AMERICAN SAMOA WATER RESOURCES STUDY

HYDROLOGIC INVESTIGATION OF SURFACE WATER FOR WATER SUPPLY & HYDROPOWER

TUTUILA ISLAND, AMERICAN SAMOA

U.S. ARMY ENGINEER DISTRICT, HONOLULU

HYDROLOGIC INVESTIGATION OF SURFACE WATER
FOR WATER SUPPLY AND HYDROPOWER
TUTUILA ISLAND, AMERICAN SAMOA
FOR
U.S. ARMY CORPS OF ENGINEERS
SEPTEMBER, 1978

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September 18, 1978

U.S. Army Corps of Engineers
Pacific Ocean Division
Building 230, Fort Shafter
Honolulu, Hawaii 96858

Attention: Mr. Kisuk Cheung
Chief, Engineering Division

Gentlemen:

Hydrologic Investigation of Surface
Water for Water Supply and Hydropower
Tutuila Island, American Samoa

We are pleased to present our final report on the water supply and hydropower potential of Tutuila Island, American Samoa, prepared for you under the terms of Contract No. DACW 84-78-C-0013.

The study describes available water resources, and impoundment area characteristics, and assesses the possible use of an impoundment at five separate locations for the dual purposes of water supply and hydropower.

The analysis provided in this report should prove valuable to the Corps of Engineers and others, in any future consideration to meeting electrical power or water supply requirements through surface water impoundment in American Samoa.

It has been a pleasure to prepare this report for you, and we hope that it meets you needs. Please feel free to contact us if you have any questions, or require further information.

Sincerely,

DAMES & MOORE

Eric Will

Eric Will
Chief Planning Engineer
Water Resources Engineering Services

S.K. Djou
Principal-in-Charge

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SUMMARY

- The small, steep drainage basins of Tutuila yield an average annual runoff of about 6 cubic feet per second (cfs) per square mile. This amount is equivalent to about 80 inches of annual runoff, which appears reasonable, considering average rainfall and evapotranspiration.

- All 23 basins delineated are quite similar in topography and shape, with steep, narrow uplands draining to the sea. Of these 23 basins, the six basins with gaged streamflows of up to 18 years of good records, exhibit similar flow patterns. Although unofficial rainfall data collected by the American Samoa government and others indicate that higher elevations receive more rainfall, the existing official data base of two long-term raingaging stations does not warrant dividing the basins into higher and lower sub-areas to estimate yields in more detail.

- The flow patterns of the five basins studied in detail, Nos. 2-Maloata, 6-Leafu, 10-Papa, 15-Maga, and 16-Pago, are such that regulated flows of about 4 cfs per square mile can be obtained with reservoir storage. Based on mass-curve analysis of the gaged basins, storages of about 300 acre-feet per cfs of regulated flow are required (see Table 3 for further detail).

- Storage sites are small, of low capacity, and need a relatively high embankment to achieve required storage. To achieve maximum storage, a site was selected in the lower reaches of each basin. Because of the limited storage volume available, embankments of more than 100 feet high are required in each case.

- Run of the river hydropower development is generally not feasible due to extremely low or intermittent stream flows.

- Even with the maximization of storage, hydropower potential is very small and unattractive when compared to the power and energy demands of the island. The best of the five basins studied, No. 6-Leafu, would only yield about 30 KW of continuous power, and about 260,000 KWh of annual energy. This is less than one-half of 1 percent of the island's 1977 energy generation.

- The potential for surface water development is more attractive. Basin 6-Leafu, with a regulated flow of about 3.3 mgd, could supply about 28 percent of the estimated average water demand in the Year 2000. The other basins could also supply reasonable portions of future water needs. Although no evaluation of reservoir construction, pumping, treatment, or distribution costs for water supply was made in this report; from a purely supply standpoint, it would seem that surface storage for future water supply development is worthy of more detailed investigation.

- Development of the selected basins, as described herein, may not be appropriate at this time. For this reason, curves of storage, elevation, and regulated flow, are shown in Plates 16 and 22. With these curves, it is possible to select lower rates of flow and find the required storage that may be in keeping with more immediate needs. Conversely, it is possible to determine the rate of flow that will result from construction of reservoirs of a less than the selected sizes.

INTRODUCTION

AUTHORITY

This study has been undertaken as a part of the American Samoa Water Resources Study (ASWRS), as authorized by Section 143 of the Water Resources Development Act of 1976, Public Law 94-587. The goal of ASWRS is to develop a comprehensive water resources plan for the waters for American Samoa, including flood plain management, hydroelectric power generation, regional water and wastewater management facilities, water quality, water-related land recreation, fish and wildlife propagation, navigation, and flood control.

In response to expressed concern on the part of the U.S. Congress, certain federal agencies, and local officials, the U.S. Army Engineer District Honolulu, contracted with Dames & Moore, consultants in the environmental and applied earth sciences, to conduct this investigation under the terms of Contract No. DACW 84-78-C-0013, executed 19 May 1978.

PURPOSE

The basic purpose of this study is to identify the drainage basins on Tutuila Island, American Samoa, with the highest potential for water supply and hydropower development and to estimate these potentials for at least five selected basins. This report will then serve as a source of information for interested federal and local agencies.

The study is a reconnaissance-level investigation, utilizing existing data, records, and previous reports. No field survey was undertaken as a part of this study; however, extensive knowledge of American Samoa from on-island experience of the Dames & Moore staff was utilized in selecting the likely candidate basins.

STUDY AREA

The island of Tutuila is the largest and most populous of the seven principal islands of American Samoa; its location is shown on Plate 1. The island is about 18 miles long, and varies in width from 1 to 6 miles; total land area is about 53 square miles. Topography is rugged, as in most Pacific volcanic islands; about 70 percent of Tutuila's land area has slopes greater than 30°.

While rainfall appears abundant, continued water shortages have been experienced in the territory since 1960. Subsequently, tens of millions of dollars have been spent in capital improvements to the water systems, on both ground water and surface water. The current American Samoa Government (ASG) water systems improvement program is directed toward further development of ground water supplies as the primary source of water for the central government system (URS, 1978). While ground water does appear to be the more desirable source, possible limitations to its development and the attractive advantages of a surface water reservoir with a gravity-fed distribution system have led some engineers and laymen alike to favor the development of more surface water sources.

Similarly, chronic operational problems with the island's diesel-powered electric generators, the likely prospect of increasing fuel and operational costs, and the steep topography of the island have led many to believe that hydropower would be a more reliable source of the island's electrical energy, if sufficient potential exists.

PREVIOUS INVESTIGATIONS

Several previous studies and reports on water supply and surface water availability in American Samoa were used as data sources in this study. They are listed in the bibliography.

In addition, unpublished United States Geological Survey (U.S.G.S.) information was reviewed. Several excellent published papers on hydropower evaluation were also used for guidance, and are referenced in the bibliography.

CLIMATE AND HYDROLOGY

The climate of Tutuila is tropical, with wet and dry seasons. During the wet or summer period, from November through April, the island lies in the inter-tropical convergence zone, with weak and variable winds, high temperatures, rainfall, and high humidity. In the dry winter seasons, from May through October, the climate is influenced by the southeasterly tradewinds, with slightly lower temperatures and less rain.

Precipitation results from the upward deflection of the trades as they pass over the island, as well as from major storms and isolated thunderstorms. The annual precipitation varies with location and elevation; the Pago Pago airport at sea level, receives an average of 125 inches per year, while nearby Mount Alava, at Elevation 1,600 feet, receives more than 250 inches. Seasonal variation is considerable, and extended dry periods of 2 or 3 months are common. Generally, the driest months are June through September, and the wettest are December through March.

In view of the small catchment areas, steep terrain, and limited storage sites, these wet and dry periods pose problems for water supply and hydropower development.

METHODOLOGY

DRAINAGE BASIN SELECTION

Twenty-three drainage basins on Tutuila were selected to be examined for the dual purpose of water supply and hydropower potential. They are shown on Plate 2.

Preliminary basin evaluation was accomplished by tabulating drainage area, years of record for gaged basins, and the lowest 7-day flow over a 10-year interval (7-day Q10), from unpublished U.S.G.S. data. Seven-day Q10 was chosen as an initial indication of flow reliability. On the basis of drainage area and 7-day Q10 rankings, Basins 2-Maloata, 6-Leafu, 7-Aasu, 8-Leaveave, and 13-Fagaalu, were selected. However, in order to provide a better east-west distribution of the final basins to be selected, and to provide more basins where gravity water supply could supply the population centers on the southern shore of Tutuila, the northern drainage Basins 7-Aasu, and 8-Leaveave, and the already developed Basin 13-Fagaalu, were discarded. The final basins selected were 2-Maloata, 6 Leafu, and 10-Papa, in the Western District, and 15-Maga, and 16-Pago, in the Eastern District.

The basin number, name, and characteristics of all 23 basins are given on Table 1. The drainage areas of the delineated basins were computed by planimetry from the U.S.G.S. topographic map of Tutuila. Identification numbers for U.S.G.S. partial-record and discontinued streamgaging stations are shown, as well as the period of record for currently active stations. U.S.G.S.-recorded average yield and unit yield, in cfs per square mile, are shown for the gaged basins. Values for 7-day Q10, from unpublished U.S.G.S. data, are also shown.

Estimated average annual yields, in cfs and acre-feet, are shown for each basin. These values were computed by multiplying the planimetered drainage area by an average value of 6 cfs per square mile. This value is the approximate average of the 83 station-years of data available from the gaged basins.

If an island-wide network of rain gages is established in the future, and if more basins are gaged for streamflow so that isohyetal maps and better runoff data can be obtained, this approximate estimate of average annual yield can be revised to accommodate differences in estimated runoff between drainage basins, and by different elevations within the same basin. For now, however, the data available does not warrant further manipulation, especially at this level of investigation.

The estimated average yields range from over 5,000 acre-feet for the largest basin (8-Leaveave) to 900 for the smallest one (21-Lepa). The last two columns in the table show the initial basins selected and the final basins selected, following the procedure previously discussed.

FLOW DURATION CURVE DEVELOPMENT

To develop flow duration curves for the final five basins selected, curves were developed for a total of ten drainage basins. Six of these basins, Atauloma, Basins 7-Aasu, 11-Leele, 14-Afuelo, 16-Pago, and 19-Alega, have stream gages with 10 to 19 years of records, monitored by U.S.G.S. One basin, 10-Papa, has only 8 years of fair to poor records. The other three, 2-Maloata, 6-Leafu, and 15-Maga, are ungaged. The curves were developed as follows:

First, flow-duration curves for the six gaged streams of Atauloma, 7-Aasu, 11-Leele, 14-Afuelo, 16-Pago, and 19-Alega, were constructed. The data were taken from a U.S.G.S. computer printout, which included a duration table of daily values for all years of record. This table shows values of discharge in cubic feet per second (cfs) with corresponding exceedance percentages. These values were plotted directly on a flow-duration curve of flow versus exceedance percentage. The six curves for the gaged basins are shown on Plates 3 through 8.

Next, the six curves were plotted together for comparison. The plots are shown on Plate 9. As shown, the curve shapes are quite similar. From this composite, and the annual average flow (AAF) for the gaged basins also given in the U.S.G.S. data, parametric duration curves were plotted. These curves show average daily flow versus AAF values as shown on Plate 10 (see Heitz 1978 for a detailed description of procedure). This graph has daily flow plotted against AAF. Values of seven different exceedance percentages were plotted for each of the six streams, and the best-fit curve was developed for each of the exceedance values. With this graph and a value of AAF, flow duration curves of ungaged streams can be constructed.

Finally, curves for the remaining basins were prepared from the parametric curves and estimates of AAF.

The values of AAF are most readily determined from streamflow data or from an isophyetal map. However, no such map has been developed for American Samoa, as there are only two official long-term rain gages on the island. The estimated AAF values from Table 1 were used for this portion and are listed below.

BASIN NO.	AAF, CFS
2, Maloata	6.2
6, Leafu	6.9
10, Papa	5.1
15, Maga	3.7

These AAF values were then used to enter the parametric duration curves on Plate 10. Values of the seven exceedance percentages were read from the curves for each of the three ungaged basins. The resultant flow duration curves for Basins 2-Maloata, 6-Leafu, 10-Papa, and 15-Maga, are shown on Plates 11, 12, 13, and 14.

Examination of the composite flow-duration curve on Plate 9 shows a marked similarity of flow pattern in all the gaged basins. This similarity inspires confidence in employing the parametric duration curve and annual flow to prepare flow-duration curves for the ungaged basins. It would appear from the curves that there is little variation in flow pattern from basin to basin, throughout the island, at least as far as can be deduced from the data available.

MASS CURVE ANALYSIS AND STORAGE-YIELD PROBABILITY

A flow-duration curve will give a good idea of the persistence of streamflow, and of the low-flow values that may be expected during dry periods. Low-flow frequency tables or graphs are also helpful, especially when considering direct diversion, or "run of the river" development without storage.

In the small drainage basins on Tutuila, however, low-flow values approach zero in most cases, and storage would be required for any reasonable development for water supply or hydropower. For storage evaluation, then, a mass curve analysis is required.

There are several ways of analyzing storage requirements with mass-curve techniques. The first method, sometimes called a Rippl diagram, is a cumulative plot of flow values for the period of record. Its advantage is that it shows the effect of carryover storage, and portrays more realistically how the reservoir would actually operate. Its principal weakness is that little can be said about the probability of yield because of the lack of certainty that the historical record will occur again in the same way.

The second method (Riggs and others, 1971), involves a way to estimate the probability of the storage reservoir being able to yield a selected draft rate, but does so by calculating the storage required to refill the reservoir each year, thereby sacrificing evaluation of the carryover storage.

A third method, probability routing, is based on a distribution of annual inflows and involves calculating the probability of the reservoir being empty at year-end under a given draft rate. This method combines the advantages of the first and second methods, but only uses annual values, and is expensive and cumbersome to use.

The first method was used to evaluate the probable flow persistence with storage in this study because it gives a better idea of how the reservoir would actually operate. Another consideration was that it is not very meaningful to compute the 50 and 100-year probabilities, required in the second method, with only 18 years of record. In addition to being cumbersome, the third method was not used because of the limited years of record available.

Plot of Annual Values - Annual values for each of the six stations with significant years of record were taken from U.S.G.S. records, accumulated, and plotted against time. The plot of these curves for the six stations are shown on Plate 15. From this plot, it was apparent that all six streams exhibit similar annual flow patterns, which would be expected from the similarity in shape of their flow-duration curves. Also, a relatively dry period from 1971 through 1974 can be noted. The rest of the years recorded exhibited more normal flows, so the period of 1971 through 1975 was utilized, to ensure that the selected draft rates would permit recovery after each dry period.

The selected draft rates appear as the regulated flows of 1 through 5 cfs in Plate 16.

Plot of Monthly Values - Monthly values for each stream-gaging station, taken from the U.S.G.S. records, were accumulated and plotted for each of the six stations. The plotted data indicated that 1974 was the more severe dry period.

Because of the five basins to be analyzed, only Basin 16-Pago, has records of suitable length for analysis, the next step was to select one or more sets of monthly values as representative of the ungaged basins. After examining the monthly plots of the six stations with long-term records, Atauloma and Basin 7-Aasu, both with good records, were considered further. Basin 14-Afuelo, was discarded because of only fair records. Data from Basin 11-Leele, was discarded because of the relatively short period of record of 10 years. Basin 19-Alega, was also used for guidance. Comparison of Basin 7-Aasu, one of the largest basins, and Atauloma, a small one, showed little difference in flow pattern, and when adjusted for basin size, were virtually identical. The six basins with long record flow showed an estimated average yield of 6 cfs per square mile. Therefore, these basins, and the estimated average yield of 6 cfs per square mile of basin area, were used to develop monthly flow data for Basins 2-Maloata, 6-Leafu, 10-Papa, and 15-Maga.

Gaging Station Data - The first step in the analysis is to examine available stream-flow records. A summary of gaging station data is given in Table 2. As shown, seven U.S.G.S. stream-gaging stations are listed, with their name, U.S.G.S. number, drainage area, average discharge, and period of record. Also, the basin number, corresponding to the basin map on Plate 2, is given for all stations except Atauloma, which was not delineated as one of the 23 basins to be considered in this study.

As noted in Table 2, two of the stream gages, 10-Papa, and 11-Leele, have been discontinued, and have shorter periods of record than the rest. Also, it is noted that 10-Papa, has records of fair to poor quality. For these reasons, the records from Basins 10-Papa, and 11-Leele, were discarded, and the analysis was based on the remaining five sets of records. These five sets of flow data, plus the flow data from Basin 16-Pago, were then accumulated and plotted in mass-curve format.

It is of interest to note that the flow rates for Basins 15-Maga, and 16-Pago, were almost exactly the same, exhibiting but little difference in pattern and magnitude. These two basins are virtually the same size, but on opposite sides of Pioa Mountain. Basin 16-Pago had its own streamflow records, while the ungaged Basin 15-Maga values were obtained by correlation from gaged basins to the west.

Based on three preliminary findings, it appears that the basins on Tutuila are very similar in flow pattern, irrespective of location or orientation, and until more data is gathered, flows and yields can be based on drainage basin size. Thus, basin size, and the estimated average yield of 6 cfs per square mile can be used, with caution, as a crude method of estimating yield from any of the other drainage basins on Tutuila.

Required Storage - Values of required storage to sustain different rates of regulated flow through the 1974 dry period were determined graphically from the mass curve plot for each basin. The maximum draft rate in each case was a rate that would permit refilling in 1975. With only 19 years of record and two dry periods for analysis, it must be noted that these maximum values should be used with caution, as considerably more storage may be required to sustain these draft rates through drier periods in the future. The draft, or regulated flow, and required storages are listed in Table 3.

As shown in Table 3 and Plate 16, Basin 6-Leafu, the largest, will yield a regulated flow of 5 cfs, about 70 percent of it long-term average flow, with about 1,650 acre-feet of storage. Basins 2-Maloata, 10-Papa, and 15-Maga, are smaller in size, and hence have proportionately lower sustainable regulated flows.

Basin 16-Pago, however, is somewhat different. Although its flow pattern is very similar to the other basins, as previously noted, it did not receive as much rainfall in mid-1975, and therefore, by the criteria of permitting refilling in the relatively dry year of 1975, cannot sustain as high a draft rate, in proportion to its size, as the other basins do. It is for this reason that the Basin 16 curve, shown on Plate 16, is shaped differently than the others.

STORAGE SITES SELECTION

In 1971, large-scale topographic maps for the entire island, 1 inch to 200 feet, were prepared by the American Samoa Government Public Works Department. These maps were used to select the most suitable storage site in each basin.

As noted previously, the basins on Tutuila are characteristically small and steep; few storage sites are available. Nevertheless, a site was selected for each basin, as far downstream as possible, to provide maximum reservoir storage capacity. Upstream reaches of each basin were examined as well, to see whether any sites might exist in the valleys at higher elevations, so that water supply by gravity could be more easily accomplished. Unfortunately, no upstream sites of storage size sufficient to sustain the selected draft rate were found, and the lower downstream site was used in each case.

At the location which appeared most suitable in each of the five basins, an earth embankment was sketched in. These preliminary layouts are shown on Plates 16, 17, 18, 19, and 20. The embankments are shown with 20-foot wide crests and slopes of 3 horizontal to 1 vertical, both upstream and downstream.

As can be seen from the plates, the embankment itself occupies a considerable portion of the storage volume in each reservoir. This fact was taken into account by planimetering around the embankment at each site in the measuring and computing of the elevation-storage relationships, shown for each site on Plate 22, Storage Volumes.

As shown on Plate 22, Basins 6-Leafu, and 10-Papa, have the best storage characteristics; more than 2,500 acre-feet of storage could be obtained at either site with an embankment 150 feet high (200 feet above mean sea level). Basins 2-Maloata, 15-Maga, and 16-Pago, are less desirable for storage since only about 1,500 acre-feet could be obtained with an embankment of the same height.

This very preliminary storage evaluation was conducted on the basis of topography only, as shown on the large-scale maps. Foundation conditions, availability of construction materials, land acquisition, sediment problems, and all the other factors involved in damsite selection were not considered at this time.

CONCLUSIONS

HYDROPOWER POTENTIAL

Examination of the storage-regulated flow curves and the storage-elevation curves given on Plates 16 and 22 permits computing a rough estimate of the hydropower potential in each basin. As shown in Table 3, Basin 6-Leafu is the most efficient storage site and will yield about 5 cfs of regulated flow with about 1,650 acre-feet of storage.

If an embankment were to be built in Basin 6-Leafu, to Elevation 180, about 1,650 acre-feet of live storage could be provided between Elevations 100 and 180. Assuming an average pool of Elevation 150, and a tailwater at Elevation 50, 100 feet of gross head would be available. At 70 percent overall efficiency, and using the formula:

$$KW = \frac{QH}{11.8}(e)$$

where

	KW	=	kilowatts generated
	Q	=	flow in cfs
	H	=	available head
	e	=	efficiency,
	11.8	=	engineering constant,

about 30 KW of continuous power would be generated.

This procedure was used to estimate corresponding estimates of hydropower potential for each of the other four basins. Table 4 lists the comparable results for all five basins. Comparing the values from Table 4 with the amount of power and energy generated on Tutuila, we find that even by assuming a 25 percent plant factor in Basin 6-Leafu, and installing 120 KW of capacity, only about 1 percent would be added to the system capacity.

From a brief review of the drainage basin characteristics presented in Table 1, it is unlikely that any of the other basins could contribute significantly more hydropower than the five basins studied. The combined annual energy contribution of the five basins studied would likewise be small. The total contribution of all five basins, about 972,000 KWh, is only about 2 percent of last year's gross generation of 61,963,700 KWh (OSI, 1977).

WATER SUPPLY POTENTIAL

A recent study prepared in August 1978 (URS, 1978), provides estimates of water supply demand on Tutuila. Table 11-6 of that report estimates the average day water demand in the Year 2000 to be about 11.9 mgd. These average system flow rates are further subdivided into service area values ranging from about 0.1 mgd to over 1.7 mgd. Even without detailed examination of the service areas and distribution systems, it would appear that the quantities of water from the five basins could provide for a substantial portion of this demand. Table 5 shows the same storage and regulated flow values for each basin, from Table 4, but expressed in water-supply units of million gallon (mg) and million gallons per day (mgd).

As shown in Table 5, each basin would yield more than 1 mgd, with the largest, Basin 6-Leafu, yielding 3.3 mgd if the required storage were provided. The total of 12.1 mgd shows that all five basins together could provide all of Tutuila's estimated water demand in the Year 2000.

There is much more to evaluating Tutuila's water supply situation than the preliminary sizing of a few catchments (see URS, 1978 for a complete discussion). Based on the findings of this preliminary investigation however, estimates show that surface water supplies are available in reasonable quantities for future development.

TABLE I - DRAINAGE BASIN CHARACTERISTICS

Basin Number	Basin Name	Drainage Area Sq. Mi. (1)	U.S.G.S. Station Number	Period of Record, Yrs.	Recorded Average Yield, CFS (6)	Recorded CFS/sq.mi. (7)	7-Day Q_{10} (8)	Estimated Average Annual Yield (9)		Initial Selection	Final Selection
								CFS	Acre-ft		
1	Unnamed	0.36	none				none	2.2	1,500		
2	Maloata	1.03	9250 (4)				0.48	6.2	4,500	*	*
3	Matavai	0.28	9240 (4)				0.06	1.7	1,200		
4	Vailolo	1.13	9220 (4) 9230 (4)				0.10	6.8	4,900		
5	Asili	0.64	9320 (4) 9325 (4)				0.40	3.8	2,800		
6	Leafu	1.15	9340 (4)				0.40	6.9	5,000	*	*
7	Aasu	1.00	9205 (2)	18	6.03	5.85	0.33	6.0	4,300	*	
8	Leaveave	1.17	9190 (4)				0.23	7.0	5,100	*	
9	Viapuna	0.37	9330 (5)				0.02	2.2	1,600		
10	Papa	0.85	9442 (3)				0.29	5.1	3,700		*
11	Leele	0.32	9175 (4)	10	1.50	6.52	0.04	1.9	1,400		
12	Vaima	0.92	9505 (4)				0.03	5.5	4,000		
13	Fagaalu	0.79	9490 (4) 9495 (4)				none	4.7	3,400	*	
14	Afuelo	0.31	9480 (2)	19	1.42	5.68	0.07	1.9	1,300		
15	Maga	0.61	9560 (4) 9565 (4)				0.22	3.7	2,600		*
16	Pago	0.69	9120 (2)	18	3.20	5.33	0.29	4.1	3,000		*
17	Tagau	0.70	9100 (4) 9095				none	4.2	3,000		
18	Mulioleval	0.38	9610 (4)				0.14	2.3	1,700		
19	Alega	0.26	9600 (4)	18	1.21	6.37	0.25	1.6	1,100		
20	Vaitolu	0.25	9060 (5)				0.01	1.5	1,100		
21	Lepa	0.21	9050 (4)				0.02	1.3	900		
22	Vailoa	0.31	9000 (5)				0.00	1.9	1,300		
23	Mulivaitele	0.42	9650 (4)				0.03	2.5	1,800		
Unnumbered	Atauloma	0.27	9310 (2)	18	1.42	5.92	0.10	1.6	1,200		

Notes:
(1). By planimetry from USGS $7\frac{1}{2}$' topo, 1963, on basins designated by U.S. Army.
(2). Continuous record, active.
(3). Continuous record, discontinued.
(4). Low-flow, partial record, active.
(5). Low-flow, partial record, discontinued.
(6). From USGS records.
(7). Based on USGS gaged catchment area.
(8). Unpublished USGS data.
(9). Based on planimetered drainage area and recorded average yields from gaged basins.

TABLE 2

GAGING STATION DATA

NAME	USGS NO.	BASIN NO.	GAGED AREA (SQ.MI.)	AVG. DISCH. (CFS)	CFS PER SQ.MI.	PERIOD OF RECORD (YRS)	REMARKS
Aasu	9205	7	1.03	6.03	5.85	18	Records good
Papa	9442	10	0.78	4.18	5.36	8	Records fair to poor - discontinued
Leele	9175	11	0.23	1.50	6.52	10	Discontinued
Afuelo	9480	14	0.25	1.42	6.58	19	Records fair
Pago	9120	16	0.60	3.20	5.33	18	Records good
Alega	9600	19	0.19	1.21	6.32	18	Records good - discontinued
Atauloma	9310	None	0.24	1.42	5.92	18	Records good

TABLE 3

REQUIRED STORAGE VS REGULATED FLOW

BASIN	CFS	GPM	ACRE-FT/YR	MGD	AVERAGE DISCHG. (CFS)	PERCENT OF AVG. DISCHG.	REQUIRED STORAGE ACRE-FT
	REGULATED FLOW						
2-Maloata	4.5	2020	3258	2.9	6.2	73	1600
6-Leafu	5.0	2245	3620	3.3	6.9	72	1650
10-Papa	3.8	1706	2751	2.5	5.1	75	1200
15-Maga	2.7	1212	1955	1.8	3.7	73	1000
16-Pago	2.5	1122	1810	1.6	4.1	61	600

TABLE 4

POWER AND ENERGY POTENTIAL

BASIN	REGULATED FLOW, CFS	REQUIRED STORAGE (ACRE-FT)	CREST ELEV. (FT)	GROSS HEAD (FT)	CONTINUOUS POWER (KW)	ANNUAL ENERGY (KWh)
2-Maloata	4.5	1,600	200	110	29.4	257,000
6-Leafu	5.0	1,650	180	100	29.7	260,000
10-Papa	3.8	1,200	170	100	22.5	197,000
15-Maga	2.7	1,000	185	110	17.6	154,000
16-Pago	2.5	600	185	80	11.9	104,000
				TOTALS	111.1	972,000

TABLE 5

WATER SUPPLY POTENTIAL

BASIN	STORAGE, MG	REGULATED FLOW, MGD
2-Maloata	521	2.9
6-Leafu	544	3.3
10-Papa	396	2.5
15-Maga	330	1.8
16-Pago	198	1.6
TOTALS	1,989	12.1

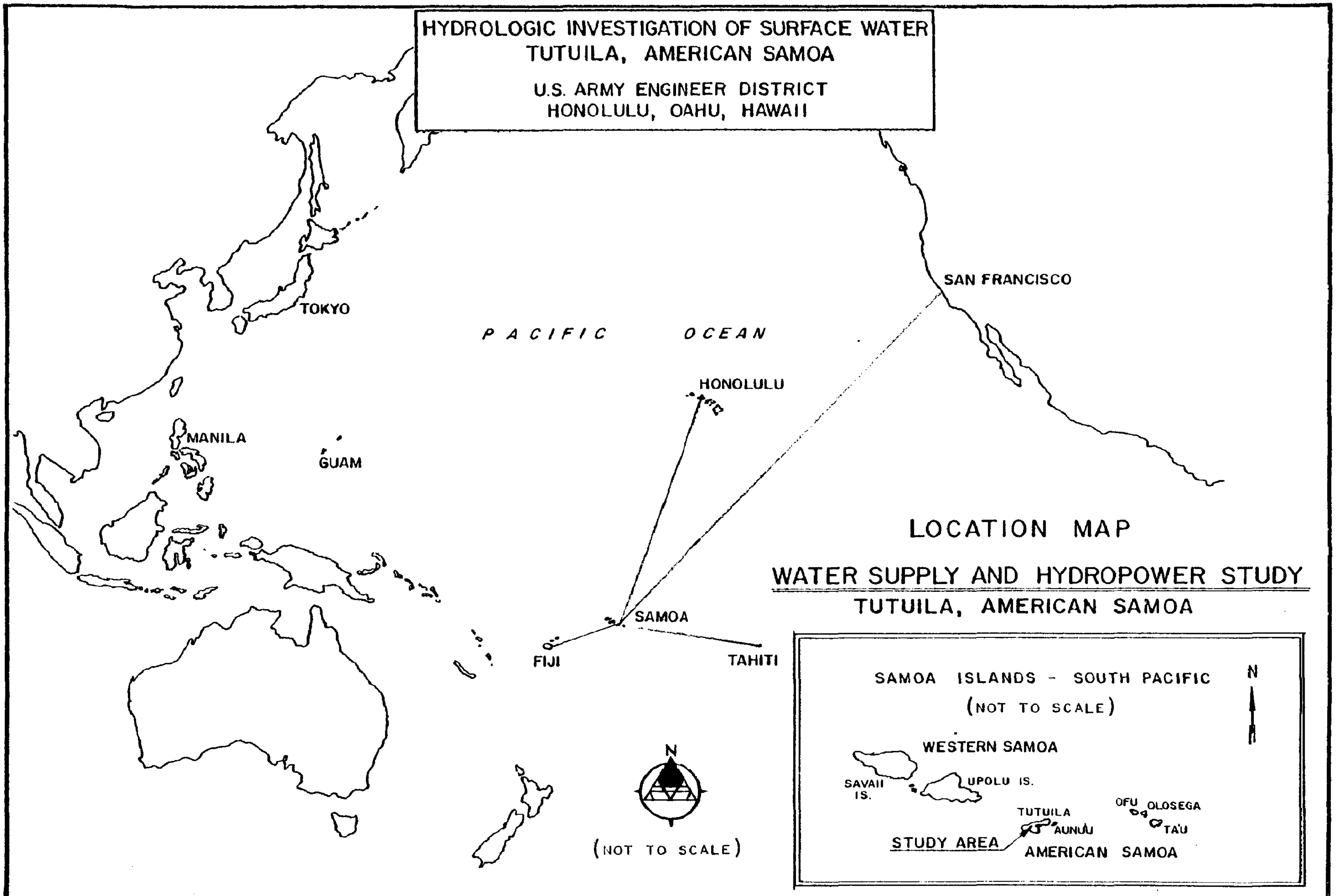
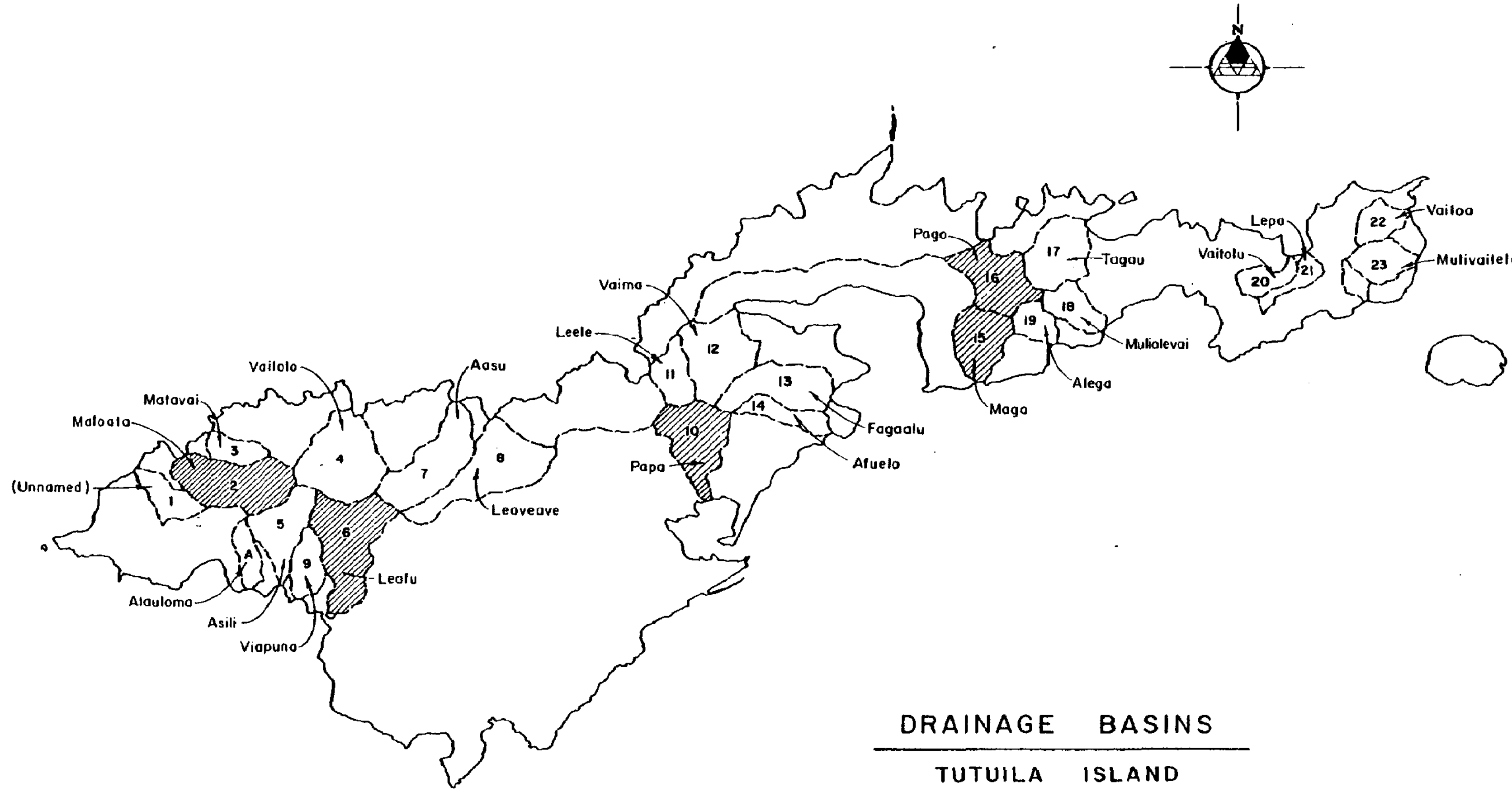

HYDROLOGIC INVESTIGATION OF SURFACE WATER
TUTUILA, AMERICAN SAMOA
U.S. ARMY ENGINEER DISTRICT
HONOLULU, OAHU, HAWAII
TOKYO
MANILA
GUAM
PACIFIC OCEAN
HONOLULU
SAN FRANCISCO
SAMOA
FIJI
TAHITI
N
(NOT TO SCALE)
LOCATION MAP
WATER SUPPLY AND HYDROPOWER STUDY
TUTUILA, AMERICAN SAMOA
SAMOA ISLANDS - SOUTH PACIFIC
(NOT TO SCALE)
N
WESTERN SAMOA
SAVAII IS.
UPOLU IS.
TUTUILA
AUNUU
OFU
OLOSEGA
TAU
STUDY AREA
AMERICAN SAMOA

PLATE 1



DRAINAGE BASINS

TUTUILA ISLAND
AMERICAN SAMOA

2 BASINS SELECTED FOR STUDY

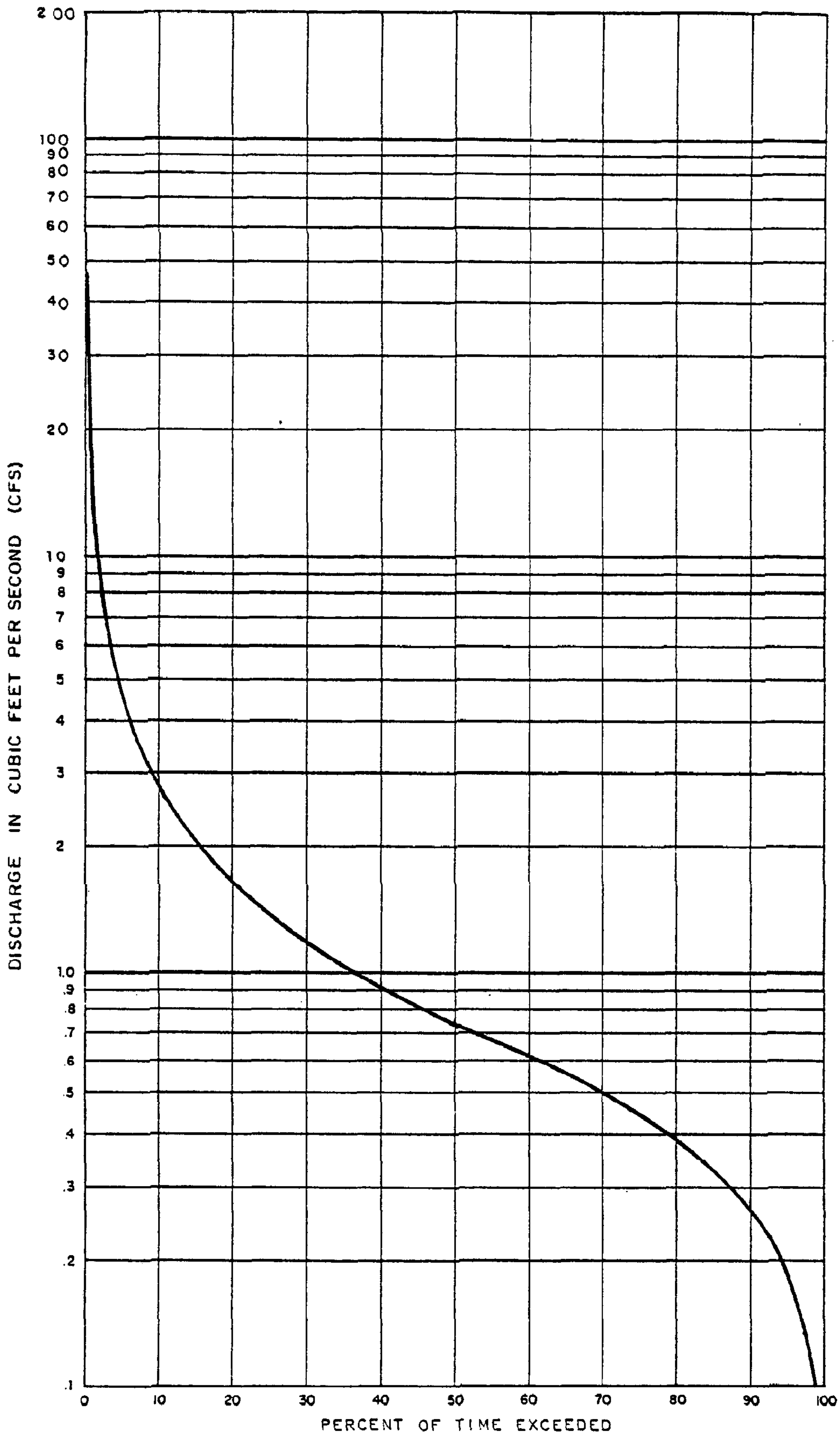
4000 0 2000 4000 8000
SCALE IN FEET

FROM U.S. ENGINEER DISTRICT, HAWAII

HYDROLOGIC INVESTIGATION OF SURFACE WATER
TUTUILA, AMERICAN SAMOA

U.S. ARMY ENGINEER DISTRICT
HONOLULU, OAHU, HAWAII

PLATE 2

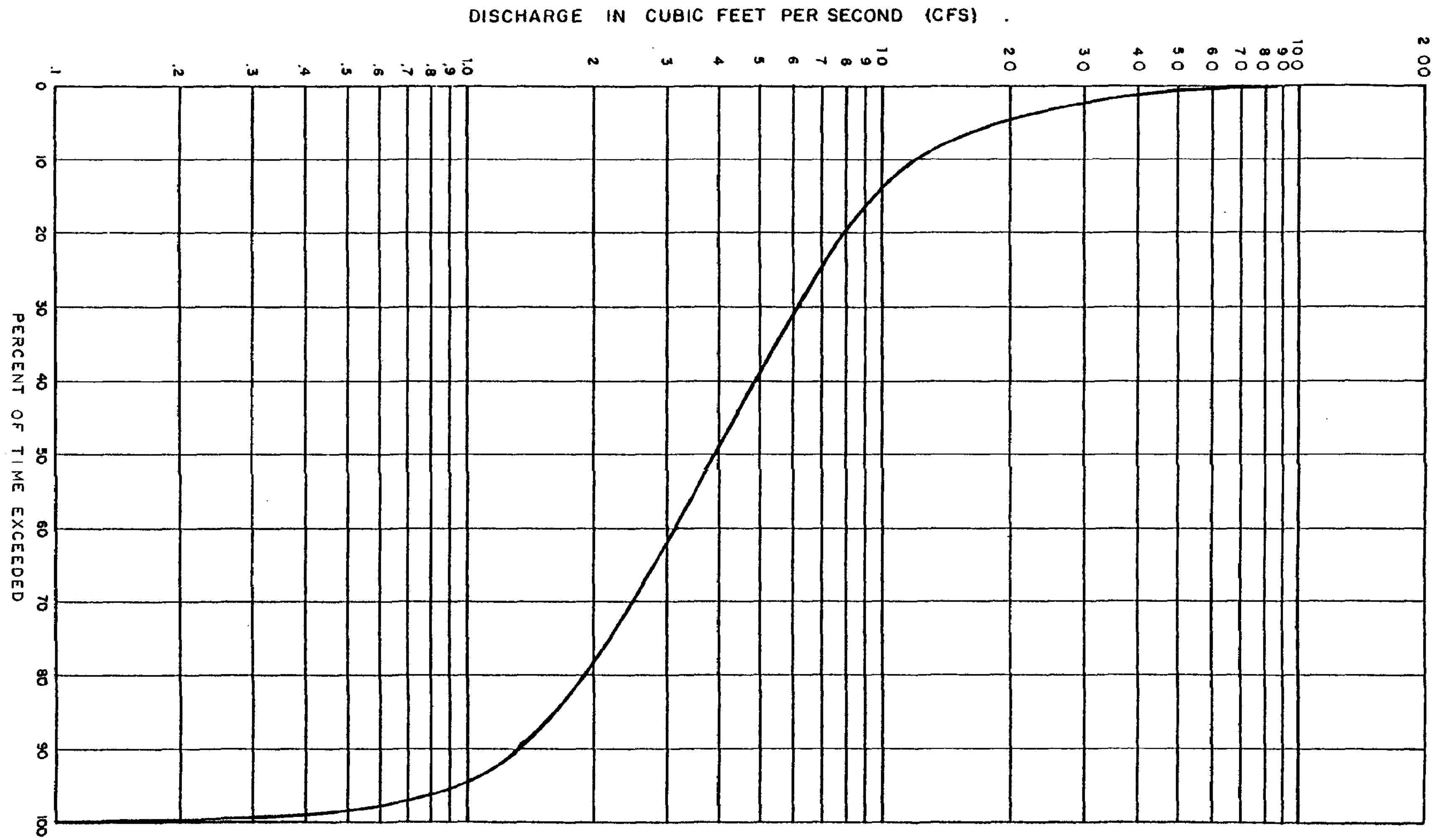


HYDROLOGIC INVESTIGATION OF SURFACE WATER
TUTUILA, AMERICAN SAMOA

U.S. ARMY ENGINEER DISTRICT
HONOLULU, OAHU, HAWAII

FLOW DURATION CURVE

ATAULOMA STREAM AT AFAO, TUTUILA, AMERICAN SAMOA
WEST OF BASIN NUMBER 5 (YEARS OF RECORD: 1960 - 1977)



FLOW DURATION CURVE

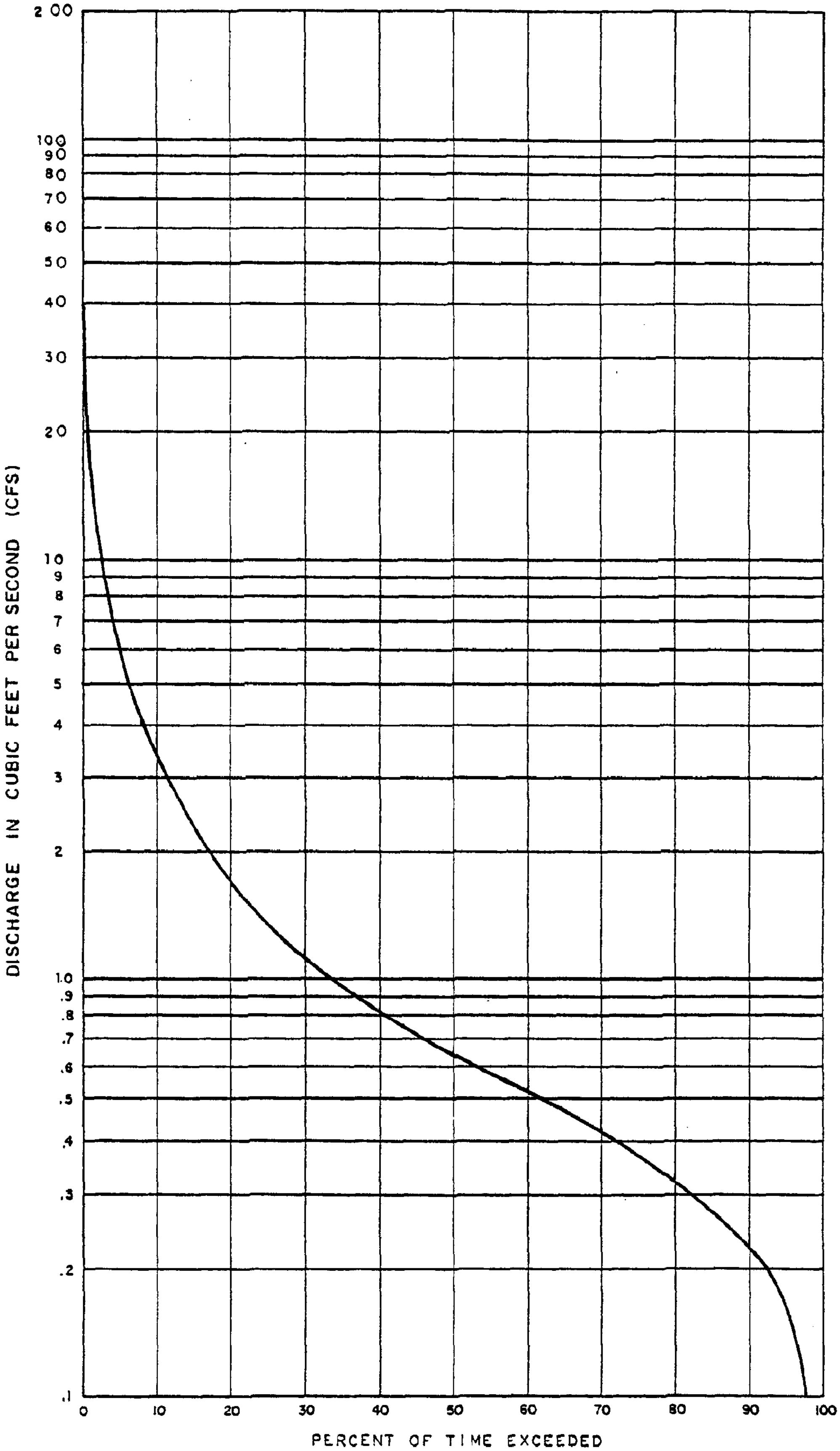
AASU STREAM AT AASU, TUTUILA, AMERICAN SAMOA
BASIN NUMBER 7 (YEARS OF RECORD: 1960 - 1977)

HYDROLOGIC INVESTIGATION OF SURFACE WATER
TUTUILA, AMERICAN SAMOA

U.S. ARMY ENGINEER DISTRICT
HONOLULU, OAHU, HAWAII

HYDROLOGIC INVESTIGATION OF SURFACE WATER
TUTUILA, AMERICAN SAMOA

U.S. ARMY ENGINEER DISTRICT
HONOLULU, OAHU, HAWAII

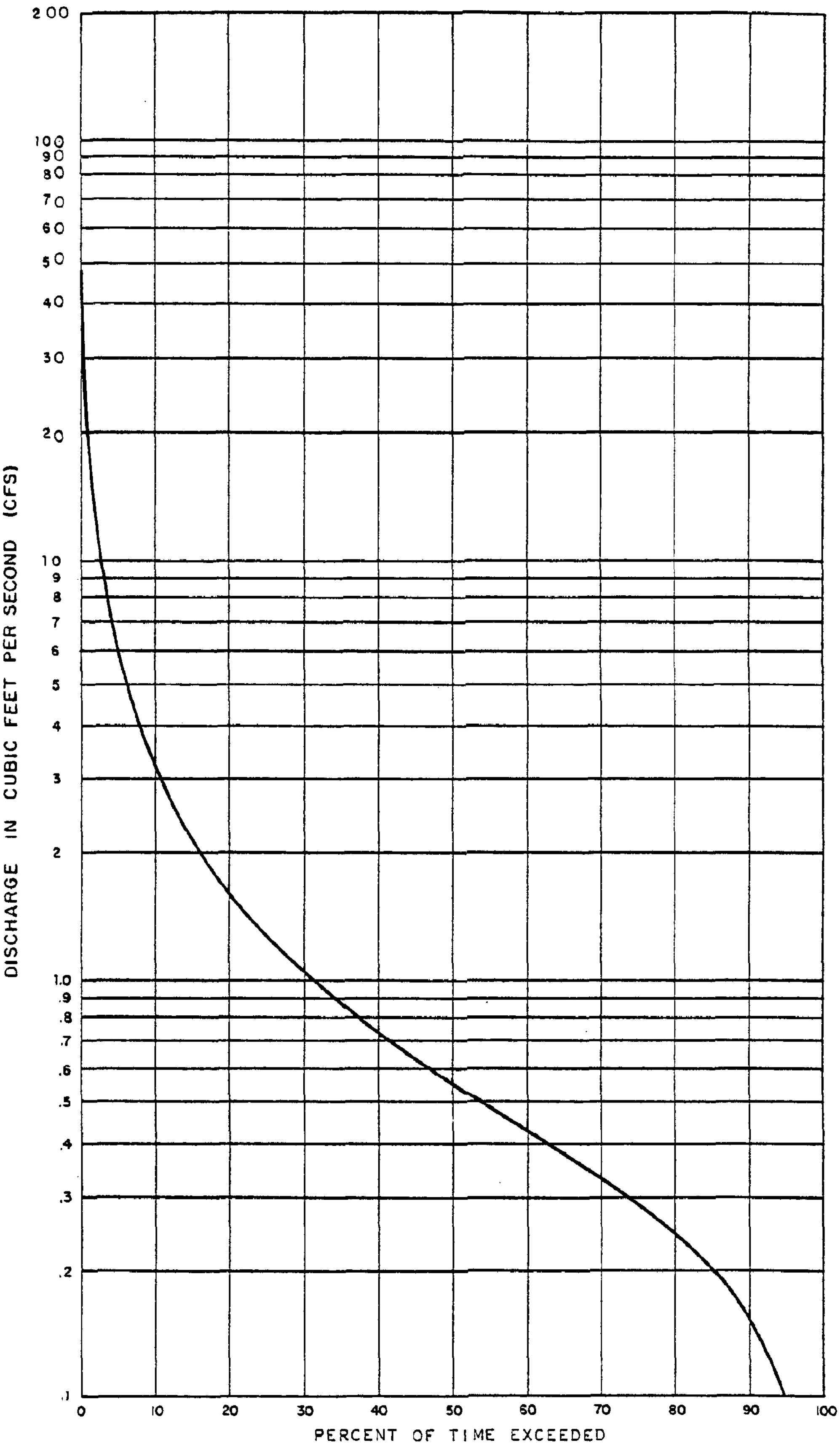


FLOW DURATION CURVE

LEELE STREAM AT MOUTH, AT FAGASA, TUTUILA, AMERICAN SAMOA
BASIN NUMBER 11 (YEARS OF RECORD: 1967 - 1976)

HYDROLOGIC INVESTIGATION OF SURFACE WATER
TUTUILA, AMERICAN SAMOA

U.S. ARMY ENGINEER DISTRICT
HONOLULU, OAHU, HAWAII

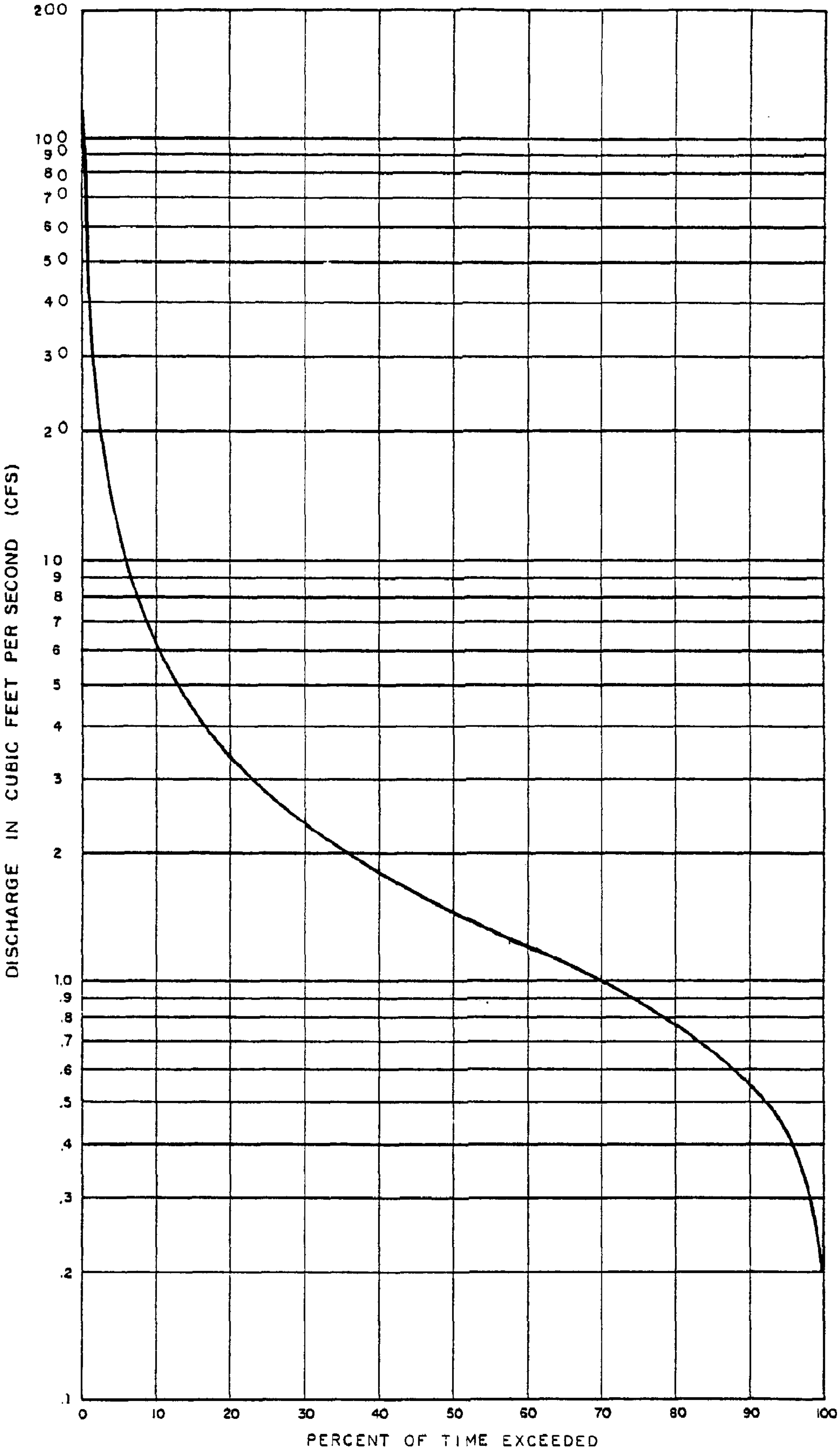


FLOW DURATION CURVE

AFUELO STREAM AT MATUU, TUTUILA, AMERICAN SAMOA
BASIN NUMBER 14 (YEARS OF RECORD: 1959 - 1977)

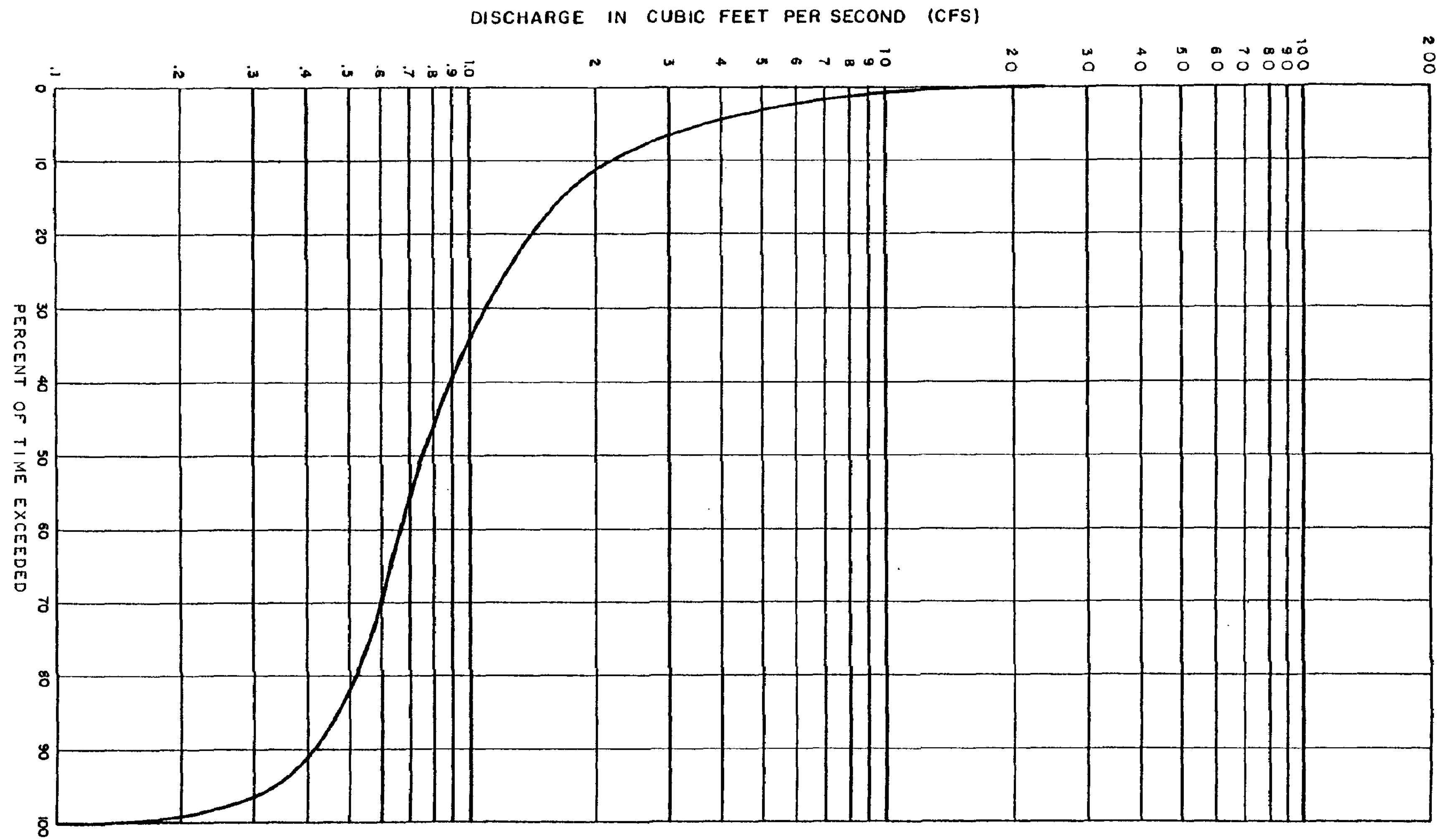
HYDROLOGIC INVESTIGATION OF SURFACE WATER
TUTUILA, AMERICAN SAMOA

U.S. ARMY ENGINEER DISTRICT
HONOLULU, OAHU, HAWAII



FLOW DURATION CURVE

PAGO STREAM AT AFONO, TUTUILA, AMERICAN SAMOA
BASIN NUMBER 16 (YEARS OF RECORD: 1960 - 1977)

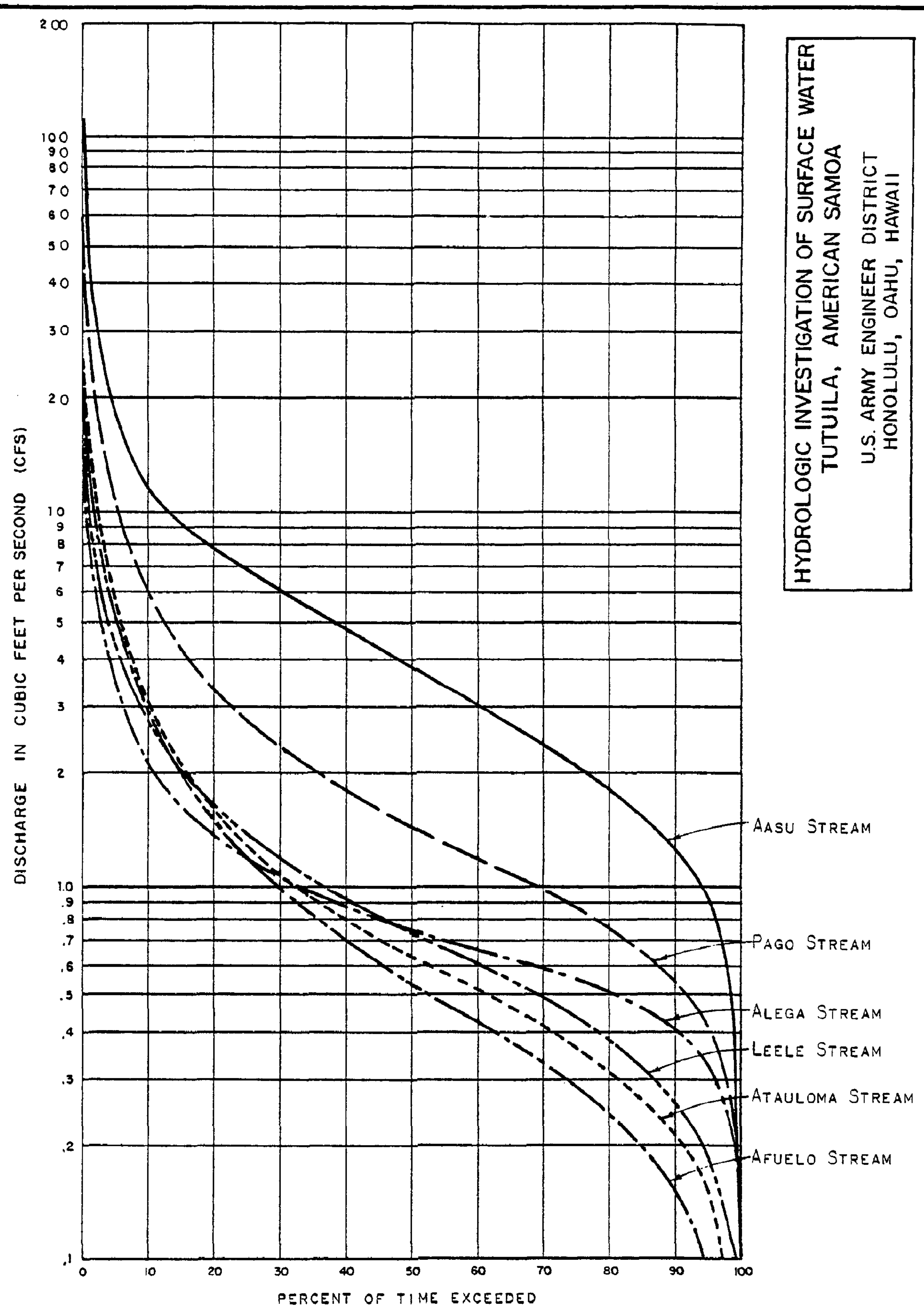


FLOW DURATION CURVE

ALEGA STREAM AT ALEGA, TUTUILA, AMERICAN SAMOA
BASIN NUMBER 19 (YEARS OF RECORD: 1959 - 1976)

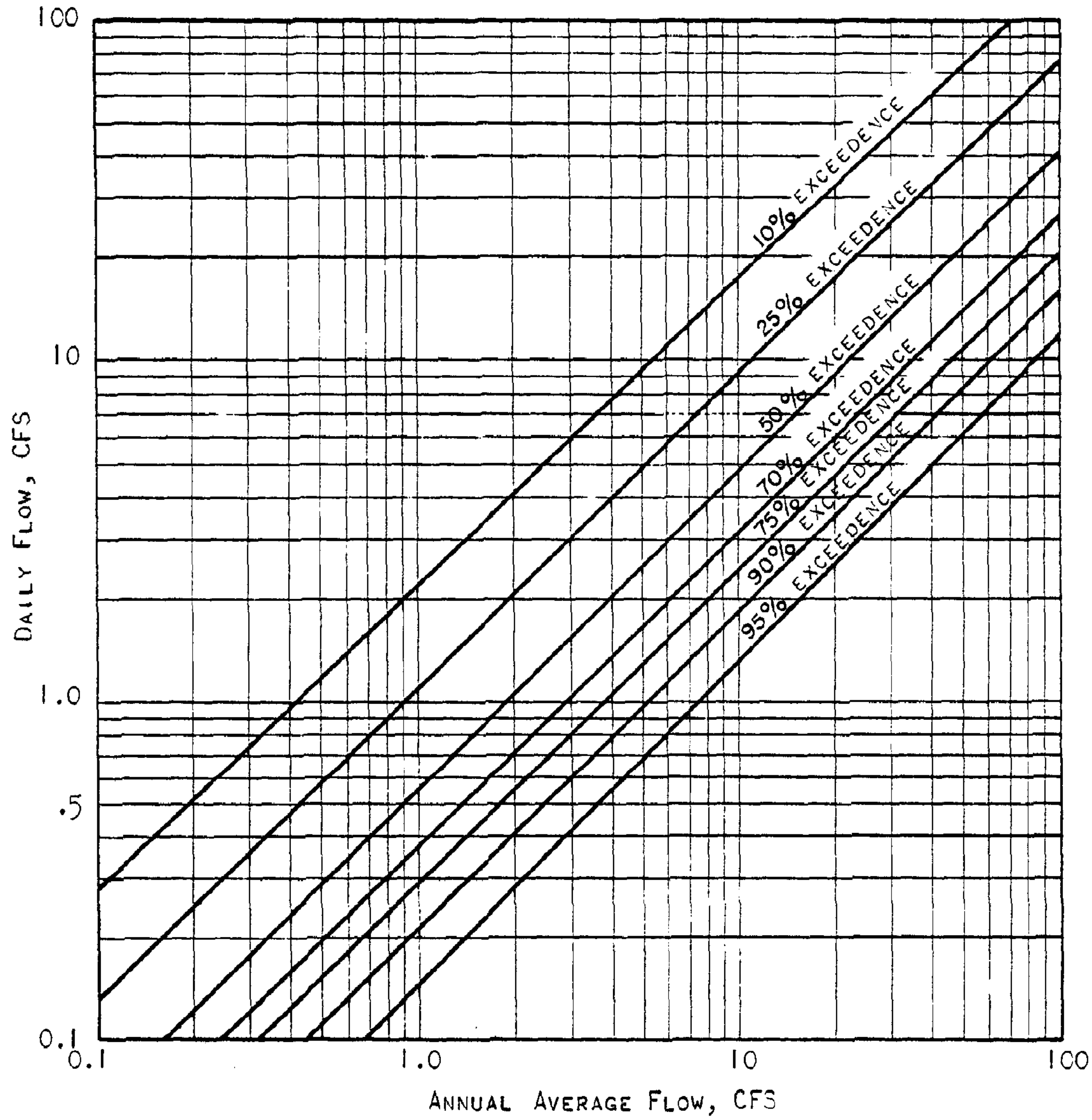
HYDROLOGIC INVESTIGATION OF SURFACE WATER
TUTUILA, AMERICAN SAMOA

U.S. ARMY ENGINEER DISTRICT
HONOLULU, OAHU, HAWAII



FLOW DURATION CURVES

(COMPOSITE)

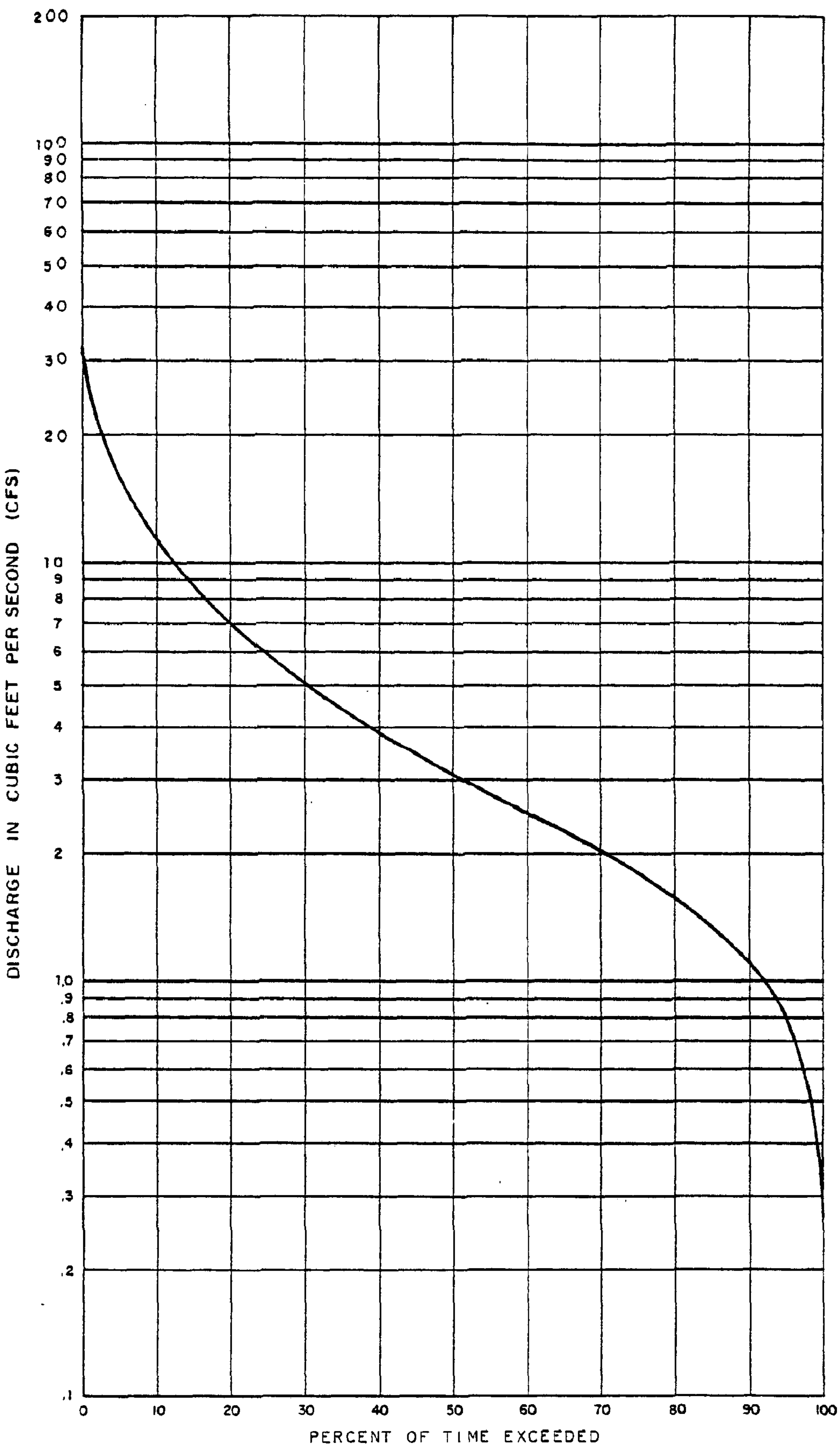


PARAMETRIC DURATION CURVES

VALUES FROM GAGED STATIONS ON AMERICAN SAMOA.

HYDROLOGIC INVESTIGATION OF SURFACE WATER
TUTUILA, AMERICAN SAMOA

U.S. ARMY ENGINEER DISTRICT
HONOLULU, OAHU, HAWAII

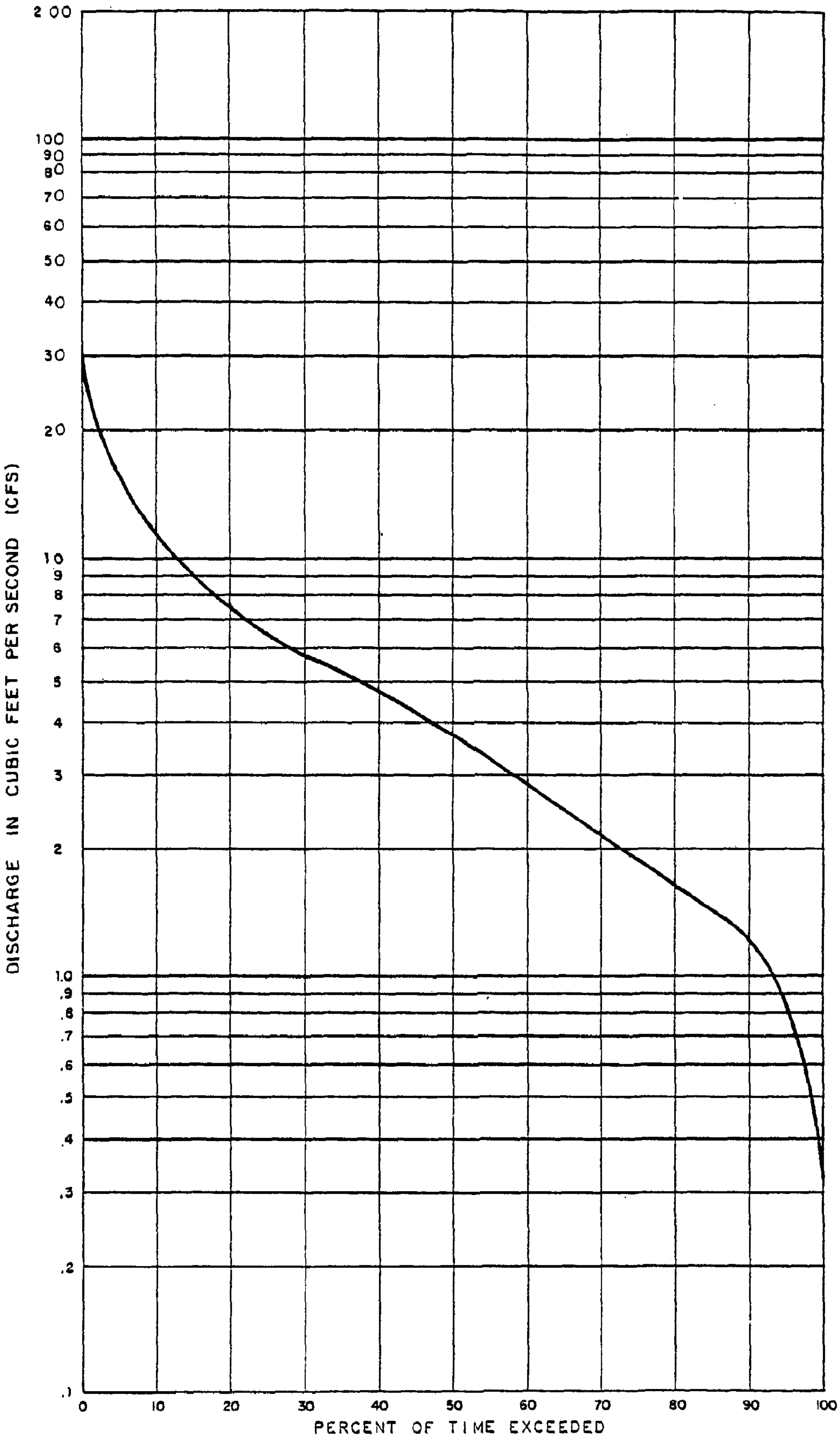


FLOW DURATION CURVE

BASIN #2 - MALOATA

HYDROLOGIC INVESTIGATION OF SURFACE WATER
TUTUILA, AMERICAN SAMOA

U.S. ARMY ENGINEER DISTRICT
HONOLULU, OAHU, HAWAII

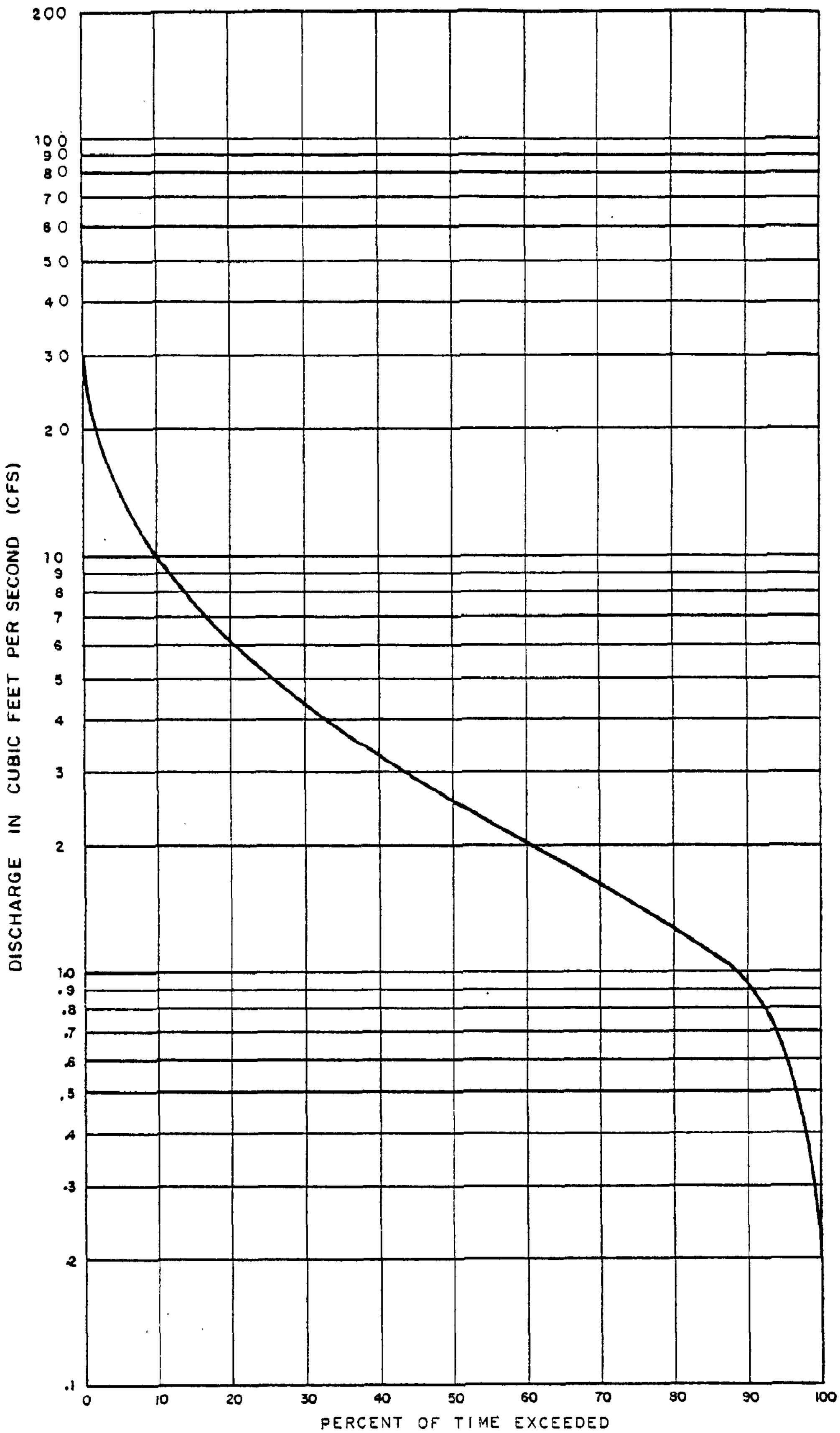


HYDROLOGIC INVESTIGATION OF SURFACE WATER
TUTUILA, AMERICAN SAMOA

U.S. ARMY ENGINEER DISTRICT
HONOLULU, OAHU, HAWAII

FLOW DURATION CURVE

BASIN # 6 - LEAFU

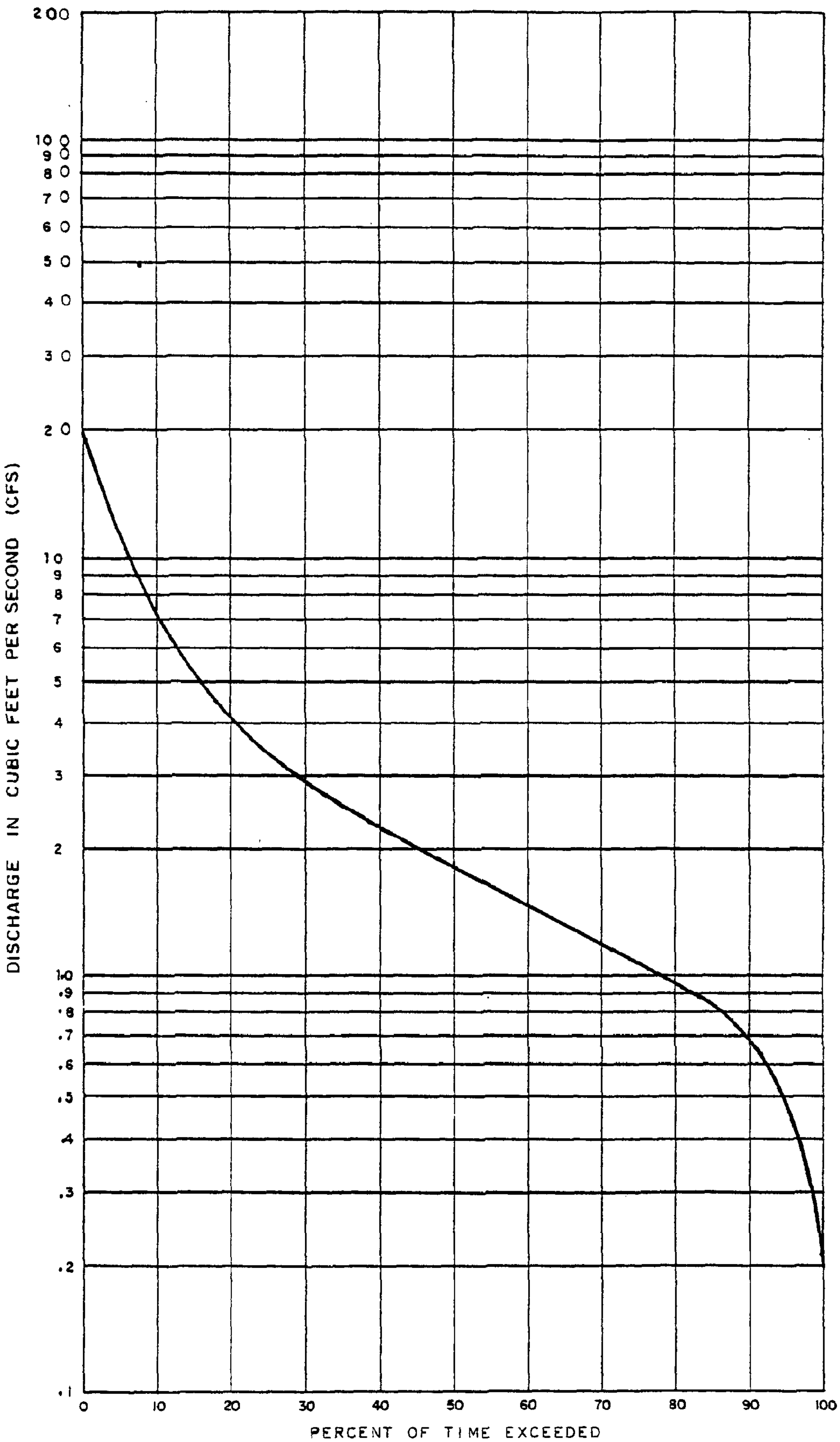


HYDROLOGIC INVESTIGATION OF SURFACE WATER
TUTUILA, AMERICAN SAMOA

U.S. ARMY ENGINEER DISTRICT
HONOLULU, OAHU, HAWAII

FLOW DURATION CURVE

BASIN #10 - PAPA



HYDROLOGIC INVESTIGATION OF SURFACE WATER
TUTUILA, AMERICAN SAMOA

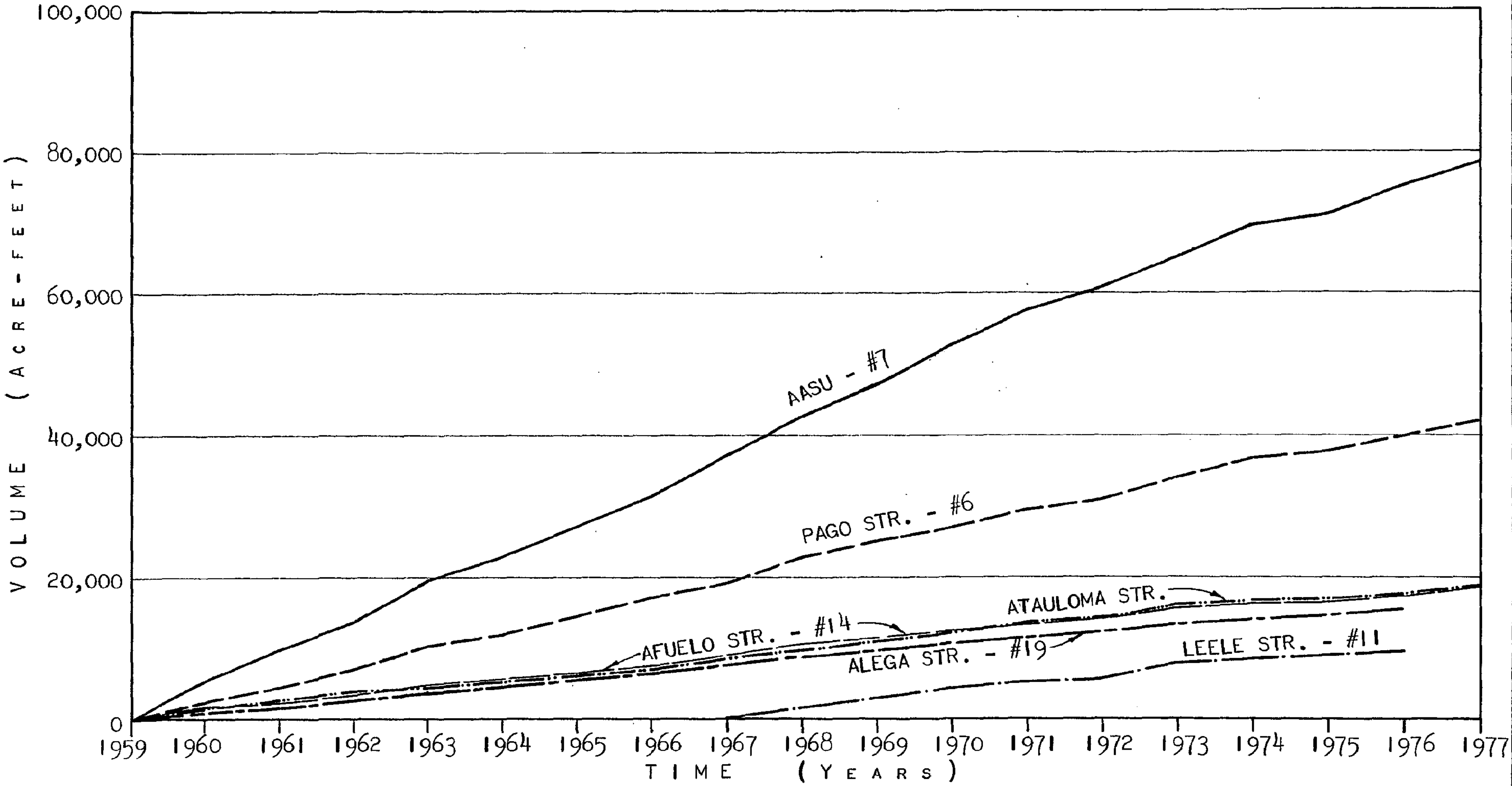
U.S. ARMY ENGINEER DISTRICT
HONOLULU, OAHU, HAWAII

FLOW DURATION CURVE

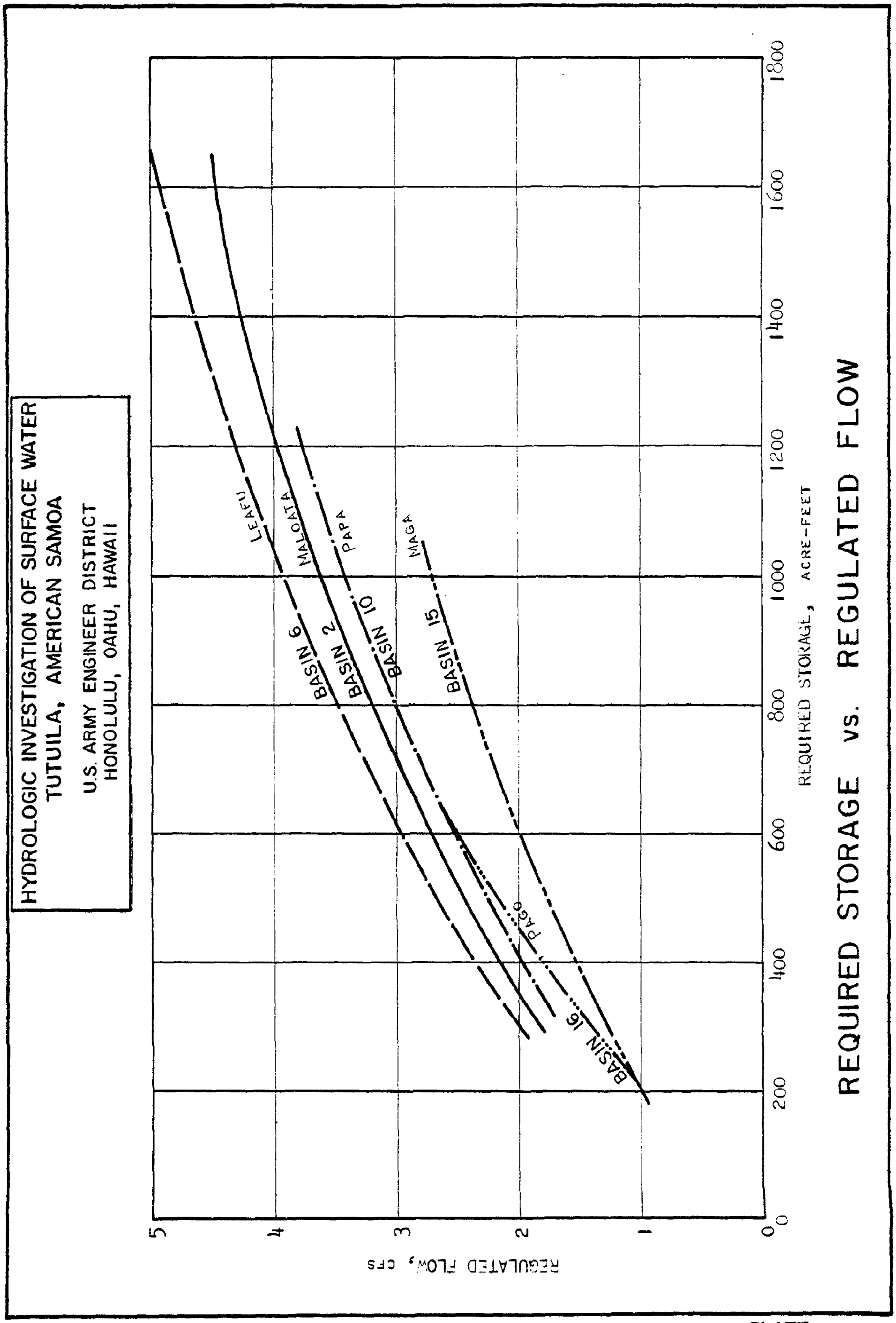
BASIN #15 - MAGA

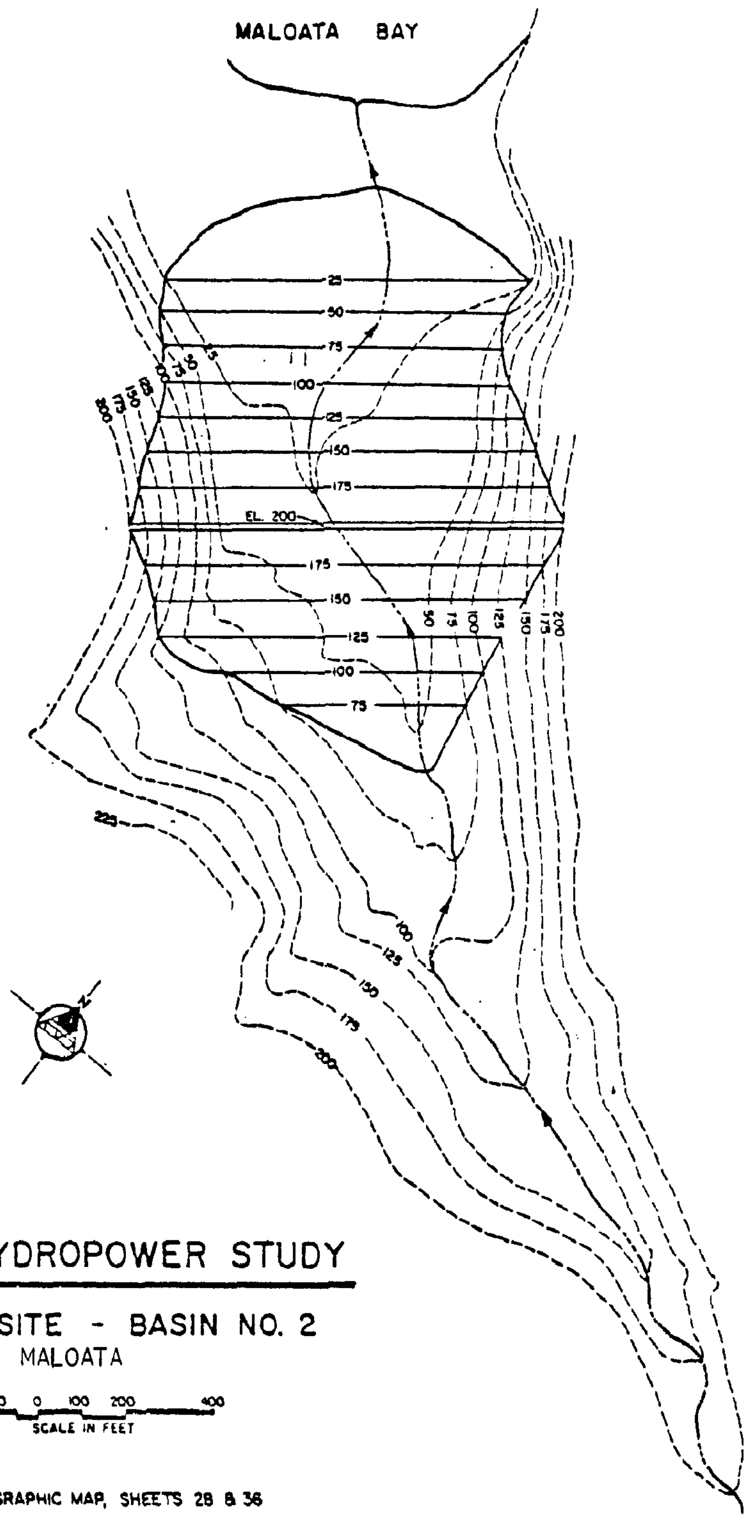
HYDROLOGIC INVESTIGATION OF SURFACE WATER
TUTUILA, AMERICAN SAMOA

U.S. ARMY ENGINEER DISTRICT
HONOLULU, OAHU, HAWAII



MASS CURVES FOR SIX BASINS


HYDROLOGIC INVESTIGATION OF SURFACE WATER
TUTUILA, AMERICAN SAMOA
U.S. ARMY ENGINEER DISTRICT
HONOLULU, OAHU, HAWAII
LEAFU
MALOATA
PAPA
MAGA
BASIN 6
BASIN 2
BASIN 10
BASIN 15
PAGO
BASIN 16
0
1
2
3
4
5
REGULATED FLOW, cfs
0
200
400
600
800
1000
1200
1400
1600
1800
REQUIRED STORAGE, ACRE-FEET
REQUIRED STORAGE vs. REGULATED FLOW



SAMOA HYDROPOWER STUDY

STORAGE SITE - BASIN NO. 2

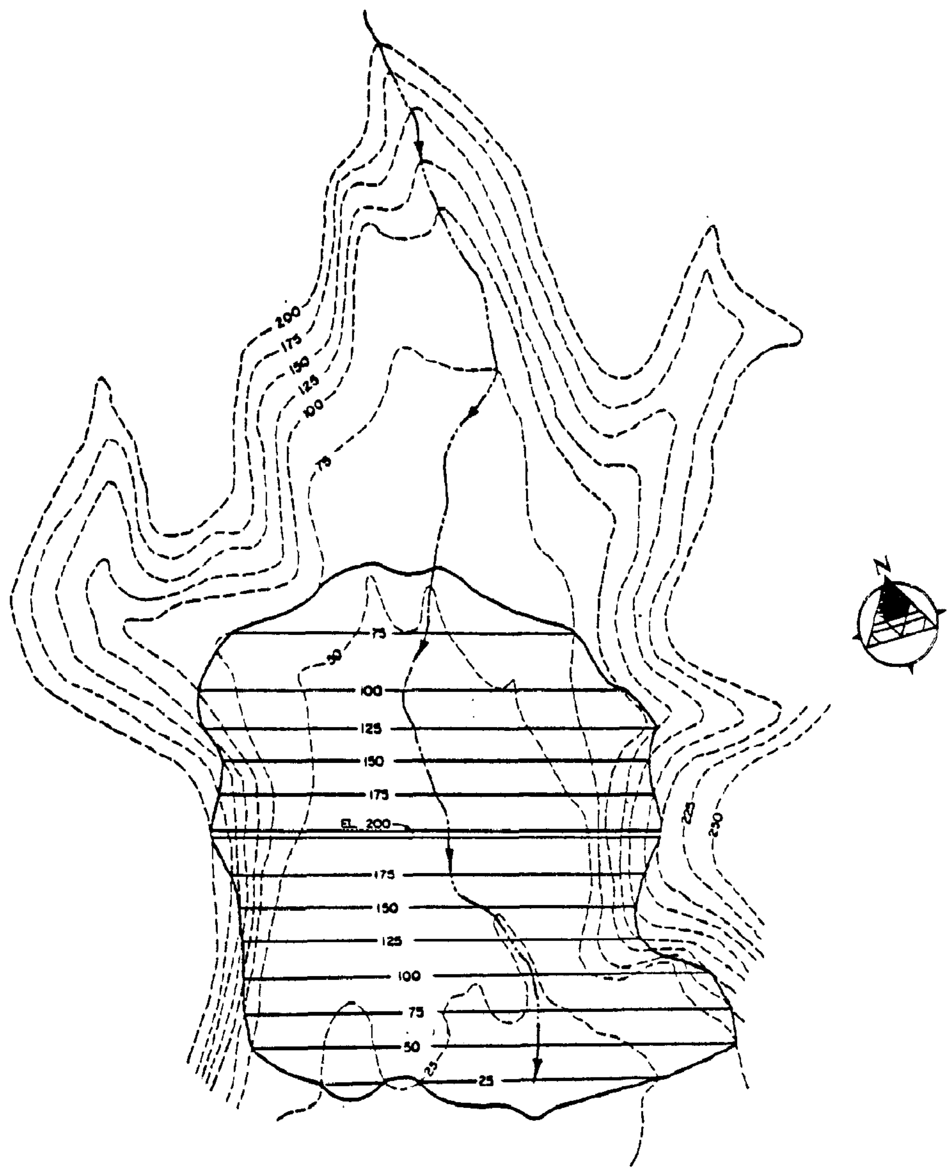
MALOATA

200 100 0 100 200 400
SCALE IN FEET

FROM PWD TOPOGRAPHIC MAP, SHEETS 28 & 36

HYDROLOGIC INVESTIGATION OF SURFACE WATER
TUTUILA, AMERICAN SAMOA

U.S. ARMY ENGINEER DISTRICT
HONOLULU, OAHU, HAWAII



SAMOA HYDROPOWER STUDY

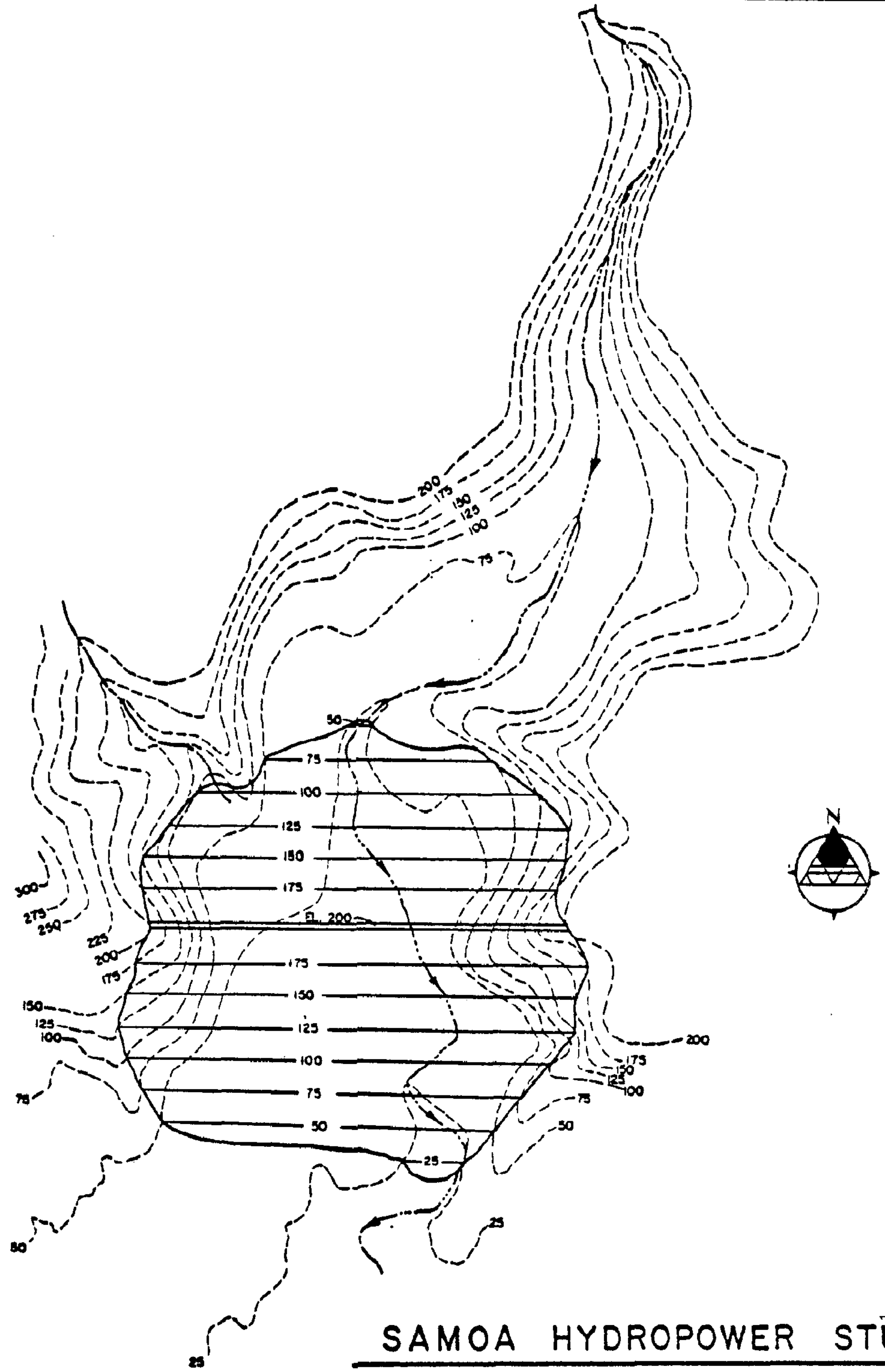
BASIN NO. 6
LEAFU

200 100 0 100 200 400
SCALE IN FEET

FROM PWD TOPOGRAPHIC MAP, SHEETS 44 & 45

HYDROLOGIC INVESTIGATION OF SURFACE WATER
TUTUILA, AMERICAN SAMOA

U.S. ARMY ENGINEER DISTRICT
HONOLULU, OAHU, HAWAII



SAMOA HYDROPOWER STUDY

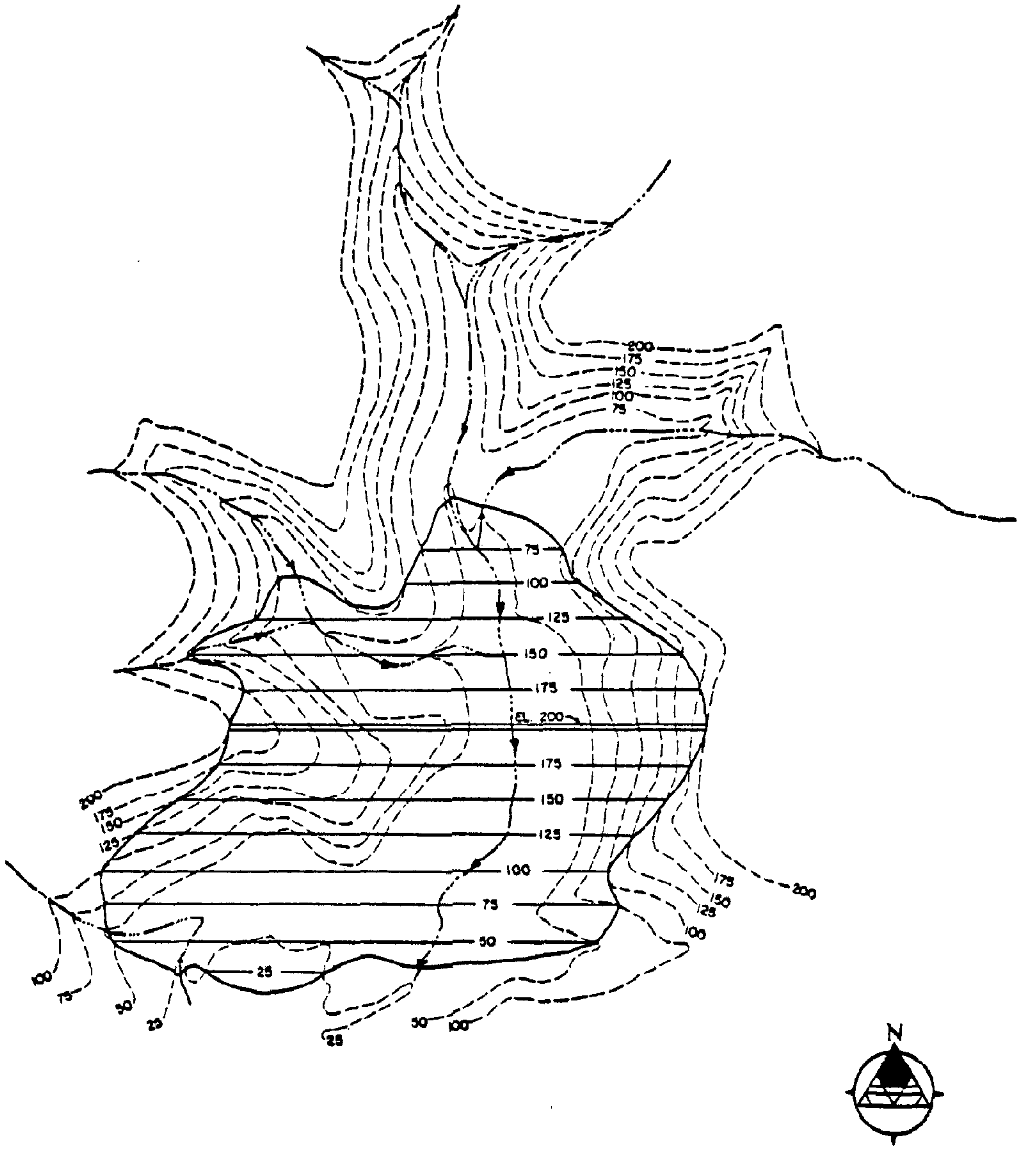
BASIN NO. 10
PAPA

SCALE IN FEET

FROM PWD TOPOGRAPHIC MAP, SHEET NO. 33

HYDROLOGIC INVESTIGATION OF SURFACE WATER
TUTUILA, AMERICAN SAMOA

U.S. ARMY ENGINEER DISTRICT
HONOLULU, OAHU, HAWAII



SAMOA HYDROPOWER STUDY

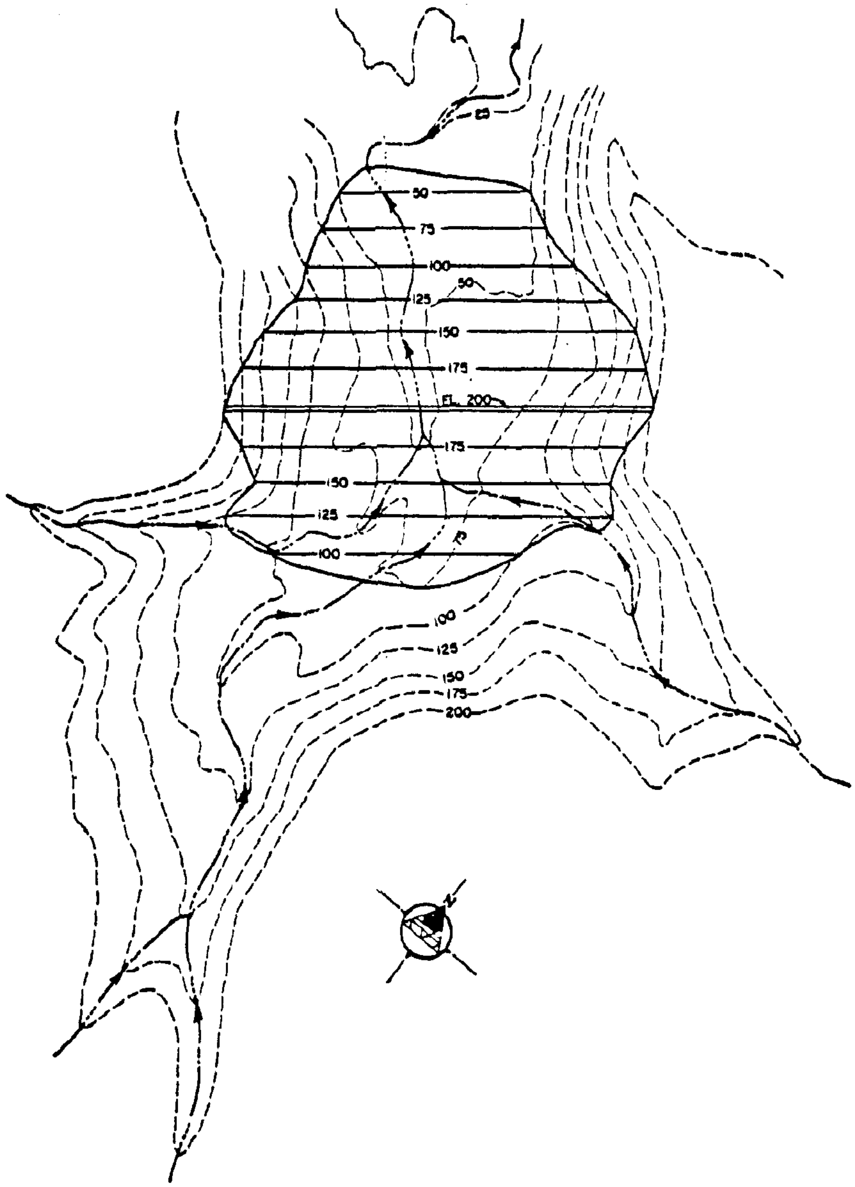
BASIN NO. 15
MAGA

200 100 0 100 200 400
SCALE IN FEET

FROM PWD TOPOGRAPHIC MAP, SHEET NO. 23

HYDROLOGIC INVESTIGATION OF SURFACE WATER
TUTUILA, AMERICAN SAMOA

U.S. ARMY ENGINEER DISTRICT
HONOLULU, OAHU, HAWAII



SAMOA HYDROPOWER STUDY

BASIN NO. 16

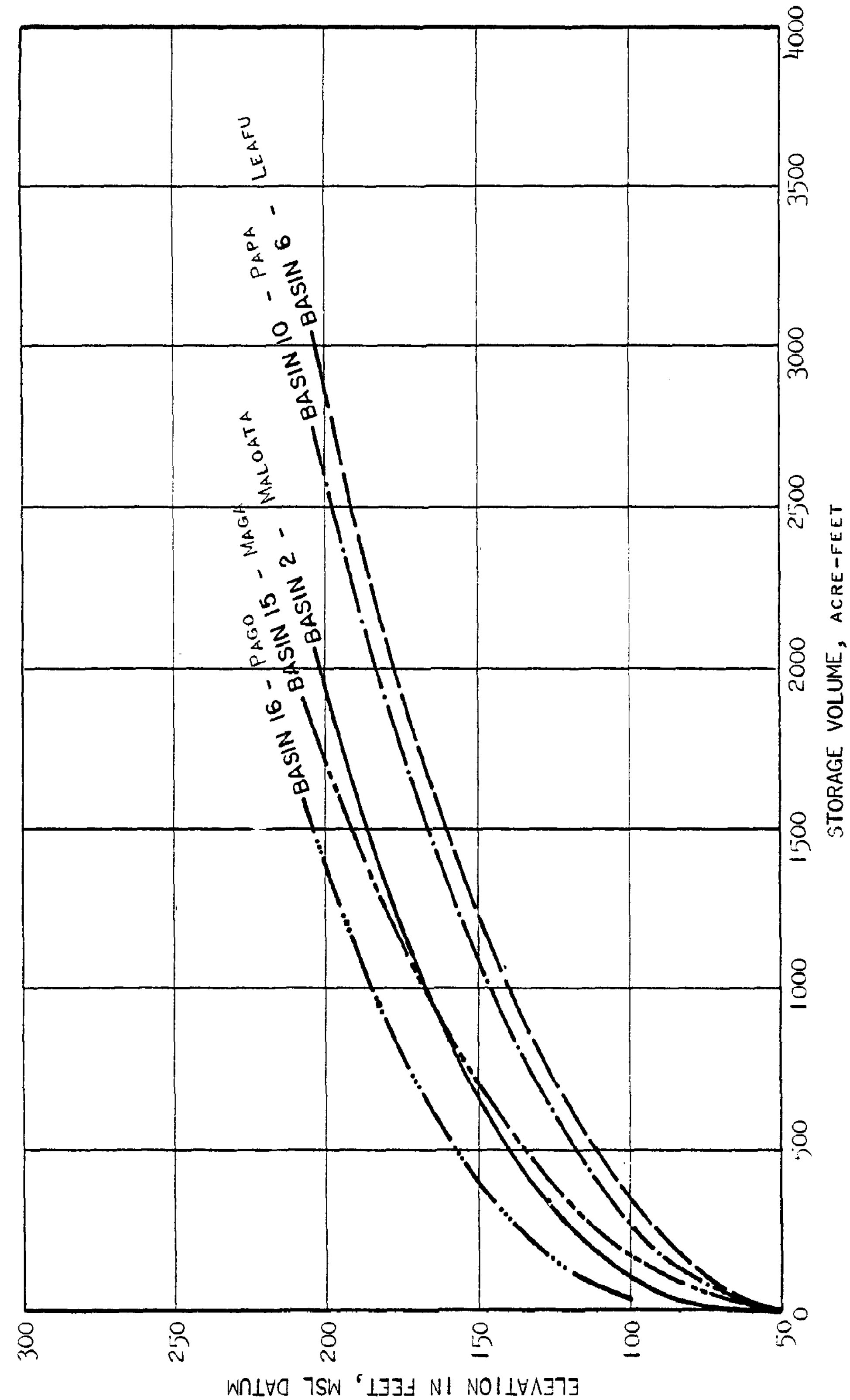
PAGO

200 100 0 100 200 400
SCALE IN FEET

FROM PWD TOPOGRAPHIC MAP, SHEET NO. 12

HYDROLOGIC INVESTIGATION OF SURFACE WATER
TUTUILA, AMERICAN SAMOA

U.S. ARMY ENGINEER DISTRICT
HONOLULU, OAHU, HAWAII



STORAGE VOLUMES FOR FIVE BASINS

HYDROLOGIC INVESTIGATION OF SURFACE WATER
TUTUILA, AMERICAN SAMOA

U.S. ARMY ENGINEER DISTRICT
HONOLULU, OAHU, HAWAII

HYDROLOGIC INVESTIGATION OF SURFACE WATER
FOR WATER SUPPLY AND HYDROPOWER
TUTUILA, AMERICAN SAMOA

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