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DEVELOPMENT OF SOLAR SALT PRODUCTION*,
SI/WES/77/802,
WESTERN SAMOA,

Terminal report

Prepared for the Government of Western Samoa
by the United Nations Industrial Development Organization
executing agency for the
United Nations Development Programme

Based on the work of Chester W. Jenkins,
the production of solar salt

United Nations Industrial Development Organization
Vienna

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STUDY OVERVIEW

Study Requirement

The objective of this feasibility study is to assist the Government of Western Samoa, through the United Nations Industrial Development Organization, Vienna, to determine the technical and economic feasibility of establishing a solar sea salt production facility at this location. This would be a new facility, as Western Samoa commercially produces no salt, but imports its total refined salt consumption.

Phase 1 of the study (as covered by this report)

1. Investigate the climatic and topographic conditions of the country and select the best regions suitable for the production of salt from sea water by solar evaporation.
2. Study the market outlets for salt, both for domestic uses and for export, as well as to make a forecast of the market potential.

If the first phase of this study is positive, then a second phase of the study would furnish all of the necessary assistance to finalize plans and studies to establish the salt production facility.

This report analyzes climatic and topographical conditions, and presents estimated investment and operating costs. Information is also included regarding the types and costs of salt now being imported, both refined or otherwise, and a projection of the future market demands.

Salt produced in a solar facility generally requires some processing, such as brine washing, to meet some of the basic market requirements for salt to be used as kitchen salt, for hides, beef packing, or in the fishing industry.

To manufacture salt to table grade specifications requires more sophisticated refining and processing. As a minimum, this operation usually consists of centrifuge washing, drying, grinding, screening, and some type of packaging facilities.

Samoa would initially produce salt to meet basic market requirements, with table grades introduced at a later date as required.

Location

The islands of Western Samoa lie in central Polynesia, between the latitudes of 13° and 15° South, and longitues 168° and 173° West. See Figure I, location map. The two main islands are Upolu, about 430 square miles, and Savaii, about 660 square miles. Apia, the capital, is situated on the island of Upolu.

Climate

Very tropical and humid. Rainfall averages a low on the Western tip of Savaii of 2230 mm, and a high near the center of Upolu of 5012 mm. There is no area on either island that has more evaporation than rainfall on an average yearly basis. The Western tips of both islands have a reported net evaporation during a six months dry season between May and October. The Western tip of Savaii, however, is the only location

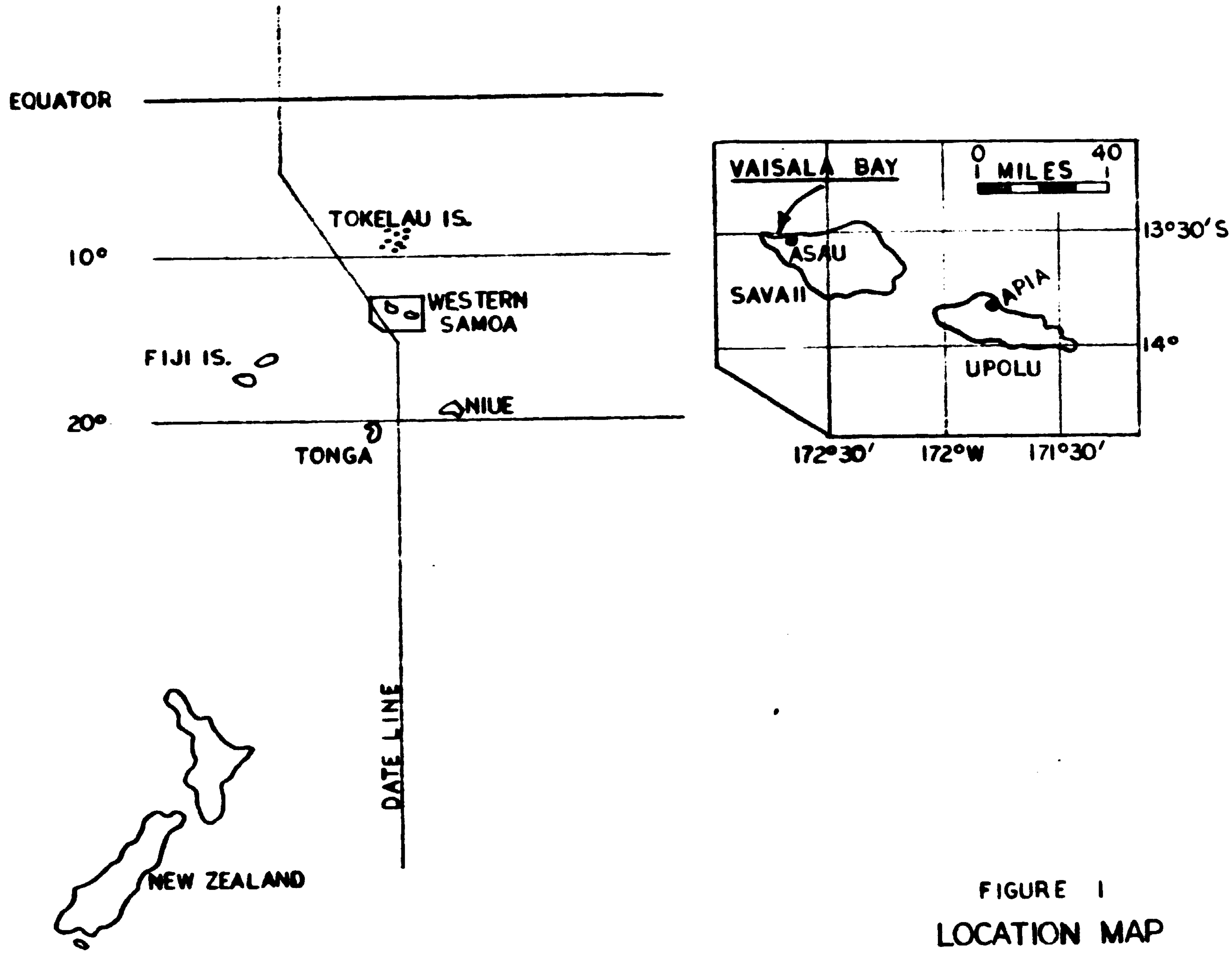


FIGURE 1
LOCATION MAP

considered to have enough evaporation during the dry season to commercially allow the crystallization of solar sea salt.

Domestic salt production

The only reported salt production is from pot holes of rocks along the coast of the Western tip of Savaii. Villagers reportedly gather salt after high tides and winds infrequently cause sea water to flood into these higher rocky areas, and as the sea water evaporates leaves a deposit of salt. It is doubtful, however, whether more than fifty to one hundred 50 kg bags are gathered a year in this fashion. Western Savaii is the only area reporting this condition.

Salt consumption

The government provided records indicating 300 tons of salt were imported to Western Samoa in 1975. They estimate the same tonnage for 1977. An average culinary and human consumption can usually be estimated at about 6 kilos per capita per year. The 151,000 population of Western Samoa would therefore have been thought to consume about 900 tons per year. A reason for this comparatively low consumption of salt may be the population lives principally along the sea coast, and much of the cooking is done with sea water, which could fulfill the major requirement for dietary salt.

Solar salt production

Solar salt from sea water is a fractional crystallization process. This is a process whereby certain compounds in sea water that are less soluble than sodium chloride precipitate before salt starts to crystallize. Other compounds, however, are more soluble and remain until most of the sodium chloride has crystallized and dropped to the bottom. Figure II illustrates the typical pattern which allows the less soluble compounds to precipitate in the sea water concentrators, and the more soluble salts to precipitate in the crystallizers.

DEPOSITION OF SALTS DURING THE EVAPORATION OF SEA WATER

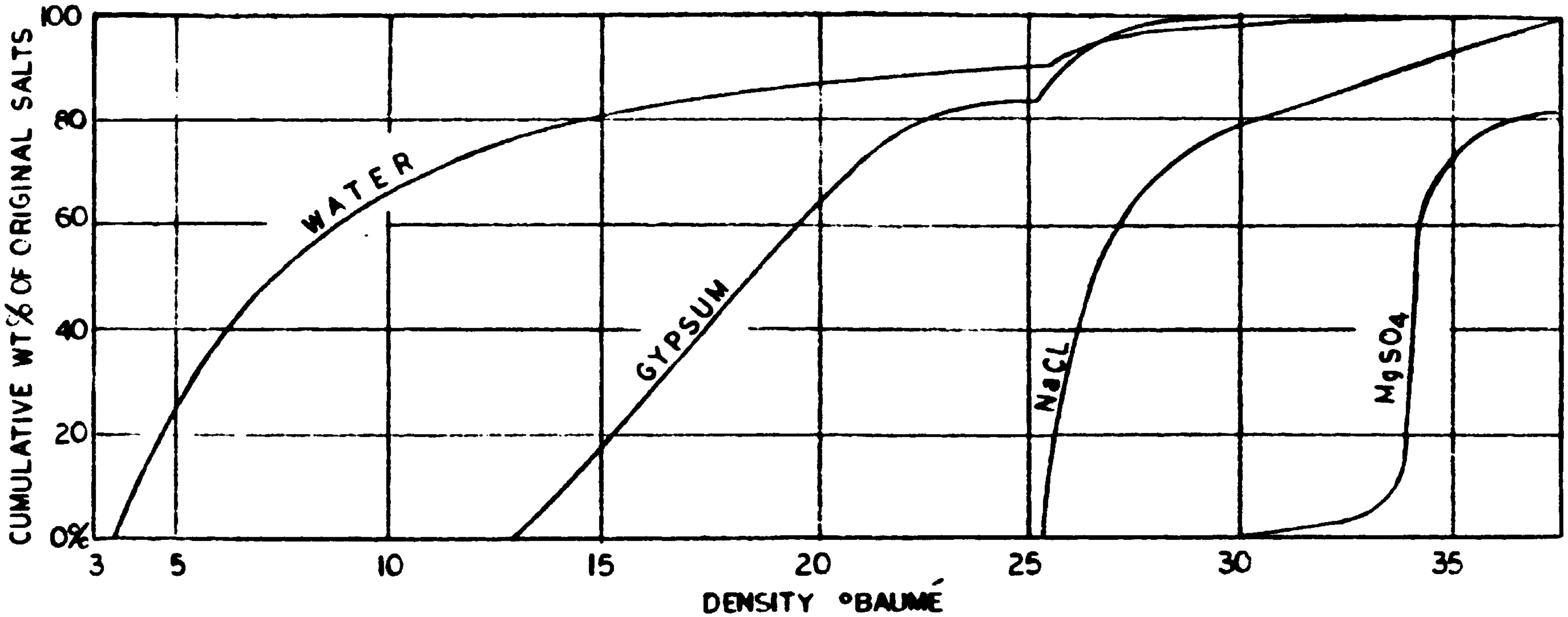


FIGURE II
DEPOSITION OF SALTS

1. SUMMARY AND RECOMMENDATIONS

The relatively small demand for salt within the country of Western Samoa, the absence of a salina type terrain upon which to construct a salt works, and the minimal climatic conditions limit solar salt production to a relatively small operation. Nevertheless, this initial study is encouraging regarding the establishment of a small domestic plant at a Savaii location.

1.1 Feasibility

Upon positive results from the recommended test program at the area site, the establishment of a solar salt plant at Vaisala Bay, Savaii, should be a feasible project, even at the suggested minimal production rate of 300 tons per year. The relatively costly production is greatly offset by the high cost of ocean freight and the 18% customs duty assessed against the ad valorem value of imported salt landed at Apia. Such a facility is intended to produce about 300 tons of non-refined salt per year for use as kitchen salt, hide salt, beef packing salt and fishery salt.

An estimated capital cost of WS $123,000 will be necessary to install such a facility at Vaisala Bay. An operating or production cost per ton is estimated on the next page for non-refined salt.

Operating Costs Vaisala Bay Facility (300 metric tons per year)

Non-refined salt

	Per ton of 2000 pounds
Maintenance	12.85
Depreciation	15.72
Labor & equipment	15.11
Bagging costs	5.00
15% contingency	7.30
10% R.O.I. (123,000 capital)	37.19
Freight to Apia	10.00
Landed cost Apia	WS$103.17

1.2 Recommendations

Approval to utilize area at Vaisala Bay will first of all be obtained, from whomever controls this property.

Following such approval, the test program should be started immediately, and in the manner described in this report, or by an alternate method to obtain equivalent results.

Upon acceptable results from the test ponding, the main design and construction can be started.

It is recommended the facility produce a coarse brine washed salt to begin with, and improve the quality as the demand increases. The product can be upgraded gradually to meet more rigid use requirements, by simple grinding to make a finer salt or drying for a free running salt. Untimately a refinery as illustrated in this report may be necessary. Additional areas of Vaisala Bay can also be dyked off if future requirements warrant the expansion.

1.3 The minimum landed cost of imported coarse salt at Apia approximates $121.50 per ton. The 18.00 difference between the projected costs per ton from a domestic facility and the imported salt still leaves some room for cost increases in production, without jeopardizing the project. The rate of return is obviously low, but the intent of this project is to allow a domestic production of salt to be obtained.

2. SALT SOURCES, PRODUCTION AND REFINING

2.1 Common methods of salt recovery

Salt in a natural solid form (rock salt) occurs in underground deposits, and is commonly mined in a similar fashion as coal. Alternatively, fresh water is sometimes pumped into these underground salt deposits, and the salt dissolved and returned to the surface by pipeline, as salt in solution, or salt brine. This brine can be steam evaporated to produce vacuum pan salt, or in some cases solar evaporated to produce crude solar salt. The most common way to produce crude solar salt is to solar evaporate sea water in large flat land areas, with the salt finally being deposited in the crystallizer section of the evaporating area. Figure III illustrates a typical solar salt plant flow diagram. Depending upon climatic and topographical conditions, an acre of land may produce anywhere between 5 and 60 tons of solar evaporated salt per year. In some instances sea water is solar evaporated to the salt saturation point and is then transferred to steam evaporators to produce vacuum pan salt.

2.2 Energy requirements

The following information is quoted from the Minerals Yearbook, 1974, USA.

> a survey of energy requirements for various types of salt production was conducted in 1974, average uses for the different classes of salt follow.

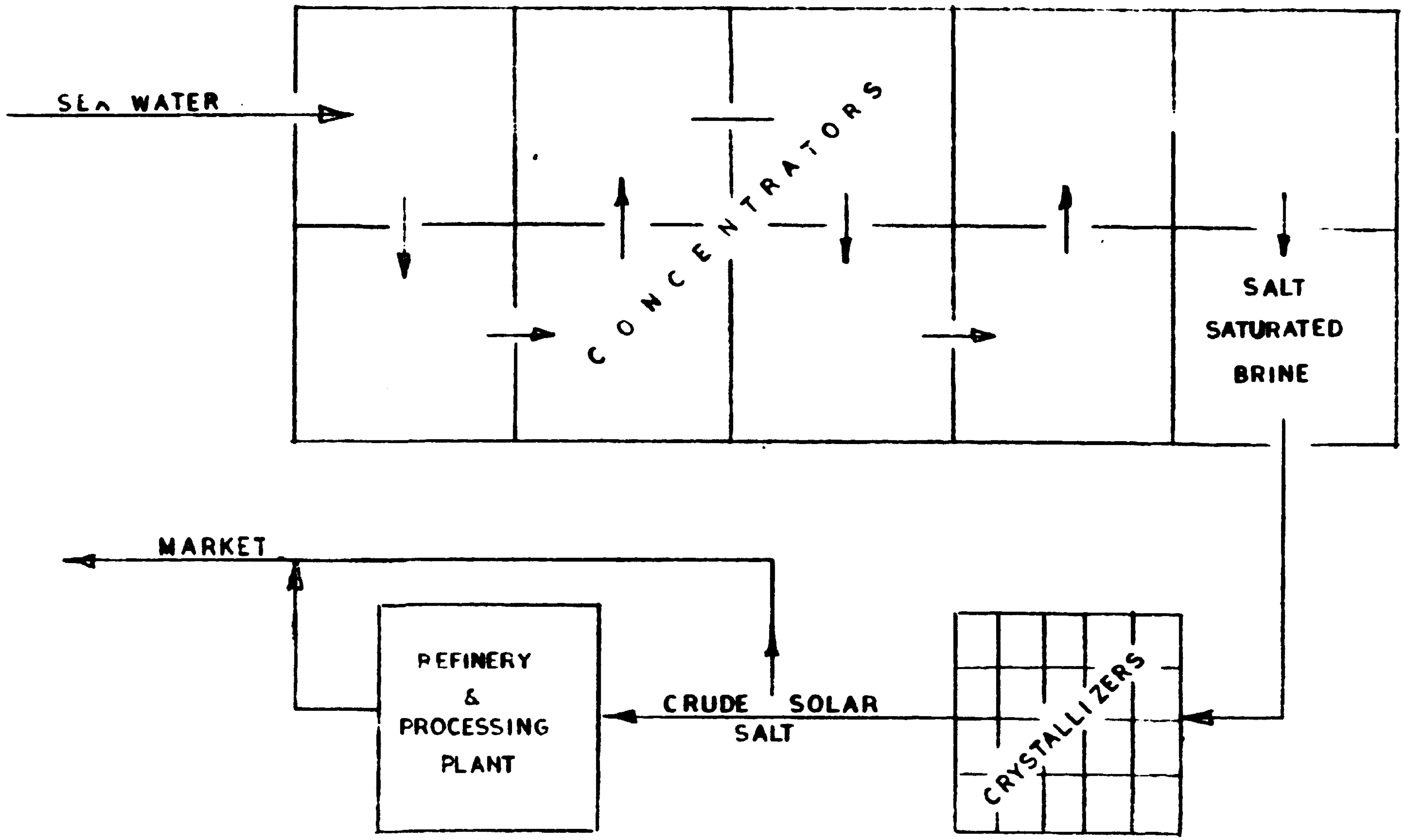


FIGURE III.

SOLAR SALT FLOW SYSTEM

	kilowatt hours per ton	thousand BTU per ton
Salt in brine	6.0	20.5
Solar evaporated salt	23.5	80.1
Mined rock salt	29.5	101.0
Vacuum pan salt	1230.0	4190.0

2.3 Preferred refining and processing systems

Because of today's high energy costs, few new salt vacuum pan systems are being installed. The trend is to produce a more energy efficient solar salt, and to refine and process it into an edible grade salt, by a process as illustrated in figure IV. This is a preferred process. Only three out of eight salt samples obtained in Apia were vacuum salt. The rest were rock or solar salt refined and processed in a system very much like that illustrated.

2.4 Salt terminology and general description

2.4.1. Crude solar salt

As it comes from the harvesting beds, or crystallizers, with usually only a primary cleansing to upgrade the quality. Moisture content $\pm$ 3%, and NaCl on a dry basis about 99.5%.

2.4.2. Stack run solar salt

Generally defined as crude solar salt as it comes from a storage pile.

2.4.3. Salt grades - not refined

Salt as it comes from the crystallizers, with a brief brine wash as it is hand harvested, and after drainage in a storage pile, can be used as kitchen salt, for the salting of cattle hides, salting and brining of fish, and other similar miscellaneous uses. It is for these uses that the first production from the Vaisala Bay area is planned. If a demand develops at some future time for screened grades of salt, a simple screening process can be later added to the facility. If table grade salt is required, then a refinery as illustrated in figure IV can be added in stages as necessary to meet the market demands.

It is recommended the Vaisala Bay facility produce a non-refined salt for basic requirements to begin with, as the initial and operating costs of a refinery are quite high. The following section on refining costs are included to emphasize this factor.

2.4.4. Refined salt

The refining process removes contaminants and improves the salt quality to a table grade. Salt can be used in this form, or it can be dried, classified and packaged, and categorized as a refined processed dalt.

Under the vacuum pan process, the common method is to dissolve impure salt in water and recrystallize the salt in steam evaporators. An alternate method is to solar evaporate sea water to the salt saturation point, and then crystallize the salt in steam evaporators.

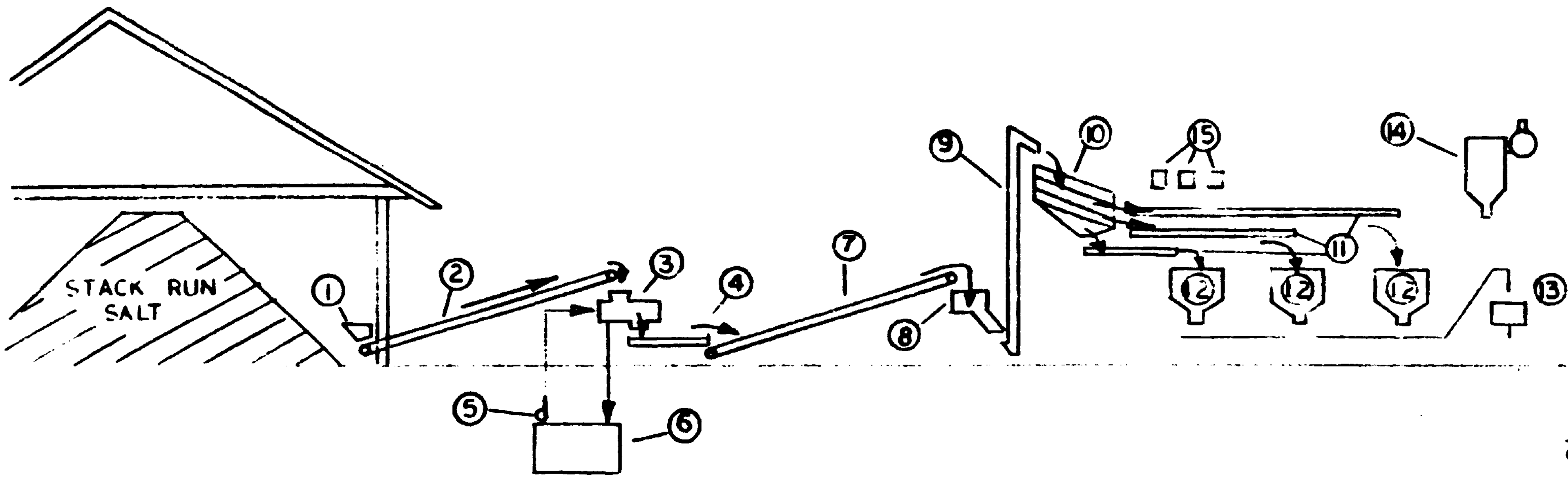
The preferred method of refining and processing salt is illustrated in figure IV. Crude solar salt is centrifuge washed in clean saturated brine to remove fine dirt particles and other impurities. The salt discharges at about 1%

moisture ana a minimum NaCl content of 99.8% NaCl. The salt is dried to about .2% moisture, crushed, and screen graded according to crystal size for various uses, which may be categorized as follows:

Kitchen salt minus 3 mm plus 1 mm grain size. Normally packaged in weights between 1 kg and 25 kg.

Table salt minus 1 mm plus .3 mm grain size. Normally packaged in weights between 500 and 750 grams.

Powder salt minus .3 mm grain size. Suitable for cattle feed, poultry feed, etc., usually in 50 kg weights.



(1) SALT RECEIVING HOPPER
(2) BELT CONVEYOR
(3) PUSHER TYPE CENTRIFUGE
(4) DRYER
(5) WASH BRINE PUMP
(6) BRINE CLARIFICATION TANK
(7) BELT CONVEYOR
(8) IMPACT CRUSHER
(9) BUCKET ELEVATOR
(10) 3 DECK HUMMER SCREEN
(11) SCREW CONVEYORS
(12) SALT STORAGE BINS
(13) HAND PACKAGING MACHINE
(14) DUST COLLECTOR
(15) SALT ADDITIVE SYSTEN

FIGURE IV
PROCESS SCHEMATIC-REFINERY

2.4.5. Estimated capital cost of processing and refining machinery
(Use with figure IV - table salt grade)

		Connected HP	Cost
1.	Salt hopper		500
2.	Belt conveyor @ 40.00 foot	2	1,500
3.	Centrifuge, piping, etc.	7.5	12,000
4.	Dryer	5	5,000
5.	Brine pump	2	1,000
6.	Brine clarification tank		1,500
7.	Belt conveyor	2	1,500
8.	Crusher	7.5	12,000
9.	Bucket elevator	2	2,000
10.	Screen	5	5,000
11.	Screw conveyors	6	6,000
12.	Storage bins		3,000
13.	Packaging machine-hand 1/2 & 1 kg.	3	10,000
14.	Dust collector, scrubber & piping		10,000
15.	Salt additive system	1	3,000
		40	74,000
	40 HP Connected @ 300.00		12,000
			86,000
	20% contingency		17,000
	Estimated machinery cost		103,000
	Process machinery building		9,000
	Total estimated capital cost		WS$112,000

2.4.6. Process and refine crude salt into table salt grades

	Depreciation	Maintenance
1. Process machinery building		
Depreciation @ 15 years	600	
Maintenance @ 5%		450
2. Machinery		
Depreciation @ 15 years	6900	
Maintenance @ 7.5%	___	7700
	7500	8150

3. Power - 40 HP load - 60,000 KWH = $4800

4. Bags - 50 kg jute/poly

   1/2k and 1 kg poly bags 5.00 per ton

5. Labor

   8 men @ 10.00 x 250 days = $20,000

<u>Estimated processing and refining costs</u>

	300 TPY	600 TPY	1000 TPY	2000TPY
Maintenance	8150	-	-	-
Depreciation	7500	-	-	-
Power	4000	4800	-	-
Labor	15000	17500	20000	-
	34650	37950	40450	40450
Cost per metric ton	$115.50	63.25	40.45	20.20
Add packaging material	5.00	-	-	-
Add 10% money & profit	37.30	18.60	11.20	5.60
Per metric ton WS$ table salt	157.80	86.85	56.65	30.80
Metric tons per hour	.2	.4	.66	1.33

3. CLIMATIC CONDITIONS IN WESTERN SAMOA

3.1. Climatological records

Very complete records were available at the Apia Observatory, which is under the Western Samoa Department of Agriculture. The various data used in this report is taken from the records of the Observatory. Table 1 lists the years of record for each station supplying climatological data. Figure V shows the various station locations on the two islands.

3.2. Rainfall

Topography and wind direction greatly regulate the distribution of rainfall over the islands. The main land ridge runs WNW to ESE and can cause rain shadowing on either side, or if the wind direction is critical to the direction of the ridge, rainfall will be evenly distributed over the island. Winds during the winter months are primarily Southeasterly, and during the summer months are variable. This causes a wet season north of the mail ridge from October through March and a dry season to occur from April through September. The distinction between these seasons becomes more pronounced toward the Western part of the islands. Using the actual rainfall records for each station, a long term estimated rainfall has been developed for each station, and the mean number of raindays. Table 1 lists this information for each station. The two westernmost locations on each island, Mulifanua on Upolu and Falealupo on Savaii have the least amounts of rainfall, and Falealupo has the least number of raindays.

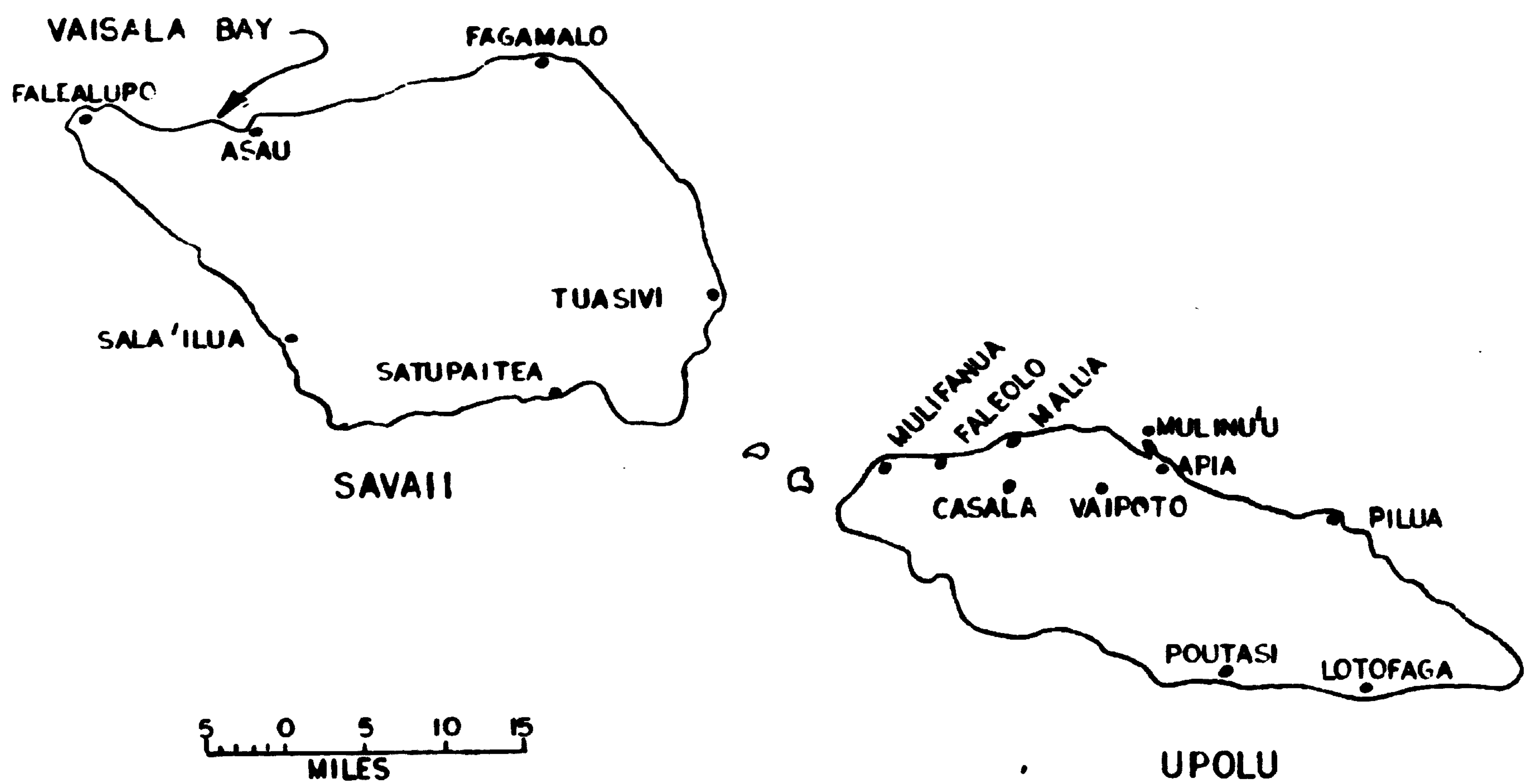


FIGURE V
CLIMATOLOGICAL STATIONS

Table 1

Station	Record Years	Estimated Long Term Rainfall mm Annual	Raindays Mean Yearly
UPOLU			
Lotofaga	31	3910	200
Poutasi	15	4170	240
Piula	42	3782	239
Vaipoto	55	3546	175
Mulinuu	73	2938	211
Casala	18	3142	198
Malua	17	2557	193
Faleolo	15	2242	191
Mulifanua	44	2270	NR
SAVAII			
Fagamalo	38	3729	220
Tuasivi	36	2899	204
Satupaitea	13	3155	215
Salailua	15	3347	167
Falealupo	34	2281	154

3.3 Relative humidity

The records for relative humidity are listed in table 3.

Table 2

MEAN MONTHLY (24 HOUR) RELATIVE HUMIDITY

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
UPOLU												
Afiamalu	93	95	95	94	93	93	92	92	92	92	93	93
Alafua	85	86	84	83	83	83	81	81	79	79	83	84
Apia(Mulinuu)	85	85	85	85	84	83	81	81	81	82	83	84
Avele	86	87	85	85	84	83	81	82	84	85	86	87
Faleolo	84	83	83	81	80	79	79	78	78	81	81	84
Nafanua	86	86	83	84	82	81	80	79	78	81	83	85
Vaipu	88	89	88	88	87	88	87	87	87	88	87	87
Togitogiga	85	85	85	85	86	86	85	85	84	85	86	85
SAVAII												
Asau	81	83	82	82	81	79	78	79	77	80	79	80

MEAN ANNUAL (24 HOUR) RELATIVE HUMIDITY (in %)

UPOLU	
Afiamalu	93.0
Alafua	82.3
Apia	83.2
Avele	84.3
Faleolo	80.8
Nafanua	82.3
Vaipu	87.4
Togitogiga	85.1
SAVAII	
Asau	80.0

Asau is the only reporting station on Savaii, and it should be noted it has the lowest humidity of any location.

3.4. Evaporation

A considerable amount of effort has been put into estimating potential evaporation rates, as periods of water stress are frequently encountered at the western tip of Savaii. The following are quotes from an observatory report.

> Despite seemingly sufficient amounts of rainfall, the Islands of Western Samoa frequently experience periods of water stress and drought. The constant air temperature and relatively small fluctuation of annual duration of sunshine (only one year in five fluctuates by more than 7% from the annual mean although monthly totals may fluctuate greatly) creates rather consistent evaporation rates. Therefore the prime cause of periods of water stress and draught is variable rainfall with an uneven distribution. Since the northwestern parts of Upolu and Savaii have not only the most uneven distribution of rainfall through the year, but the highest variability of rainfall as well, it is not surprising that these areas are most affected by drought. Also contributing to this problem is the geologic structure of many areas. Soils are very young and rather permeable which allows rainfall to quickly perculate through the zone of effective root depth. Because they are well aerated, the soils also dry out rapidly during dry periods.

Of all the parameters involved solar radiation intensity produces the greatest effect on the rate of evaporation. Therefore, the northwest areas of the Islands may be 15% lower than those of the northwest regions. Most northwest areas of both islands experience water stress periods of three consecutive months at a rate of eight or nine times every ten years. South coast stations experience water stress periods less frequently, a water stress period of two or three consecutive months usually occurs only about 10% of the time in these areas.

To assist in analyzing these drought problems, potential evaporation has been calculated by the Observatory for nine stations on Upolu and five stations on Savaii. This calculated evaporation was checked against measured evaporation at Mulinuu (Apia), and over a 31 months period the difference was found to be less than .7 of 1%. There is no location on either island where a positive net evaporation is experienced on a yearly average basis, although there are a few areas where a net evaporation is experienced during a dry period. These areas are identified in table 3 for Upolu and table 4 for Savaii. The determinations are made by subtracting the long term mean monthly estimated rainfall from the mean monthly potential evaporation. The greatest net evaporation is found on the Western tips of each island, Mulifanua on Upolu and Falealupo on Savaii. The Western tip of Savaii, however, near Falealupo or Asau, is the only location considered to have enough net evaporation during the dry season to commercially allow the crystallization of solar sea salt.

Table 3

RAINFALL - EVAPORATION DATA - MM

UPOLU		Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	MM Totals
Lotofaga	Eo	175	151	167	149	137	117	132	145	161	171	163	171	1861
	Rain	414	397	284	289	393	271	238	267	261	380	335	382	3910
	Net Yearly													(2049)
	Net Dry													
Poutasi	Eo	175	145	167	140	129	113	123	139	145	165	163	172	1780
	Rain	346	312	305	275	415	249	295	319	346	480	434	394	4170
	Net Yearly													(2390)
	Net Dry													
Piula	Eo	162	137	145	135	132	109	126	141	150	161	157	162	1741
	Rain	464	410	393	330	287	206	160	175	206	324	378	449	3782
	Net Yearly													(2041)
	Net Dry													
Vaipoto	Eo	162	143	162	145	139	126	138	154	158	176	173	167	1869
	Rain	544	452	445	271	204	144	120	119	171	256	331	488	3546
	Net Yearly													(1677)
	Net Dry							18	35					53
Mulinuu	Eo	174	148	159	151	141	127	138	152	165	174	179	178	1746
	Rain	431	362	354	251	178	129	105	109	147	212	271	380	2938
	Net Yearly													(1192)
	Net Dry							33	43	18				94
Casala	Eo	162	135	154	157	137	133	139	153	150	184	176	180	1890
	Rain	447	371	405	294	179	182	92	107	155	232	297	381	3142
	Net Yearly													(1252)
	Net Dry							47	46					93
Malua	Eo	171	145	167	149	143	127	139	156	173	178	178	175	1901
	Rain	343	364	314	213	172	123	93	93	100	206	215	322	2558
	Net Yearly													(657)
	Net Dry						4	46	63	73				181
Faleolo	Eo	175	151	167	153	140	130	139	156	171	178	183	175	1918
	Rain	312	289	243	161	161	99	83	96	100	178	207	313	2242
	Net Yearly													(324)
	Net Dry						31	56	60	71				218
Mulifanua	Eo	180	151	175	149	140	127	139	153	161	186	183	185	1949
	Rain	313	275	263	186	138	112	91	80	126	182	220	283	2270
	Net Yearly													(321)
	Net Dry					2	15	48	73	35	4			177

Eo - Potential Evaporation Rate
Rain- Long Term Estimated Monthly Mean
Net Yearly - Evaporation Less Rainfall - Yearly Total
Net Dry - Those Months with Net Evaporation

Table 4

RAINFALL EVAPORATION DATA - MM

SAVAII		Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	MM Totals
Fagamalo	Eo	162	145	175	140	135	113	130	141	161	171	174	170	1818
	Rain	539	472	419	319	229	188	152	152	170	268	378	444	3729
	Net Yearly													(1911)
	Net Dry													
Tuasivi	Eo	175	151	167	149	135	122	134	150	161	178	174	175	1890
	Rain	347	296	258	241	232	188	119	135	180	263	281	360	2899
	Net Yearly													(1009)
	Net Dry							15	15					30
Satupaitea	Eo	175	151	162	146	129	113	123	141	153	160	168	175	1793
	Rain	285	264	197	184	260	250	227	199	255	342	400	293	3155
	Net Yearly													(1362)
	Net Dry													
Salailua	Eo	180	157	179	157	148	135	147	162	179	186	183	185	2019
	Rain	348	295	310	226	251	161	221	268	214	329	352	373	3347
	Net Yearly													(1328)
	Net Dry													
Falealupo	Eo	180	166	183	157	151	141	149	167	179	189	190	189	2041
	Rain	367	352	306	182	117	77	56	55	64	145	221	339	2281
	Net Yearly													(240)
	Net Dry					34	64	93	112	115	44			462

Eo - Potential Evaporation Rate
Rain - Long Term Estimated Monthly Mean
Net Yearly - Evaporation Less Rainfall - Yearly Total
Net Dry - Those Months with Net Evaporation

3.5. Wind

The wind averages just over 7 MPH on the average, with a total of 62,000 miles of wind movement per year. This amount of wind is considered to be within normal limits as compared to other solar salt producing areas.

3.6. Evaporation Ecomparisons

A comparison between some areas producing solar salt is listed below. Evaporation rates are from pan evaporimeters, with the exception of the Falealupo/Asau location, which was calculated by the observatory at Apia.

Inches	Gross evap/yr.	Rainfall	Net evap.
Dry Creek, S. Australia	80.6	18.6	62.0
Port Augusta "	67.9	9.4	58.5
Port Price "	50.0	12.0	38.0
Geelong, Victoria	49.4	22.3	27.1
Rockhampton, Queensland	69.5	32.8	36.7
Lake Grassmere, N.Z.	46.4	24.5	21.9
San Francisco, California	46.4	18.0	28.4
Falealupo/Asau, W. Samoa	79.5	88.9	*(9.4)

* During a six months period between May and October, an average yearly net evaporation of 18.2" is calculated. It is this dry period that will be utilized for salt production.

One area in Guatemala, not listed above, quite successfully produces solar salt during a similar six months dry period each year, with the walt works completely flooded out with rain the rest of the year.

4. SITE SELECTION

4.1. Climate factor

The climatic conditions in Western Samoa indicate there are only two areas where a significant "seasonal dry belt" occurs, the Western tip of Upolu and the Western tip of Savaii. The latter area has the most pronounced dry weather with an average net evaporation during the dry season of about 462 mm in the Falealupo/Asau area. The other dry area was on Upolu, but here the dry season net evaporation only averages about 218 mm at the Faleolo vicinity, dropping off slightly toward the Mulifanua location. For this reason the Falealupo/Asau area of Savaii was selected as having the best climatic conditions for this production of solar salt. Just inland from these coastal areas are high mountains where the rainfall is much greater.

4.2. Topographical & Terrain

There are no areas located on either island typical of the normal land used for the production of solar evaporated salt. Usually such lands are of an impermeable clay nature, or have an underlying strata of clay with silt or fine sand as an overlying top surface. This type of terrain is typically found at river deltas or along coastal lagoon type areas. These terrains are usually quite flat, and lend themselves to inexpensive dyke construction procedures using ordinary earth moving type machinery. Western Samoa is geologically too young to have such characteristics. Both islands are of recent volcanic origin, permeable soil, steep rocky shorelines, and with no significant clay deposits, or flat areas, particularly in the coastal sections which have seasonal dry periods with net evaporation. Rainfall run-off finds its way into almost all sections of the coastal areas of both islands in the form of above ground and below ground rivers and springs. Much of the coastal sea water is diluted by this fresh water run-off, which may approach the amount of one cubic meter per second per kilometer of coastline. This was particularly noticeable around the Mulifanua area of Upolu. Specific gravities of ocean water was checked with a hydrometer at various locations, and these readings are shown in Figure VI. One villager described this dilution with the statement "high tide, sea water, low tide, fresh water."

An area located between Cape Salia and Tufutafoe on Savaii was map designated as marshland. Approximately 12" to 18" of fresh water covers this area on a year round basis, but only one small open area contained water grass, the rest of the area containing huge trees and other growth. This area seemed to afford no possibilities of being converted to an open salt water evaporating area.

4.3. Vaisala Bay area

Only one area seems at all suited for the establishment of a solar salt evaporating area. See Figure VII. This is a small section of the Vaisala Bay which is well protected at most times of the year by a reef between the shallow bay and the ocean. At this location an area of between fifty and eighty acres at low tide is practically dry, with only pockets

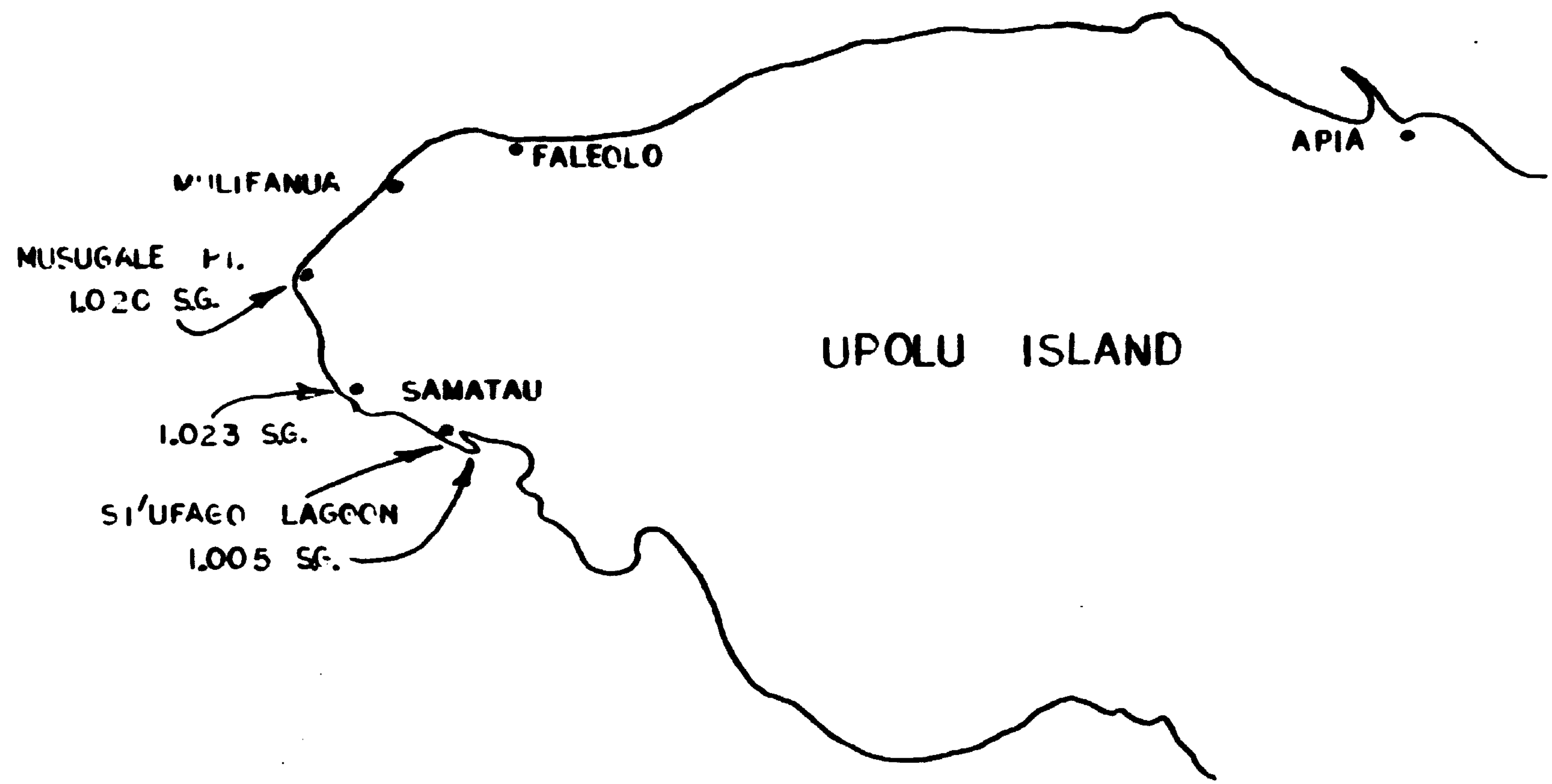


FIGURE VI
COASTAL WATER S.G.

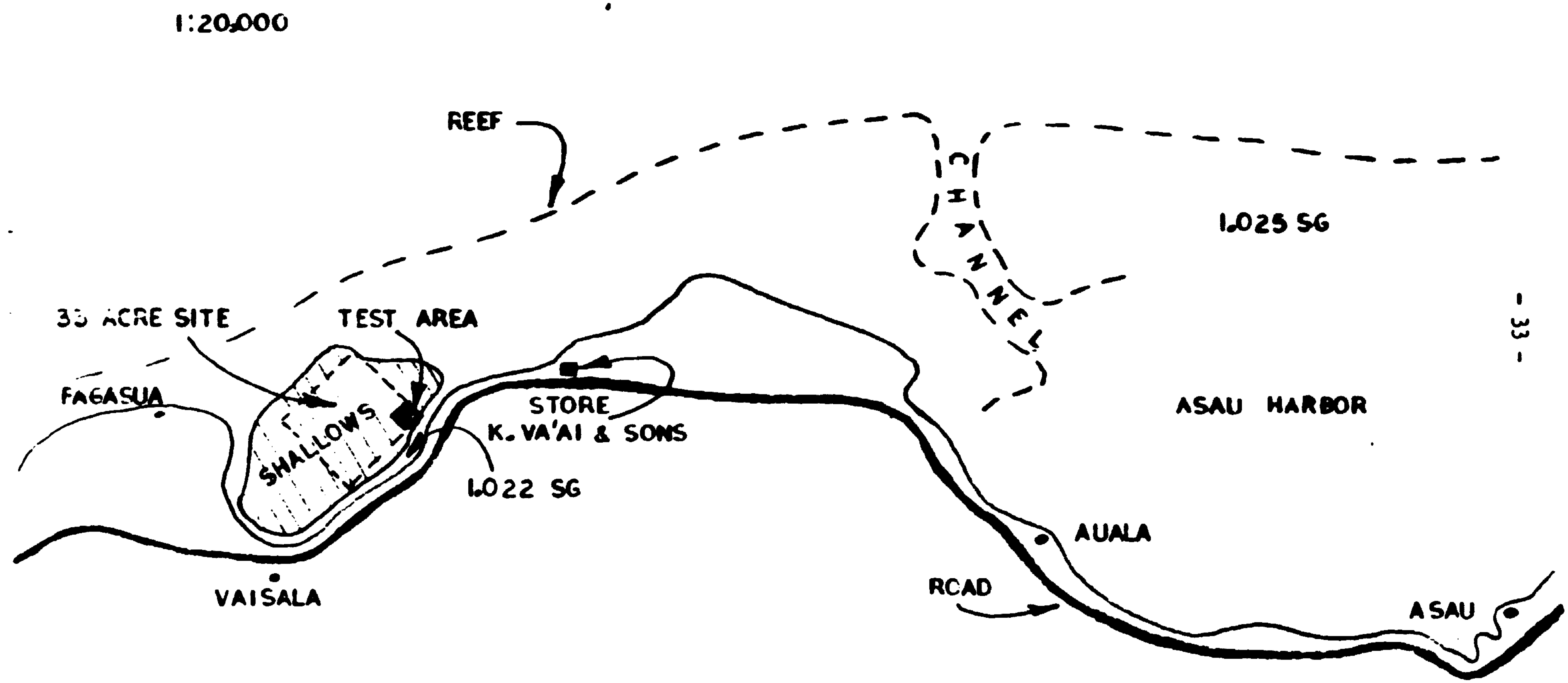


FIGURE VII

VAISALA BAY - SAVAII

of water remaining. The bottom formation appears to be solid coral and limestone, and no signs of water springs were observed. This is an extremely level part of the bay. There appeared to be some fresh water seepage into the bay along the shoreline, but it would probably not affect this level area as a dyke would divert the water away. To utilize this area, a sea wall type dyke would be constructed to surround this area on four sides from tide water intrusion. The shore side dyke would parallel the shoreline, with about twenty meters distance between the dyke and shoreline to divert the fresh water seepage away from this area. Figure VIII illustrates the facility layout proposed for 33 acres of this area. This area is comparatively level as it is now formed, but some additional bottom leveling would be desirable at some stage of the construction phase, after the test ponding had been completed. A very thin layer of water could be maintained, which would make an efficient evaporation area. Sea water would be used at high tide for controlled flooding of the area, allowing a gravity water flow system, except for the final pick-up and discharge of the bitterns from the crystallizers.

It is anticipated these dykes will be constructed by hand with large rocks and concrete or mortar. This will be expensive construction as compared to other salt works because of the required cement. A bulldozer will be required to bulldoze a quantity of large rocks from the area to form sea wall protection in addition to the reef, and to also provide some rock for the dyke construction. Although this is not the conventional type of area used for solar works, there is no reason it cannot be successfully used. It will of course be recommended that test ponding be done at this location before committing the entire program, to determine there are no springs of fresh water in the area of intended use and that the bottom is impermeable to the extent saturated brine can be developed with solar evaporation.

5. RECOMMENDED TEST PROGRAM

As it has elsewhere been stated in this report, the Vaisala Bay area at Savaii is not typical of a usual solar salt evaporating area. However, there is no reason this area cannot be successfully used for the manufacture of solar salt. There are, however, two major concerns that should be thoroughly checked out prior to the commitment of the entire program.

1) actual evaporation check against the theoretical
2) testing for both fresh water and sea water intrusion through the bottom of a dyked off section of the bay. Such intrusion may not become apparent unless an area is sea walled off causing a differential in water levels both inside and outside the area as the tide rises and falls.

It is therefore recommended that pan evaporimeters and a rain gauge be installed at the Vaisala bay area at the earliest opportunity, in order to obtain records for the dry season which is just starting. The observatory has extensive experience in this type of work and are well staffed and equipped for this type of undertaking.

To check whether an intrusion of water will be experienced, a section of the bay area will have to be sea walled off. A suggested program will be as follows:

A. Do an on site survey of this shallow part of the Vaisala bay with a civil engineer, and determine precisely the extent of this useful area, and the boundaries. To initially help identify this area as shown in figure 4-1, associate expert/geologist Carel Brands, headquartered at the observatory could be helpful. He has examined this area at low tide, and is familiar with the terrain and the requirements of the project.

B. Once the large area is identified, a 33 acre site could be marked out in the Southeast Corner, to roughly conform to the facility layout in Figure 6-1.

C. A bulldozer could be employed to level and move the large rocks to the periphery of the area and clean and clear the bottom so it can be more easily observed.

D. A 160' x 160' square section could then be laid out in the Southeast Corner, just off shore, as a test area. A sea wall could be constructed around the periphery to prevent high tides from flooding the enclosed areas. This sea wall of large rock and mortar or concrete would have a simple tidegate in one corner. At low tide the water would be allowed to drain out through this gate, which would then be closed. As the tide rises, a differential in water level and consequent pressure within the enclosed area would quite readily prove or disprove the permeability of the bottom surface. The sea water trapped on the inside of the enclosure could also be monitored for evaporation purposes.

Such a test construction program is estimated to cost about $10,000. If the test facility is located at the Southeast corner of the 33 acre future area, then probably at least half the sea wall could be utilized in the final scheme.

The rest of the area not enclosed by the seawall could be closely observed at low tides, for possible evidences of fresh water intrusion within the area.

Such a program is recommended as essential before proceeding with the main project.

6. RECOMMENDED PRODUCTION FACILITY LAYOUT

This section reviews the land area requirements necessary for the production of solar salt under the climatic conditions that are assumed to exist at the western tip of Savaii. This section in particular refers to the Vaisala Bay area, which is the only level terrain located in a "seasonal dry belt" area of the islands of Western Samoa. Figure VIII is a projected solar salt facility layout for the Vaisala Bay location.

6.1. Solar salt plant - estimated area requirement for conditions at a Falealupo-Asau location, Savaii.

Land area requirements vary with evaporation rates, length of evaporation cycles, brine recovery and operating inefficiencies, and seepages. Area requirement may be generally estimated as follows:

1) Evaporation rates: The rate of sea water evaporation decreases as specific gravity increases. During the concentration and crystallizing cycle a rate 50% that of fresh water is estimated.
   462 mm evaporation at Falealupo = 231 mm brine evaporation.
2) Inefficiencies: Filling concentrators at the beginning of the season, rain loss of brine, operating losses - assume 50%.
   231 mm @ 50% efficiency = 115 mm brine evaporation.
3) Effective evaporation per hectare of land area:
   10,000 m^2 x 115/1000 = 1150 tons water evaporation per year.

4) Sea water (1.025 S.G., 3.5 baume) = 96.52% H_2O (water) and 2.7% NaCl (salt).

5) At 1.260 S.G. (30 baume) 97.6% of the water has been evaporated for a 79% salt recovery. Figure 2.
(96.52 x .976) = 94.3 tons water evaporation per ton of salt.

6) 94.3/2.13 = 44.3 tons water evaporation per ton of salt.

7) Compensate 10% seepage and 5% handling loss.
44.3/90 x 100/95 x 100 = 51.8 tons evaporation per ton of salt.

8) Salt production per hectare:
1150 tons water evaporation/51.8 = 22.2 tons salt per hectare.

9) Area requirements per 100 tons of salt production per year.
100/22.2 = 4.5 hectares for each 100 tons of salt.
4.5 x 2.47 = 11 acres for each 100 tons of salt.
100/11 = 9 tons salt per acre of land production per year.

6.2. Crystallizing area estimate - Falealupo/Asau

The size of the crystallizing area depends upon the amount and rate of evaporation that the crystallizer brines receive. They normally evaporate at about 1/3 the rate of fresh water. Factoring the 426 mm evaporation rate for the above area, and allowing for a 50% inefficiency factor, it is calculated we receive (462 x .333 x .5) 77 mm of brine evaporation or (10,000 m^2 x 77/1000) 770 tons of evaporation per hectare.

During the salt crystallizing process 5.7% of the original water in sea water evaporates, and 79% of the original salt is recovered. (.057 x 96.52)/(2.7 x .79) = 2.58 tons of water evaporation produce 1 ton of salt.

To allow for a 10% leak factor and a 5% salt handling loss, this ratio becomes:

2.58/90% x 100/95% x 100 = 3 tons water evaporation per ton of salt.

Each hectare of crystallizer then produces:

770 tons water evap/3 = 257 tons of salt.

A 100 ton production then requires:

100/257 = .39 hectares or 1 acre per 100 tons.

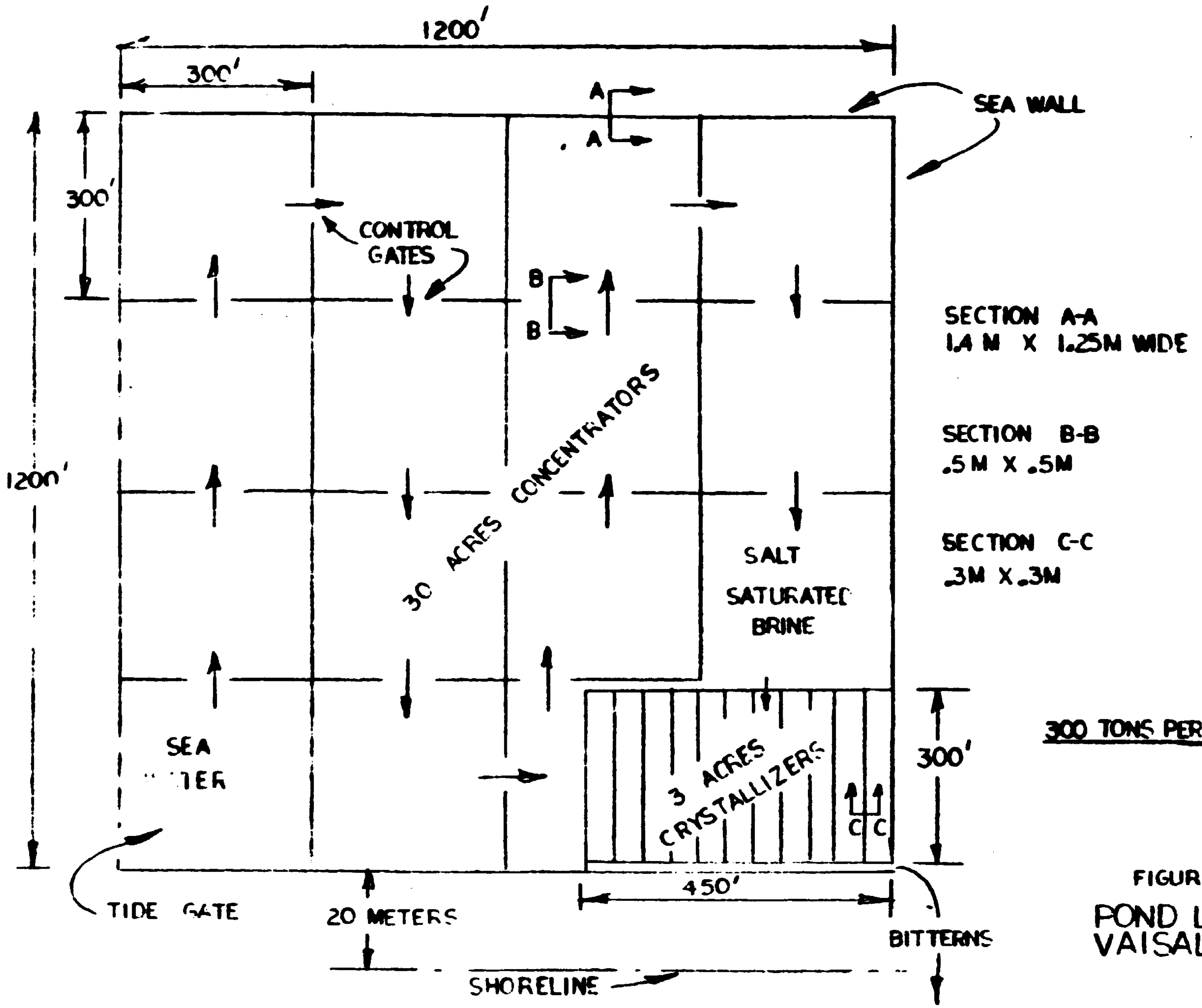
Concentrator to crystallizer ratio.

A ratio of ten concentrating units to one crystallizing unit is then required for the salt plant, or a 100 tons per year production requires 10 acres of concentrators and 1 acre of crystallizer. A typical layout for the Falealupo/Asau locality to produce 300 tons per year is illustrated in Figure 6-1.

6.3. Concentrator to crystallizer ratios

The preceding sections estimate that a combined concentrator and crystallizer area totaling eleven acres will produce 100 tons of salt per year under the climatic conditions of the Falealupo/Asau location, and that one acre out of this eleven should be a crystallizer area. A 10:1 ratio is therefore established. Figure VIII illustrates a 10:1 ratio facility.

Normally under a wet climate seasonal dry period type of operation such as this, a ratio of 20:1 or more is usually enclluntered. The overall production of 9 tons per acre of total area should not change, but the ratio of concentrators to crystallizers could change under actual operating conditions. This ratio can only be determined under actual operating conditions, or from a practical test pond arrangement.



300 TONS PER YEAR

FIGURE VIII
POND LAYOUT
VAISALA BAY

7. POND CAPITAL AND PRODUCTION COSTS - NON-REFINED SALT

7.1. This section estimates the capital costs of constructing a salt facility at Vaisala Bay, Savaii, and estimates the cost of producing and packaging 300 tons of crude non-refined salt in 50 kg bags per year. This salt would be suitable for cattle hide salting, beef salting, and other miscellaneous uses not requiring a table grade type refined salt. This crude salt produced at Vaisala Bay would be perfectly suitable for use as a coarse kitchen salt for cooking purposes, and could be hand ground for table use if desired. Any so-called impurities in this salt would be nothing more than those natural elements of sea water. The type of salt to be produced here can also be known as a "Natural Sea Salt," and is a much sought after item in sophisticated world markets, particularly as a health food store item.

7.2. Pond Capital and Construction Costs

Vaisala Bay, Savaii

4800' Dyke section A-A	1463m x $32.80	48,000
72000' " " B-B	2194m x $ 4.70	10,000
3000' " " C-C	914m x $ 1.70	1,500
1 tide gate		1,000
14 concentrator brine control gates		500
11 crystallizer " " "		300
11 " " drain gates		300
1 bittern drain gate through seawall		500
	Dyke and gate costs	62,100
Bulldozer to level area and move rocks		2,000
Level crystallizer bottom with sand 2"/12" x 43560 x 3/27 x $4.00 yard		3,000
Pour 1 1/2" of concrete on crystallizer surface, or equivalent such as clay tiles, concrete tile 1 1?2"/12" x 43560 x 3/27 x $35.91 yard		21,500
	Crystallizer bottoms cost ($8835 per acre)	26,500
	Combined cost	88,600
	20% contingency	17,400
Pond construction costs		WS$106,000
Salt storage building		15,000
Pond draining pump		2,000
Estimated total capital costs		WS$123,000

7.3 Costs to produce and package 300 tons of non-refined salt in 50 kg bags per year.

	Depreciation	Maintenance
1. Pond system		
Depreciation @ 30 years	3500	
Maintenance @ 2.5%		2500
2. Salt storage building		
Depreciation @ 15 years	1000	
Maintenance @ 5%		750
3. Pond draining portable pump		
Depreciation @ 3 years	700	
Maintenance & operating		1000
	5200	4250
4. A. Labor - hand harvest with barrows and hand stock in salt storage building. 6 men for 100 days @ 6.00 per day =	4000	
B. Expendable equipment, barrows, shovels, etc.	1000	
Labor & light equipment	$5000	

Estimated production costs for 300 metric tons per year.

	Total	Per metric ton	Per ton of 2000 pounds
Maintenance	4250	14.17	12.85
Depreciation	5200	17.33	15.72
Labor & equip.	5000	16.66	15.11
Bagging costs		5.50	5.00
15% contingency		8.04	7.30
10% ROI	12300	41.00	37.19
F.O.B. salt plant		WS$102.70	WS$93.17

8. ALTERNATE FACILITY COST ANALYSIS

The concentration of brine in heavy rainfall areas by solar evaporation was described in a paper by Buchanan. Such a system drained the brine from the concentrating areas into covered deep storage during rainfall, and then the brine was rapidly pumped back onto the evaporating field after the rains had passed. Such a system in combination with covered solar crystallizers to protect them from rainfall has been tentatively suggested by the New Zealand Department of Scientific and Industrial Research as a possible method to solar crystallize salt from sea water under the very adverse climatic conditions of Apia, Western Samoa. This exercise is highly theoretical and very costly, as the following brief analysis indicates. Where applicable, construciton unit costs from the Vaisala Bay analysis have been used.

300 tons per year production - 35,000 M^2 total area.

<u>Cost analysis</u>

Prepare crystallizers @ 8835 per acre	15,000
Roof over 7000 M^2 of crystallizers @ 12.50	87,500
2,000,000 gallon deep storage tanks	40,000
Roof over deep storage 3100 M^2 @ 12.50	40,000
Slope 28,000 M^2 @ 12.50	56,000
Install pump	10,000
Dyke construction	10,000
10% contingency	52,000
Minimum construction costs	WS$ 311,000

	per ton
311,000 @ 30 years depreciation/300 tons	35.00
311,000 @ 2 1/2% maintenance/300 tons	26.00
Labor	12.00
ROI @ 10%/300 tons	103.00
Minimum cost per ton	WS$ 176.00

9. SALT MARKET ANALYSIS, WESTERN SAMOA

The following section reviews the volume of salt used and the cost of salt imported into Western Samoa. This information indicates the economics of producing a coarse grade salt in Western Samoa in a sufficient volume to at least supply the local demand should be acceptable. This initial production has been estimated at 300 tons per year.

9.1. Because Western Samoa is a non-producer of salt, the number of imported tons should be a good guide as to overall usage. The following tonnages are from Government publications, but there is no information available past 1975.

Tons of imported salt per year

Country of Origin	1972	1973	1974	1975
United Kingdom	.35	.80		5.10
Australia	123.50	169.95	33.65	83.4
New Zealand	7.35	1.35	3.40	7.75
W. Germany	60.50	68.0	51.10	88.00
Netherlands	118.00	114.6	56.95	89.55
Rumania	5.[illegible]0			
USA	.20	4.6	3.65	19.65
Fiji Islands		45.6		
	315.05	404.9	148.75	293.45

9.2. Current salt demand

To determine the amount of salt to first be produced at Savaii, some individual consumers and retailers were contacted regarding their requirements. Current salt demand is estimated at about 300 tons per year, with a strong growth pattern as indicated by the following information.

9.2.1. Western Samoa Trust Estates Corporation is a government owned organization that operates plantations, cattle farms, a soap factory, and various other enterprises. They have a strong growth rate, and indicate they could probably absorb 300 tons of salt a year in their facilities in the near future.

9.2.2. A large meat processor, Samoa Meat Products, currently use in excess of 50 tons of salt per year. They predict a strong future growth.

9.2.3. Two retail stores report a combined sales of about 60 tons of coarse salt per year.

9.2.4. The fishing industry uses only about five tons of salt per year, but predict their volume should increase as their growth continues.

9.3. Landed cost of imported salt

To obtain a more current cost structure, the following information was solicited from individual salt importers. These costs are the landed cost of salt, including invoice cost, ocean freight, insurance, local charges and custom duty, which is generally 18% of ad valorem value. Generally coarse salt is less expensive than the more refined vacuum salt. However, there is a large fluctuation of salt costs due to exchange rates and competitive bidding, causing vacuum salt to sometimes be used in place of coarse salt, and vice versa. Salt costs are rising rapidly, so these costs represent probably a minimum cost.

Landed costs of salt	WS$ per 2000 lb. ton
Vacuum salt (Australia)	172.50
" " (USA)	112.60
" " (Germany)	148.00
" " (")	152.37
" " (")	121.50
Coarse salt (Australia)	122.00

9.4. Adjoining islands salt use

The estimated coarse salt needs of other adjoining islands to Western Samoa can be estimated as follows:

A) Assume 6.0 kg per year per capita consumption.

B) Assume 50% of above consumption is coarse crude salt.

	Est. Population	Metric tons per year
Cook Islands	19,000	115
Fiji Islands	535,000	3,200
Ellice Islands	56,000	335
Solomon Islands	195,000	1,170
Tonga	100,000	600
New Hebrides	86,000	520
Total salt at 6 kg per capita per year		6,000
Coarse crude salt requirements @ 50%		3,000
Less possible Fiji production		1,800
Adjoining islands requirements		1,200 tons

10. REFERENCE BOOKS, REPORTS, AND GUIDELINES

10.1. Kaufman, D.W. "Sodium Chloride, the Production and Properties of Brine," 1960. Reinhold Publishing

10.2. Buchanan "Salt Manufacture from Sea Water" Chemical Processing, 1960

10.3. Garret Research & Development Company "Factors in the Design of Solar Salt Plants"

10.4. Department of Scientific and Industrial Research, New Zealand, Letter dated January 1978 titled "Salt Production in Western Samoa from Sea Water"

10.5. Apia Observatory, Department of Agriculture, Western Samoa. The following reports and studies:

Climatological Technical Report No. 5

" " " No. 6

Summary of Wind at Apia

" " Humidity in Western Samoa

10.6. Pacific Islands Business and Trade Directory June, 1977

10.7. Trade, Commerce & Shipping of Western Samoa - Calendar Years 1972, 1973, 1974, & 1975.

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