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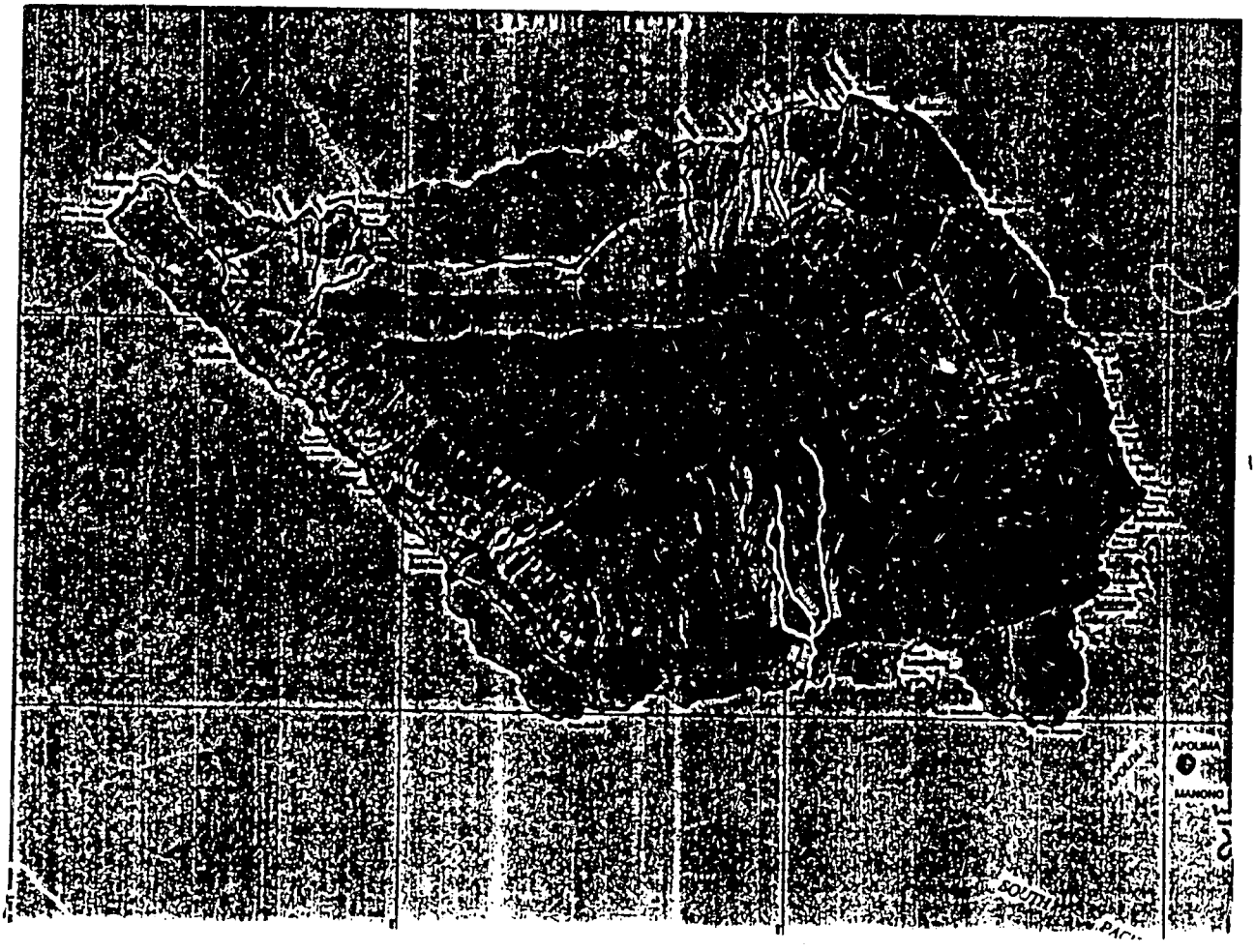
SAVAII ISLAND
SILI RIVER PROJECT

PREFEASIBILITY STUDY



For

GOVERNMENT OF WESTERN SAMOA
PUBLIC WORKS DEPARTMENT

By

Bechtel—Civil and Minerals Inc
Oct. 1985

THE GOVERNMENT OF THE INDEPENDENT STATE
OF
WESTERN SAMOA

SILI RIVER MULTI-PURPOSE PROJECT

PRE-FEASIBILITY STUDY

November, 1985

Bechtel Civil and Minerals, Inc.
San Francisco, California

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(7759E)

SECTION 1

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

1.1 INTRODUCTION

This report presents the results of a prefeasibility study of the potential for development of the water resources of the Sili River Basin in southeastern Savaii Island of Western Samoa. This study was performed in accordance with the Agreement for Technical Services dated 21 August 1985 between the Government of the Independent State of Western Samoa (the Client) and Bechtel Civil and Minerals, Inc. of San Francisco, California (Bechtel). A copy of the Scope of Services is provided as Appendix A to this report.

1.2 OBJECTIVES

The primary objective for water resource development in the Sili River Basin will be the provision of potable water supplies in the populated areas along the island's shores. As directed by the Agreement, an evaluation was made of water supply in two specific zones:

- Zone 1: Foaluga to Gataival to Fa'ala (i.e., approximately, the southern coastal area of Savaii)
- Zone 2: Moata to Tuasivi to PuaPua (i.e., approximately, the southern half of the east coast)

The corresponding water demands for year 2010 populations, and allowing for 20% transmission losses, were defined as:

- Zone 1: 55 litres/second
- Zone 2: 60 litres/second

In addition, a separate evaluation was made of the potential for utilizing the Sili River Basin to supply the entire coastal reach from Sili village westward to the Asau District. This portion of the island was studied in some detail in 1981 by G. M. Meredith & Associates (Ref. 1) and determined to have significant water supply problems which could be rectified through provision of a central high-pressure system.

The potential use of Sili River water resources for hydroelectric generation purposes was evaluated as a secondary objective, with irrigation usage also considered.

1.3 APPROACH TO WORK

A three-man team, composed of a lead hydroelectric and water resources engineer, a senior geologist and a senior hydrologist, visited Western Samoa in late August 1985 to review the project with the Client and to obtain technical and reference data. The team also made an air and ground reconnaissance of the Sili River Basin, paying particular attention to the hydrologic and geologic parameters. The data and references obtained were then evaluated in light of the assessment made of the Basin's physical characteristics, and alternative water resource development schemes postulated. Conceptual schemes for water supply and for hydroelectric power production were laid out, estimated at the pre-feasibility level, and evaluated in order to identify the appropriate next steps toward final project definition as presented herein.

1.4 CONCLUSIONS

1.4.1 General.

The Sili River rises on the southern slopes of Mt. Teelagi, and debouches into the sea over a waterfall near Puleia about 17 kilometers west of Salelologa in southeastern Savaii. The potential for water resource development lies in the three principal tributaries of the river which converge at the village of Sili. These three

tributaries, named Vaitai Stream and the Lata and Vaiola Rivers on the 1:200,000 topographic map, are referred to herein as the Eastern, Central and Western Branches, respectively, of the Sili River because of inconsistences in their naming in other references. The locations of the basin and the tributaries are shown on Figure 1.

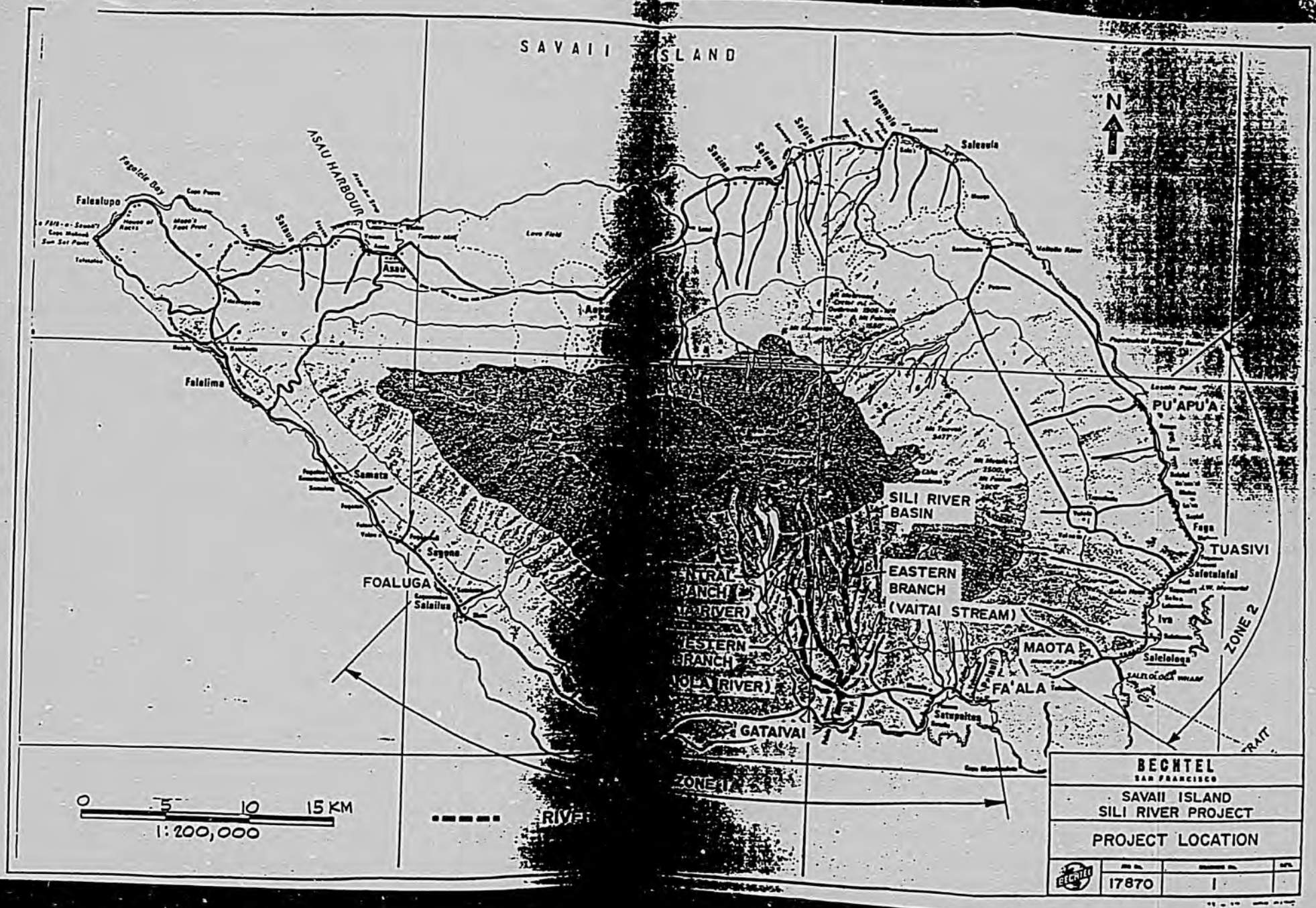
These perennial streams flow from the steep and heavily-vegetated slopes of Mt. Teelagi across (and through) volcanic-origin rock. The amount of water flowing beneath the surface is variable, but is evidently substantial and even total in some places. This characteristic, and its cause, have a major influence on the potential water development schemes. The flows of the Eastern and Central branches appear to be approximately equal, and both are significant relative to the estimated water supply needs. The flow of the Western branch appears inadequate for development except perhaps as an adjunct to a scheme involving one of the other two branches.

1.4. Eastern Branch Development.

The flows of the Eastern Branch have been gauged, with some discontinuities, since mid-1981. These measurements were analyzed to produce a flow-duration curve, which indicates the stream to have the capacity to supply the 115 liters per second specified for Zones 1 and 2 about 94 percent of the time. The Eastern Branch is not considered viable for the development of dam and reservoir storage, because of the high porosity of the geology upstream from the gauging site and the lack of suitable dam sites downstream from that point. A low diversion dam located near the existing gauging station would probably be feasible.

1.4.3 Central Branch Development.

While no flow data exists for the Central Branch, visual evidence indicates an approximately similar discharge to the gauged Eastern branch.



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The Central Branch could be diverted for water supply almost anywhere within its canyon but, considering the possible need for hydroelectric energy development, diversion should be made at a location about 2.5 kilometers upstream from the Sili village, at about El. 200 m (650 ft. contour on 1:20,000 topographic map). This location is just downstream from the confluence of two flowing streams of the Central Branch. While a location further upstream would create more head for hydro power production, there would be a substantial loss in discharge volume. The canyon at this point is located in an ancient lava flow and its abutments are covered with clay soils. It appears to be the only site anywhere in the Basin suitable for a storage structure, although detailed site investigations and soils testing will be required to confirm this assessment.

1.4.4 Western Branch Development.

The flow in the ungauged Western Branch appears inadequate for an independent water supply development. It might however be suitable as an adjunct to a Central Branch development, with a possibility for relatively simple diversion into the Central Branch basin upstream from the proposed dam and reservoir site described above. While the Central Branch seems to be adequate as a water supply source by itself, additional inflow from the Western Branch could enhance a hydro power project. Flow measurements at the potential diversion site on the Western Branch will be required before the justification for such a feature can be evaluated.

1.4.5 Hydroelectric Development.

There is no justification at the present time for construction of a hydroelectric power project in the Sili River Basin, given the present free energy available from the plant at the Asau mill and the transmission intertie project now underway between Asau and

Salelologa. However, it appears that ample hydro power could be developed on the Central Branch, and storage sites suitable for that purpose should be reserved for future development in the event the Asau supply is discontinued for any reason. A hydro project could be added to a properly-planned water supply project without difficulty.

1.5 RECOMMENDATIONS

Based on the findings of this study, we recommend as follows:

1. An expanded program of hydrologic and geologic data collection should be initiated now for the Sili River Basin, as described in Section 9 of this report. Its purpose will be to permit detailed planning and preliminary design of potable water supply systems serving the southern/eastern and western portions of Savaii Island.

2. The Central Branch of the Sili River Basin should be developed now to supply a central, high-pressure potable water system serving the western portion of Savaii from Sili village to the Asau District. Existing water systems in this region are generally inadequate.

3. Design of the Central Branch diversion facility should be such as to permit its future incorporation into a dam providing storage for both water supply and hydro power purposes.

4. A site should be reserved on the Western Branch of the Sili River for construction of a diversion facility which would convey flows into the Central Branch, above the diversion/storage site thereon. This will permit future augmentation of the flows of the Central Branch if justified for hydro power production.

5. The Eastern Branch of the Sili River should be reserved for water supply to the southern and eastern portions of the island at such time as the existing supply from Faleata River proves insufficient or the existing Fa'asalele'aga water supply system needs to be replaced.

6. A strong watershed management program should be undertaken to protect the fragile ecology of the entire Sili River Basin, so that this watershed is not lost to erosion.

SECTION 2

SITE VISIT

2.1 GENERAL

The pre-feasibility study was initiated by a visit to Western Samoa by three Bechtel specialists: a hydroelectric and water resources engineer, a senior geologist, and a senior hydrologist. The study team left San Francisco on August 20 and arrived at Apia on August 21, 1985. The next day they met with representatives of the Departments of Works and Foreign Affairs, and of the Apia Observatory. Pertinent information was collected, and on August 22 the team left by a small chartered plane for an air-reconnaissance flight over the lower drainage basin of the Sili River, followed by landing on the Naota airstrip for a stay at Salelologa.

Ground reconnaissance of the Eastern Branch was made from the confluence at Sili village to a point approximately 200 m upstream from the location of the existing stream gauging station. This branch of the river is located in recent lava flow, and the stream disappears in the lava completely for a 50 m stretch about 300 m downstream from the gauge. The field reconnaissance did not proceed further upstream because the flow in the river decreases by an estimated two-thirds between the gauge and the point approximately 200 m upstream therefrom. The decrease in flow seems to be progressive upstream, so that the gauge location is about the farthest upstream location of full flow available in the Eastern Branch. No potential damsites were noted on the Eastern Branch downstream from the gauging station.

The Central Branch was visited twice. This branch flows in a deep canyon eroded in the old lava flow, and appears to present the only potentially suitable location for a dam and reservoir storage on any of the three branches of the Sili River.

The Western Branch has the lowest discharge of the three. It was inspected near Sili village, but does not appear to have potential for development except possibly as a supplement to a scheme developing one of the other branches.

SECTION 3

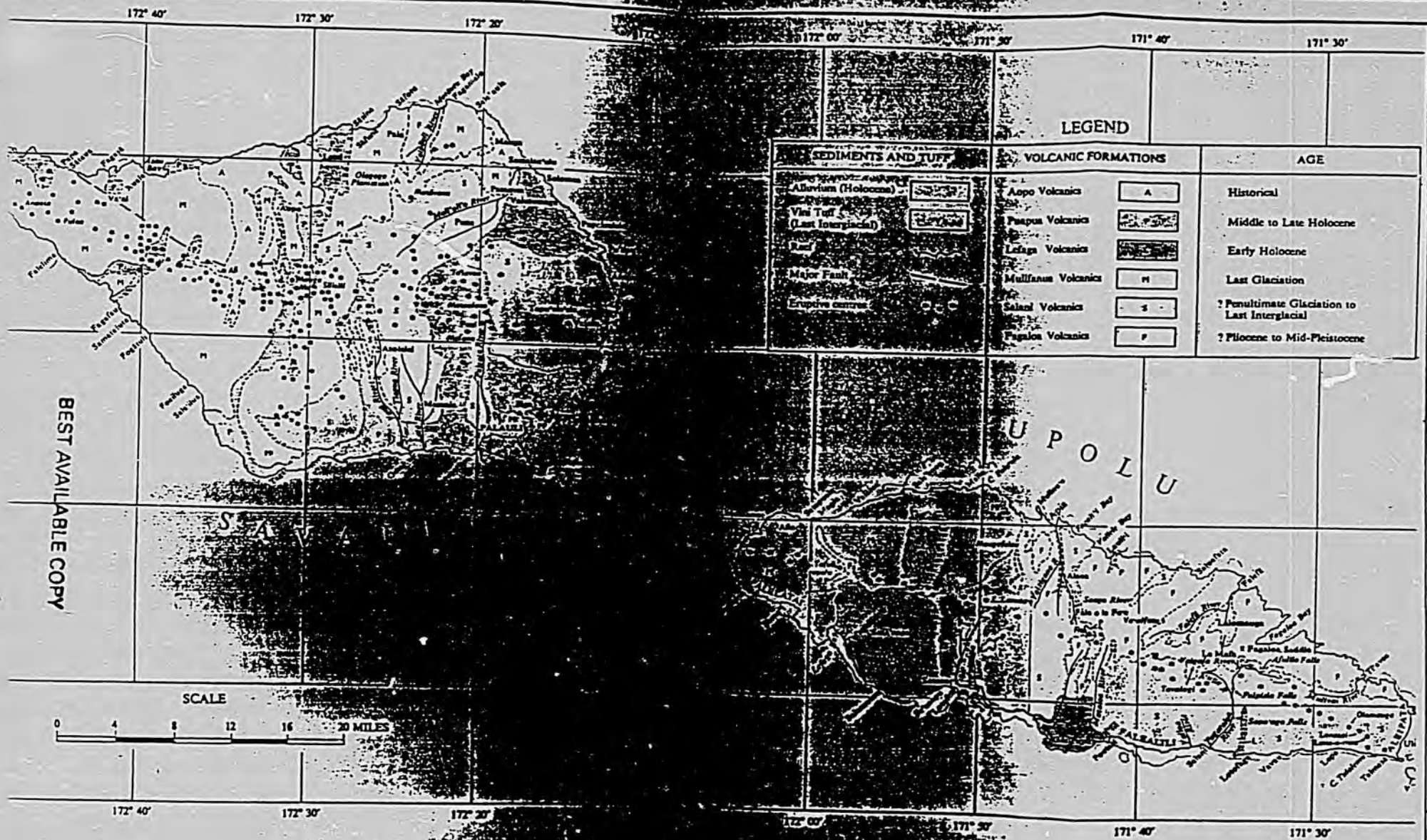
GEOLOGY

3.1 GENERAL

Savaii is a volcanic island in which vulcanism is still active, the most recent episodes occurring in 1905 through 1911, but with other historical flows occurring in 1902 and 1960. Most of the historical volcanic activity has taken place on the north side of this west-northwest elongated island. The highest peaks are approximately 1860 m high.

The Sili River on the south side of the island has developed a branching system composed of the three main perennial branches. On the geologic map of Savaii accompanying the Kear and Wood report (Ref. 2), reproduced as Figure 2, the drainage appears to be largely developed on the Salani Volcanics, one of the older formations on the island being middle to upper Pleistocene in age. The relationship of the Salani Volcanics to other West Samoan volcanics is presented in Table 3-1. Although recent paleomagnetic studies on the ages of the Samoan Island volcanics by Keating (Ref. 3) indicate probable discrepancies in the ages of some of the units, this would not affect the conclusions in this report.

The geologic features of each stream, and the engineering geology assessment of possible development facilities, are reviewed in the following paragraphs. Photographs referred to, which were taken during the site visit, are presented at the end of the section.



SOURCE: "GEOLOGY AND HYDROLOGY OF WESTERN SAMOA"
D. KEAR AND B.L. WOOD. 1959

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SAVAII ISLAND
SILI RIVER PROJECT

WESTERN SAMOA
GEOLOGIC MAP

2

Name	Cover of Vegetation	Weathering Zone and Soil	Present Reef	Boulders on Uneven Land	Alterations to Cone Form	Surface Water	Olivine Nodules	Age
Aopo Volcanics ..	None or poor	None	None	Very common	None	None	Rare	Historical
Tafagamanu Sand ..	Sedimentary formations approximately contemporaneous with Puapua Volcanics							Post-Glacial + 5 ft sea level
Nu'utele Sand ..								Post-Glacial + 15 ft sea level
Lalomauga High-level Alluvium								Post-Mulifanua
Puapua Volcanics ..	Normal	Very thin	None	Very common	None	Virtually none	Rare	Middle to late Holocene
Lefaga Volcanics ..	Normal	Intermediate	Close inshore	Very common	Little	Virtually none	Rare	Early Holocene
Mulifanua Volcanics	Normal	Intermediate	Far offshore	Common, weathered, angular	Crater filling	Rare	Uncommon	Last Glaciation
		Erosional unconformity, with canyon formation						
Salani Volcanics ..	Normal	Thick (over 12" soil)	Far offshore	Very weathered rounded	Gorges cut in flanks	Sometimes	Present	? Penultimate Glaciation or Last Interglacial, to early Last Glaciation
Vini Tuff	Marine tuff rings, definitely pre-Lefaga, post-Fagaloa, and probably early Salani							Last Interglacial (about + 30 ft sea level)
		Great erosional unconformity, beneath younger volcanics						
Fagaloa Volcanics ..	Can be poor (leaching)	Very thick	None or close inshore	Rare	Up to complete destruction, dykes exposed	Always	Common	Pre-Penultimate Glaciation – possibly late Pliocene

TABLE 3-1
WESTERN SAMOAN
ROCK FORMATIONS

3.2 EASTERN BRANCH (VAITAI STREAM)

During the field trip described in Section 2, the Eastern Branch was followed to a point above the existing gauging station, at about El. 175 m and, in theory, well into the Salani Basalts. The river was running on the top of Pahoehoe Lavas throughout most of this stretch but with obvious variations in volume from place to place as the percentage of flow travelling through the rock fluctuated. Photos #1 and #2 show the extreme case where the entire surface flow disappeared into a lava tube for about 50 m before emerging as a large spring. This feature is located several hundred feet downstream from the gauging station pond. Photo #3 shows the gauging station pond.

Figure 3 is an enlargement of Aerial Photo #692 of the 1981 survey flights from which the topographic maps were prepared. It serves both as a location diagram for the photos used in this section, and to illustrate some of the pertinent geomorphic points. Foremost among these is the peculiar behavior of Eastern Branch and its tributaries to at least El. 175 m. There is fresh in-place rock on or very near the surface all along its main course in spite of the heavy forest vegetation on the hillsides and the cultivation of crops and groves of trees in the valley. The stream has yet to cut a permanent channel in the lava and there appears to be as much or more water flowing below the land surface as above. As seen in Photo #4 and on Figure 3, braiding of the stream is not unusual; many of the channels shown on the topographic map were not apparent on the ground and most likely carry water only during floods.

It seems clear that the Eastern Branch flows on and through very young lavas from at least El. 175 m. The older Salani Volcanics that, based on the geologic map, were anticipated above the 75 to 90 m elevation, appear either to have been buried by the PuaPua Lavas, or else the Vaitai valley has had intracanyon basalts flow into it from higher up the mountains. The latter is more probably the case, with these intracanyon basalt flows being of PuaPua age.

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3.3 CENTRAL BRANCH (LATA RIVER)

The Central Branch canyon, although young, is well developed and, from the area seen, not as subject to subterranean flow as is the Eastern Branch. The main canyon and its tributaries are well developed being incised at least 30 m or more into the rock. The canyon bottom, where examined near El. 105 to 120 m, was floored with boulders. While bedrock outcrops no doubt exist, they were not immediately apparent. Rock outcrops were not apparent either in the steep-sloping canyon sides; all that was visible through the vegetation was the brown clayey soil. Finally, as can be noted in the accompanying photos, the waters from the Central Branch are discolored by sediment when compared with those from the Eastern Branch (the air photos with the hand-held camera were all taken within one-half hour in time). It is thus clear that the present channel of the Central Branch is older than the Eastern and that, at least at the elevations visited, it is cut into older and less permeable rocks.

In Photo #5, the Eastern and Central branches of the Sili combined are once more flowing on the surface. Photo #7 shows the Recent PuaPua Basalt flows along the coast line (note the small waterfall at the mouth of the Sili River). The coastal plain is clearly composed of younger basalts. The formations showing incised drainages are identifiable as older volcanics and certainly fit the description of the Salani Volcanics as mapped.

3.4 WESTERN BRANCH (VAIOLA RIVER)

The Western Branch was only visited in the vicinity of the village of Sili, shown in Photo #5. The water was murky in color, similar to that of the Central Branch, implying passage over older volcanics in its upper reaches. The flow at this point was distinctly less than that of the Central Branch, but since the river is believed flowing over the recent PuaPua Volcanics at this location, some flow may be underground.

The weakly-incised drainage of this tributary below El. 350 suggests that the recent lavas may have encroached on this Western Branch from the west. This would imply a blockage of the drainage, probably by the

PuaPua Lavas. A wedge of river-deposited sand and gravel would likely be present on the ground surface between the recent lava and the more eroded volcanics.

3.5 ENGINEERING GEOLOGY

3.5.1 Eastern Branch.

The field inspection indicated that any significant storage reservoir on the Eastern Branch would have to be fully lined to prevent excessive leakage. Rock for rockfill dam construction would presumably be available by quarrying, although a site for a quarry was not specifically identified . Impervious material for the dam core and reservoir lining etc. was not apparent although it could possibly be present to the east of the stream. A low diversion dam (3 m high or less) at the site of the present gauging station would probably be practical. Even for that small a feature, however, significant seepage loss is a distinct possibility unless lining were provided for the pond.

3.5.2 Central Branch.

The Central Branch of the Sili River is in an older volcanic series than the Eastern Branch, with obvious weathering and a well-developed canyon which appears to be topographically suitable for a dam. Water flow appears essentially constant in the canyon reach, with no large increases or decreases in volume due to sub-surface flows, and the sides of the canyon are generally soil-covered. These factors suggest that the valley is less pervious than other parts of the watershed, and thus potentially suitable for reservoir storage.

While no construction material sources were specifically identified, detailed investigations may uncover sufficient quantities of core and filter material on the flatlands to the west of the canyon where the surface soil seems moderately developed. Rock for shell material was not noted at the proposed dam site, but can be expected to be available within a few kilometers.

3.5.3 Western Branch.

As the Western Branch was inspected only in the vicinity of Sili village, specific damsite geological and hydrological conditions are not known at present. Only a small diversion structure has been contemplated for this branch, however, so that siting of a suitable structure and location of construction materials should not prove a serious problem.

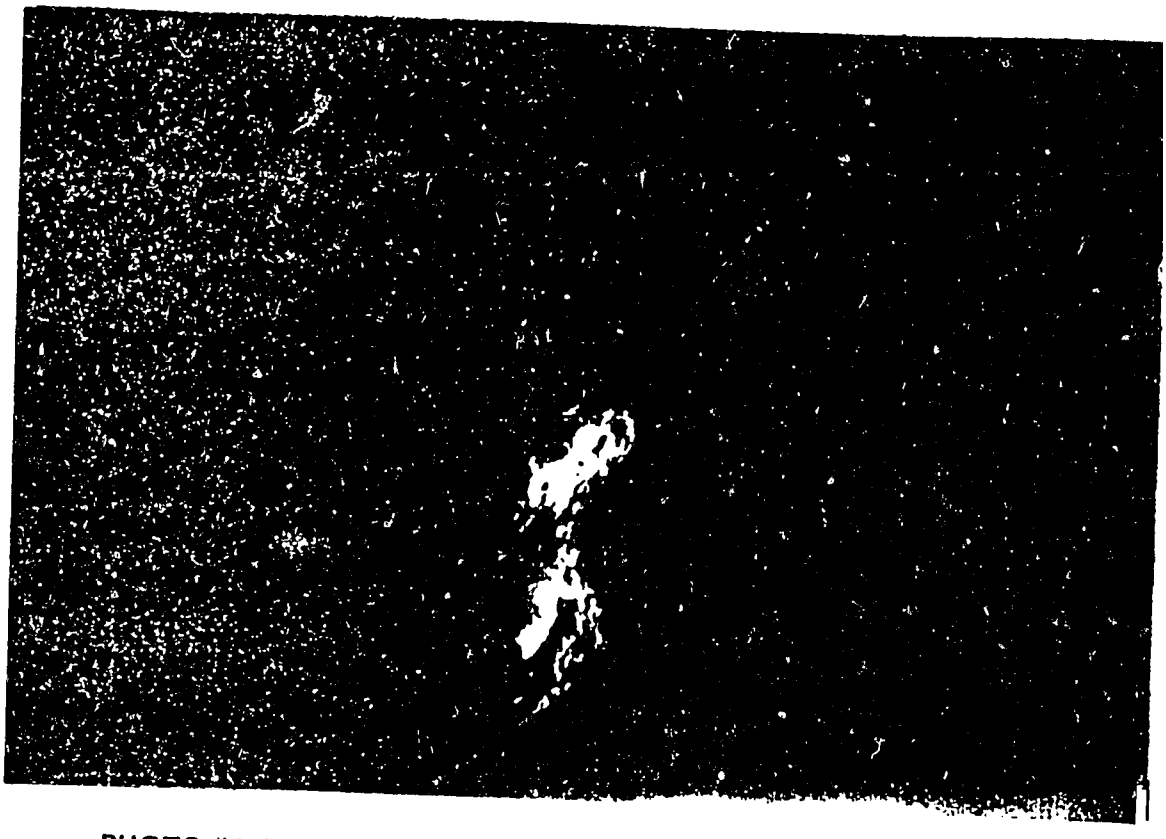


PHOTO #1 VAITAI STREAM (EAST BRANCH OF SILI RIVER) DISAPPEARING INTO AND EMERGING FROM A LAVA TUBE UPSTREAM FROM RIVER GAGE

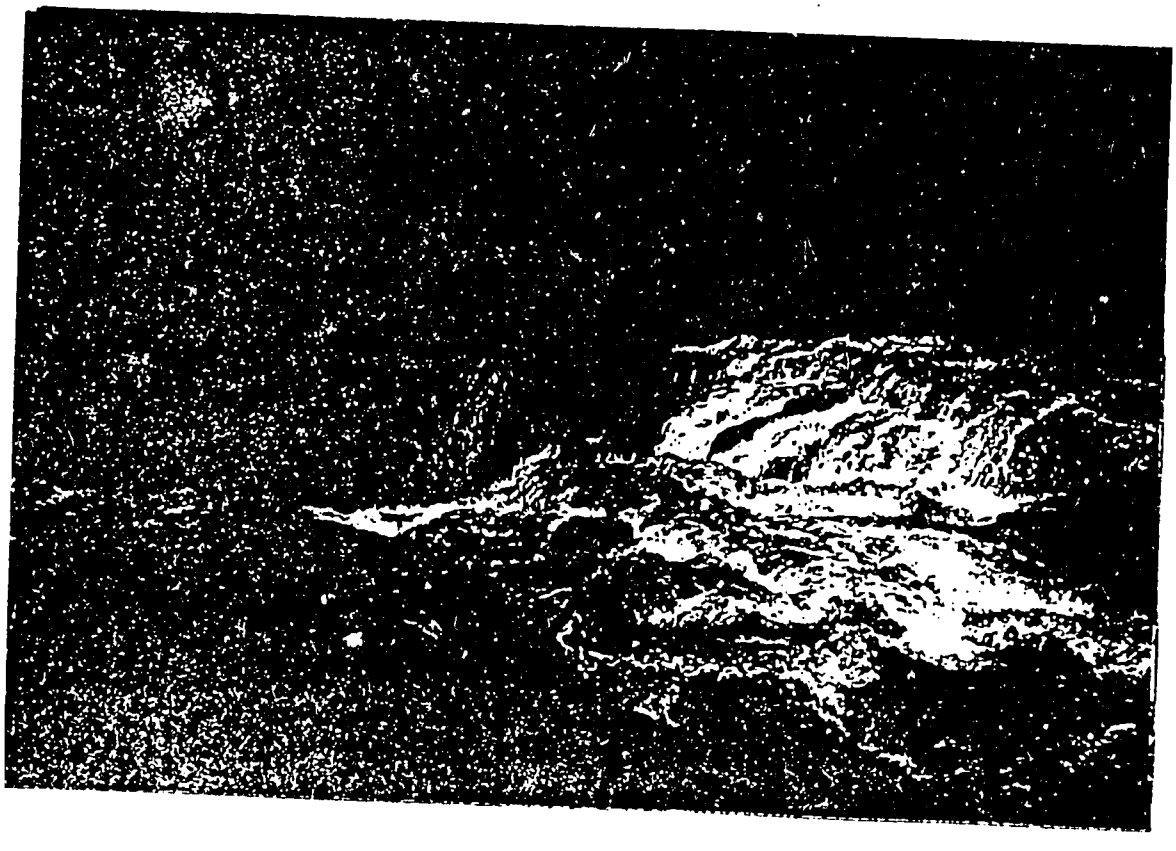


PHOTO #2 GROUND VIEW OF VAITAI ENTERING LAVA TUBE IN PHOTO #1

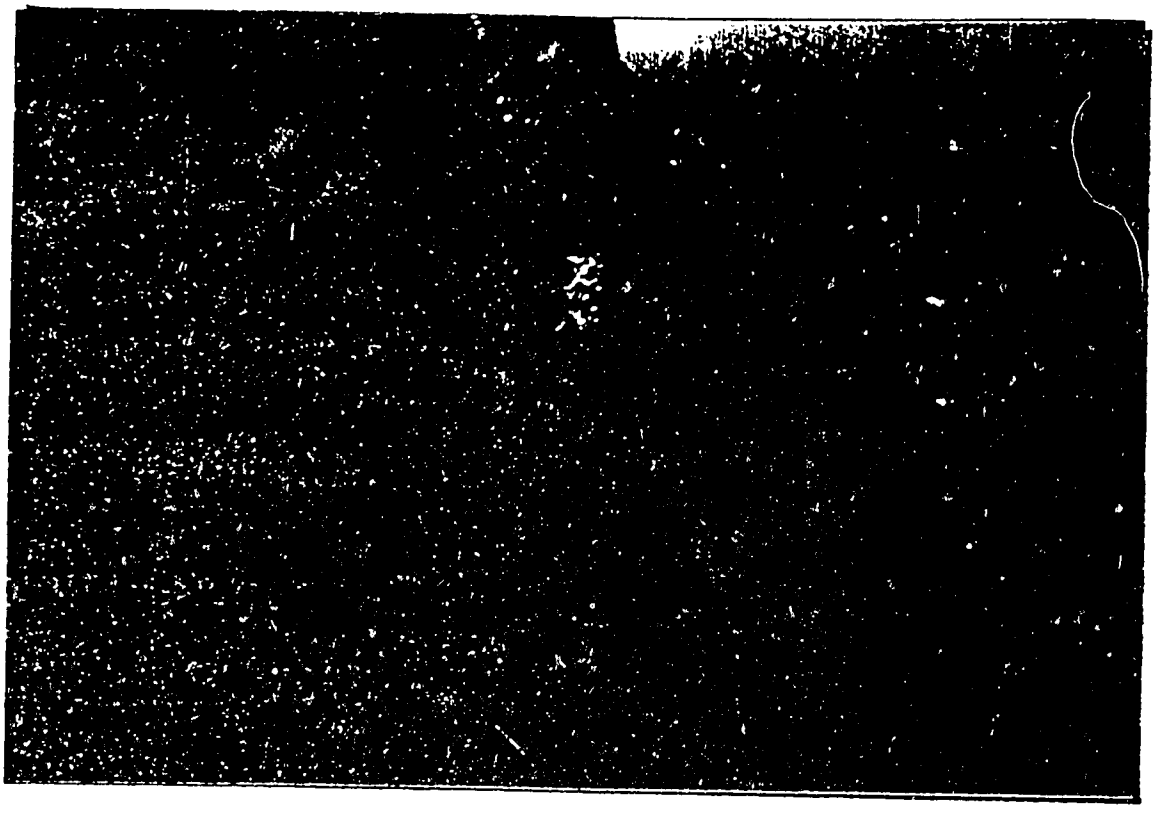


PHOTO #3 LOCATION OF GAGING STATION POND ON THE VAITAI STREAM

PHOTO #4 VAITAI STREAM SHOWING MAIN STREAM AND TWO DIVERGENT CHANNELS FLOWING ON TOP OF VIRTUALLY UNERODED LAVAS

PHOTO #5 COMBINED FLOWS OF THE EASTERN AND CENTRAL BRANCHES OF RIVER AT FORD (NOTE PERSON CROSSING) WITH WEST BRANCH VISIBLE AT TOP LEFT OF PHOTO

PHOTO #6 TYPICAL RUGGED TERRAIN AND JUNGLE LOOKING DOWNSTREAM ALONG THE CENTRAL BRANCH (LATA RIVER) OF THE SILI. NOTE DISCOLORATION OF WATER IN PHOTOS #5 AND #6

PHOTO #7 THE MAIN SOUTH COAST ROAD BRIDGE CROSSING THE SILI RIVER. NOTE THE WATERFALLS OVER THE RECENT LAVA FLOW ALONG THE SHORELINE. THE LAVA IS CONSIDERED PART OF THE PUAPUA VOLCANICS

SECTION 4

HYDROLOGY

4.1 CLIMATE

The Samoan Islands have a moderate tropical climate with an average annual temperature of 26.5° C (80° F) in the coastal areas. Both seasonal and diurnal fluctuations in temperature are relatively small. Rainfall varies from a minimum of 2300 mm (90 in.) in the northwest part of the island of Upolu, to 6000 mm (240 in.) per year in the highlands of Savaii (Kear, Kammer & Brands, Ref. 4).

The temporal and spatial distribution of rainfall in the Samoan Islands is heavily influenced by the wind direction and topography. The southeasterly trade winds are predominant throughout the winter months and prevail more than half of the time during the summer months. As a result, land areas to the northwest of the main ridge of Savaii have a wet season during the summer months (October through March) and a drier season during the winter months. On the southeastern side of the ridge, the rainfall is reportedly more evenly distributed throughout the year (Salifaleupolo, Ref. 5). The southeast portion of the island of Savaii is partially in the rain shadow of Upolu. In addition, the volcanic peaks in Savaii rise to an elevation of 1858 metres (6095 ft.) compared to about 1100 metres (3610 ft.) on Upolu. These differences result in significant differences in the spatial and temporal distribution of rainfall on the two islands.

A rainfall station and water level recorder were installed on the Eastern Branch of the Sili River during the latter part of 1980. The rainfall and water level records are discontinuous, however, with major gaps in the data. The monthly rainfall data from July 1981 to September 1984 are given in Table 4-1. Although the rainfall record is short and incomplete, there seems to be no clear pattern indicating distinctive wet and dry seasons.

Table 4-1

Rainfall (mm) in Sili Basin

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
1981							308	613	820	819	713	522
1982	333	489	251	198			351	1056	361	471	6371	550
1983	312	495	296	483	223	399		155				
1984		356		410	208		394	645	970			

urce: Zavalas, Ref. 6.

The records of the Tigitogiga station, situated on Upolu but similar in topography and wind direction, were also reviewed to determine if there were any seasonal trends in the rainfall distribution. The record period is short (1978 to 1985) and the records were incomplete, but the available data do not suggest the distinctive wet and dry seasons found at Apia, on the north side of the island of Upolu. No long-term rainfall records exist for any station on either island comparable to the Sili station, so that synthesis of rainfall records through regression analysis was not possible.

2 EFFECT OF GEOLOGY ON SURFACE WATER HYDROLOGY

The surface water hydrology is heavily influenced by the geology of the Samoan Islands. In some areas, the high permeability of the young volcanic formations results in rapid infiltration into the groundwater system which discharges to the ocean. Somewhat older formations have intermittent streams, and perennial streams are only found in some of the oldest formations.

For the perennial streams, the high spatial variability of the rock formations which underlie the drainage basins inhibits the prediction of runoff characteristics. This high spatial variability results in poor correlation between drainage area and runoff volume. This characteristic is particularly apparent on the Eastern Branch. Flow

records for the Sili River Basin cannot be transposed from one location to another in a different branch or even within the same branch without at least some spot measurements for correlation. In addition, given this high spatial variability in the stream flow, final selection of a site for diversion for water supply or hydroelectric power generation will require considerably more hydrologic data than are presently available.

EASTERN BRANCH

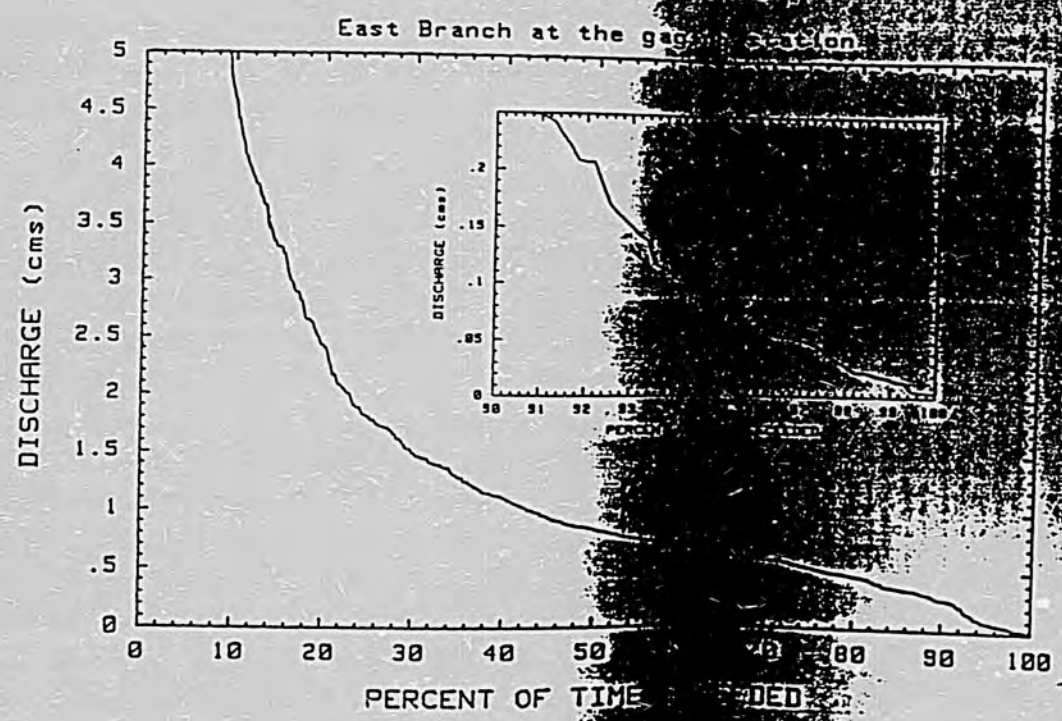
A rating curve for the gauging station on the Eastern Branch of the Sili River has been developed by the Apia Observatory using discharge measurements which were made periodically when the instruments were serviced. These discharge records are included in Appendix B of this report. The records are discontinuous, with numerous large gaps which make analysis difficult. Reconstruction of the flow records is unfortunately not possible due to the major gaps which also exist in the rainfall records. In addition, there is not sufficient data for low flow frequency analysis for the evaluation of firm yield for either water supply or power generation. However, because there are no distinctive wet and dry seasons in the Sili basin, all available daily discharge records from October 1980 to August 1984 (575 days) were analyzed to develop a preliminary flow-duration curve for the Eastern Branch as shown on Figure 4.

Figure 4 indicates that the median discharge of the Eastern Branch at the gauging station is approximately 0.85 cms, and that the desired water supply of 115 liters/sec. for Zones 1 and 2 would be available 94 percent of the time even without storage. Because the flow records are not sequential, it is difficult to evaluate the amount of storage that would be required to develop the 115 liters/sec. on a firm basis. However, simplified interpolation of the flow-duration curve was used to give a preliminary indication of this storage requirement. Figure 5

indicates that about 130,000 cubic meters of storage would be needed. The geologic characteristics which make it impractical to develop this amount of storage on the Eastern Branch are also the probable cause of the low level of flows during the relatively dry periods.

CENTRAL AND WESTERN BRANCHES

Although spot discharge measurements have been made on the Central and Western Branches of the Sili River, insufficient flow data are available to provide specific conclusions about the potential for water supply or power development. However, because there are indications that the geology underlying the Central Branch is less permeable than that found in the Eastern Branch, the low flows may not drop as low relative to median flows. Consequently, the Central Branch may be a more reliable source of water than the Eastern Branch. The collection of additional hydrologic data will be necessary to evaluate the relative reliability of each of these potential sources of water supply.



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FLOW DURATION CURVE		
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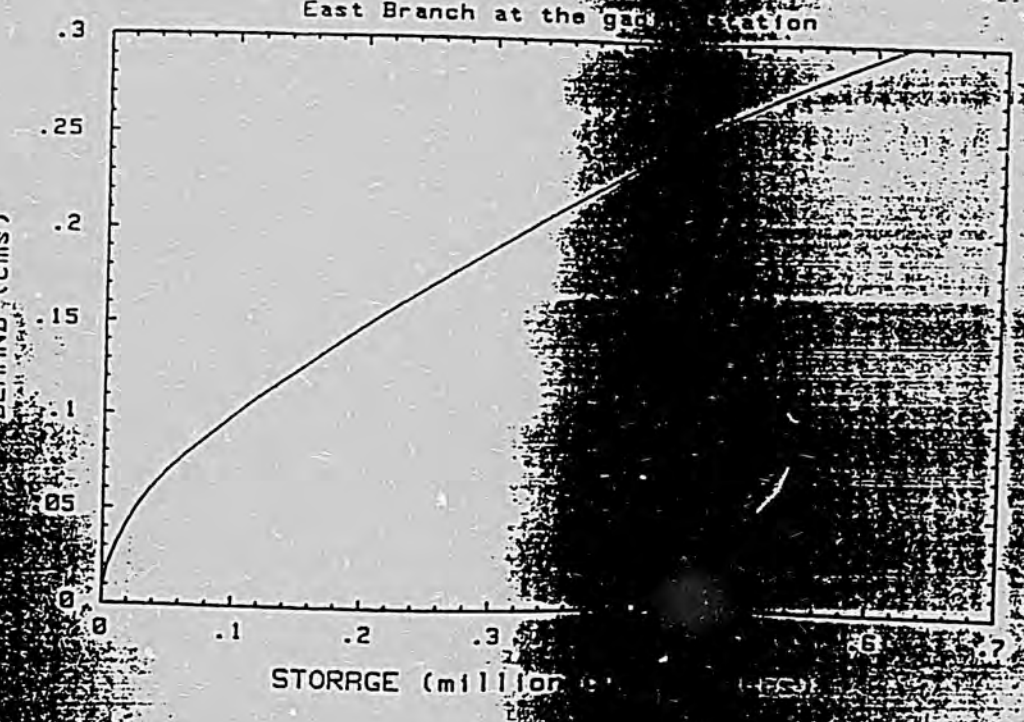

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SILI RIVER PROJECT

REQUIRED STORAGE

17870 | 5

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SECTION 5

CONCEPTUAL PROJECTS

GENERAL

This section describes the conceptual water supply projects which have been developed and analyzed during this study. The water resource development schemes are presented first, followed by the water supply pipeline systems and alternatives. Finally, a hydroelectric power option is discussed. The need for gravity water supply to the farthest demand points dictates a minimum elevation for a diversion pond in the order of El. 150 m, while a minimum intake elevation in the order of El. 200 m would be required for any hydroelectric development.

All figures referred to in this section are located at the end of the section.

.2 WATER RESOURCE DEVELOPMENT

The combination of field reconnaissance and hydrologic assessment previously described indicated two potential diversion sites in the Sili River Basin with appropriate characteristics to serve as water supply sources. These were:

- At about El. 200 m on the Central Branch
- At about El. 150 m on the Eastern Branch, in the vicinity of the existing gauging station.

For geologic reasons discussed earlier, only the Central Branch alternative appears to offer the option for a dam and the storage reservoir which would be required to enhance the reliability of water supply, or to provide the flow regulation needed to serve a hydroelectric powerhouse. The Eastern Branch site near the gauging station appears suitable only for a low diversion dam.

E)

No flow data exist for the Central Branch, but on the assumption that the Eastern Branch flows are comparable, the required regulating storage would be in the order of 130,000 cubic meters for water supply reliability only. To provide for both reliable water supply and hydroelectric power generation, a regulating storage of over one million cubic meters would be required as noted later in this section.

In view of the relatively high apparent reliability of water supply without storage (about 94%), and the lack of data at present, development of the Central Branch is envisioned in two stages: first, a simple diversion system for water supply, similar to that which could be provided on the Eastern Branch; and second, the addition of storage when demands or conditions dictate.

Conceptual structures required for diversion and storage of the stream flows are described below.

5.2.1 Central Branch Diversion.

The location of the proposed first-stage diversion for the Central Branch alternative is shown on Figure 6, and conceptual details of the diversion weir are presented on Figure 7. The diversion would be effected by a low concrete weir structure, about 3 m high at maximum section, with a weir crest length of about 10 meters. A single grout curtain would be provided to cut off subsurface flow beneath the weir. This structure would need to be designed considering the possible storage dam into which it might be incorporated later in stage two. The 500 mm diameter water supply pipeline intake would be located just below pond surface level and to the right of the weir, and would be controlled by a hand-operated slide gate. A sluice at the bottom of the pond, also with slide-gate control, would be used to aid in cleaning out sediments from the pond during maintenance. The road used for construction would be maintained as the operational access to the structure.

A 500 mm diameter, six-kilometer long steel water main, located alongside the access road, would convey the water down the mountainside to the head of the water supply pipeline(s) at the junction with the coastal road, as shown on Figure 6.

5.2.2 Eastern Branch Diversion.

The intake for the Eastern Branch water supply alternative, also shown on Figure 6, would be sited on the same pool as the existing gauging station, just downstream from a waterfall and at about El. 150 m. Conceptual details of the intake structure are depicted on Figure 8. No sluice is considered necessary at this site, as the long moderate river gradient upstream from the waterfall will result in gravel deposition there.

The 500 mm diameter intake, located on the left of the structure, would supply the 4.5-kilometer long pipeline connection to the head of the water supply pipeline(s) at the coastal road. The slope to the diversion is more gentle than that for the Central Branch, and access road and pipeline construction would be easier.

2.3 Storage Dam.

The second-stage storage dam on the Central Branch would be a rockfill structure with an upstream concrete membrane to provide the cutoff. The concrete diversion weir used for first-stage water supply operations would be incorporated into the toe of the membrane. Cutoff grouting required for the dam would be done from the crest of the diversion weir prior to construction of the dam. The general layout, section and details which were used to develop a preliminary cost estimate for the dam are shown on Figures 9 and 10. This dam would provide not only a firm yield of 115 liters/sec. for water supply purposes, but would also provide for hydroelectric power generation as discussed later in this section.

The dam would be provided with a low-level outlet controlled by valves and a downstream dispersion valve. The outlet pipe would be used also during construction as a diversion conduit. The outlet would take care of all flows except floods in excess of 4 m^3/sec. A concrete spillway chute slab on the downstream face of the rockfill was allowed for in the cost estimate. However, later studies should consider the alternative of reinforced rockfill to allow excess flow to pass through and over the rockfill, as is done in Australian practice. This could be practical and more economic.

.3 WATER SUPPLY PIPELINES

.3.1 Existing Situation.

The existing potable water supply situation on the island of Savaii is described in detail in the 1981 study by G. M. Meredith & Associates (Ref. 1). Water supply to the east of the Sili River Basin is provided from a central system diverting from Faleata River, with supplemental input from a pumped bore at Faga. This system supplies all coastal communities from Fa'ala to PuaPua with relatively high quality water, although isolated shortages occur such as at Logoipulotu College. To the west of the Basin, and in the Sili-Satupa'itea area at the Basin's mouth, potable water is supplied by several small non-centralized systems conveying water derived from springs and pumped bores. While some of these are more satisfactory than others, collectively they suffer from the following problems:

- They are expensive to operate and maintain, particularly those requiring deisel fuel for pumping.
- They are unreliable; pump breakdown can leave communities without water for extended periods, and some springs have quite variable production.
- They suffer relatively high water losses as some conveyance and distribution pipe systems are old and in poor condition.

- In some cases, borehole supplies have high salinity content due to seawater contamination; World Health Organization limits are exceeded in some of the larger systems.

As the Meredith study clearly demonstrates, a central water supply system is needed to serve the western portion of Savaii, from Sili village to the Asau District. This could be supplied from the Sili River Basin development plan described herein. The eastern portion of the island, from Sili village to PuaPua, generally appears to be adequately served by the existing system at least for the needs of the present population.

5.3.2 Southern And Eastern Systems.

Responsive to the requirements of the Agreement for Technical Services, an evaluation was made of needed water transmission pipelines and appurtenant facilities from the Sili River Basin for possible service to potable water in two zones of interest to the Department of Works in the eastern portion of the island:

- Zone 1: Foaluga to Gataival to Fa'ala
- Zone 2: Moata to Tuasivi to PuaPua

The proposed overall layout of the pipeline systems required to serve Zones 1 and 2 is shown on Figure 11, for the alternative diversions on the Central and Eastern Branches of the Sili River. Water delivery requirements have been based on population data supplied by the Department of Works, and an assumed future demand of 240 litres per person per day, including 20 percent transmission losses. The system adopted is based on a pressure pipeline following the main coastal road.

Consideration was given to supplying Zone 2 water requirements from a high elevation pipeline from the Central or Eastern Branch to the vicinity of Tuasivi. It was determined that it would be very

expensive and ecologically damaging to install such a pipeline across the difficult terrain of the island. A road would have to be pioneered and continuously maintained for construction access and pipeline maintenance, and as noted in Section 8 of this report this could have a serious adverse ecological impact on the Sili River Basin and adjacent watersheds. No savings in pipeline costs would result from the lower pipeline pressure, because the pipes required along the coastal route would already be of minimum wall thickness, governed by handling considerations rather than design pressure.

Storage tanks serving individual villages would be supplied by off-takes at each village, rather than from more intermittent major "center-of-demand" off-takes, so that the main pipeline diameter and thus the pipeline cost can be reduced as the required carrying capacity diminishes. Storage tank capacities have been based on population supplied as indicated in the Meredith report (Ref. 1). Materials other than steel could be used for the distribution lines leading from the storage tanks to the villages, and these should be investigated during more detailed feasibility studies as considerable savings may be achievable. Orifice devices would be used to control inflow into the tanks to avoid the problem of excessive draw-off of water near the head of the supply pipeline and resulting deficiency of water toward the end of the line.

Water treatment is not specifically included in the proposed system at present, although a chlorination plant could be provided at little cost. It is noted that while no provision for water treatment was included in the Asau water supply study, treatment is in fact being used for the Apia supply system. The question of treatment needs should be investigated during the detailed feasibility study.

3.3 Alternative Western Savaii Water Supply.

An evaluation was also made of the alternative of supplying potable water from the Sili River Basin to the western part of the island up

to the Asau area, to determine the comparative cost of this alternative and to enable the Department of Works to evaluate the two possibilities in the context of overall water supply for the whole island. The layout of this pipeline system is shown on Figure 12, for both alternative diversion points on the Central and Eastern branches of the Sili River. The criteria for sizing of the pipeline and appurtenant facilities were generally the same as described above for the Zone 1 and 2 supply. In this layout, the crossing of the Falealupo peninsula was eliminated in favor of an alignment around the peninsula, which would permit service from the chosen diversion points without the need for booster pumps.

HYDROELECTRIC PROJECT

For purposes of evaluating the potential and cost of hydroelectric energy generation within the Sili River Basin, development of the water resources of both the Central and Western Branches was considered. The project would include a storage dam and reservoir on the Central Branch adequate to meet the water supply demand of 115 litres/second and also to provide a significant amount of firm power, plus a facility for diverting flows from the Western Branch into the Central Branch above the dam site. Because of the lack of available data, a detailed study to optimize facility sizes was not deemed justified for this pre-feasibility investigation. However, the sizes of the facilities adopted through engineering judgement are believed reasonable and appropriate for present purposes of estimating unit costs of hydroelectric energy. The proposed hydroelectric project would be composed of three principal elements: the storage reservoir, penstock, and powerhouse. These are discussed in more detail below.

5.4.1 Storage Reservoir.

In order to estimate the amount of storage which would be needed for this project, a simplified operation study was performed. It was found that provision of reservoir storage in the order of 1.25 million cubic

meters would meet the 115 litres/second potable water demand and generate power, with a reliability approaching 100 percent both for the water supply and in terms of meeting daily peak power demands. Daily operation of the power plant assumed a 1.5 MW peak for four hours and a 0.6 MW average load for the remaining 20 hours, resulting in an annual energy output of 6.57 GWh. This energy and capacity is considerably in excess of current usage on Savaii, as shown in the 1984 data obtained from the Electric Power Corporation (Appendix C). Thus the facility sizing described herein is that which would essentially maximize the potential of the water resource, rather than to meet any specific projection of energy and capacity needs. During more detailed feasibility studies, optimization of project sizing should be carried out against more detailed power requirement forecasts.

The dam required to create the storage reservoir on the Central Branch would be a concrete-faced rockfill structure approximately 22 meters high, as discussed in Paragraph 5.2.3.

5.4.2 Penstock.

As shown on Figures 6 and 10, the penstock would consist of two reaches of steel pipe:

- 1700 m of 800 mm diameter steel pipe from the dam, sited adjacent to the access road and the water supply main; then,
- 350 m of 700 mm diameter steel pipe down the side of the canyon to the powerhouse.

The flow of water into the penstock would be controlled by a gate valve in the vertical access shaft at the dam, with both penstock and water supply main encased in concrete through the embankment.

.4.3 Powerhouse.

The powerhouse would be located on the right bank of the Central Branch at about El. 60 m, thus providing an operating hydraulic head

of about 160 m at full reservoir. The proposed layout of the powerhouse is shown on Figures 13 and 14. This conceptual layout includes two 750 kw Ossberger units. These units are considered ideal for such an installation as they operate satisfactorily from full flow to one-third flow, thus having the flexibility to follow widely-varying load demands. The Ossberger is an impulse unit, and requires only a simple sump underneath it to receive the discharged water, which would be returned to the Central Branch stream channel.

The generators, rated at 800 kw, are shown with speed-increase couplings to the Ossberger units, but direct coupling may be more appropriate. Each turbine, generator, electric governor, and shutoff and relief valves would in fact be supplied as a packaged unit.

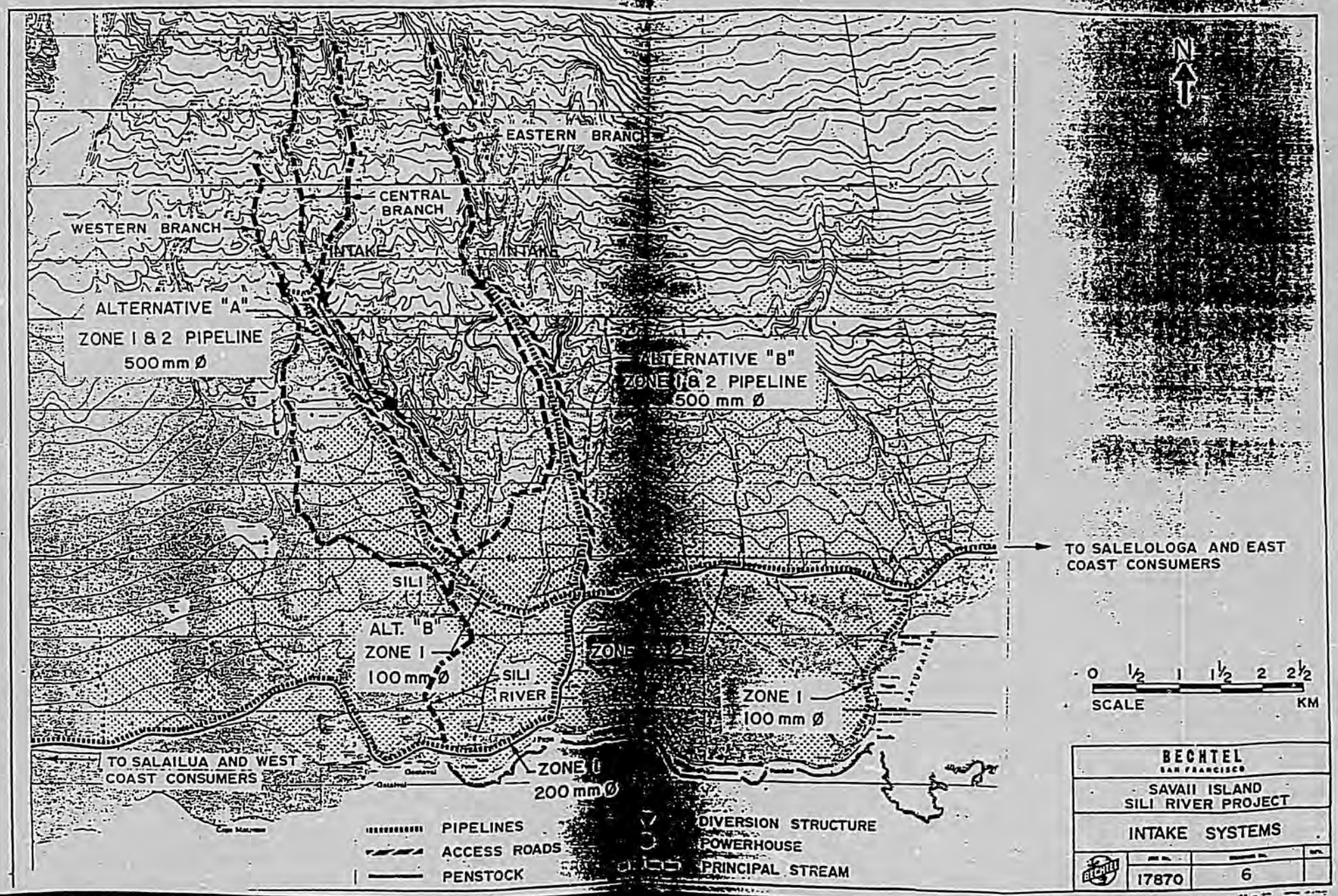
The powerhouse itself would have a simple concrete substructure and a galvanized steel superstructure with galvanized cladding and fan ventilation. Excitation for operation would presumably be provided from the transmission line, from a Salelologa diesel standby unit.

IRRIGATION

Irrigation was referred to as a potential water demand during the Bechtel team's site visit, but no specific information could be obtained on requirements, crops, or extent or frequency of need. The following observations are therefore general, and would require investigation for specific applicability to the area. The excess river flows, and especially the power station discharges of stored water, may indeed have some potential for irrigation use in the Sili area.

It is expected that the soils of the area have high permeability and low moisture-holding capacity because of their origin. Thus, even short dry spells may lead to excessive depletion of available moisture in the soils, and thus to plant wilt and crop reduction. In such

circumstances, drip irrigation would seem to be indicated as appropriate, although this system involves relatively high installation and maintenance costs. Drip irrigation would need to be evaluated in relation to the enhancement of crop input (existing crops), or to the potential for the introduction of high value crop production. The siltiness observed in the Central and Western Branches would require investigation, in relation to the filtration needs for a drip irrigation system. The storage reservoir might eliminate this need, if the source of sediments is upstream from the reservoir.



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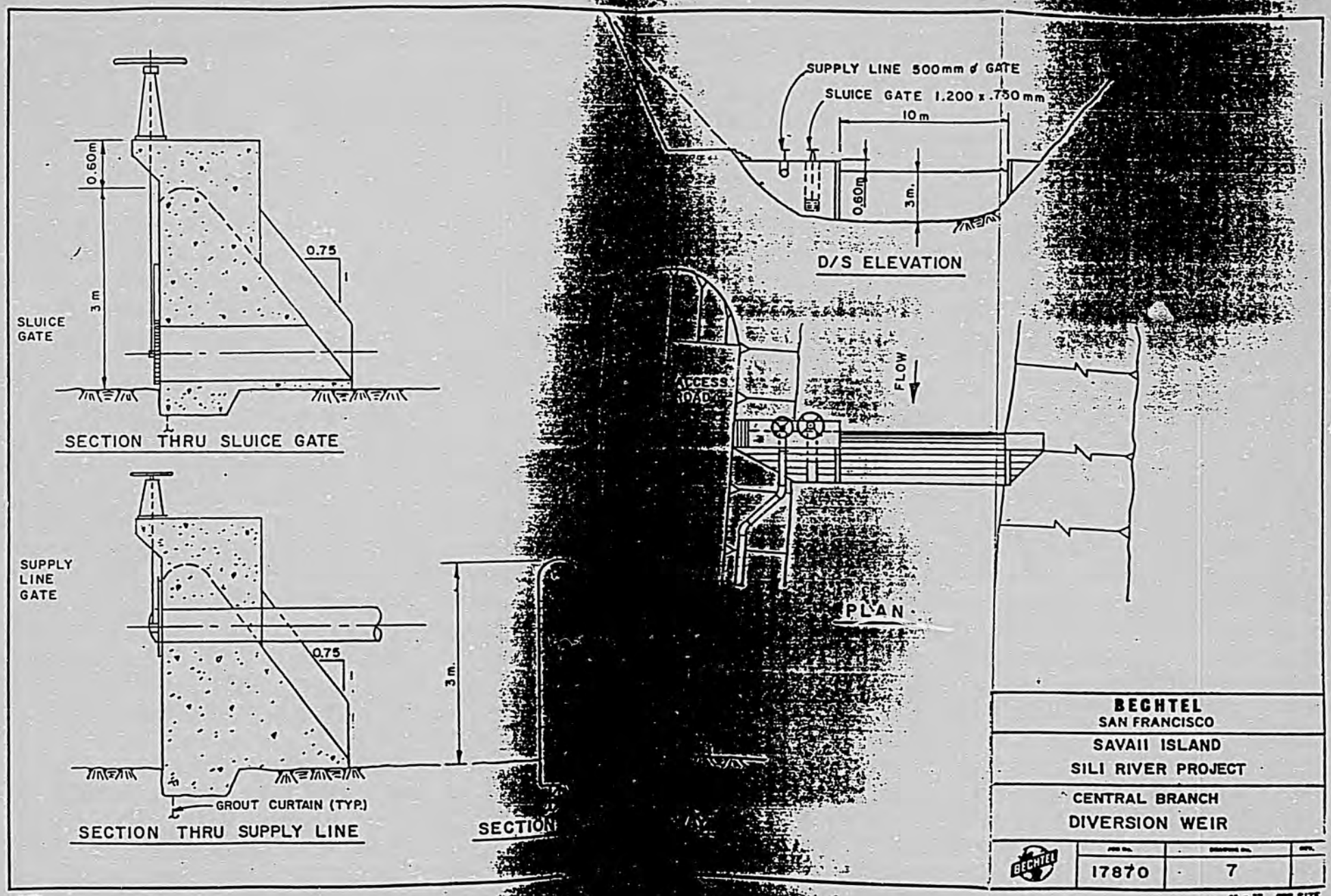

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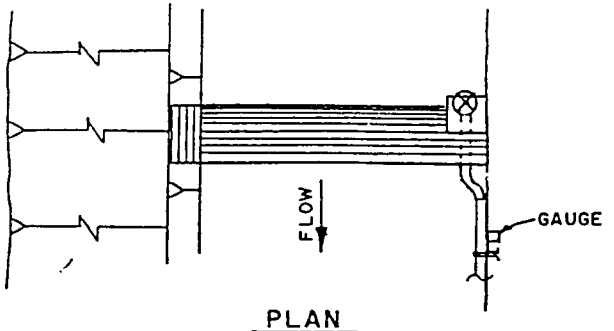
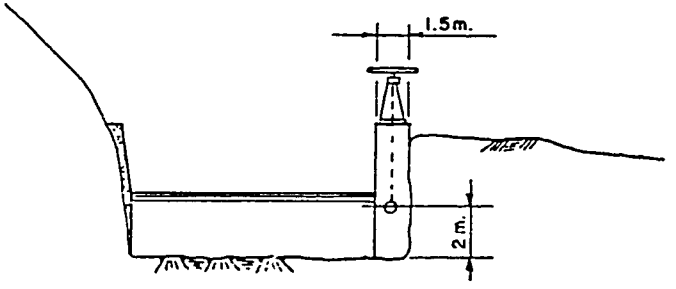


PLAN



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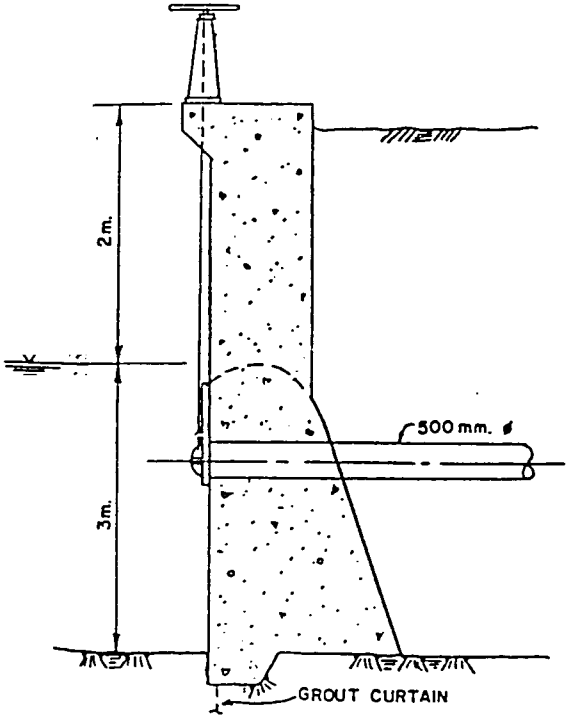
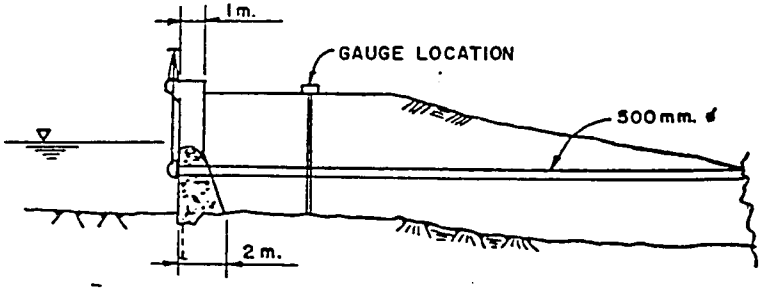


SECTION THRU SUPPLY LINE



ELEVATION

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SILI RIVER PROJECT

EASTERN BRANCH
DIVERSION WEIR

JOB NO.	DRAWING NO.	REV.
17870	8	

11 x 17 "B" SIZE

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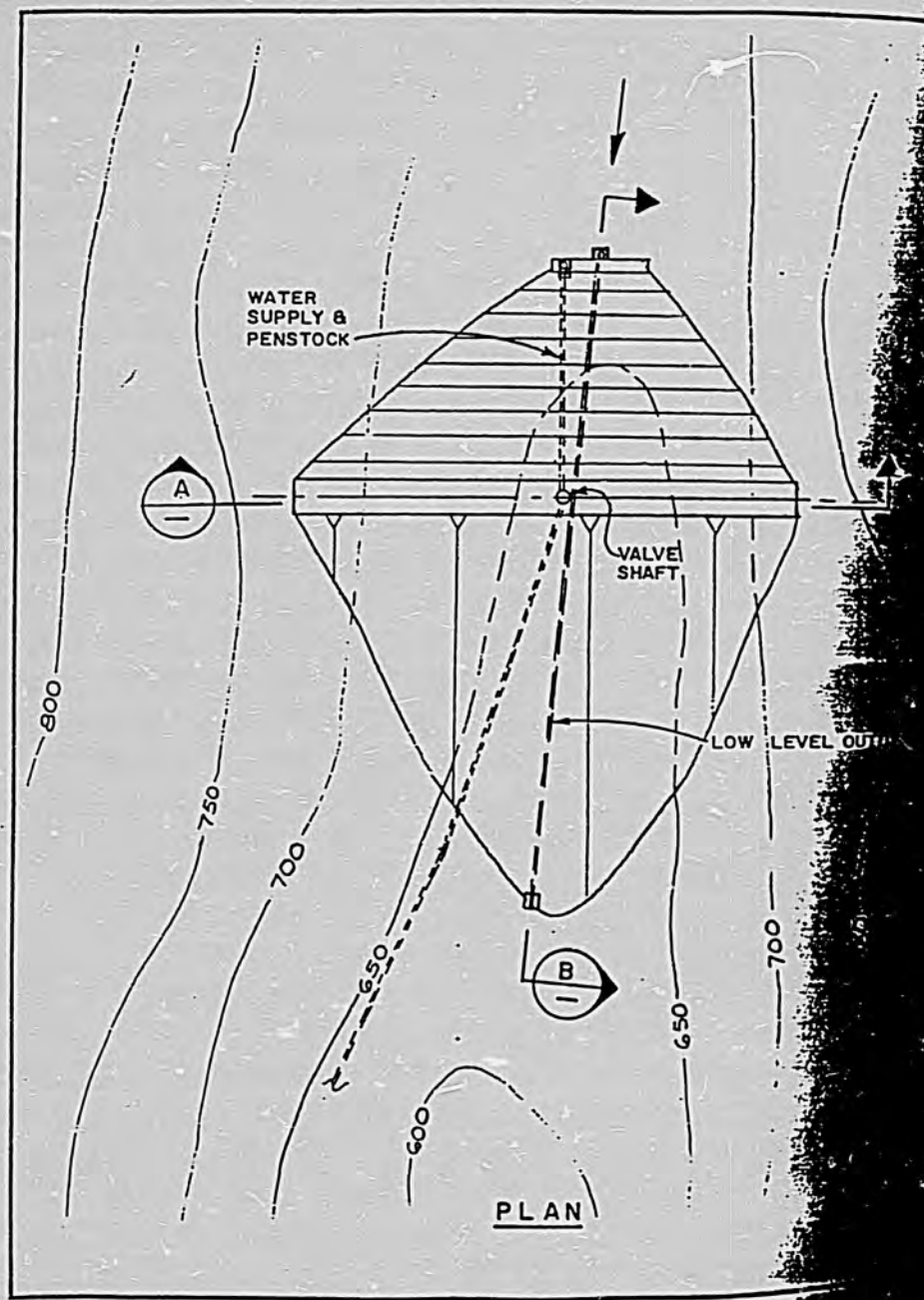

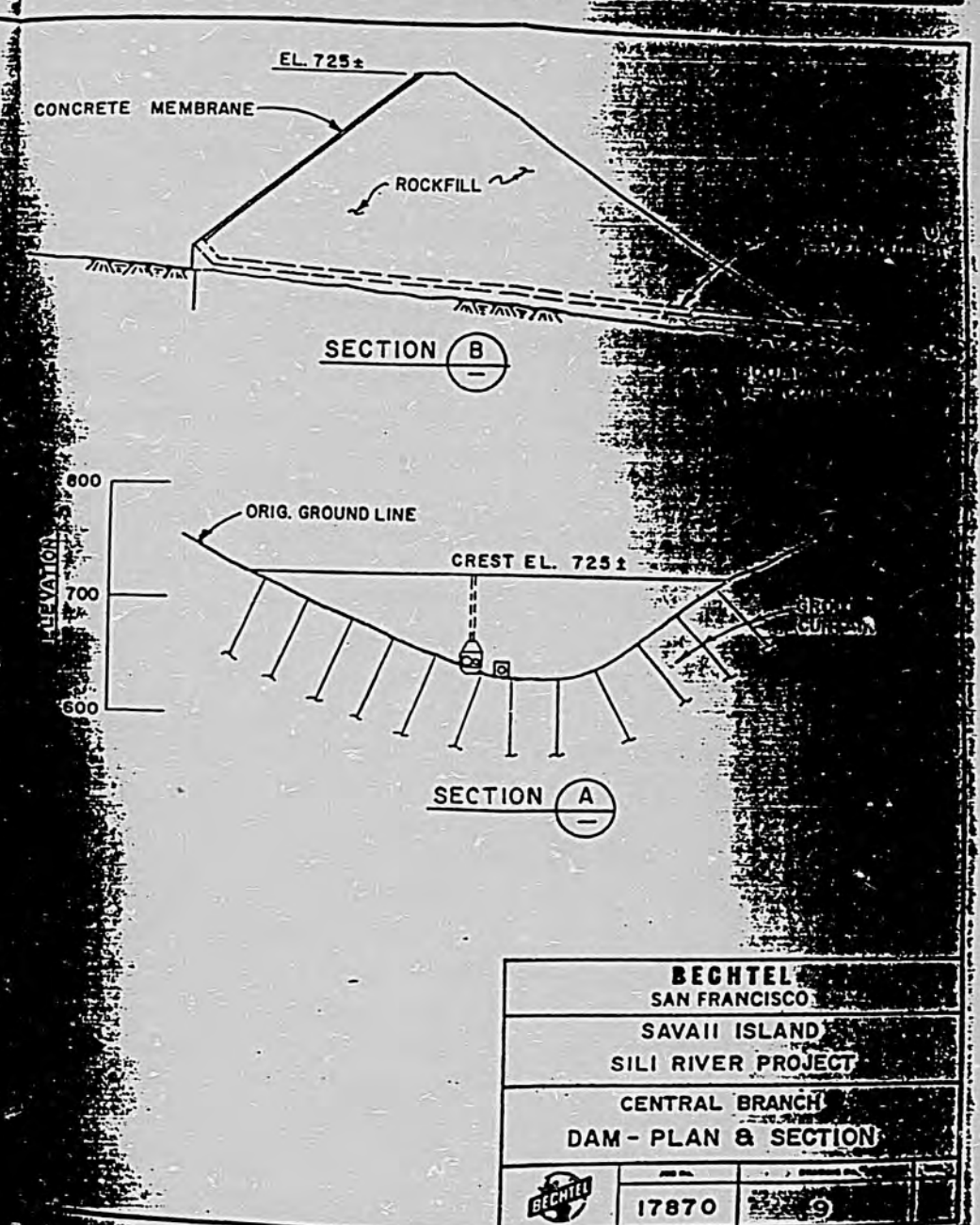

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SAVAII ISLAND
SILI RIVER PROJECT

CENTRAL BRANCH
DAM - PLAN & SECTION

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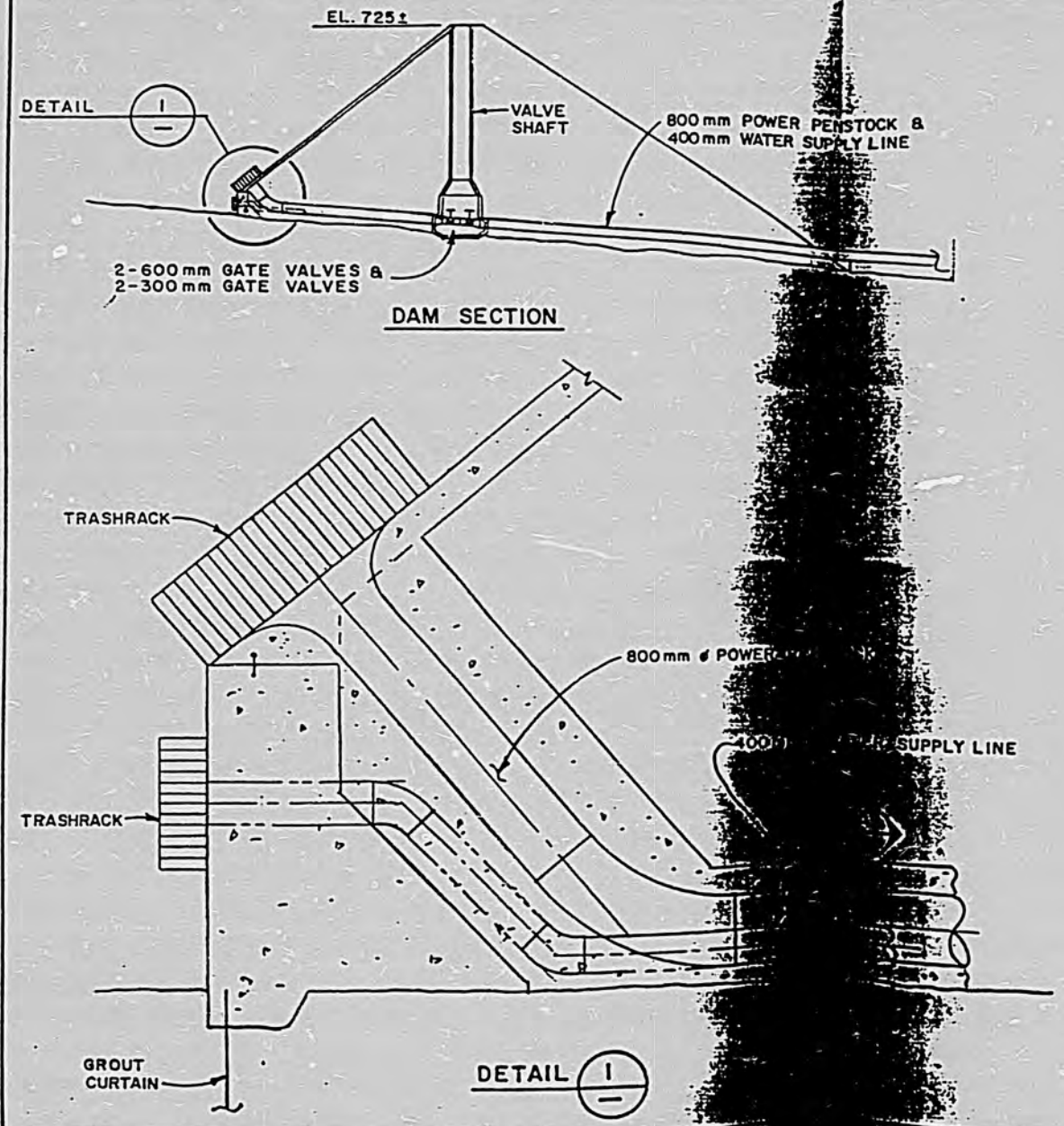
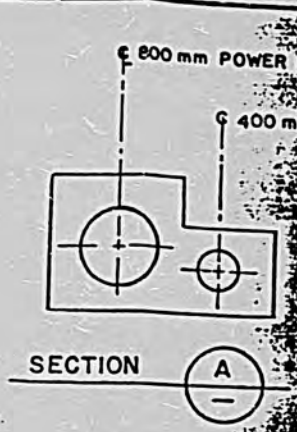
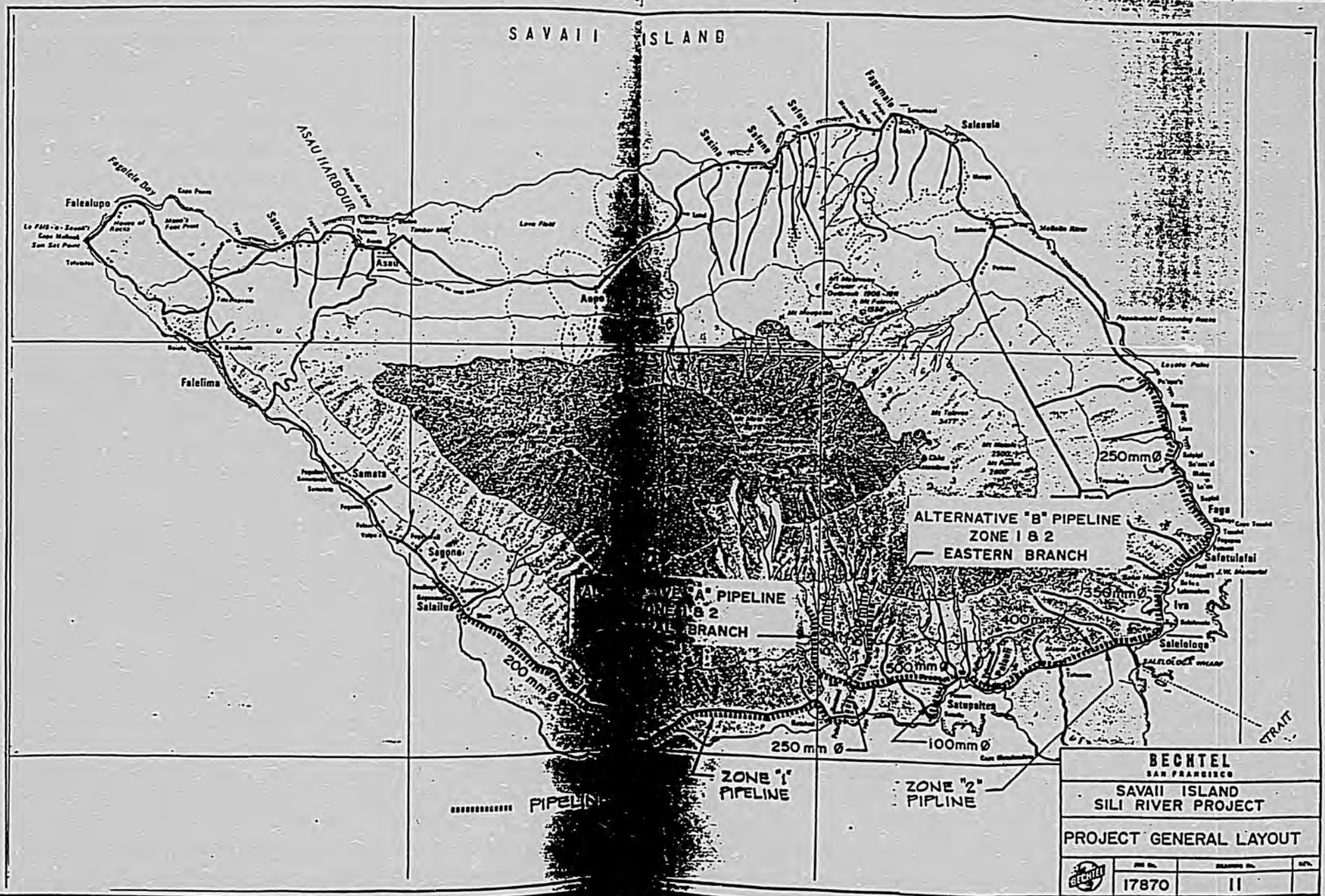




BECHTEL SAN FRANCISCO			
SAVAII ISLAND SILI RIVER PROJECT			
CENTRAL BRANCH DAM - SECTIONS & DETAIL			
BECHTEL	JOB NO. 17870	DRAWING NO. 10	REV.

11 x 17 "B" SIZE



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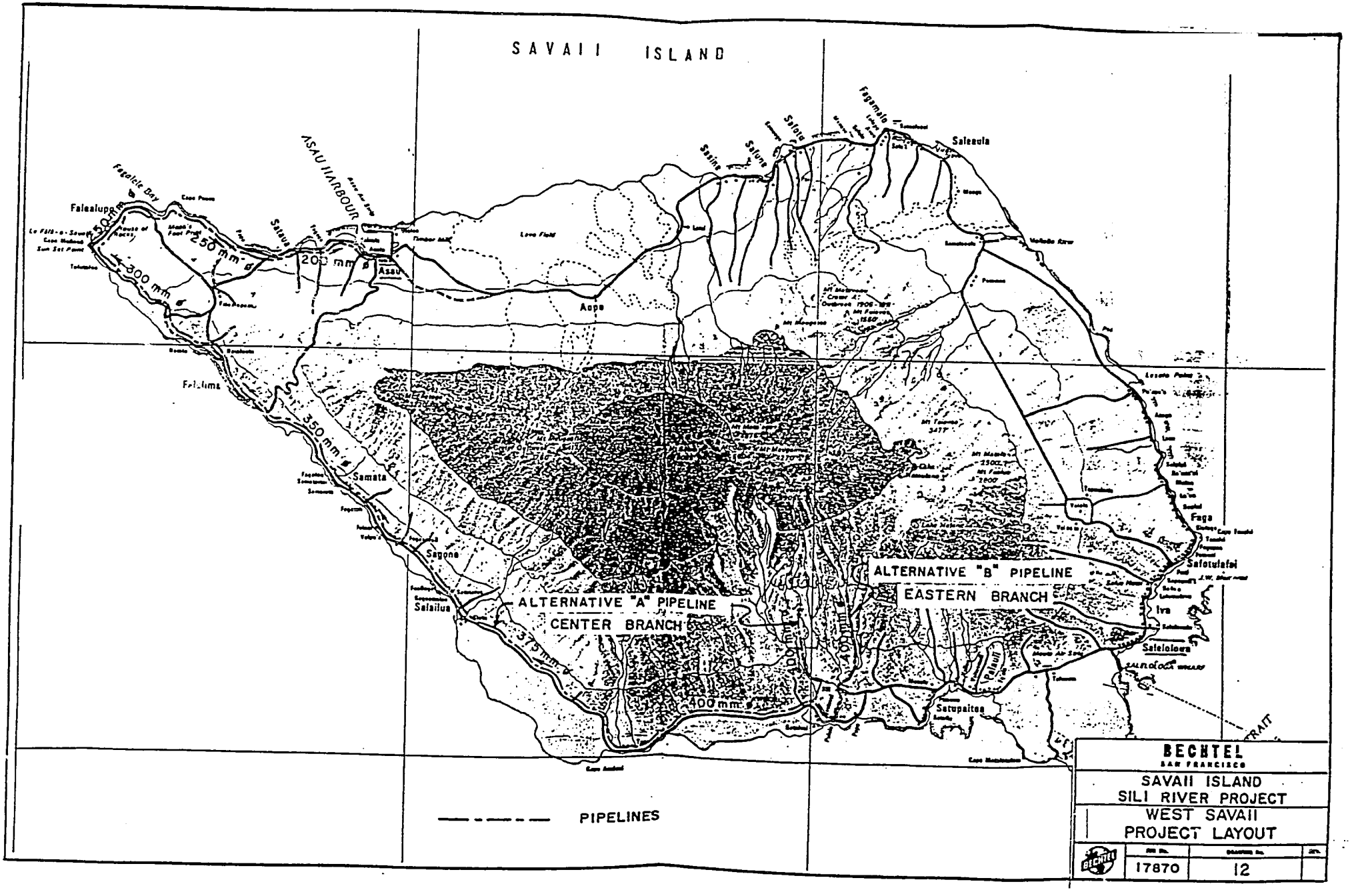
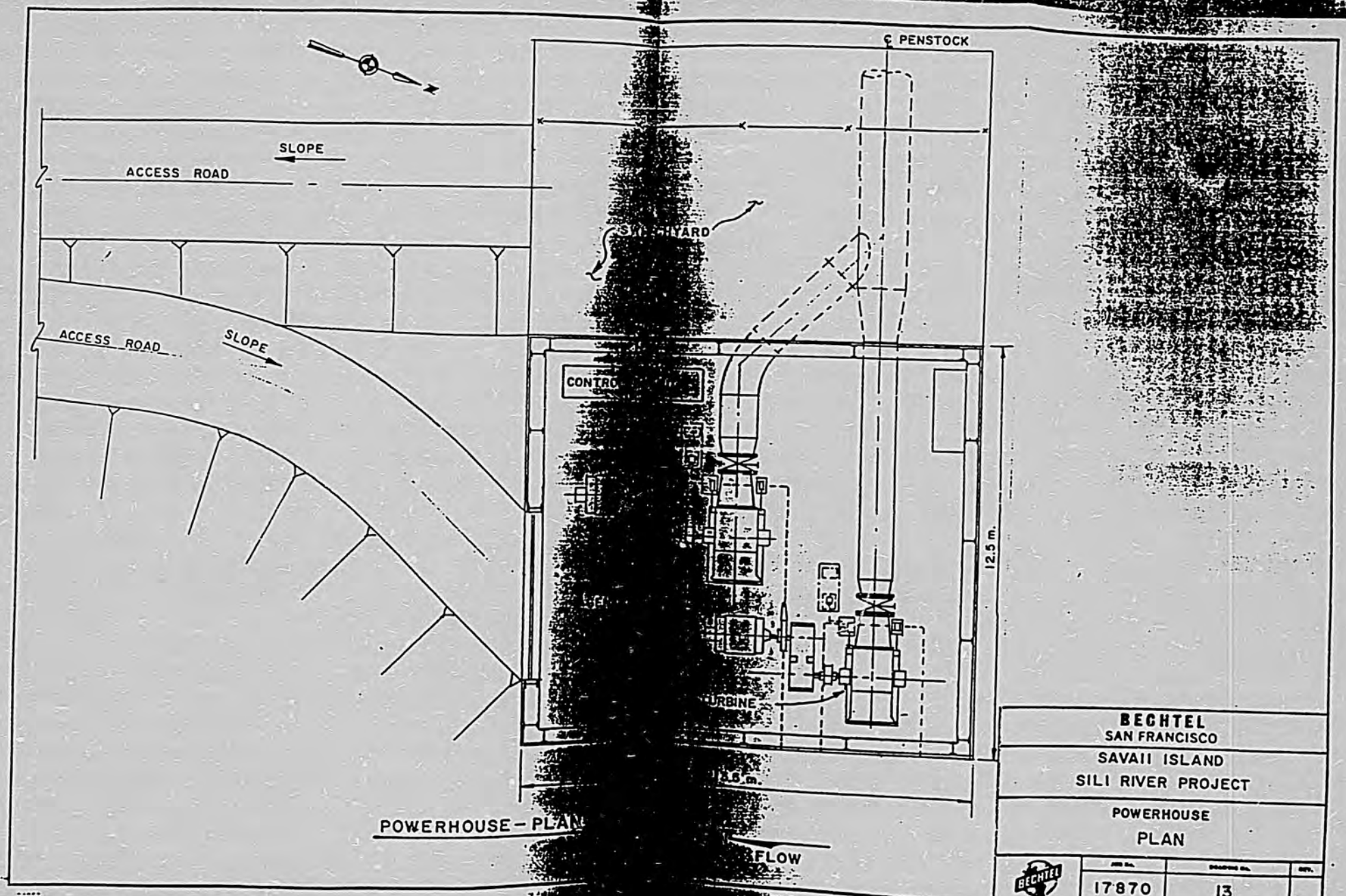

SAVAII ISLAND
ASAU HARBOUR
Fagaloa Bay
Falealupo
Satuia
Asau
Aopo
Saleaula
Fagamalo
Salega
Salua
Sasina
Fei'ilima
Samata
Sagone
Salailua
Satupaitea
Fagaloa
Safotulafai
Iva
Saleleloga
Palauli
ALTERNATIVE "A" PIPELINE
CENTER BRANCH
ALTERNATIVE "B" PIPELINE
EASTERN BRANCH
300 mm
250 mm
200 mm
350 mm
375 mm
400 mm
PIPELINES
BECHTEL
SAN FRANCISCO
SAVAII ISLAND
SILI RIVER PROJECT
WEST SAVAII
PROJECT LAYOUT
17870
12



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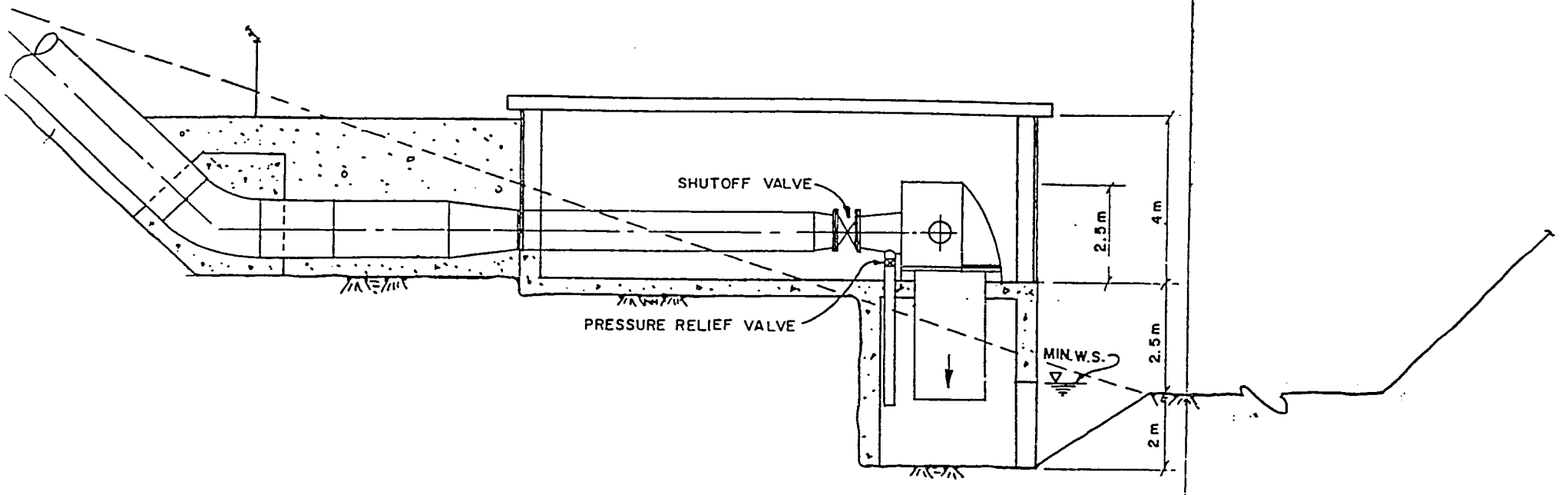

SECTION THRU PENSTOCK

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SILI RIVER PROJECT

POWERHOUSE
SECTION

JOB NO.	DRAWING NO.	REV.
17870	14	

11 x 17 "B" SIZE

SECTION 6

COST ESTIMATES

6.1 GENERAL

Reconnaissance-level cost estimates have been prepared for a variety of options for water supply from the Sili River Basin, as well as for the hydroelectric project described in Section 5. These are shown in the following Tables 6-1 through 6-7.

Tables 6-1 and 6-2 summarize the cost of potable water supply systems serving the Southern and Eastern portions of Savaii Island and the alternative Western system, as described in Section 5. Tables 6-3, 6-4, 6-5 and 6-6 provide detail for the estimated costs of the main supply pipelines serving those systems. The other significant costs, for storage tanks and the distribution (reticulation) systems serving consumers from those tanks, were based on data obtained from the Department of Public Works and the Meredith report.

Table 6-7 summarizes the reconnaissance-level cost estimate developed for the hydroelectric project described in Section 5.

As expected, Tables 6-1 and 6-2 show that the Southern and Eastern portions of the island could be served most economically from the Eastern Branch of the Savaii River, while the Western portion of the island could be served most economically from the Central Branch. The differences in cost are small, however. For practical purposes, the economic evaluation of unit water costs in Section 7 of this report will be based on the use of the lowest cost system in each case.

6.2 BASIS OF ESTIMATES

All cost estimates are based on the assumption that work will be awarded to offshore contractors, either New Zealand or Australian, with local labor being used for unskilled work such as pipelayers, drivers, laborers and helpers.

Structural concrete, forms, reinforcing steel and concrete storage tank construction prices are based on recent bid costs experienced on similar type work in Western Samoa. In the case of the hydro power project, it was assumed that the diversion weir would already be in place when the storage dam is constructed. Should that not be the case, the cost of the power project would increase by approximately W.S. $150,000.

Pipe material prices are based on Japanese supply. Gates, valves, turbines, governors, and generator prices are based on manufacturers' quotes.

Installation of pipelines, except for penstocks on the hydro power project, is based on use of local labor with foreign supervision. Installation of penstocks is based on use of mainly foreign labor and supervision due to the specialized nature of the work involved. Installation of turbines, generators, and associated equipment is also based on use of mainly foreign labor and supervision.

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TABLE 6-1

COST OF WATER SUPPLY PROJECT
SOUTHERN AND EASTERN SYSTEMS

(All costs in W.S. $)

	Central Branch Diversion	Eastern Branch Diversion
Diversion Structure	$ 25,200	$ 18,200
Gates	26,500	6,500
Access Roads	127,500	30,000
Main Supply Pipeline (a)	6,077,900	5,887,800
Storage Tanks	2,484,000	2,484,000
Distribution	2,479,100	2,479,100
Sub-Total	11,220,200	10,905,600
Contingency 20%	2,244,000	2,181,100
TOTAL (b)	$ 13,464,200	$ 13,086,700

See Tables 6-3 and 6-4 for detail.

At October 1985 Price Levels.

TABLE 6-2

COST OF WATER SUPPLY PROJECT
ALTERNATIVE WESTERN SYSTEM

(All costs in W.S. $)

	Central Branch Diversion	Eastern Branch Diversion
Diversion Structure	$ 25,200	$ 18,200
Gates	26,500	6,500
Access Roads	127,500	30,000
Main Supply Pipeline (a)	7,760,000	8,160,300
Storage Tanks	1,404,000	1,404,000
Distribution	1,401,200	1,401,200
Sub-Total	10,744,400	11,020,200
Contingency 20%	2,148,900	2,204,100
TOTAL (b)	$ 12,893,300	$ 13,224,300

See Tables 6-5 and 6-6 for detail.

At October 1985 Price Levels.

TABLE 6-3

MAIN SUPPLY PIPELINE COST
SOUTHERN AND EASTERN SYSTEMS
CENTRAL BRANCH DIVERSION

Sections to East	Distance M	Flow l/Sec.	Pipe Dia. mm	Friction Loss M	Gradient Level	Weight Kg.	Cost W.S. $
1. Intake to Sili Intersection	6,000	115	500	5.57	150	480,000	1,036,800
2. Sili Intersection to Fa'ala	9,700	92	500	5.77	144	776,000	1,676,160
3. Fa'ala to Salelavalu	8,200	60	400	6.80	138	508,400	1,098,140
4. Salelavalu to Tuasivi	6,500	44	350	6.37	132	193,400	417,740
5. Tuasivi to PuaPua	10,000	21	250	11.90	125	227,000	490,320
Branch: Mosulato Satufia	3,000	-	100	-	-	48,000	103,680
SUBTOTAL	43,400			36.41	113	2,232,800	4,822,840
Sections to West							
1. Sili Intersection to Gataivai	5,000	23	250	7.50	144	113,500	245,160
2. Gataivai to Foaluga	26,000	11	200	29.25	136	467,540	1,009,890
SUBTOTAL	31,000			36.75	107	581,040	1,255,050
GRAND TOTALS	74,400					2,813,840	6,077,890

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TABLE 6-4

MAIN SUPPLY PIPELINE COST
SOUTHERN AND EASTERN SYSTEMS
EASTERN BRANCH DIVERSION

Sections to East	Distance M	Flow 1/Sec.	Pipe Dia. mm	Friction Loss M	Gradient Level	Weight Kg.	Cost W.S. $
1. Intake to Sili Intersection	4,500	115	500	4.18	150	360,000	777,600
2. Sili Intersection to Fa'ala	9,700	92	500	5.77	146	776,000	1,676,160
3. Fa'ala to Salelavalu	8,200	60	400	6.80	140	508,400	1,098,140
4. Salelavalu to Tuasivi	6,500	44	350	6.37	133	193,400	417,740
5. Tuasivi to PuaPua	10,000	21	250	11.90	127	227,000	490,320
Branch: Mosulato Satufia	3,000	-	100	-	-	48,000	103,680
SUBTOTALS	41,900			35.02	115	2,112,800	4,563,640
Sections to East							
1. Sili Intersection to Gataivai	5,000	23	250	7.50	144	113,500	245,160
2. Gataivai to Foaluga	26,000	11	200	29.25	136	467,540	1,009,890
Branch: Intersection to Sili	2,000	-	100	-	-	32,000	69,120
SUBTOTALS	33,000			36.75	107	613,040	1,324,170
GRAND TOTALS	74,900					2,725,840	5,887,810

(7976E)

TABLE 6-5

MAIN SUPPLY PIPELINE COST
ALTERNATIVE WESTERN SYSTEM
CENTRAL BRANCH DIVERSION

Sections to East	Distance M	Flow l/Sec.	Pipe Dia. mm	Friction Loss M	Gradient Level	Weight Kg.	Cost W.S. $
1. Intake to Palauli District	6,000	67.0	400	6.20	200	372,000	803,520
2. Palauli La Falefa	13,500	63.8	400	12.70	194	837,000	1,807,920
3. Palauli West	20,800	54.7	375	20.20	181	1,206,400	2,605,820
4. Salega-Falelima Village	19,600	39.0	350	14.00	161	578,200	1,248,900
5. Alataua West	8,000	25.3	300	5.47	147	216,000	466,560
6. Falealupo	5,000	19.8	250	5.54	141	113,500	245,160
7. Vaisigano West	7,500	15.8	250	5.27	136	169,000	365,040
8. Vaisigano East	5,600	9.9	200	5.10	131	100,200	216,430
TOTAL	86,000			74.48	126	3,592,300	7,759,350

7976E)

TABLE 6-6

MAIN SUPPLY PIPELINE COST
ALTERNATIVE WESTERN SYSTEM
EASTERN BRANCH DIVERSION

Sections to East	Distance M	Flow l/Sec.	Pipe Dia. mm	Friction Loss M	Gradient Level	Weight Kg.	Cost W.S. $
1. Intake to Palauli District	9,000	67.0	400	9.31	150	558,000	1,205,280
2. Palauli La Falefa	13,500	63.8	400	12.70	141	837,000	1,807,920
3. Palauli West	20,800	54.7	375	20.20	128	1,206,400	2,605,820
4. Salega-Falelima Village	19,600	39.0	350	14.00	108	578,200	1,248,050
5. Alataua West	8,000	25.3	300	5.47	94	216,000	466,560
6. Falealupo	5,000	19.8	250	5.54	88	113,500	245,160
7. Vaisigano West	7,500	15.8	250	5.27	83	169,000	365,040
8. Vaisigano East	5,600	9.9	200	5.10	78	100,700	217,510
TOTAL	89,000			77.59	72	3,778,800	8,161,340

7976E)

Table 6-7

COST OF HYDROELECTRIC PROJECT

(All costs in W.S.$)

Item	Cost
Diversion of Western Branch	123,090
Rockfill dam	941,200
Outlet pipe	26,280
Outlet dispersion valve	120,000
Penstock line	515,740
Bifurcation	25,330
Trashrack	3,750
Concrete encasement of pipes	57,300
Access shaft	18,400
Outlet gate valves	40,000
Penstock gate valves	9,000
Powerhouse excavation & backfill	7,790
Substructure	19,040
Superstructure	35,190
Turbines, Generators, Governors, Shut-off valves	974,000
Miscellaneous electrical equipment	168,000
Switchyard	300,000
Transmission line	243,000
Access roads	74,250
Sub-Total	3,701,360
Contingency 20%	740,240
Total (a)	$4,441,600

(a) At October 1985 Price Levels

974E)

SECTION 7

PROJECT EVALUATION

7.1 WATER SUPPLY - SOUTHERN AND EASTERN SYSTEMS

The following analysis of unit water cost has been made on the basis of the water supply pipeline providing the design quantity of water at 55 l/sec. to Zone 1 and 60 l/sec. to Zone 2. The total annual consumption on this basis would be 3.6 million cubic meters. As noted in Section 6, it is appropriate to consider diversion from the Eastern Branch of the Sili River for service to the southern and eastern portion of the island. The cost per cubic meter of water has been evaluated from the cost data developed in Section 6, for the following discount rates applied to capital costs:

1. Zero
2. 2 percent
3. 5 percent
4. 10 percent

With the annual maintenance costs taken as 0.5 percent for main supply pipelines and storage tanks, two percent for diversion structures and distribution lines, and five percent for roads, the cost of annual maintenance for the Eastern Branch water supply system will be:

Diversion Structures	500
Access Roads	1,500
Main Supply Pipelines	29,400
Storage Tanks	12,400
Distribution Lines	49,600
Total	W.S.$ 93,400

Thus, for a 30-year project life, the estimated total annual costs and cost per cubic meter of water delivered from the Eastern Branch scheme are:

	W. S. Tala			
	Zero	2%	5%	10%
Capital Cost	436,200	584,300	851,300	1,388,200
Maintenance	93,400	93,400	93,400	93,400
Total	529,600	677,700	944,700	1,481,600
Cost per cubic meter (W.S. $)	0.146	0.187	0.261	0.409

Based on the projected year 2010 population of approximately 41,000 in this service area, the investment cost per head of population served would be $320.

It should be noted that at the present time consumers pay nothing for the water supplies they receive. Further, it is considered impractical to recover the cost of construction and maintenance of a new water supply system through consumer charges. No metering has been included in the cost estimates for distribution systems presented herein; addition of the cost of meter installation and maintenance, meter reading, and billing systems would have a significant impact on the unit water costs shown above.

7.2 WATER SUPPLY - WESTERN SYSTEM

On the assumption that the alternative system serving the western part of the island of Savii would be supplied from the first-stage diversion facility constructed on the Central Branch, the justification for which is developed in Section 6, comparable figures for the total annual costs and cost per cubic meter of water delivered to the Western System are:

	W. S. Tala			
	Zero	2%	5%	10%
Capital Cost	429,800	575,700	838,700	1,367,700
Maintenance	81,000	81,000	81,000	81,000
Total	510,800	656,700	919,700	1,448,700
Cost per cubic meter (W.S. $)	0.241	0.311	0.435	0.685

According to the Meredith report (Ref. 1), projected year 2010 population in this service area is approximately 24,000, which gives an investment cost per capita served of $540. The unit costs per cubic meter shown above are based on a total annual consumption of 2.1 million cubic meters.

7.3 HYDROELECTRIC PROJECT

As noted in Section 5, the Central Branch annual energy production has been estimated on flows recorded at the Eastern Branch gauge. Assuming that all of the estimated dependable energy production of 6.57 GWh per year can be marketed, the unit cost of energy would be:

	W. S. Tala		
	Zero	5%	10%
Capital Cost	148,050	288,930	471,170
Maintenance (2%)	2,960	2,960	2,960
Total	151,010	291,890	474,130
Cost per KWh (W.S. $)	0.023	0.044	0.072

The above figures exclude the costs of owner's administration, operation, and insurance.

In normal circumstances, these energy costs would be considered quite reasonable. However, as long as the existing Asau steam plant is generating virtually free energy by burning timber slashings, there is no incentive to develop a new hydroelectric energy source at considerable cost. Even if the Asau generators need to be replaced by new units, that capital cost would still be less than a hydroelectric plant regardless of the discount rate used. Further, when the intertie now under construction between Asau and Salelologa is completed, the expensive present diesel power generation at Salelologa can be eliminated and the diesel units placed on stand-by service.

The life of the present Asau mill will be limited by the availability of economically-accessible timber resources. If the mill is rebuilt at a new location in the future, the capital cost of a new electricity generation facility and of the chip fuel may — and probably should — be recovered through energy charges. Alternatively, if the mill is abandoned, the source of the present free power will be lost. The hydroelectric resource of the Sili River Basin will always be available as a standby alternative provided the watershed is preserved by careful ecological management and provided further that water is not diverted for other purposes upstream from the recommended dam and reservoir site on the Central Branch of the Sili River.

8. ECOLOGICAL CONSIDERATIONS

The watershed of the Sili River is the largest such river basin on the island of Savaii. It should be considered as a common watershed with the adjoining Gataivai because it is impossible to completely separate the two resources. This watershed provides the best source of potable supply for central systems serving the populated perimeter of the island, from the Asau District in the northwest to PuaPua on the eastern coast. Furthermore, it is the only stream that could provide hydroelectric energy and irrigation water supplies in the future.

The problem with all the streams on the island is that although their yields are plentiful during periods of rain, they quickly decrease during dry periods because the watersheds are small and the soil cover generally is not sufficiently deep to provide significant retention of the rain water. Finally, the underlying lava rock is extremely pervious. Thus, it is essential that the Sili River watershed be carefully managed ecologically now and in the future, to preserve the water retention capability available at present in order that at least the minimum flow is maintained and the river remains a perennial stream. The vegetative cover is the most important factor in preserving the ecologic integrity of the watershed and the water supply as a usable resource.

The tropical forest of the Sili River Basin is a precariously balanced ecology, contrary to general opinion which sees the existing luscious jungle as having unlimited ability for growth and regeneration. Removal of the vegetative cover, such as by timbering or the construction of extensive access roads, would result in rapid erosion of the steep hillsides. This would generate landslides, and could lead to total disappearance of the soil cover. The water supply facilities would become fouled with sediments that

would clog intakes, water pipelines, and storage tanks, and could require expensive treatment for removal. The abrasive sediment material could damage turbine blades and clog irrigation lines. With loss of the water retention function of the vegetation and soil, the river would possess only two flow regimes: disastrous flash floods during heavy rains, with attendant heavy erosion, and dry river beds during dry periods. Strong watershed management will be required to avoid such consequences.

9. RECOMMENDATIONS FOR FURTHER STUDY

9.1 GENERAL

From the pre-feasibility study work described in this report, it is concluded that the Sili River Basin is a viable source of supply for potable water service to a significant portion of the population of the island of Savaii. While hydroelectric power generation cannot be justified at the present time, it can be added when needed to a properly-planned water supply project. Careful management of the fragile ecology of the Sili River watershed will be necessary to preserve this important resource for present and future development. Additional hydrologic and geologic data will be needed on which to base more detailed project feasibility studies and final design.

9.2 FURTHER STUDY NEEDED

The next steps in developing a potable water supply project in the Sili River Basin would involve two phases:

- Phase I - additional hydrologic and geologic data collection
- Phase II - detailed investigations and preliminary engineering with cost estimates to a level adequate to support financing commitments

9.2.1 Phase I

This phase would involve installation of a stream gauging station on the Central Branch of the Sili River; a program of simultaneous comparative flow measurements on the Eastern, Central and Western Branches; and site-specific geological and soils investigations and testing at the sites chosen for diversion and storage structures, as described briefly below:

- Stream Gauging. A recording-type stream gauge should be installed on the Central Branch at or near the site recommended herein for water diversion and storage. If this is done immediately, ample

records should be available to support detailed planning of a hydroelectric project in the future should one be required due to planned relocation or shutdown of the Asau mill.

- Flow Measurements. Pending accumulation of data from the new gauge described above, a program of simultaneous stream flow measurements should be undertaken between the Western, Central and Eastern Branches of the Sili River. The purpose would be to verify the general flow relationship between these branches so that the existing stream flow records from the gauge on the Eastern Branch can be used with more confidence in planning a water supply project involving diversion from the Central Branch. This should permit adequate planning of such a project, since the required water supplies will be small relative to the mean flows available.

- Geologic and Soils Investigations. Geotechnical exploration for the feasibility study should consider the possibility of construction of a storage dam in the future so that the initial diversion structure on the Central Branch required for water supply can be expanded into a storage dam as explained in the report. Exploration during the feasibility studies should include preliminary topographic location of the dam site followed by subsurface exploration using hand-dug test pits on each abutment. These would permit determination of the depth of overburden, and allow examination of the underlying rock surface. Soils samples should be taken and analyses made to determine the characteristics of the overburden, particularly with regard to its permeability.

  A geologic reconnaissance should be made of the future reservoir area, to evaluate potential problems with respect to landslides, exposed lava flows, and the like. The reconnaissance should also identify potential sources of construction materials for the dam.

Finally, the geotechnical exploration program should include reconnaissance of proposed pipeline alignments, to identify trenching conditions and other data needed for pipeline design and construction cost estimating.

9.2.2 Phase II

Following establishment of flow-duration relationships for the Eastern and Central Branches adequate to determine the sizing of system storage needed to provide essentially a 100 percent firm water supply, work can proceed with detailed layouts and sizing of water supply pipelines, storage tanks and ponds, distribution systems, etc. serving the Southern and Eastern systems and/or the alternative Western system as may be desired. During this phase, preliminary design drawings and draft tender documents should be prepared and cost estimates developed to the level of accuracy needed to support funding commitments.

Needed storage for water supply reliability could be provided either through creation of small pondages at the points of diversion, or alternatively by over-sizing the storage tanks located along the main supply pipelines. The latter would have the advantage of improving system reliability and operational flexibility, but would probably be somewhat more costly. However, as noted earlier in this report, it is likely that development of any significant pondage at the diversion point on the Eastern Branch will require measures to limit losses due to seepage, possibly including lining of the entire pond, and in this case provision of the needed system reliability directly in the storage tanks serving the villages would become more attractive.

10. REFERENCES

The following reference data and reports were accessed during the Sili River Multi-Purpose Project pre-feasibility study:

1. G. M. Meredith & Associates, Water Supply in Savaii Western Samoa, September 1981.

2. Kear, D., Wood, B., "Geology and Hydrology of Western Samoa", New Zealand Geologic Survey, Bull. No. 63 (1959).

3. Keating, B., "Paleomagnetic Studies of the Samoan Islands: Results from the Islands of Tutuila and Savai'i" V. of H. in "Geologic Investigations of the Northern Melanesian Borderland", Circum-Pacific Council for Energy and Mineral Resources, Earth Science Series. AAPG T.M. Brocher, ed. (1985).

4. Kear, Kammer, Brands, "The Hydrogeology and Water Supply of Western Samoa", 1979.

5. Saifaleupolo, S., Personal Communication, August 1985.

6. Zavalas, B., "Background Information on the Sili River Basin", undated document.

7. Stearns, H., "Geology of the Samoan Islands" Bull. GSA, V. 55, No. 11 (1944)

8. Aerial Photographs of the Sili drainage area. Scale: 1:20,000 approx.; Date: 30 June 1981.

9. Topographic Maps - Western Samoa Topographic Maps 1:20,000 Sheet 12 - Mafane, Sheet 15 - Satupaitea. Map of Western Samoa, L&S 15, Edition 3, 1983.

APPENDIX A

SCOPE OF WORK

inspected, and the needed number, type and location of additional stations will be indicated in the event further study is found justified. Particular attention will be given to local geology and potential permeabilities of the subsurface materials. Data relative to local construction costs will be obtained also. Previous engineering reports supplied by Owner will be reviewed for applicability to the present study including:

- The Geology and Hydrology of Western Samoa, D Kear and B. Wood, 1959, New Zealand Geological Survey
- The Hydrogeology and Water Supply of Western Samoa, D. Kear, D. Kammer, C. Brands, 1979, DSIR, Wellington, New Zealand.
- Water Supply, Savaii, Western Samoa, GM Meredith and Associates, 1981.

2. HYDROLOGIC STUDY

As only limited streamflow data exist for the Sili River and its tributaries, Bechtel will therefore develop flow-duration curves for potential project reservoir sites using transposition techniques. Bechtel has applied transposition techniques successfully for other Pacific Island projects. These techniques basically combine available local data with other data taken from hydrologically similar regional settings. The flow-duration curves will be used for estimating the dependable water supply and electrical energy production of the proposed project(s). All hydrological calculations, assumptions, used curves produced etc. will be submitted as an Appendix to the main report, for evaluation by the Owner.

3. CONCEPTUAL PROJECT LAYOUTS

Several alternative potential projects will be identified, and schematic layouts developed for each. These initial project layouts will be designed to make maximum use of all potential water storage sites, possible water conveyance routes, and topographic drops where hydroelectric potential can be developed. One or more of the most promising schematic plans will be further developed to identify the principal cost components of a water supply/hydro project.

Bechtel shall specifically take the following into account:

- water supplies for drinking water purposes are to take precedence over water required for hydro-electric generation purposes

- the rehabilitation of the existing water supply system from Foaluga (Palauli West) to PuaPua should receive primary consideration. Bechtel should give consideration to supplying water <u>by gravity</u> to two water supply zones, as follows:

  - o Zone 1: Foaluga to Gataival to Fa'ala
  - o Zone 2: Moata to Tuavivi to PuaPua

  consideration will be given to supplying Zone 2 water requirements by gravity from a high level intake on one or more of the most eastern tributaries of the Vaiola River (Vaitai Stream), and bringing a high elevation pipeline due east to the general vicinity of Tuasivi, to feed north and south of Tuasivi.

- estimated water supply requirements for Zone 1 and Zone 2, assuming a water use of 200 litres per head per day, year 2010 populations, and 20% transmission losses are as follows:

  - Zone 1: 55 litres per second
  - Zone 2: 60 litres per second

4. RECONNAISSANCE-LEVEL COST ESTIMATES

Reconnaissance-level construction cost estimates will be prepared for one or more of the most promising schematic plans. These estimates will be based on quantified project components, local costs of materials and labor, and cost of imported equipment. Allowances for the cost of transmission of water supplies and electricity from the point of production to the place of use will be included.

5. PROJECT EVALUATION AND STUDY REPORT

Project construction cost estimates will be combined with water and energy production forecasts to determine the unit costs of new water and energy supplies. These will be compared with existing supplies and costs, to judge if further project investigation is warranted. Outline economic analyses, at pre-feasibility level of detail, will be presented for the water supply component of the project, and figures for cost of water delivered to consumer in WS Tala per cubic metre at 10%, 5%, 2% and 0% discount rate, and investment cost per head of population, will be given. A Study Report will be prepared which summarizes the work performed for each study task, presents Bechtel's evaluation of the apparent feasibility of a water supply/hydro project, and contains recommendations for further, more detailed studies if justified. Ten copies of the report shall be delivered to Owner.

APPENDIX B

HYDROLOGIC DATA

SILI - BASIN/HYDROLOGICAL GEOLOGICAL DATA
1980-1985

1. HISTORY

Installation was undertaken in the beginning of 1980 to produce reliable data for the basis of future hydropower and water supply development. A Leupold Stevens Type F water level recorder and Lambrecht rainfall stations were installed on 11th March 1985.

2. STATUS OF THE DATA: About 70-80% of the MDQ are missing since installat due to several factors. The prime factor is the unsuitable selection of the site. A continue draught blowing from upstream results in fluctuatior with the stilling well, the leucite reservoir and pen tip often tears the chart. The other major reason is the isolation of the station.

3. GEOLOGY : Describe in detail by Kear and Wood in their 1959 edition The Geology and Hydrology of W. Samoa.

4. HYDROLOGY

(a) Spot-Gaugings: Flow measurements were undertaken on all branches of Lata River in 1976 and 1977 year period. This will be produce in separate r report.

(b) Rating Equaton: As a result of the above rating equation was computed on a two point method (E. Zavalas report) which in this case is not applicable. The Linear Regression method was applied and the age: Q = 5.309h 4.547. This is used for computing the Mean Daily Flows.

(c) Mean Daily Discharge (MDQ) - Refer to separate forms.

(d) Correlation Purposes: Photo copies of mean daily discharges a Tiapapata Station Vaisigano Basin in Upolu Island is enclosed for reconstruction and model simulation if the purpose of simulation is valid in this case. 4 years of data is produced.

A.K. Titimaea
SNR/HYDROLOGIST
29/8/85.

GAUGING STATION

WEST INDIES

STATION

BEST AVAILABLE COPY

CO. TION: SILI BASIN EASTERN BRANCH.

DRAINAGE AREAS

PERIOD OF RECORD:

GAUGE TYPE:

TRENDS:

REMARKS:

DISCHARGE, CUBIC METRES PER SEC, WATER YEAR: OCT '80 - SEPT '81

DAY	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY.	JUNE.	JUL.	AUG.	SEPT.
	*	.819	.262	*	*	.034	*	*	*	*	*	*
		.617	.189			.022						
		.553	.231			.022						
	*	.446	2.988			.018						
		.322	1.001			.014						
		.342	.557			.014						
	*	*	.250			.030						
			.355	*	*	.058						
			.718			.045	*	*				
10	*	*	1.525			.246						
11			.604			.729						
12		*	*	1.398		*	*					
13				.578								
14				.386								
15	*	*		.271	*	*		*	*			
16				3.292								
17				1.524								
18		*	*	.719			*	*				
19				.532								
20				2.403								
21				3.288								
22	*	*		1.148		*	*					
23	5.144			1.818	*	*		*	*			
24	8.338			.729	2.128							
25	2.643	*	*	.471	.077							
26	5.355	.333	.317	.088			*	*				
27	18.033	.249	.532	.073								
28	4.652	.221	.269	.050	*	*						
29	3.491	.207	.257	.034								
30	1.746	.263	.209	.058			*	*				
31	1.126	*	.422	.067	*	*	*	*				
TOT.	44.528	4.420	29.343	2.575	1.227				11.871	35.498	34.273	7.190	14.827
MEAN	4.948	.402	.947	.322	.112				1.024	1.200	1.267	.654	.927
MAX.	18.033	.819	3.292	2.128	.729				2.060	5.100	4.320	1.140	1.725
MIN.	1.126	.207	.189	.039	.014				.532	.304	.044	.339	.444

M(M³/Sec/Km²)

- D - A (mm)

-B-SIT (mm)

ANNUAL YR: TOTAL: MEAN: MAX: MIN: PEAK:

ANNUAL YR: TOTAL: MEAN:

GAUGING STATION

[illegible]

BEST AVAILABLE COPY

STATION

STATION: SILI BASIN EASTERN BRANCH.

DRAINAGE AREA:

PERIOD OF RECORD:

[illegible] TYPE:

[illegible]:

[illegible]:

DISCHARGE, CUBIC METRES PER SEC, [illegible] OCT '81 - SEPT '82

Y	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY.	JUN.	JUL.	[illegible]
	.874	5.309	*	*	*	*	*	*	*	*	*
	.859	3.664		*	*						
	.493	2.516									
	1.893	[illegible]									
	*	*	*	*							
				*	*						
					*	*					
		*	*								
	*	*									
				*	*						
		*	*								
		3.288									
		4.572									
		2.893									
	*	2.164									
		1.715	*	*							
		1.479			*	*					
		1.285									
		1.119									
		.945									
	*	.889	*	*							
		.847			*	*					
		2.649									
		.919									
		*	*								
				*	*						
		*	*								
	*										
	4.205	*	*								
	3.147			*	*	*	*				

Y	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY.	JUN.	JUL.	[illegible]
					*	*	.549	*	*	*	*
							.466				
					*	*	.648				
						8.089	.435				
						8.183	*	*	*	*	*
						4.091	1.299				
						4.844	1.027				
						2.818	1.243				
						2.083	1.032	*	*	*	*
						2.006	.748				
						2.347	2.669				
						1.795	1.787				
						1.512	1.836				
						2.630	2.447				
						1.656	1.226	*	*	*	*
						1.359	.847				
						1.130	.672				
						.848	.835				
						.600	.544				
						.553	.339	*	*	*	*
						.518	.619				
						.482	1.921				
						.471	.644				
						.466	.497				
						.453	.565	*	*	*	*
						.505	.442				
						.787	.425				
						.567	*	*			
						.564					
						.716	*	*	*	*	*
						.762					

TA:

[illegible]:

X:

[illegible] (M^3/Sec/Km^2)

[illegible] - A (mm)

[illegible]-B-LIT (mm)

[illegible] YR: TOTAL: MEAN: MAX: MIN: PEAK:

[illegible]

12

GAUGING STATION [illegible]

[illegible] . [illegible]

STATION

BEST AVAILABLE COPY

STATION: SILI BASIN EASTERN BRANCH.

CATCHMENT AREA:

PERIOD OF RECORD:

GAUGE TYPE:

REMARKS:

REMARKS:

DISCHARGE, CUBIC METRES PER SEC, [illegible] YEAR: OCT 82-SEPT 83

DAY	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY.	JUNE.	JUL.			
1	*	1.676	26.234	.963	1.444	21.546	.636	1.803	*	314	*	*	*
2		1.414	22.663	.797	1.238	1.774	.626	1.104		.349			
3		.301	21.143	.723	1.098	3.741	.622	.877		.347			.454
4		3.052	18.467	1.713	.489	1.690	.613	.738		2.354	*	*	.409
5	*	.573	16.691	3.072	.408	1.264	.623	.656	*	3.745	1.022		.368
6		5.910	12.345	5.726	.863	1.212	2.052	.622		5.655	1.152		.353
7		1.456	11.759	3.344	.749	1.127	1.001	.604		1.384	1.277		.336
8		.631	12.262	*	*	3.836	9.561	.432	1.039	*	1.359		.320
9		.406	11.275			.814	1.725	7.423	.830	*	1.324		.293
10	*	.299	7.671			.723	1.364	5.363	.627	*	.538		.343
11			9.275			.698	1.279	3.228	1.565	.886	.549		.307
12		10.785	8.360	*	*	.664	1.359	2.875	.704	.754	.704		.288
13		9.485	8.548		*	*	1.049	1.881	.844	* .664	.103		.301
14		8.568	10.415				.912	1.367	*	.613	.207		.269
15	*	7.889	7.922	*	*	*	.808	1.148	*	.565	*	*	.256
16	.117	7.376	1.072				.733	1.056	6.055	.462			.309
17	.138	10.270	.984			*	.768	.413	2.912	1.088	.508		.242
18	.171	17.765	.871	*	*	4.410	.692	*	2.014	.811	.436		1.266
19	.104	56.482	.851	2.164	3.454	*	*	1.778	.773	.497	*	*	.249
20	.079	*	.581	2.252	4.055		.723	*	.921	.672			2.621
21	.063		.862	1.893	3.988	*	.645		2.817	*	*		*
22	.655		.819	1.969	3.892		.617		*				
23	.048	*	.746	2.076	3.836	*	.602		.863				
24	.03	86.365	.566	2.470	3.817	1.528	.595	*	1.062		*	*	
25	.02	42.216	.841	3.012	3.955	1.148	.607		.693	*	*		
26	.081	39.857	.757	2.165	4.022	.957	.907		.601				
27	.062	64.922	1.881	1.618	8.239	1.582	.703		.625		*	*	
28	.111	69.441	3.341	3.279	22.148	1.312	.602	*	.569	*	*	*	
29	.259	60.713	1.396	2.445		.889	.586		.982				
30	1.929	31.734	2.495	1.720		.738	19.203		.430				
31	1.493		1.450	1.276		.723		*	*	*	*	*	

(m^3/Sec/km^2)

D - A(mm)

-B-PET (mm)

YR: TOTAL: MEAN: MAX: MIN: PEAK:

YR: TOTAL: [illegible]

13

BEST AVAILABLE COPY

STATION: SILI BASIN EASTERN BRANCH.

DRAINAGE AREAS

PERIOD OF RECORD:

GAUGE TYPE:

DATUM:

REMARKS:

DISCHARGE, CUBIC METERS PER SEC, DAILY MEAN OCT 83 - SEPT 84

DAY	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.
1	*	*	*	*	*	*	*	*	*	*	*	*
2	*	*	*	*	*	*	*	*	*	*	*	*
3	*	*	*	*	*	*	*	*	*	*	*	*
4	*	*	*	*	*	*	*	*	*	2.754	*	*
5	*	*	*	*	*	*	*	*	*	4.576	*	.000
6	*	*	*	*	*	*	*	*	*	5.222		.449
7	*	*	*	*	*	*	*	*	*	*	*	.559
8	*	*	*	*	*	*	*	*	*	*	*	.017
9	*	*	*	*	*	*	*	*	*	*	*	.203
10	*	*	*	*	*	*	*	*	*	*	*	.150
11	*	*	*	*	*	*	*	*	*	8.032		1.277
12	*	*	*	*	*	*	*	*	*	3.645		.678
13	*	*	*	*	*	*	*	*	*	1.825	*	.624
14	*	*	*	*	*	*	*	*	*	1.462		.565
15	*	*	*	*	*	*	*	*	4.410	1.601		.486
16	*	*	*	*	*	*	*	*	1.444	*	*	.754
17	*	*	*	*	*	.828	*	*	.989			.476
18	*	*	*	*	*	.720	2.575	*	.765			.506
19	*	*	*	*	*	1.446	1.618	*	.661			.467
20	*	*	*	*	*	2.430	*	*	1.109			.574
21	*	*	*	*	*	1.703	*	*	1.618			.460
22	*	*	*	*	*	1.190	*	*	.775	*	*	.457
23	*	*	*	*	*	*	*	*	.656			.422
24	*	*	*	*	*	*	*	*	.569			.390
25	*	*	*	*	*	*	*	*	.538			.354
26	*	*	*	*	*	*	*	*	.505			.336
27	*	*	*	*	*	*	*	*	.572			.304
28	*	*	*	*	*	*	*	*	.566	*	*	.328
29	*	*	*	*	*	*	*	*	.467			.742
30	*	*	*	*	*	*	*	*	.425		3.05	.712
31	*	*	*	*	*	*	*	*	.386		.463	.711
									.350		.490	1.386
									.356		1.876	.765
									.334		1.126	.766
									.382		2.048	.025

TOTAL:

MIN:

MAX:

MEAN:

RCV (M^3/Sec/Km^2)

- D - A(mm)

-B-FIT (mm)

MONTH: TOTAL: MEAN: MAX: MIN: [illegible]

YR: TOTAL: MEAN: MAX: MIN: [illegible]

RCV - Runoff Volume

14

APPENDIX C

ELECTRIC POWER GENERATING DATA FOR SAVAII

I. GENERATING PLANT IN SERVICE *

Designation	Nameplate Rating kW	Derated Capacity kW	Location	Year Commis-sioned
SAVAII - SALELOLOGA - DIESEL				
Salelologa No. 1	100	100	Salelologa	1978
Salelologa No. 2	100	100	Salelologa	1978
Salelologa No. 3	100	100	Salelologa	1978
Salelologa No. 5	60	60	Salelologa	1982
Salelologa No. 6	60	60	Salelologa	1982
Subtotal Salelologa System	420	420		
SAVAII - ASAU - FREQUENCY CONVERTERS				
Asau No. 1	600	600	Asau	1984
SAVAII - ASAU - DIESEL				
Asau No. 3	300	250	Asau	1984
TOTAL Capacity	1,320	1,270		

II. MONTHLY ENERGY GENERATED, PEAK LOAD AND FUEL CONSUMPTION 1984 SALELOLOGA SYSTEM *

Month	Energy Generated kWh	Fuel Used Litres	Peak Load kW
January	73,370	34,234	259
February	65,710	32,590	258
March	70,880	37,735	258
April	68,950	36,505	242
May	72,210	38,240	257
June	67,650	36,660	243
July	69,950	38,130	258
August	71,260	38,050	188
September	70,050	38,764	-
October	74,200	37,350	261
November	71,130	37,550	268
December	77,710	40,570	298
TOTAL	853,430	446,378	298

* Data reproduced from 1984 statistics by EPC.