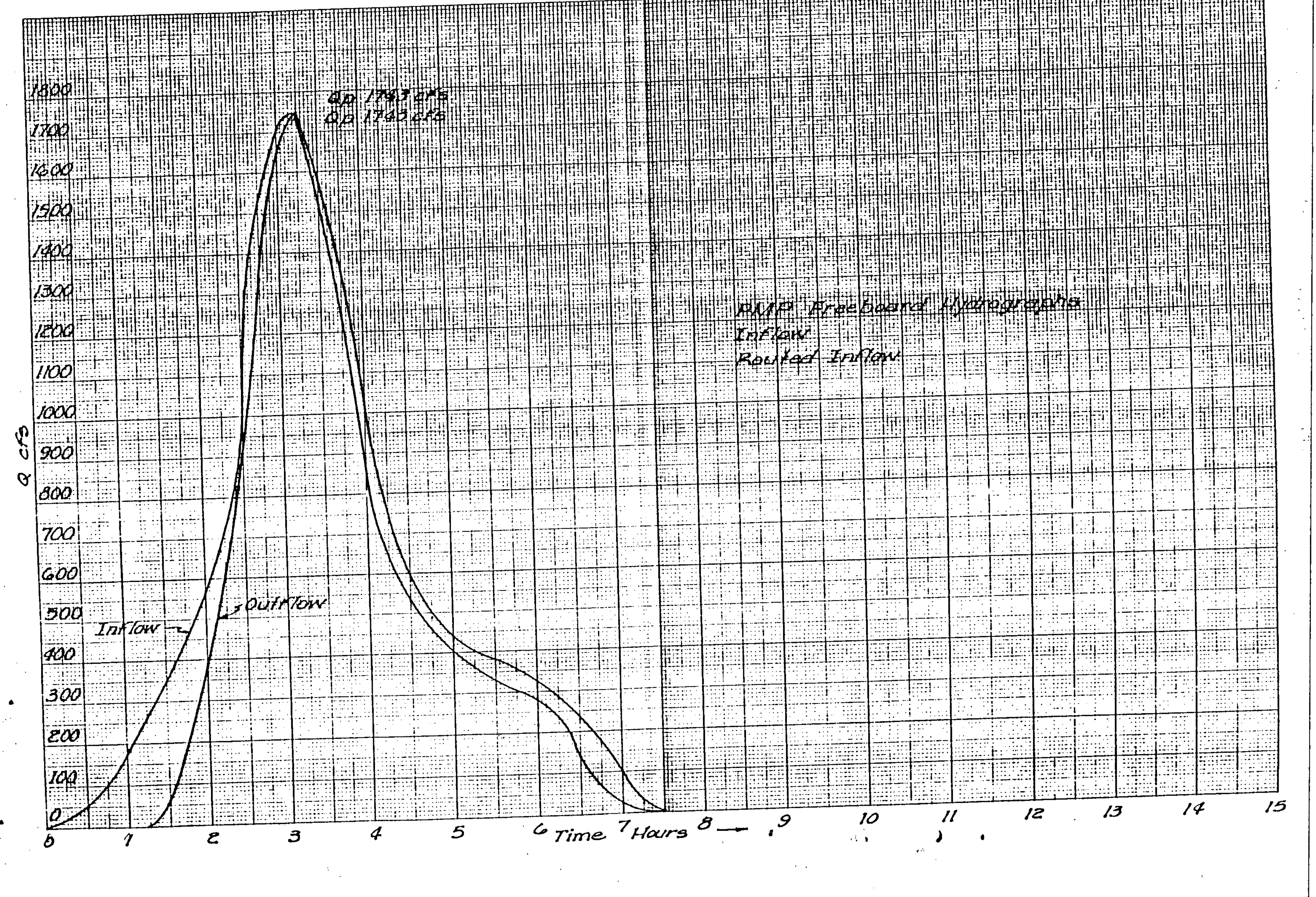
The 100 year 6 hour design peak inflow of 293 cfs was reduced via storage to a 198 cfs peak on the reservoir outflow hydrograph. This is less than the calculated existing undeveloped peak inflow of 213 cfs, therefore the detention reservoir will function to prevent any increase in peak runoff rates from the basin due to development. In addition, the detention reservoir will meet spillway and freeboard requirements to provide adequate dam safety for the PMP storm event.

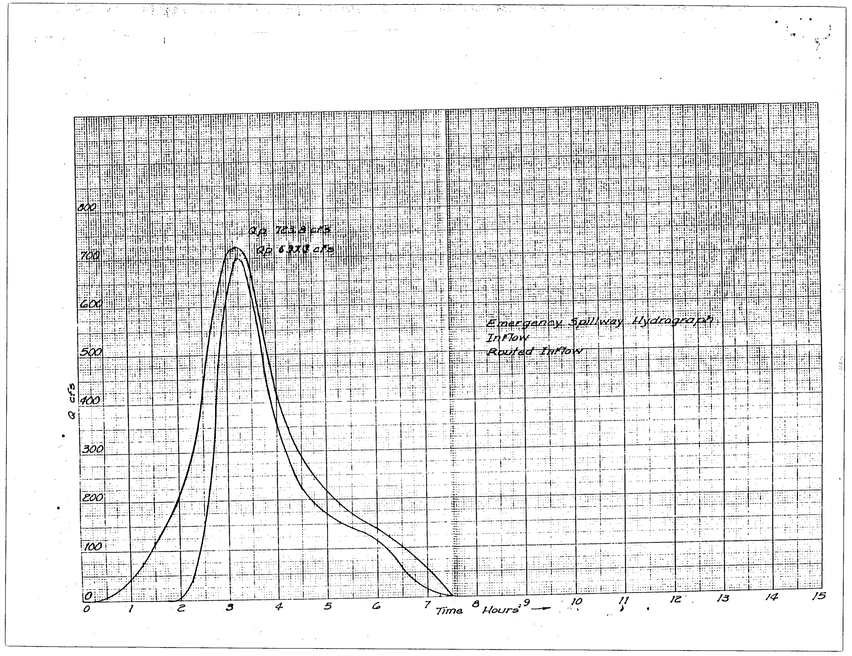
APPENDIX A

HYDROGRAPHS


Qp = 212.7 cfs
Existing Condition Hydrograph
100 year - 6 hour storm
Inflow Hydrograph
Q cfs
300
250
200
150
100
50
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Time Hours


Future Condition Hydrographs
100 year - 6 Hour Storm
Inflow
Routed Inflow
Q = 2927 cfs
Q = 1981 cfs
Q cfs
Time in Hours
0
50
100
150
200
250
300
350
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15


Qp 1743 cfs
Qp 1740 cfs
PMP Freeboard Hydrographs
Inflow
Routed Inflow
Inflow
Outflow
Q cfs
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
0
1
2
3
4
5
6
Time
7
Hours
8
9
10
11
12
13
14
15


Emergency Spillway Hydrograph
Inflow
Routed Inflow
Q in cfs
Time in Hours
0
100
200
300
400
500
600
700
800
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15