DAMBREAK STUDY REPORT

FOR

GUADALUPE FLOOD RETARDING STRUCTURE

FLOOD CONTROL DISTRICT

OF

MARICOPA COUNTY

FCD 88-65

MAY, 1990

Greiner

Dambreak Study Report
For
Guadalupe Flood Retarding Structure

Submitted to:
Flood Control District of Maricopa County
Maricopa County, Arizona
Contract No. FCD 88-65

Submitted by:
Greiner, Inc.
7310 N. 16th Street, Suite 160
Phoenix, Arizona 85020
(602) 275-5400

Registered Professional Engineer (Civil)
CERTIFICATE NO.
17756
SHU-EN
SHIAU
Date Signed 5/15/90
ARIZONA, U. S. A.

Job No. E124034

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Registered Professional Engineer (Civil)
CERTIFICATE NO.
17756
Date Signed 5/15/98
ARIZONA, U.S.A.

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1. EXECUTIVE SUMMARY

The three dams of the Guadalupe Flood Retarding Structure (GFRS) were studied individually by utilizing the DAMBRK program developed by the National Weather Service (NWS). Inundation maps were prepared for evacuation use in the event of dam failure.

One-half Probable Maximum Precipitation (PMP) was developed per Hydrometeorological Report No. 49 and was input as inflow hydrograph to the dambreak analysis (see Section 3).

To determine the breach parameters, three methods were used: 1) the Statistical Method, 2) the Parametric Method, and 3) the Breach Erosion Method. A sensitivity test was conducted to derive the breach parameters to be used in the final DAMBRK models. Test runs for Reservoir Storage Routing and Dynamic Routing were then conducted to verify the effect for downstream routing (see Section 4).

Inundation area routing was also studied and discussed in this report. Two conditions were considered when the routing models were developed: with- and without-block-walls. The results show that the maximum elevation generally increases and the maximum flow decreases when the block walls are included in the model. The inundation map was developed based on this result.

The floodplain boundaries were delineated on the inundation map on which areas with various water depths were identified for estimating damage costs due to dam breach (see Section 5).

2. INTRODUCTION

A. Purpose

As part of its Safety of Dams Program, the Arizona Department of Water Resources (ADWR) requested the Flood Control District of Maricopa County (FCD) to prepare Emergency Action Plans for all dams within its jurisdiction which includes the GFRS. The plans would include maps delineating the areas that will be inundated should the dams fail and evacuation plans. The FCD determined the dambreak analysis to be performed using the NWS DAMBRK computer program.

The DAMBRK model was first presented by Daniel Fread, Senior Research Hydrologist of NWS, in 1977 and was updated several times since then. The latest version of the model, DAMBRK-88, was used for this project. This computer model is used to develop an outflow hydrograph from a dam and hydraulically route the flood through the downstream valley.

There are three dams within this flood retarding structure. Greiner, Inc. was contracted by the FCD in August 1989 to perform the DAMBRK analysis for these dams and prepare the inundation area maps for evacuation use in the event of dam failure.

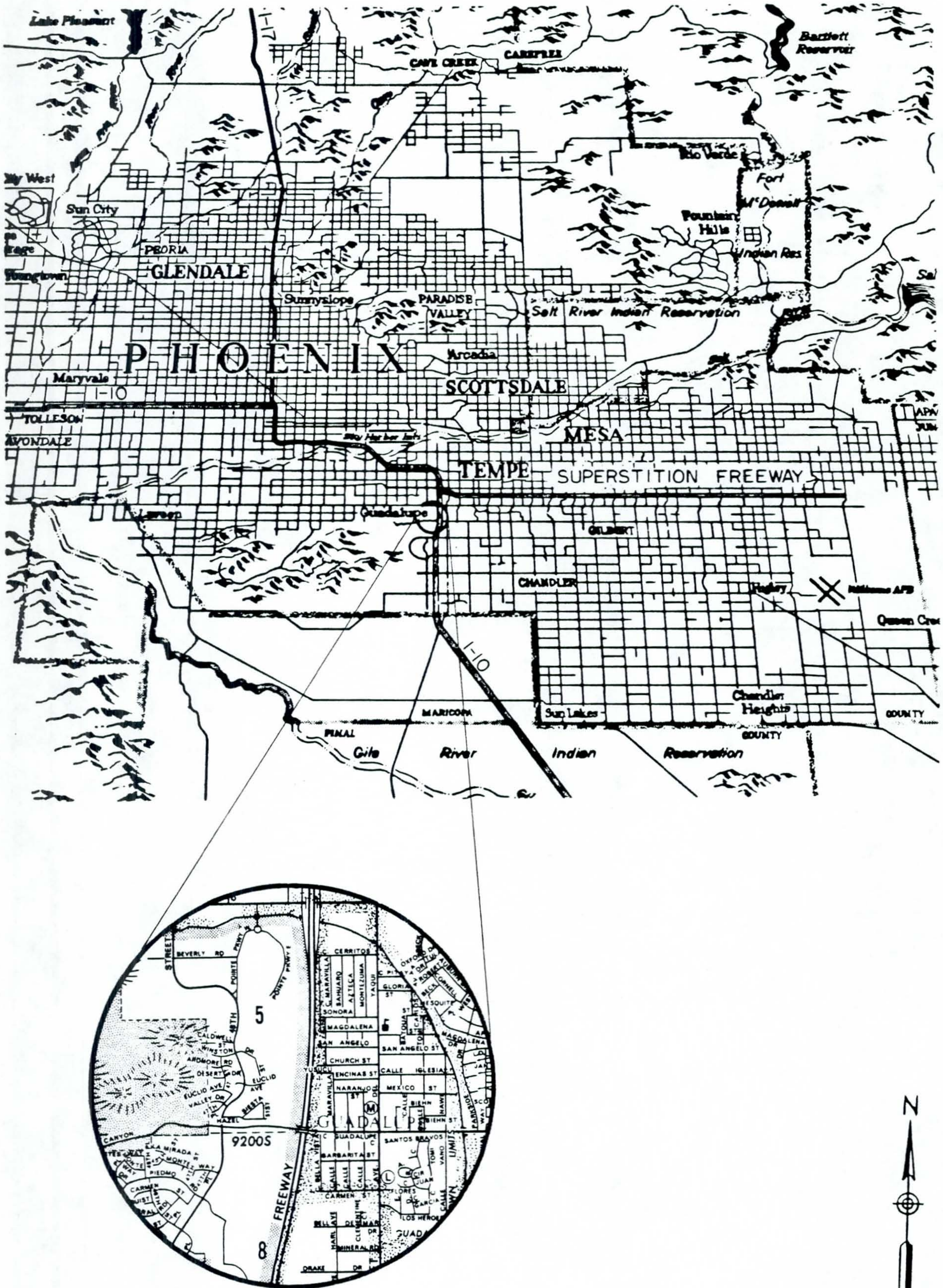
B. Project Description

The GFRS is a small flood control structure located midway between Baseline Road and Guadalupe Road just west of Interstate Highway 10 (I-10), Phoenix, Arizona (Figure 1). The GFRS consists of three dams, North Dam No. 1 (Saddledike section), North Dam No. 2 (center section) and East Dam (I-10 section). An emergency overflow spillway, approximately 200 feet wide and with crest at elevation 1,274 feet, is located between North Dam No. 1 and the Pointe Parkway. The principal spillway is a 30-inch controlled low level outlet pipe structure extended through North Dam No. 2. The pipe conveys floodwater released from the GFRS to the Western Canal, which is located approximately 5,470 feet to the north. The upstream inlet consists of an ungated standpipe with a gated inlet at the bottom.

The GFRS was constructed in 1975 by the Soil Conservation Service (SCS) to reduce the potential for floodwater and sediment damage from the 100-year flood to the community of Guadalupe and the surrounding portions of the cities of Phoenix and Tempe. Significant flood damages had been incurred as recently as 1969 (Reference 1).

The GFRS was originally constructed on state-owned land. As the local sponsor, the FCD obtained a perpetual easement from the state for the purpose of maintaining the structure. In 1981, Gosnell Development Corporation, developer of the Pointe at South Mountain, obtained ownership of the site through land trades with the state. Subsequently, the structure was incorporated into the resort's golf course. The FCD still maintains operational control of the GFRS and is responsible for the structural and functional integrity of the facility. The developer is responsible for maintaining the emergency spillway, erosion control of the embankments and landscaping.

Land uses within the GFRS watershed are either related to the Pointe at South Mountain Resort development or the Phoenix South Mountain Park Preserve (Figure



PROJECT VICINITY MAP

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FIGURE 1

2). The Pointe at South Mountain is a high density, mixed-use development anchored by a resort complex comprised of hotels, restaurants, golf courses and other related amenities. Commercial and office buildings, detached and multiple residential units are located around the resort core. The Phoenix South Mountain Park Preserve is an undeveloped desert mountain area dedicated for preservation in its current natural state. Improvements within the park are limited to paved and unpaved access roads and trails. A small portion of the Pointe development golf course extends into public lands through a lease agreement with the City of Phoenix which owns the park.

C. Scope of Study

The scope of study was to perform the DAMBRK analysis for the GFRS and develop the evacuation plans for the area downstream of the structure in the event of a dam failure, based on the best available information, hydrologic and hydraulic methodologies, and current ADWR dam safety criteria. The information obtained through site reconnaissance is also incorporated.

The Scope did not include on-site physical testings to obtain data for analysis and interpretation. No remedial solutions are provided for protecting the downstream properties from flooding.

The project consists of hydrology/hydraulics, dambreak analysis and development of evacuation plans. The objectives are:

- o Collect and review all available published and unpublished hydrological, geotechnical and as-built information.
- o Conduct site investigations to verify existing hydrological and hydraulic data, and research for unfound information.
- o Perform hydrological model simulations for the inflow hydrograph.
- o Perform sensitivity analysis on various models to obtain representative breach width and time to failure for each dam.
- o Complete dambreak analysis by defining breach parameters, selecting breach locations, developing failure outflow hydrographs, and performing downstream routing.
- o Prepare evacuation plans based on the interpretation of DAMBRK results.
- o Estimate the structural inventory within the inundation areas.
- o Analyze the economic and social impacts to the downstream areas.
- o Prepare technical memorandums, hydrological report and dambreak report for this study with supporting tables, graphs and drawings.

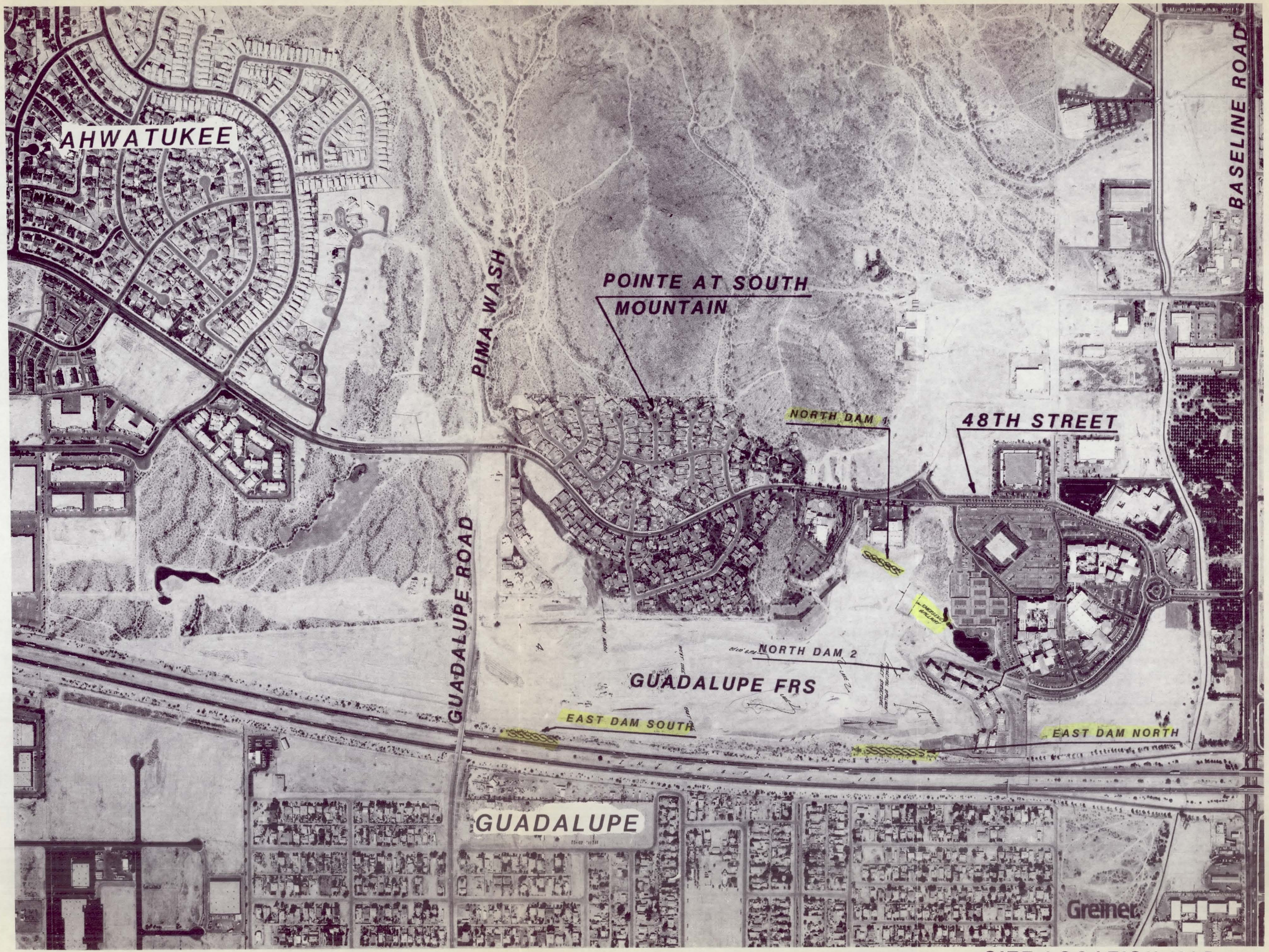

FIGURE 2 SITE LOCATION MAP

D. Acknowledgements

The assistance of various individuals during the course of this study is greatly appreciated, especially the assistance and understanding of Mr. Steve Waters, Project Manager, FCD, Arizona. Also, special thanks to Mr. Paul Siders, Project Engineer, Gosnell Development Corporation, Phoenix, Arizona for his assistance in providing the most recent information and data for this study.

3. HYDROLOGY

The GFRS is located at the mouth of Pima Wash between Guadalupe and Baseline Roads and west of the Maricopa Freeway (I-10). The GFRS is grass lined and in use as a golf course.

The tributary watershed is 1.81 square miles. The lower 0.3 square miles (including the GFRS itself) are developed with recreational, resort, commercial and multi-residential development. The remainder of the watershed is undeveloped desert. The watershed for the GFRS is shown in Figure 3.

Prior to development of the Pointe Resort and construction of I-10, runoff from Pima Wash and its tributaries would discharge over a wide spread area. The SCS estimated that under no-project conditions, a 2.5 square mile area would be inundated during the 100-year flood (Reference 10). West of the present location of the GFRS, Pima Wash and its tributaries are well defined mountain streams.

The elevations within the watershed range from 2,550 feet (msl) at the upper reaches to 1,190 feet (msl) in the north corner of the watershed. The general land slope is to the northeast.

In the upper mountainous watershed, soils are shallow to very shallow and rocky. Exposed rock is granite gneiss or schist. According to the General Soil Maps for Maricopa County, these soils belong to Hydrologic Group D (References 5 and 9).

Valley soils on the alluvial fan immediately west of I-10 are relatively deep and fine textured. They have been classified as belonging to Hydrologic Group B.

Natural vegetation over the entire watershed is sparse. Desert shrub and cacti dominate with a minor amount of annual grasses. Dominant desert brush includes creosotebush, mesquite and palo verde. Within the Pointe Resort area, exotic as well as native, trees and shrubs have been planted along streets, common areas and within residential areas. The golf courses, within and around the GFRS, are covered by turf.

The inflow hydrograph for the watershed to the GFRS was calculated utilizing the HEC-1 Flood Hydrograph Package computer program, which was developed by the U.S. Army Corps of Engineers.

Six-hour Probable Maximum Precipitation (PMP) was developed per Hydrometeorological Report No. 49. The PMP was calculated using the general method, the average depth method, and areal distribution method. The method that yielded the greatest total storm depth (areal distribution method) was then used. After total PMP inflow into the GFRS was calculated, each hydrograph ordinate is reduced by the specified ratio of 0.5. This yields the one-half PMP hydrograph that was used as the inflow hydrograph to the reservoir in the dam-break analysis (see Table 1).

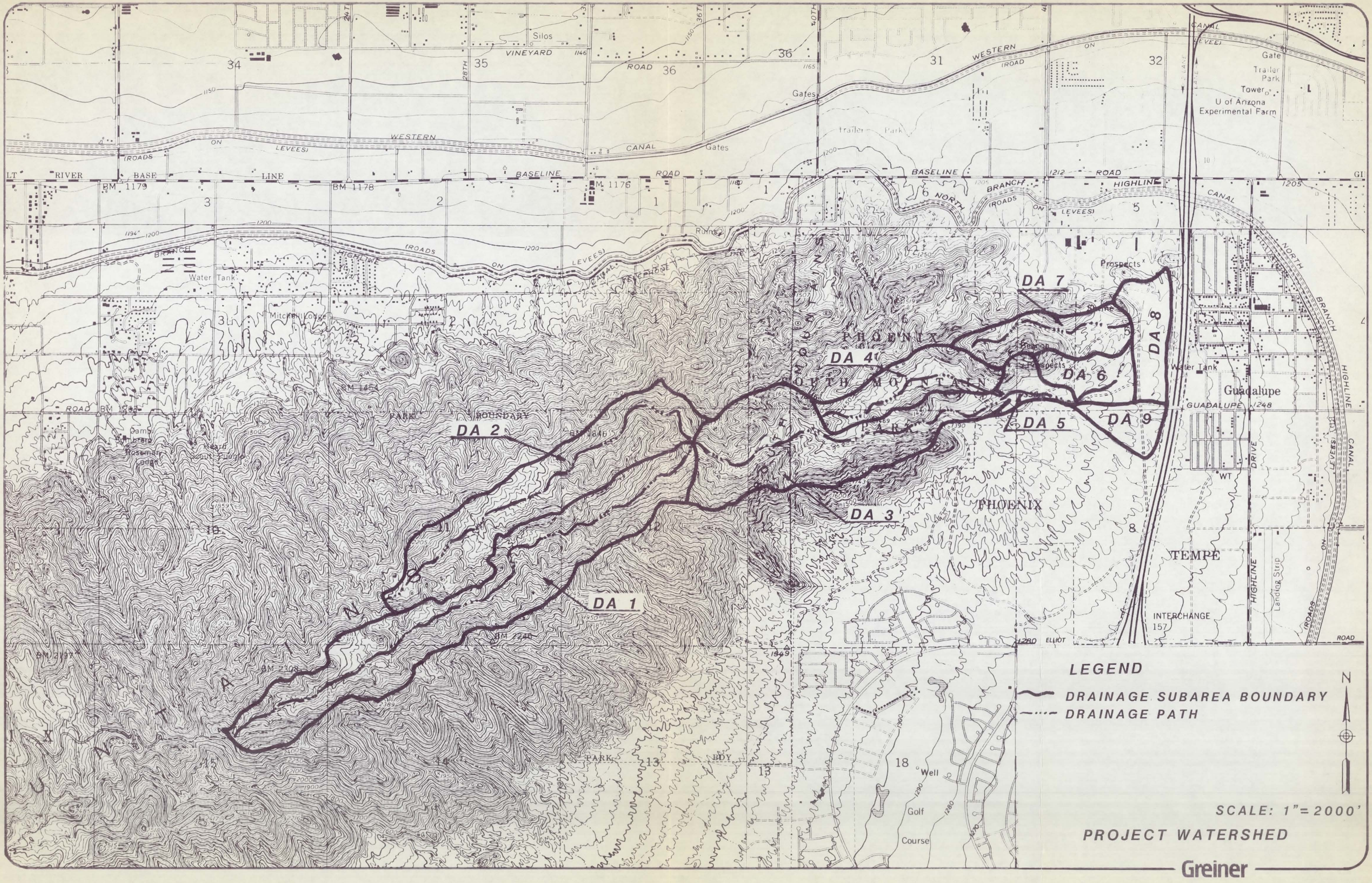
DA 1
DA 2
DA 3
DA 4
DA 5
DA 6
DA 7
DA 8
DA 9
PHOENIX
SOUTH MOUNTAIN
PARK
TEMPE
Guadalupe
BASELINE ROAD
WESTERN CANAL
HIGHLINE CANAL
INTERCHANGE 157
U of Arizona Experimental Farm
LEGEND
DRAINAGE SUBAREA BOUNDARY
DRAINAGE PATH
N
SCALE: 1"= 2000'
PROJECT WATERSHED
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FIGURE 3

3. HYDROLOGY

The detailed documentation of PMP calculations, the procedures and methodology are included in the "Hydrology Report for Guadalupe Flood Retarding Structure," dated April 1990 (Reference 17).

Table 1

One-Half PMP Hydrograph

Time (Hour)	Inflow (cfs)	Time (Hour)	Inflow (cfs)	Time (Hour)	Inflow (cfs)
0.00*	0.0	2.53*	4,856.0	4.60*	731.0
0.53	1.0	2.60	5,306.0	4.67	681.0
0.60	1.0	2.67	5,683.0	4.73	633.0
0.67	2.0	2.73	5,939.0	4.80	589.0
0.73	3.0	2.80*	6,039.0	4.87	549.0
0.80	5.0	2.87	5,971.0	4.93	515.0
0.87	8.0	2.93	5,742.0	5.00	486.0
0.93	11.0	3.00	5,390.0	5.07	458.0
1.00	15.0	3.07*	4,956.0	5.13	425.0
1.07	20.0	3.13	4,477.0	5.20	394.0
1.13	27.0	3.20	4,003.0	5.27	368.0
1.20	37.0	3.27	3,562.0	5.33	345.0
1.27	48.0	3.33	3,167.0	5.40	325.0
1.33	60.0	3.40	2,823.0	5.47	304.0
1.40	74.0	3.47	2,529.0	5.53	284.0
1.47	89.0	3.53	2,277.0	5.60	264.0
1.53	106.0	3.60	2,061.0	5.67	245.0
1.60	124.0	3.67	1,877.0	5.73	226.0
1.67	142.0	3.73	1,720.0	5.80	206.0
1.73	161.0	3.80	1,587.0	5.87	194.0
1.80	179.0	3.87*	1,475.0	5.93	181.0
1.87	196.0	3.93	1,382.0	6.00	170.0
1.93	213.0	4.00	1,304.0	6.07	158.0
2.00	228.0	4.07	1,230.0	6.13	144.0
2.07	507.0	4.13	1,146.0	6.20	131.0
2.13*	1,425.0	4.20	1,068.0	6.27	120.0
2.20	2,562.0	4.27	1,001.0	6.33	110.0
2.27	3,600.0	4.33	944.0	6.40	101.0
2.33	4,164.0	4.40	890.0	6.47	91.0
2.40	4,265.0	4.47	837.0	6.53	82.0
2.47	4,456.0	4.53	784.0	6.60*	72.0

*Data used in BREACH/DAMBRK model

4. DAMBREAK ANALYSIS

A. Dam Breach

The development of a breach hydrograph (outflow hydrograph from the reservoir under the condition of a dam failure) is highly dependent upon conditions existing at the time of breach initiation: water surface elevation, breach geometry and total time of breach formation.

For the East Dam, there are two potential breach locations that will result in different downstream flooding. One breach location was selected near the south portion of the dam so that larger flooded areas will be covered in the event of dam failure. Another breach location is near the north end of the dam where the largest breach flow will occur. The selection of breach location for the North Dams was based on the potential of producing the largest discharge flow and/or the largest inundation area.

The dams and sections map is depicted in Figure 4. Figures 5 through 8 show the cross sections of the dams at breach locations which were considered for the DAMBRK analysis.

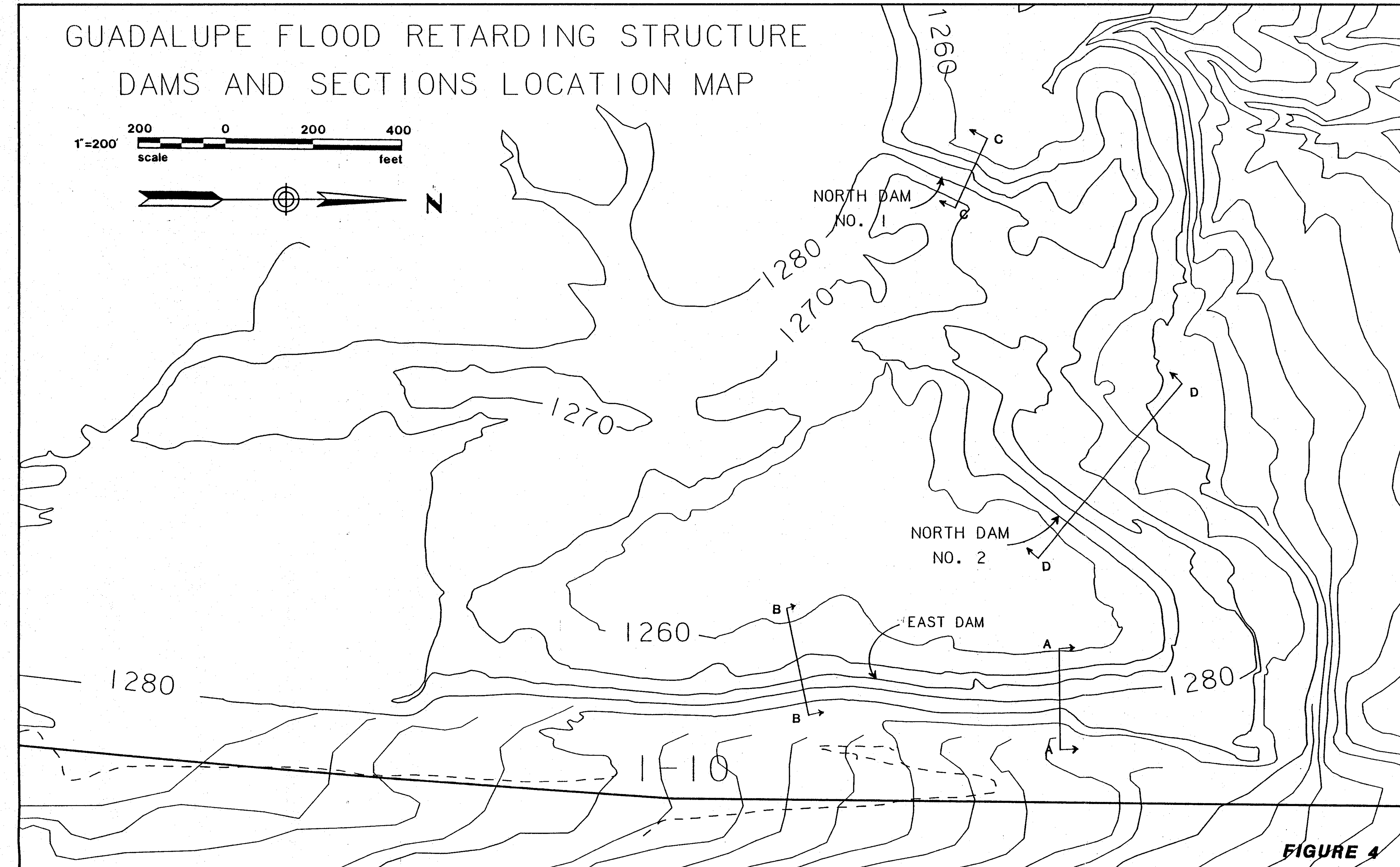
To define the type of dam failure (overtopping or piping) in the simulation model, the maximum water level in the reservoir was checked. The peak flow for one-half PMP is 6,039 cfs. The top of the dam is at elevation 1,281.0 and the crest of the emergency spillway is at elevation 1,274.0. The maximum outflow discharge from the emergency spillway at elevation 1,281.0 is 10,400 cubic feet per second. It is evident that dam failure shall occur as a result of piping condition, but not overtopping.

For breach analysis, the breach parameters were derived by different methods: 1) the Statistical Method, 2) the Parametric Method, and 3) the Breach Erosion Method. A sensitivity test was conducted to verify breach parameters to be used for the final dambreak models.

For simplicity, the typical dam cross section shown in Figure 9 was used for dam breach parameters sensitivity tests and the derivation of the breach hydrograph. The breach model was used for physical erosion test runs in combinations of various initial breach elevations, downstream channel widths and channel shapes. An initial water surface elevation of 1,275 feet was used. The results of maximum breach width of 25 feet for the typical dam section indicates that in order to maximize the breach width, the initial breach elevation shall be set close to the bottom of the dam. The breach time is between 0.1 and 0.16 hour.

In order to define the maximum breach that can possibly occur, a prolonged high inflow hydrograph was incorporated in the breach model. The results indicate that the maximum breach width is 28.4 feet for this particular material and the configuration of the dam.

To generate the breach outflow hydrograph, two extreme conditions were possible when the dam breached: 1) the lake could have been full when one-half PMP started, or 2) the lake could have been empty when one-half PMP started. The test runs of DAMBRK models indicated that the empty lake (1,258 feet) will result in a higher breach flow of 11,504 cfs as the breach occurs during the rising limb of the hydrograph. The lake full condition (1,275 feet) of peak



GUADALUPE FLOOD RETARDING STRUCTURE
DAMS AND SECTIONS LOCATION MAP
200 0 200 400
1"=200'
scale
feet
N
1260
C
NORTH DAM
NO. 1
C
1280
1270
1270
D
NORTH DAM
NO. 2
D
B
EAST DAM
1260
A
1280
1280
B
A
I-10

FIGURE 4

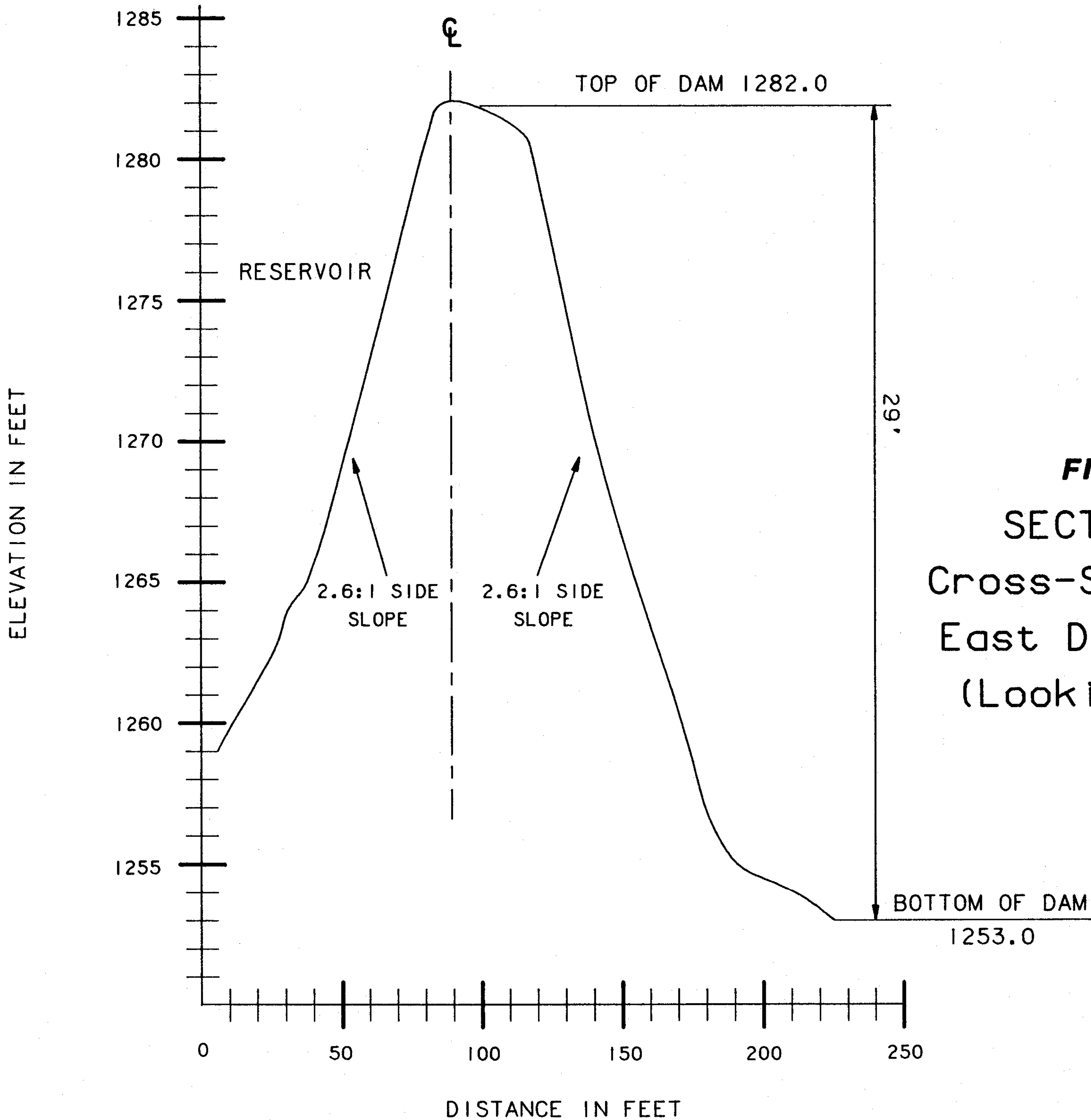


FIGURE 5

SECTION A-A

Cross-Section for East Dam (North) (Looking North)

H: 1":50'
V: 1":5'

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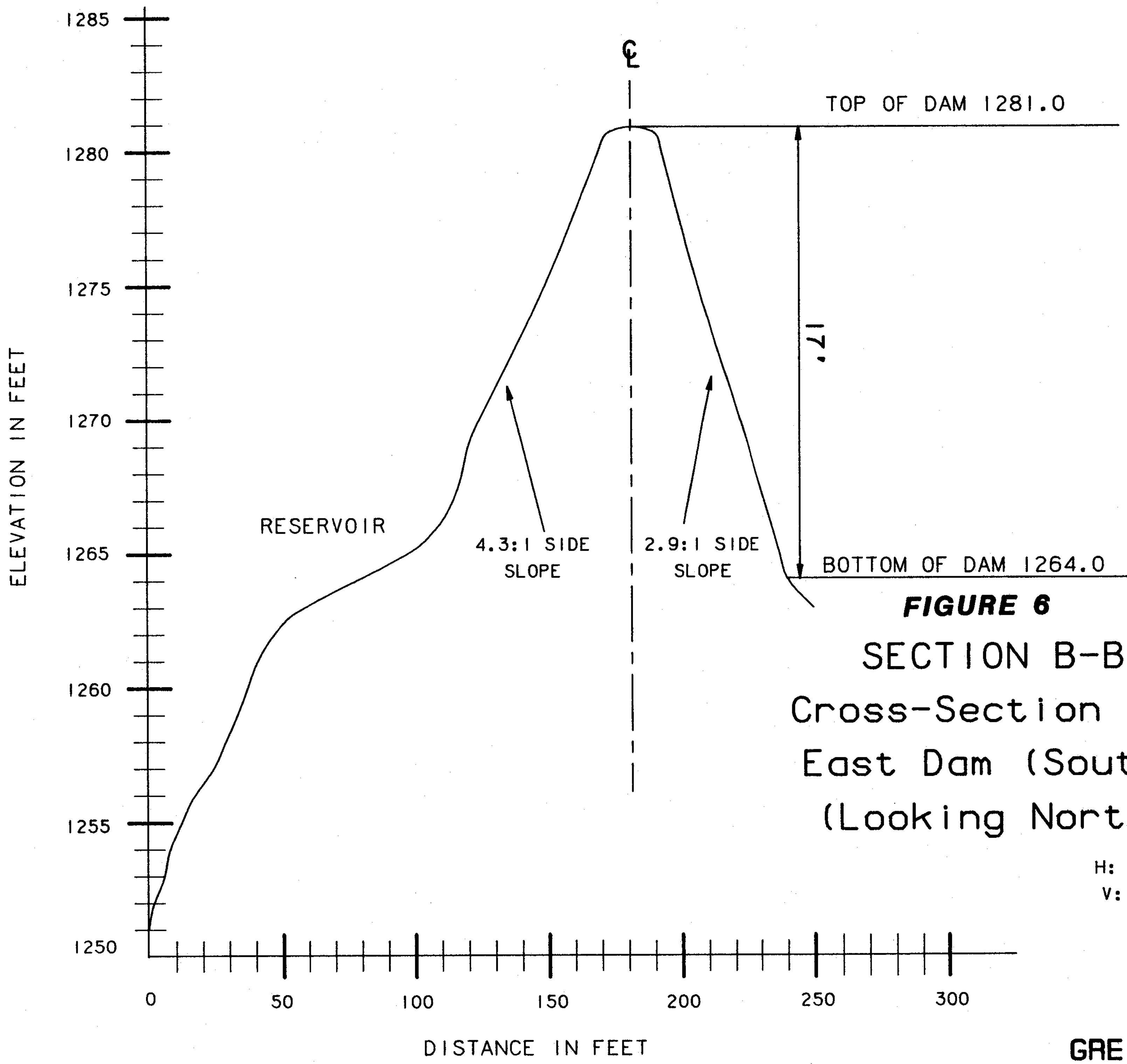

FIGURE 6

SECTION B-B

Cross-Section for East Dam (South) (Looking North)

H: 1":50'
V: 1":5'

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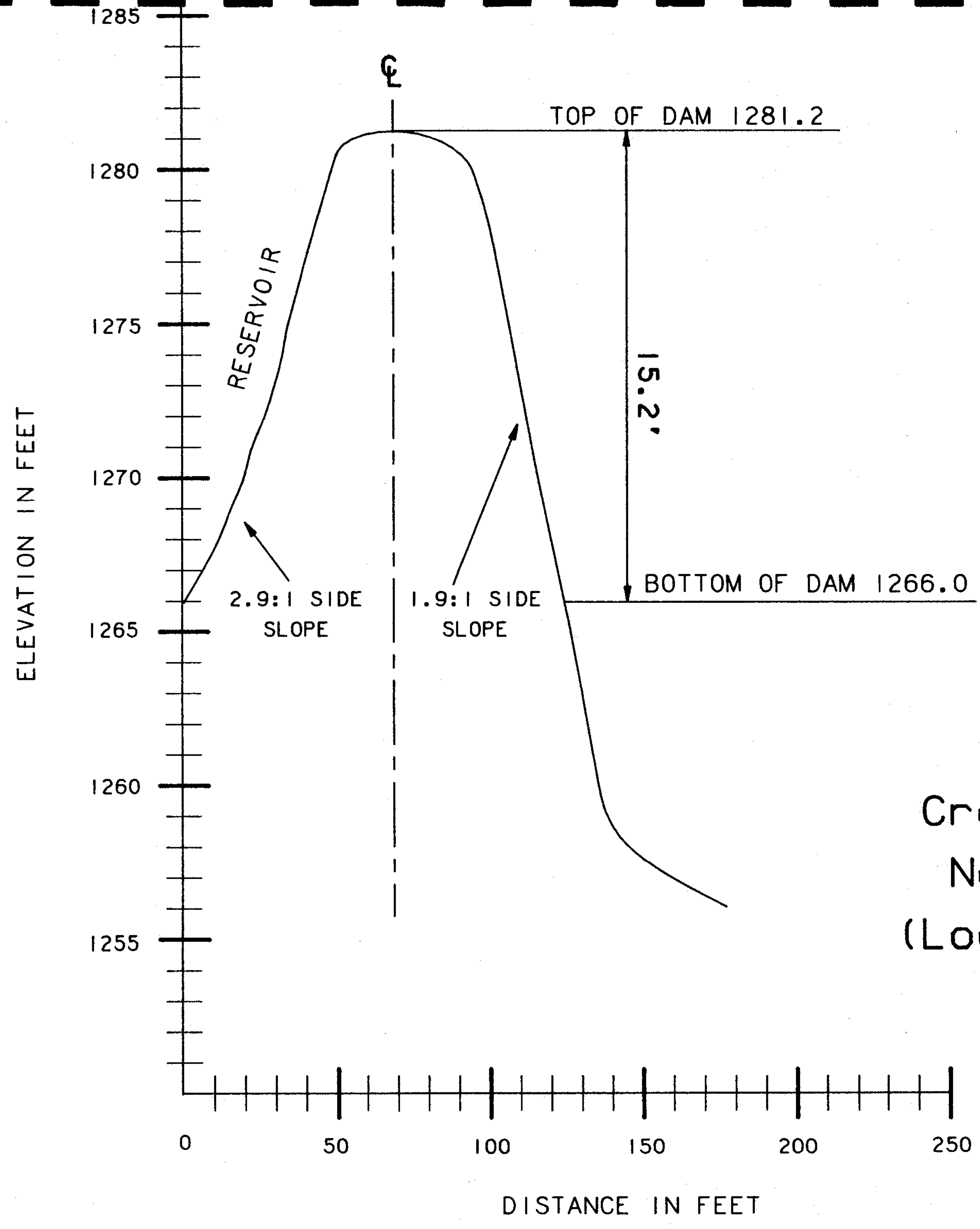

FIGURE 7

SECTION C-C
Cross-Section for
North Dam No. 1
(Looking Southwest)

H: 1":50'
V: 1":5'

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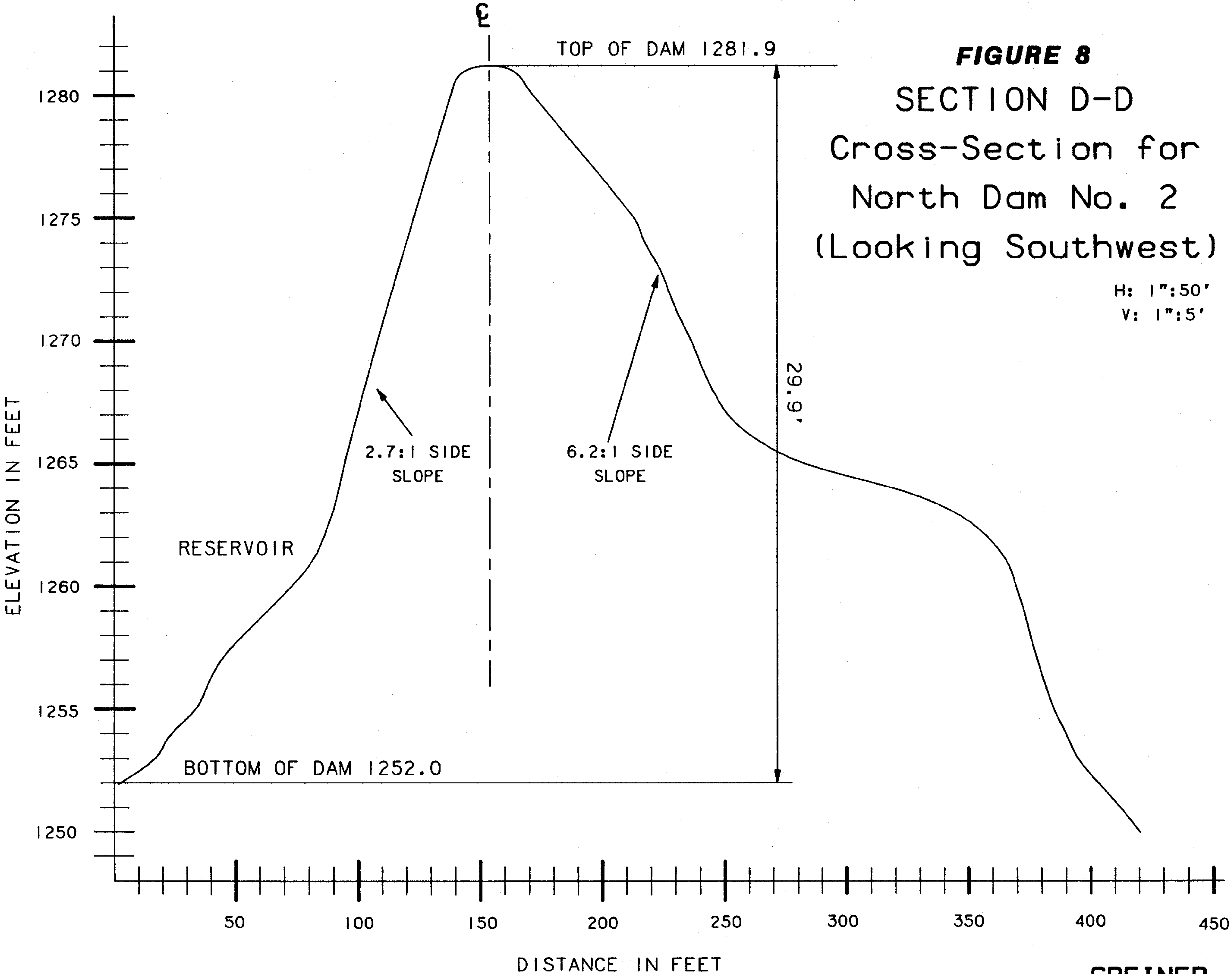

FIGURE 8

SECTION D-D

Cross-Section for North Dam No. 2 (Looking Southwest)

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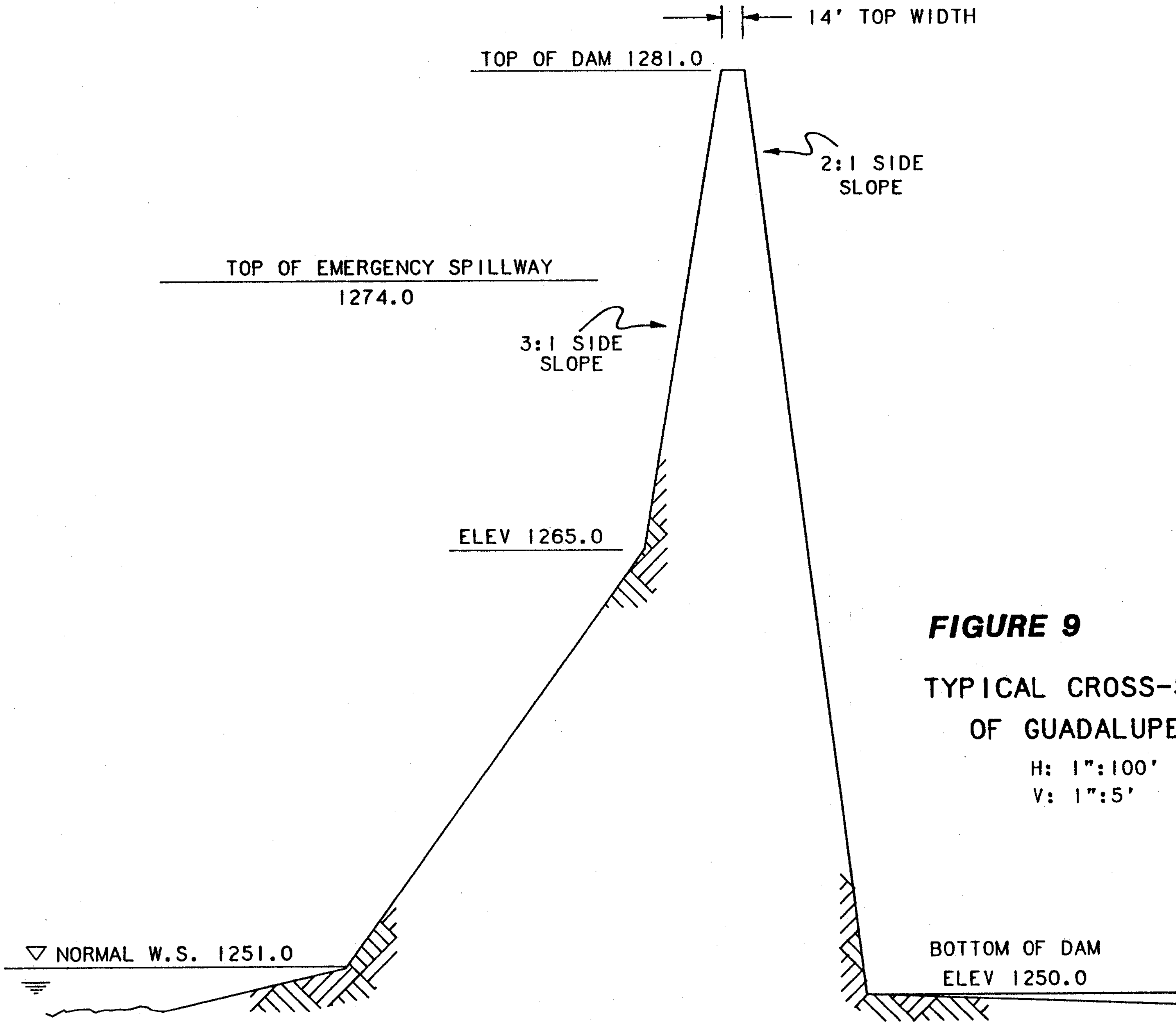

FIGURE 9

TYPICAL CROSS-SECTION OF GUADALUPE FRS

H: 1":100'
V: 1":5'

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flow of 9,673 cfs indicates that damage shall arise if the dam is breached when it is full during a less intense flood.

After the breach parameters were obtained, the DAMBRK model was used to run the damage and sensitivity tests for the downstream routing with various breach widths and time of breach. The breach parameters for each potential dam breach location were obtained and were used for the final dambreak modeling (Table 2):

Table 2

Summary of Breach Parameters

Dam	Breach Width (Ft)	Breach Time Empty Lake (Hr)	Breach Time Full Lake (Hr)	Peak Discharge (cfs)
East Dam North	27	0.28	0.14	8,903
East Dam South	17	0.24	0.12	5,205
North Dam No. 1	15	0.26	0.13	5,095
North Dam No. 2	30	0.32	0.15	9,981

The detailed documentation of dam breach analysis, its procedures and methodology are included in the "Technical Memorandum - Dambreak Study for Guadalupe Flood Retarding Structure," dated April 1990 (Reference 17).

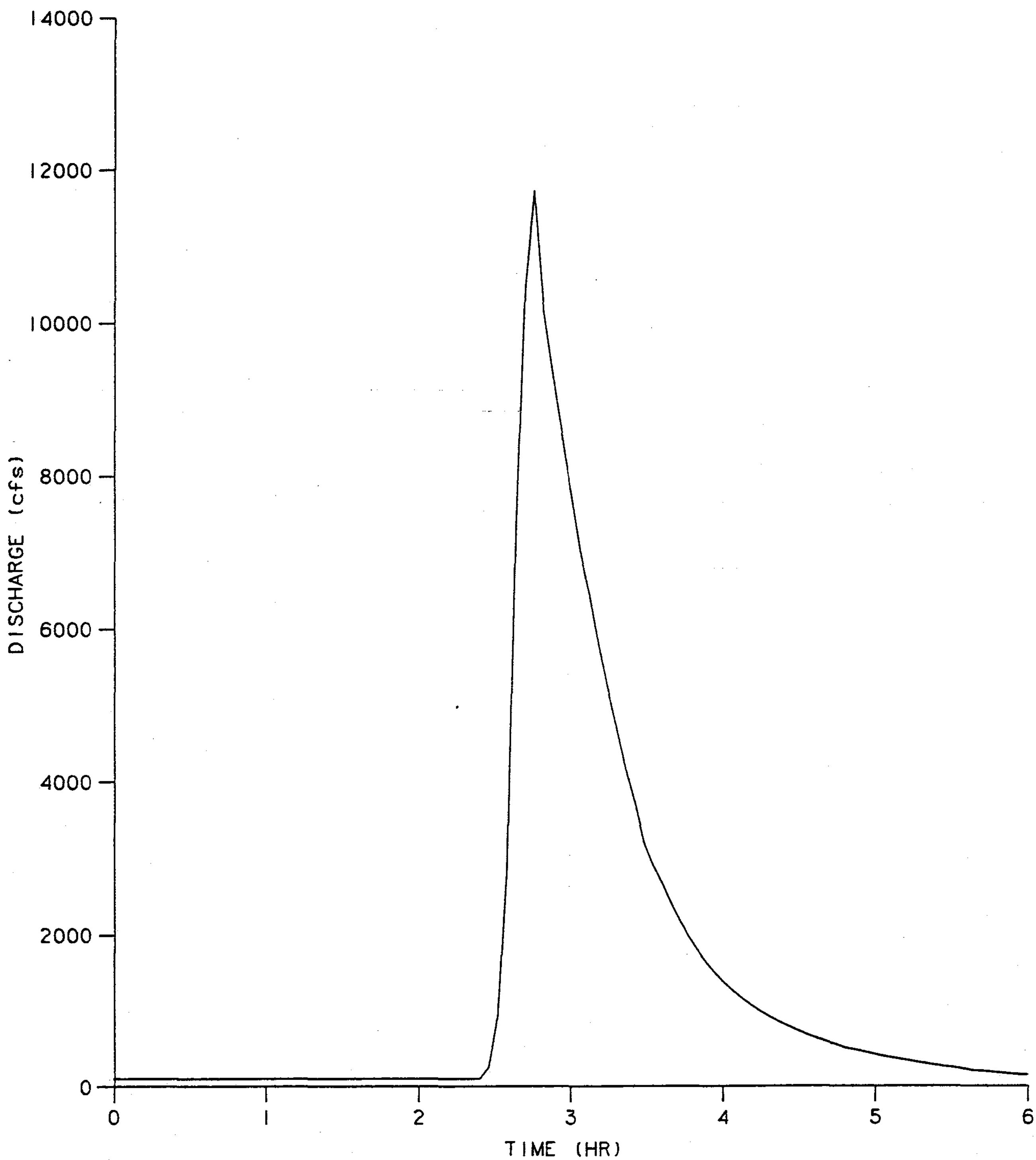
Test runs for reservoir storage routing and dynamic routing were then conducted. The results indicate there is a little difference in the breach hydrographs generated and there is no difference in the downstream inundation routing (see Figures 10 and 11).

B. Inundation Area Routing

By utilizing the DAMBRK model, the breach outflow hydrograph was routed downstream from the breach location of each dam. However, the results of the computer runs show that the inundation areas for the East and North Dam's two breach locations are very similar. Therefore, the inundation area maps were prepared for the extreme cases in which the largest impact to the downstream areas will occur from a single breach location.

The cross section data for downstream routing were input to the DAMBRK model according to the net top widths versus stage. The net top width for water to pass through is equal to the total top width at an elevation minus the widths occupied by buildings and obstructions. The width between the block walls where water cannot pass through was considered non-effective and was assumed zero. The curves for the net top width versus water depth were adjusted to obtain smooth flow transition in the downstream sections and eliminate non-conveyance problems associated with the DAMBRK model. The floodplain was delineated based on the maximum water elevations reached at the cross sections. See graphs provided in Appendices A and B. The detailed documentation of curve adjustment is included in the "Technical Memorandum - Dambreak Study for Guadalupe Flood Retarding Structure," dated March 1990 (Reference 17).

FIGURE 10



OUTFLOW HYD. (STORAGE ROUTING)

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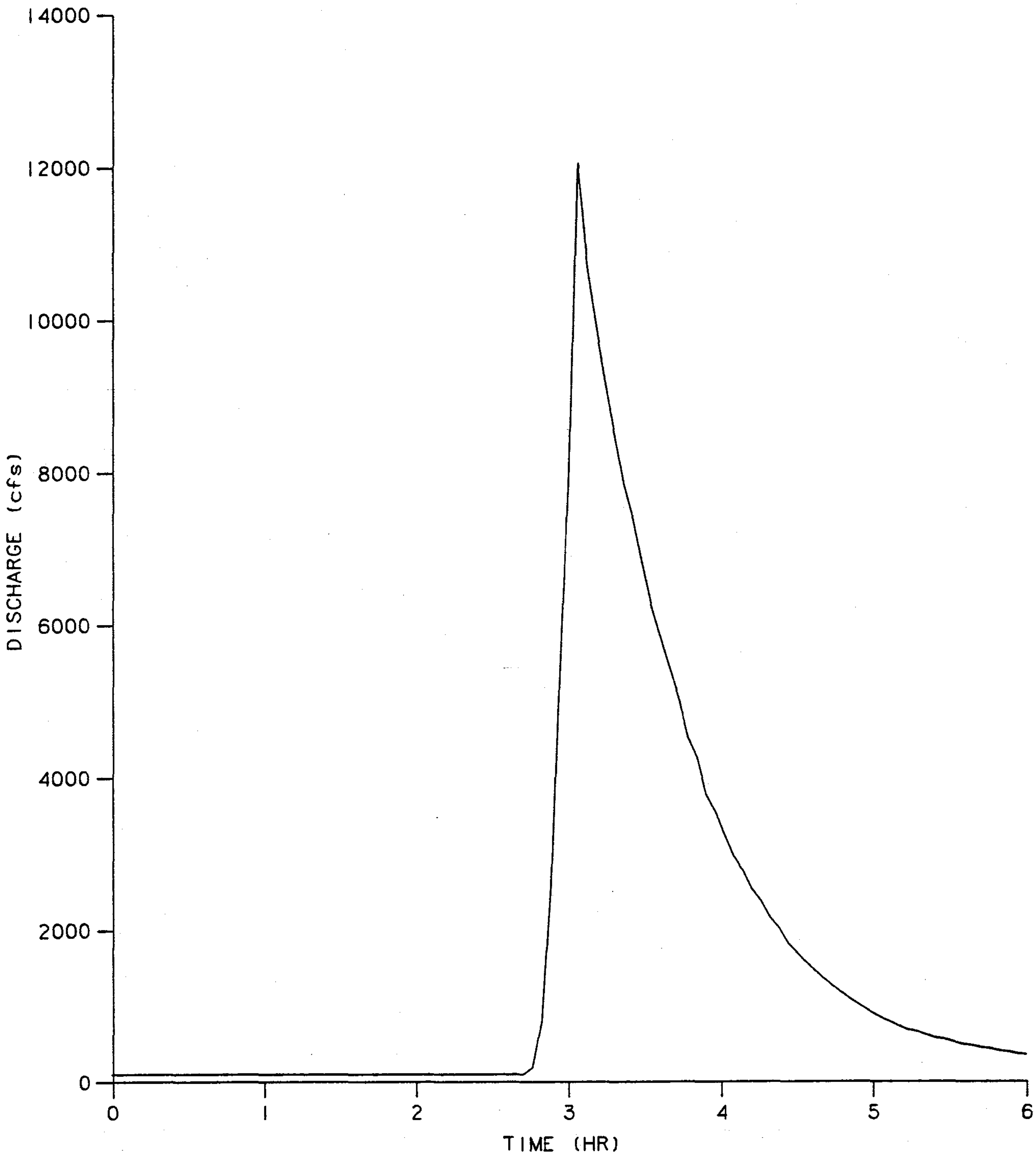
FIGURE 11



OUTFLOW HYD. (DYNAMIC ROUTING)

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Two conditions were considered when the routing models were developed: with- and without-block-walls. The block walls constructed at different downstream locations of the dams would greatly affect the flow path. For the without-block-wall conditions, the walls were assumed to collapse during flooding.

On the east side of Interstate Highway 10 (I-10), existing block walls could be seen within an area enclosed by 56th Street, Kyrene Road, Superstition Freeway and Baseline Road. Some block walls also exist along the Highline Canal and its neighborhood. On the west side of I-10, block walls were constructed along the Highline Canal and Western Canal between I-10 and 48th Street, along 48th Street between Southern Avenue and Baseline Road, within the neighboring subdivisions, and between Maricopa Freeway and Broadway Road within the inundation areas.

In the event of East Dam failure, water will flow to the area between 56th Street and I-10 due to the block wall located along the Highline Canal on the east of 56th Street. The main exits for the flow could be 56th Street, Baseline Road, Hardy Road and Kyrene Road with water ponding between 56th Street and I-10 and south of the Superstition Freeway.

In the event of either North Dam failure, water will flow mainly along 48th Street and some small streets in the neighboring subdivisions. When the water gets to Broadway Road, it flows mainly along this road with water ponding in areas between Broadway Road and the Maricopa Freeway due to the existing block walls located in streets such as 40th Street and other quarter-mile streets.

For the North Dam, the results for both with- and without-block-wall conditions are shown in Tables 3 and 4 respectively.

Table 3

Summary of Dambreak Results for North Dam - Without-Block-Wall Condition

Cross Section Number	Distance From Dam Mile	Maximum Elevation Feet	Maximum Flow cfs	Time to Maximum Elevation Hours	Time to Flood Elevation* Hours
1	0.133	1,242.43	9,912	0.32	**
2	0.322	1,226.32	9,859	0.33	**
3	0.417	1,216.28	9,783	0.37	**
4	0.549	1,207.59	9,799	0.37	**
5	0.682	1,198.34	9,788	0.39	**
6	0.824	1,190.16	9,777	0.40	**
7	1.051	1,180.13	9,703	0.43	0.22
8	1.178	1,172.96	9,694	0.45	**
9	1.269	1,169.69	9,686	0.46	0.26
10	1.557	1,158.58	9,644	0.48	**
11	1.600	1,157.23	9,641	0.50	0.31
12	1.701	1,154.44	9,611	0.52	0.32
13	1.867	1,148.78	8,523	0.70	0.35

Table 3 (Continued)

Summary of Dambreak Results for North Dam - Without-Block-Wall Condition

Cross Section Number	Distance From Dam Mile	Maximum Elevation Feet	Maximum Flow cfs	Time to Maximum Elevation Hours	Time to Flood Elevation* Hours
14	2.296	1,138.33	7,782	0.91	**
15	2.609	1,133.18	7,829	1.05	**
16	2.924	1,130.80	8,577	1.18	0.50
17	3.206	1,126.38	7,587	1.43	0.54
18	3.494	1,123.89	8,446	1.68	0.78
19	3.824	1,118.71	7,295	1.98	**
20	4.141	1,114.19	7,142	2.26	1.31
21	4.899	1,100.79	7,160	2.93	**

*The flood elevation was set at two feet above channel bottom.
**Maximum water elevation is less than two feet deep.

Table 4

Summary of Dambreak Results for North Dam - With-Block-Wall Condition

Cross Section Number	Distance From Dam Mile	Maximum Elevation Feet	Maximum Flow cfs	Time to Maximum Elevation Hours	Time to Flood Elevation* Hours
1	0.133	1,244.50	9,613	0.36	0.1
2	0.322	1,228.58	8,641	0.54	0.2
3	0.417	1,218.28	8,226	0.63	0.3
4	0.549	1,209.69	7,493	0.88	0.4
5	0.682	1,200.35	6,960	1.00	0.5
6	0.824	1,192.31	6,653	1.15	0.5
7	1.051	1,181.85	6,140	1.38	0.7
8	1.178	1,174.21	6,013	1.38	0.8
9	1.269	1,170.93	5,980	1.45	0.9
10	1.557	1,160.42	5,672	1.68	1.1
11	1.600	1,157.41	5,646	1.68	1.1
12	1.701	1,154.25	5,624	1.74	1.1
13	1.867	1,148.75	5,608	1.74	1.2
14	2.296	1,139.72	4,124	2.52	1.6
15	2.609	1,134.24	3,755	3.27	2.5
16	2.924	1,131.19	3,486	3.72	2.8
17	3.206	1,126.26	3,430	4.09	3.0

Table 4

Summary of Dambreak Results for North Dam - With-Block-Wall Condition

Cross Section Number	Distance From Dam Mile	Maximum Elevation Feet	Maximum Flow cfs	Time to Maximum Elevation Hours	Time to Flood Elevation* Hours
18	3.494	1,124.30	3,274	4.46	3.3
19	3.824	1,119.47	3,228	4.88	3.6
20	4.141	1,116.56	3,030	5.28	4.1
21	4.899	1,103.84	2,668	6.24	5.1

*The flood elevation was set at two feet above channel bottom.

Comparatively, the water depth along the downstream routing under with-block-wall condition is higher. The increase in water depth at the same location between these two conditions varies from zero to three feet. The maximum flow is highly decreased with with-block-wall condition. The discharge to the Salt River is 2,668 cfs instead of 7,160 cfs for without-block-wall conditions. The model with with-block-wall condition is considered as the most appropriate. The attenuation of the peak dam breach flow from 10,003 cfs to 2,668 cfs is a result of the vast floodplain storage capacity.

For the East Dam, the results for both with- and without-block-wall conditions are shown in Tables 5 and 6 respectively.

Table 5

Summary of Dambreak Results for East Dam - Without-Block Wall Condition

Cross Section Letter	Distance*** From Dam Mile	Maximum Elevation Feet	Maximum Flow cfs	Time to Maximum Elevation Hours	Time to Flood Elevation* Hours
A	0.1975	1,247.49	8,861	0.28	0.11
B	0.3220	1,237.16	8,837	0.29	0.17
C	0.4782	1,224.51	8,782	0.31	**
D	0.6487	1,213.41	8,722	0.34	**
E	0.8258	1,204.32	8,647	0.39	**
F	1.0653	1,190.94	8,496	0.44	0.32
G	1.2311	1,184.10	8,424	0.48	0.41
H	1.3182	1,181.51	8,109	0.57	0.54
I	1.4157	1,176.44	8,045	0.67	**

*Flood elevation was set at two feet above channel bottom.
**Maximum water elevation is less than two feet deep.
***Station number conversion for the computer station can be found in the Technical Memorandum, Table 19.

Table 6

Summary of Dambreak Results for East Dam - With-Block-Wall Condition

Cross Section Letter	Distance** From Dam Mile	Maximum Elevation Feet	Maximum Flow cfs	Time to Maximum Elevation Hours	Time to Flood Elevation* Hours
A	0.1975	1,247.43	8,827	0.29	0.1
B	0.3220	1,237.70	8,687	0.32	0.2
C	0.4782	1,225.62	8,176	0.40	0.2
D	0.6487	1,215.07	7,306	0.65	0.3
E	0.8258	1,205.56	6,719	0.90	0.6
F	1.0653	1,190.61	6,580	1.02	0.8
G	1.2311	1,185.24	6,425	1.14	0.9
H	1.3182	1,182.05	6,223	1.31	0.9
I	1.4157	1,177.36	6,098	1.39	1.0

*The flood elevation was set at two feet above channel bottom.
**Station number conversion for the computer station can be found in the Technical Memorandum, Table 19.

Comparatively, the water depth along the downstream routing under with-block-wall condition is higher and varies in the range of 0 to 1.5 feet. The maximum flow for with-block-wall conditions is approximately 2,000 cfs lower.

The inundation maps were prepared based on the results of with-block-wall conditions because they simulate more closely the actual conditions of dam failure.

The detailed documentation of inundation area routing, its procedures and methodology are included in the "Technical Memorandum - Dambreak Study for Guadalupe Flood Retarding Structure," dated April 1990 (Reference 17).

5. INUNDATION AREAS AND STRUCTURAL INVENTORY

A. Inundation Areas

The inundation area maps were developed based on the results of the dambreak study for the downstream routings of the dams with a scale of 1 inch = 1,000 feet. All cross-section lines used for modeling were shown on the maps with the floodplain boundaries delineated. Since approximately 90 percent of the flooding area was common for either breaching locations at the East Dam, and 80 percent common for either breaching at North Dam No. 1 or North Dam No. 2 location, the inundation area map was prepared for the breach location covering the maximum impact areas.

From the results of inundation area routing, the areas with different water depths were identified on the inundation area map with 1-foot increments. The cross section number and its distance along channel, maximum stage, time to maximum stage, estimated flood elevation and time to flood elevation were tabulized in Figure 12. The peak time to a flood depth of two feet for water traveling downstream of the dam is shown with 0.25 hour intervals for the East Dam and 0.5-hour intervals for the North Dams (see Figure 13).

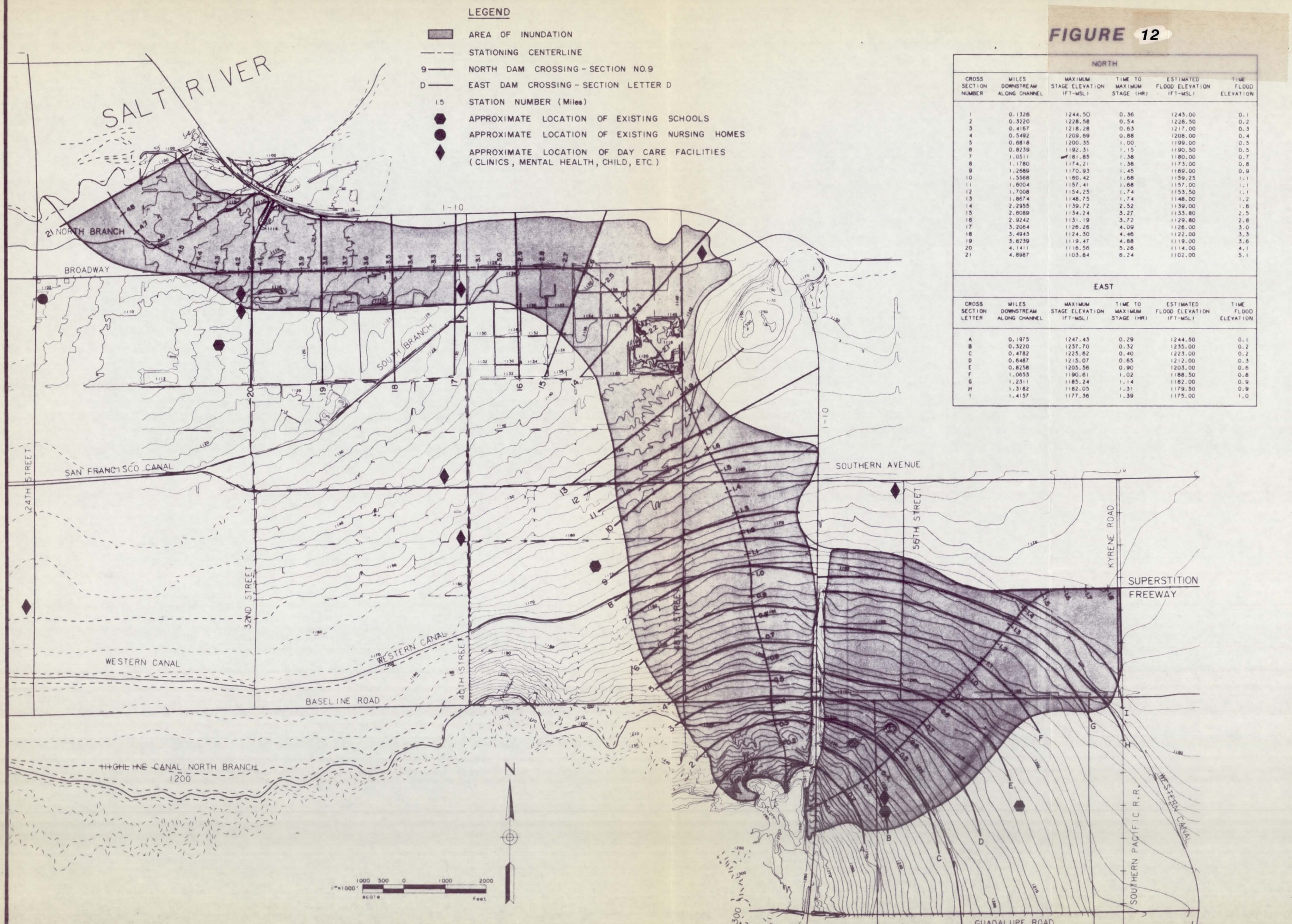
The maximum inundation areas during the breach of either North Dam No. 1 or North Dam No. 2 was identified on the map (see Figure 12). The east and north boundaries of the inundation area are close to the west and south edges of I-10 excluding the high elevation location near the Westcourt in the Butte. The west and south boundaries are at approximately one-quarter mile west of 48th Street and one-quarter mile south of Broadway Road to the Salt River. The total inundation area is approximately 2.8 square miles and is broken down into smaller areas for different water depths.

The study results indicated that when either of the North Dams breaches, half of the areas between 48th Street and I-10, and north to Southern Avenue will be inundated with a water depth of more than three feet. This area is approximately 0.7 square mile. It covers almost 95 percent of the Gosnell's development located north of the North Dams, including the warehouses. Approximately 65 percent of this area is residential subdivisions located between Baseline Road and Southern Avenue. Some commercial properties at the intersection of Southern Avenue and 48th Street will be subject to three feet or more inundation. Another area which will suffer a water depth of more than three feet is located north of Broadway Road between 32nd Street and 42nd Street. Most of this area is used for light industry and multi-family residences.

There is a 0.07-square-mile pit located west of 48th Street and a quarter-mile south of Broadway Road. This pit area was treated as off-site storage in the dambreak modeling and will be filled up with two to three feet of water above the level ground.

There are three daycare facilities, including clinics, mental health, child care, etc., which will be flooded with one to two feet of water. The approximate locations for these facilities are at Broadway Road near 32nd Street, 40th Street and 48th Street (see Figure 12).

FIGURE 12



NORTH					
CROSS SECTION NUMBER	MILES DOWNSTREAM ALONG CHANNEL	MAXIMUM STAGE ELEVATION (FT-MSL)	TIME TO MAXIMUM STAGE (HR)	ESTIMATED FLOOD ELEVATION (FT-MSL)	TIME FLOOD ELEVATION
1	0.1326	1244.50	0.36	1243.00	0.1
2	0.3220	1228.58	0.54	1226.50	0.2
3	0.4167	1218.28	0.63	1217.00	0.3
4	0.5492	1209.69	0.88	1208.00	0.4
5	0.6818	1200.35	1.00	1199.00	0.5
6	0.8239	1192.31	1.15	1190.50	0.5
7	1.0511	1181.85	1.38	1180.00	0.7
8	1.1780	1174.21	1.38	1173.00	0.8
9	1.2689	1170.93	1.45	1169.00	0.9
10	1.5568	1160.42	1.68	1159.25	1.1
11	1.6004	1157.41	1.68	1157.00	1.1
12	1.7008	1154.25	1.74	1153.50	1.1
13	1.8674	1148.75	1.74	1148.00	1.2
14	2.2955	1139.72	2.52	1139.00	1.6
15	2.6089	1134.24	3.27	1133.80	2.5
16	2.9242	1131.19	3.72	1129.80	2.8
17	3.2064	1126.26	4.09	1126.00	3.0
18	3.4943	1124.30	4.46	1122.00	3.3
19	3.8239	1119.47	4.88	1119.00	3.6
20	4.1411	1116.56	5.28	1114.00	4.1
21	4.8987	1103.84	6.24	1102.00	5.1

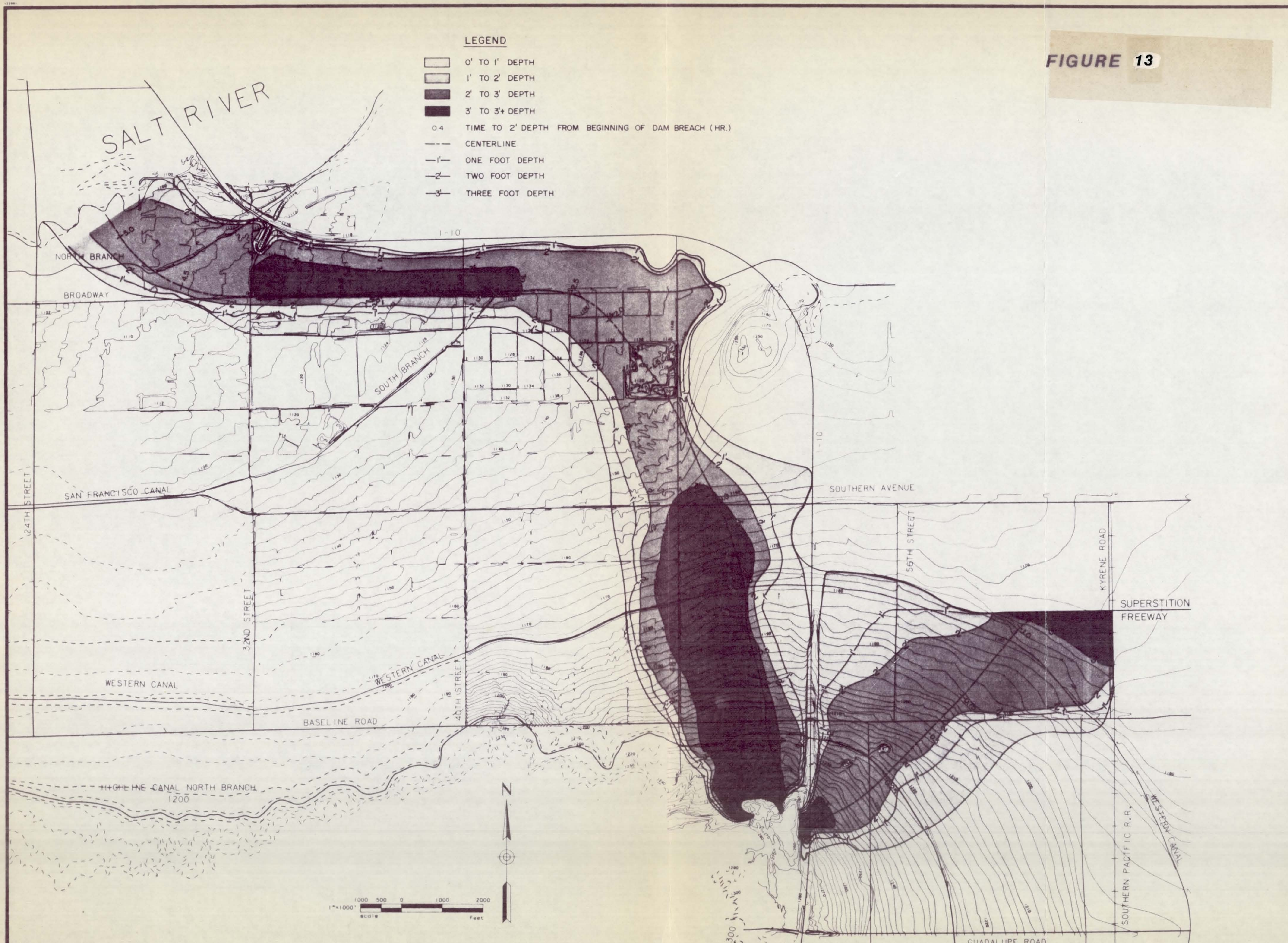
EAST					
CROSS SECTION LETTER	MILES DOWNSTREAM ALONG CHANNEL	MAXIMUM STAGE ELEVATION (FT-MSL)	TIME TO MAXIMUM STAGE (HR)	ESTIMATED FLOOD ELEVATION (FT-MSL)	TIME FLOOD ELEVATION
A	0.1975	1247.43	0.29	1244.50	0.1
B	0.3220	1237.70	0.32	1235.00	0.2
C	0.4782	1225.62	0.40	1223.00	0.2
D	0.6487	1215.07	0.65	1212.00	0.3
E	0.8258	1205.56	0.90	1203.00	0.6
F	1.0653	1190.61	1.02	1188.50	0.8
G	1.2311	1185.24	1.14	1182.00	0.9
H	1.3182	1182.05	1.31	1179.50	0.9
I	1.4157	1177.36	1.39	1175.00	1.0

GUADALUPE FLOOD RETARDING STRUCTURE
DAM FAILURE INUNDATION MAP - 1 of 2

Greiner
7310 N 16th Street Suite 160 Phoenix Arizona 85020 602 275 5400
555 East River Road Suite 100 Tucson Arizona 85704 602 887 1800

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY
3335 W Durango Street Phoenix, Arizona 85009 / 602 262-1501

FIGURE 13



GUADALUPE FLOOD RETARDING STRUCTURE
DAM FAILURE INUNDATION MAP - 2 of 2

Greiner
7310 N 16th Street Suite 160 Phoenix Arizona 85020 602 275 5400
555 East River Road Suite 100 Tucson Arizona 85704 602 887 1800

FLOOD CONTROL DISTRICT OF
MARICOPA COUNTY
3335 W. Durango Street Phoenix, Arizona 85009 / 602 262-1501

Figure 13 also shows the time required to fill the inundation area with two feet of water after the dams are breached. It will take about five hours to reach the area near the Salt River which is located approximately five miles downstream from the North Dam.

The maximum inundation area during the breach of the East Dam was identified in Figure 12. The west and north boundaries of the inundation area are along the east edge of I-10 and south edge of the Superstition Freeway. The east and south boundaries are at approximately Kyrene Road and one-half mile south of Baseline Road running northeasterly to Kyrene Road and Baseline Road. The total inundation area is approximately 1.3 square miles. Figure 13 shows the inundated areas delineated for various flood depths.

The study results indicate that during the breach of the East Dam, two areas will suffer serious flooding of more than three feet of water. The size of these areas is approximately 0.1 square mile. The first area is located right at the downstream of the dam. It covers an area of approximately 0.03 square mile within the City of Guadalupe. The second area is located near the intersections of the Superstition Freeway and Kyrene Road. The size is approximately 0.07 square mile. Approximately half of this area covers a mobile home area. Water will pond at this low area to a depth at which water begins overflowing into the Superstition Freeway and exits to the north side of Kyrene Road. This remote area can reach a water depth of two feet in an approximate time of one hour. There are school and daycare facilities located near 56th Street and one-half mile south of Baseline Road which will be flooded with one to two feet of water during dam failure. Most of the inundated areas are residential with approximately 5 percent for commercial and industrial uses.

B. Structural Inventory

The types of land use and buildings within a specified flood area were identified on a 1 inch = 200 feet work map which incorporates both the topographic and aerial information. Table 7 summarizes the area of each specified flood depth in which the numbers of dwellings and buildings are provided.

Table 7

Structural Inventory Within GFRS Inundation Areas

Location	Flood Depth (Ft)	Area (Mi^2)	Number of Dwellings*	Number of Buildings Commercial and Industrial*
North Dams	0-1	0.5	511	63
	1-2	0.4	526	52
	2-3	1.2	863	83
	3-3+	0.7	848	47 (Not Including Pointe Development)
Total		**2.8**	**2,748**	**245**

Table 7 (Continued)

Structural Inventory Within GFRS Inundation Areas

Location	Flood Depth (Ft)	Area (Mi^2)	Number of Dwellings*	Number of Buildings Commercial and Industrial*
East Dam	0-1	0.4	245	6
	1-2	0.2	425	2
	2-3	0.6	979	40
	3-3+	0.1	142	0
Total		1.3	1,791	48

*Approximate number counted from latest aerial photograph.

Based on some guidelines provided by the Federal Emergency Management Agency (Reference 18) and other assumptions, the damage costs due to flooding at the downstream of each dam failure were estimated.

These guidelines and assumptions are:

1. The structural value for each residential dwelling is $60,000. Its contents are assumed to be 25 percent of the structural value.

2. Damage as percent of total value with varying flood depths for both residential and commercial/industrial:

Flood Depth (Ft)	Structure (Percent)	Contents (Percent)
0-1	5	14
1-2	14	39
2-3	23	61
3-3+	30	75

3. Average building area for commercial/industrial use is assumed to be 10,000 square feet. The dollar worth per building square foot is assumed to be $50. Its contents are equal to 65 percent of the structural value.

Table 8

Damage Costs Due to Flooding at the Downstream of GFRS

Dam Location	Flood Depth (Ft)	Residential		Commercial/Industrial		Total Damage Cost ($)
		Structural ($)	Contents ($)	Structural ($)	Contents ($)	
East	0-1	735,000	514,500	150,000	273,000	1,672,500
	1-2	3,570,000	2,486,250	140,000	253,500	6,449,750
	2-3	13,510,200	8,957,850	4,600,000	7,920,000	34,998,050
	3-3+	2,556,000	1,597,500	0	0	4,153,500
Sub-Total		20,371,200	13,556,100	4,890,000	8,456,500	47,273,800
North	0-1	1,533,000	1,073,100	1,575,000*	2,866,500*	7,047,600
	1-2	4,418,400	3,077,100	3,640,000	6,591,000	17,726,500
	2-3	11,909,400	7,896,450	9,545,000	16,454,750	45,805,600
	3-3+	15,264,000	9,540,000	22,050,000*	35,831,250*	82,685,250
Sub-Total		33,124,800	21,586,650	36,810,000	61,743,500	153,264,950

*Estimated worth of $50 million for the Pointe development at the Downstream of North Dams is included.

Table 8 shows that the total damage cost at the downstream of East Dam due to dam breach is approximately $47 million and the North Dams are approximately $153 million.

6. CONCLUSIONS

This report has presented the results of a dambreak analysis of the downstream flooding resulting from a simulation after the failure of the GFRS. Computer models have been used for simulation and the projected areas of inundation plotted for the worst scenarios.

If either of the North Dams fail (under conditions of one-half PMP, lake empty, with walls, etc.), approximately 2.8 square miles of area will be inundated downstream with different flood depths. The total damage cost is estimated to be $153 million, about one-third of the damage is within the residential areas and the rest in the commercial and industrial locations. The flood depth can reach more than three feet at some areas and the water will finally flow to the Salt River which is approximately five miles from the North Dams.

If the East Dam fails, approximately 1.3 square miles of area will be inundated at the downstream with different flood depths. The total damage cost is estimated to be $47 million, about three-fourths of the damage is within the residential areas, and the remaining in the commercial and industrial locations. The flood depth can reach more than three feet at some locations and the water will finally overflow to the Superstition Freeway, which is approximately 1.4 miles from the East Dam.

Because of the high degree of urbanization below the GFRS and the velocity of the flood wave, loss of life may be unavoidable if adequate warning of dam failure and timely evacuation of the downstream area are not provided. Devastation of property is unavoidable in any case. Traffic will be paralyzed on I-10 due to serious flooding at the immediate downstream of the East Dam. Electrical, telephone, water and sewage utilities in the inundated areas would likely be interrupted or even destroyed in the event of dam failure.

7. REFERENCES

1. Soil Conservation Service, Watershed Work Plan, Guadalupe Watershed, Maricopa County, Arizona, January 1971

2. Hydrology Report, "Dambreak Study for Guadalupe Flood Retarding Structure," Greiner, April 1990

3. Fread, D.L., The NWS DAMBRK Model Theoretical Background/User Documentation, Office of Hydrology, National Weather Service, Silver Springs, Maryland, June 20, 1988

4. Design of Small Dams, Bureau of Reclamation, United States Department of the Interior, Second Edition, 1973

5. Safety of Dams, Flood and Earthquake Criteria, National Academy Press, Washington, D.C., 1985

6. Safety of Existing Dams, Evaluation and Improvement, National Academy Press, Washington, D.C., 1983

7. GFRS Final Design Report by Gosnell Development Company, 1986

8. Geological Report, Geological Consultants, February 1986

9. Construction Data Review and Evaluation of Proposed Modifications to Guadalupe Flood Control Structure, Thomas-Hartig & Associates, Inc., October 20, 1986

10. USGS Topographic Maps, Scale 1"=2,000′, Photorevised 1982

11. City of Phoenix, Topographic Maps, Scale 1"=100′, October 1971

12. City of Tempe, Topographic Maps, Scale 1"=200′, October 1965

13. Topographic Maps, Kenny Aerial Mapping, Inc., Scale 1"=50′, April 1989 (Post Development)

14. Aerial Maps by Cooper Aerial Survey, Inc., Scale 1"=200′, June 9, 1984

15. Soil Mechanics, Material Testing on Guadalupe Watershed, Regional Service Center, Portland, Oregon, August 1970

16. Technical Memorandum "Dambreak Study for Guadalupe Flood Retarding Structure," by Greiner, Inc. dated August 28, 1989, Revised Edition

17. Technical Memorandum "Dambreak Study for Guadalupe Flood Retarding Structure," by Greiner, Inc. dated April 1990

18. Floodproofing Non-Residential Structures, FEMA 102, Federal Emergency Management Agency, May 1986

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Appendix A

8. APPENDICES

Appendix A

Results of Downstream Routing for East Dam
(Figures A Through D)

FIGURE A

EAST DAM

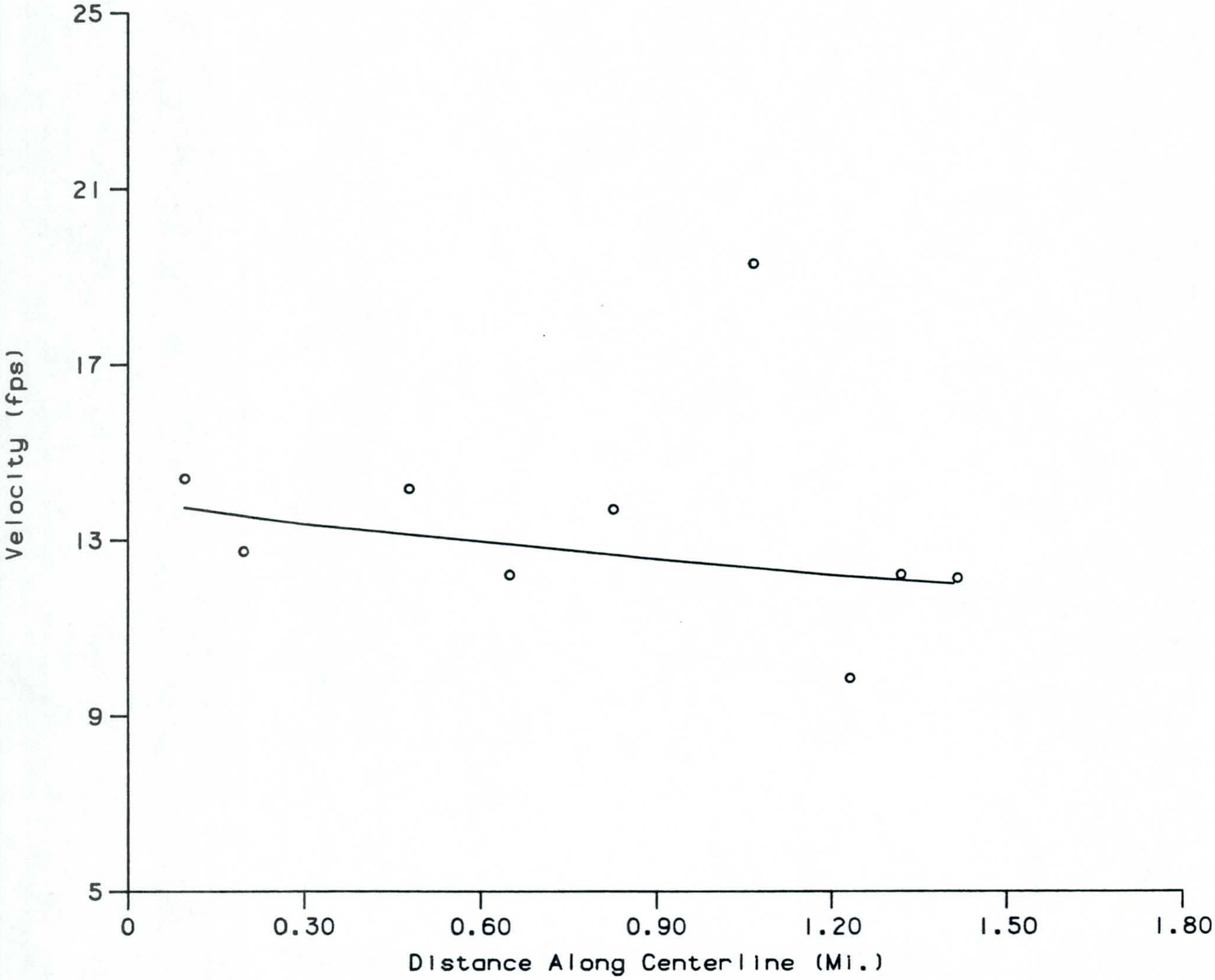

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FIGURE B

EAST DAM

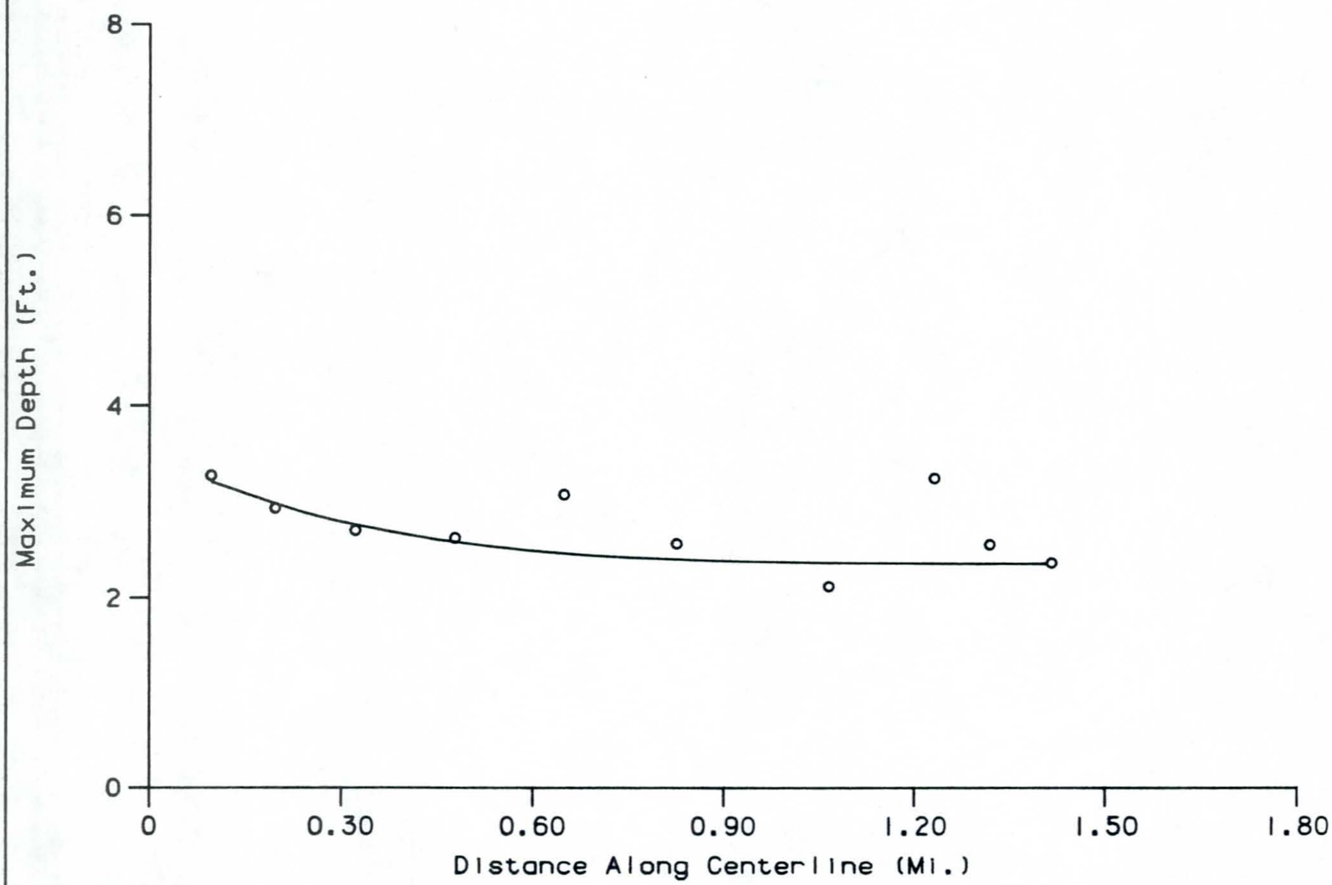

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FIGURE C

EAST DAM

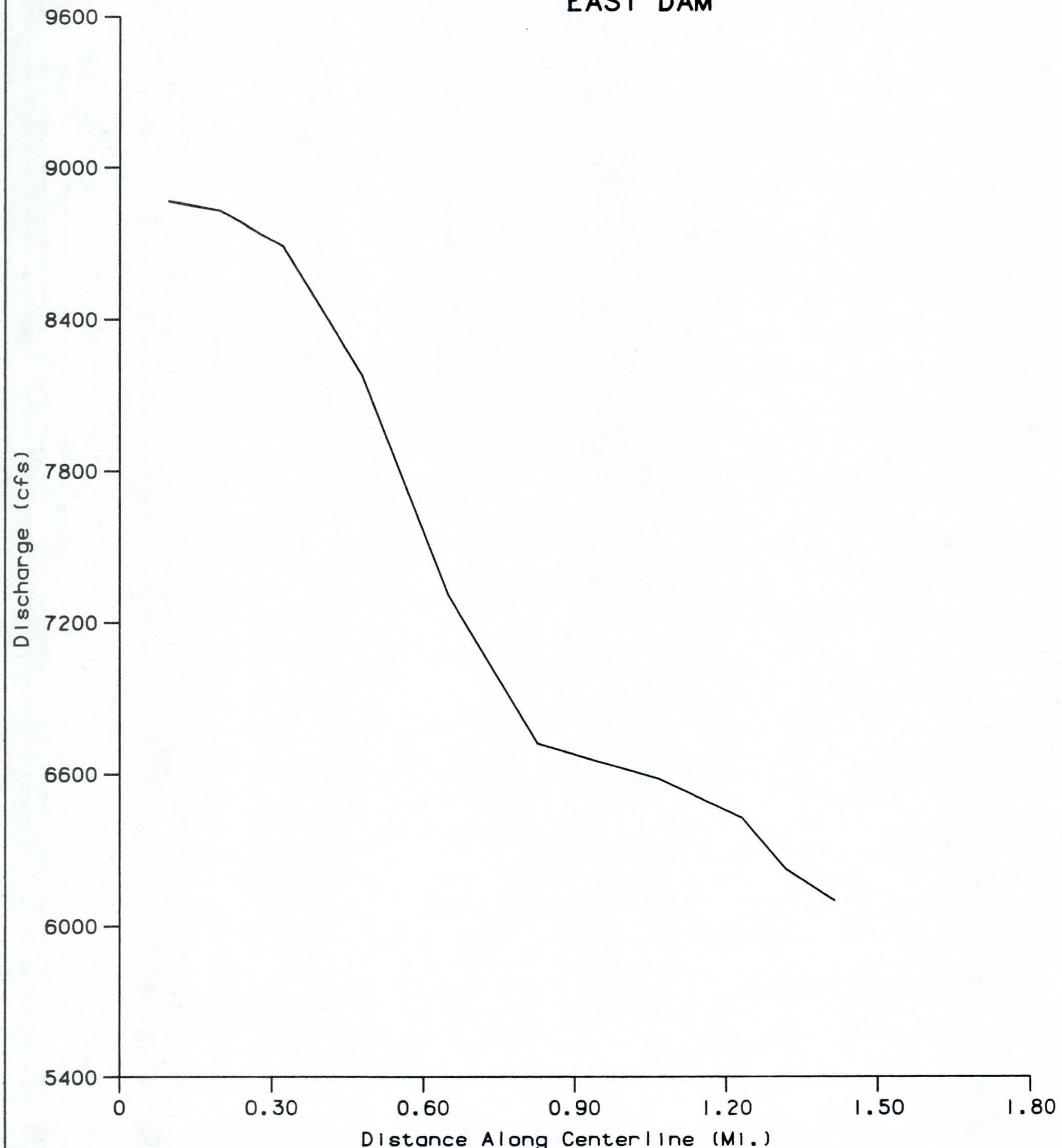

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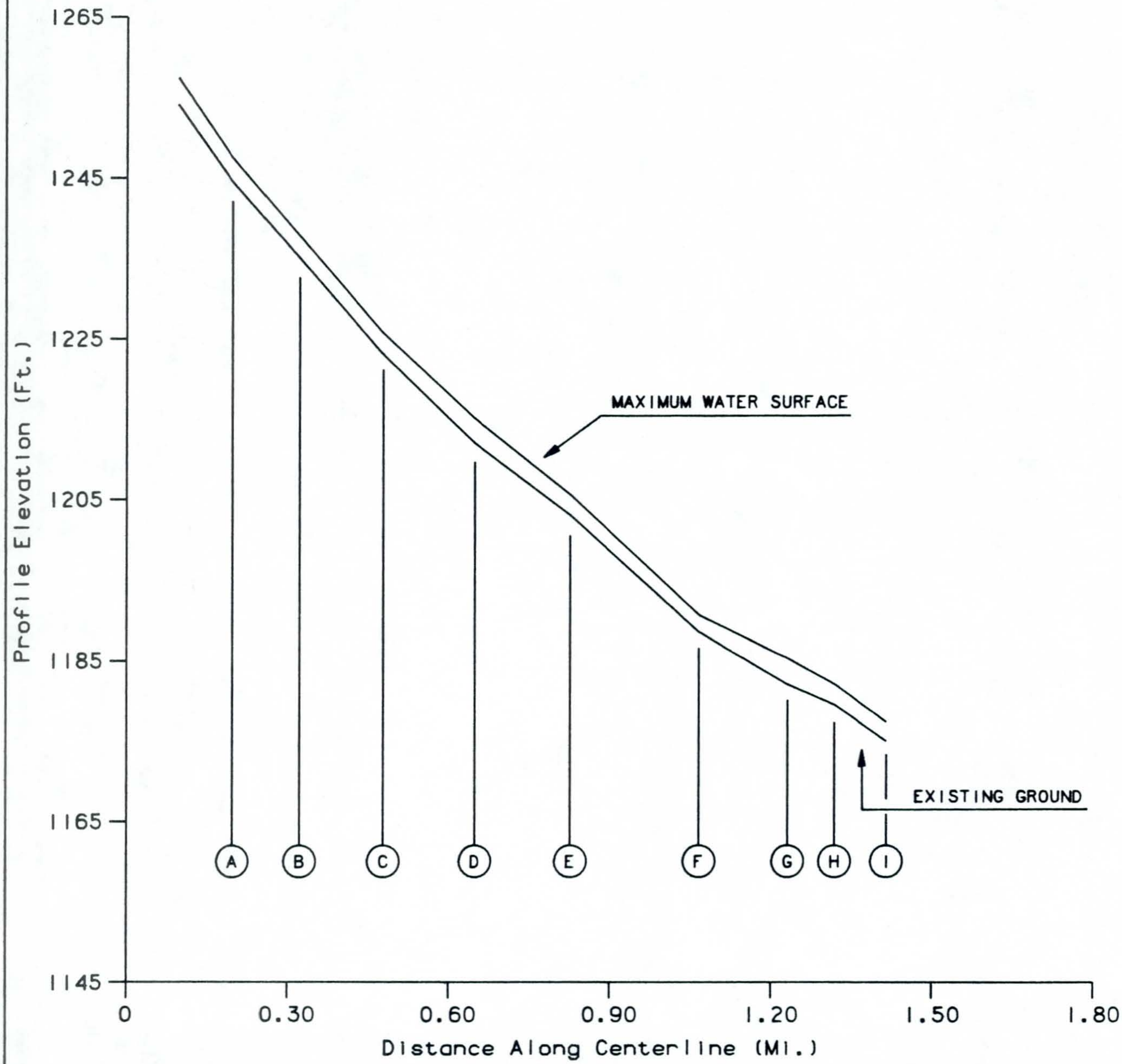
FIGURE D

EAST DAM



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Appendix B

8. APPENDICES

Appendix B

Results of Downstream Routing for North Dam
(Figures A Through D)

FIGURE A

NORTH DAM

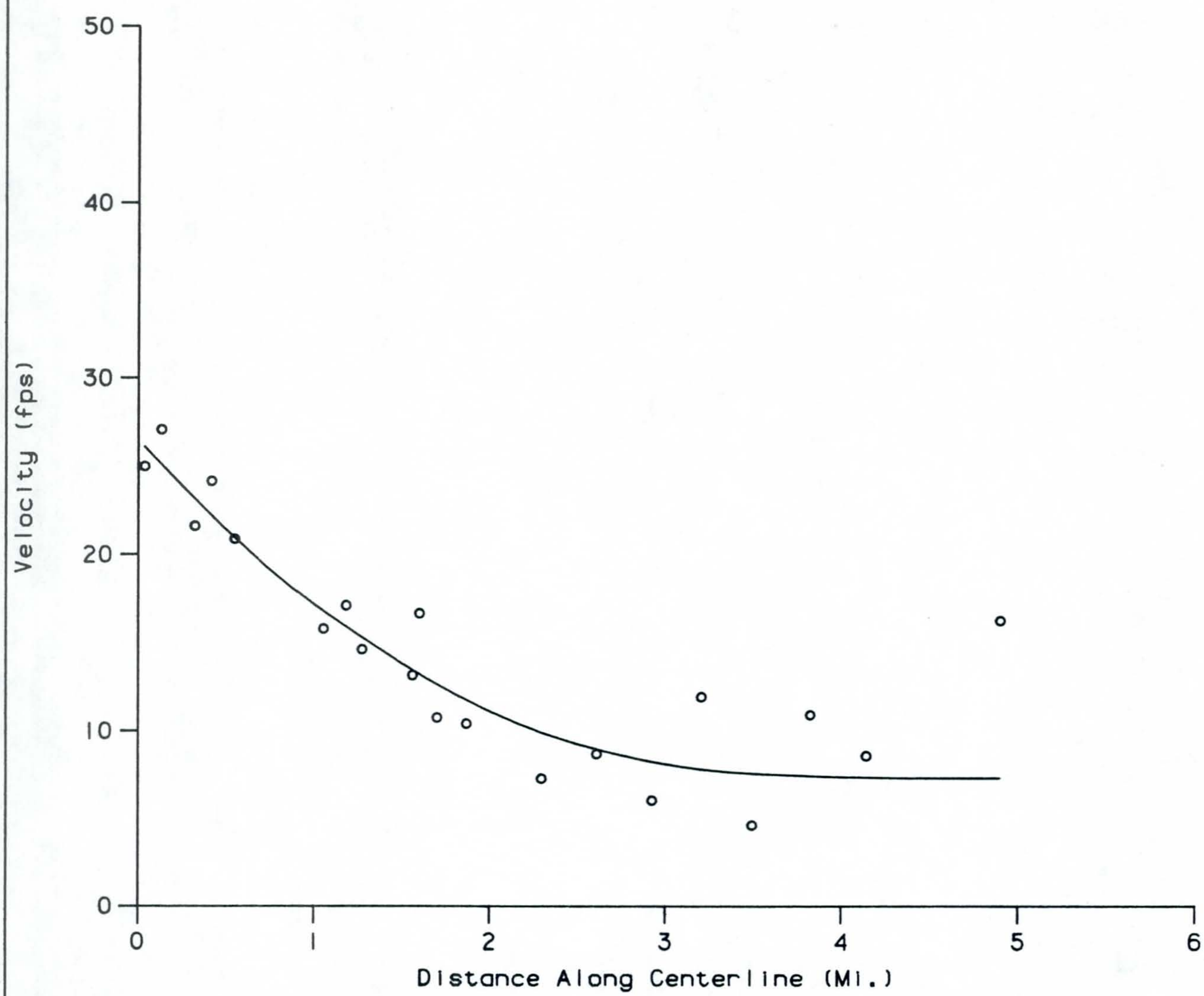

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FIGURE B

NORTH DAM

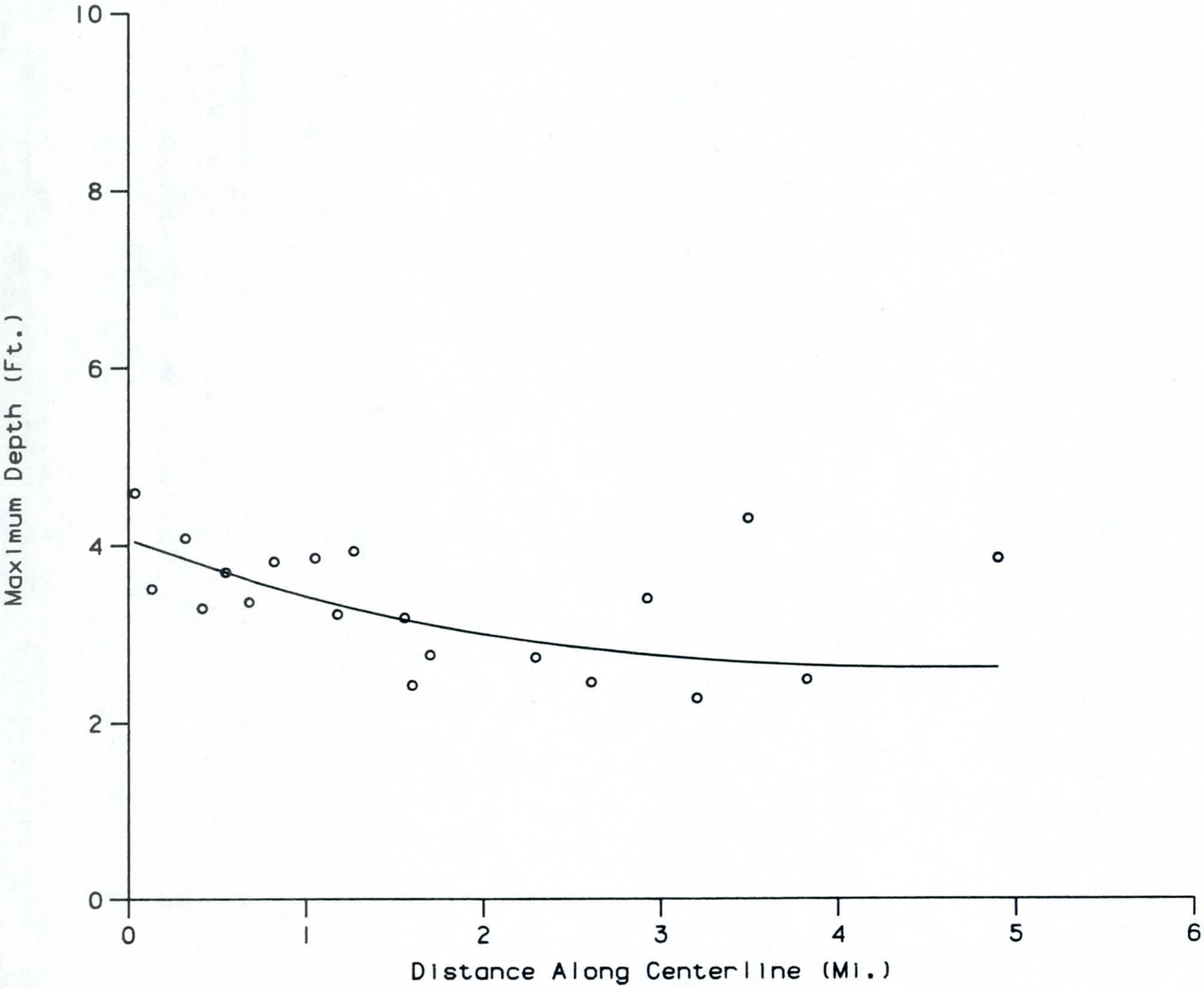

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FIGURE C

NORTH DAM

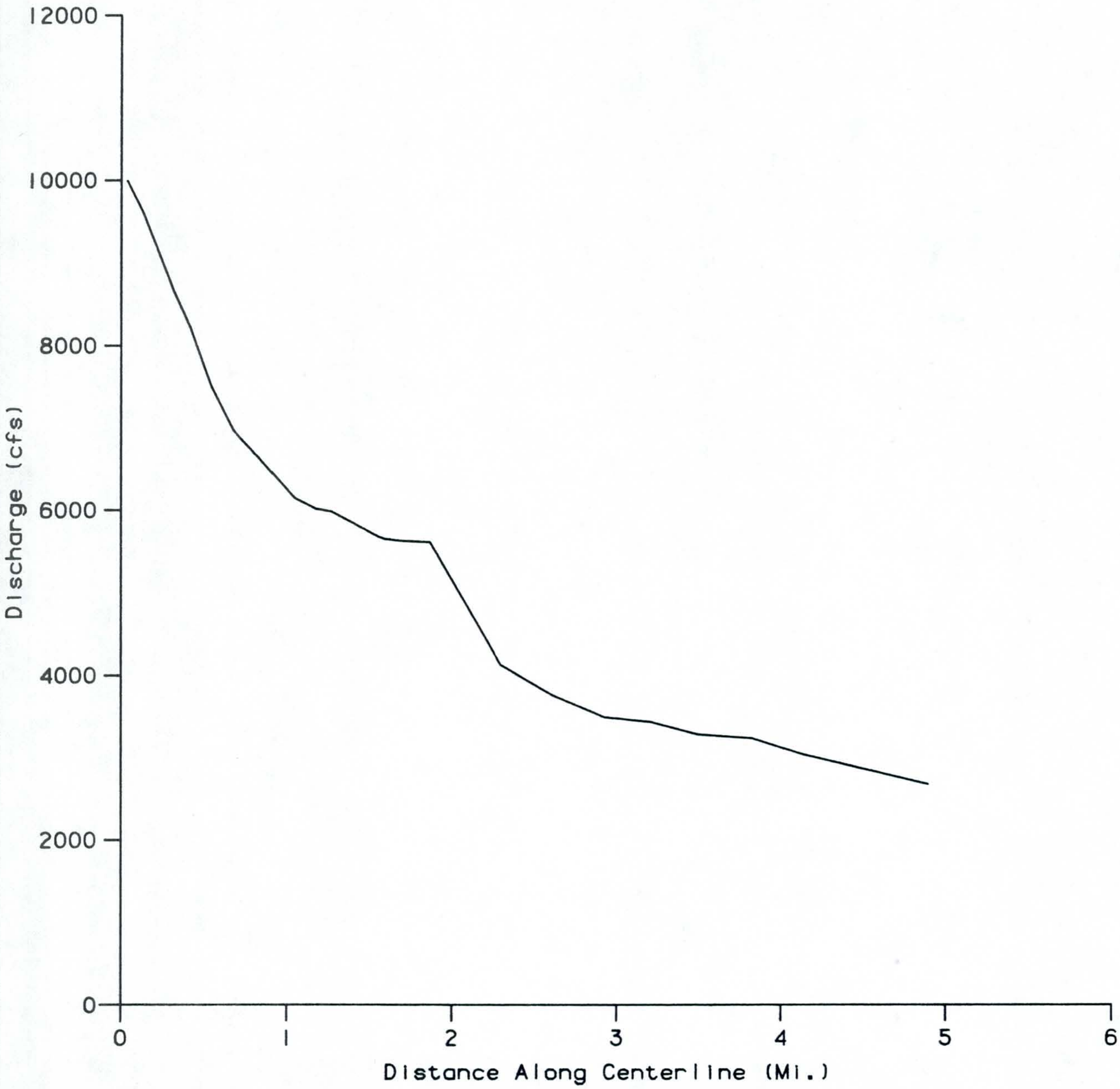

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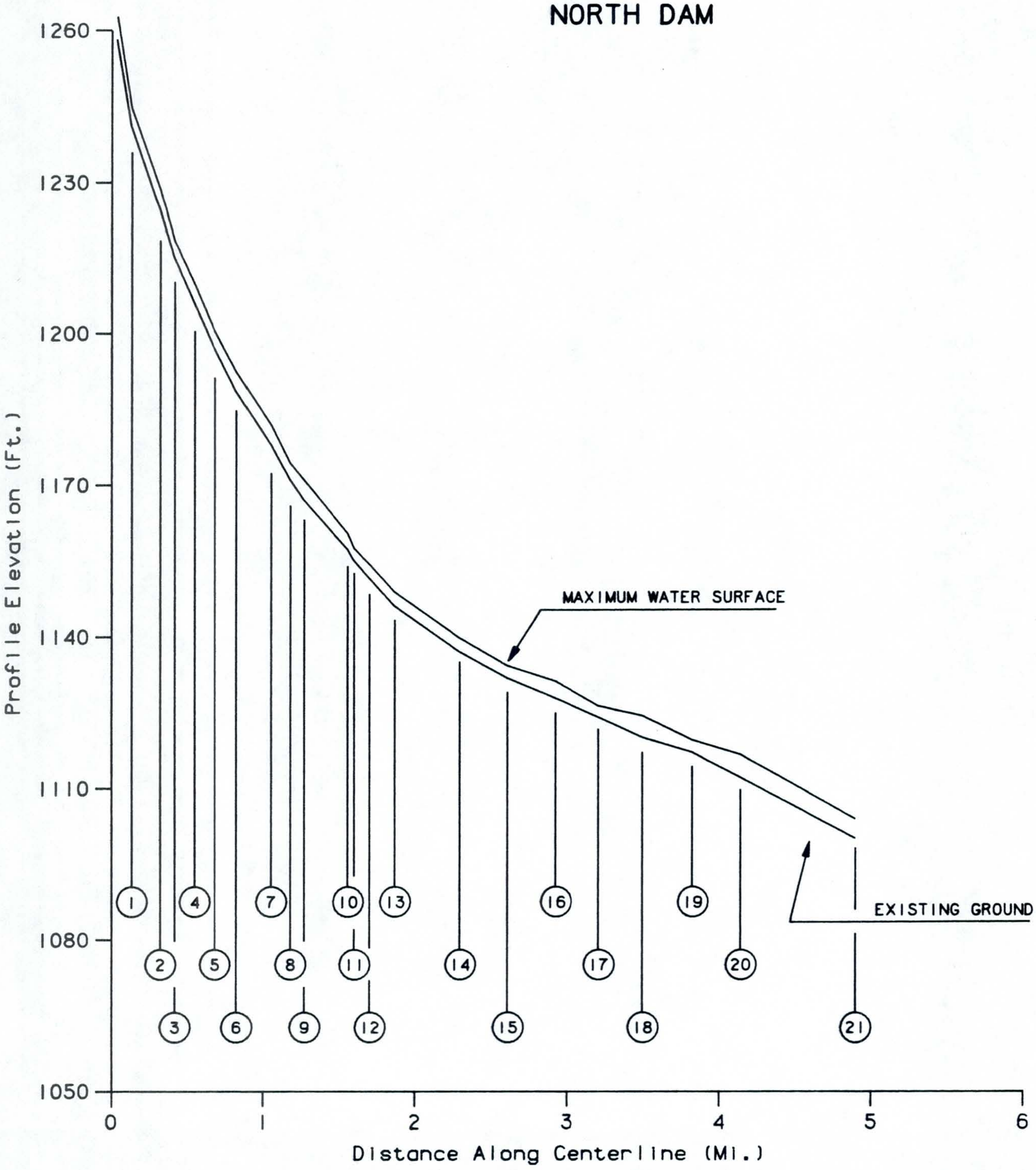
FIGURE D

NORTH DAM



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