DOE/CE/26572--T1

WAIKIKI

DISTRICT COOLING UTILITY

PROJECT REPORT

DEPARTMENT OF ENERGY
OFFICE OF PROCUREMENT OPERATIONS
SOLICITATION NUMBER
~~DE-PS01-88CE26540~~
FG01-88CE26572

20 FEB 90

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DOE/CE/26572--T1

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WAIKIKI DISTRICT COOLING UTILITY

HONOLULU, HAWAII

PROJECT REPORT

20 FEB 90

Prepared By:

Darrow-Sawyer & Associates, Inc.
Makai Ocean Engineering, Inc.
Smith, Young & Associates, Inc.

WAIKIKI DISTRICT COOLING UTILITY
DEPARTMENT OF ENERGY SOLICITATION DE-PS01-88CE26540

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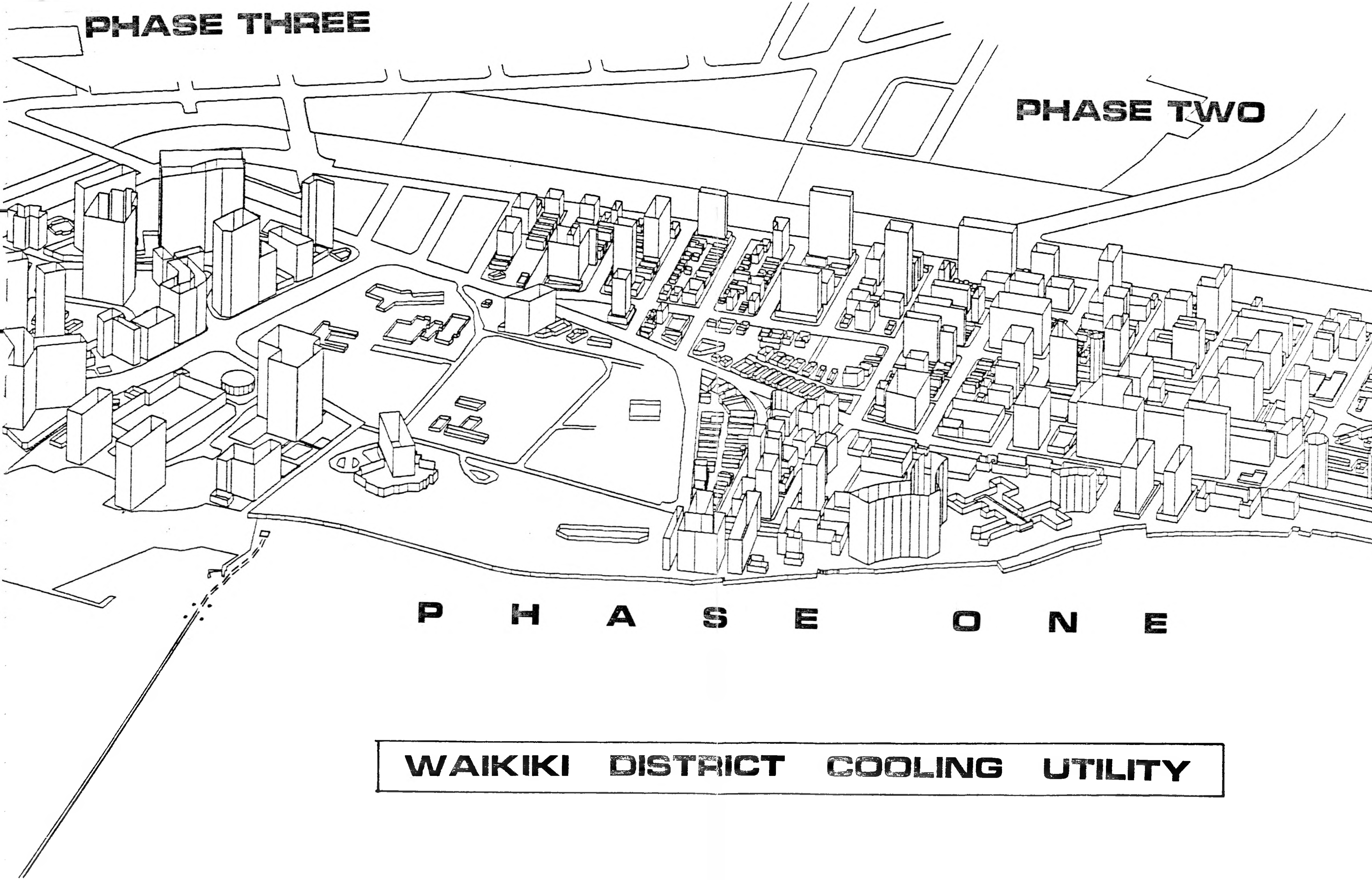

WAIKIKI DISTRICT COOLING UTILITY

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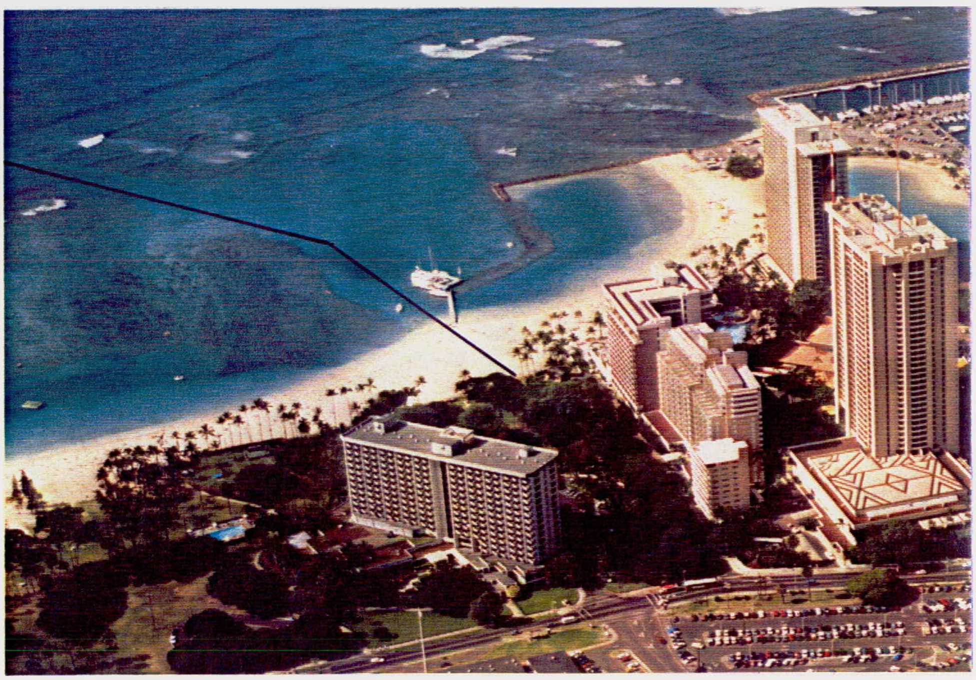

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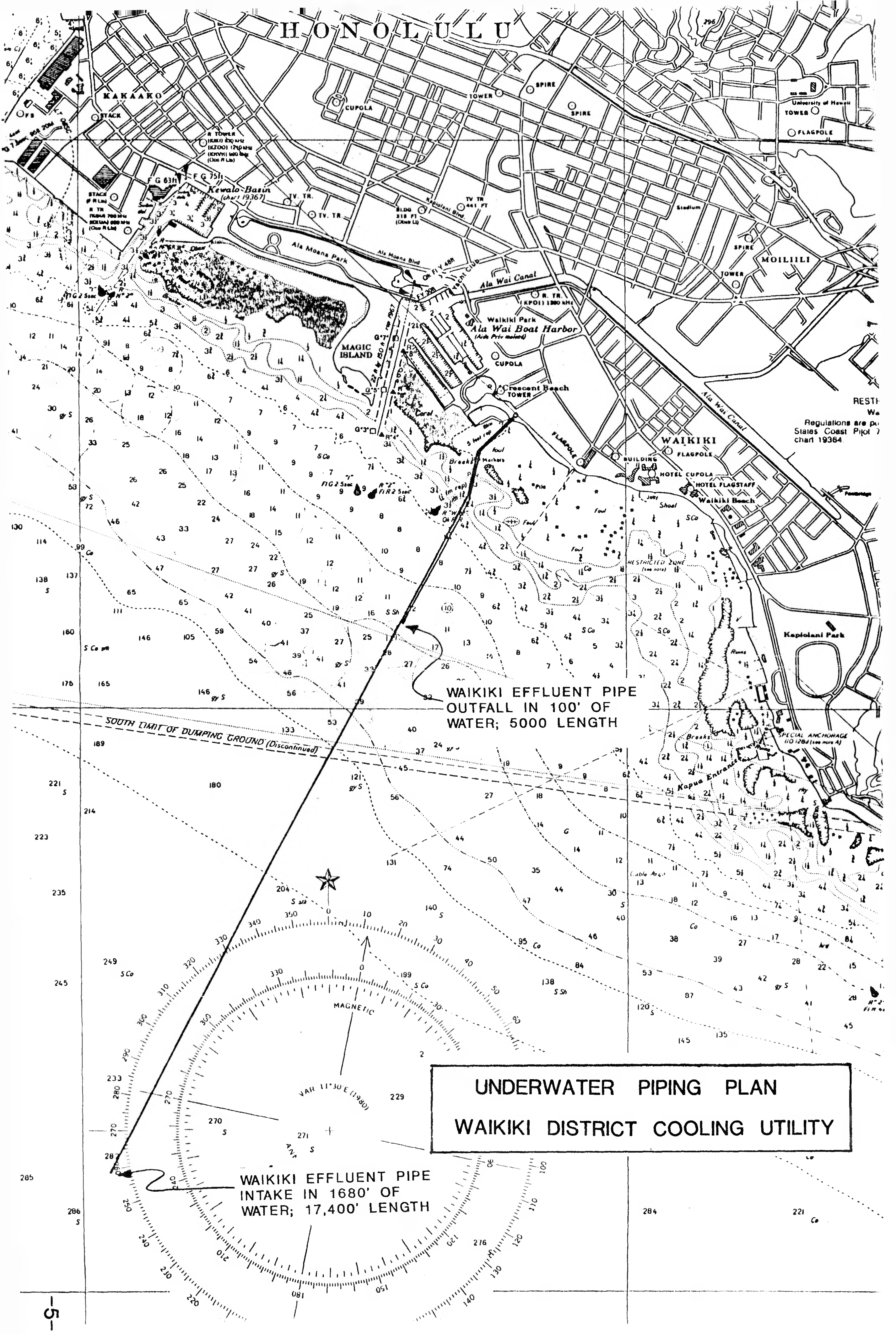
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WAIKIKI DISTRICT COOLING UTILITY

PROJECT DESCRIPTION

WAIKIKI DISTRICT COOLING UTILITY
HONOLULU, HAWAII

WAIKIKI DISTRICT COOLING UTILITY
DEPARTMENT OF ENERGY SOLICITATION DE-PS01-88CE26540

BACKGROUND

The Hawaiian Islands are of volcanic origin and as such are structured with cities and villages located, for the greater part, near relatively deep ocean waters. The surface water surrounding the islands is approximately 73 degrees F. At a depth of 1680 feet three miles off Waikiki on the island of Oahu, the temperature of the seawater is about 45 degrees F. This seawater at this temperature is a very valuable asset which can be used as shown in the following paragraphs.

High density Waikiki has many large buildings including hotels, condominiums and office buildings with air conditioning systems that require 45-48 degree F. water. Presently this water is chilled by refrigeration machines which consume a tremendous amount of electrical power.

It has been estimated by the Hawaiian Electric Company that the 107 Megawatts consumed in Waikiki, 51.4 Megawatts are used by air conditioning chillers and their auxiliaries.

Therefore, if the deep, low temperature ocean water can be delivered to the buildings, a major energy savings can be effected. This would involve laying a pipe on the ocean floor and conveying the cold seawater to a battery of heat exchangers located in a central pumphouse near the beach. From this point, chilled fresh water will be circulated through a District Cooling System to the users, bypassing the need for most of the refrigeration.

This direct use of cold seawater has been extensively studied by DOE since the 1970's. A similar system has been successfully installed for condenser water in Hong Kong. Technology developed by DOE will be integrated into the project. New innovations involving District Cooling Systems will be used.

The Hawaiian planning began in 1974 at the time of the original Arab oil embargo and has continued to be a goal of the Hawaiian participants ever since. The engineering has been continued, but lacking financial partners and declining oil prices, this work has been done on a self financed basis, plus a grant of $44,187. from the US Department of Energy Solicitation DE-PS01-88CE-26540.

The economic savings and the announced goal of the State of Hawaii demonstrate that this project has the potential for actualization in the next few years. By using cost effective engineer-designs, this project can attract financiers who will implement not only Waikiki District Cooling with seawater but elsewhere in Hawaii and in other coastal areas in the U.S.

WAIKIKI DISTRICT COOLING UTILITY
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PROJECT DESCRIPTION

The use of cold seawater to replace water chilled by air conditioning and refrigeration compressors and their auxiliaries represents a cost effective savings applied to the largest single power user in Waikiki. Of the 107 Megawatts used here, 51.4 are identifiable with air conditioning that is subject to energy reduction by the use of cold seawater.

The project will consist of laying an ocean intake pipe a minimum of 48" in diameter approximately three miles offshore to a depth of 1680 feet. Water will be pumped to a machine room which will house a bank of titanium plate heat exchangers and salt water and chilled water pumps. Here the salt water will cool fresh water which will be circulated through a district cooling system to users in Waikiki. A second seawater pipe will return the slightly warmed water approximately one mile offshore.

The scope of the work covered by this application is to specifically attain greater detail into this already well accepted general plan using advanced district cooling and DOE technologies already accepted, so that construction costs and economics can be accurately ascertained. The ultimate goal being to obtain construction financing and have this project become a reality.

ENERGY COSTS:

Considering energy charges alone, the 54.1 Megawatts, represent to the Hawaiian Electric Company a monthly billing of $2,276.000. dollars per month using schedule "P" block rate of $.065/kw-hr. Demand charges are in addition to this billing.

ENERGY SAVINGS:

Energy savings have been projected from 50 to 80% by various personnel in this project and in others. Argonne National Laboratories in Report ANL/ICES-TM-10 stated that 70 to 80% of the electrical energy used for air conditioning can be saved by converting to this technique. Taking an average of 75% savings and applying it to the above utility billing represents a potential $1,707,000. per month. One third of this or $569,000. per month is a minimum cost that could be avoided in the first phase of this project.

UTILITY LOAD LEVELING:

This will be a substantial factor in the reduction of the Electric Utility Demand brought about by the peaking of loads at certain times. The storage effect of the chilled water loop will have a marked effect. In addition to this, the additional capacity from any chilled water tank storage will aid this materially.

OTHER ECONOMIC SAVINGS:

In addition to direct energy savings, there are considerable other savings and benefits which will accrue to the users of the chilled water utility. These are:

* Outright elimination of cooling towers in many installations.

* Drastic reduction in water required for cooling tower evaporation, carryover, and bleed-off.

* Reduction in the use of chemical water treatment in the cooling towers.

* Less power consumption from cooling tower fan motors and condenser water pumps.

ENVIRONMENTAL:

This project is environmentally clean. It will draw cold seawater in a corrosion resistant pipe from a depth of approximately 1680 feet at a distance of three miles offshore, and return the water to the ocean through a second pipe over a distance approximately one mile offshore.

The only prime movers in the system will be pump motors which will be electrically powered. There will be no contaminants of any kind introduced into the seawater system.

A very special benefit that will accrue locally and Internationally is that there will be a great reduction in the amount of CFC's (ozone layer destroyers) that will be needed to operate the refrigeration compressors in the air conditioning systems. The primary refrigerant that will be reduced in use will be R-11 which is used in most centrifugal compressors.

RENEWABLE SOURCE OF ENERGY:

It is most obvious that the cold seawater is an endless, renewable, clean source of energy for this project.

UTILIZATION OF PRIOR GRANTS.

This Study will utilize additional technologies that have been developed by prior grants under the Department of Energy and other organizations striving to improve conservation.

Some of these are the use of advanced fluids (slippery water), underground leak detection, additives on corrosion, and chilled storage.

OTHER USES & BENEFITS:

Refrigeration, fluid cooling and other systems requiring the use of cooling towers, evaporative condensers, or even air cooled condensers are candidates for the use of this proposed chilled water district cooling loop. The project will contribute in a reduction in waste heat generated by utility operation.

The use of chilled water for condensing purposes will lower head pressures in compressors remaining in the system resulting in lower power input. It will also mean cooler and quieter machine rooms.

ENDORSEMENTS:

The principle of this concept has been endorsed by all who have obtained knowledge of the project. Included among them are:

Honorable Spark M. Matsunaga, U.S. Senator
Hawaii State Government
City & County of Honolulu
Hotel Chains - Sheraton, Hyatt and Outrigger
Electric Utilities for four islands
Chamber of Commerce - Energy Committee
Financial Community Representatives

PROVEN TECHNOLOGY:

The basis on which this project has been developed has come from proven technology that has been put to practical use - from the knowledge and experience of engineers and technicians that have been involved in the following areas of work applicable to this project for many years:

Underwater Pipelines.
Pumping Systems - Step Constant and Variable.
Corrosion Control.
Marine Concrete Structures.
Cool Storage.
District Piping Design.
Civil Easements and Rights of Way.
Environmental Impact Statements.

Firms chosen for participation in this endeavor represent long experience and have demonstrated great innovation. The enclosed resumes of the key personnel bear out only a portion of what can be covered in this brief report.

SUMMARY:

This concept is valid from every aspect. It substitutes seawater for imported oil, is efficient, pollution free, and is economically sound.

The work to be established under this application is to continue the effort that is already well underway. Specifically what is needed is funding that will permit the necessary and further engineering to attain an accurate users plants and equipment.

DESIGN TEAM

WAIKIKI DISTRICT COOLING UTILITY
HONOLULU, HAWAII

WAIKIKI DISTRICT COOLING UTILITY
DEPARTMENT OF ENERGY SOLICITATION DE-PS01-88CE26540

DEVELOPMENT APPROACH

The direction of the work involved in this application is involved chiefly with proceeding further with the work that has been accomplished. The basic plan has been established, and in order to attract venture capital, more detailed site investigation and engineering work needs to be done to allow contracts to arrive at better construction estimates.

The members of the A & E Teams are already generally familiar with the ocean bottom, beach, sites, streets, utilities, utility corridors, major building, air conditioning and refrigeration equipment in the Waikiki area. They are also familiar with the operation and maintenance personnel of the hotels and other key installations.

The task breakdown on the basic investigative items and the consulting firm which will be responsible for the work is as follows:

*	Prime Contractor:	Darrow-Sawyer & Assoc.
*	Ocean & Channel Work: Seawater Pumping	Makai Ocean Engineering
*	Pumphouse Design:	Alfred Yee Division
*	Heat Exchangers & Chilled Water Pumps:	Darrow-Sawyer & Assoc.
*	Civil Plan & District CW:	Smith, Young & Assoc.
*	Power & Electrical Design:	D.V. MacMahon, Ltd.
*	Major Building Connections:	Darrow-Sawyer & Assoc.

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COMMITMENT

The firms participating in this work as shown in the application narrative have the following additional qualifications or back-up:

* All are long established engineering firms in Hawaii. The youngest being 14 years in practice here.

* Principals and supporting staff that are thoroughly experienced in their discipline.

* All participants have already put in a minimum of three years of thought and work in this project. Some have participated since 1974.

* All have participated in a marine oriented designs and/or installations in the Pacific Ocean areas.

* Leo A. Daly and Associates, parent affiliate of Alfred A. Yee Division, have had extensive experience in District Heating and Cooling.

The Mechanical, Electrical and Civil Engineers are desirous and capable of carrying out an on-going program of detailed study, design, planning and implementation of a district cooling system if called upon for further activities beyond this grant program.

WAIKIKI DISTRICT COOLING UTILITY
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CAPABILITY

The effectiveness of the product to be produced as a result of the report is based on the experience and past performance of the principals of the engineering firms and their staffs. This proposal can only begin to show the depth of this team in the space or time allotted.

The enclosed data should be sufficient to show adequately the experience and knowledge in the areas that are pertinent to this project.

Design progress has been accomplished by team member on other projects which have been closely related to the technology involved in this endeavor. One for each of the major consultants is:

1. Offshore pipe installation. Notably, the OTEC underwater pipeline at Keahole Point, Hawaii. Makai Ocean Engineering.

2. Marine plate heat exchanger installations using Alfa-Laval titanium units and corrosion resistant pumps, piping and controls. Hawaii State Capitol Building. Darrow-Sawyer & Associates.

3. Reinforced concrete marine structures - both underwater and floating. ROFOMEX I. Alfred Yee Division.

4. District underground piping installations, and electric power distribution design. Sheraton Hotels. Waikiki. Smith, Young and Assoc. And Douglas V. MacMahon, Ltd.

WAIKIKI DISTRICT COOLING UTILITY
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THE A/E TEAM FOR PHASE I OF THE WORK

Mechanical Engineers (Prime)	DARROW-SAWYER & ASSOCIATES, Inc. 1724 Kalauokalani Way Honolulu, HI 96814 (808) 949-4155 Van O. Darrow, CEO
Ocean Engineers	MAKAI OCEAN ENGINEERING Makapuu Point Waimanalo, Oahu 96795 (808) 259-8871 Joe Van Ryzen, President
Civil Engineers	SMITH, YOUNG & ASSOCIATES 3049 Ualena St. Honolulu, HI 96814 (808) 836-0015 Russell Smith, President
Electrical Engineers	DOUGLAS V. MACMAHON, Ltd. 1131 Kapahulu Avenue Honolulu, HI 96816 (808) 735-2468 Douglas V. MacMahon, President
Structural Engineers	ALFRED A. YEE DIVISION - LEO A. DALY 1441 Kapiolani Boulevard Honolulu, HI 96814 (808) 973-1800

OCEAN PIPING

WAIKIKI DISTRICT COOLING UTILITY
HONOLULU, HAWAII

WAIKIKI DISTRICT COOLING UTILITY
DEPARTMENT OF ENERGY SOLICITATION DE-PS01-88CE26540

OCEAN PIPING DESIGN

This paper discussed the design, deployment and costs associated with the development of a cold water intake and effluent disposal system for Waikiki, Honolulu, Hawaii. The cold water from this system would be used in an innovative, centralized air conditioning system to reduce the required conventional air conditioning loads in a number of large Waikiki hotels.

Makai Ocean Engineering, Incorporated has been responsible for the design and assisted in the deployment of three cold water pipes (CWP) developed at Keahole Point, Hawaii. The cold water from these pipelines, drawn from a depth greater than 2000;, has been used for aquaculture, mariculture and ocean thermal energy conversion experimentation.

The pipeline design described here for Waikiki differs from past designs primarily because of the considerable differences in site characteristics. Compared to the steep, rough slopes off of Keahole Point, Hawaii, the submerged slopes off Waikiki are very gradual and flat requiring a very long intake pipe to obtain adequately cold water temperatures for this project. The selected pipeline design is based on a 48" high density polyethylene pipe which is anchored to the bottom at intervals down its 17,400' length with custom designed concrete pipe anchors.

In addition to the intake pipeline, a 5000' long, 42" diameter effluent pipeline of similar design is installed immediately adjacent to it. This pipe handles the outfall of the used cold water after it has passed through a bank of heat exchangers.

The final performance of these pipelines can be estimated as follows:

Intake Pipe:

Length	17,400’
Diameter	48"
Intake Depth	1680’
Discharge	Shoreline

Effluent Pipe:

Length	5000’
Diameter	42"
Discharge Depth	100’

Pumps:

Number	4 (2 required, 2 standby)
Intake Suction Head	15.0’
Effluent Discharge Head	5.7’
Power Required *	56 KW (Intake) 22 KW (Effluent)

Seawater:

Flow	18,200 gpm
Intake Temp. CWP	44.6 deg. ± 1 deg. F.
Outlet Temp. CWP	45.3 deg. ± 1 deg. F.

* Assumes Pump efficiency of 80% and motor efficiency of 90% and does not include power required to pump water through heat exchangers.

The installation of intake pipe could easily be done in two sections. The first section, 4200’ long, would stretch from the shoreline to maximum depth of 60’. The second section would be brought out the following day and would be 13,200’ long. This section could be attached at sea to the previously deployed section and submerged to a maximum depth of 1680’. The effluent pipeline could be deployed in one section on the third day of deployment.

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OCEAN PIPING EXPERIENCE

The cold water pipe (CWP) configuration used in this design for the Waikiki air conditioning project is based on pipelines which have already been installed at Keahole Point, Hawaii. Makai has designed three installed pipelines for the Natural Energy Laboratory of Hawaii *NELH) and for the Hawaii Ocean Science and Technology (HOST) Park, both located at Keahole Point. These pipelines vary somewhat in design, ranging from 12" through 40" in diameter, but for the purposes of this study, are nearly identical.

Makai designed the 40" polyethylene cold water pipe illustrated in Figure 101 for the HOST Park. This pipeline is approximately 6560' long and has an intake depth of 2200'. The offshore portion of this pipeline is one continuous, free-spanning inverted catenary over 3280' long. The polyethylene material is buoyant in water, and this portion of the pipeline stays well above the bottom. The catenary concept was used at this location because of the very irregular bottom bathymetry that was difficult to otherwise cross. The HOST Park 40" pipeline is discussed in detail in a paper in the Appendix.

The most recently installed pipeline at NELH is the 18" pendant pipeline illustrated in Figure 1-2. A primary goal of this pipeline design was to install, at minimum cost, a reliable deepwater system. This pipeline differs from the HOST pipeline in that the deep water portion is buoyed approximately 40' off the bottom and hung on a series of pendants. The deployment was accomplished without major offshore equipment and was successfully deployed in October 1987 and the pipe is now online servicing NELH.

All of the pipelines installed at NELH/HOST Park use polyethylene as the pipeline material. Polyethylene has significant advantages for these pipelines in that it is inert and will neither corrode nor contaminate the water. Polyethylene lengths are heat fused together to form a long, continuous pipeline with joints that are as strong as the pipeline itself. Polyethylene has excellent strength and flexibility, and the polyethylene pipe is far easier to deploy than other materials. Furthermore, the polyethylene is buoyant in water; this characteristic provides a great deal of design flexibility and deployment ease. Figure 1-3 illustrates the typical pipe sizes which are available from one major polyethylene supplier, DuPont Canada. This study has concentrated on pipe sizes from the 40" to the 63" size. With the new resins that are now available from DuPont, pipe DRs lower than shown on the table are possible. In general DuPont can supply one DR increment lower than any shown in this figure.

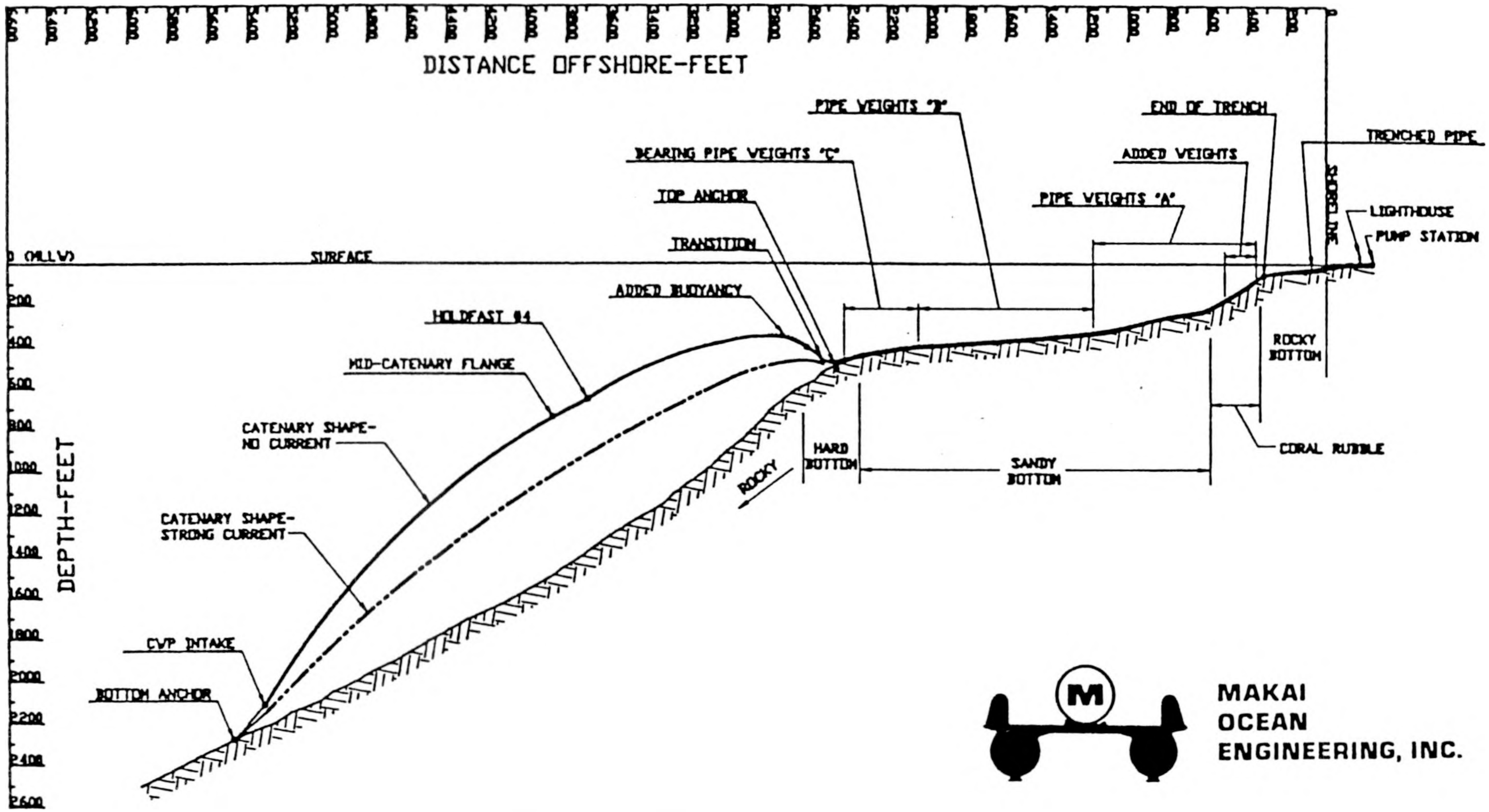

Figure 1-1: Typical "Catenary" Style of CWP Installation. Two pipelines at Keahole use this design, a 12" and a 40".

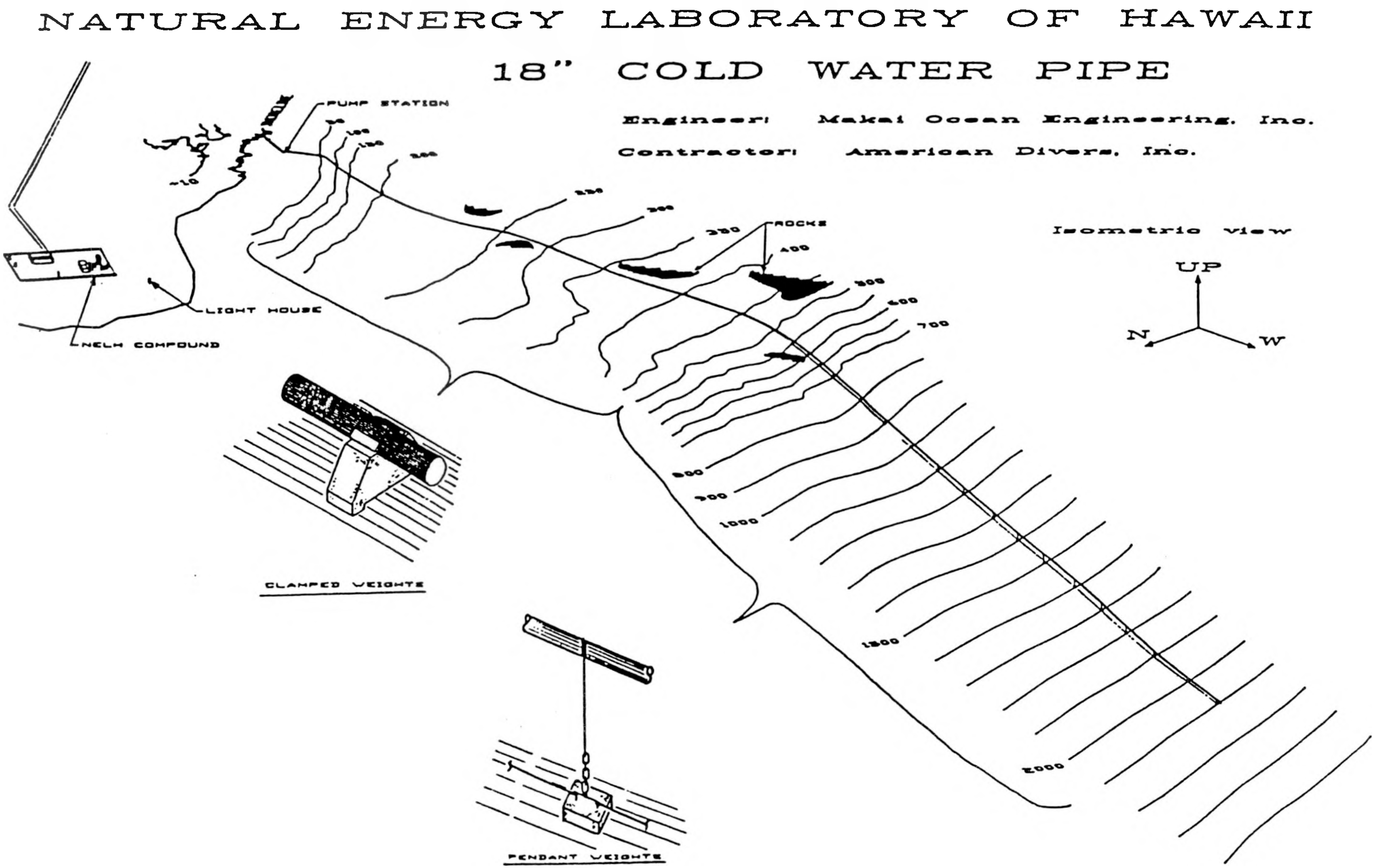

Figure 1-2: Typical "Pendant" Style of CWP Installation.
This 18" CWP was recently installed for NELH.

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PIPELINE DESIGN AND OPERATION

There are two pipelines involved in the Waikiki cold water supply system: The cold water pipe and an effluent pipe. From preliminary analysis and site selection it was determined that a 17,400' long intake pipeline would be required to descend to a depth of 1680' offshore of Waikiki. Such an intake depth would obtain waters of adequate temperature for the air conditioning purposes of this project. Figure 2-1 shows a layout of the pipe path from the selected shore landing east of the Hilton Hawaiian Village Boat Dock to its deep water intake.

DESIGN ANALYSIS:

A CWP intake pipeline flow analysis curve is shown in figure 2-2 which represents flow through a cold water intake pipeline 17,400' long at the Waikiki site. The horizontal axis is the flow in thousands of GPM, and the vertical axis is the total suction head on the pipeline in feet of seawater. The flow characteristics for five different pipeline sizes ranging from 40" to 63" are shown on this curve. All the flow curves how a static suction head requirement of 2.7' even when there is no flow through the pipeline. This is due to the higher density of seawater at 1680'.

Superimposed on Figure 202 are constant power curves showing the required pump power to overcome pipe flow losses (a product of water flow and pressure head divided by 80% pump efficiency and 90% motor efficiency). As flow increases for any particular pipeline's size, power also increases.

Figure 2-2 is used to select a pipeline size. With a decrease in pipeline size, there is a decrease in pipeline cost but a corresponding increase in required pumping power. A 48" intake pipeline was selected for the design flow of 18,200 gpm. The design point is indicated on Figure 2-2.

When analyzing the water flow trough a very long suction line, the suction pressure on the pipeline is a primary factor in determining wall thickness. The suction is greatest at the shore end of the pipeline, immediately before the pump station, and is lowest at the intake end. As a result, the pipeline wall thickness is generally staggered, the heavier walls are near shore and the thinner wall pipeline offshore. In addition, the minimum pipe wall is also determined by deployment limits. The loads on the pipeline during deployment can sometimes be the major loads that the pipe will see during its entire lifetime. Therefore, a combination of the suction loads and the deployment loads determine the wall thickness of the pipeline. In Makai's flow analysis of these pipelines, the pipe walls are staggered and as flow is increased through a given pipeline, the wall thickness is increased appropriately.

Figure 2-3 illustrates the minimum required pipe DR (outside diameter divided by wall thickness) as a function of suction head. This curve can be used to find the maximum pipe wall thickness that is necessary for any give pipeline flow condition. The required DR is independent of pipe diameter.

Figure 2-4 illustrates the flow characteristics of the effluent pipe. This is a pressurized pipeline. The DR selected for this pipeline is 32, and the wall thickness is not staggered. This heavy walled polyethylene pipe can be safely deployed and operated for a very long design life.

WATER TEMPERATURES:

No oceanographic survey of deep water temperatures or their seasonal variations offshore of the Waikiki site has been conducted. In lieu of exact information, a reasonable estimate of these water temperatures can be obtained from data collected for previous pipe lays off Keahole Point, Hawaii.

Figure 2-5 is a very heavily used chart showing the seasonal temperature variations at Keahole Point. Makai Ocean Engineering has assumed that the intake depth for the cold water pipe is at 1680' (512 m). At this depth, Figure 205 indicates 44.6 deg. (6 deg. C). water can be reached and going further offshore does little to provide cooler water. The cold water has little, if any, seasonal variation in situ but the water is warmed as it is pumped to the surface. The amount of warming of the cold water is a function of the water flow and the pipe wall thermal characteristics.

Makai computed the cold water pipe temperature rise as a function of flow. The results are illustrated in Figure 2-6. Illustrated are temperature rises under both summer and winter conditions. Note the total temperature rise drops dramatically with the increased flow and that the difference between the two sites under winter and summer conditions becomes very small with large flows. The cold water temperature supplied on shore at Waikiki will be 44.6 deg. $\pm$ 1 deg. F. plus the appropriate rise shown in Figure 2-6.

EFFLUENT DISCHARGE:

No outfalls exist in Hawaii for the discharge of cold water effluent. The most proven discharge concept is through an outfall, but even then the required discharge depth will be debatable. The requirements for such discharge would probably be dictated by the State Department of Land and Natural Resources and possible the State Board of Health - the actual line of authority is unclear. The most likely resulting requirement will be to discharge between 100' and 300' depth. This 100' depth would require an effluent pipe 5000' long for the Waikiki site. The cold water effluent is clean, pathogen free, and will sink due to its higher density. The only environmental concern is the naturally increased level of nutrients in the deep cold water.

PIPELINE DESIGN:

The design of the Waikiki CWP is essentially a weighted bottom pipe. The pipe is held just off the bottom with concrete anchors clamped to the pipeline along its entire length. The only deviation from this design is at the pipeline's intake and at its outlet. To elevate the pipe's intake off the bottom and avoid any sediment and particulate entry, a series of pendants precede the intake end of the pipe, and the pipe floats above the bottom. For aesthetic and sump design considerations the near shore end of the CWP is buried.

The use of the CWP concept is limited to sites with smooth bottom features. In general, the bottom roughness should not exceed half the pipe diameter, since the clearance under the pipe is 0.75 diameters. In areas of moderate roughness where it is uncertain whether the polyethylene pipe may contact the bottom, protective sleeves may be placed over the pipeline. The bottom terrain offshore of Waikiki appears to fit this description very well.

ANCHORS:

The first of the pipe anchors is illustrated in Figure 2-7. The pipeline anchors are staggered along the pipeline depending upon the weight requirements. The nearshore pipe anchors will be designed to hold the pipeline in place in the presence of design currents and storm wave loading. For the deeper pipeline, the anchors are reduced in weight to reduce the large spans between them, as the deep water pipeline is more lightly loaded and does not required as many lbs per linear foot to hold it in place. The last four anchors are even lighter, and hold the pendants attached to the pipeline.

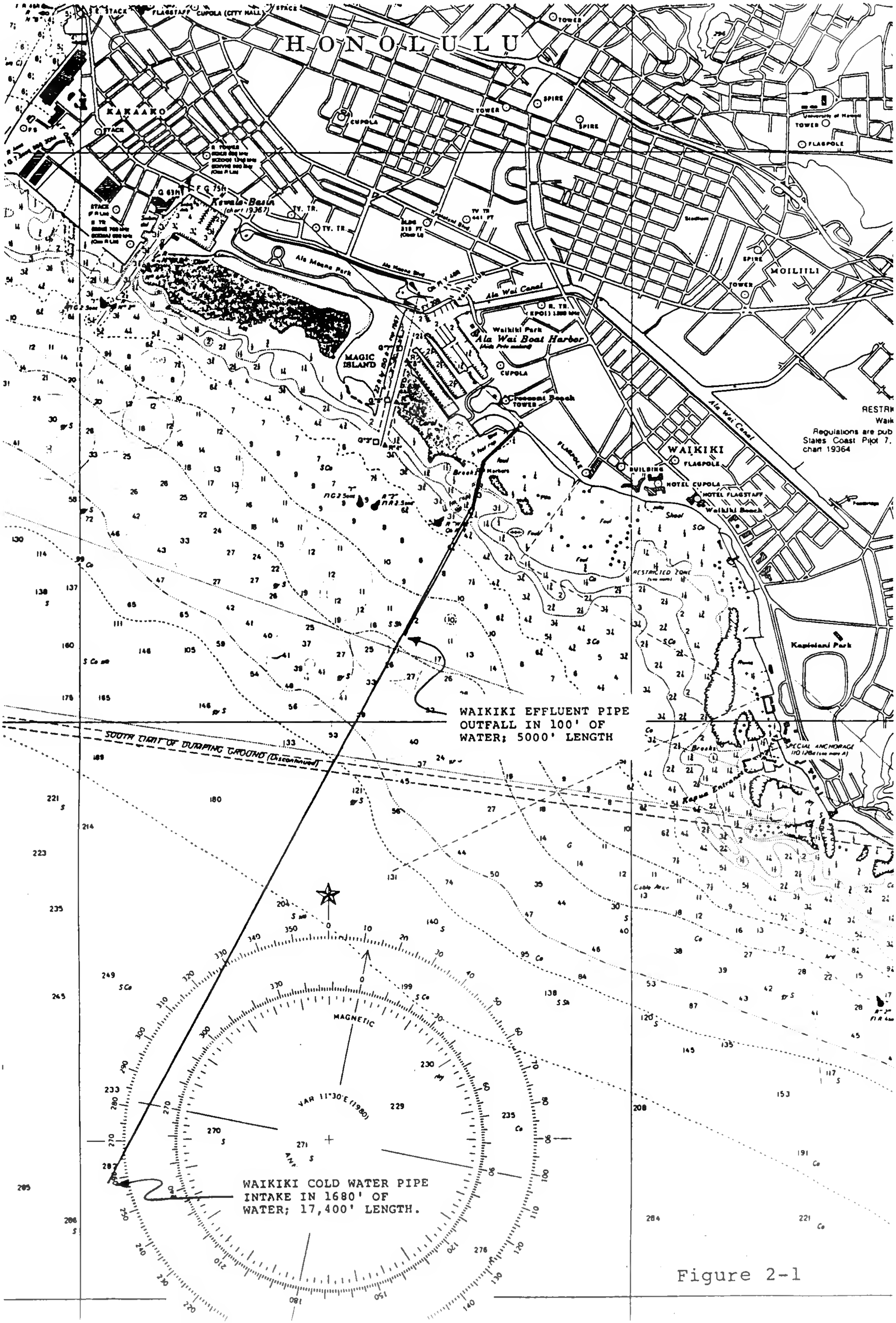
The pipeline is deployed by floating the air-filled pipe on the surface with the anchor weights attached. In many cases the nearshore weight added to the pipe has to be limited in order to achieve a minimum of 20% reserve buoyancy during towing and deployment. Because of this limitation, there is often a need to increase the weight per foot in the shallower portion of the weighted pipe section where the wave and current loading of the pipeline is the greatest. Saddle weights have been designed to be added to the pipeline after it is placed on the bottom.

Figure 2.8 shows a cross-sectional view of a typical saddle weight and an example of how these weights are configured after deployment. Note that a protective polyethylene sleeve is positioned on the pipe section where the saddle weights will be placed, and the saddle weights are placed up slope from the standard pipe anchor.

INTAKE:

Figure 2-9 details the intake end of the weighted bottom pipe design. to raise the intake above the bottom a series of pendants with bottom anchors are attached to the pipeline. The pendant line length gradually increases as one moves offshore. These pendant constraints increase the risk of the pipe making contact with the bottom during high current conditions. Therefore, extra buoyancy may be required at the intake in an amount which is rough inversely proportional to the pendant line length. This buoyancy is added in the form of deep water fishing floats, which are an inexpensive, durable and conveniently sized form of buoyancy for use at these depth. Some of these floats are shown in Figure 2-9.

The intake end of the pipeline is an open pipe without screens or restriction of any form. This has proved to be satisfactory for previous pipelines. If any filtering or screening is necessary, it is recommended it be done immediately prior to the pump facility such that these screens can be adequately cleaned and serviced.



HONOLULU
KAKAAKO
Kewalo Basin
Ala Moana Park
Ala Wai Canal
Ala Wai Boat Harbor
MAGIC ISLAND
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Kapiolani Park
Waikiki Beach
SOUTH LIMIT OF DUMPING GROUND (Discontinued)
WAIKIKI EFFLUENT PIPE
OUTFALL IN 100' OF
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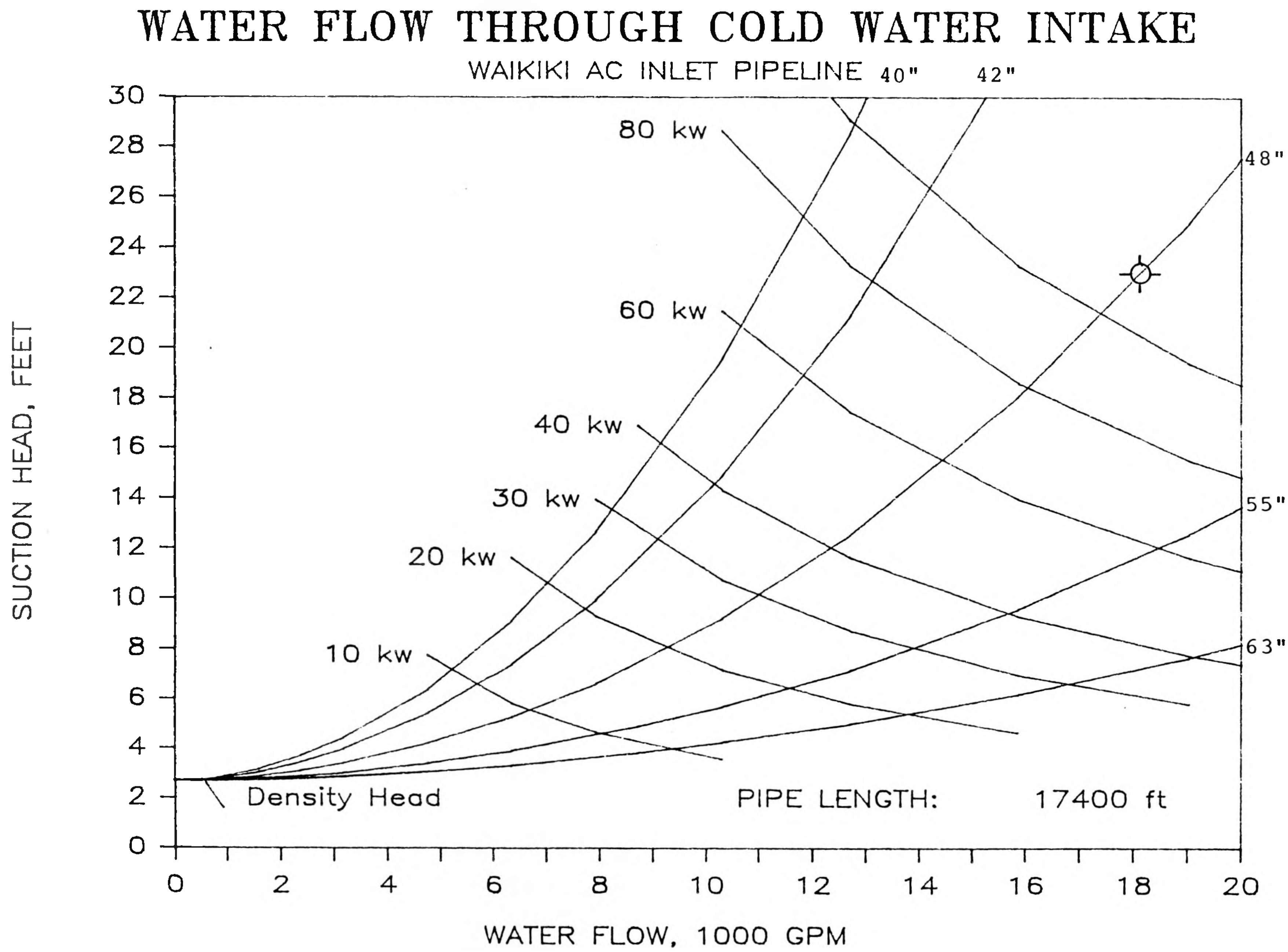
WAIKIKI COLD WATER PIPE
INTAKE IN 1680' OF
WATER; 17,400' LENGTH.
MAGNETIC
VAR 11°30'E (1980)

Figure 2-1


WATER FLOW THROUGH COLD WATER INTAKE
WAIKIKI AC INLET PIPELINE
40"
42"
48"
55"
63"
80 kw
60 kw
40 kw
30 kw
20 kw
10 kw
Density Head
PIPE LENGTH: 17400 ft
SUCTION HEAD, FEET
WATER FLOW, 1000 GPM
0
2
4
6
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10
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18
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22
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26
28
30

Figure 2-2

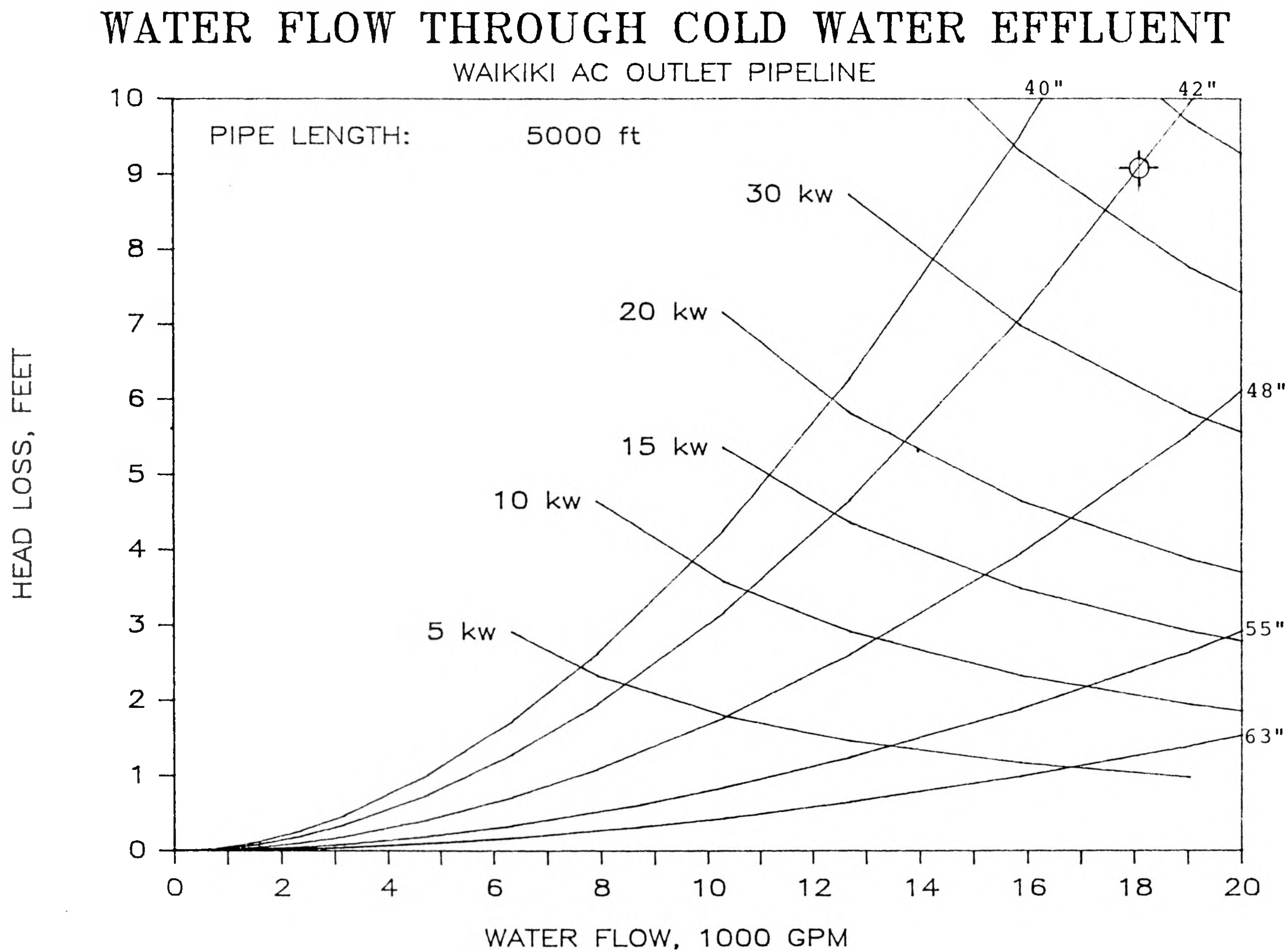

WATER FLOW THROUGH COLD WATER EFFLUENT
WAIKIKI AC OUTLET PIPELINE
PIPE LENGTH: 5000 ft
30 kw
20 kw
15 kw
10 kw
5 kw
40"
42"
48"
55"
63"
HEAD LOSS, FEET
WATER FLOW, 1000 GPM
0
1
2
3
4
5
6
7
8
9
10
0
2
4
6
8
10
12
14
16
18
20

Figure 2-4

CWP TEMPERATURE RISE VS PIPE FLOW

WAIKIKI AC OCEAN INTAKE PIPELINE

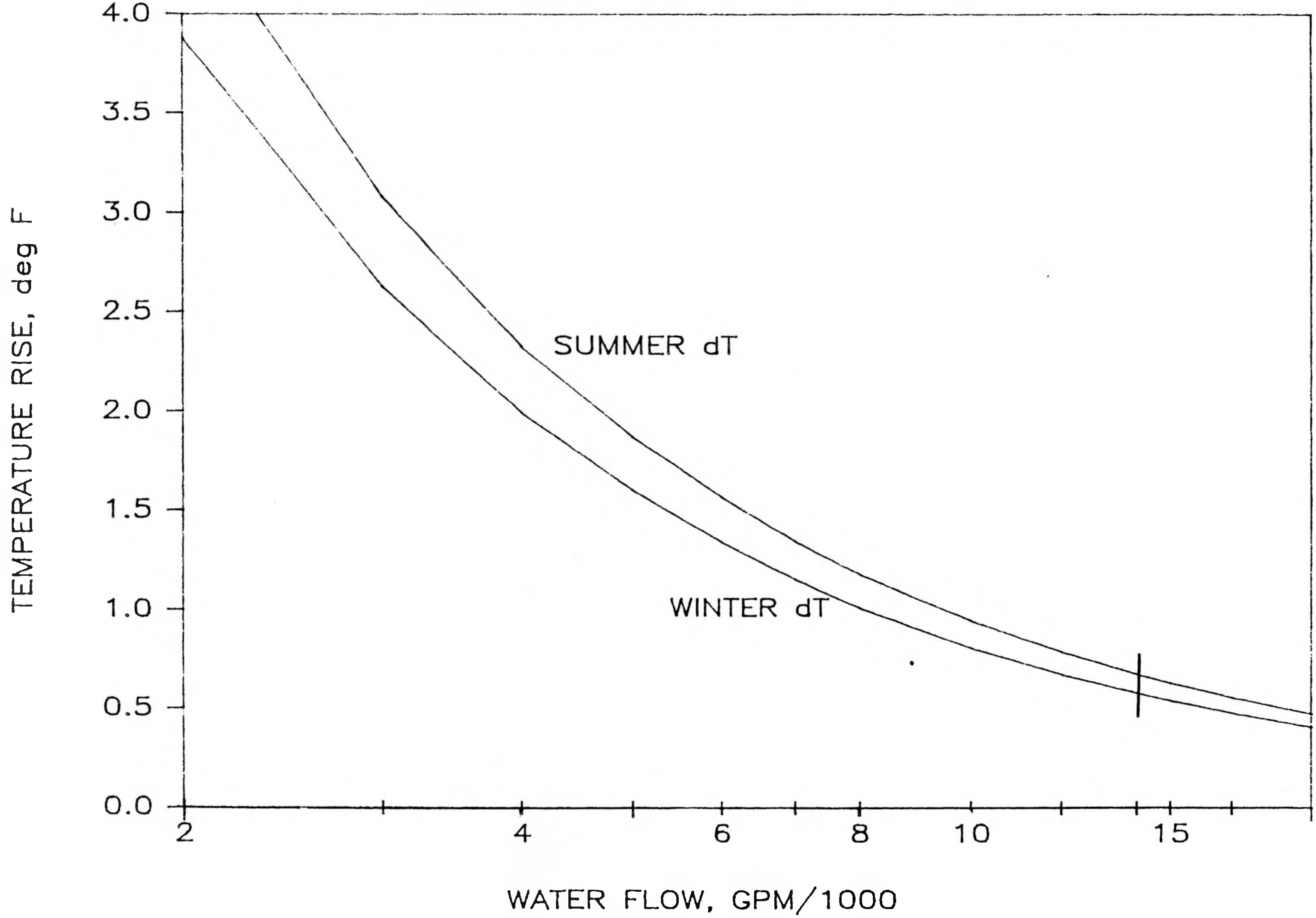
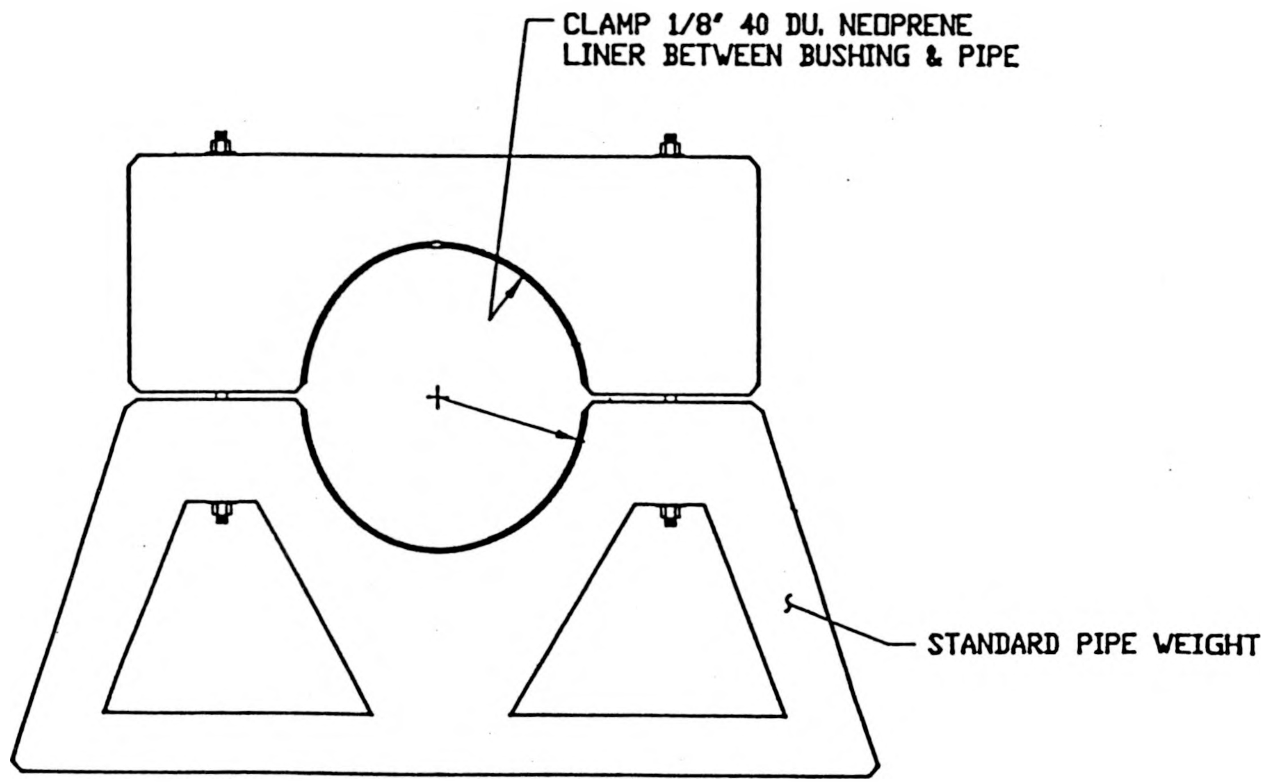
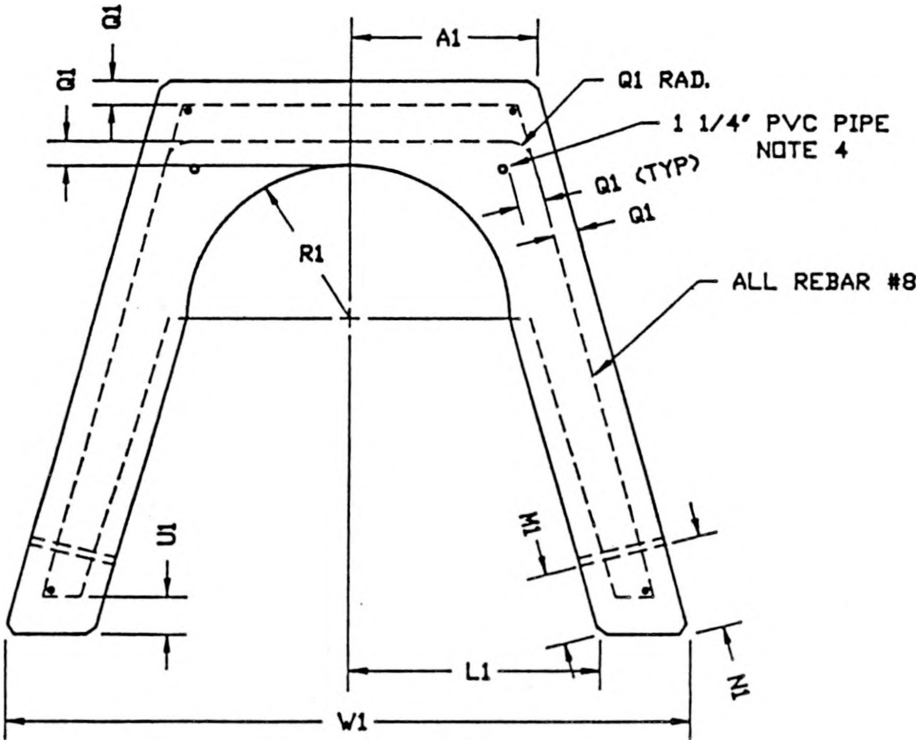


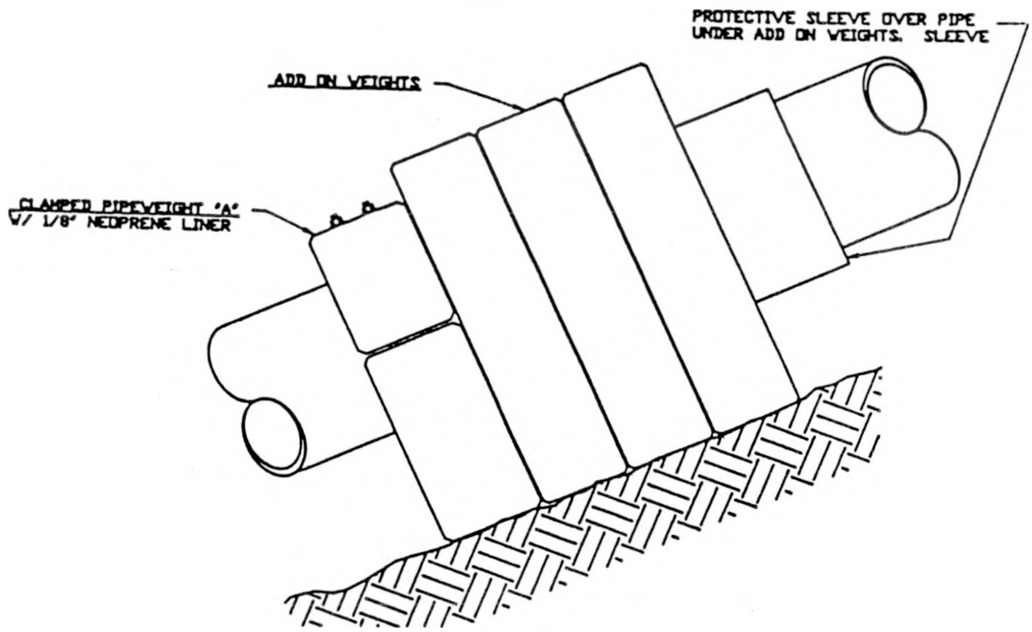
Figure 2-6



CLAMPED PIPE WEIGHT 'B' W/ POLYETHYLENE BUSHING

FIGURE 2-7





ADDED PIPE WEIGHTS
AFTER DEPLOYMENT

FIGURE 2-8

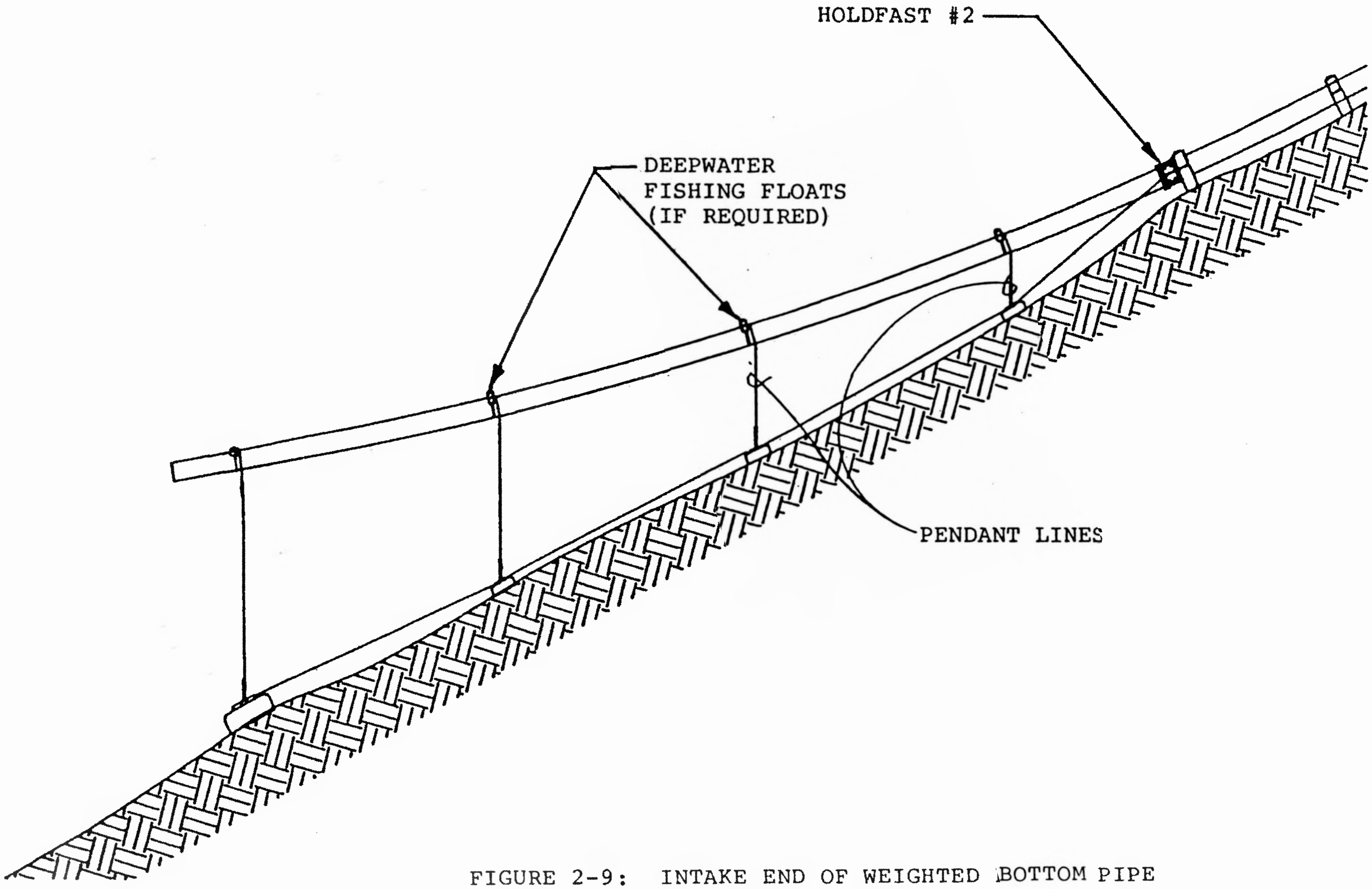


FIGURE 2-9: INTAKE END OF WEIGHTED BOTTOM PIPE

WAIKIKI DISTRICT COOLING UTILITY
DEPARTMENT OF ENERGY SOLICITATION DE-PS01-88CE26540

SHORE LANDING AND SUMP PUMPS

SHORE LANDING:

There are two sites along Waikiki Beach that were considered as possible pipe routes for the CWP and the effluent outfall. The first is a sand channel that is directly offshore from the Hilton Hawaiian Village Boat Dock and that runs out the navigable channel used by the Hilton Catamaran. The second is a sand channel which extends southwest in front of the Halekulani Hotel. Both these sites are indicated in Figure 3-1.

A snorkeling survey of these two sites and the adjacent shoreline areas was conducted to determine which site appeared most appropriate for a CWP installation. A brief description of these two sites is presented in the following paragraphs:

HILTON SITE:

The sand channel in front of the Hilton Boat Dock runs to shore along the western side of the boat dock. On the eastern side of the boat dock, where it would be preferable to install the pipeline to minimize disruption of the hotel's water front activities, the bottom is a shallower coral reef. The sand channel could be joined directly offshore from the boat dock where the water depth is already 8 to 10 feet. The channel is a very broad, gradually sloping expanse out to the channel markers. At the markers the channel narrows. Near the outermost channel markers the sandy portion of the channel is only 25' wide over a distance of 50 to 100'. Steep walls of coral border either side of this channel indicating it was probably a dredged, man made channel. Further offshore the sandy channel widens, and there appears to be just a thin layer of sand over a flat, featureless, coral rubble bottom.

HALEKULANI SITE:

The Halekulani sand channel is a natural feature. It does not drop off as fast nor does it extend unbroken all the way out to the deeper waters as does the Hilton Hawaiian Village Channel. These are important features that make this a less desirable location for a CWP installation. The Halekulani channel is a coral rubble sub-bottom. The sand channel very gradually slopes offshore and is strewn with 2" to 6" diameter chunks of coral out to a point about 500-600 meters offshore. Here the sand abruptly stops in about 12 feet of water. A flat, featureless, coral rubble bottom about 6-7" deep extends for several hundred meters further offshore before the sand channel is rejoined, and the bottom gradually begins to slope offshore again.

The suitability of the beach adjacent to these two sites is also an important consideration, as it will have to support the construction activities and an underground pump sump. On either side of the Hilton Boat Dock is as wide an expanse of beach as can be found in Waikiki. There would be ample space to the east of the boat dock to construct a pump sump and house construction equipment with a minimal disruption to the other activities on the beach. The same cannot be said for the Halekulani site where the beach disappears, and a sea wall has been constructed immediately in front of the hotel. Any construction activity on the beach there would present a major disruption to the normal beach traffic and activities. At both sites the beach is only 3-4 feet above sea level.

From these descriptions it is clear that the Hilton Hawaiian Village site has several characteristics that recommend it over the Halekulani Hotel site. This site was selected for further design analysis relative to pipe burial and pump sump design.

PIPELINE BURIAL:

From an aesthetic point of view it will be desireable to bury the pipelines in the area immediately adjacent to the beach and up to the pump sump. For the pipe's safety and the safety of people navigating the shoreline water, it will be necessary to bury the pipelines about 12 feet deep. The pipeline burial will be an expensive operation compared to just laying a weighted bottom pipe on the sand bottom. This will especially be true in the area immediately east of the Hilton boat dock where a shallow, dead, coral reef covers the bottom. Therefore, every effort will be made to limit the extent to which burial is required.

PUMP SUMP DESIGN:

Figures 3-2 and 3-3 are the plan view and profile view, respectively, of the pump sump designed for the Waikiki CWP. The sump share and dimensions are laid out according to the design standards set out by the Hydraulic Institute to limit the introduction of vortices in the sump and encourage an evenly distributed flow of water to the pump suction bells.

The size and depth of the sump is primarily influenced by the fluid flow dynamics important in such a very long intake pipeline. Pump start up and shut down dynamics is the critical factor. The long intake line has a tremendous mass of water which strongly resists any change in velocity. It takes many minutes for water in the long pipeline to reach full speed, and when it does, the flow can oscillate for 5 minutes or more. On shut down, the pumps stop, but the flow continues for several minutes. The sump must be sized to handle the flow without experiencing undesirable overflow conditions.

During steady state pumping, the cold water pipe flow into the sump equals the pump flow out of the sump. If pump flow increases, the level of the sump lowers proving a greater suction to the pipeline which in turn increases the flow. If the change in flow is abrupt, the level of the sump will oscillate. The larger the pump flow variation, the larger these oscillations will be. Typical pump flow variations are caused by starting and stopping pumps, and the most severe problems are caused by the following:

1. Start of the "last" pump: In a design with multiple pumps providing the total flow, starting the last pump in the start up sequence will cause the largest dip in the sump water level. The sump must be designed such that this water

level does not go below the pump intakes or cause the pumps to cavitate because of an improper available Net Positive Suction Head.

2. Stopping all pumps: The most catastrophic shut off would be with a power failure where all the pumps suddenly cease to operate. In this case water will continue to flow into the sump possible causing overflow, sump cover damage or possible even pump motor flooding. Once the sump fills, the pipeline water flow can reverse, possibly drying the sump and completely evacuating the inlet line causing the CWP to collapse.

The most significant parameters affecting the pump sump dynamics are the length of the pipe, the total water flow, the number of pumps, the surface area of the sump, the height of the sump and the diameter of the pipeline. For designing purposes, the surface area of the sump, the sump elevation and the number of pumps are design variables that can be altered to optimize the sump design.

The pumping dynamic analysis performed to arrive at the presented sump design is illustrated in Figure 3-4. The graph shows the water level in the sump under various dynamic conditions. The large sinusoidal curve shows the sump water levels vs time when all the pumps stopped simultaneously. Note that the water level starts at the steady state level of -129'. The other 2 curves are the water level variations for starting each of the pumps. The curves assume that the pump was started at the steady state level that would exist when that particular pump was turned on. The data provided in Figure 3-4 is for a 48" pipeline, 17,400' long with a flow of 18,2000 gpm. The area of the sump is 597 sq. ft. and there are a total of 4 pumps; each pump delivers 9,100 gpm (only two pumps run at any one time, the remaining two are standbys).

The critical factors in this evaluations was the maximum and minimum water levels in the sump. The required water levels should not be much higher than what can be conveniently constructed on the site nor should they be considerably lower than the steady state levels required to operate the pipeline. At the Hilton site it was deemed unacceptable to have any sump overflow because of a power failure, therefore, the sump was designed such that the maximum water level will be 2' below the reinforced concrete sump cover. Because of the very long length of the intake pipe the mass of water critically damps the dynamic response due to the start of the second pump. Therefore, pump startup dynamics do not add to the sump depth. The sump depth of '21.65' is set by the steady state friction losses in the intake pipeline and the required submergence of the pump intake bell.

PUMP SELECTION:

The anticipated total pumping head for the Waikiki cold water loop primarily includes friction losses in the CWP, losses through the bank of heat exchangers and friction losses in the effluent outfall pipe. Only the heat exchanger head losses cannot be adequately predicted at this time. The pipe friction and intake/discharge losses will equal approximately 21' of head for the heat exchanger losses, the pumping requirements will still fit well into the category of a low head high flow pump with a specific speed of 9230 to 10583. These specific speeds fall between the mixed flow and axial flow impeller pumps.

In this preliminary analysis both mixed flow and axial flow submersible pumps were investigated. Submersible pumps will alleviate any concern over pump motor flooding during a power failure and simplifies sump design. Figures 3-5 and 3-6 are the family of Flygt submersible mixed flow and axial flow pumps from which pump selections were made. Flygt submersible pumps have been used in past CWP projects. At 7000 gpm either a 3530 mixed flow pump or a 7050-1175 propeller pump appear to be satisfactory. For this preliminary design a set of four axial flow propeller pumps equipped with 63 kw (84.5 hp) motors is selected. This selection is based on good hydraulic end efficiency of 78% for the pump (see Figure 3-7 for performance curves for selected pump), and the simplicity of installation these propeller pumps afford. if these heat exchanger head losses are significantly higher than those assumed, then a mixed flow pump would be a better selection.

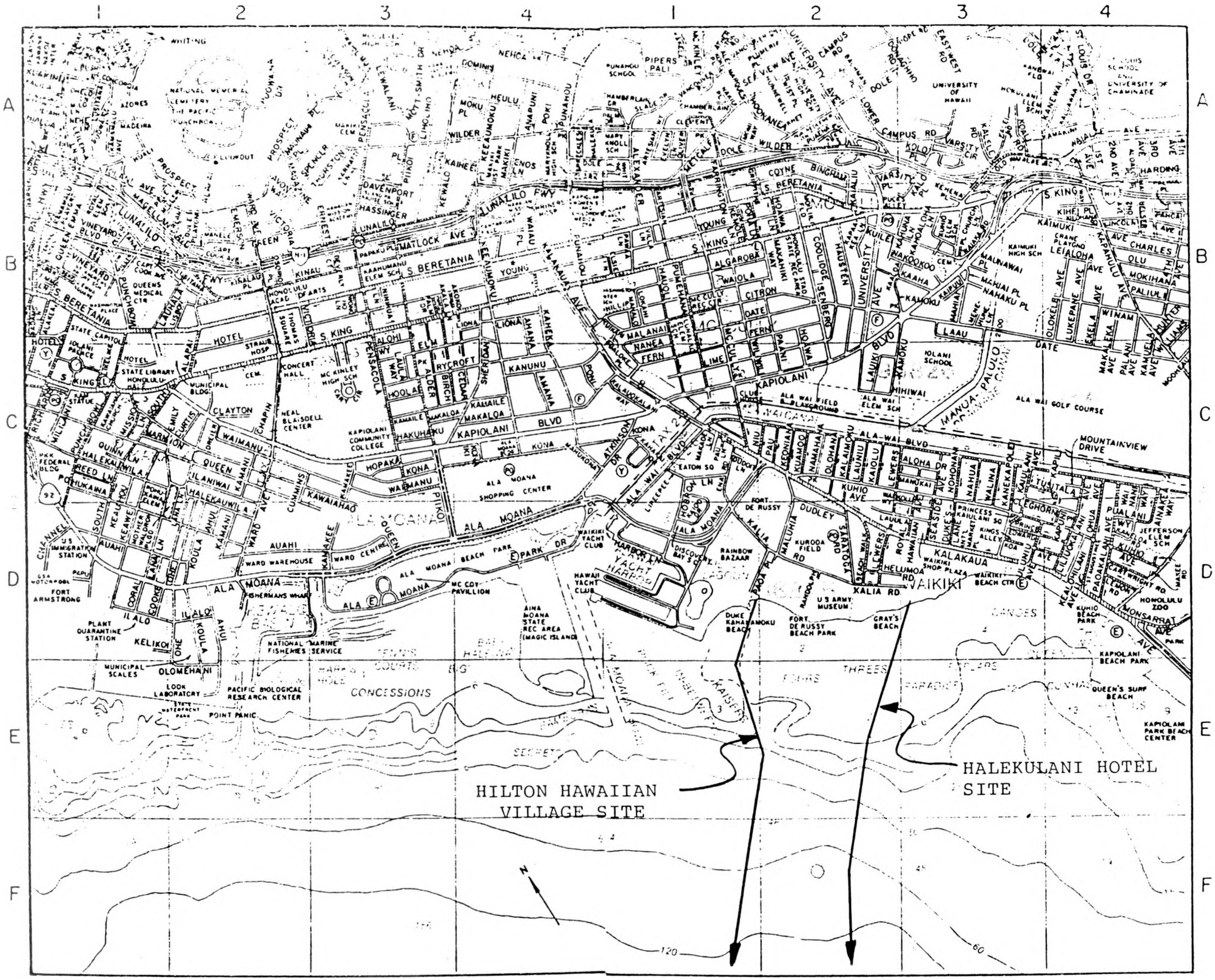
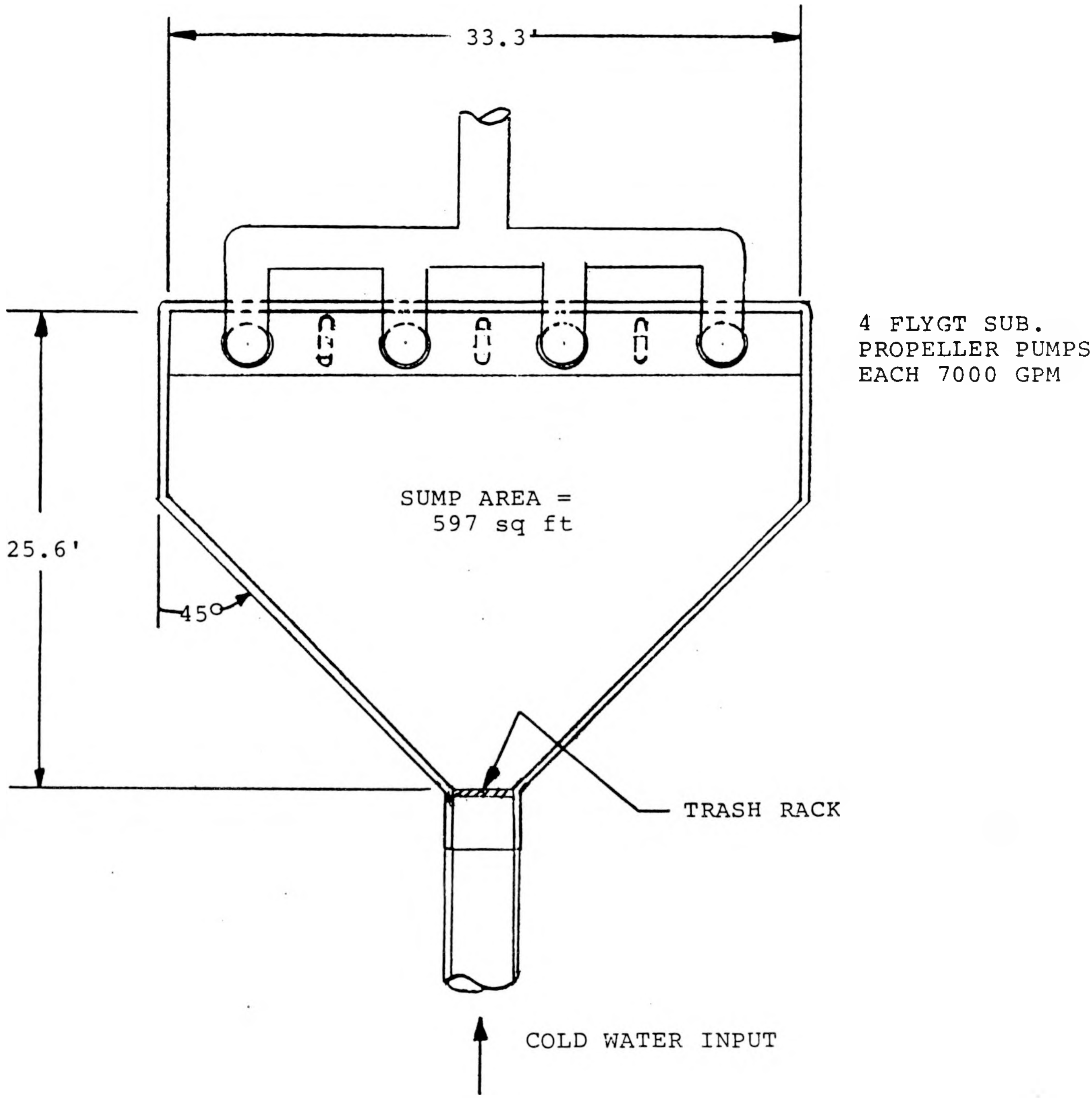


Figure 3-1



WAIKIKI COLD WATER PUMP SUMP

PLAN VIEW

Figure 3-2

WAIKIKI COLD WATER PUMP SUMP

PROFILE

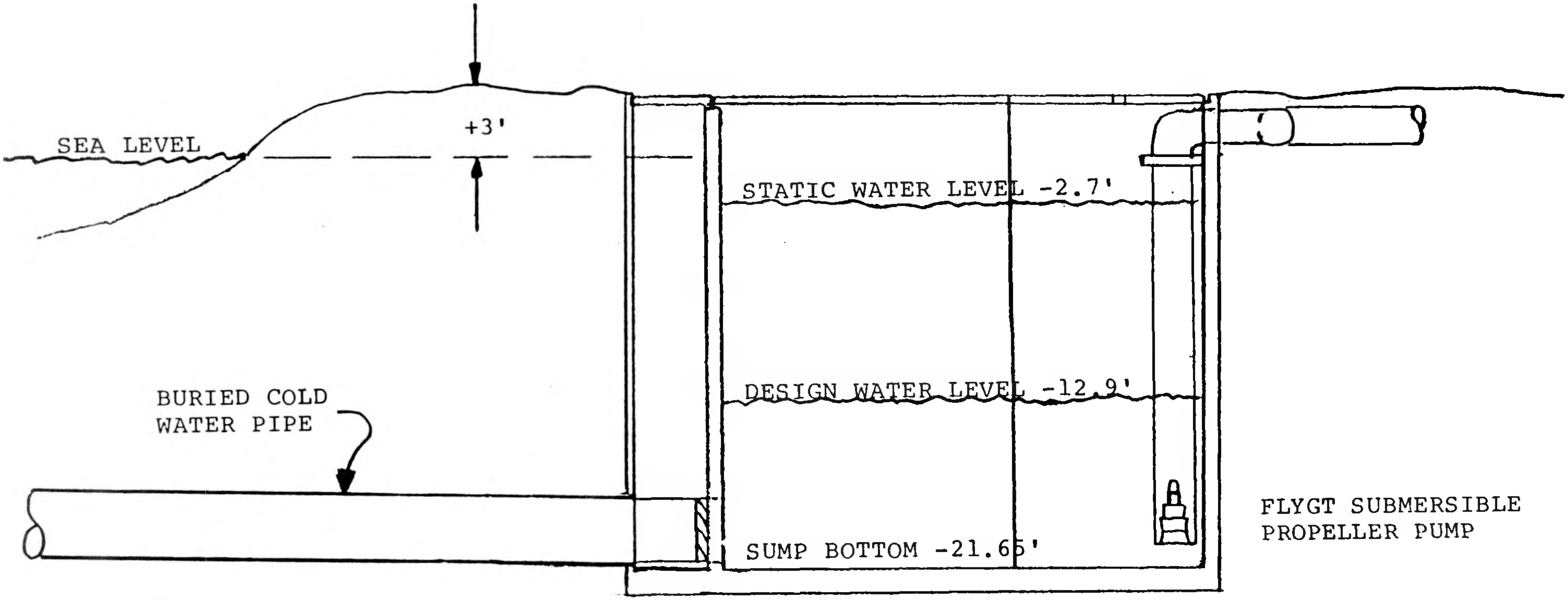


Figure 3-3

MECHANICAL PLAN

WAIKIKI DISTRICT COOLING UTILITY
HONOLULU, HAWAII

WAIKIKI DISTRICT COOLING UTILITY
DEPARTMENT OF ENERGY SOLICITATION DE-PS01-88CE26540

MECHANICAL PLAN

GENERAL:

For the Purposes of this Report the Mechanical Plan will consist of the work involved with the Heat Exhangers, Chilled Water Pumps and the Connections of the Potable Chilled Water Piping at each User Terminal. The Seawater Intake and Effluent Pumps are already covered under the Ocean Piping Section.

HEAT EXCHANGERS:

It is proposed that the units be Plate and Frame type with Titanium Plates. Plate and Frame Exchangers have been accepted for a long time in many applications throughout the world. Seawater units have been especially proven in Hawaii.

For efficiency, they are outstanding, and are able to effect very close approaches, sometimes within one or two degrees depending on the application.

Maintenance costs will be at a minimum compared to any other kind of Heat Exchanger as unskilled labor can be used effectively and without penalty to keep the plates clean and descaled.

Operating costs will also be low as there are no moving parts during operation. The only costs will be periodic replacement of gaskets. Experience in Hawaii shows that this is very infrequent.

Space requirements are very low due to the high efficiency of the units. The tall configuration will fit very well with the pump house and sump design.

The Heat Exchangers will be installed in multiple, so that one or more banks may be cleaned while others can carry the load. The cleaning cycle is so short, that this is a minor factor.

USER TERMINAL CONNECTIONS:

Each User will have its own unique application -- in size, building location, and control. Existing Machine Rooms may be located in basements, mid-floor or on the upper levels. Connection arrangements will be made with each individual user.

Each application will offer one, two or three connections as follows:

1. Direct Connection to the building chilled water system Fan-coil or air handling units.

2. Connection to the building condenser water system so that existing User plants can be used as desired by each individual.

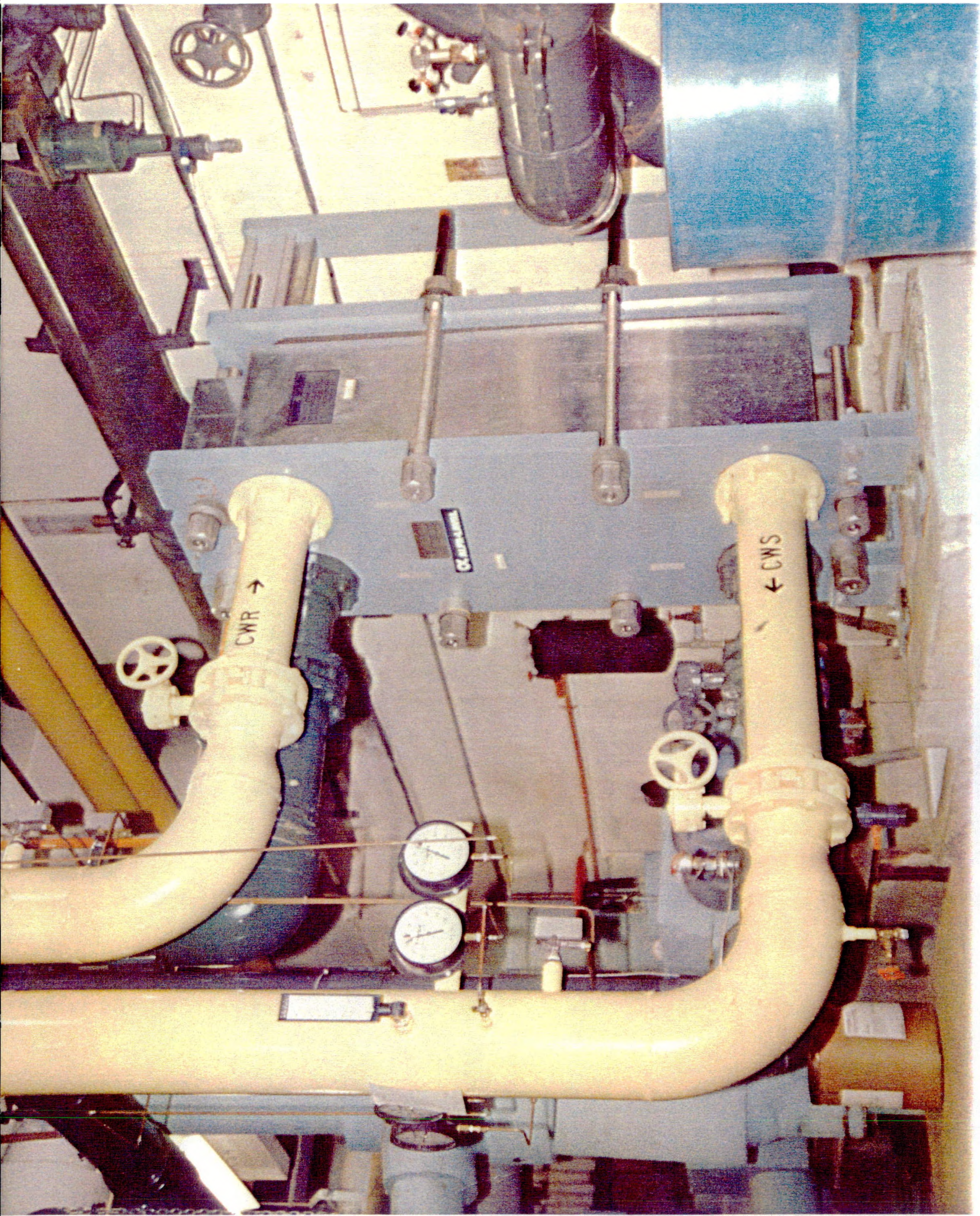
3. Appropriate By-pass Piping Design to permit each User to maximize his equipment and chilled water purchase.

METERING:

Each User will be metered as with present Gas, Water, or Electricity. The preferred system will be to use BTU Meters, but these have not proved their reliability at this writing. It is contemplated that standard water meters in conjunction with temperature recordings will be used unless technology improves before this project is built.

CHILLED WATER PUMPING:

This will be accomplished by using the latest technology in variable flow pumping system. It is rapidly becoming accepted in the air conditioning industry as a standard for large systems. Again, the application has been available for many years and has been substantially proven.



TYPICAL HEAT EXCHANGER

CIVIL PLAN

WAIKIKI DISTRICT COOLING UTILITY
HONOLULU, HI

WAIKIKI DISTRICT COOLING UTILITY
DEPARTMENT OF ENERGY SOLICITATION DE-PS01-88CE26540

CIVIL DESIGN CONCEPT

GENERAL:

Several factors are involved in the Civil Engineering aspect of the Phase One Waikiki district Cooling Utility design. Special considerations must be given to the pipe sizing where a balance is to be maintained between pressure loss and heat transfer to the chilled water as a result of friction from high flow rates, desired flow rates at the user end, and restrictions in pipe size owing to the available routing through Waikiki.

The preliminary concept presents two major branches of the chilled water line. One line is to serve the Hilton Hawaiian Village and Rainbow Tower, the Lagoon Apartments, the Ilikai Hotel, and the Yacht Harbor Hotel. It is estimated that a total flow of 4,700 gallons per minute (GPM) is required to adequately serve these hotels. The minimum main size would be a 12-inch diameter pipe. However, a larger diameter pipe will reduce friction owing to flow. For the final design, the pipe diameter may be as large as 18-inches in diameter.

The second line from the pump station will provide chilled water to the Hale Koa Hotel, Reef Cinerama, Halekulani, Imperial Hawaii, Sheraton Waikiki, Royal Hawaiian annex, Outrigger Waikiki, Moana/Surfrider/Ocean Lanai complex, and the Princess Kaiulani/Outrigger East complex. The total estimated required flow to these hotels is 11,840 GPM.

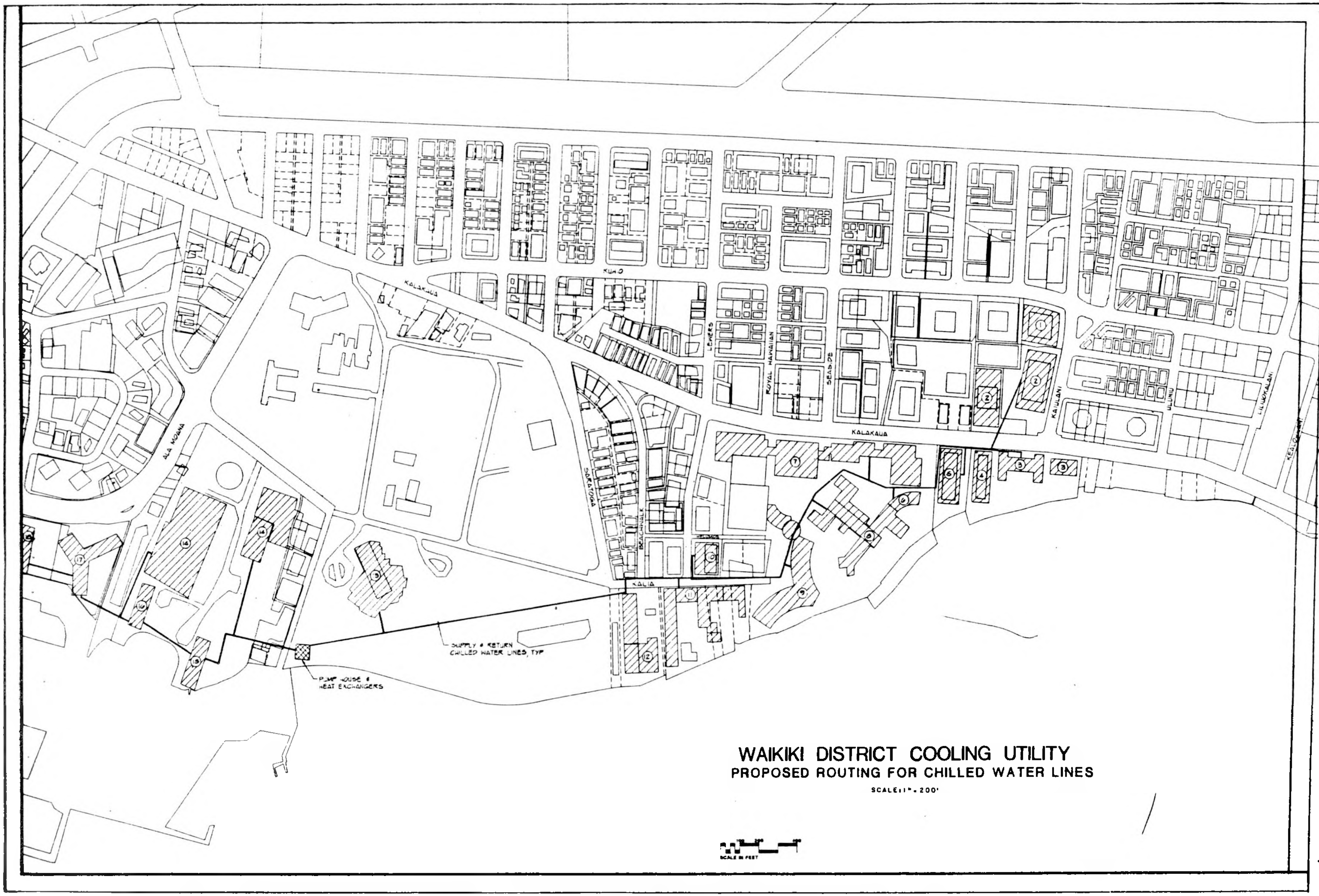
The range of pipe size considered for the main would be from a 24-inch diameter pipe to a 36-inch diameter pipe. The pipe main would decrease in size as chilled water is drawn by the hotels. The main serving the Princess Kaiulani/Outrigger Hotels complex would be in the range of 8 to 10 inches in diameter.

Special note should be made regarding the Moana and Princess Kaiulani Hotels. With the completion of the recent renovation of the Moana, the Primary physical plant for the Surfrider, Moana, and Ocean Lanai (Moana Annex) is located in the common basement that these hotels share. Thus, three hotels could be provided with chilled water at one connection point. The Princess Kaiulani Hotel provides water to the Moana Hotel via a 6-inch diameter pipe that runs through a tunnel under Kalakaua Avenue. This tunnel would permit the connection of the Princess Kaiulani/Outrigger East Hotels by running the supply and return pipe through the existing tunnel. The main physical plant for these hotels is in the basement of the Princess Kaiulani Hotel.

In order to maintain a supply and return pipe in the same trench, considerations must be made in determining allowable trench width. If the pipe was to be stacked, a standard width trench would be adequate. This may result in an excavation depth of 5 to 6 feet. The second consideration would be a side by side configuration which allows for a shallow depth of excavation but requires a greater width. Both the supply and return pipes will require installation. The pipes will be individually wrapped with a foam type of insulation.

The routing of pipe shown on the drawings, although in schematic form indicates the intent to minimize disruption of any City and County streets, hotel operations and tourist inconvenience, and to utilize open areas on Hotel grounds. Effort has been made to avoid beach areas.

The installation of the above piping is facilitated by the relatively short runs requiring public easement. By far, the greater part of the fresh water distribution system lies entirely on the private lands owned by the client hotels. We have every reason to look forward to their coordination of our routing effort based on the numerous benefits the installed system will create for them.


KUHIO
KALAKAUA
ALA MOANA
LEWERS
ROYAL HAWAIIAN
SEASIDE
KAIULANI
ULUNIU
LILIUOKALANI
SARATOGA
BEACHWALK
KALIA
SUPPLY & RETURN CHILLED WATER LINES, TYP
PUMP HOUSE & HEAT EXCHANGERS
WAIKIKI DISTRICT COOLING UTILITY
PROPOSED ROUTING FOR CHILLED WATER LINES
SCALE: 1" = 200'
SCALE IN FEET

GENERAL PROJECT DATA AND ECONOMICS

WAIKIKI DISTRICT COOLING UTILITY
HONOLULU, HAWAII

WAIKIKI DISTRICT COOLING UTILITY
DEPARTMENT OF ENERGY SOLICITATION DE-PS01-88CE26540

GENERAL PROJECT DATA

LOCATION	Honolulu, Hawaii District of Waikiki - Island of Oahu
PHYSICAL DATA	Area: Approximately One Square Mile No. of Hotel Rooms: 38,000 No. of Residential Apartments: 20,000
ELECTRIC POWER	1067 megawatts Total Power 54.1 Megawatts Air Conditioning 75% Compression or High Side AC Power 1.75 KW/Room or Apartment 10,000 KWHr/Room or Apartment
POWER COST DATA	$.065/KWHr Energy and Demand Dec 1989 $.075/KWHr Energy and Demand projected 1990 Highest Utility Load Factor in the US $2,7000,000. per month AC High Side Cost
FUEL DATA	$20.66/Bbl Dec 1989 Economic Efficiency $5.24/Bbl Energy Efficiency 37.15%

CONSTRUCTION COST (MM)

$9.5	Pipeline
4.1	Pumps, Exchangers, Pumphouse
2.7	District (Civi)Piping & Metering
2.2	Mechanical Terminus Piping & Metering
1.6	General Eletrical
2.2	Fees - A/E, Environmental

WATER DATA

18,200	Saltwater Flow Gpm
16,540	Chilled Water Flow Gpm
150	HP Intake Pumps
60	HP Effluent Pumps
120	HP Booster Chilled Water Pumps

WAIKIKI DISTRICT COOLING UTILITY
DEPARTMENT OF ENERGY SOLICITATION DE-PS01-88CE26540

ECONOMICS FOR PHASE I

The utility will distribute some 18,200 gallons per minute of chilled water which will displace 9,000 of air conditioning. At 1 KWH per ton/hour. A load of 9000 tons requires 9000 kwh/hour or:

9000 kwh/ x 8760 hrs/yr = 78.8 million kwh/hrs

Then, the proposed displacement will eliminate the need for compressors, chillers and cooling tower fans which make up 80% of the power draw.

78.8 million kwh/yr x .80 = 62.4 million kwh/yr

Assuming the utility is funded-build by 1995 when Hawaii "P" schedule electrical rates are priced at 11 cents kwh, the Utility would have a gross margin of $6.86 million year.

Assuming the Utility can provide operation, maintenance & depreciation expense at a 50% cost of sale, the Net Revenue in 1995 would be $3.43 million. Based as a physical plant construction cost of $22,300,000. the hotels would generate a 17.2% in a year. The Return on Investment would increase to 18.77% when "P" rates reach 13 cents per kwh.

WAIKIKI DISTRICT COOLING UTILITY
DEPARTMENT OF ENERGY SOLICITATION DE-PS01-88CE26540

CONCLUSION

The concept of this Project is astonishing in how real Energy Reduction can be effected. It is an outstanding example of both being a renewable source of Energy as well as being ecologically clean in every respect.

It is worth bending every possible effort to make this Project become a reality, not just for possible investors but for the good of the citizens of the State of Hawaii and for humanity in general as it will greatly reduce the need for fossil fuels, for which Hawaii is completely dependent upon.

The economic incentives for Hotels and other major users in pledging to purchase cooling from this system in order to finance it are great. Going one step further and envisioning the users owning the utility jointly makes great economic sense. It is worth making any and every effort to make this a reality.

Participating in the Support of this Report have been the United States Department of Energy -- Mr. Floyd Collins, Program Manager, Building Services Division, Conservation and Renewable Energy; and Thomas C. J. Gleason, Consultant for the International District Heating and Cooling Association. Their help and guidance has been invaluable.