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WRE PROJECT No. 189034

DAM BREAK STUDY
MOCCASIN RESERVOIR
TUOLUMNE COUNTY, CALIFORNIA

Technical Report Presented to:

UTILITIES ENGINEERING BUREAU

CITY AND COUNTY OF SAN FRANCISCO

MAY 1989

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DAM BREAK STUDY

MOCCASIN RESERVOIR
TUOLUMNE COUNTY, CALIFORNIA

1. INTRODUCTION

1.1 PROJECT DESCRIPTION

The Moccasin Reservoir and dam are located in the western foothills of California's Sierra Nevada (See Figure 1), at a point roughly three miles upstream of the confluence of the Moccasin Creek with the Tuolumne River. The reservoir has a storage capacity of about 500 acre-feet and a surface area of approximately 30 acres when filled to the spillway crest level. The dam is an engineered structure with a reinforced concrete core wall along the dam axis, extending from bedrock to three feet below the dam crest; a clay core is covered by a graded rock fill placed at slopes of 2.5:1 and 2:1 (Horizontal to Vertical) on the upstream and downstream faces of the dam, respectively. The dam crest is 855 feet long and is at an elevation of 929 feet (USGS Mean Sea Level Datum; all elevations in this report will be referred to the same datum). The dam has an uncontrolled ogee type spillway with its crest approximately at elevation 919 feet and a total discharge capacity of 9,800 cfs; an auxiliary overflow spillway with crest elevation at 922 feet, raising the total spill capacity to 15,500 cfs, was constructed in May 1989.

The valley bottom immediately downstream of the Moccasin Dam is less than 1,000 feet wide and valley sides rise sharply to the northeast and southwest. Discharges from the Moccasin Reservoir flow down Moccasin Creek into the Don Pedro Reservoir, which is formed by damming primarily Tuolumne River flows. When the Don Pedro Reservoir is at its normal high water level of 830 feet, its pool extends to a point about 0.7 miles downstream of the

Moccasin Dam. The confluence of Moccasin Creek and Tuolumne River is 2.6 miles downstream of the Moccasin Dam.

Man-made facilities located downstream of the Moccasin Dam which would be affected by a dam failure include a State Fish Hatchery, the Highway 120 bridge and embankments, a Low-Head Hydroelectric installation located dowstream of the highway bridge, and access roads in the vicinity of these facilities.

1.2 SCOPE OF DAM BREAK STUDY

This study was conducted to define the extent of inundation produced by a potential failure of Moccasin Dam and to determine the characteristics and time of travel of the flood waves produced by dam breaks. A sensitivity analysis was performed to investigate the variations in discharges and water surface elevations due to different assumptions regarding the nature and timing of the dam breaching and the hydraulic conditions downstream. The upstream limit of the study was at the upstream end of the Moccasin Reservoir. The downstream limit of the study was the Don Pedro Reservoir; for purposes of simulating flood waves, cross sections as far as 9 miles downstream of the Moccasin-Tuolumne River confluence were used.

2. METHOD OF ANALYSIS

2.1 COMPUTATIONAL METHODS

The analysis of the potential failure of Moccasin Dam was performed with the aid of two widely used, tested, and accepted numerical models: the National Weather Service's DAMBRK model developed by Dr. D. L. Fread, and the U. S. Army Corps of Engineers' HEC-2 model developed by Bill S. Eichert of the Hydrologic Engineering Center in Davis, California. The water surface profiles (HEC-2) model was used to preliminarily analyze the hydraulic characteristics of the Moccasin Creek channel under steady flow conditions. The dam-break flood forecasting (DAMBRK) model was used to simulate different dam breaching scenarios.

The DAMBRK model consists of a breach component to provide a temporal and geometrical description of the breached dam, and a routing component to determine the modifications to the dam-break wave as it advances downstream. The model computes the reservoir outflow hydrograph resulting from a breach via a broad-crested weir approximation, taking into account submergence and approach velocity effects, storage depletion, and upstream flows into the reservoir. The dynamic routing component is based on a weighted four-point, non-linear finite difference solution of the one-dimensional equations of unsteady flow (Saint Venant Equations). The DAMBRK model has been tested on several dam failures and the observed peak discharges and elevations were satisfactorily reproduced by the model (Ref. 1).

2.2 DEFINITION OF FLOW SYSTEM

For purposes of the dam break study, the following elements, identified in Figure 2, were analyzed:

- Moccasin Reservoir, shown in Photograph 1, including inflows from Moccasin Creek and the Moccasin Power Plant.

- Moccasin Dam, including primary and auxiliary spillways, outlet conduit, and intake to low-head hydroelectric facility; see Photographs 2, 3, and 4.

- Moccasin Creek channel downstream of dam, including State Fish Hatchery facilities and lower low-head plant installations on left overbank; the portion of channel between the dam and the Highway 120 bridge is shown in Photograph 5.

- Highways 49 and 120, including the road embankments and Highway 120 bridge over Moccasin Creek.

- Don Pedro Reservoir in the vicinity of Moccasin Creek, including a reach of the Tuolumne River extending 3 miles upstream and 9 miles downstream of the Moccasin Creek confluence; results are reported only to the downstream end of the study, 2.1 miles downstream of the confluence.

2.3 HYDRAULIC CONDITIONS INVESTIGATED

Federal Energy Regulatory Commission (FERC) guidelines for the analysis of dam break events indicate that a "fair weather" dam break is the minimum condition to be analyzed. A "fair weather" dam break is defined as one occurring with the reservoir at normal maximum pool elevation with normal streamflow prevailing. Other flood conditions should be analyzed, according to the same guidelines, if they would identify special flooding problems.

Several sets of hydraulic conditions were analyzed in this study to define a worst-case scenario. The following parameters were considered:

- Water surface elevations in Moccasin Reservoir at the time of failure; elevations ranging from normal maximum pool to dam overtopping were analyzed; level-pool and sloping pools were also considered in the routing of reservoir flows.

- Inflows to Moccasin Reservoir before, during, and after dam failure; constant and variable inflows were analyzed; the spillways are capable of handling up to 15,500 cfs with the pool at its normal maximum level; a discharge of 20,000 cfs into the reservoir would be required to bring the pool to the dam crest; to analyze overtopping, higher discharges were required: inflows of 1.5 and 2.0 times the PMF discharge of 15,500 cfs were analyzed.

- Water surface elevation in Don Pedro Reservoir at the time of Moccasin Dam failure; the normal low pool elevation of Don Pedro Reservoir, according to information supplied by Turlock Irrigation District, is 750 feet; the normal maximum pool level is at elevation 830 feet. The full range of Don Pedro Reservoir pool elevations was analyzed.

- Tuolumne River flows into Don Pedro Reservoir; discharges ranging from 0 to 100,000 cfs were analyzed.

- Breaching of Highway 120 embankments; since the road embankments restrict the flow path to the area under the bridge, flood levels upstream of the bridge could be expected to be substantially higher than in the downstream area, and flow velocities through the bridge opening may reach highly scouring levels, presenting the possibility of bridge and embankment failure; analyses were performed for both cases, with and without embankment failure.

- o Outlet conduit and low-head intake discharges; analyses were performed with and without these outlets in operation.

- o Channel cross sections and roughnesses; roughness coefficients were estimated from a visual inspection of the project site and the U. S. Geological Survey Water Supply Paper 1849 (Ref. 2) titled "Roughness Characteristics of Natural Channels." Cross sections were selected at representative locations along the Moccasin Creek and Tuolumne River channels, as shown in Figure 3; the section at Moccasin Dam was labeled "Mile 0" for the numerical analysis and other sections were named in river miles according to their distance from the dam.

2.4 DAM BREACH CONDITIONS ANALYZED

A dam breach is hereby defined as the opening in the dam as it fails. While early attempts to analyze dam breaches generally assumed an instantaneous occurrence, the DAMBRK model allows the simulation of a more realistic timed breach, with the opening progressively increasing in size. The numerical model uses the breach parameters identified in Figure 4 and described following:

- o Shape parameter "Z" which identifies the side slope of the breach; this value depends on the angle of repose of the compacted and wetted materials through which the breach develops.

- o Average width of breach, "$\overline{BR}$"; statistically derived predictors for earthen dams have recently been developed

(Ref. 1) which relate the average width to reservoir volume in acre-feet, "Vr", and height of dam, "Hd":

$$\overline{BR} = 9.5 \text{ Ko } (\text{Vr Hd})^{0.25} \tag{1}$$

The coefficient Ko is 1.0 for non-overtopping failures and 1.4 for overtopping failures.

- o Bottom width of breach, "BB", describing the anticipated final width of the breach; the terminal width is related to the average width by:

$$BB = \overline{BR} - Z \text{ Hd} \tag{2}$$

- o Minimum elevation of breach, "YBMIN", generally the dam's footing or foundation elevation.

- o Time to failure, "THF", defined as the interval of time from the moment the breach commences until it reaches its final shape; for overtopping failures the beginning of breach formation is after the downstream face of the dam has eroded away and the resulting crevasse has progressed back across the width of the dam crest to reach the upstream face. Statistically derived indicators (Ref. 1) relate time to failure to dam height and reservoir volume by the expression:

$$THF = 0.8 \, (\text{Vr}/\text{Hd}^2)^{0.5} \tag{3}$$

Since the actual dam failure mechanics are not well understood, it is impossible to predict with certainty the value of any of the parameters listed above. Analyses are based on the consideration of probable ranges of values selected from statistical data.

For Moccasin Dam, based on Equations (1), (2) and (3) above and assuming a storage volume of 500 acre-feet and a dam height of 60 feet, the following values were analyzed:

- Z: The full range of statistically determined side slopes for earthen dams (Refs. 1, 3) was studied, from Z=0.25 to Z=1.0.

- $\overline{BR}$: Average breach widths ranging from 125 to 175 feet were analyzed.

- BB: Bottom widths of 115 and 160 feet were analyzed, for side slopes of 1.0 and 0.25, respectively.

- THF: The time to failure computed using Equation (3) was 0.3 hours or 18 minutes. Considering that the worst-case scenario would involve a breach by overtopping, and that the dam has compacted rock slopes and a concrete core wall, a more rapid time to failure is highly improbable. However, since FERC guidelines specify a range of THF from 0.1 to 1.0, the low value of 0.1 hours (6 minutes) was also tested.

Figure 5 shows an elevation view of Moccasin Dam and illustrates the dimensions of the maximum breach used during the study.

3. RESULTS OF ANALYSIS

3.1 HYDRAULIC CHARACTERISTICS OF FLOW SYSTEM

Analysis under both steady and unsteady flow conditions indicated that the flow conveyance system from Moccasin Reservoir to Don Pedro Reservoir is divided into three distinct reaches with well defined characteristics:

- Reach 1: Moccasin Dam to Highway 120 Bridge, characterized by a relatively mild channel slope and flows generally at subcritical stages; this portion of the channel actually extends to about 500 feet downstream of the bridge; the channel has a wide, flat left overbank where the fish hatchery area is located; the embankments of Highway 120 constrict the flow area, limiting the flow path to the area directly under the bridge.

- Reach 2: Moccasin Creek from downstream side of bridge to Don Pedro Reservoir pool, characterized by a relatively steep channel slope and flows at supercritical stages for the entire range of flows tested. Since supercritical flow stages propagate from upstream to downstream, this reach of channel effectively separates the upstream reach from the Don Pedro Reservoir pool, eliminating any possible backwater effects. The water surface elevations in Reach 1, therefore, are totally independent of Don Pedro Reservoir pool levels.

- Reach 3: Don Pedro Reservoir pool, starting on Moccasin Creek and extending to the Tuolumne River. Depths of water at the confluence of Moccasin Creek and Tuolumne River range from 130 to 210 feet (for reservoir pool elevations of 750 and 830 feet, respectively).

3.2 OUTFLOWS FROM BREACHED DAM

The discharges from a dam failure event were calculated for different sets of assumptions and the results examined for sensitivity to different variables. The findings are summarized following:

- Peak outflows were higher when the outlet conduit and low-head intake were inoperative, forcing the totality of the inflow to be conveyed through the dam breach.

- The inflow to the reservoir, assumed high in all cases since at least 15,500 cfs would be required to take the reservoir pool to maximum levels, produced some variations in outflow; changing the inflow from 15,500 cfs to 23,250 cfs raised the peak outflow by approximately 10%.

- The side slopes of the breach had some effect on the outflows, with the steeper slopes (Z=0.25, BB=160 feet) producing a peak outflow about 5% higher than the milder slopes (Z=1.0, BB=115 feet).

- The peak outflows were highly sensitive to time of failure assumptions. A breach occurring in 6 minutes produced outflows about 60% higher than those generated by an 18-minute failure.

- Breaching of the downstream Highway embankments had no appreciable effect on peak dam outflows.

- The pool level assumed at Moccasin Reservoir at the time of failure produced small changes in the peak outflow. A "Fair Weather" dam break with pool at elevation 927 feet produced peak outflows about 10% lower than those generated by an overtopping failure.

Table 1 summarizes the sensitivity of peak outflows to different variables. Figure 6 illustrates the outflow hydrographs for four basic conditions: a "fair weather" dam break occurring in six minutes, an overtopping failure occurring in six minutes, an overtopping failure occurring in 18 minutes, and a six-minute overtopping failure with breaching of the downstream road embankments. As the graph in Figure 6 indicates, the highest peak discharges were recorded for six-minute failures.

3.3 FLOOD LEVELS DUE TO BREACHED DAM

Flood levels varied depending on the assumptions made, but in all cases were high between the dam and Highway 120 and almost imperceptible once in the Don Pedro Reservoir pool. Due to the constriction at the Highway 120 bridge, the flood wave raised water levels above the 900-foot elevation for most of the conditions tested, thus overtopping the road embankments at the intersection of Highways 49 and 120. Figure 7 shows the resulting flood stages between the dam and the road embankments for the same four sets of assumptions listed in the previous report section. The highest flood stages were reached for the six-minute failures, with overtopping failures showing peak elevations about two feet higher than fair weather break failure. The breaching of the road embankments is shown to have little effect on peak stages; the breach at the road embankment does allow the flood levels to recede more rapidly.

The magnitude of the flood wave decreased in intensity as it moved downstream of the bridge. Figure 8 shows water surface elevations at four different locations, from the dam to the beginning of the Don Pedro Reservoir pool; the elevations plotted correspond to the worst-case scenario tested (six-minute overtopping failure). Figure 9 shows the small fluctuations in level experienced in the Don Pedro Reservoir due to the dam break

MOCCASIN RESERVOIR: DAM BREAK STUDY

TABLE 1

PEAK OUTFLOWS FROM BREACHED DAM

Breach Side Slope Z	Breach Bottom Width (Ft)	Breach Bottom Elev. (Ft)	Time to Complete Breach (Minutes)	Maximum Reservoir Inflow (CFS)	Reservoir Level at Failure (Ft)	PEAK BREACH OUTFLOW (CFS)
0.25*	160	882	6	23,250	929.25	121,730
0.25	160	882	6	23,250	929.25	118,740
1.00	115	882	6	23,250	929.25	113,844
0.25	160	882	6	23,250	927.00	112,904
0.25	160	882	6	15,500	927.00	109,795
0.25	160	882	18	23,250	929.25	74,725

* Includes breaching of the Highway 120 bridge; the simulation reported on the second line assumed no breaching of the bridge.

wave; reservoir pool levels increased by less than a foot for a peiod of less than one hour; flows in the Tuolumne River (discharges up to 100,000 cfs were tested) had no impact on these levels.

The effect of channel roughness on flood stages was examined. Manning's "n" values of 0.045 for the channel and 0.06 for overbank areas were assumed for most of the simulations. A higher roughness coefficient of 0.065 for channel and overbank areas was found to have little effect on overall results.

Table 2 summarizes water level information for several of the simulations performed, and also contains flow velocity data. Velocities were always greatest going through the constricted bridge area. The extremely high velocities, in excess of 50 feet per second in most cases, would produce significant scouring, could undermine the bridge footings, and could carry large quantities of scoured material downstream. The DAMBRK model does not account for changes to the channel cross sections nor does it provide any indication of scoured volumes.

3.4 FLOOD WAVE TRAVEL TIMES

Moccasin Reservoir's storage capacity of about 500 to 550 acre-feet would be rapidly depleted by a dam failure. As Figure 8 indicates, the reservoir level would go from its overtopping maximum to its after-failure minimum within 15 minutes (assuming a six-minute failure). The surge in discharge and water level rise would be totally dissipated within one hour.

The flood wave for a six-minute dam failure would reach the upstream end of Don Pedro Reservoir within five minutes. Figure 10 shows the movement of the wave from the dam to a point 4.7 miles downstream.

TABLE 2

PEAK WATER SURFACE ELEVATIONS AND FLOW VELOCITIES

	FAIR WEATHER BREAK		OVERTOPPING 6-MINUTE FAILURE		OVERTOPPING 18-MINUTE FAILURE	
Cross Section No.	W.S. Elev. (Ft)	Max. Vel. (Ft/sec)	W.S. Elev. (Ft)	Max. Vel. (Ft/sec)	W.S. Elev. (Ft)	Max. Vel. (Ft/sec)
0.15	911.3	68	912.6	73	908.0	49
0.39	858.9	20	860.0	21	856.2	18
2.60	-	-	830.7	1	-	-

Cross Section Locations:

Section 0.15: Between dam and Highway 120 bridge; reported velocities correspond to constriction under bridge

Section 0.39: Moccasin Creek downstream of bridge, approximately at location of low-head power plant

Section 2.60: Confluence of Moccasin Creek and Tuolumne River

3.5 FLOOD INUNDATION BOUNDARIES

Inundation boundaries were mapped onto an enlarged copy of the USGS 7.5 Minute Series Topographic Quadrangle for Moccasin, California, which was labeled Figure 11. The USGS map has a 50-foot contour interval; additional contour lines were added where appropriate using maps provided by the Turlock Irrigation District and the Utilities Engineering Bureau. A list of the drawings used for the preparation of the inundation boundary map is included in the reference section of this report.

The dam breach simulation producing the highest discharges and water surface elevations was selected for mapping the inundation boundaries. A list of the simulation assumptions follows:

- Moccasin Reservoir inflow: 1,000 cfs initially, rising to 23,250 cfs (1.5 x PMF) in one hour and staying at that level for the remainder of the simulation.

- Dam breach parameters:
  Side slopes, Z=0.25
  Bottom width of breach, BB=160 feet
  Minimum breach elevation, YBMIN=882 feet
  Time from beginning to end of failure, THF=6 minutes
  Breach due to overtopping.

- Downstream Channel: Roughness coefficient of 0.045 for channel and 0.060 for overbanks; Highway 120 embankments assumed to fail (the non-failing assumption produced very similar peak stages and discharges).

- Don Pedro Reservoir: Assumed at its maximum normal pool elevation of 830 feet; no lateral inflow from Tuolumne River (lateral flows did not affect results appreciably).

The inundation boundaries presented in Figure 11 represent the maximum water surface elevations recorded during the simulation, even if they did not occur simultaneously. Table 3 lists the maximum stages recorded at each cross section and the times of their occurrence. As indicated in Figure 11 and in accordance with the elevations shown in Table 3, the following structures are within the flood boundaries:

- The low head hydroelectric plant intake structure.

- Moccasin Dam and its primary spillway.

- The fish hatchery ponds and the unidentified structures between the downstream face of the dam and the fish hatchery ponds.

- The houses located along Highway 49 between the dam and Highway 120.

- The sewage treatment plant's sludge beds and septic tank, and the base of the sewage treatment plant tank; the top of the tank and the sewage treatment plant office are outside the flood area.

- The Highway 120 embankments and a segment of the roadway.

- The lower low-head hydroelectric plant and the three structures in its immediate vicinity.

- A portion of the access road leading to the lower low-head hydroelectric plant.

Given the limitations imposed by the uncertainties regarding actual failure conditions, the inundation boundaries should be considered only as general guidelines; all of the structures listed above will fall within the flooded area only in the highly unlikely occurrence of a six-minute overtopping dam failure.

MOCCASIN RESERVOIR: DAM BREAK STUDY

TABLE 3

PEAK DISCHARGES AND ELEVATIONS FOR OVERTOPPING 6-MINUTE DAM FAILURE

Distance from Dam (Miles)	Maximum Elevation (Ft)	Maximum Discharge (CFS)	Time of Max. Elev.* (Minutes)	Maximum Velocity (Ft/sec)
0.00	929.4	121,730	1	24
0.15	912.6	121,730	6	6
0.19	908.4	119,575	6	33
0.20	875.7	119,575	6	76
0.39	860.0	117,799	7	21
0.64	832.4	102,195	10	12
0.94	830.8	106,153	10	7
1.54	830.8	110,764	11	1
2.10	830.8	114,238	12	<1
2.60	830.7	118,583	13	1
3.30	830.6	122,498	14	<1
4.70	830.5	133,056	16	<1

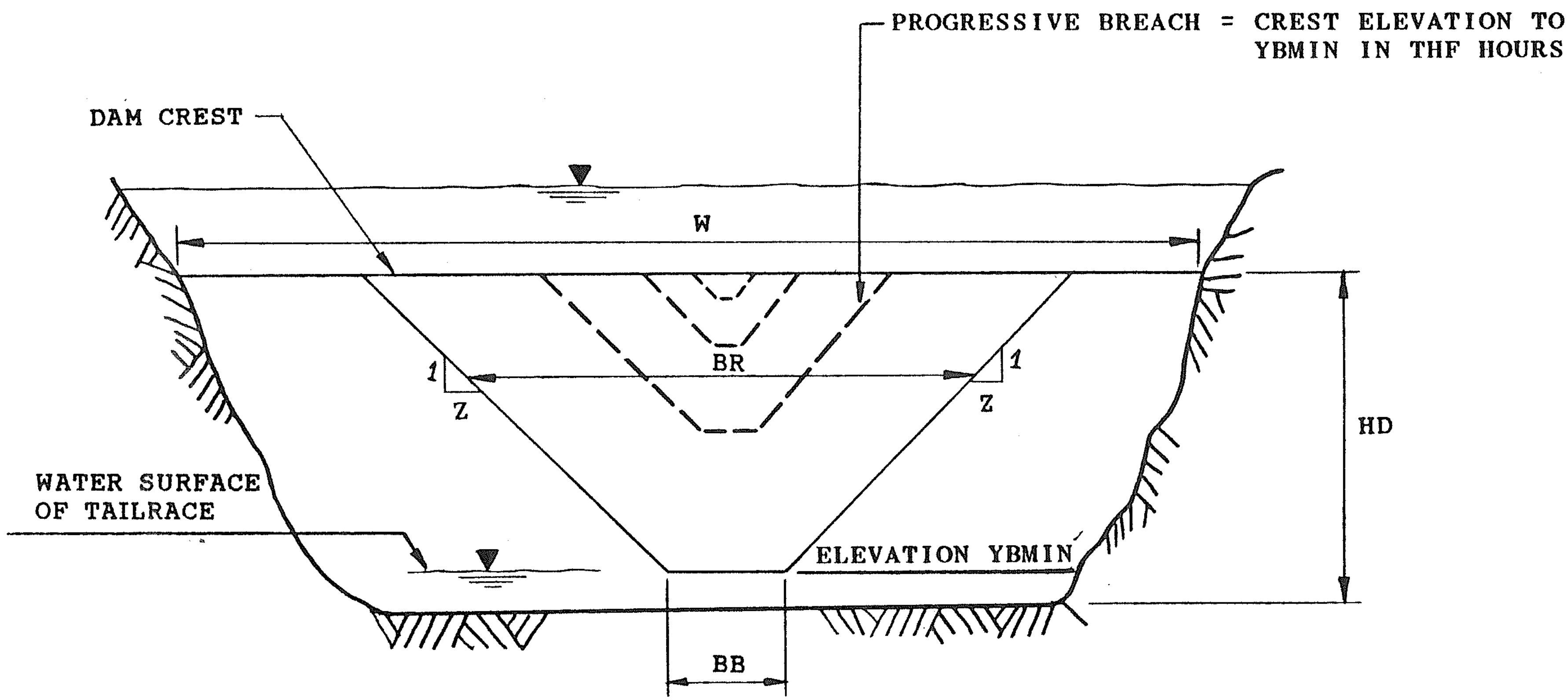
* Breaching of dam is initiated at Time=0; breach reaches full width and depth at Time=6 minutes

4. ILLUSTRATIVE MATERIALS

FIGURES 1-10

PHOTOGRAPHS 1-5

INUNDATION MAP (FIGURE 11)



HD = HEIGHT OF DAM
W = LENGTH OF DAM CREST
BR = AVERAGE WIDTH OF DAM BREACH
BB = BOTTOM WIDTH OF FINAL BREACH
Z = SIDE SLOPE OF BREACH
YBMIN = MIMIMUM ELEVATION OF BREACH
THF = TIME FROM BEGINNING TO END OF BREACH

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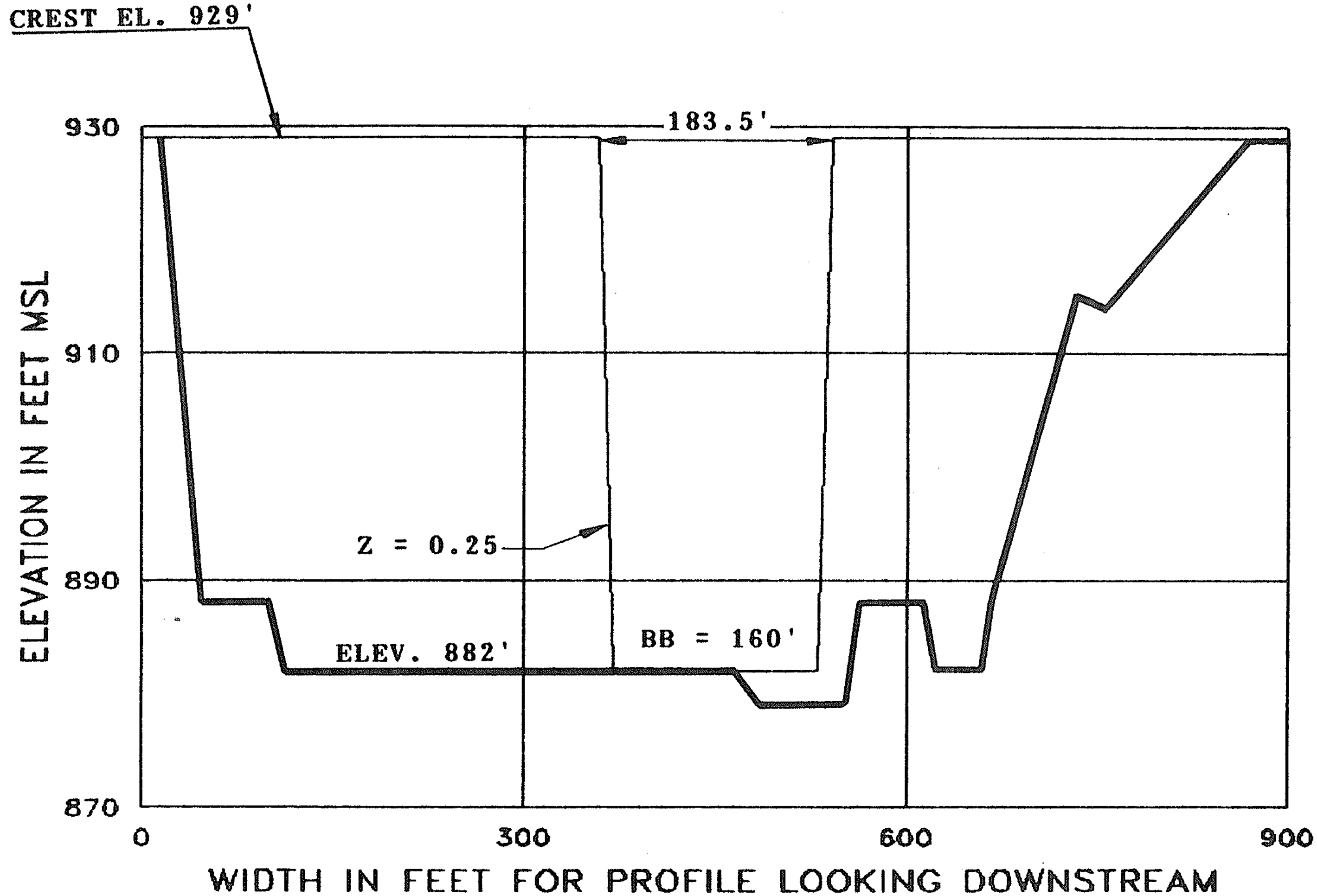
DATE: 05·10·89		REVISED

SCHEMATIC DEFINITION OF BREACH PARAMETERS

MOCCASIN RESERVOIR: DAM BREAK STUDY

DRAWING NUMBER Fig. 4



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DATE: 05·11·89		REVISED

ELEVATION VIEW OF MOCCASIN DAM
SHOWING BREACH DIMENSIONS

MOCCASIN RESERVOIR: DAM BREAK STUDY	DRAWING NUMBER Fig. 5

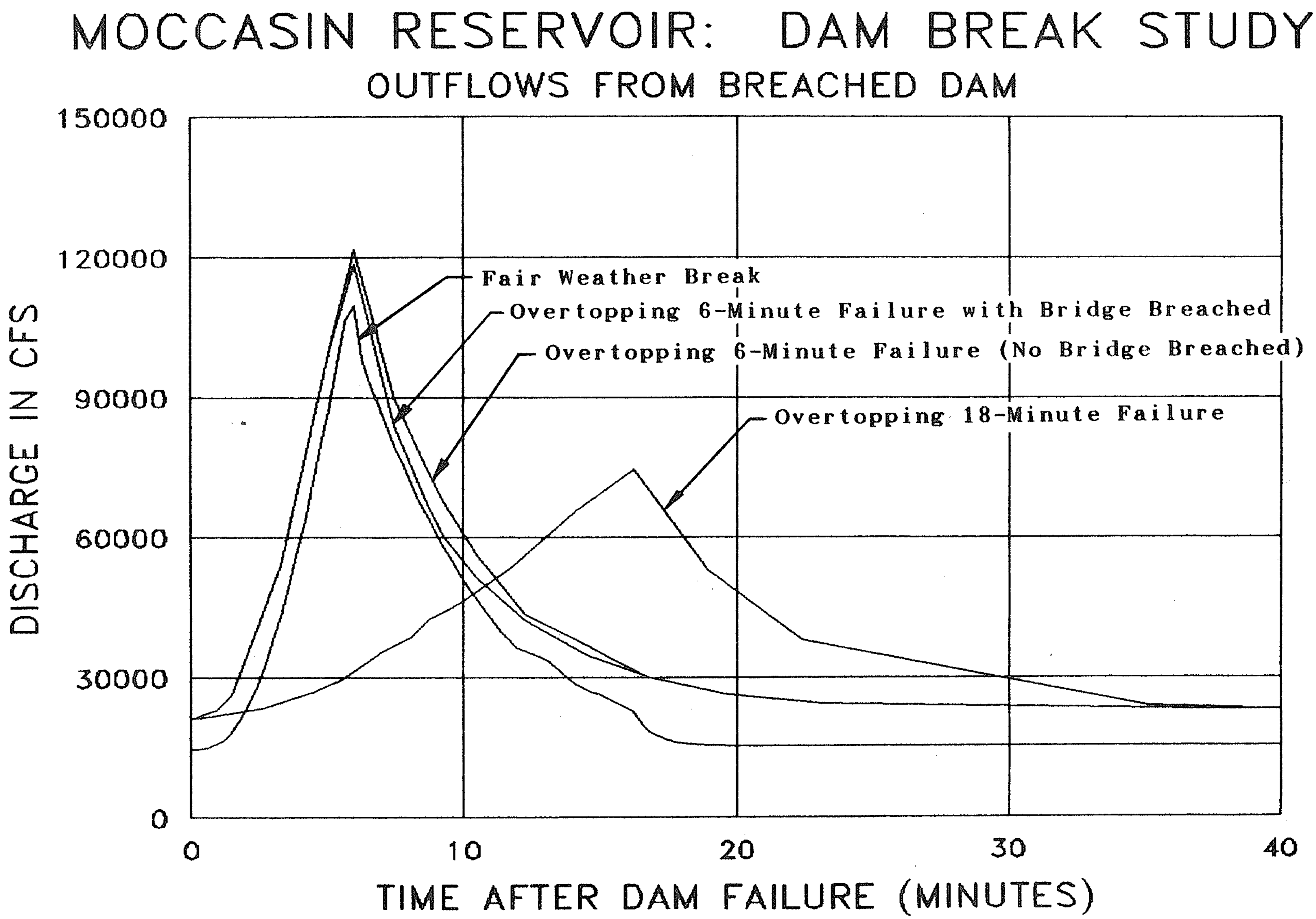

MOCCASIN RESERVOIR: DAM BREAK STUDY
OUTFLOWS FROM BREACHED DAM
DISCHARGE IN CFS
150000
120000
90000
60000
30000
0
0
10
20
30
40
TIME AFTER DAM FAILURE (MINUTES)
Fair Weather Break
Overtopping 6-Minute Failure with Bridge Breached
Overtopping 6-Minute Failure (No Bridge Breached)
Overtopping 18-Minute Failure

Fig. 6

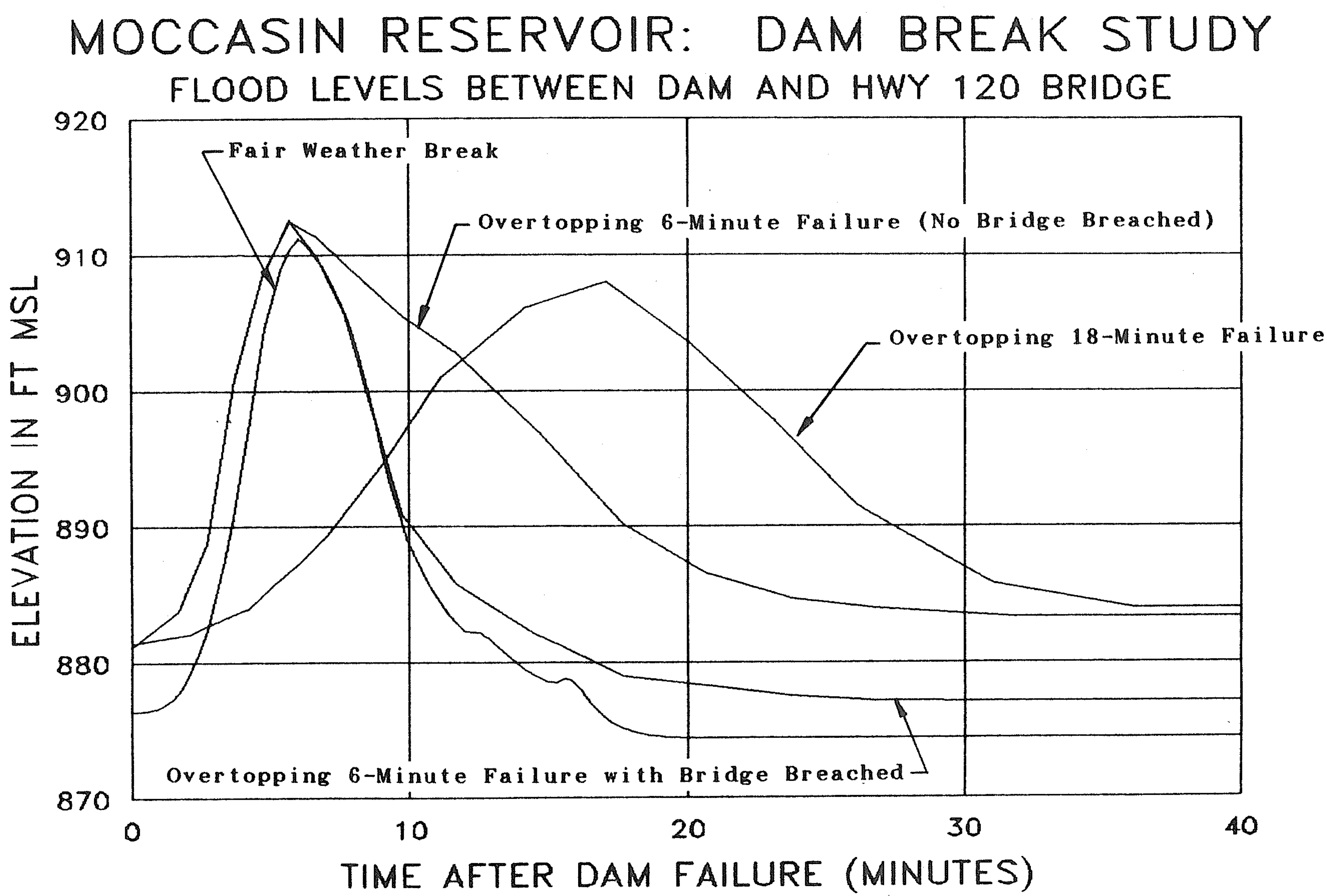

MOCCASIN RESERVOIR: DAM BREAK STUDY
FLOOD LEVELS BETWEEN DAM AND HWY 120 BRIDGE
Fair Weather Break
Overtopping 6-Minute Failure (No Bridge Breached)
Overtopping 18-Minute Failure
Overtopping 6-Minute Failure with Bridge Breached
ELEVATION IN FT MSL
920
910
900
890
880
870
0
10
20
30
40
TIME AFTER DAM FAILURE (MINUTES)

Fig. 7

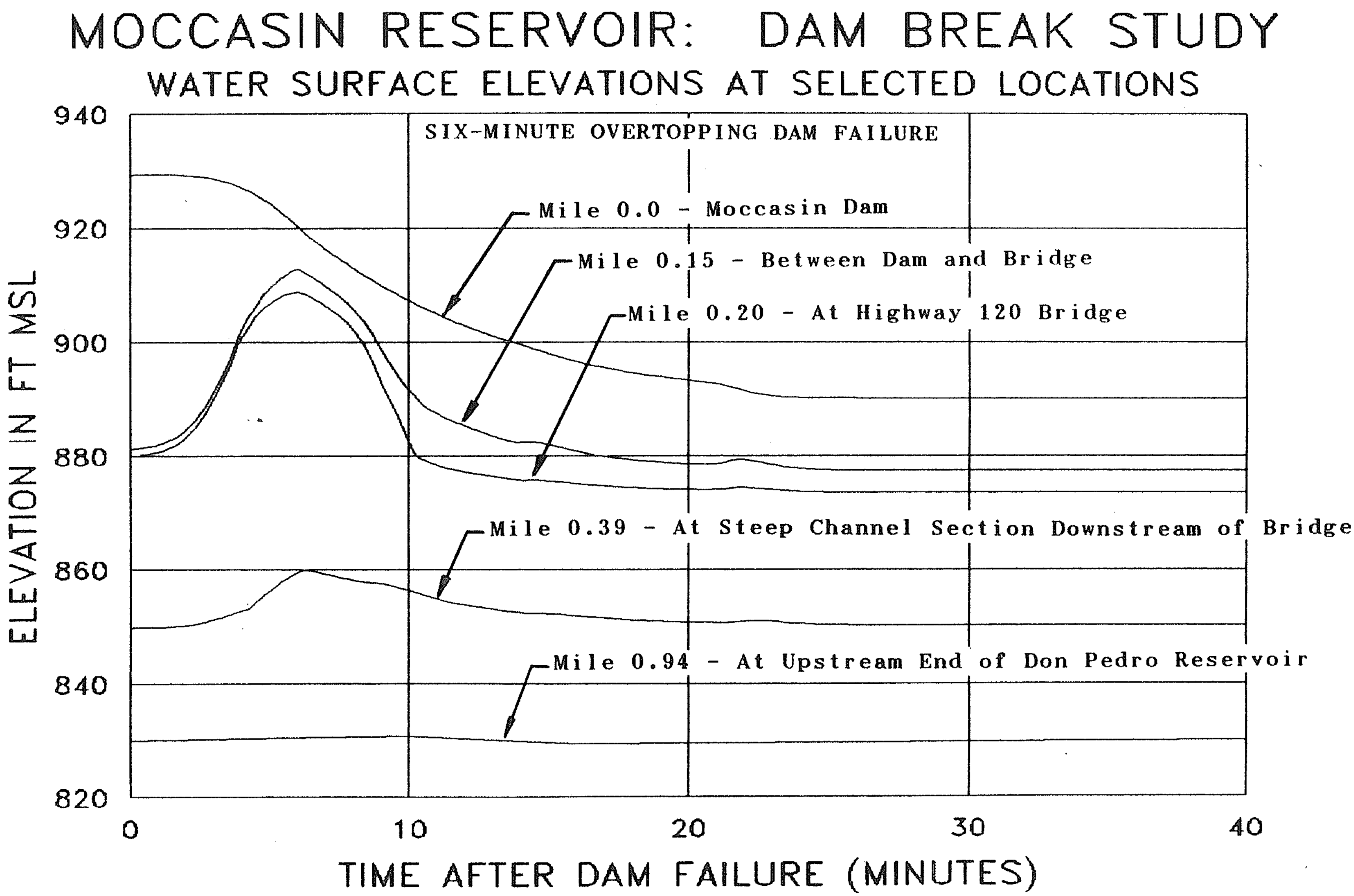
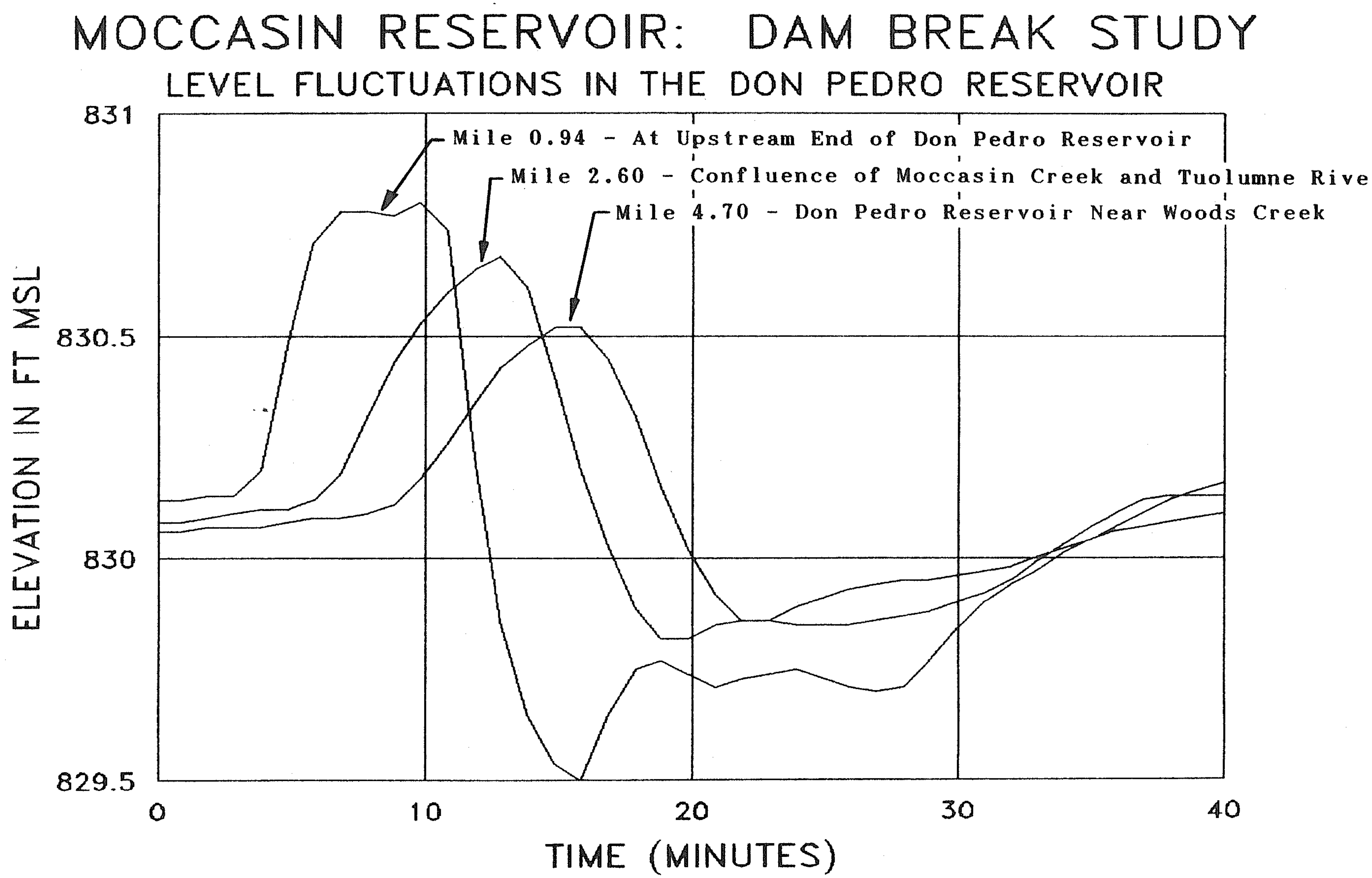

MOCCASIN RESERVOIR: DAM BREAK STUDY
WATER SURFACE ELEVATIONS AT SELECTED LOCATIONS
SIX-MINUTE OVERTOPPING DAM FAILURE
Mile 0.0 - Moccasin Dam
Mile 0.15 - Between Dam and Bridge
Mile 0.20 - At Highway 120 Bridge
Mile 0.39 - At Steep Channel Section Downstream of Bridge
Mile 0.94 - At Upstream End of Don Pedro Reservoir
ELEVATION IN FT MSL
940
920
900
880
860
840
820
0
10
20
30
40
TIME AFTER DAM FAILURE (MINUTES)

Fig. 8



MOCCASIN RESERVOIR: DAM BREAK STUDY
LEVEL FLUCTUATIONS IN THE DON PEDRO RESERVOIR
Mile 0.94 - At Upstream End of Don Pedro Reservoir
Mile 2.60 - Confluence of Moccasin Creek and Tuolumne River
Mile 4.70 - Don Pedro Reservoir Near Woods Creek
ELEVATION IN FT MSL
831
830.5
830
829.5
0
10
20
30
40
TIME (MINUTES)

Fig. 9

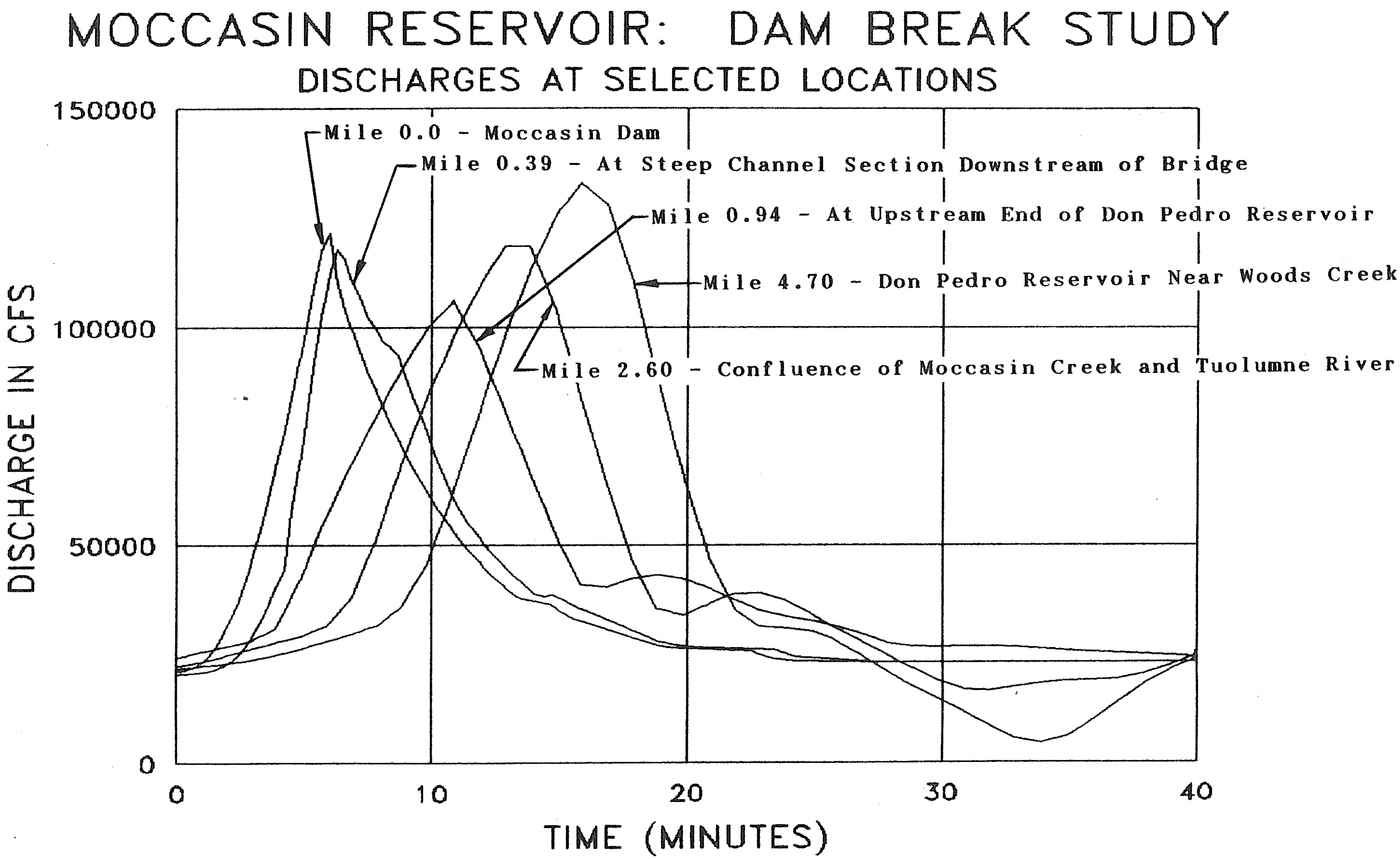

MOCCASIN RESERVOIR: DAM BREAK STUDY
DISCHARGES AT SELECTED LOCATIONS
150000
100000
50000
0
DISCHARGE IN CFS
0
10
20
30
40
TIME (MINUTES)
Mile 0.0 - Moccasin Dam
Mile 0.39 - At Steep Channel Section Downstream of Bridge
Mile 0.94 - At Upstream End of Don Pedro Reservoir
Mile 4.70 - Don Pedro Reservoir Near Woods Creek
Mile 2.60 - Confluence of Moccasin Creek and Tuolumne River

Fig. 10

MOCCASIN RESERVOIR: DAM BREAK STUDY

PHOTOGRAPH No. 1

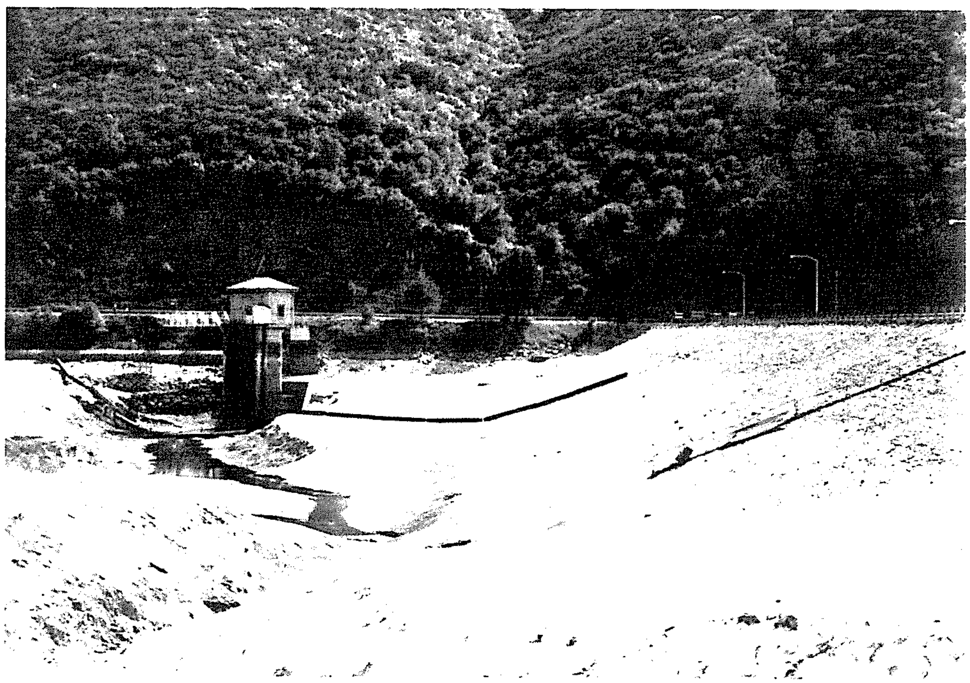
MOCCASIN RESERVOIR: View of empty reservoir, looking upstream from the crest of the dam; auxiliary outlet tower and Moccasin Creek Diversion conduit in foreground; Moccasin Power Plant in background.

MOCCASIN RESERVOIR: DAM BREAK STUDY

PHOTOGRAPH No. 2

MOCCASIN DAM AND PRIMARY SPILLWAY: View of upstream face of dam and spillway; dam crest at elevation 929 ft MSL; spillway weir crest at elevation 918.29 ft MSL. Low Head Plant intake (not on picture) is located to the right of the primary spillway.

MOCCASIN RESERVOIR: DAM BREAK STUDY



PHOTOGRAPH No. 3

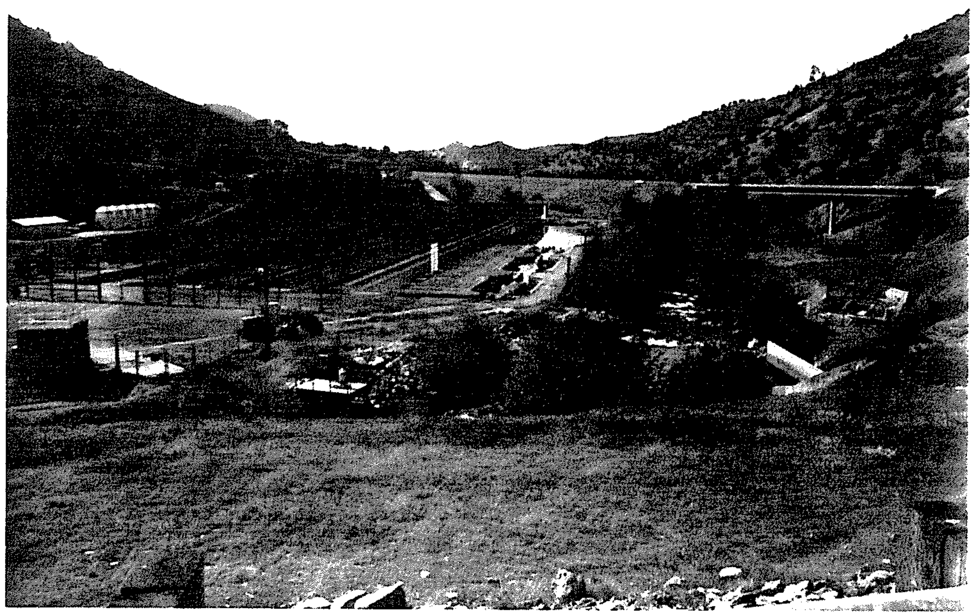
MOCCASIN DAM AND MAIN CONTROL TOWER: View of upstream face of dam, with control tower to the left; Highway 49 in background.

MOCCASIN RESERVOIR: DAM BREAK STUDY

PHOTOGRAPH No. 4

MOCCASIN DAM, SPILLWAY AND OUTLET CONDUIT: View of downstream face of dam with spillway on foreground, outlet conduit discharging in the middle, Highway 49 in background.

MOCCASIN RESERVOIR: DAM BREAK STUDY



PHOTOGRAPH No. 5

MOCCASIN CREEK: View of creek looking downstream from dam crest; fish hatchery facilities on the left; Highway 120 bridge in background.

5. REFERENCES

1. D. L. Fread, "**THE NWS DAMBRK MODEL: THEORETICAL BACKGROUND/USER DOCUMENTATION**," National Weather Service, June 20, 1988.

2. H. H. Barnes, "**ROUGHNESS CHARACTERISTICS OF NATURAL CHANNELS**," U. S. Geological Survey Water Supply Paper 1849, U. S. Government Printing Office, Washington, 1967.

3. "**REVISED EAP GUIDELINES**," Federal Energy Regulatory Commission, February 22, 1988.

4. "**GEOTECHNICAL INVESTIGATION REPORT, AUXILIARY MOCCASIN DAM SPILLWAY, TUOLUMNE COUNTY, CALIFORNIA**," AGS, Inc., August 1988.

5. "**DESIGN AND MODEL STUDY, AUXILIARY MOCCASIN DAM SPILLWAY**," Hydronetics, Inc., July, 1988.

6. "**DON PEDRO LAKE, RESERVOIR REGULATION FOR FLOOD CONTROL**," Department of the Army, Sacramento District, Corps of Engineers, August 1972.

7. "**DON PEDRO DAM, DAM BREAK STUDY**," Bechtel Civil, Inc., January 1989.

8. Drawings from the Utilities Engineering Bureau, City and County of San Francisco, as follows (Drawings marked with an Asterisk (*) were used for the development of the inundation map presented in Figure 11 of this report):

Drawing No.	Title and Date
C-939	Moccasin Dam, Core Wall, Typical Cross Section and Profile, March 1929
C-1048	Moccasin Dam, Plan and Cross Section, 09-06-29
R-599	Moccasin Dam Maximum Section, 1930
B-813	Moccasin Re-Regulating Reservoir, Auxiliary Outlet Control Tower, General Map, Location of Bridge, 07-07-37
D-31 (*)	Moccasin Reservoir Topography, June 1968

D-32	(*)	Moccasin Reservoir Topography, June 1968
D-33	(*)	Moccasin Reservoir Topography, June 1968
D-115	(*)	Proposed Kelley Flat Pumped Storage Power Plant, Topography, September 1974
D-116	(*)	Proposed Kelley Flat Pumped Storage Power Plant, Topography, September 1974
D-187		Moccasin Re-Regulating Reservoir, One Acre Plots, June 1977
R-317		Moccasin Re-Regulating Reservoir, Profile of Bottom of Corewall Trench, Undated
D-2167		Inundation Map of Moccasin Dam, 01-02-74
D-245		Proposed Moccasin Low Head Power Plant, Extended Topography and Property Lines, 03-25-82
D-248		Proposed Moccasin Low Head Power Plant, Extended Topography of Moccasin Creek Streambed Around Island Below City Property, 06-25-82
B-249		Proposed Moccasin Low Head Power Plant, Extended Topography of Moccasin Creek at Fork Around Island, 06-25-82
D-260	(*)	Proposed Moccasin Low Head Power Plant, Topography of Proposed Alternate Penstock Alignments East of Moccasin Dam Spillway, 01-20-83
D-261		Proposed Moccasin Low Head Power Plant, Topography of Proposed Alternate Penstock Alignments, Sheet 2, 02-14-83
D-262		Topography East Side Moccasin Reservoir for Proposed State Fish Hatchery, Fish Water Supply Line Extension, Sheet 1 of 3, 03-01-83
D-263	(*)	Topography East Side Moccasin Reservoir for Proposed State Fish Hatchery, Fish Water Supply Line Extension, Sheet 2 of 3, 03-01-83

D-264 (*)	Topography East Side Moccasin Reservoir for Proposed State Fish Hatchery, Fish Water Supply Line Extension, Sheet 3 of 3, 03-01-83
R-266 (*)	Proposed Moccasin Low Head Power Plant, Topography of Proposed Alternate Penstock Alignments, Sheet 3, 03-23-83
D-307 (*)	Project H-852, Topography, Proposed Additional Spillway at Moccasin Dam, Sheet 1 of 2, 04-19-88
D-308	Project H-852, Topography, Proposed Additional Spillway at Moccasin Dam, Sheet 2 of 2, 04-19-88
C-238	Proposed Lower Moccasin Power Plant, Site Topography, 09-18-81 (4 Sheets)
C-239	Proposed Lower Moccasin Power Plant, Site Topography, 09-18-81
D-2567	Moccasin Auxiliary Spillway, General Plan, Existing Facilities and Contours, Nov 1988 (Sheet 1 of 8)
D-2501	Moccasin Reservoir and Vicinity, 04-25-86 (Sheet 2 of 6)

9. Drawings from Turlock Irrigation District, as follows (Drawings marked with an Asterisk (*) were used for the development of the inundation map presented in Figure 11 of this report):

Drawing No.	Title and Date
2299-110	Don Pedro Reservoir, Topography, Property & Project Boundary, Undated
2299-141 (*)	Don Pedro Reservoir, Topography, Property & Project Boundary, 07-15-80
2299-142	Don Pedro Reservoir, Topography, Property & Project Boundary, 07-15-80

2299-143	(*)	Don Pedro Reservoir, Topography, Property & Project Boundary, 07-15-80
2299-145		Don Pedro Reservoir, Topography, Property & Project Boundary, 07-15-80

10. USGS 7.5 Minute Series (Topographic) Quadrangles for (Drawings marked with an Asterisk (*) were used for the development of the inundation map presented in Figure 11 of this report):

    (*) Moccasin, California
    Standard, California
    Penon Blanco Peak, California
    Chinese Camp, California
    La Grange, California