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BURRELL DAM SAFETY EVALUATION

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PURPOSE AND SCOPE OF STUDY

An inspection and brief evaluation of Burrell Lock and Dam conducted in 1980 under the National Dam Inspection Program concluded that the dam may not meet federal dam safety standards. The deficiency indicated in the Phase I report was the dam has inadequate capacity to handle the Probable Maximum Flood. As standard procedure of the National Dam Safety Program the inspection report's conclusion of potential deficiency required a Phase II study be conducted to provide a detailed hydrologic and hydraulic evaluation of the specified concerns.

This study addresses the hydrologic and hydraulic adequacy of Burrell Dam. Other factors, such as structural and foundation stability, seepage, mechanical equipment and maintenance, were found by the Phase I inspection to meet safety criteria. The objectives of this study are to 1) provide a detailed assessment of the Burrell Dam safety with respect to likelihood and impacts of failure by overtopping of the dam and 2) identify possible remedial measures which may (subject to further evaluation) correct any deficiencies and hazardous conditions found to exist.

NATIONAL DAM SAFETY PROGRAM

The National Non-Federal Dam Safety Inspection Program authorized by Congress in the National Dam Inspection Act (PL 92-367) in 1972 requires that all non-federal dams surpassing threshold criteria be inspected for safety. The Dam Safety Program is administered by the U. S. Army Corps of Engineers (Corps). The inspection program is carried out in phases with a Phase I investigation being a relatively quick overall evaluation of the dam, including a site inspection. If a potential inadequacy is found during the Phase I evaluation, the owner is required to provide a Phase II evaluation. Phase II studies are required to provide a detailed study to ascertain whether there is indeed a deficiency. If so, a third step must be completed to determine appropriate remedial measures.

Under the Program dams are classified according to size and also by degree of hazard associated with a particular location. Size classification is well defined. Hazard classification involves considerable judgment. The three size classifications are small, intermediate and large. Large dams are those which are either 100 feet or greater in height or have 50,000 acre-feet or more storage capacity. The storage capacity of Burrell is approximately 400,000 acre-feet at the design high stage putting it in the large class although the dam height is only about 12 feet.

Hazard classification is based on socio-economic impacts of failure. Classification is again into three groups as follows:

low hazard	- no loss of life expected - no damage to residential structures - minimal damage to farm buildings, agricultural land and local roads - minimal economic loss
significant hazard	- possible loss of a few lives - damage to a small number of residential structures - possible damage to secondary roads or railroads, interruption of service of relatively important public utilities - appreciable economic loss to agriculture, industry or structures
high hazard	- possible loss of more than a few lives - damage to more than a small number of residential structures - possible serious damage to agricultural, industrial, and commercial facilities, important public utilities, main highways or railroads - excessive economic loss to community, industry, commerce or agriculture

Considering the residential areas and agricultural lands downstream of Burrell Dam on Haines Creek and on Lake Griffin, the impacts of failure on Canal 231 and Moss Bluff Lock and Dam downstream of Lake Griffin, the Leesburg municipal wastewater treatment plant and other impacts, the Burrell Dam is considered a high hazard dam. Even if it were unquestionably safe, it would still be classified as a high hazard dam due to its location.

Hydrologic criteria have been established (13) to determine the adequacy of a spillway based on the dam classification. For large, high hazard dams, the spillway design flood (SDF) is the Probable Maximum Flood (PMF). If a spillway does not handle the SDF in a controlled, safe manner the spillway is considered inadequate. However, for a dam to be designated as unsafe all of the following three conditions must prevail (13):

1. There is a high hazard to loss of life from large flows downstream of the dam.
2. Dam failure resulting from overtopping would significantly increase the hazard to loss of life downstream from the dam from that which would exist just before overtopping failure.
3. The spillway is not capable of passing one-half the probable maximum flood without overtopping the dam and causing failure.

   (In cases where overtopping failure would be catastrophic, particularly with respect to loss of life, a magnitude greater than one-half of the PMF should be used.)

These are the criteria and recommended standards by which the safety of Burrell Dam is evaluated.

DESCRIPTION OF WATERSHED

General

Burrell Lock and Dam is located in the Oklawaha River Basin, a tributary to the St. Johns River, in central peninsular Florida as seen on Figure 1. The dam is located approximately midway along Haines Creek, a 5.3 mile long creek through which Lake Eustis flows into Lake Griffin. These two lakes are the most downstream of a group known as the Oklawaha Chain of Lakes which also includes Lakes Dora, Beauclair, Harris and Little Lake Harris and Lake Apopka as seen in Figure 2. The lakes in this group upstream of Burrell Dam and downstream of Lake Apopka will herein be referred to as the Haines Creek Chain of Lakes. Lake Apopka upstream of Lake Beauclair is controlled by the Apopka Beauclair Lock and Dam. Lake Griffin is controlled by Moss Bluff Lock and Dam.

Two watersheds form the headwaters of the Haines Creek Chain of Lakes; the Lake Apopka Watershed and the Palatlakaha River Watershed with approximate drainage areas of 153 and 260 square miles, respectively. The total drainage area at Burrell Dam is about 620 square miles.

The Burrell Dam drainage area is characterized by many lakes, swamps, and marshes with well drained sandy upland areas. Karst topography is dominant with many sinkhole lakes and depressional areas with no surface water outlet. Drainage gradients are generally very flat, which, in combination with the large surface water storage areas, greatly reduce peak flood flows

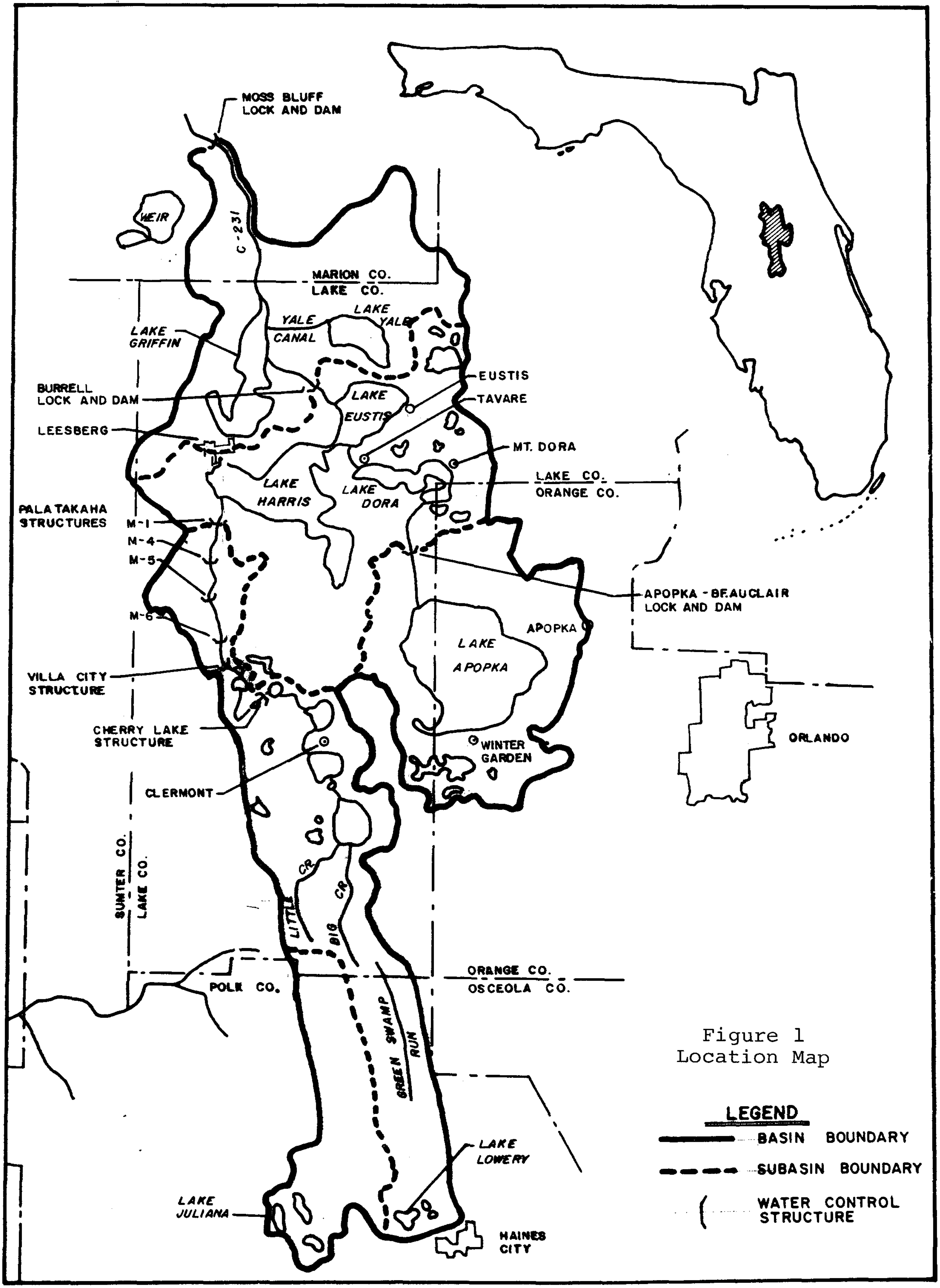

Figure 1
Location Map

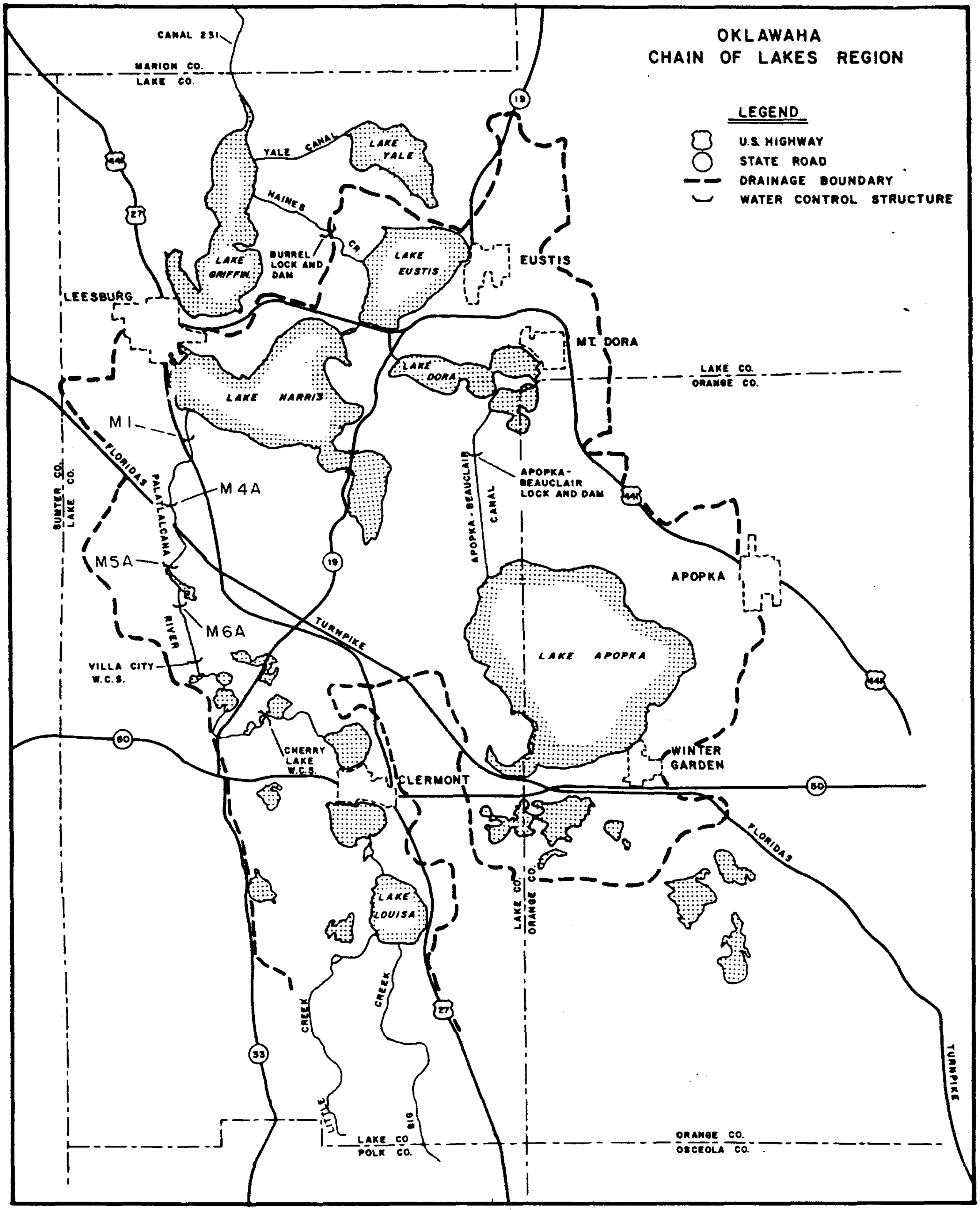

FIGURE 2 Watershed Map

which would otherwise result from periodic intense rainfall events.

Precipitation

The region receives an annual average rainfall of about 51 inches, of which approximately 60 percent occurs during the June through September rainy season. Heavy rainfall events typically occur as summer thunderstorms or associated with hurricane storm systems. Some of the larger rainfall events, however, have occurred during the spring months. The March 1960 regional storm and the April 1982 storm over the Ocala vicinity are two recent examples. The 1960 storm produced over 11 inches of rainfall over a 4 day period at Clermont, Florida. This storm and a second large storm in September 1960 were particularly damaging due to the high rainfall and wet conditions which existed prior to the storms. The 1982 storm produced 16 inches of rainfall over a three day period at the Ocala rainfall station, 11.75 inches of which fell in a 24 hour period. Other storms in the area include 13.95 inches on September 5-6, 1933 and 15.64 inches on June 23-24, 1945, both recorded at the Lake Alfred Experiment Station. At Yankeetown on the west coast about 60 miles from the study area, 38.70 inches of rainfall was recorded over a 24-hour period on September 5-6, 1950. About 35 inches fell over a three day period in October 1941 at Trenton, approximately 90 miles northwest of Burrell Lock and Dam.

Surface Water Hydrology and Hydraulics

The Burrell Dam drainage area can for physiographical reasons, be divided into three subareas for purposes of description - the Palatlakaha River Watershed, the Lake Apopka Watershed and the Haines Creek Chain of Lakes Watershed (the area downstream of the Apopka-Beauclair and Palatlakaha M-1 structures).

Palatlakaha River Watershed

The drainage area at the outlet of the Palatlakaha River has been given as 260 square miles. However, because of diverted areas and areas with no surface outlets, the actual drainage area contributing to the Oklawaha Basin is believed to be more accurately 185 square miles. The head waters include Big Creek and Little Creek which originate in the Green Swamp area and discharge to Lake Louisa in southern Lake County. These watersheds have several high water interconnects. That is, water flows between these lakes during high water periods. The western and southern drainage boundaries of Little Creek are poorly defined. Drainage ditches have been constructed which are believed to divert nearly all of the low flows and an unknown portion of high water period runoff from a large area in Little Creek to the Withlacoochee River.

The middle Palatlakaha River Basin includes a group of lakes, known as the Clermont Chain of Lakes, including Lakes Cherry, Minneola, Minnehaha, and Louisa. These lakes are all controlled by the Cherry Lake Outlet structure. This structure consists of two gates each 12 feet wide by 6 feet high. The normal water level drop across this structure is only about two feet. An embankment several hundred feet long creates the Cherry Lake impoundment. This embankment is likely to be overtopped in a severe flood event.

The lower Palatlakaha River Basin in its natural state included flat marshy flood plain with many interconnected ponding areas. At the downstream end the channel slope increases abruptly and outfalls to Lake Harris. A series of five control structures are located in the lower basin. These structures are part of a Soil Conservation Service flood control project. The most downstream structure, known as M-1, has two 10 feet by 5 feet radial gates. Most of the channel remains in a natural or near natural state. As such the conveyance capacity and channel slope are restrictive to high flood flows. Major highways, including the Florida Turnpike, also restrict flows from extreme flood events.

Lake Apopka Watershed

The Apopka-Beauclair Canal and the Apopka-Beauclair Lock and Dam were constructed in 1957 providing water level control of Lake Apopka. Previously the outflow from the lake was via Double Run Swamp to the northwest at water levels exceeding about 69 or 70 feet MSL and flowed into Lake Harris. The lake is surrounded by high sandy ridges on nearly all sides with only a relatively narrow band of upland area draining to the lake.

Since 1943, large portions of the north end of the lake have been diked off and farmed. Most of the ground elevation in these areas is about 6 feet below the normal lake level. The levees are typically at elevations 68 to 69 feet. These agricultural lands total about 28 square miles compared to the lake area of 58 square miles. The remaining 67 square miles of the total watershed is upland sandy ridges and upland lake area.

Haines Creek Chain of Lakes

Burrell Dam controls the water levels in this group of lakes. The chain of lakes constitutes about 30 percent of the total drainage area. Less agricultural land is found along these lakes, but residential and urban development is much greater. The cities of Eustis, Leesburg, Tavares and Mt. Dora are the major developed areas although many unincorporated residential areas are located in low lying areas subject to flooding.

Lake Harris flows through a short channel known as Dead River into Lake Eustis. Water level differences through this channel are minimal even at relatively high flows.

Lake Apopka discharges into Lake Beauclair as does Lake Ola. Lake Beauclair then flows into Lake Dora which discharges to Lake Eustis through the Dora Canal. The Dora Canal is a natural connection which has been channelized. Bridges and roads across the floodplain do present restrictions to flow, however. Consequently, Lake Dora and upstream lakes are somewhat higher than Lake Eustis during high flows. When Lake Eustis is near the high regulation stage (63.5 feet), a maximum discharge (560 cfs) from Apopka can create high water conditions in a residential area near the outlet of the Apopka-Beauclair Canal.

Downstream Areas

Downstream of Lake Eustis and Burrell Dam is Lake Griffin. This lake also has areas of heavily developed shoreline. Many residential areas are found along the southern end of the lake and along numerous canals totalling several miles in length. Approximately 8.5 square miles of agricultural land protected by levees and as much as 6 feet below Lake Griffin regulation levels are located along the northeastern side of the lake as seen in Figure 3. The lake water level is controlled by Moss Bluff Dam

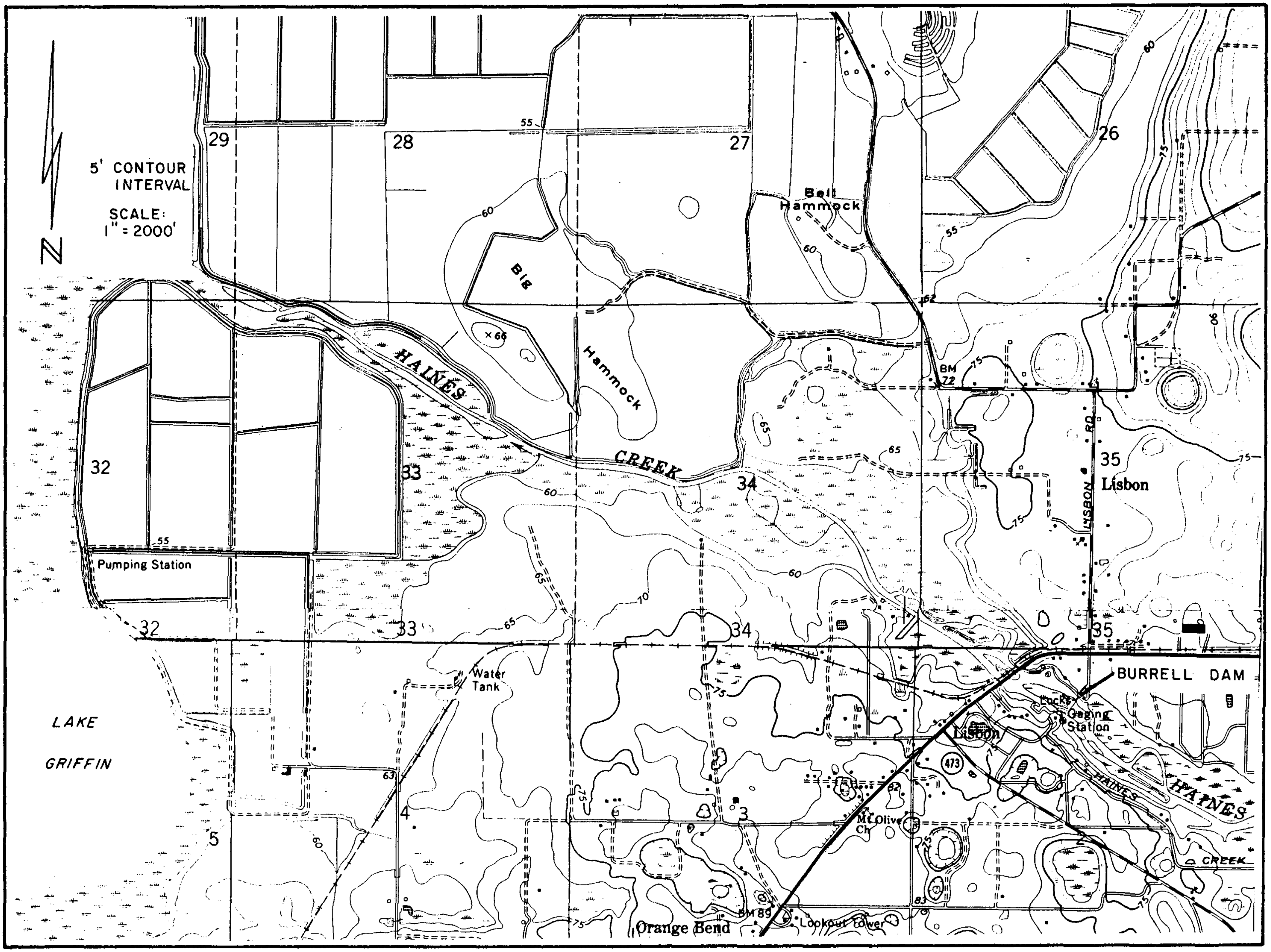

FIGURE 3

LOWER HAINES CREEK AREA

located about seven miles north of the lake and connected by Canal 231 (C-231). Both the canal and the dam were constructed by the U. S. Army Corps of Engineers during 1969-1974 as part of the Four River Basins Flood Control Project.

BURRELL LOCK AND DAM

General

The existing Burrell Dam and spillway were constructed in 1979. The existing lock is the original lock constructed in 1957 by the Oklawaha Basin Recreation and Water Conservation and Control Authority. In 1976, after completion of a study, the original spillway was determined by the Oklawaha Basin Board of SJRWMD to be deficient due to deterioration and downstream erosion problems. Greiner Engineering Sciences was contracted to design replacement facilities. The resulting master plan (3) recommended construction of a new spillway, dam modifications, and a new navigation lock. The recommended dam modification called for raising the dam crest to elevation 68.0 feet and was later revised to about 66.0 feet. The earth work below 66.0 feet was completed as designed, however, resulting in the current dam crest width of approximately 50 feet.

Physical Description

The dam is located in Lake County on Haines Creek 3.2 miles upstream from Lake Griffin, 2.5 miles downstream from Lake Eustis and approximately 500 feet upstream from the SR 44 bridge over Haines Creek. The structure consists of a single lock adjacent to the left bank (looking downstream), an earthen embankment and a gated spillway as seen in Figure 4. The lock access and exit channels were excavated creating an island across which a portion of the dam embankment was constructed.

The spillway is a rather complex hydraulic structure with four overflow weir gates each measuring 4 feet by 14 feet wide

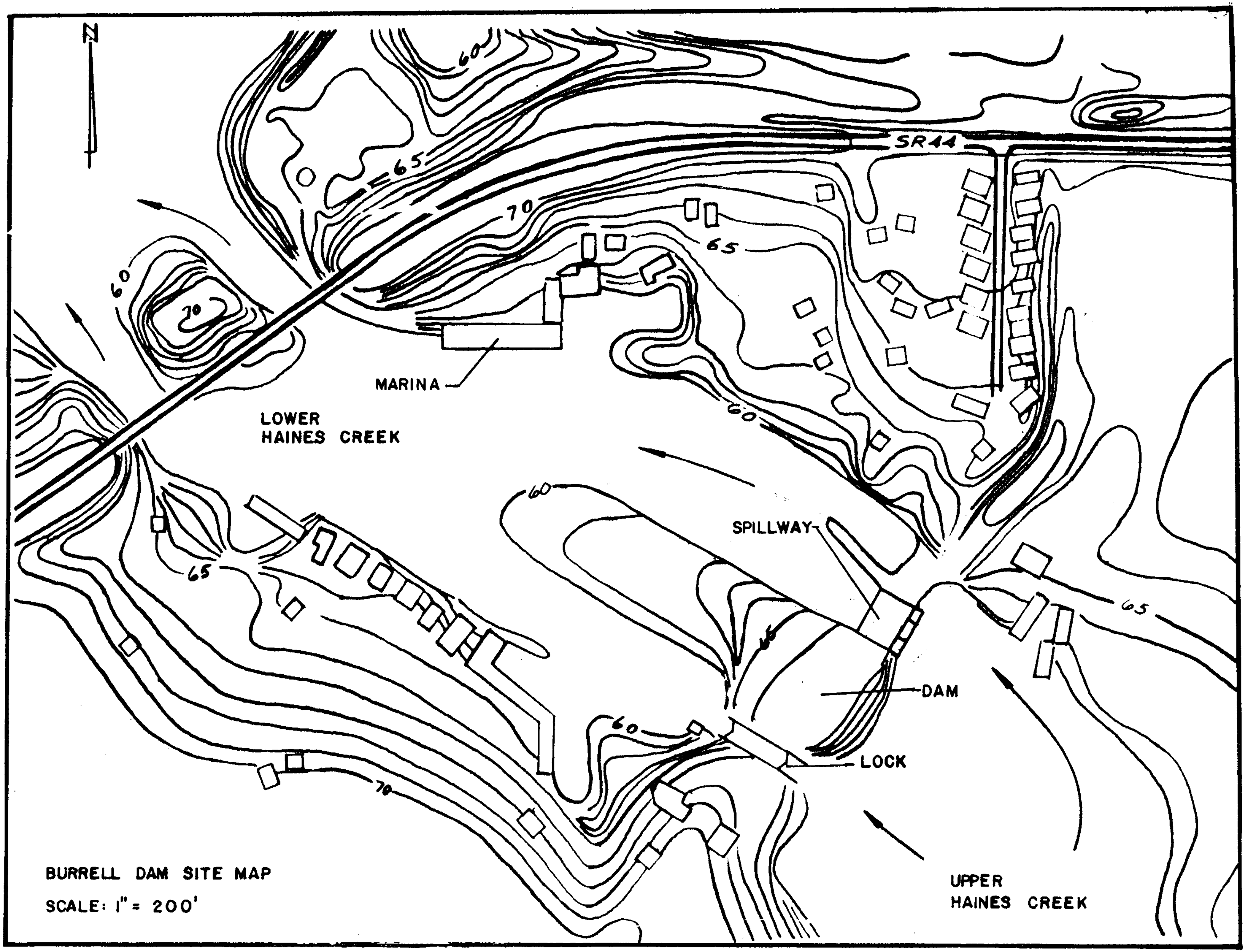

FIGURE 4 Plan of Dam Area

and two sluice gates each measuring 5 feet by 14 feet wide. The sluice gates sit at the sides of a rectangular forebay (i.e. parallel to the direction of flow in Haines Creek). After passing the gates and entering the forebay the flow exits via six 8 feet by 6 feet wide and two 8 feet square concrete culverts. The forebay area is divided into three cells by two concrete partitions with openings which allow flow between the cells. The culverts discharge to a stilling basin with blocks and an end sill. Physical data for the spillway and dam are summarized in Table 1.

Elevation-pool area and elevation-pool storage data for Burrell and also for Apopka-Beauclair and Moss Bluff are given in Figures 5, 6, and 7, respectively.

Operation of the Burrell Spillway is done by the locktender who lives at the site. Gate openings are authorized through the Engineering Division of the St. Johns River Water Management District. Discharges at the three structures are made to maintain the fluctuation of water levels within adopted desirable regulation schedules. The ratio of discharge capacity to inflow rates is relatively small such that little reduction in flood levels can be accomplished in the short period of reliable predictions prior to a storm event. Aside from the seasonal variation in regulation schedule (Figure 8), gate operation is based on lake stages rather than forecasting methods. A study is being conducted by the SJRWMD to investigate use of forecasting models to improve lake regulation.

TABLE 1

BURRELL DAM DATA

Drainage Area

Total drainage area	640 square miles
Local drainage	206 square miles
Controlled lake surface area	57 square miles

Elevations

Top of dam - low point (existing condition)	66.1 approx. 90 ft. length
Design Maximum Pool	64.0
Regulation Stage Minimum	62.5
Maximum	63.25
Maximum Desirable Stage	63.5
Minimum Desirable Stage	62.0

Dam

Type	Earthfill
Length	500 ft.
Height	12 ft.
Top width	50 ft.

Side Slopes (design)

Upstream	2H:1V
Downstream	4H:1V

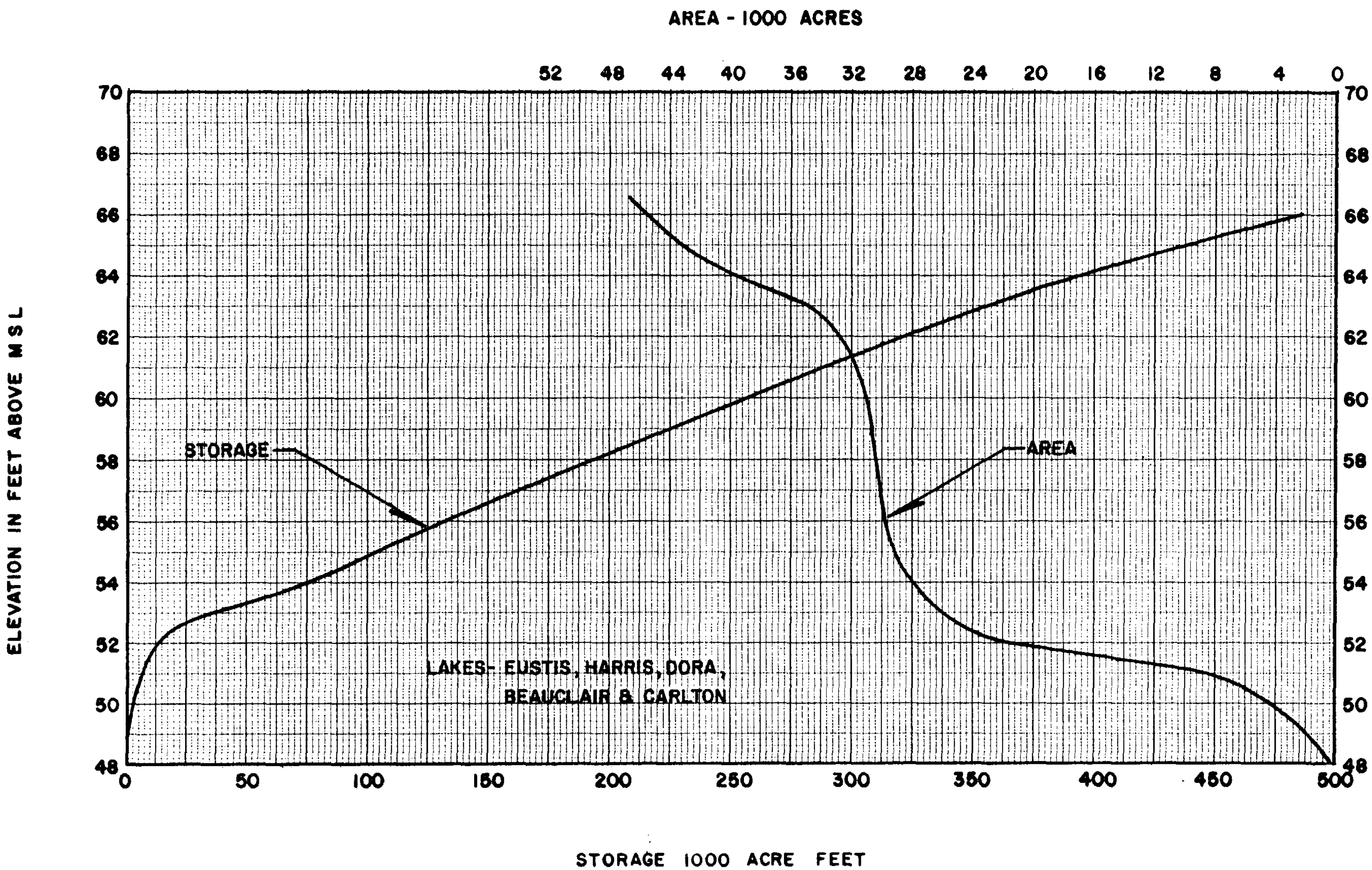

FIGURE 5 Stage-Area-Storage, Haines Creek Chain of Lakes

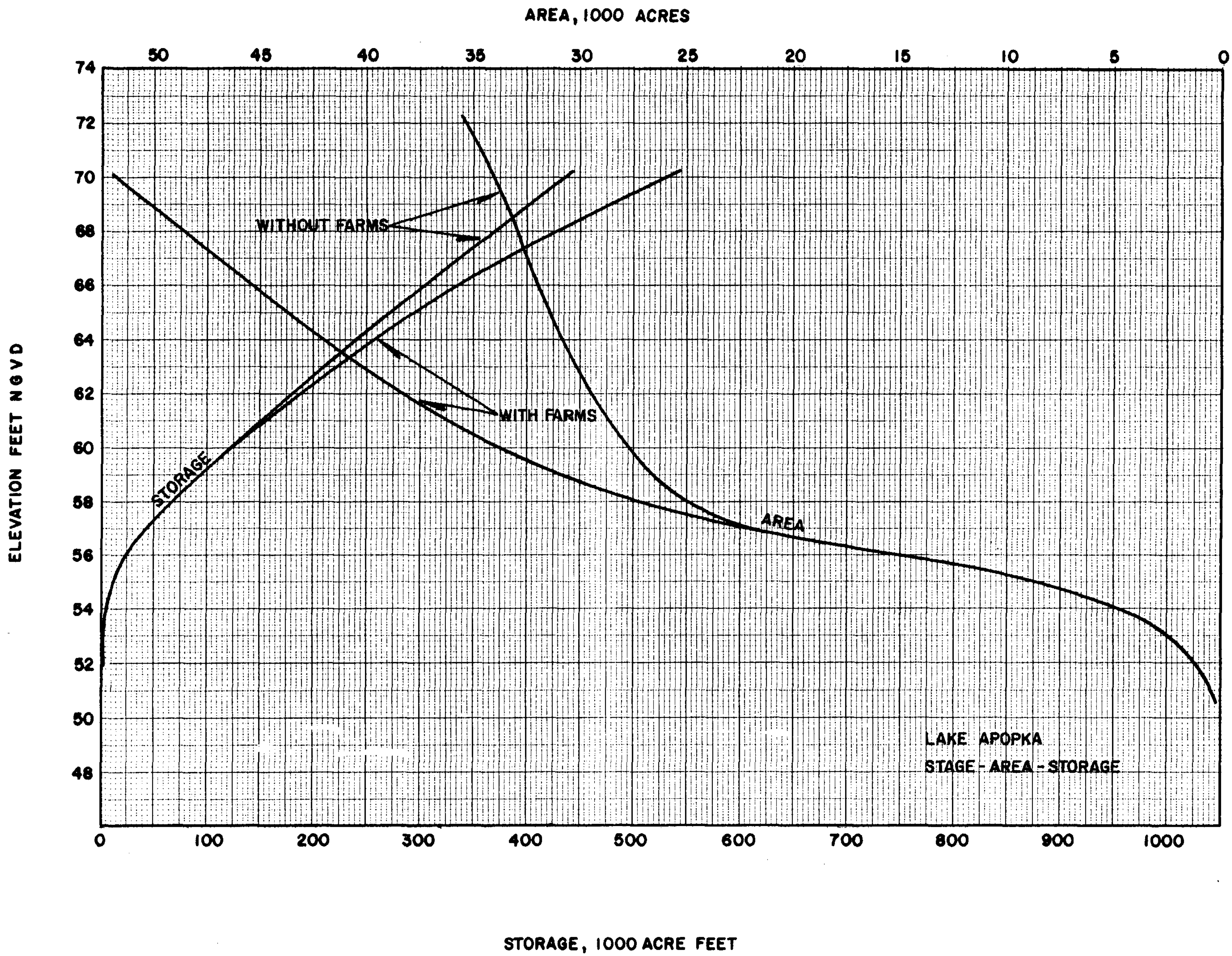

FIGURE 6 Stage-Area-Storage, Lake Apopka

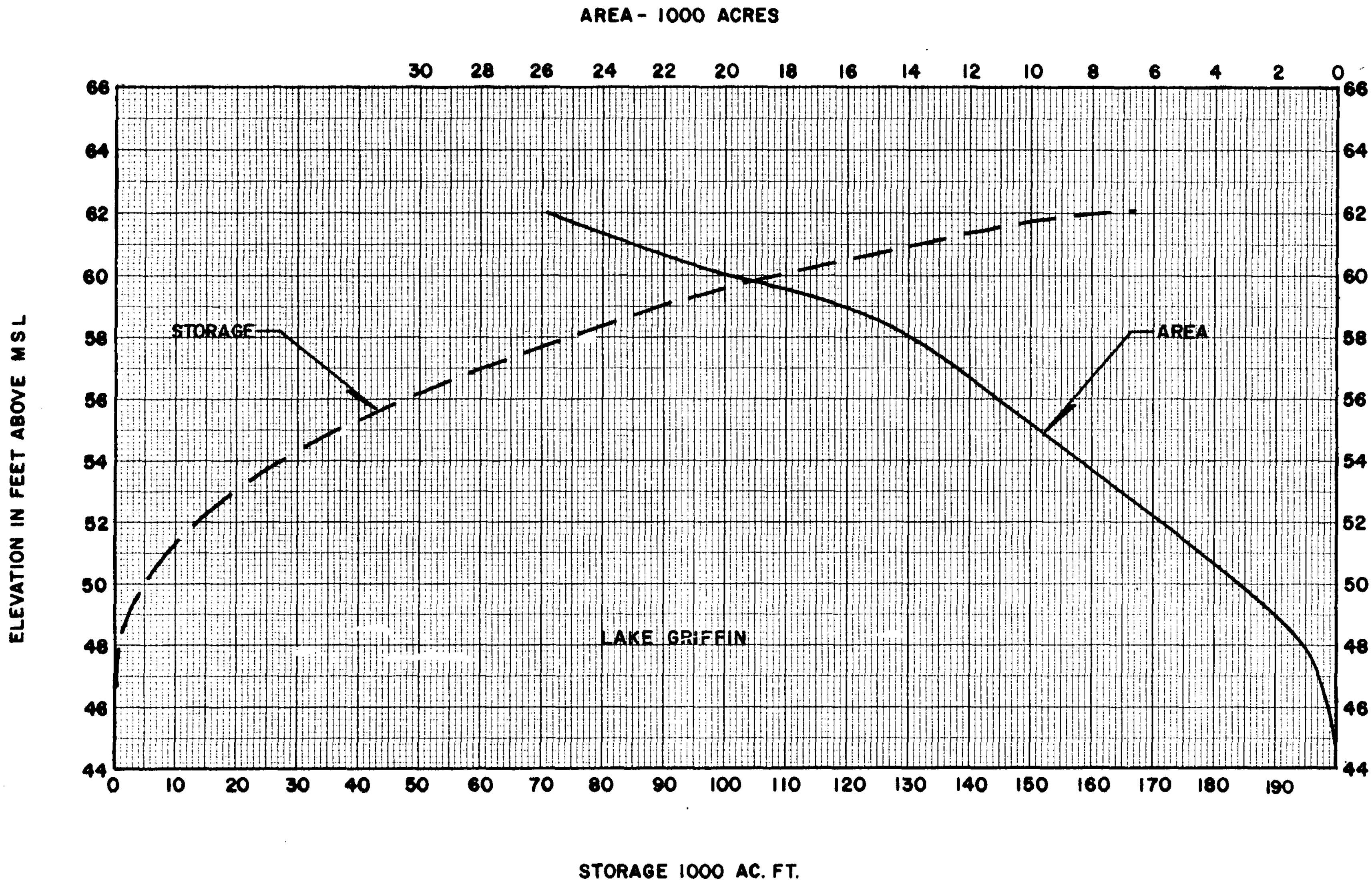

FIGURE 7 Stage-Area-Storage, Lake Griffin

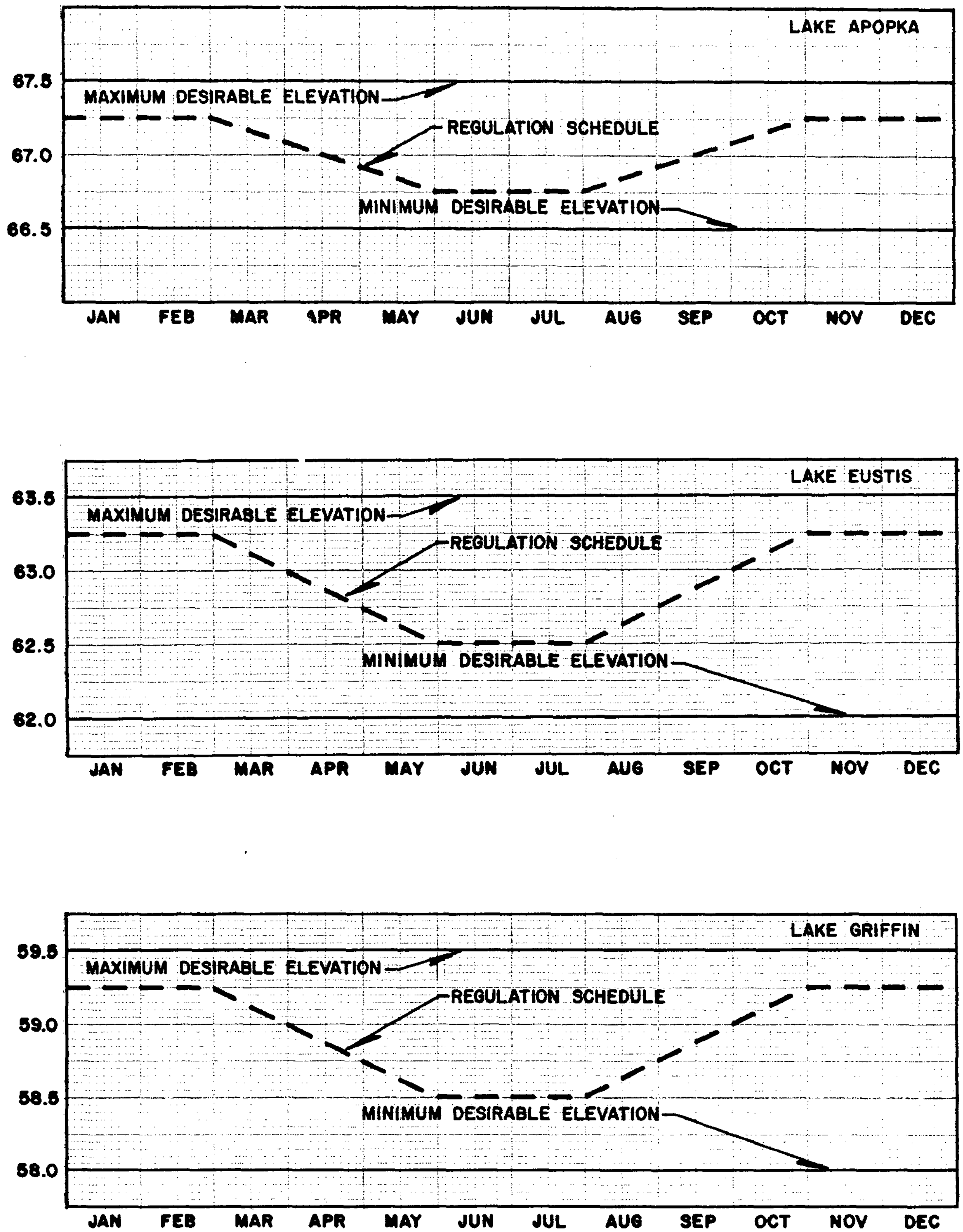

FIGURE 8 REGULATION SCHEDULES FOR LAKES APOPKA, EUSTIS, AND GRIFFIN

Some uncertainty exists as to the design discharge capacity of the Burrell spillway. The Master Plan (3) for the existing dam provides the rating curve seen in Figure 9 (Curve A) which is the same as included in the Phase I Inspection Report. A second curve, produced later, which considers backwater in the downstream channel, gives a significantly lower discharge capacity (Curve B). Discharge measurements made in 1982 and 1983 indicate that Curve B is approximately correct, at least in the range of elevations up to about 63 feet.

It is believed that additional measurements and analysis are necessary to establish a more reliable rating curve. In the absence of this information, however, curve B is assumed to be the best available information. Three tailwater rating curves are also given in Figure 9. Each curve applies to a given Lake Griffin stage.

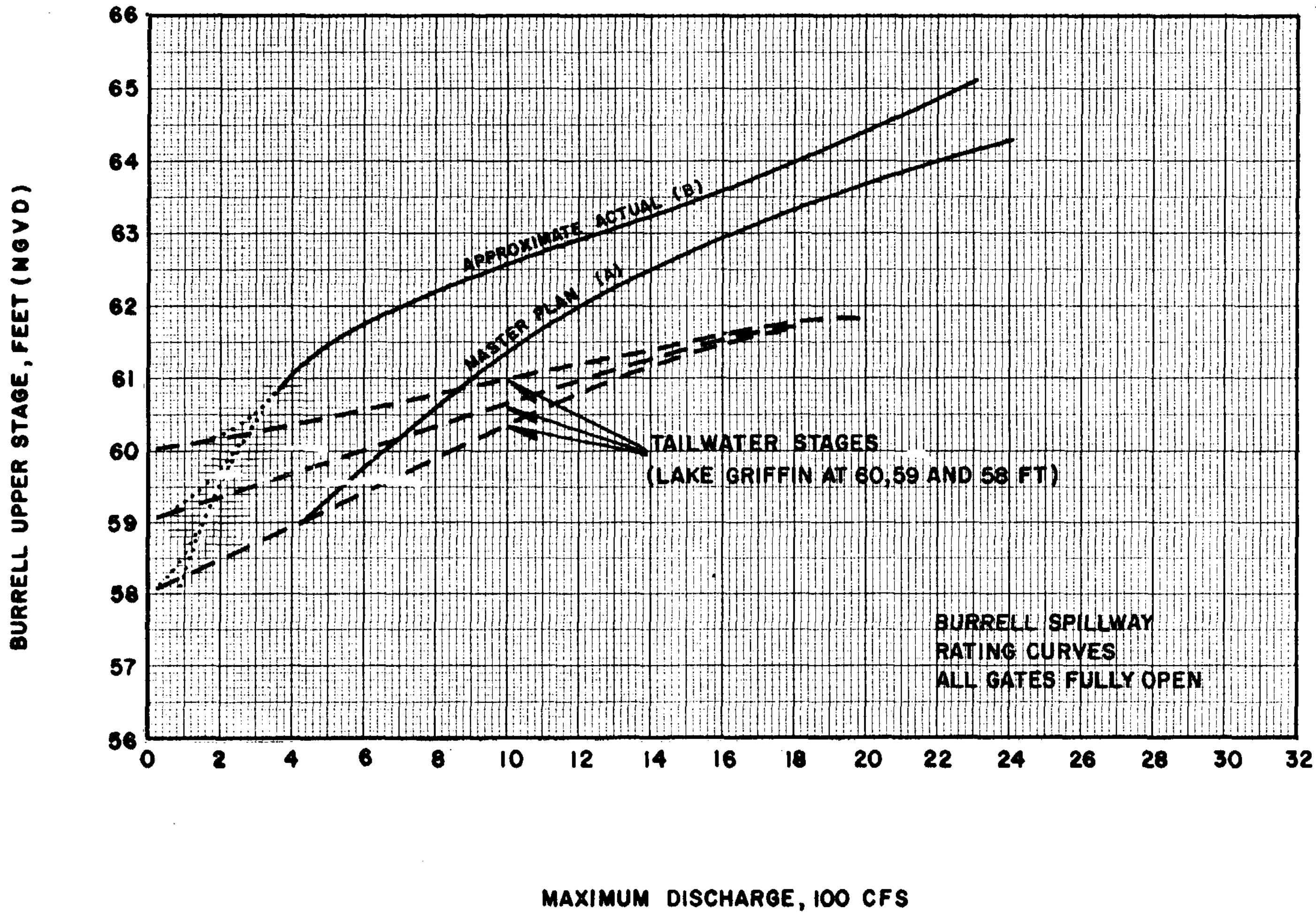

FIGURE 9 Burrell Spillway Rating Curves

ENGINEERING ASSESSMENT OF BURRELL DAM

Methodologies

As discussed in section II, an assessment of the capability of Burrell Dam to safely handle the PMF or one-half the PMF is required. The PMF is defined (13) as "the flood that may be expected from the most severe combination of critical meteorologic and hydrologic conditions that are reasonably possible in the region." The PMF is normally generated from Probable Maximum Precipitation (PMP) estimates and standard methods of determining runoff depths, hydrograph transformations and flood routings.

It was assumed in this evaluation the PMP event occurred during relatively wet hydrologic conditions. Water control structures at the Palatlakaha and Apopka watershed outlets were assumed to be flowing at design capacity. The Haines Creek Chain of Lakes were assumed to be at 63.0 feet at the start of the storm.

The Corps' HEC-1 (16) computer model was used to generate the PMF inflow hydrograph to Lake Eustis. The PMP rainfall distribution option in HEC-1 was used to distribute a 48-hour PMP rainfall. The Soil Conservation Service (SCS) Runoff Curve Number method (9) was used to estimate rainfall excess from the rainfall data. The SCS dimensionless hydrograph was used to transform the rainfall excess to a runoff hydrograph. Storage routing was done using the Modified-Puls method while channel routings used the Muskingum Method.

The Corps HEC-2 model was used for hydraulic analysis of channels to determine conveyance capacity and water surface profiles. Four different methods were used to estimate dam breach discharges.

Rainfall

The PMP rainfall and fractions thereof were used to generate flood hydrographs. The rainfall depth-duration-drainage area relationships used were obtained from standard sources (18, 19, 20). For comparison rainfall data based on frequency analysis is given with the PMP data in Table 2.

TABLE 2
RAINFALL DATA

Rainfall Event	Rainfall Depth (Inches)			
	6 hr.	12 hr.	24 hr.	48 hr.
10 year (1)	5.1	6.1	7.0	8.1
50 year (1)	6.5	8.0	9.1	11.0
100 year (1)	7.2	8.9	10.2	12.1
500 year (2)	-	-	17.0	17.6
PMP (620 sq. mi.)	19.8	24.4	28.7	33.4
PMP (200 sq. mi.)	23.2	27.5	31.7	36.0

(1) based on 200 sq. mi.

(2) Corps of Engineers

The PMP data given in Table 2 was reduced to account for the general situation of the areal storm pattern not conforming with watershed shape. The Hop Brook method (16) optional in HEC-1 was used. This method provides a 12 percent reduction for a 200 square mile watershed, resulting in a 48 hour PMP of 31.6 inches.

The physiographical characteristics of the Burrell Watershed, particularly the location of the Haines Creek Chain of Lakes, provide a situation whereby a higher intensity, small area storm located over the lakes near the outlet could create a more critical flood than a larger storm over the entire watershed but with a lesser average depth. Both cases were evaluated to determine which would be more critical. An insignificant difference in peak stages resulted while the entire area case produced a greater total runoff volume as would be expected.

The rainfall distribution during the storm is a particularly important consideration for this watershed because of the location of the lakes at the outlet. Rainfall on the lakes results in a corresponding rise in lake level. Occurrence of the highest intensity period near the end of the storm when the lakes are already high and Burrell Dam is near failure, results in a shorter time available for emergency action. The distribution used places the highest intensity period of the 48-hour storm near the end and at a critical period for Burrell Dam.

Haines Creek Hydraulics

Haines Creek is 5.7 miles long and Burrell Dam is located 2.5 miles downstream from Lake Eustis. In its natural state, the channel meandered through a floodplain ranging in width from about 500 feet to nearly 2000 feet. The dam site was selected at one of the naturally narrowest points along the creek.

In its current state, the conveyance at high flows has been constricted by private agricultural levees along the most downstream two miles. The levees are in various states of maintenance. The construction and foundation materials of the levee are not good and frequent maintenance would be needed to maintain uniform levee slopes and crest elevations. Aerial photos taken in September 1972 (11) with one foot contours indicate that at that time levee crest elevations ranged from above 66.0 feet to about 59.0 feet NGVD at one point along the left overbank. Most of the levee is at 60.0 to 61.0 feet. Since the high regulation stage in Lake Griffin is 59.25 feet, it is likely the levees are normally maintained at an elevation exceeding 59.25 feet.

Approximately 500 feet downstream from Burrell Dam the SR 44 bridge spans Haines Creek. The bridge is relatively new and the bridge deck is well above flood levels. The road embankment, however, constricts flow only to the channel and creates some backwater for flood flows. There has been only a small loss of natural flood plain storage between the bridge and the dam due to encroachment, but several structures including mobile homes and a marina are located along the channel.

Water surface profile analysis was done for Haines Creek. Cross section data was obtained from channel bottom profile and cross section soundings and from one foot contour maps. The HEC-2 water surface profile model for lower Haines Creek (below the dam) was calibrated with the range of flows available which included flows up to approximately 1500 cubic feet per second (cfs). Reasonably good agreement was obtained for this reach. The model for upper Haines Creek was calibrated with stage data for Burrell headwater and Lake Eustis. The recorded stage differences were quite variable, however, and did not provide good calibration data. This may be due to wind set up effects on the Lake Eustis stage data.

Figure 10a is a set of rating curves for Lake Eustis stage with each curve corresponding to a given stage immediately upstream of Burrell Dam. The lower boundary curve indicates the Lake Eustis rating curve as if Burrell Dam did not exist. The other curves are for selected stages upstream of Burrell, but do not relate to discharge capacity at the dam or to the dam crest elevation.

Figure 10b is a set of rating curves for Burrell tailwater, each curve corresponding to a given Lake Griffin stage. It is observed that for Lake Griffin stages below 61.0 feet and discharges greater than about 2,000 cfs, the Burrell tailwater is independent of Lake Griffin stage. In event of a failure of Burrell Dam the tailwater stages would therefore be expected to be independent of Lake Griffin stage, at least in the early hours following the failure. The hazard associated with a failure of the dam is primarily related to the rate of increase in water levels. The most critical condition then would exist when Lake Griffin stages were low prior to failure. This would result in a larger change in water level over the same time period. (An argument might also be made that the failure period would be shorter in this case due to a larger initial water drop across the dam.) A Lake Griffin stage of 60.0 feet was assumed for this

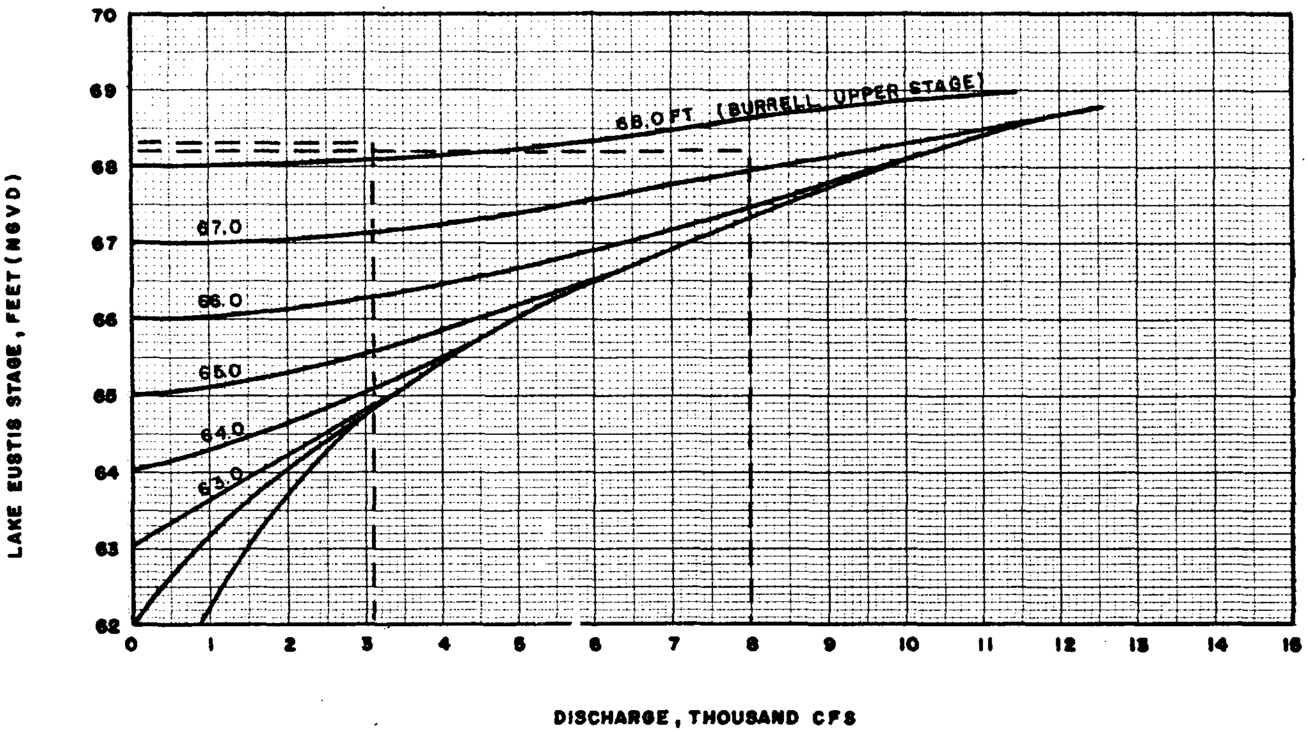

FIGURE 10a Haines Creek Rating Curve Above Dam

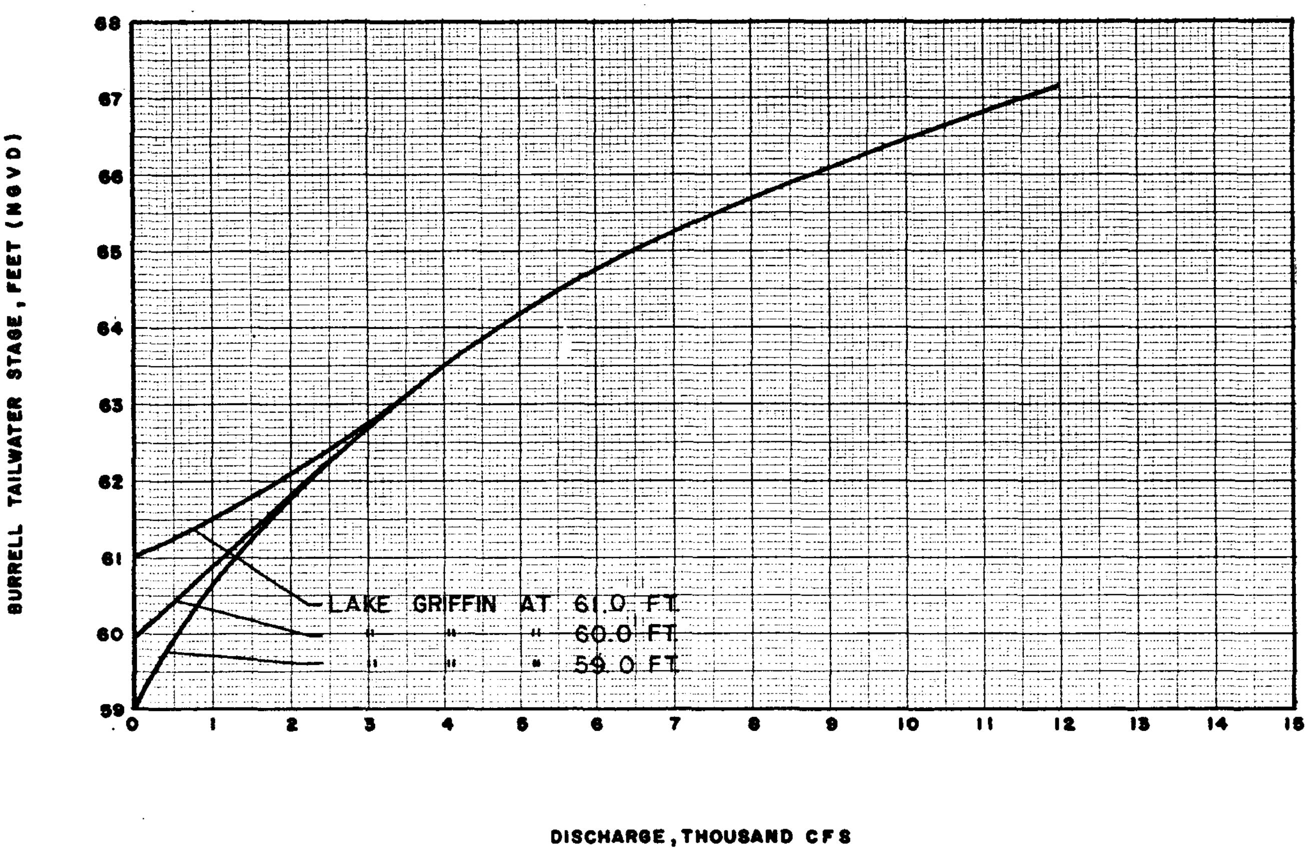

FIGURE 10b Haines Creek Rating Curve Below Dam

study. It is extremely unlikely that the combination of wet antecedent hydrologic conditions and a PMP event centered over the Haines Creek Chain of Lakes would coincide with Lake Griffin stages lower than 60.0 feet, or approximately a 5-year flood stage (7).

Figure 11 is a water surface profile for given steady flow conditions. Levee crest elevations are plotted on this figure, also. It is observed that discharges exceeding about 5000 cfs would overtop the levees on both sides of Haines Creek even with no freeboard allowance. This would in all likelihood result in failure of these levees. The impact of levee failure at the lowest point along the levee on upstream water levels is indicated in Figure 12. The profiles are plotted assuming Burrell Dam did not exist. It was assumed that water levels in Haines Creek at the point of levee failure were at critical depth after failure. It is observed that levee failure at the location indicated has little impact on water levels downstream of Burrell Dam.

Dam Breach Hydraulics

Hydraulic analysis of failures of earthen dams is a complex problem. The majority of the uncertainties associated with such an evaluation relate to the formation of the breach itself, however, rather than in estimating the discharge through a given breach geometry. Factors affecting final breach configuration and rate of growth include intrinsic physical properties of the soil, bulk properties such as compaction and water content, and physical dimensions of the dam. The hydraulic factors include

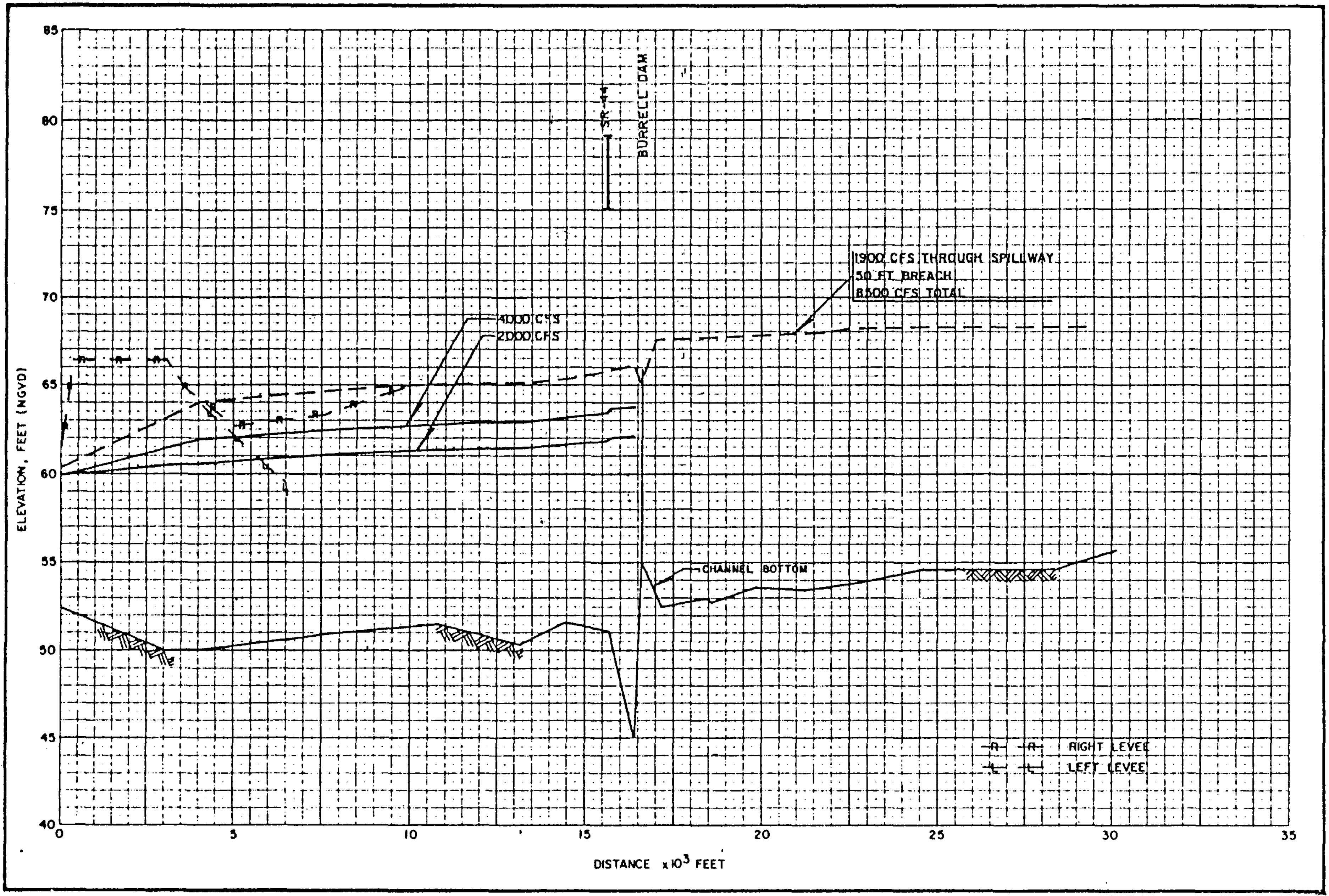

FIGURE 11
HAINES CREEK WATER SURFACE PROFILES

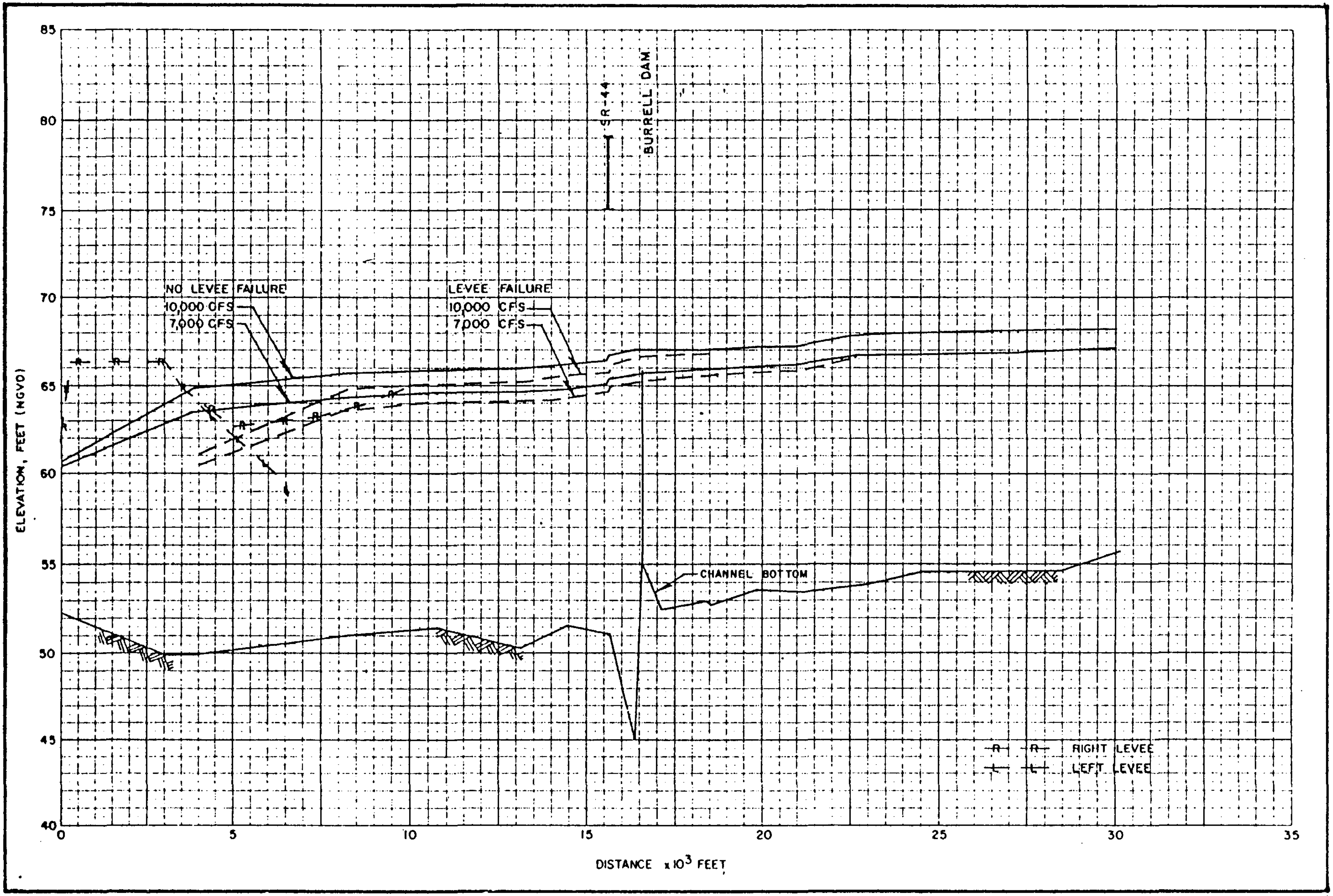

FIGURE 12

Haines Creek Water Surface Profiles with
Downstream Levee Failure

flow velocity and total volume which will flow over the dam or through the breach. Only recently has significant effort been made to provide the information to predict the size and configuration of dam breaches (5). Little experience or test information is available for dams which are somewhat similar to Burrell Dam.

Two important factors should be considered in predicting the breach growth rate and final configuration of Burrell Dam. The first is the soil of which the dam is constructed. The soil is not as cohesive as better dam soils and consequently would be more easily eroded. This would result in an unusually rapid breach growth. The second factor is that the dam crest is relatively wide (50 feet minimum). Hydraulic analysis of flow over the dam crest without failure indicates that this flow would be subcritical except near the downstream side of the crest where a hydraulic drop and supercritical flow would occur.

Figure 13 shows discharge rate per foot of dam width as a function of head at the dam. This relation is based on water surface profile analysis using mannings equation with n=0.015 (a conservatively low value) and assuming critical depth at the downstream edge of the 50 feet wide dam crest. A weir flow curve is also given with a broad crested weir coefficient of 2.63 (1). This comparison indicates that as long as the dam remains intact, the weir flow equation with a typical coefficient over predicts the discharge.

Average flow velocities as a function of flow are also given on Figure 13. The downstream velocities are for critical depth and since flow depth would actually be below critical depth the velocities would be slightly higher. Critical depth velocity remains below 5 ft./sec., however, for head water stages of up to 68.5 feet. Velocities in general remain below 4 ft./sec. for head water stages up to 68.0 feet.

Assuming the dam is overtopped and does fail, the breach is expected to grow to a bottom width of about 50 feet maximum. Figure 14 is a profile showing the dam crest elevation looking downstream, the lock and spillway location and a possible breach location are also indicated.

Several methods and equations are available to estimate maximum outflows through a dam breach. Four methods were used to provide checks and comparisons. The methods tested are described below. Discharges predicted from these equations and assumed breach geometry are given in Table 3.

1. HEC-1 Dam Breach Equation.

The HEC-1 model uses the equation

$$Q = 3.08 * BRWID * (WSEC-BREL)^{1.5} + 2.44*Z*(WSEL-BREL)^{2.5}$$

where BRWID = bottom width of breach, feet
WSEL = water surface elevation
BREL = elevation of breach bottom
Z = breach side slope, horizontal to vertical

2. SCS TR No. 66 (8)

The TR No. 66 peak flow equation is strictly empirical and based on estimated flows from actual failures

$$Q = 65 * H^{1.85}$$

where H = depth of water at the dam at time of failure, feet

3. Modified Schoklitsch Equation (12)

$$Q = \left(\frac{7}{27}\right) Wb \left(\frac{Wd}{Wb} \frac{Ho}{Hb}\right)^{0.28} \sqrt{g}\, Hb^{3/2}$$

$$= 1.68\ Wb \left(\frac{Wd}{Wb} \frac{Ho}{Hb}\right)^{0.28} Hb^{3/2}$$

where Wb = width of breach, feet
Wd = width of dam, feet
Ho = depth of water at dam, feet
Hb = height of breach, feet

4. HEC-2 water surface profile

The model's optional special bridge routine was used to estimate hydraulic relationships based on energy and Mannings equations, treating the fully developed breach as a bridge opening.

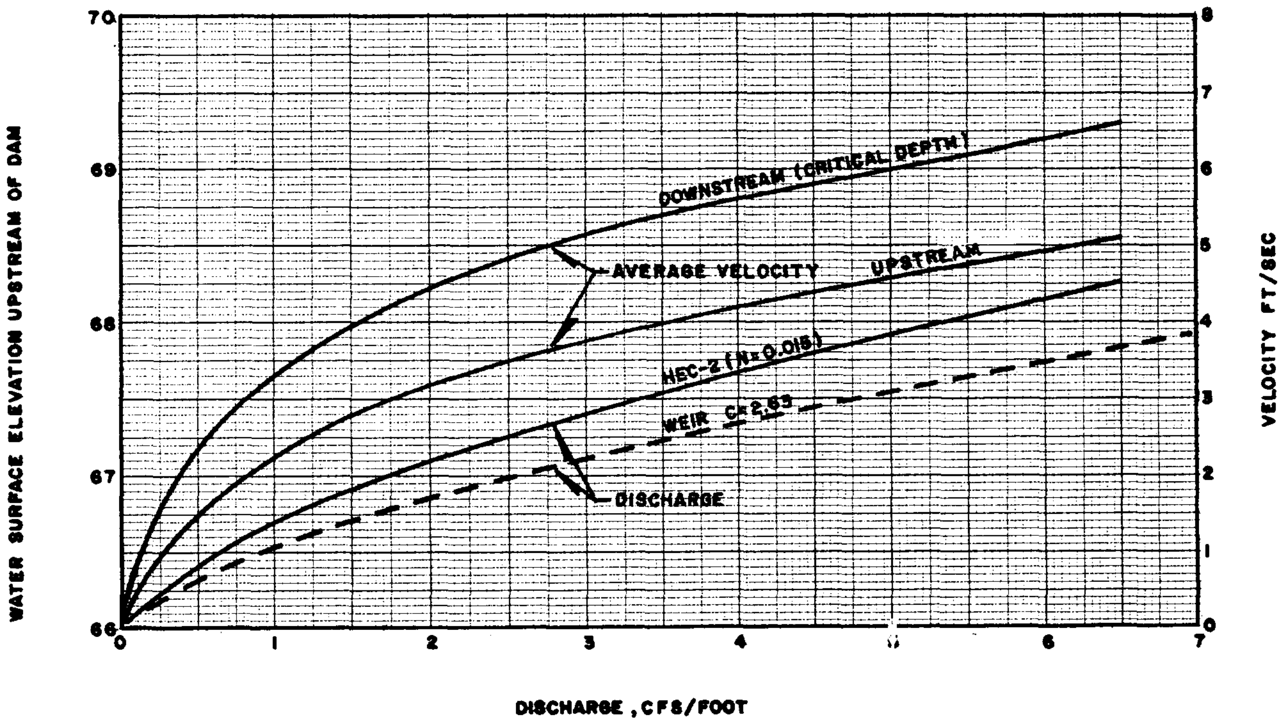

FIGURE 13 Dam Crest Rating Curve

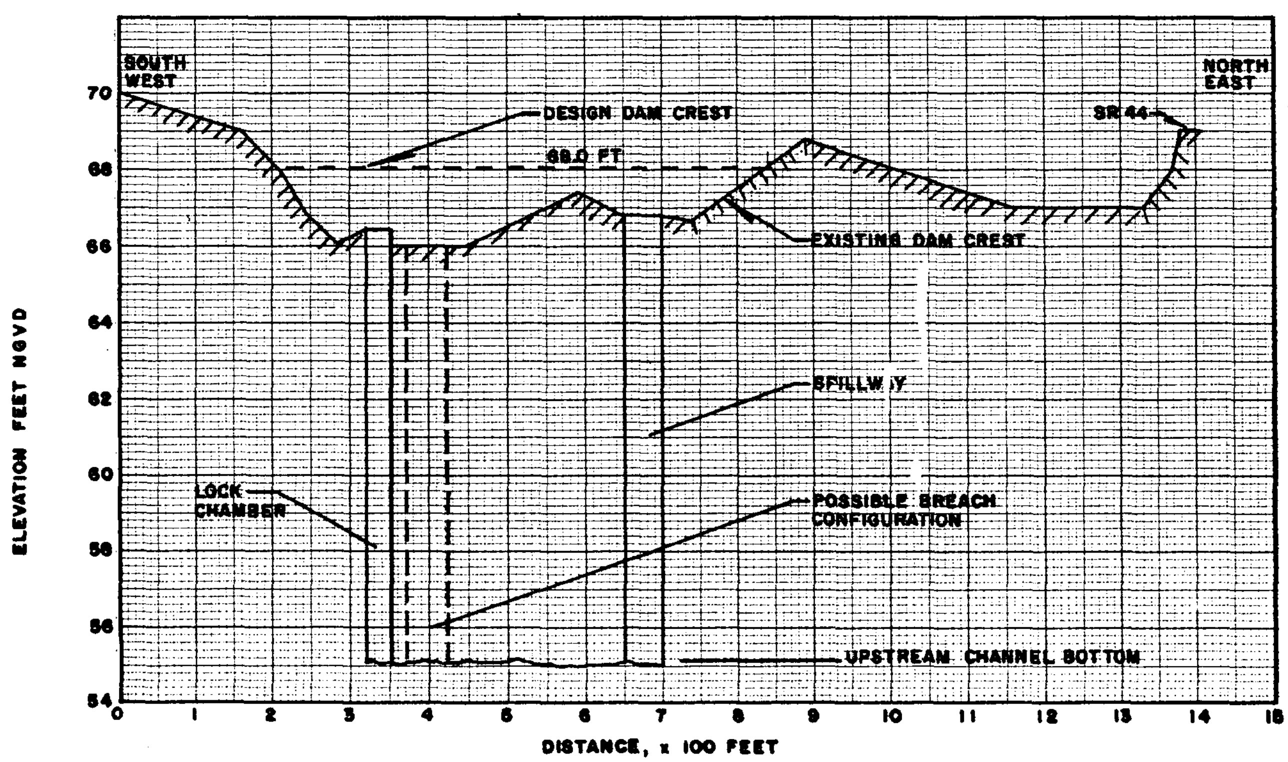

FIGURE 14 Top of Dam Profile

TABLE 3

PEAK DISCHARGE FOR DAM BREACH

Headwater Stage	HEC-1 (1)	TR NO. 66 (2)	Modified Shocklitsch (3)	HEC-2 (4)
69	8962	8575	6248	8500
68	7962	7477	6120	7100
67	7010	6448	5984	5800
66	6110	5489	5840	4600

(1) Z = 0.5, BREL = 55, BRWID = 50

(2) H = WSEL - 55.0

(3) Wb = 50 feet, Wd = 500 ft., Ho = WSEL - 55, Hb = 11

(4) bottom elev. = 55, breach bottom width = 50, Z = 2.0
WSEL upstream from breach drawdown

The flows estimated are in fairly close agreement. The HEC-2 results indicated that flow would remain subcritical through the breach with Froude numbers (4) remaining below 0.7. This indicates that methods based on critical flow, such as the HEC-1 method, may be conservative, at least following establishment of the assumed breach and steady flow conditions.

Flood Hydrograph

The HEC-1 model was used to predict the inflow hydrographs resulting from hypothetical storm events. The watershed was broken into sub-basins based on uniformity of drainage characteristics and significant storage areas. Hydrologic data for the sub-basins are given in Table 4. The sub-basins are as delineated in Figure 15.

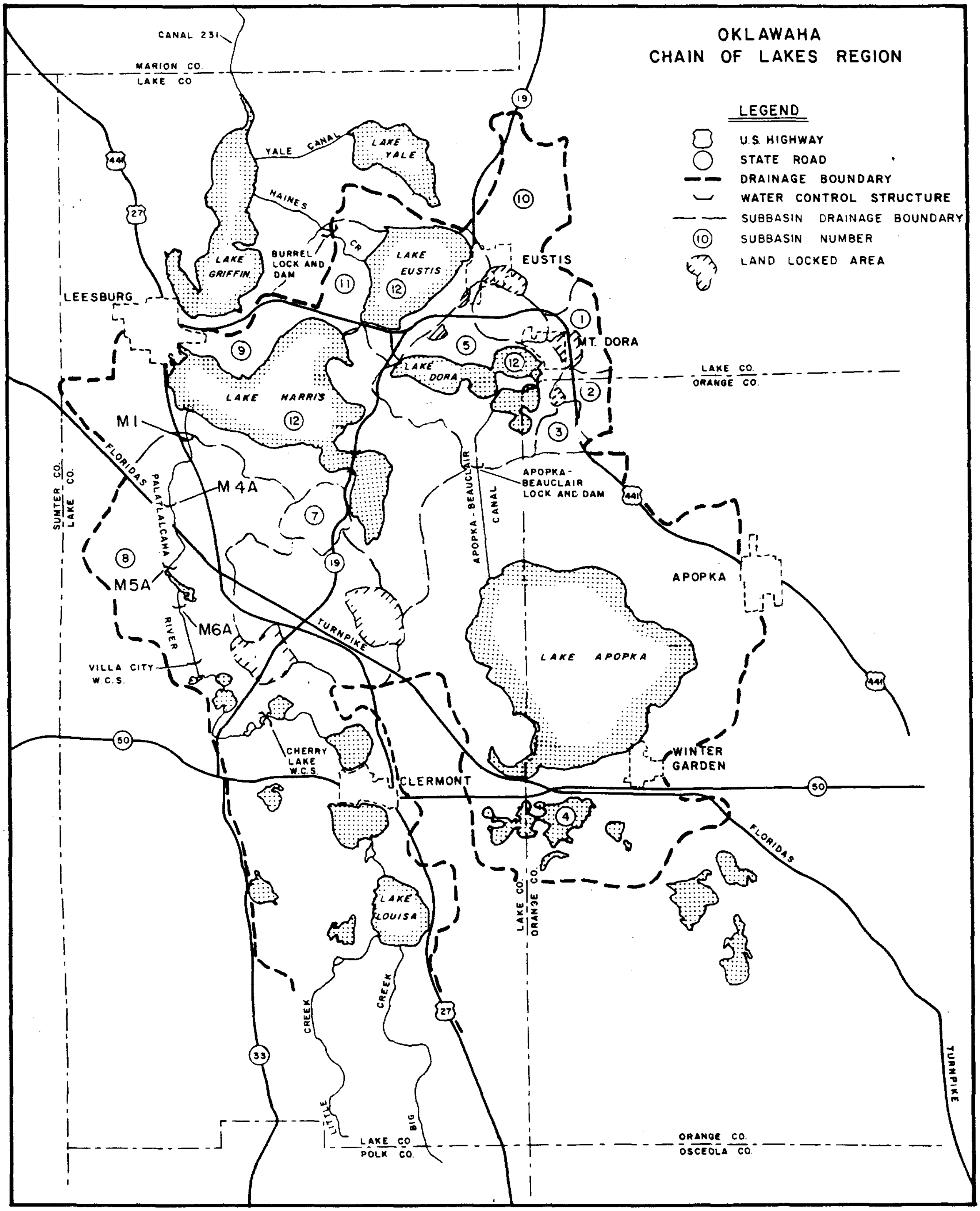

FIGURE 15 Sub-basin Map

TABLE 4

SUB BASIN HYDROLOGIC DATA

Sub Basin No.	Drainage Area (sq. mi.)	Runoff Curve Number	Lag Time (hours)
1	4.08	80	5.0
2	2.88	80	5.0
3	2.79	85	1.0
4	153.	-	-
5	21.4	80	12
6	25.38	85	10
7	5.86	85	10
8	260	-	-
9	51.45	75	6
10	19.24	85	6
11	16.49	80	10
12	57.0	100	0.1

The Haines Creek Chain of Lakes was treated as a single sub-basin. Based on HEC-1 analysis and other hydrologic considerations, the Apopka Watershed was assigned a constant outflow of 600 cfs, approximately the outflow capacity of the Apopka-Beauclair Dam. This dam is not expected to fail due to the large storage capacity available upon failure of the agricultural levees around the lake. The Palatlakaha Watershed was assigned a constant discharge of 1100 cfs which is the approximate discharge capacity of structure M-1. The elongated shape of the basin, the diversion potential in Little Creek, the storage in swamp and marshes, the narrow, heavily vegetated channel and major road crossings, such as the Florida Turnpike, all contribute to preventing extremely large outflows from the Palatlakaha basin.

The average rainfall runoff for the PMP event for the watershed excluding the lake area is 33.2 inches (loss of 2.8 inches). The 0.5 PMP results in 15.3 inches. The actual runoff into the lakes in each case is somewhat less, however, due to storage in upland areas. The Sunset Valley, Grass Pond, and Trout Lake sub-basins (sub-basin numbers 1, 2 and 10, respectively) are examples where significant storage volume and flooding depths would be experienced. Major transportation routes in these areas would likely be cut off. The peak inflow rate to the Chain of Lakes is 410,000 cfs and 203,000 cfs for the PMP and the 0.5 PMP, respectively. The peak is mainly due to direct rainfall on the lake surface.

A storage routing using the modified-Puls method was calculated to determine the stage hydrograph for Lake Eustis. Various assumptions for the discharge of Burrell Dam were used. Three hypothetical scenarios are discussed below:

1. No failure - This case was analyzed to predict what would occur if the existing dam were capable of acting as a spillway without failure. The results of this simulation are similar to those which would occur if an emergency spillway approximately 300 feet wide with a crest elevation of 66.0 feet were constructed.

2. Failure due to overtopping - This case is believed to be the most reasonable, yet conservative, assumption of what would actually occur as a result of the PMF. The dam was assumed to fail beginning at the time that the headwater level rose to 68.0 feet or two feet over the top of the dam. At that point, a

trapezoidal breach would begin to develop and reach a final size in one half hour. The bottom of the breach was assumed to be 50 feet wide and the side slopes 1 foot horizontal to 2 feet vertical.

3. Total failure - This case would be similar to either the dam being totally eroded away early in the storm or construction of a hypothetical spillway with capacity equal to Haines Creek (i.e., a spillway limited by tailwater rather than the structure).

All of these cases where applicable assumed that the existing spillway discharge was at 1900 cfs. The peak stages in Lake Eustis resulting from the routings are summarized in Table 5. Stage hydrographs for Case 2 are given in Figure 16.

TABLE 5

LAKE EUSTIS PEAK FLOOD STAGES

	Peak Stage, Feet NGVD		
Case Description	0.33 PMF	0.50 PMF	1.00 PMF
1. No Failure	65.0	66.1	69.1
2. Failure at 68.0	65.0	66.1	68.3
3. Total Failure	64.8	65.7	68.1

It is observed that the peak stage is not very sensitive to outflow conditions. This is true because the outflow via Haines Creek, even with no obstructions (e.g. Burrell Dam), is small relative to inflow and storage increases in the upstream lakes. The peak stage of 69.1 feet resulting from the no failure assumption and the full PMF results very late in the simulation due to

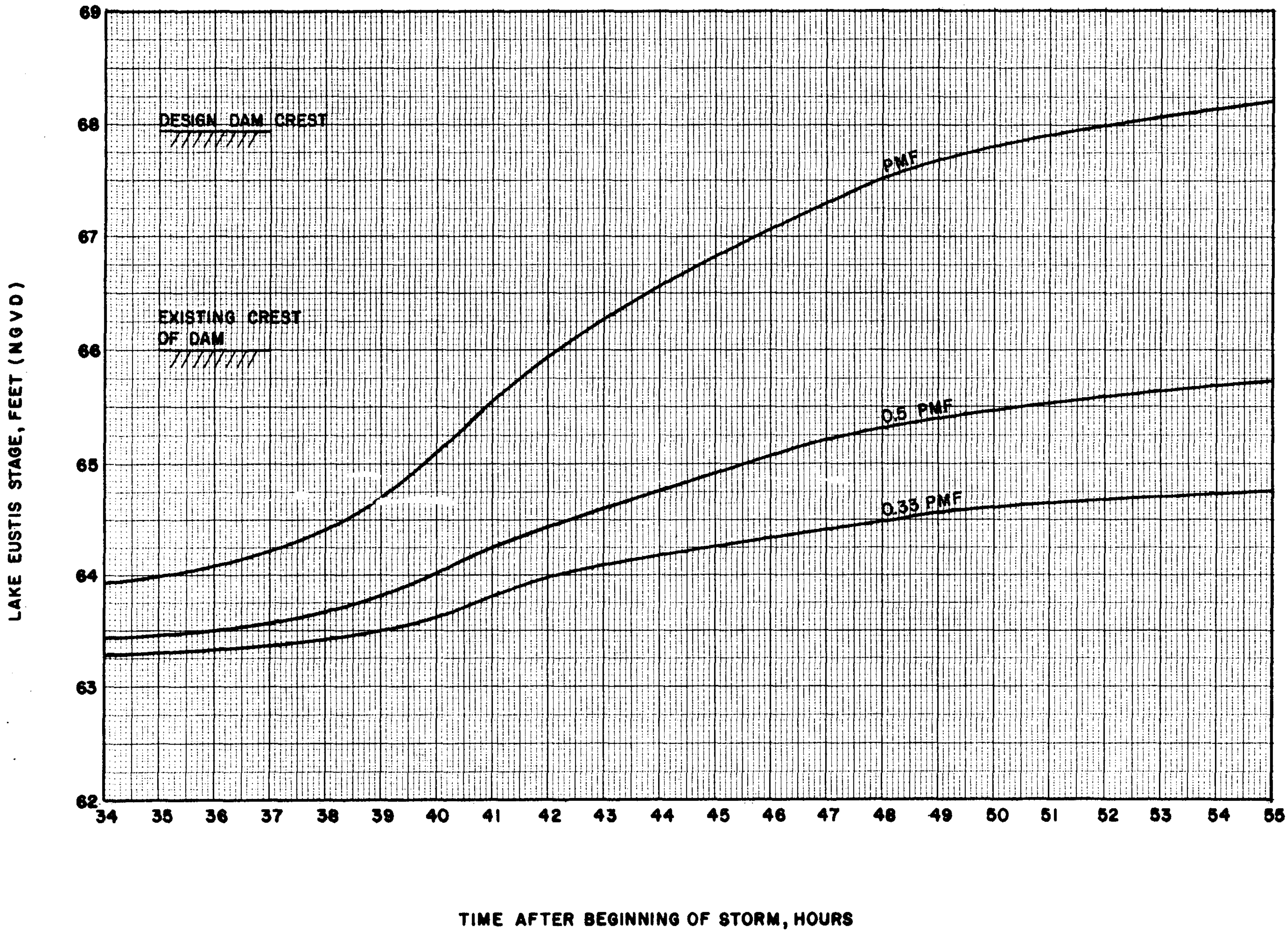

FIGURE 16 Lake Eustis Stage Hydrographs

the constant inflow rate of 1700 cfs from the Apopka and Palatlakaha Watersheds is nearly as large as the discharge capacity of the existing structure. Uncontrolled runoff to Lake Eustis, therefore, has to subside to a low value before the total inflow can fall below outflow and allow lake levels to begin to fall.

Since it is observed that the peak stages are not sensitive to estimates at discharge of Burrell, it is concluded that the Burrell Dam would be overtopped by more than 2 feet during a PMF and lake stages would rise to the crest of the dam as a result of the 0.5 PMF. These conditions result even with what is believed to be an optimistic assumption of discharge capacity of the existing spillway of 1900 cfs.

Using these peak stage data, the peak flow below Burrell Dam can be estimated. Figures 17a and 17b are the same as Figures 10a and 10b except that two headwater rating curves have been added - one for flow over the dam without failure and one for steady flow with a 50 feet wide breach. For the PMF case with a Burrell upstream stage of 68.3 feet and a 50 feet wide breach the flow would be 9500 cfs. The stage immediately upstream of Burrell, however, would not be at 68.3 feet when Lake Eustis is at 68.3 feet due to the water level drop in the 2.5 miles of Upper Haines Creek. By trial and error use of Figures 17a and 17b it is found that the steady flow with Lake Eustis at 68.3 feet would be about 8000 cfs with the Burrell headwater stage of 67.3 feet. The tailwater stage would be 65.7 feet. A similar method is used to find that the discharge immediately before

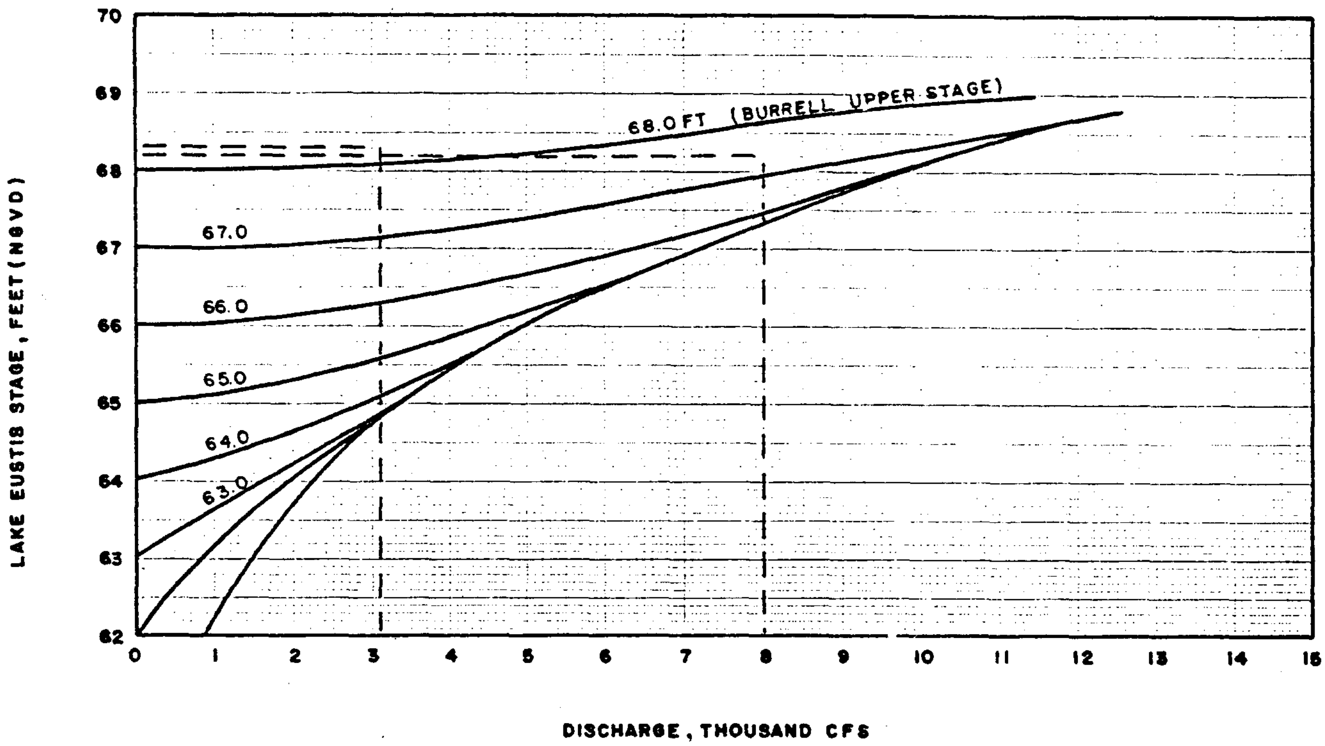

Figure 17a Haines Creek Rating Curves, Below Dam

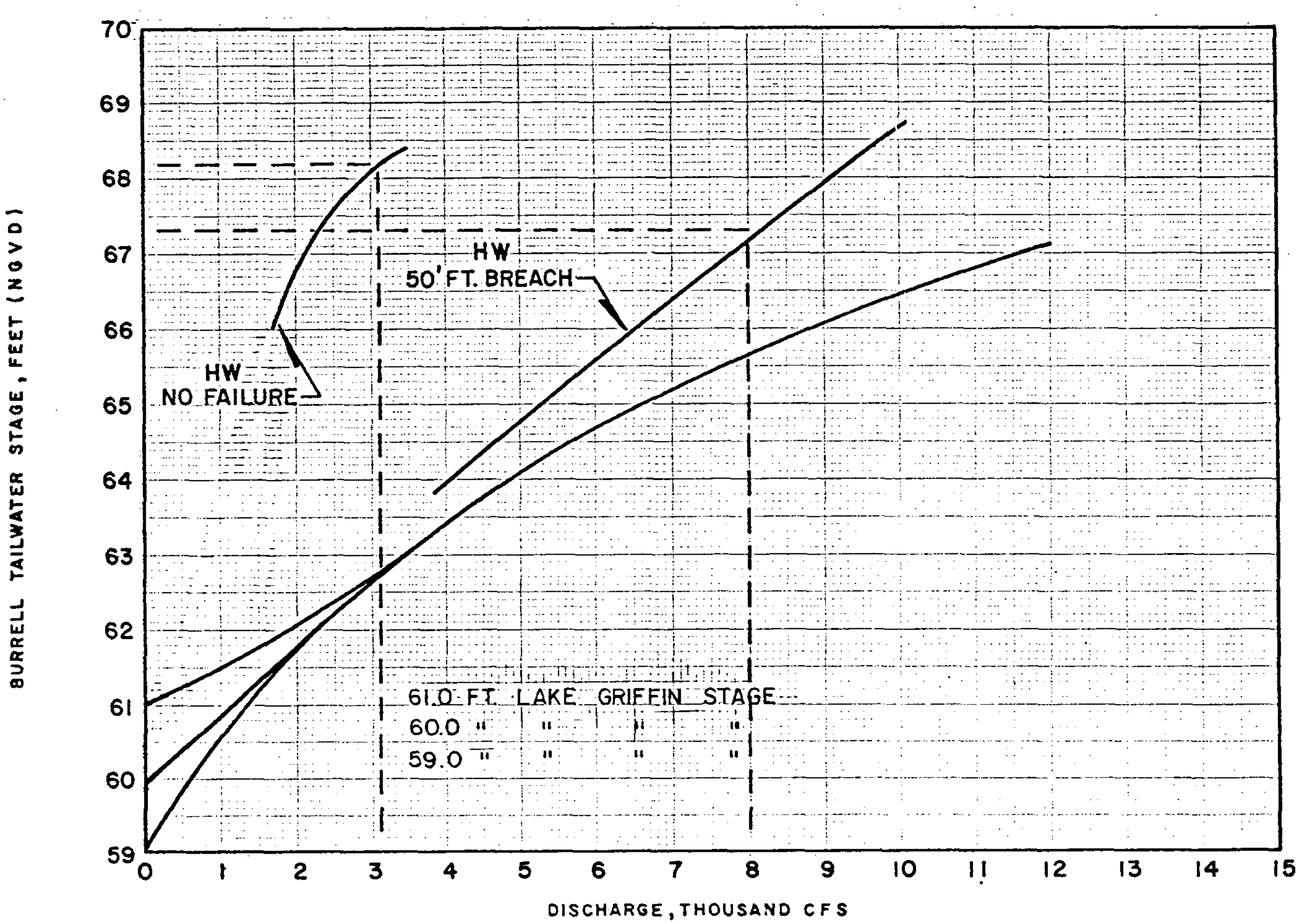

Figure 17b Haines Creek Rating Curves, Above Dam

failure is 3100 cfs with a headwater stage of 68.2 feet and a tailwater stage of 62.8 feet. The increase in discharge due to the failure is therefore 4900 cfs and the increase in tailwater stage is 2.9 feet. Table 6 summarizes the before and after failure conditions for given cases.

TABLE 6

FAILURE IMPACTS ON STEADY FLOW CONDITIONS [a]

Case	Before Failure			After Failure			Change	
	HW	Q	TW	HW	Q	TW	Q	TW
PMF								
50 ft. breach	68.2	3100	62.8	67.3	8000	65.7	4900	2.9
Total Failure	68.2	3100	62.8	66.5	10000	66.5	6950	3.7
0.5 PMF								
50 ft. breach	66.0	1900	61.8	64.7	4900	64.0	3000	2.2
Total Failure	66.0	1900	61.8	64.2	5100	64.2	3200	2.4

----

a stages in feet (NGVD), flows in cfs, HW is headwater stage, TW is tailwater stage and Q is Haines Creek discharge

The conditions given in Table 6 are for steady flow where the water levels and discharges at a given point along Haines Creek are not changing. This simplification is believed to be adequate. Upon failure the flow at the dam would be greater than the steady state flow as water is removed from wedge storage in Upper Haines Creek and filling wedge storage in lower Haines Creek. Since the wedge storage involved is on the order of 100 to 300 acre feet, steady flow would be reestablished within one hour. The storage changes would be effective, however, at damping out surge waves traveling in both the upstream and downstream directions from Burrell. Such surge waves would result from a rapid change in flow at the dam.

Burrell Dam Assessment

The Burrell Dam would be overtopped by a PMF event. The 0.5 PMF event would raise water levels to the crest, with no freeboard allowance. A freeboard allowance is considered necessary due to wave action during the long period of high stage and as normal practice to provide a safety margin against unexpected events and engineering errors. It is concluded that Burrell Dam is, therefore, not adequate to handle the 0.5 PMF. To meet federally recommended standards, Burrell Dam should adequately handle the full PMF.

As discussed in Section II, the deficiency of Burrell Dam with respect to the recommended design flood does not necessarily make the dam unsafe. The three criteria for being declared unsafe are stated and discussed below:

1. There is high hazard to loss of life from large flows downstream of the dam.
2. Dam failure resulting from overtopping would significantly increase the hazard to loss of life downstream from the dam above that which would exist just before overtopping failure.
3. The spillway is not capable of passing one-half the PMF without overtopping the dam and causing failure.

It was demonstrated in Section V that "expected" failure conditions could result in an increase in water levels in lower Haines Creek of 2.0 to 3.0 feet over the period of failure. This failure would be expected to occur a few hours after overtopping begins due to the flow velocities over the dam crest which would be moderately erosive and because of the wide crest of the dam. After beginning of failure the time for the breach to fully develop is expected to be on the order of one half hour or greater. One half hour is believed to be a conservative estimate for the Burrell Dam.

The rate of rise of the lake level is an important consideration for Burrell Dam safety. The rate of rise in the lakes is closely related to rainfall intensity which is given as 20.2 inches or 1.68 feet over the most intensive 6-hour period. The PMF modeling results give a maximum rate of rise of about 0.5 feet per hour with a 6-hour maximum increase of 2.0 feet. With the rainfall distribution used (see Figure 18) overtopping began at the 42nd hour of the 48 hour storm. The 5- and 100-year flood stages for Lake Eustis are 64.0 and 65.0 feet, respectively. The times between exceeding these stages and overtopping of the dam are 7 and 2 hours, respectively. These are significant since they provide estimates of time periods between various levels of awareness and impending failure.

Based on HEC-2 results, average flow velocities in the lower Haines Creek channel are generally less than 5 ft./sec. This is a relatively high velocity for Haines Creek, but is not believed

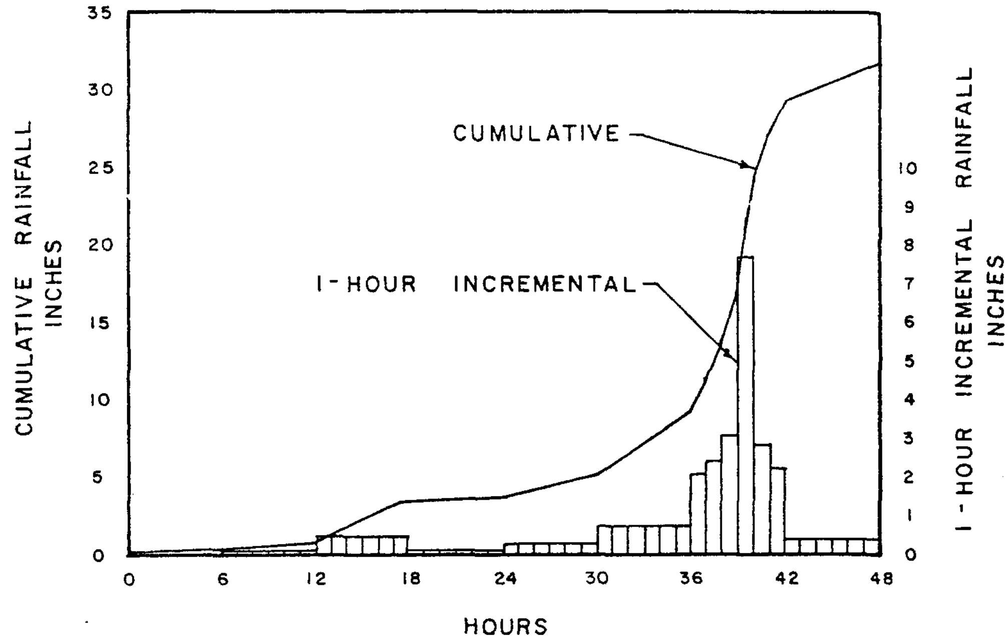

Figure 18. PMP Rainfall Distribution

to be extremely high so as to create a large increase in hazardous conditions in Haines Creek.

There are approximately 50 residences and a marina immediately downstream of Burrell Dam. The locations and surrounding ground elevations of most of these are seen on Figure 19. The peak flood stages for the area from the Total Failure case are indicated on the figure. More than one half of these structures are susceptible to flooding for the PMF. The six residences immediately adjacent to the south side of the channel would appear to be the most seriously impacted. Water depths there could be as much as five feet and accompanied by strong currents exceeding 5 ft./sec. These structures could be swept from their foundations or have the bank eroded out from below them by these currents. Other structures would be subjected to lesser depths of inundations and are also more protected from swift currents. Figure 20 shows flood extents for lower Haines

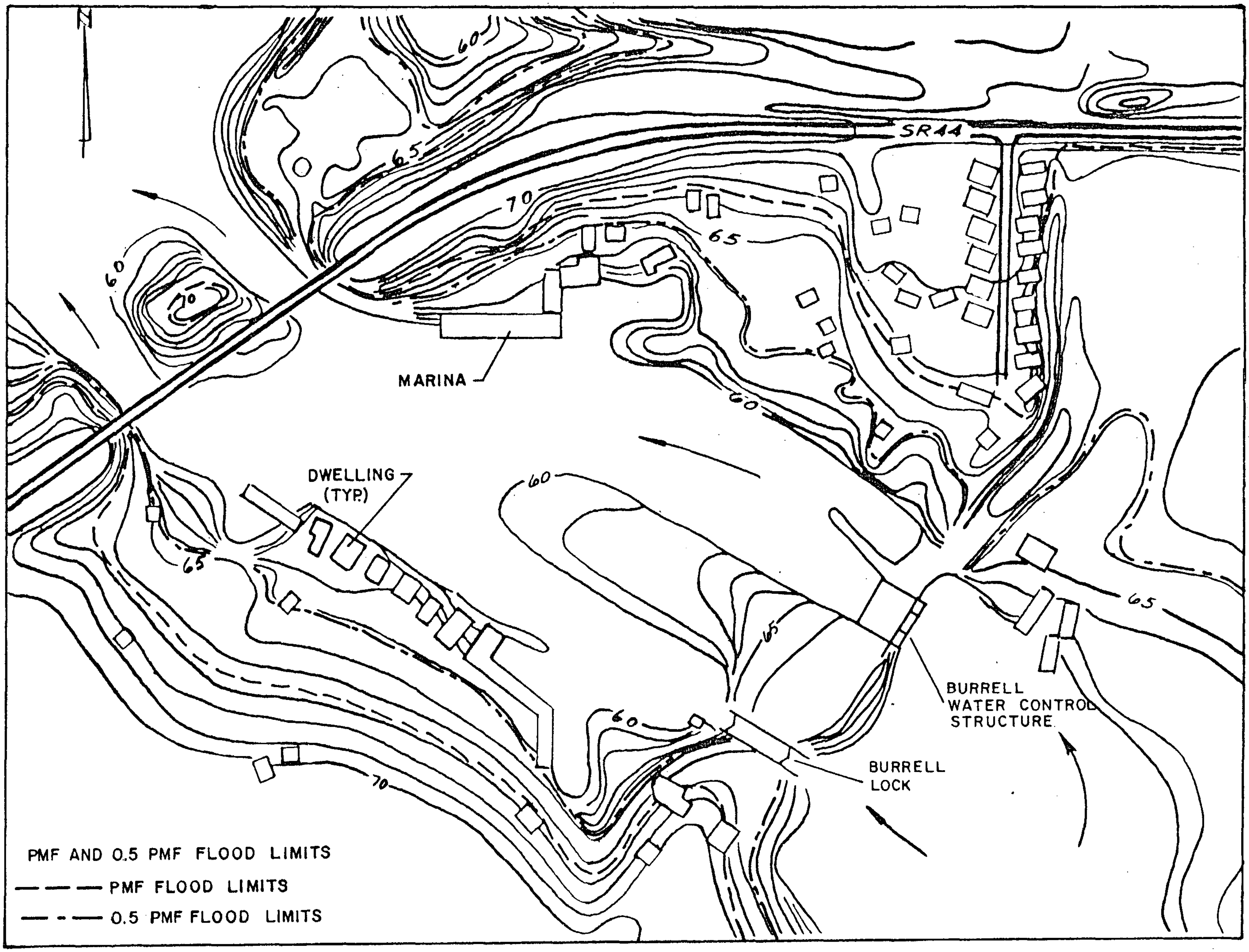

FIGURE 19. Burrell Tailwater Flood Limits

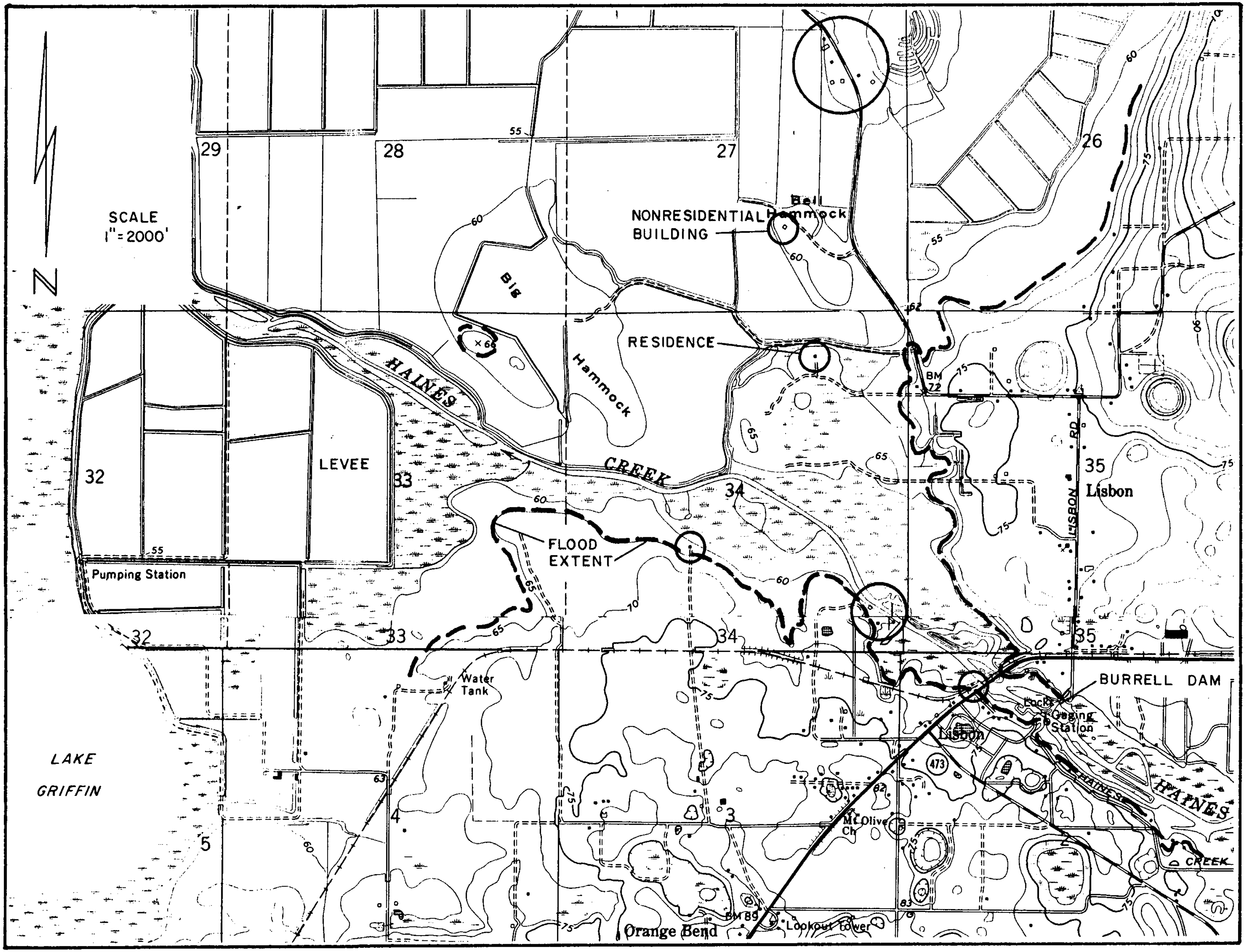

FIGURE 20.

LOWER HAINES CREEK FLOOD LIMITS

Creek in its entirety. Locations of existing residences and agricultural structures potentially impacted by a PMP related failure are also indicated on Figure 20.

Based on this information it is concluded that the danger of loss of life extends to approximately six residences. This is believed to be sufficiently hazardous to classify the dam as unsafe. It is also believed, however, that a reasonable emergency action plan and warning system could be quickly implemented at minimal cost which would remove this risk of loss of life so that the dam could be classified as safe.

Rates of rise in water levels and total changes are not believed to be extreme and permit at least a few hours between indication of potential danger and impending failure. This should be adequate time to warn and evacuate persons in hazardous locations.

As discussed earlier, the 0.5 PMF causes Lake Eustis to rise to 66.1 ft., approximately the elevation of the dam crest at the lowest point. This is not an acceptable condition so the dam must be considered to be overtopped and fail.

To summarize, based on the Corps' criteria for dam classification, the Corps' classification of the Burrell Dam as unsafe appears to be a correct classification. The PMF would present a substantial risk of loss of life for residents of about six dwellings immediately downstream of the dam. This hazard could be avoided with a high degree of reliability by an emergency action plan and warning system due to the proximity of the dwellings and the relatively slow rates of increase in flood stage. Such warning systems are common. It is believed that with this improvement the dam could be classified as safe according to the Corps criteria.

ALTERNATIVES

One objective of this study is to identify alternatives which might be feasible remedial measures to correct any deficiencies found to exist. Evaluation of the alternatives is not an objective of the study although preliminary evaluation is necessary to produce a meaningful list of alternative measures.

Possible remedial measures to reduce risks and losses resulting from floods exceeding the current capacity of Burrell Dam include but may not be limited to the following:

1. Warning system
2. Raise the dam to prevent overtopping
3. Increase spillway capacity
4. Stabilize the dam against failure due to overtopping
5. Lower regulation stages
6. Remove the dam

Some of the major considerations and factors related to each of these are discussed below.

1. Warning System

An early warning system could be implemented to provide adequate time to warn residents and others in potentially hazardous areas of impending danger. Such systems are used in many areas currently. Multiple levels of alert could be employed to prevent too frequent public wide alerts yet provide early detection by proper responsible persons. Advantages of this measure are the protection against loss of life at a relatively low cost. The major limitation, of course, is that while it would reduce risk of loss of life it would in no way reduce other socio-economic impacts associated with failure. _This alternative is feasible only as a measure to classify the dam as safe rather than unsafe._

2. Raise Dam

This alternative could provide a dam which is both safe and adequate to handle the required design flood, the PMF. This alternative would, however, raise flood levels throughout the Haines Creek Chain of Lakes by more than one foot for the PMF. This increase would create large economic loss upstream of Burrell Dam for the PMF. The increased flood damage would involve an estimated 1,000 residences. Since SJRWMD would be liable for the increase in flood damage, purchase of the property, or flood easement, or assumption of the liability would result. This alternative is consequently costly and is not expected to be the least cost or best alternative.

3. Increase Spillway Capacity

This might be accomplished by replacing all or a portion of the earth dam with an uncontrolled emergency spillway or a gated spillway. Capital costs for this would be relatively high compared to raising the embankment. Only slight decreases in maximum flood stage for the PMF could be achieved even with a spillway with a capacity as large as that of lower Haines Creek although the duration of the flood stages would be reduced. The remainder of the earthen dam would need to be raised to prevent overtopping.

4. Stabilize Spillway Against Failure

The earth dam is assumed to fail due to surface erosion by the flow over the crest. If the existing dam could, with minor modifications, be made resistant to erosion then failure could be eliminated (subject to verification of other factors such as stability against sliding, uplift, etc.). This alternative is actually a special case of increasing the spillway capacity, since the existing dam would act as an emergency spillway. There are several different configurations which could technically satisfy the requirement. Emergency overflows have in some cases been constructed as grassed earthen channels of flat enough slope to keep flow velocities below erosive limits. Other possibilities include replacing the earth embankment with non-erodible material such as protective riprap or gabions (wire containers filled with rock) as seen in Figure 21. Another alternative would be to drive steel or concrete sheet piling along the length of the dam which could withstand the small water level differences if the earth embankment were completely eroded.

A rigid non-erosive shell or paving of the existing embankment is an alternative, but adequate prevention of internal erosion during overflow and detection of cavities beneath the covering created by seepage or other causes are important concerns.

5. Lower Regulation Stages

By lowering regulated water levels the storage available for storm runoff is increased. This alternative has been investigated in an earlier study (10) which dealt with more general

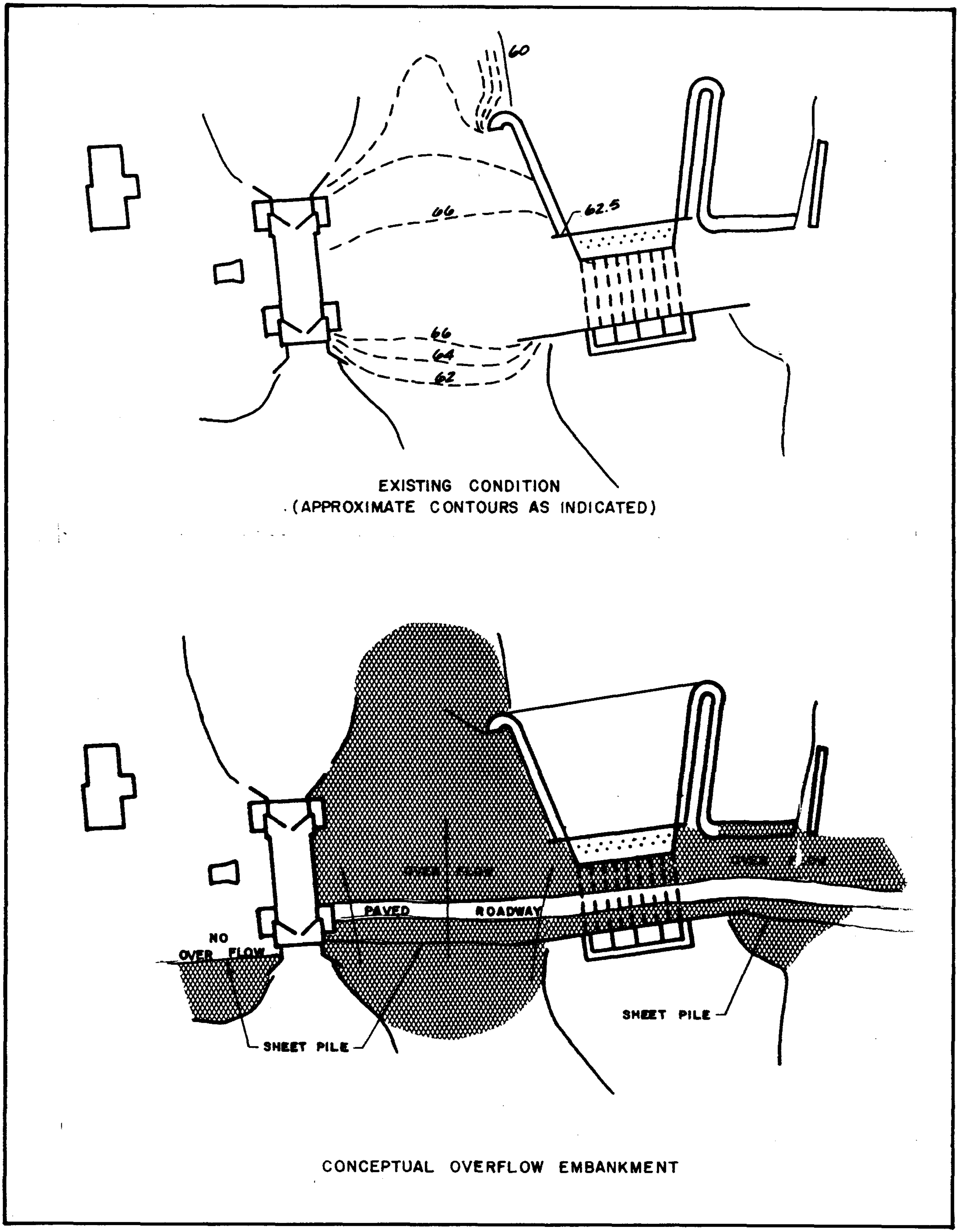

Figure 21 Conceptual Drawing of Burrell Overflow Embankment Rehabilitative Alternative

water management objectives for the Oklawaha River and was determined to be a potential solution to minimizing flood damages. It is clear that even the most drastic lowering of regulation stages would not prevent overtopping of the existing Burrell Dam during a PMF. This alternative would, therefore, need to be combined with other measures to meet the overall objective.

6. Remove Burrell Dam

This case is a special case of lowering regulation stages. By removing Burrell Dam, control of Haines Creek Chain of Lakes would be transferred to Moss Bluff Dam. Since the original Burrell Dam was constructed as a navigation project and much lake front development has occurred since the construction in 1954, this alternative would have very extensive socio-economic and environmental impacts. As such this alternative is not considered feasible.

It is possible that no single one of the feasible measures described could provide the desired results. A combination of two or more would very likely be required to optimize such a remedial works plan. Such a plan should be developed based on all technical and socio-economic factors involved, both upstream and downstream of Burrell Dam.

Based on data available at this time and engineering judgement, a flexible protective covering such as riprap or gabions and the sheet pile wall alternatives would appear to be the most feasible alternatives. These would maintain flood damages at the current conditions, presumably resulting in no increased liability, but prevent damages resulting from failure of the dam. A few concerns which will need to be considered include:

1. Can a sheet pile wall be driven near the approximately 30 year old lock structure without damaging the lock?
2. Can overflow be allowed over the lock gates and the existing gated spillway?
3. Can the embankment be secured against erosion by these measures?

SUMMARY

This study was conducted to satisfy the requirements of the National Dam Safety act and Corps of Engineers Phase II studies. The objectives of the study were to determine through detailed hydrologic analysis any deficiencies of Burrell Dam based on federally recommended standards, the potential impacts resulting from these deficiencies, and possible remedial measures to correct the problems.

Burrell Dam is classified as a large, high hazard dam because of the upstream storage capacity and socio-economic impacts in the event of failure. Federal guidelines indicate that the Spillway Design Flood (SDF) for this dam is the Probable Maximum Flood (PMF). Conclusions of this study are that the PMF would overtop the existing dam by about two feet for an extended period of time resulting in failure of the dam. The 0.5 PMF would raise upstream water levels to slightly above the dam also resulting in failure. The 0.33 PMP has a peak flood stage of 65.0 feet. Assuming a 2.0 foot minimum freeboard allowance is adequate, the maximum flood event which Burrell could safely handle is the 0.33 PMP, or about 12 inches of rainfall in 48 hours. This rainfall is about a 100-year frequency 48-hour duration event. The minimum freeboard for design purposes should be at least 3 feet (18) to provide a margin of safety for design errors, wind set up, and wave run up. Based on historic stage records and a 3 feet freeboard requirement, the existing dam would be adequate for only a 5-year frequency flood stage. Burrell Dam is therefore considered inadequate.

The height of Burrell Dam and the hydraulic characteristics of Haines Creek are such that a large increase in risk of loss of life is not expected to result from failure. However, approximately six residences are located in a hazardous area. The dam does, therefore, meet the federal guidelines criteria to be classified as unsafe. It is believed that the dam could be classified as safe after implementing an emergency action plan and early warning system. A proposed emergency action plan is included as an addendum.

For the dam to be classified as adequate it needs to be capable of handling the PMF without failure. Alternatives which prevent overtopping are very expensive either in construction cost or purchase of property and flood easements. It is believed likely that the embankment can be made secure against failure by erosion due to overtopping by one of several measures utilizing sheet piling, riprap, and/or gabions at a cost significantly less than the cost of other alternatives.

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PROPOSED

EMERGENCY ACTION PLAN

FOR

BURRELL DAM

ST. JOHNS RIVER WATER MANAGEMENT DISTRICT

APRIL 1985

I. GENERAL

II. ANALYSIS

- A. Description of Dam
- B. Antecedent Conditions
- C. Initial and Failure Conditions
- D. Downstream Impacts
- E. Conclusions

III. EMERGENCY CLASSIFICATIONS

IV. IMPLEMENTATION

- A. Organization
- B. Assigned Responsibilities
- C. Other Agencies

V. ADVANCE PREPARATION

- A. Warning System
- B. Stockpiled Materials

VI. DAMAGE ASSESSMENT

I. GENERAL

This Emergency Action Plan (EAP) for Burrell Dam describes the responsibilities of the St. Johns River Water Management District (SJRWMD) staff to minimize the impacts of failure of the dam due to an extreme flood event. Measures are discussed for the preparation, implementation, and damage assessment stages of the EAP, and responsibility for execution of each measure is assigned to a specific person, group, or agency.

II. ANALYSIS

Studies of the adequacy of Burrell Dam (1, 2) indicate that the dam may fail by overtopping as a result of a major storm event. Results of the analysis for the most severe flood condition believed to be reasonably possible, the Probable Maximum Flood (PMF), are summarized here.

A. Description of Dam

Burrell Lock and Dam are located on Haines Creek which flows from Lake Eustis into Lake Griffin. The dam is located 3.2 miles upstream from Lake Griffin and 2.5 miles downstream from Lake Eustis. The earthen dam is 12 feet in height and approximately 400 feet in length. The lake area impounded at normal high regulation stage is 57 square miles, which includes lakes Eustis, Harris, Dora, Carlton and Beauclair. The total drainage area is 620 square miles.

The Burrell Dam discharge is via a gated spillway (four overflow weir gates) with a discharge capacity of about 1900 cubic feet per second (cfs). Downstream from Burrell Dam, Haines Creek discharges into Lake Griffin. Lake Griffin is regulated by Moss Bluff Dam constructed by the United States Army Corps of Engineers and operated by St. Johns River Water management District. The City of Leesburg is located on the southern shore of Lake Griffin and extensive development is found along the southeastern and southwestern shores. Scattered residential areas are found along lower Haines Creek including several residences immediately downstream of the Burrell Dam.

B. Antecedent Conditions

It was assumed that the failure would result from a severe flood event. The Lake Eustis stage prior to start of the storm was assumed to be 63.0 feet. Hydrologic conditions were assumed to be wet such as might be expected from high seasonal rainfall.

C. Initial and Failure Conditions

The dam was assumed to fail by erosion due to overtopping. The storm analyzed was the Probable Maximum Precipitation (PMP), which is 32.5 inches in 48 hours. The dam breach was assumed to begin when the upstream water level rose to 68.0 feet, about 2.0 feet over the low point in the dam crest. The breach was assumed to grow to a maximum bottom width of 50 feet over a 30 minute period. The spillway was assumed to be discharging at 1900 cfs throughout the storm event. The two control structures discharging to the Burrell Dam watershed, the Apopka-Beauclair and Palatlakaha M-1 structures, were assumed to be discharging at their design maximum discharge capacities of 600 cfs and 1100 cfs, respectively, throughout the storm period.

D. Downstream Impacts

Lake Griffin was assumed to be at 60.0 feet prior to the start of the storm. The maximum discharge from the PMF following failure was estimated to be 8000 cfs. The failure resulted in a 3.0 feet increase in tailwater stage over the period of growth of the breach. The maximum water surface profile along Haines Creek is seen in Exhibit 1.

A large area downstream of Burrell Dam could be impacted. Water levels in Lake Griffin for the situation analyzed (PMP over Burrell Dam watershed, but not over the Lake Griffin region) would rise to 63.0 feet following the dam failure. This would result in shallow flooding of many residential areas and local roads.

The most serious risk is for those residences located along lower Haines Creek. Residential areas may be isolated as access roads are flooded, making evacuation hazardous. Agricultural levees would fail, flooding fields and isolated residences. This area is seen in

Exhibit 2. Immediately downstream of the dam several residences are located along the left bank. Water levels along that portion of Haines Creek would rise rapidly. Some of these residences seen in Exhibit 3, would be subject to flood waters as much as five feet deep and possibly possessing hazardous and erosive streamflow currents.

E. Conclusions

Occurrence of a PMF event for Burrell Dam would result in overtopping of the earthen dam and probable failure by erosion. Residential areas along Haines Creek downstream of the dam could be subject to life threatening conditions as a result of failure. Extensive agricultural and residential property damage around Lake Griffin would result. Levee 212 between Lake Griffin and Moss Bluff Dam would be subject to higher than design water levels and could fail.

III. EMERGENCY CLASSIFICATIONS

Emergency classifications for the Burrell Dam EAP include four levels of increasing severity. These classifications are based on water levels on the upstream side of Burrell Dam. In the most extreme case, little time would elapse between the later classifications. The potential problems relating to reaction time have been considered and incorporated into the EAP.

Rainfall depths and forecasts are not considered in the emergency classifications. These factors are important and will influence decisions regarding implementation of various emergency action measures. The emergency classifications are as follows:

Emergency Classification	Burrell Upper Stage	Description
I	64.00 - 64.99	High water - no immediate danger
II	65.00 - 65.99	Extreme high water - potential for overtopping
III	66.00 -	Imminent danger - Probable overtopping
IV		Failure

TABLE 1.--EMERGENCY OPERATIONS

	St. Johns River Water Management District				Lake County	
	Emergency Action Team					
Emergency Classification	Executive Director's Office	Division of Engineering	Department of Operations	Burrell Lock Tender	Department of Emergency Management	Sheriff's Department
EC-I		Assessment		Monitor & Report		
EC-II 65.00-65.99	Interagency coordination	Assessment & coordination	Assessment mobilization	Monitor & report Issue alert Prepare for sandbagging	Preparation standby	
EC-III 66.00-	Interagency coordination	Assessment & coordination	Sandbagging	Monitor & report Issue alert	Begin evacuation	
EC-IV (Failure)	Interagency coordination	Assessment & coordination Advise regarding repair	Protection of SJRWMD property & public Standby for repairs	Monitor & report	Services for evacuees	
Post Failure	Authorize emergency repairs	Coordinate repair work Damage assessment	Repair Damage assessment			

IV. IMPLEMENTATION

Communications and responsibilities within the SJRWMD throughout the implementation of the EAP will generally follow the normal organizational scheme. An Emergency Action Team (EAT) will be established to monitor, assess, coordinate and report throughout the emergency period.

The primary duties of each division within SJRWMD at various Emergency Classifications are summarized in Table 1. Further description of these follows. Initiation of the emergency measures will be guided by the emergency classifications. Appropriate consideration of current hydrologic conditions and short range meteorologic forecasts should be made.

Executive Director's Office

The office of Executive Director will be responsible for overseeing the overall District operations. The office will be responsible for coordinating with other agencies or entities should they become involved. Should the emergency condition progress to EC-IV, the Executive Director will be responsible for making authorization with other agencies and/or private concerns needed to assist in prevention or repair works. Requests from the District for assistance and reporting to the State Division of Disaster Preparedness will be through the Executive Director.

Division of Engineering

The Director of the Division of Engineering and designated engineering staff will be members of the Emergency

Action Team. Engineering will be responsible for assessing conditions throughout the emergency to provide data and recommendations to the EAT regarding implementation of the various emergency measures. Engineering will be responsible for advising the EAT on matters regarding preventative and repair measures for structures and coordinating those operations. Engineering will have primary responsibility for conducting damage assessments and preparing reports.

Department of Operations

The Director of Department of Operations will be responsible for carrying out the actual emergency measures provided by the EAP and the EAT. He will be responsible for maintaining in non-emergency times the warning systems and materials stockpiled for emergency operations. He will be responsible for mobilizing and overseeing the operations staff as necessary to best implement the preventative and repair measures. He will assist Engineering in damage assessment and reporting.

Lock Tenders (Moss Bluff and Apopka-Beauclair)

As timely monitoring and reporting are essential to implementation of emergency operations, Lock Tenders will remain accessible at their stations to report rainfall and water levels.

Lock Tender (Burrell)

The Burrell Lock Tender will remain accessible to report rainfall and water levels. Upon directive from the EAT, he will sound the emergency warning to alert residents in the vicinity of Burrell Dam. Second priority responsibilities include assistance with preventative measures such as sandbagging and alerting local officials as requested.

Other Agencies

A storm event of the magnitude required for implementation of this EAP will probably result in local and possibly state emergency agencies being called into action for problems unrelated to Burrell Dam. The local emergency organization will in any case be responsible to plan, coordinate and oversee the issuance of direct warnings and evacuation of areas classified as hazardous. SJRWMD will maintain and operate a warning signal system adequate to alert those high hazard areas immediately downstream of Burrell Dam. SJRWMD will assist the local emergency agency to as great an extent as possible.

The local emergency agencies which are to be notified are:

1. Lake County Department of Emergency Services
   315 W. Main St.
   Tavares, FL 32778
   Phone (904) 343-2351

2. Lake County Sheriffs Office
   315 W. Main St.
   Tavares, FL 32778
   Emergency Phone (904) 343-2101

Exhibit D is a list of residences within the high hazard area immediately downstream of Burrell Dam. These residences should be given priority in issuance of warnings and in evacuation.

V. ADVANCE PREPARATION

A. Warning System

An automatically activated warning system will be installed to monitor upstream water levels and, at staged levels, alert the lock tender and the public of high water levels. An audible signal will alert the lock tender at water level of 64.0 feet (NGVD). An audible signal will alert persons located within a minimum of 0.5 mile downstream of the dam. The system will have a manual override.

The local emergency agency will be responsible for planning the evacuation procedures, instructing the residents within the range of the signal as to purpose and proper reaction, and overseeing evacuation.

B. Stockpiled Materials

Failure of the earthen dam will be very difficult to quickly repair under the flood conditions. Repair would be expected to be accomplished by driving piling across the breach. It may be desirable or necessary to artificially raise downstream water levels, reducing flow velocities, to accomplish this. Materials which may be required for this include H-piles, steel sheet piles, and large riprap. Heavy equipment possibly required includes pile driver, dozer, and dump trucks. This material need not be stockpiled for this specific purpose. The SJRWMD Department of Operations will maintain a list of contractors available in the area which could supply these materials and equipment.

Materials useful for preventative measures include sandbags. The Department of Operations will maintain a suitable stockpile of sandbags to protect the approximately 500 foot length of Burrell Dam to an elevation of 69.0 feet NGVD to prevent failure of the dam by overtopping.

VI. DAMAGE ASSESSMENT

Fast and accurate assessment of damages is important to prepare reports outlining immediate necessary repairs, other needs, and document damages. Reporting is important when assistance from state or federal agencies is requested (reference 3). The Division of Engineering will be responsible for damage assessment reporting. Department of Operations will assist as much as possible. Other agencies, such as the county engineers office, may provide assistance also.

Assessment will include (in order of priority) damage to:

1. SJRWMD property
2. Contractor work and equipment
3. Utility systems
4. Private property resulting from the dam failure

REFERENCES

1. "Burrell Lock and Dam I.D. No. FL708, St. Johns River Water Management District, Phase I, Inspection Report National Dam Inspection Program", Department of the Army, Jacksonville District Corps of Engineers, Jacksonville, Florida.

2. "Burrell Dam Safety Evaluation", St. Johns River Water Management District, March 1985.

3. "Natural Disaster Plan, State of Florida", Office of the Governor, June 1978.

EXHIBIT D

List of residents in high hazard area

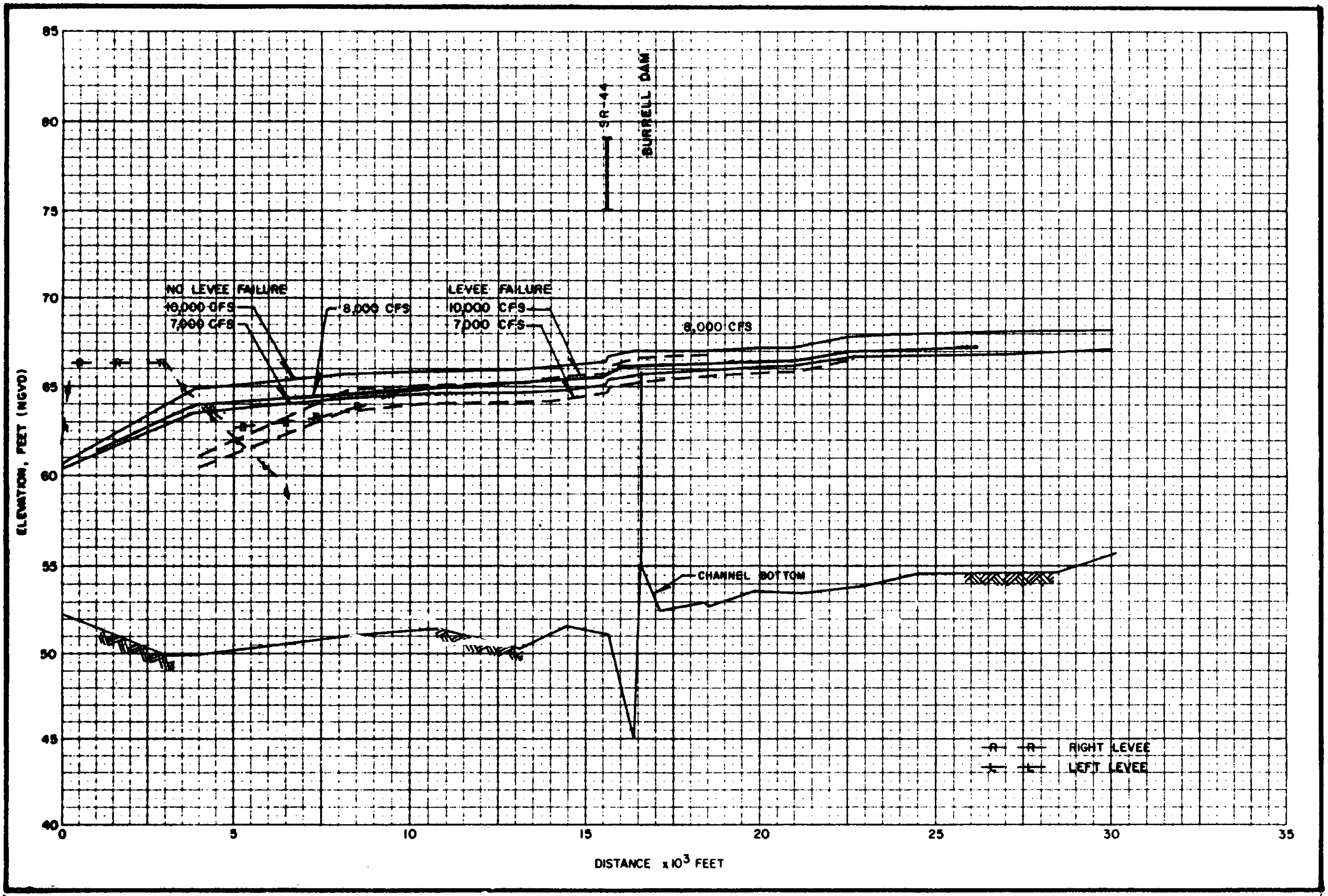

Exhibit 1

HAINES CREEK WATER SURFACE PROFILES

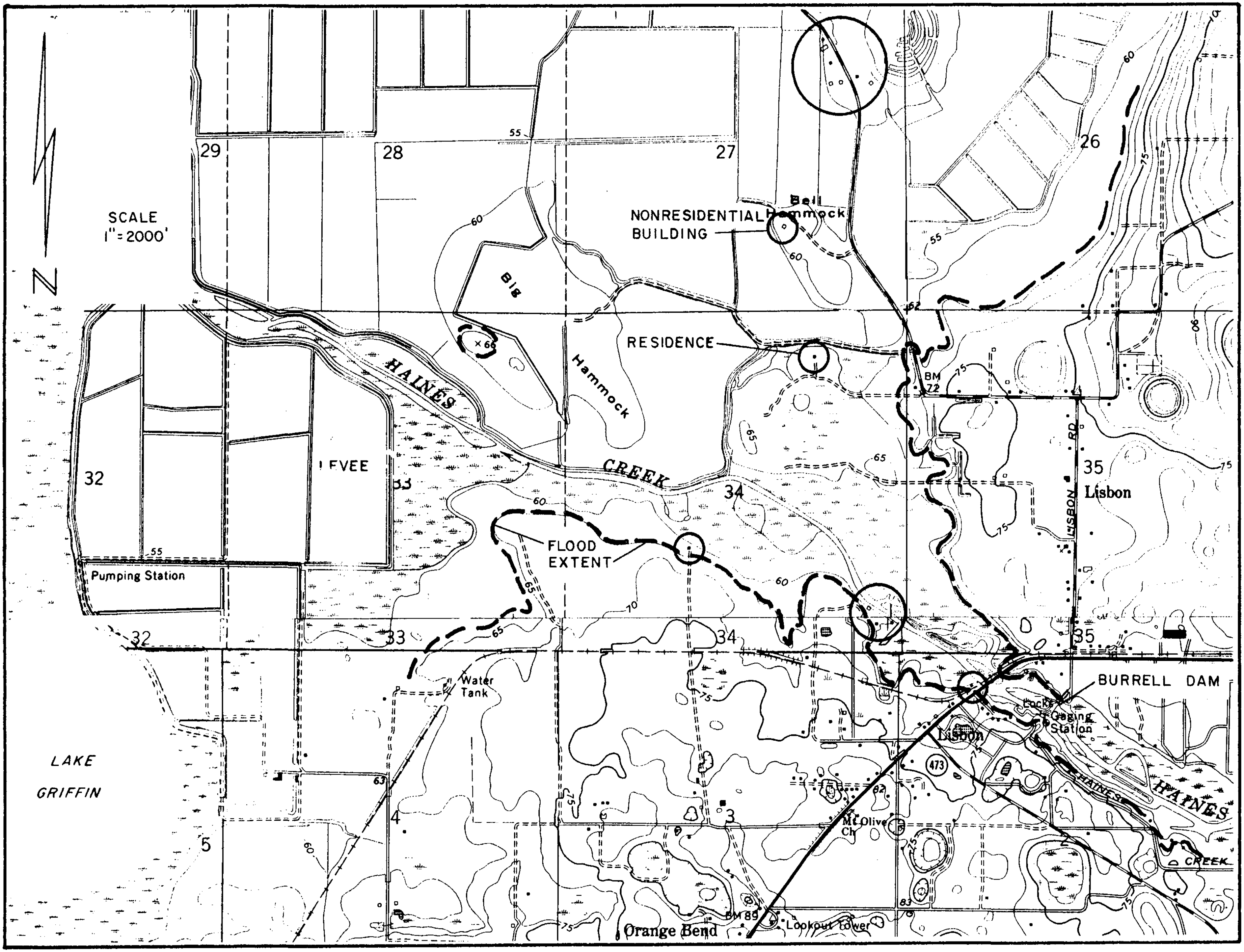

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Exhibit 2

LOWER HAINES CREEK FLOOD LIMITS

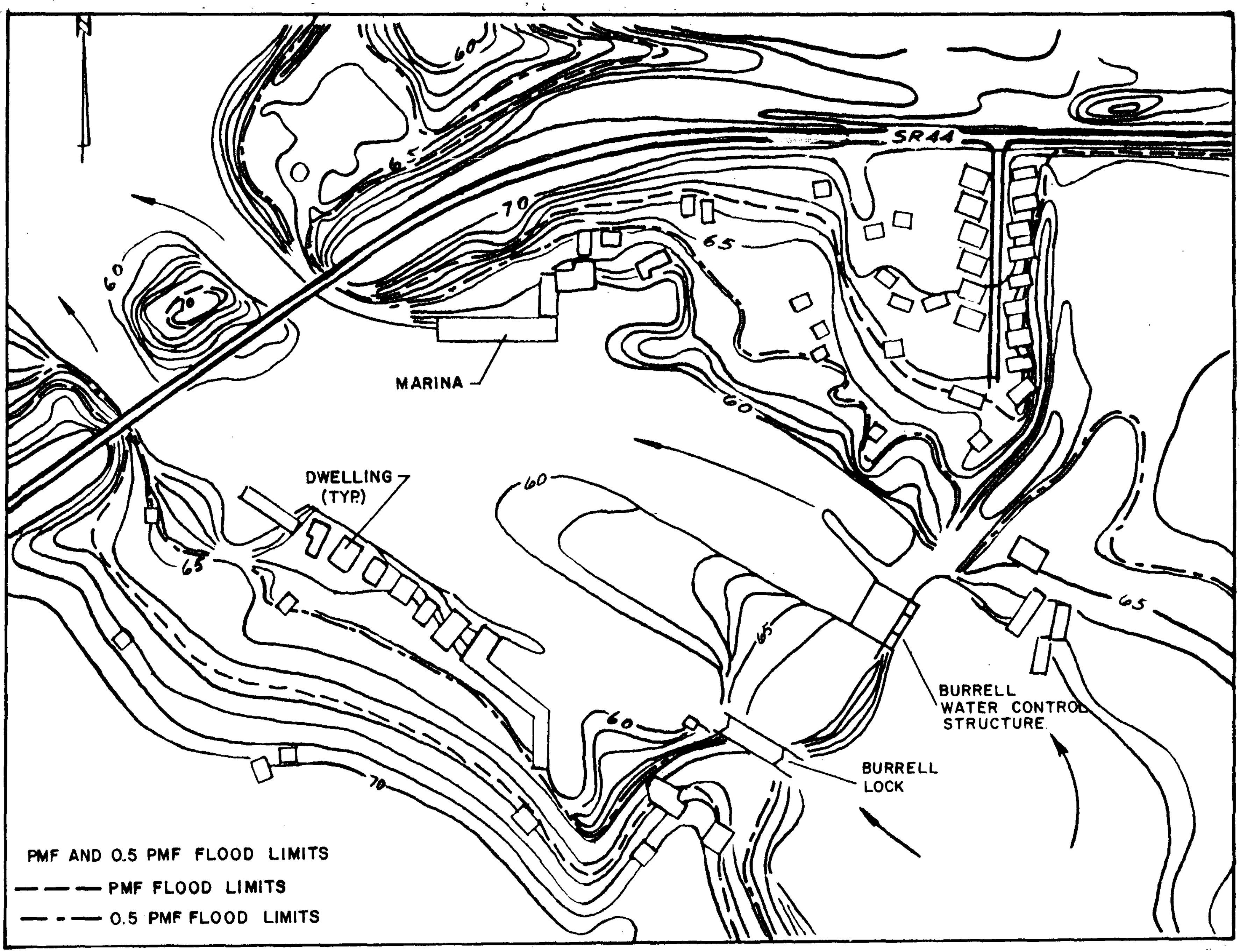

Exhibit 3 Burrell Tailwater Flood Limits

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