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A PRELIMINARY DESIGN, ECONOMIC AND ENERGY ANALYSIS, AND ENVIRON--ETC(U)  
MAR 77 J HIRSHMAN N68305-77-C-0012

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A PRELIMINARY DESIGN, ECONOMIC AND ENERGY ANALYSIS,  
AND ENVIRONMENTAL IMPACT ASSESSMENT FOR A SEAWATER  
COOLING PROJECT NAVAL SECURITY GROUP FACILITIES AT  
WINTER HARBOR, MAINE.

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A number of alternate enhancement methods were examined, and preliminary designs developed, including one for a solar/desiccant drying system. The existing air conditioning system was also considered for use for enhancement, if desired. The initial costs would be lower than for a new enhancement system; however, life cycle costs for this option would be higher due to greater energy use. The life cycle costs for the seawater system are lower than for a conventional system.

If the seawater system can be used without enhancement, it can save 87% of the electrical energy used for air conditioning. With enhancement it can save 68% of the electrical energy. No significant long-term adverse environmental impacts are foreseen. Minor temporary disturbance of the site will occur during construction.

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## FOREWORD

The seawater cooling concept has been investigated by ERDA (1)(2)(3) for use in a district cooling system. The U.S. Navy (4) has examined the concept as a conservation system for Naval facilities. The basic concept is quite simple. Considerably less energy is required, under favorable circumstances, to pump natural cold water from the sea or a lake, through air conditioning coils, than to chill the water by means of refrigeration for this purpose. The above studies indicate that 70% to 80% of the energy normally used for air conditioning can be saved by this method.

The Energy Program Office of the U.S. Navy Civil Engineering Laboratory in Port Hueneme, California, has issued Contract No. N68305-77-C-0012 to Tracor Marine, Inc. to perform a preliminary Design, an Economic & Energy Analysis, and an Environmental Impact Assessment for a seawater air conditioning system for a building in the Naval Security Group Activity in Winter Harbor, Maine. This building requires year-round air conditioning and is close to the sea.

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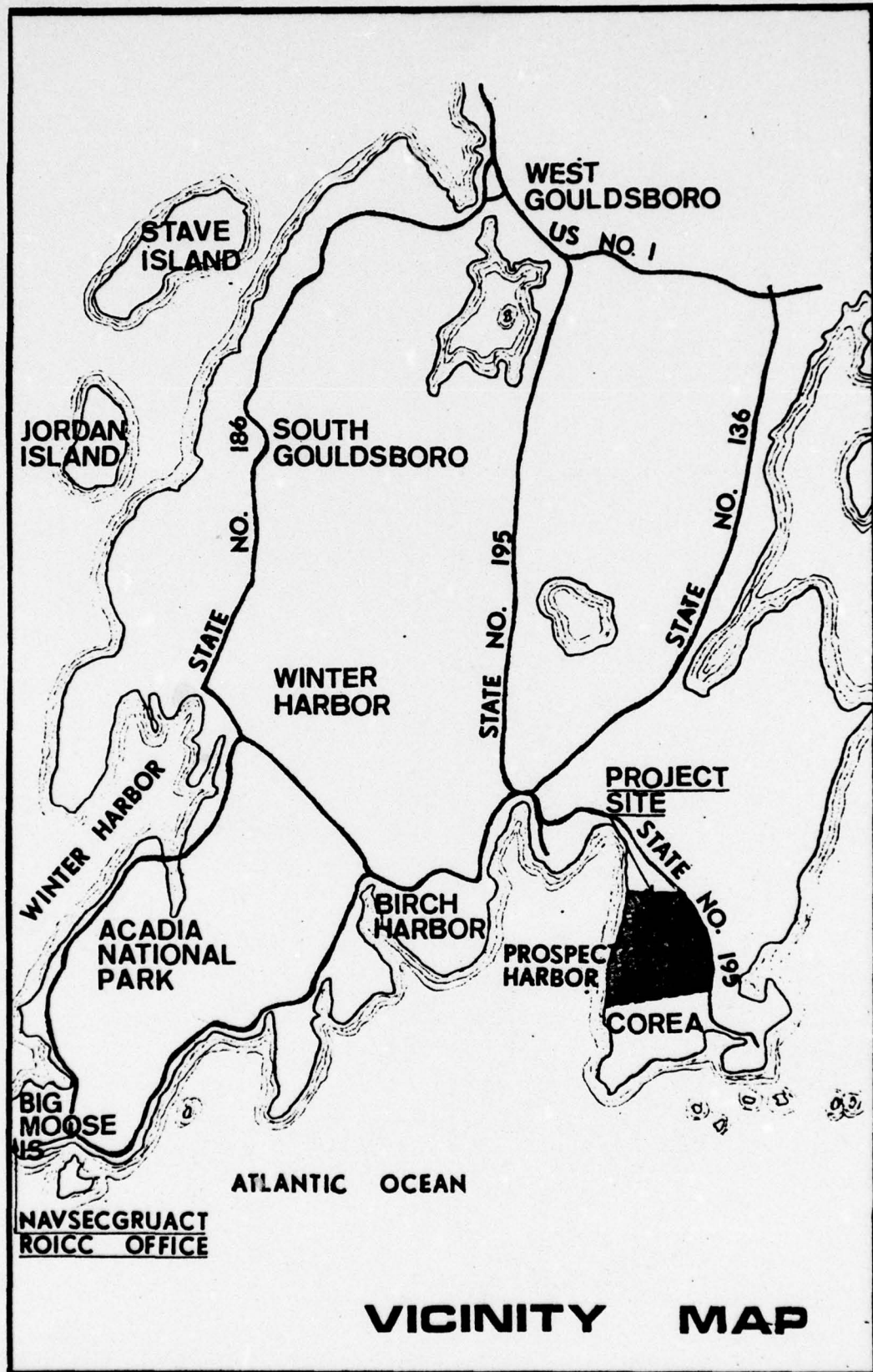


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I. SUMMARY AND CONCLUSIONS

A Preliminary Design, Economic & Energy Analysis and an Environmental Impact Assessment have been performed for a proposed seawater air conditioning system for an existing U.S. Navy building at Corea, Maine.

Two major options were examined. The first, to use seawater for the entire cooling load (100 tons); the second, to use additional cooling and dehumidification if and when the seawater temperature exceeds 50°F. A number of alternate enhancement methods were examined, and preliminary designs developed, including one for a solar/desiccant drying system. A simple packaged air cooled DX system (total 40 tons) was selected for the enhancement. Seawater bottom temperature measurements must be made in Prospect Harbor during the summer/fall season to determine the amount of enhancement, if any, that will be required.

The existing air conditioning system can be used for enhancement, if desired. The initial costs would be lower than for a new enhancement system; however, life cycle costs for this option would be higher due to greater energy use.

(a) Estimated Annual Energy Usage

|    |  |               |
|----|--|---------------|
| 1) | Seawater system                                      | - 111,100 KWH |
| 2) | Seawater system w/enhancement                        | - 249,540 KWH |
| 3) | Seawater System with existing A/C system enhancement | - 321,660 KWH |
| 4) | Conventional A/C system                              | - 861,300 KWH |

If the seawater system can be used without enhancement, it can save 87% of the electrical energy used for air conditioning. With enhancement it can save 68% of the electrical energy.

(b) Life Cycle Cost

|    |   |             |
|----|---|-------------|
| 1) | Seawater system                           | - \$305,449 |
| 2) | Seawater system w/enhancement             | - 380,498   |
| 3) | Seawater system with existing enhancement | - 396,554   |
| 4) | Conventional A/C system                   | - 404,044   |

The life cycle costs for the seawater system are lower than for a conventional system, using a 7% differential escalation rate for energy over other costs, and a FY 77 energy cost of \$.024 per KWH.

(d) Environmental Impact Assessment

No significant long-term adverse environmental impacts are foreseen. Minor temporary disturbance of the site will occur during construction.

The net environmental impact to the region will be positive (beneficial), because electrical energy conservation reduces demand, thus reducing power plant requirements.

(e) Implementation Schedule

Preliminary scheduling indicates that if construction of the system is to be completed prior to the winter of 1978, site survey work (land and marine) and the development of a monitoring and evaluation program must be completed prior to the fall of 1977.

## II. DISCUSSION OF DESIGN

### 1. General Guidelines

- (a) Integration with existing system.
- (b) Installation not to interfere with operation.
- (c) Life cycle costs within reasonable bounds.
- (d) Seawater system is considered to be a "demonstration" aimed at obtaining additional engineering data.

### 2. Design Criteria Used

- (a) Conserve significant amount of energy.
- (b) Uninterrupted year-round operation.
- (c) Existing air conditioning system to remain as backup.
- (d) System to be expandable to include second building.
- (e) Room design conditions  $72^{\circ}\text{DB} \begin{matrix} +2^{\circ}\text{F} \\ -7^{\circ}\text{F} \end{matrix}, 45\%\text{RH} \begin{matrix} +15\% \\ -5\% \end{matrix}$
- (f) Utilize as much of existing system as possible.
- (g) Utilize as much "off the shelf" equipment as possible.
- (h) Comply with Federal, State, and Local regulations.

### 3. Design Data Used (Site-Specific)

#### (a) Air Conditioning Design

- (1) Building plans as provided by USN, Winter Harbor.
- (2) Electrical current demand (amps) of electronic equipment in buildings, as provided by USN, Winter Harbor. 115 VAC and a power factor of 1 were used to determine wattage unless otherwise noted in data.

- (3) People loads, as provided by USN, Winter Harbor.



(4) Engineering weather data and psychometric summaries, as obtained from the National Climatic Center.

(b) Pipeline Route Design

(1) Commercially available aerial photos.

(2) Commercially available U.S. Government topographic and bathymetric sheets.

(3) Visual inspection (snow cover).

(c) Water Temperature Data

(1) Surface and bottom temperature measurements in Penobscot Bay (courtesy Central Maine Power Co.).

(2) Literature search, survey of institutions in Maine, National Data Center Computer Search.

(d) Cost of Energy

(1) Actual cost, as provided by USN, Winter Harbor.

4. Design Approach

Because the seawater system is an unproven prototype meant to service an important facility, overriding consideration is given to uninterrupted operation and non-interference with the existing system should backup be required. Frost conditions, rocky terrain, biologically rich waters (biofouling), and uncertainty regarding maximum bottom water temperatures in Prospect Harbor during summer months place further design constraints on the system.

Our approach in this work is to treat each of these potential problems in the most conservative manner, by providing preliminary design solutions and estimated costs for all of them.

The most critical part of the system, the seawater supply, is designed to be wholly redundant. The seawater intakes, pumps, and discharge lines are duplicated, and each is capable of handling the entire load by itself. This is done to permit shutdown of one system to permit cleaning in the event of severe fouling (or routinely to prevent fouling buildup). It is not known at this time if this will be necessary; however, duplication is further justified by the requirement that the system be capable of expansion to the other building on the site. The choice of using a larger diameter pipeline or a duplicate smaller diameter pipeline also favors the duplicate in this case, because water velocities can be kept high enough to reduce fouling in the smaller pipeline. The cost of a duplicate is higher than its larger diameter alternate, but since construction costs far outweigh material costs, laying two pipelines at the same time is relatively inexpensive.

The preferred technique of transferring heat from the air conditioning coils to the seawater is to utilize a plate-type heat exchanger that isolates the seawater from a fresh chilled water system. This permits rapid cleaning of the heat exchanger in the event of fouling. In this application, two factors permit us to

consider elimination of the fresh water loop and the heat exchanger by circulating seawater directly into special salt water coils located in the air system. The main factor that permits consideration of this option in this case is the location of the coils. Unlike most chilled water systems that have large numbers of coils with separate controls located throughout a building, this system has two large coils (with a third under construction) located in machinery spaces outside the building proper, with a complex air handling system inside the building. Normally, we would prefer not to circulate seawater throughout a building because of the potential damage that could be caused by a leak or break in the line. In this case, however, the seawater lines would be confined to the machinery spaces and adequate protection for other machinery can be provided in case a leak or break does occur.

The second factor is that the approach temperatures attainable in even the best heat exchangers ( $2^{\circ}$  LMTD) would adversely affect this system. Seawater temperatures in Prospect Harbor will reach about  $50^{\circ}\text{F} \pm 3^{\circ}\text{F}$  in the warmest months. The cooling efficiency of available coils and particularly their ability to remove moisture falls off rapidly at  $50^{\circ}\text{F}$ . A two or a three degree loss in the heat exchanger at these temperatures could require an additional 30 or 40 tons of vapor compression enhancement or dehumidification.



Thus, circulation of seawater directly through special chilled water coils not only improves performance of the system during the critical warm period, but eliminates the expensive plate-type exchanger (titanium) and could eliminate the need for additional enhancement. A penalty must be paid for these advantages since the type of coil used cannot be readily cleaned, and fouling of these coils must be positively prevented by filtering for larger organisms and biocidal techniques for smaller organisms. This cost penalty is offset by the elimination of the plate-type heat exchanger. Both options are considered in our preliminary design.

### III. THE PRELIMINARY DESIGN

#### 1. The Air Conditioning System

The present system consists of three air conditioning and heating zones. The first zone consists of what was the original building and primarily houses the computer facilities. The system for temperature control consists of a chilled water coil, steam coil, and steam humidifiers. The second zone consists of the first addition and is primarily designed to house sensitive electronic equipment. The temperature control system is basically similar to the first zone. Finally, the third zone consists primarily of office space and is currently under construction. The system for temperature control includes a heating coil, humidifier and a direct expansion evaporator coil for air conditioning. This system has been slightly oversized so that areas previously supplied by and included in other zones have been added to zone three. This has been achieved by necessary ductwork.

A detailed air conditioning load was computed for all three zones to ascertain a preliminary size of the cooling coils. This is summarized in Table I. The total air conditioning load was estimated at 100 tons, thus requiring about 300 gpm of seawater at temperatures varying from 40°F to 50°F. When the seawater temperature exceeds 50°F, a chiller or a DX system is used for augmentation. Owing to the large quantities of seawater

TABLE I  
CONVENTIONAL SYSTEMS A/C ANNUAL LOAD

|          | <u>TOTAL HOURS</u> | <u>TONNAGE</u> | <u>KW/TON</u> | <u>KWH</u>     |
|----------|--------------------|----------------|---------------|----------------|
| 99 - 95  | 1                  | 93T            | 1.09          | 101            |
| 94 - 90  | 11                 | 93T            | 1.12          | 1146           |
| 89 - 85  | 42                 | 93T            | 1.15          | 4492           |
| 84 - 80  | 128                | 93T            | 1.22          | 14523          |
| 79 - 75  | 249                | 81T            | 1.29          | 26018          |
| 74 - 70  | 411                | 78T            | 1.42          | 45522          |
| 69 - 65  | 585                | 77T            | 1.42          | 63964          |
| 64 - 60  | 786                | 75T            | 1.42          | 83709          |
| 59 - 55  | 775                | 73T            | 1.42          | 80337          |
| 54 - 50  | 727                | 72T            | 1.42          | 74328          |
| 49 - 45  | 672                | 70T            | 1.45          | 68208          |
| 44 - 40  | 658                | 68T            | 1.45          | 64879          |
| 39 - 35  | 771                | 66T            | 1.45          | 73785          |
| 34 - 30  | 824                | 65T            | 1.45          | 77662          |
| 29 - 25  | 566                | 63T            | 1.45          | 51704          |
| 24 - 20  | 473                | 61T            | 1.45          | 41837          |
| 19 - 15  | 355                | 59T            | 1.45          | 30370          |
| 14 - 10  | 288                | 58T            | 1.45          | 24221          |
| 9 - 5    | 199                | 56T            | 1.45          | 16159          |
| 4 - 0    | 114                | 54T            | 1.45          | 8926           |
| -1 - -5  | 70                 | 52T            | 1.45          | 5278           |
| -6 - -10 | 37                 | 52T            | 1.45          | 2790           |
| -10 →    | 18                 | 52T            | 1.45          | 1357           |
|          | <u>8760</u>        |                |               | <u>861,316</u> |

$$\text{EQUIVALENT FULL LOAD HOURS} = \frac{861,316}{93 \times 1.22} = 7591$$



to be circulated and the desire to use the present system as a complete and independent backup, it was decided to not use the present chilled water coils in zone one and two but to design separate seawater coils. Since the third zone is designed with a DX system, it too requires an independent seawater coil.

## 2. Discussion of Design Options

There are two basic ways the seawater system can be designed. The first method involves the circulation of cold seawater directly through the chilled water coils after it has been suitably treated to prevent the fouling of the coils. The presence of brine requires the use of a cuprous-nickel alloy coil in place of the standard copper coils. The advantage of this system is that the temperature of the entering cooling water is very close to that being pumped from the Bay. However, the fouling may be a problem.

The most serious fouling organisms in this area are the mussels and hydrozoa. These can be sucked into the system in the larval stage, and will affix to any hard surface and grow, if given the opportunity. The size of these larvae is in the 50-200 micron range. A sand filter would trap the larger larvae, but a diatomaceous earth filter or equivalent is required to trap the smaller organisms. Bacteria and other microscopic organisms require either a chemical biocide or killing irradiation, such as ultra-violet (UV) light.

Where seawater is circulated directly through the chiller coils, we have specified the use of mechanical filters (sand and diatomaceous earth). These can be backflushed as part of a routine maintenance program in the warm months. The coils are designed for seawater use and can be drained without removal, permitting cleaning with chemical cleaning solutions, if necessary. In addition, we have specified the use of ultra-violet biocidal equipment to prevent biofouling in the coils. In options where a seawater/fresh water heat exchanger is used (next paragraph), only the mechanical filtering is required.

The second method utilizes a seawater/fresh water heat exchanger, with treated fresh water circulating through the chilled water coils. Titanium plate heat exchangers are used. These may be readily opened and cleaned if necessary. The cold water entering the chilled water coils will be somewhat warmer owing to a temperature rise in the heat exchanger; thus, the system for augmentation will kick in a little earlier and more enhancement tonnage would be required.

Regardless of whether a seawater/fresh water heat exchanger is used or whether the seawater is circulated directly through the coils, there are a number of options available. The basic options are illustrated in Figures 2 through 5.

(a) If the seawater is cold enough year-round (less than 50°F), no enhancement will be required (Figure 1).

(b) If enhancement is required during the warmest months:

(1) The seawater (or chilled water) can be further cooled by passing it through a conventional chiller (air or water-cooled) before passing it through the coils (Figure 2).

(2) Additional coils (either chilled water or DX) can be placed in the air systems. These can be supplied by either individual small compressor units, or by a single large unit. The compressor units can be air or water-cooled (Figures 3 and 4).

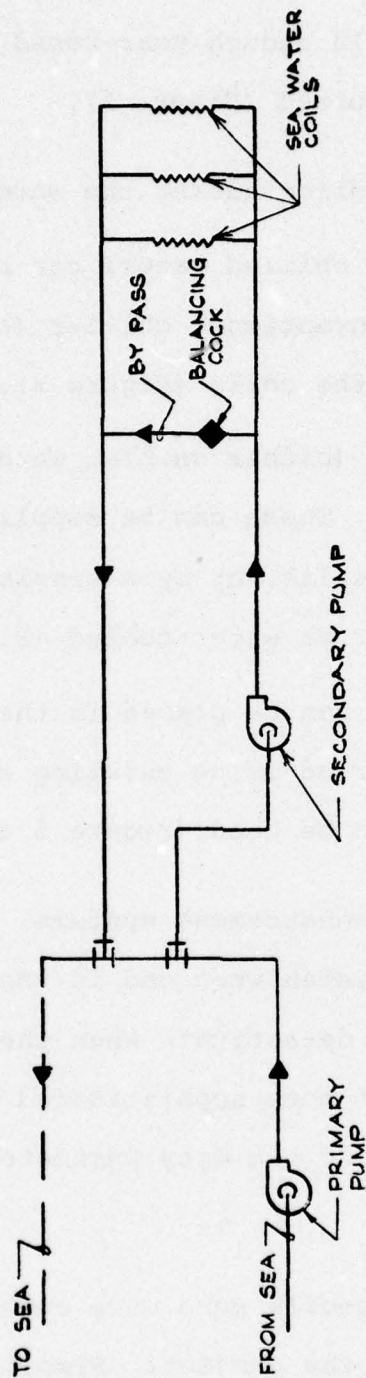
(3) Desiccant dryers can be placed in the air systems. The desiccant can in turn be dried using existing steam or hot water; or a solar dehumidifier can be used (Figure 5 and Appendix C).

In each of the above enhancement systems, controls would activate the enhancement system when and if the seawater temperature rises above 50°F, and de-activate when the seawater temperature dropped below 50°F. A more sophisticated control system could monitor temperature and humidity parameters of the air leaving the seawater coils.

Engineering/cost trade-offs were made considering each of the above options early in the project. Simplicity of installation of the enhancement system was given great weight, since the main objective in this program is the evaluation of the basic seawater system.



FIGURE 1  
DIRECT SEAWATER COOLING  
NO ENHANCEMENT.



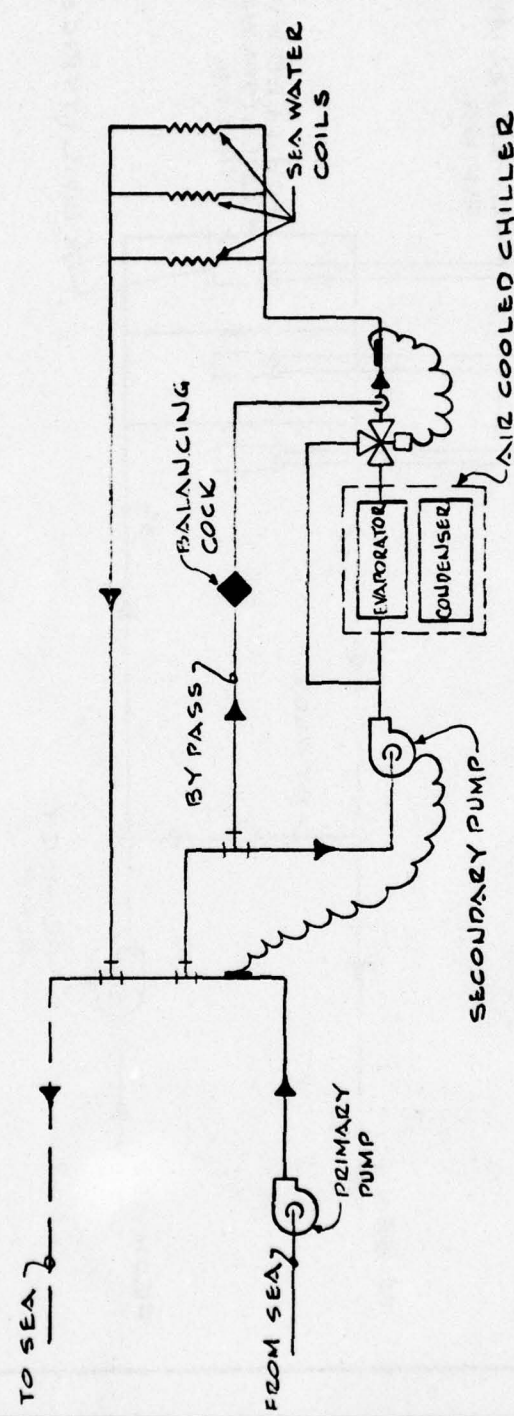
SCHEMATIC PIPING DIAGRAM

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FIGURE 2.  
SEAWATER COOLING  
WITH SERIES ENHANCEMENT  
OF CHILLED WATER.

1. AIR COOLED CHILLER CAPACITY 40 TONS.  
2. SECONDARY PUMP 270 GPM CAPACITY.



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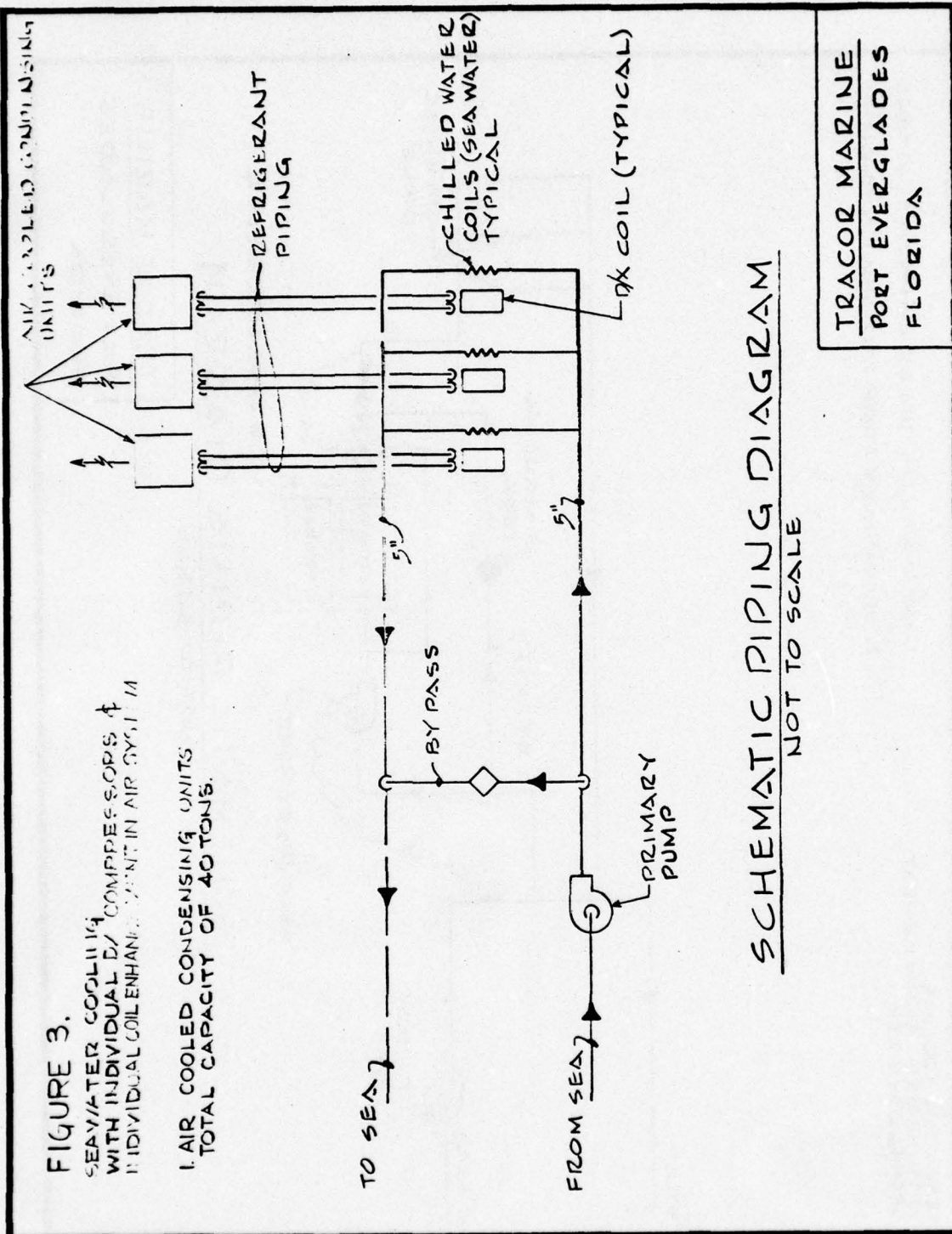
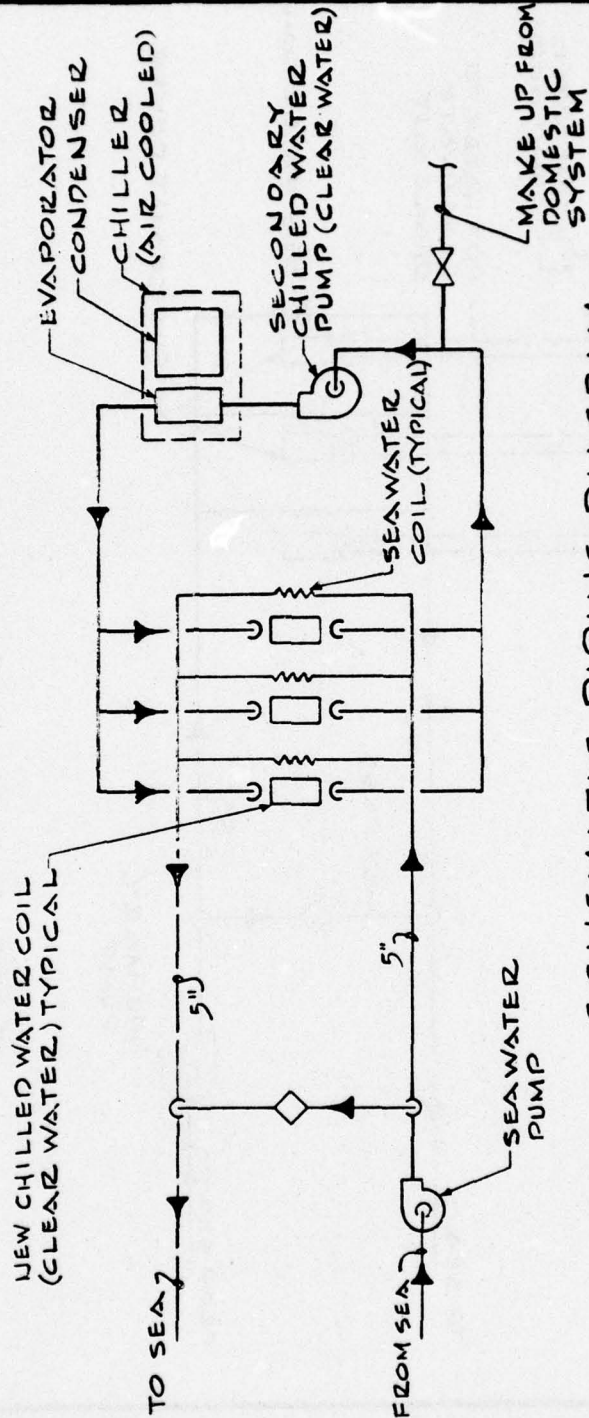




FIGURE 4

SEAWATER COOLING  
WITH CENTRAL CHILLER &  
INDIVIDUAL CHILLER COIL ENHANCEMENT  
IN AIR SYSTEM.

1. AIR COOLED CHILLER 40 TONS.
2. SECONDARY CHILLED WATER PUMP  
270 GPM CAPACITY.



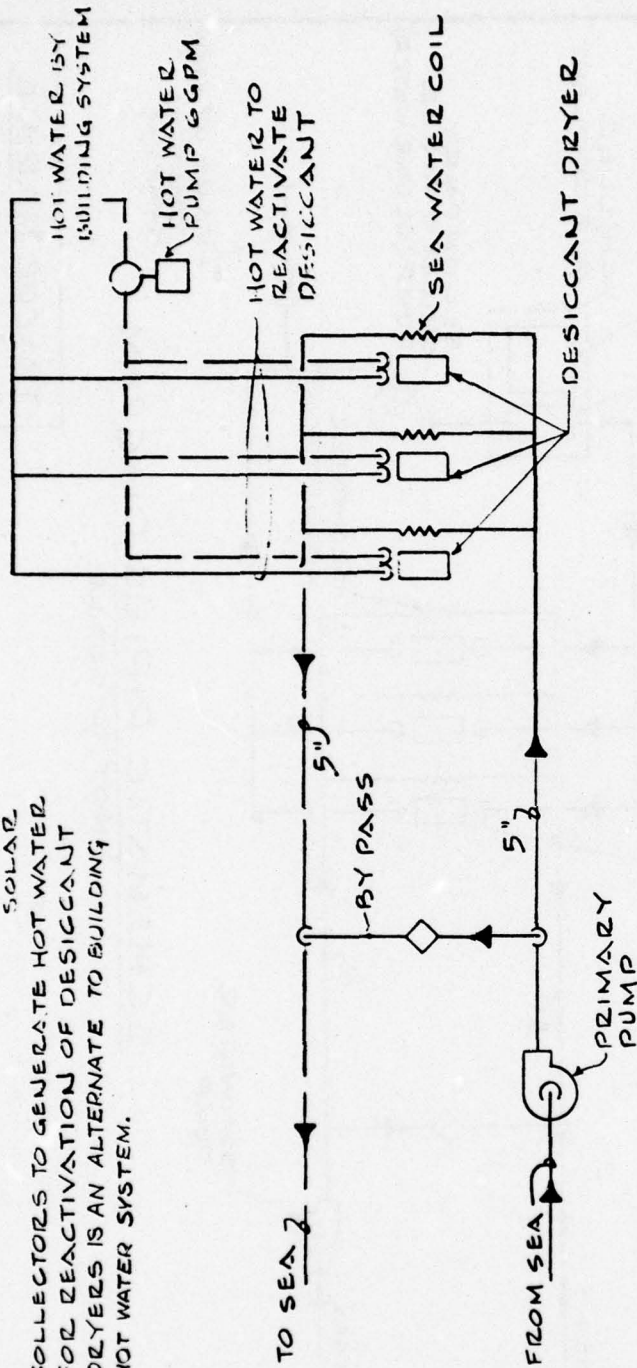
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FIGURE 5. DESICCANT REHYDRATION

SOLAR  
COLLECTORS TO GENERATE HOT WATER  
FOR REACTIVATION OF DESICCANT  
DRYERS IS AN ALTERNATE TO BUILDING  
HOT WATER SYSTEM.



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Enhancement systems of the type described in paragraph (b) (1) above, augmented cooling of all the chilled water, require significantly more refrigeration than individually controlled "dehumidification" coils in the air system. This results in a higher initial cost and higher energy use costs.

Desiccant drying systems require little energy, but have high initial costs. These require a good deal of space in the ducts, and the existing ducts would require extensive modification, if indeed they could be made to fit. Maintenance is high in these systems.

Of the systems described in (b) (2) above, additional coils in the air system, the following comments can be made:

a) Air-cooled DX systems are cheaper, more easily installed and maintained, are not subject to freeze-up, and the coils take up less space in the air ducts. They are "off-the-shelf" systems and can be purchased as packaged units. They are, however, somewhat less efficient than water-cooled chiller systems.

b) Several individually controlled "packaged" compressor/coil units would be simpler and easier to install and maintain than a single compressor serving several coils. With the existing three-zone system in the building, some energy savings might be realized as well.



### 3. The Preferred Design Option - (Figure 6)

The choice was made to eliminate the seawater/chilled water heat exchanger and to circulate seawater directly to the chiller coils. The additional cost of filters, biocidal equipment and seawater resistant coils is roughly equivalent to the cost of a good titanium plate heat exchanger. However, because we expect that seawater temperatures in the warm months will be 50°F or slightly above, and since this is the limiting seawater temperature that we can conservatively tolerate with the coils available, two degrees lost in the seawater/chilled water heat exchanger might require an additional 25 tons of vapor compression enhancement. Fortunately, the existing system permits us to eliminate the heat exchanger without the need to circulate seawater in the building.

No seawater temperature data is available for Prospect Harbor; thus, data from neighboring areas must be used and extrapolated to Prospect Harbor. Data from Penobscot Bay and Arey Cove was used to predict the amount of enhancement that would be required during the warmer months (see Table II). A total of 40 tons of enhancement is required, with individual units of 27 tons, 8 tons, and 5 tons for the three zones.

In this preliminary design, the enhancement system selected is individual DX compressor/coil units. The DX coils are installed in the air systems, each having its own controls and roof-mounted compressor. In this selection we have eliminated the possibility

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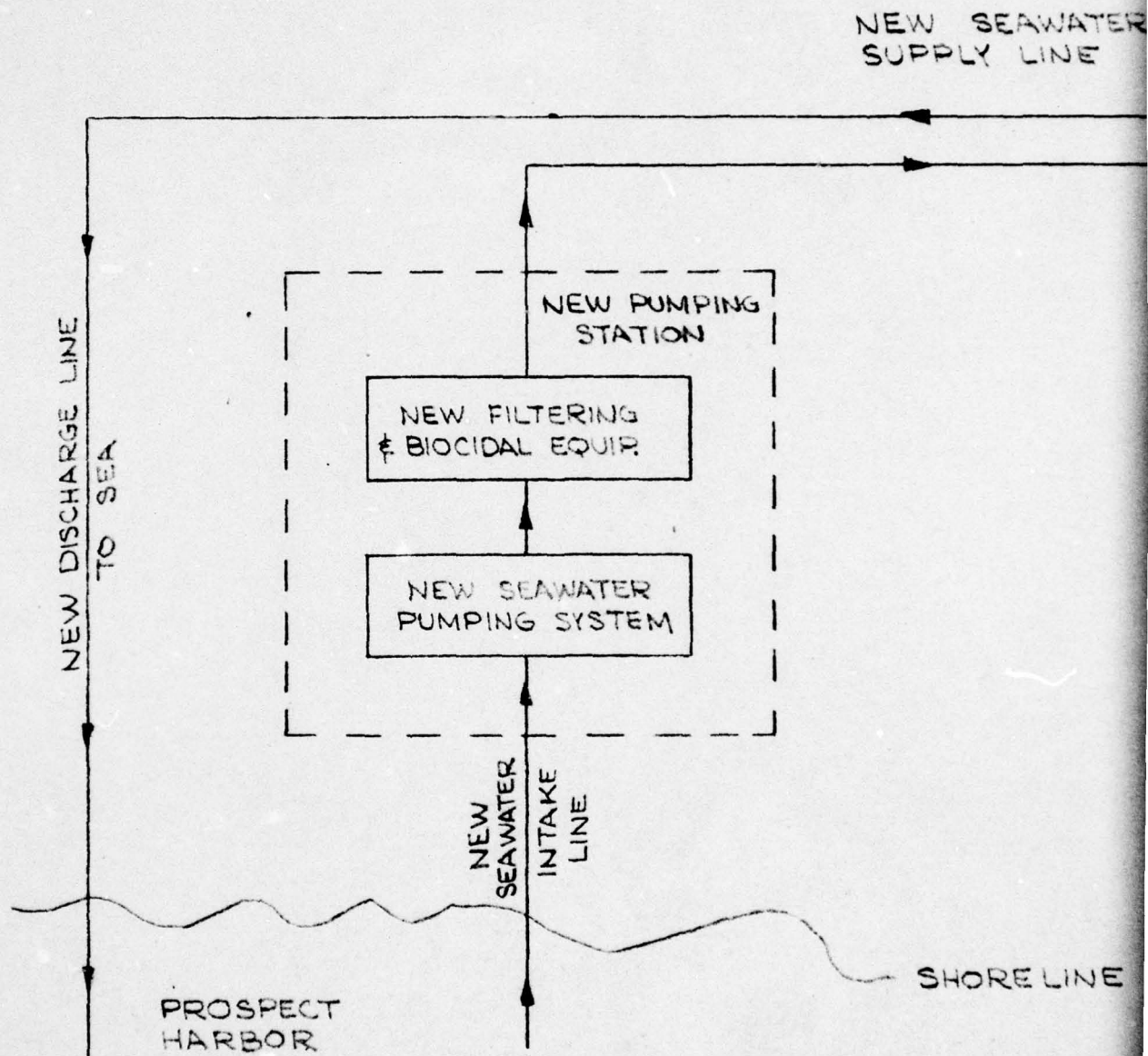


FIGURE 6 - SCHEMATIC OF  
AIR COND

2

3 ZONES IN BUILDING

EXISTING  
AIR-HANDLING  
SYSTEM

AIR

EXISTING  
CHILLER-COILS

NEW SEAWATER  
CHILLER-COILS

AUX. DX  
COMPRESSOR

NEW DX  
COILS  
(ENHANCEMENT)

AIR

EXISTING AIR  
DISTRIBUTION  
SYSTEM

AIR  
TO ROOMS

EXISTING BUILDING

NEW SEAWATER  
SUPPLY LINE

SHORE LINE

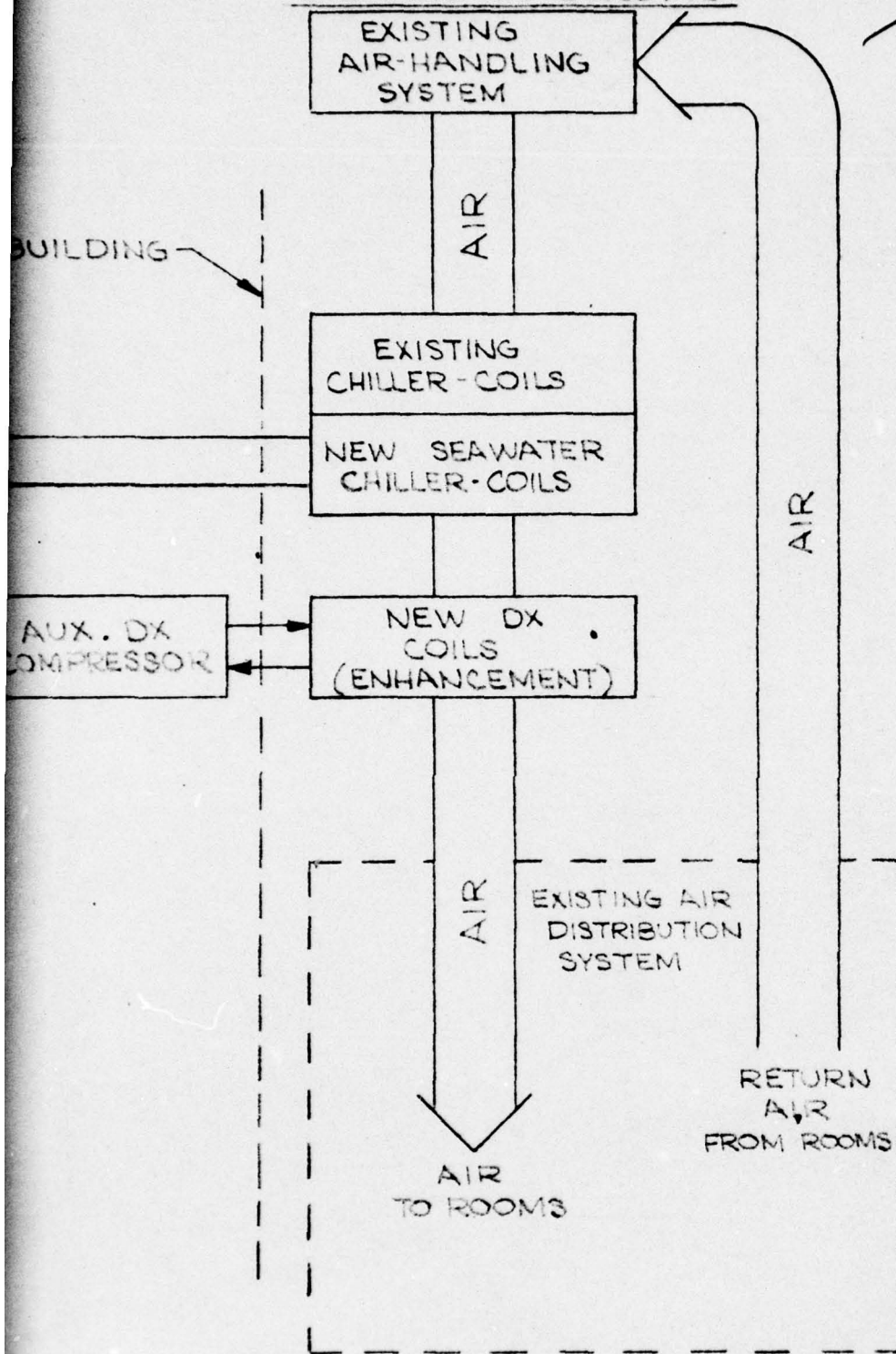
6 - SCHEMATIC OF PROPOSED SEAWATER  
AIR CONDITIONING SYSTEM

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3 ZONES IN BUILDING

3



WATER

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TABLE II

ANNUAL LOAD  
A/C ENHANCEMENT BY INDIVIDUAL  
DX COILS IN AIR SYSTEM (FIGURE 3)

AUGUST, SEPTEMBER, OCTOBER AND PART OF NOVEMBER

|               | <u>TOTAL HOURS</u> | <u>TONNAGE</u> | <u>KW/TON</u> | <u>KWH</u> |
|---------------|--------------------|----------------|---------------|------------|
| 80° and above | 50                 | 45T            | 1.09          | 2452       |
| 75 - 79       | 78                 | 39             | 1.15          | 3498       |
| 70 - 74       | 182                | 37             | 1.29          | 8686       |
| 65 - 69       | 270                | 37             | 1.42          | 14185      |
| 60 - 64       | 365                | 36             | 1.42          | 18658      |
| 55 - 59       | 373                | 35T            | 1.42          | 18538      |
| 50 - 54       | 371                | 34T            | 1.42          | 17911      |
| 45 - 49       | 330                | 33T            | 1.42          | 15463      |
| 40 - 44       | 280                | 32T            | 1.42          | 12723      |
| 35 - 39       | 248                | 31T            | 1.42          | 10916      |
| 30 - 34       | 200                | 31T            | 1.42          | 8804       |
| 25 - 29       | 106                | 30T            | 1.42          | 4515       |
| 20 - 24       | 38                 | 29T            | 1.42          | 1564       |
| 15 - 19       | 13                 | 28T            | 1.42          | <u>516</u> |
|               |                    |                |               | 138439     |

of freezing and the required modifications are least complex. In addition, the control scheme is very straightforward and maintenance is minimal.

In a less critical application, we would probably recommend that the enhancement is unnecessary. We are confident that the seawater coils specified can handle the entire sensible load, and the latent load in this building is quite low due to the high electronic load. However, because of the critical nature of this application, and because the seawater system is not proven, we do recommend that enhancement be made available in the event seawater temperatures do exceed 50°F and the seawater system alone cannot remove sufficient moisture to maintain the specified humidity.

One option not previously discussed is to utilize the existing air conditioning system in the building in the event enhancement is required, and forego the installation of additional equipment for this purpose. This has the obvious benefit of reducing the initial cost, but energy costs will be higher. We estimate that systems of this type cannot be cut back more than 50 percent of capacity.

#### 4. The Seawater System

The seawater system is required to supply a maximum of 280 gpm of bottom Bay water to the air conditioning system. This



will adequately provide cooling for the building during the warmest periods of the year. During colder weather, the air conditioning load in the building is reduced to about 60% of its peak load, requiring less seawater for cooling. The amount of seawater required is further reduced because the temperature of the water is considerably lower during these periods as well.

The preliminary design calls for three identical 140 gpm constant speed pumps to operate in parallel. During high demand periods, two of the pumps operate together to supply 280 gpm. During colder weather, only one pump will be operated to further conserve electricity. The third pump is a spare.

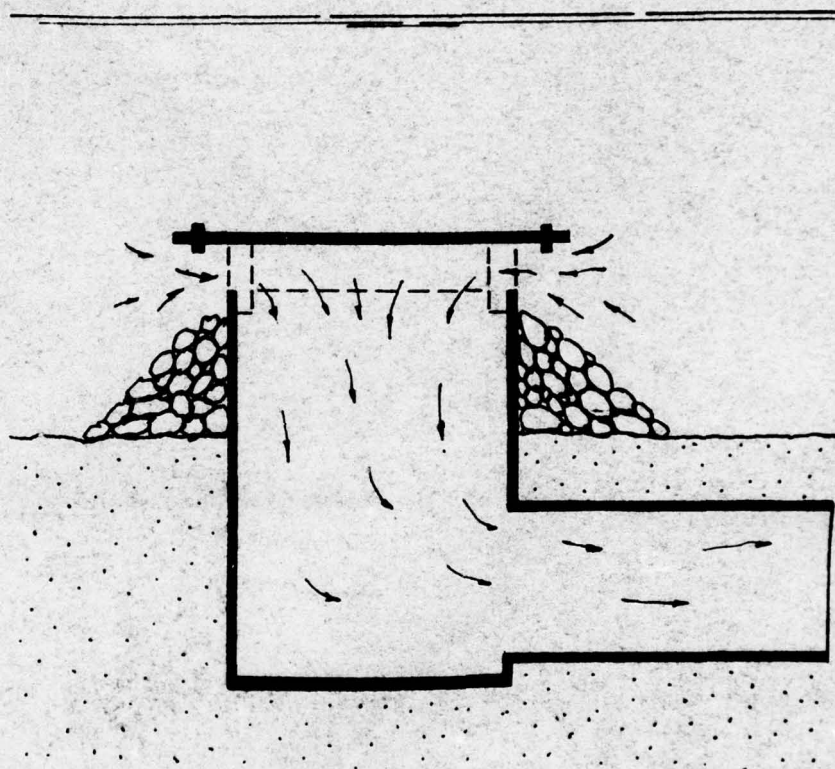
The pumps are to be located in a sheltered and frost-protected pumping station. This station should be as close to sea level as possible to maintain seawater suction, yet high enough for protection against storms. Due to the large tidal excursion, and the presence of cliffs along the shore, these criteria may require high placement of the shelter with excavation of rock or soil to a level suitable for suction pumping (essentially an underground pumping station). Other options would be to build the pumping station into the face of the cliff (there are existing indentations in the rock), or to locate the station behind a cobble beach that exists in a major break in the cliffs, and depend on an existing cobble berm for storm protection. Other considerations, such as selection of the optimum pipeline route, will limit these options.

The selection of the pipeline route will have to be based on more detailed topographic, soils and bathymetric data than is available at this time. Surveys to obtain this information are specified in the design specification. Plate I of this report delineates a zone of possible pipeline routes that encompasses a variety of terrain and ground cover.

(a) Offshore Route

Several types of routes for the submerged portion of the pipeline are apparent from the aerial photos and the NOAA bathymetric charts. Most of the zone has a rock ledge only a few feet below low water that extends offshore for several hundred feet. At the southern end of our zone, this ledge has a relatively sharp drop-off to deeper water. This drop-off is much gentler in other portions of the zone. The off-shore ledge is paralleled on land by a twenty-foot cliff at the water's edge. A large break in this cliff forms a cove with a cobble beach near the northern part of our zone. This break appears to extend through the offshore ledge, and provides a gentler slope from the treeline to the shore and thence offshore. The beach here is made up of well-rounded cobble, about the size of softballs. The cobble has been thrown up by wave action to form a high berm that protects the treeline. Driftwood and other floating debris is found behind the berm, indicating that some water does break over the berm. A detailed bathymetric survey and diver examination of the offshore zone will reveal additional design factors.



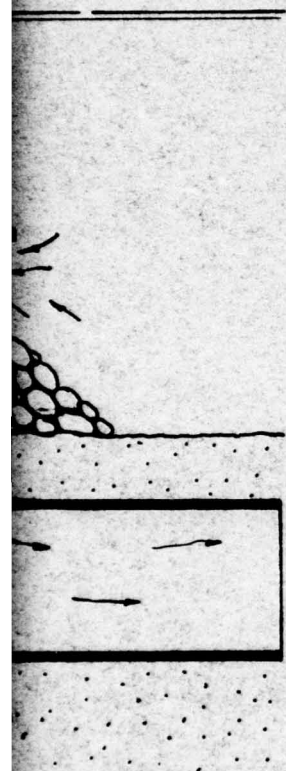


TYPICAL SEAWATER INTAKE STRUCTURE

NOT TO SCALE



2



THE STRUCTURE

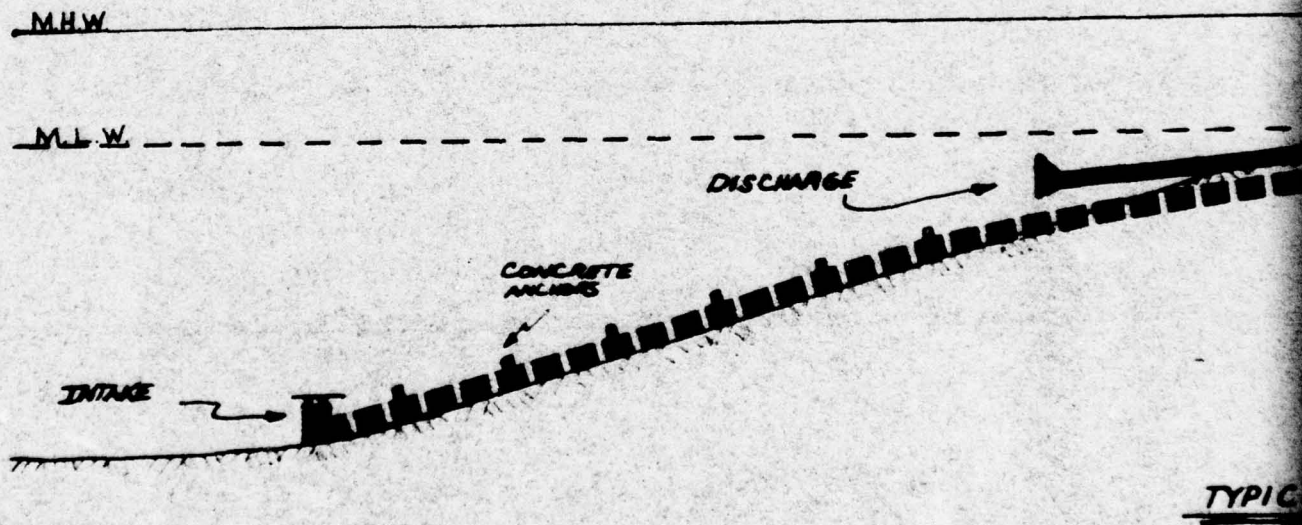
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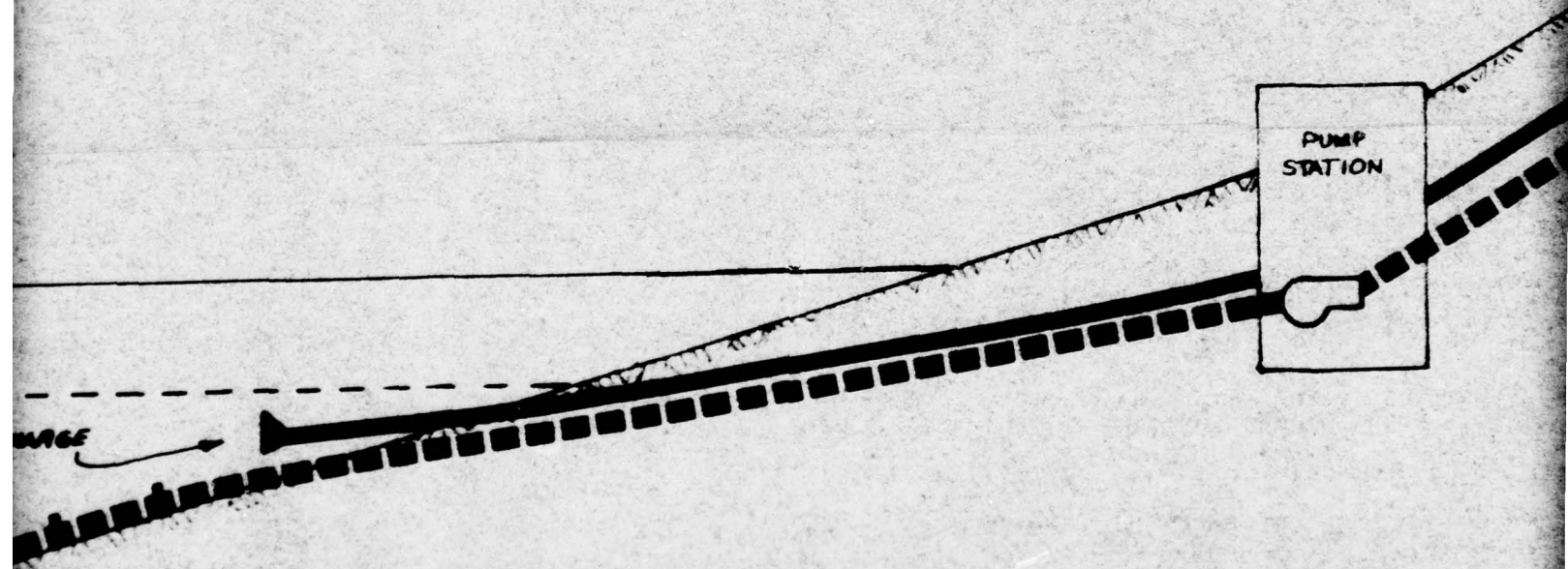
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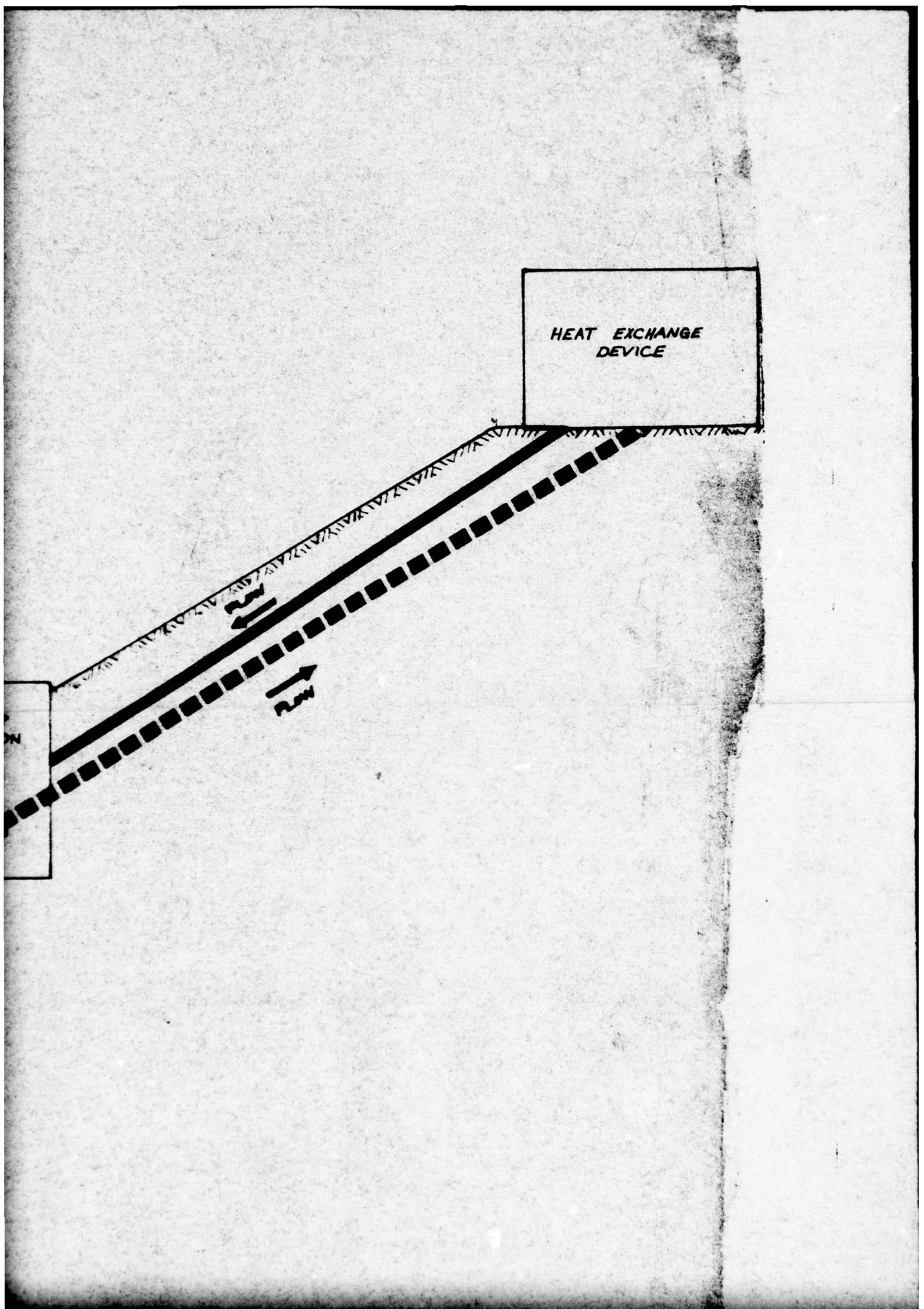


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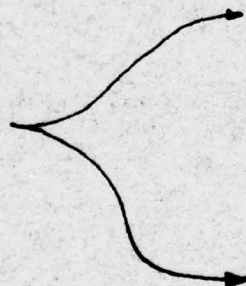
TYPICAL PUMPING SYSTEM PROFILE  
NOT TO SCALE





6

INTAKE  
STRAINERS



10"  $\phi$  HDPE PIPE




DISCHARGE  
DIFFUSERS



LEGEND

 - GATE VALVE

 - CHECK VALVE





7

DISCHARGE  
DIFFUSERS

10"  $\phi$  HDPE PIPE

140 GPM

140 GPM

140 GPM

LEGEND

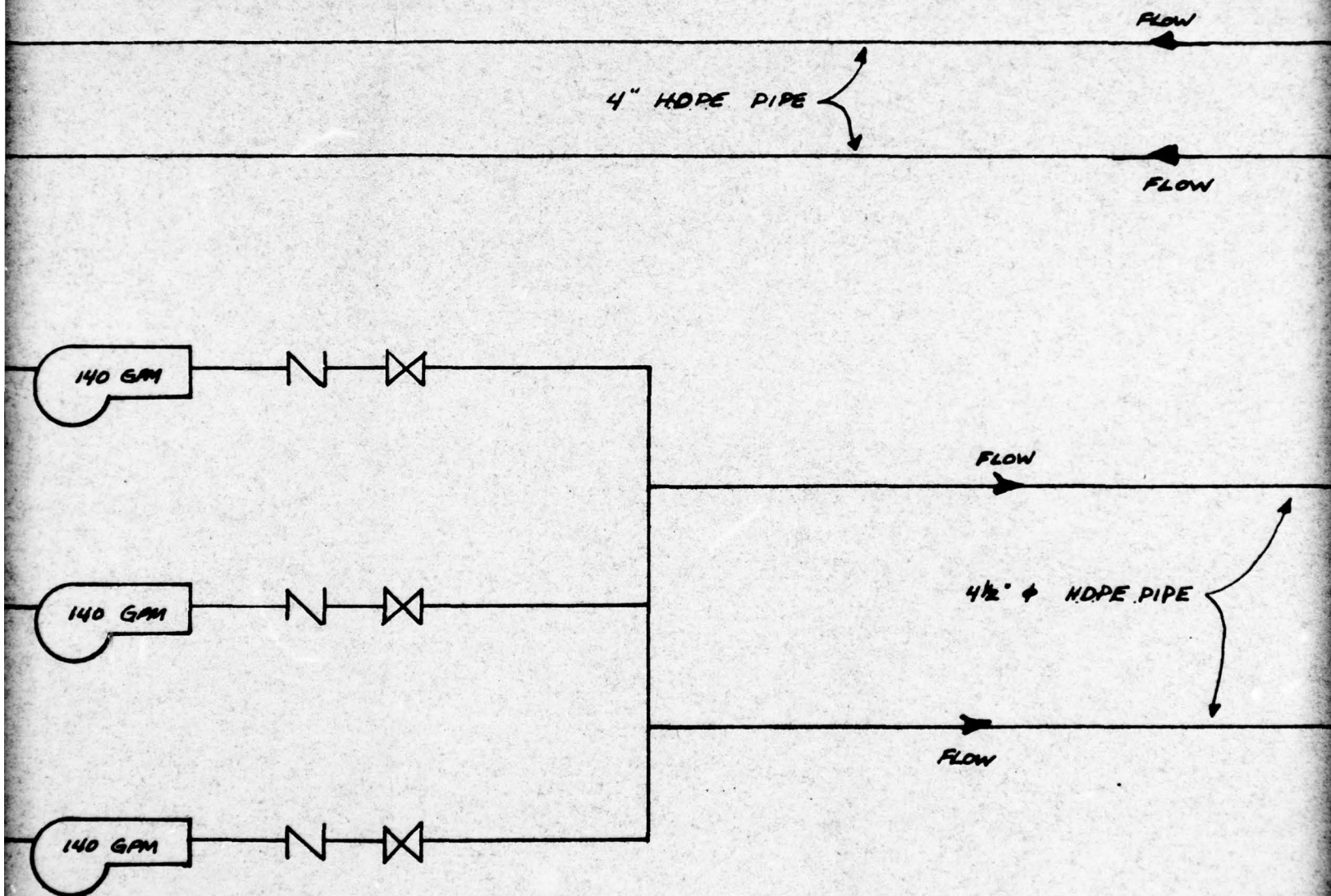
— GATE VALVE

— CHECK VALVE

— FOOT VALVE



8



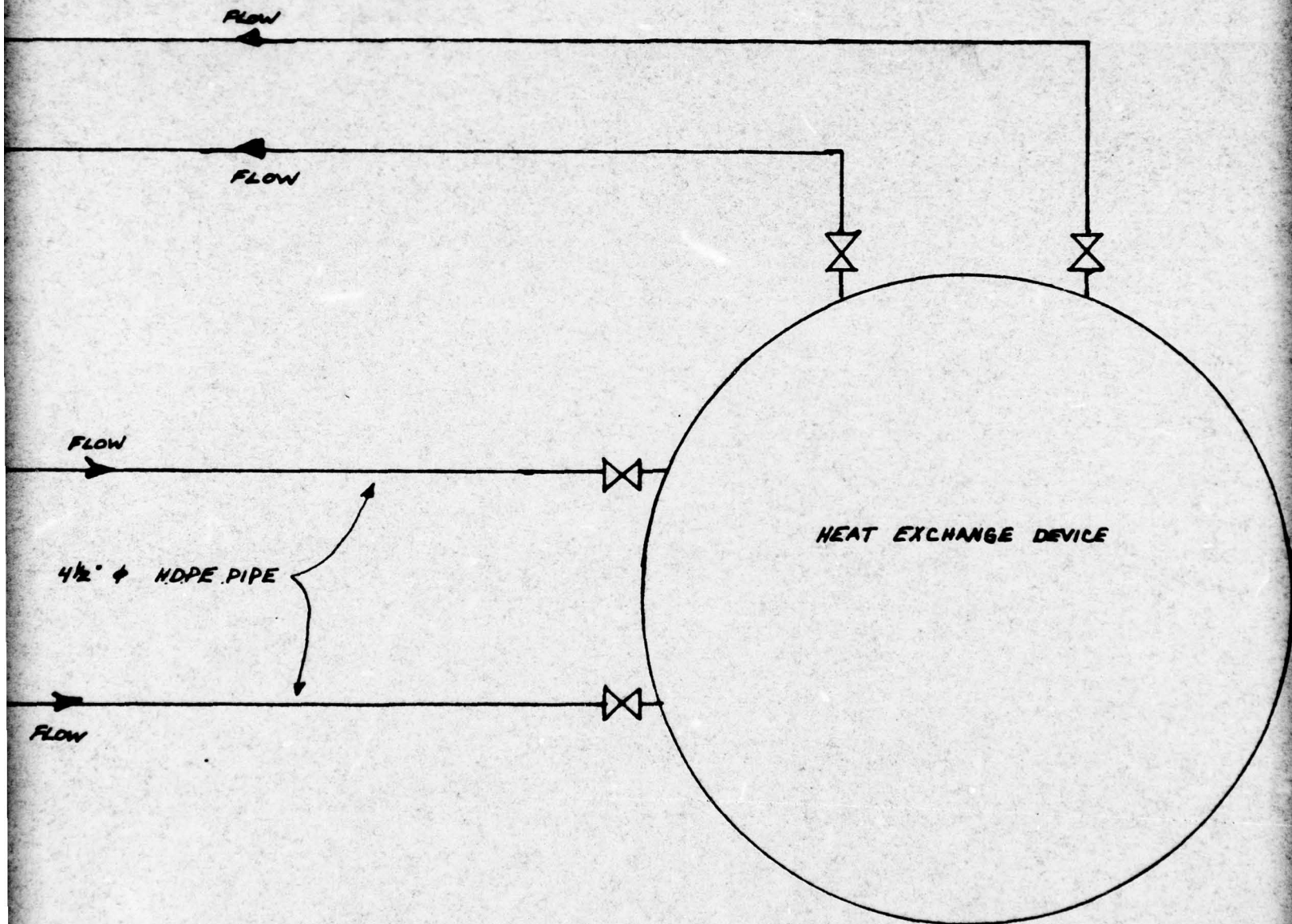
TYPICAL PUMPING SYSTEM SCHEMATIC

NOT TO SCALE

TYPICAL PUMPING SYSTEM PROFILE

NOT TO SCALE

9





10

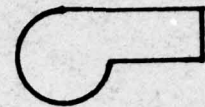


LEGEND

 - GATE VALVE

 - CHECK VALVE

 - FOOT VALVE

 - PUMP ; 140 GPM AT 120' <sup>1</sup>  
WITH 7½ HP TE

H.D.P.E - HIGH DENSITY POLYETHYLENE

12

ND \_\_\_\_\_

VALVE

VALVE

VALVE

— PUMP ; 140 GPM AT 120' TDH, ALL BRONZE CONSTRUCTION  
WITH 7½ HP TEFC MOTOR

HIGH DENSITY POLYETHYLENE

13

TYPICAL PUMPING SYSTEM SCHEMATIC

NOT TO SCALE

1



14

|                                    |                        |
|------------------------------------|------------------------|
| PROJECT                            |                        |
| DRAWING NUMBER:<br>5102 E 13.002 E | DATE:<br>FEB. 28. 1977 |
|                                    | FB PP                  |
| DRAWN BY<br>KO                     |                        |
| CHECKED BY:                        |                        |
| SHEET:<br>2 of 2                   |                        |
| COMM. NO.<br>5102 E                |                        |

(b) The Land Route

A visual inspection of the indicated zone was made during the winter (snow cover). Features in the southern end of the zone that resemble rock outcrops in the aerial photos are in reality bog features. No rock outcrops were observed except along the shore, and soil cover appears to exist over the entire area. This should be confirmed by a detailed survey during a warmer period (without snow) since State maps indicate rock outcrop in this area.

Ground cover varied from large trees to low brush in the bogs. Several zones of previous "cuts" were overgrown with a thick young scrub. An open cut containing electric cable conduit runs westerly from the building area to an electronic unit about 1000 feet down the slope.

In selecting the land route for the pipeline, the existing road or the existing cut through the trees should be utilized as much as possible, not only for obvious environmental reasons, but to reduce the cost of an access road to the pump station.

For example, a route along the southern boundary of the zone would follow the main road to its bend, then proceed downslope through the bog to the treeline. Probably a considerable amount of fill will be required for pipeline burial and an access road through the bog. At the landward side of the treeline, the route should turn sharply, then proceed to the pump station at an angle

to the main route so that trees hide the main part of the route when viewed from the Bay. This route would be suitable if both buildings are to be supplied eventually, but presents construction difficulties due to its termination on the cliff.

A route following the northern-most edge of the zone would utilize the existing cable route for a good part of the run, then would cut downslope through trees to the shore. This route could be modified to run to the cobble beach, or to the cliff, as desired. This would appear to be the best route to service the northern building only.

Other suitable routes exist, and final selection will depend on a number of design and site-related factors.

#### (c) The Pipeline

After consideration of other candidate pipe materials (e.g., steel, fiberglass, PVC), high-density polyethylene (HDPE) was selected, for the following reasons.

- Good heat insulation properties.
- Good "smoothness" factor.
- Can be essentially joint-free to reduce biofouling.
- Is not brittle in cold.
- Is not oversensitive to sunlight (deterioration).
- Does not corrode.
- Is lightweight.
- Can tolerate some movement once installed (frost and storms).
- Will conform to topography.

Perhaps the most important reason is its ease of installation.

The offshore portion is either extruded continuously, or sections



are welded to form one piece. The end is sealed and the pipeline is floated in the Bay, where concrete weights are attached (see Figure 7). It is then towed into position and installed on the bottom by controlled flooding. While some preparation of the sea-bed route is required, the pipeline as installed does not require firm anchoring (embedment anchors) to the sea-bed (Ref. 5), and the degree of foundation preparation required is considerably less than that needed for other materials.

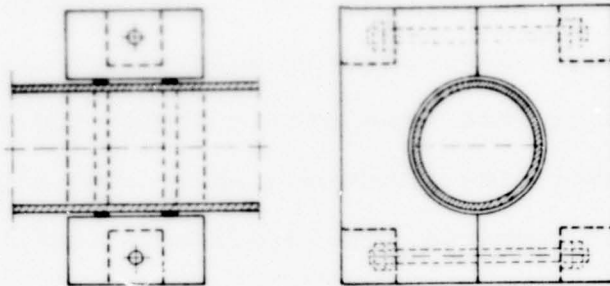
Because HDPE is subject to chafing and erosion, it is protected through the tidal and surf zones by a steel conduit (that must be firmly anchored).

Other features of the pipeline are shown in Plate II of this report and further described in the section on Design Approach and in the Specification section.

The filtering and biocidal equipment discussed earlier will be located in the pumping station and will prevent fouling in the seawater system beyond this point. Several techniques are available to keep the offshore pipeline from clogging.

A common technique used with duplicate intake lines is to alternately shut one line down for a period of time. This causes the trapped seawater to stagnate (turn anaerobic). If this is done about every two weeks, young organisms inside the pipeline will die and not accumulate. Other variations of this technique are to fill the unused pipeline with fresh water for this period or to add

HDPE pipe with concrete loading weights



Loading weight, Type Essemplast I

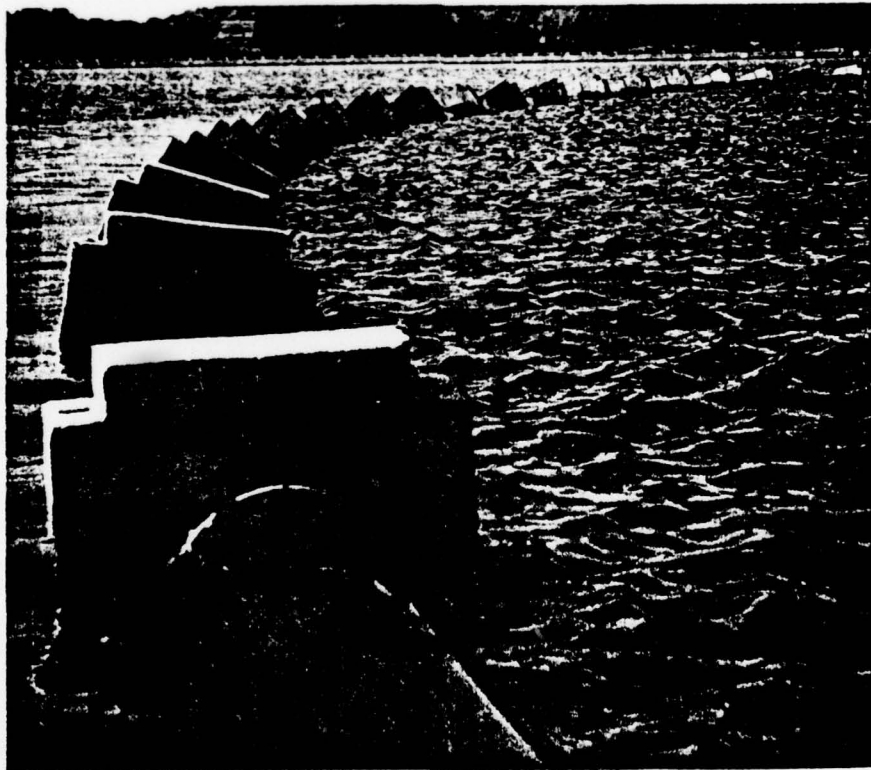


Figure 7. HDPE pipe with concrete loading weights.

From Janson (5)

chlorine or another biocide. If these techniques fail, we have provided (in the specification) for mechanical cleaning of the pipeline as a backup.



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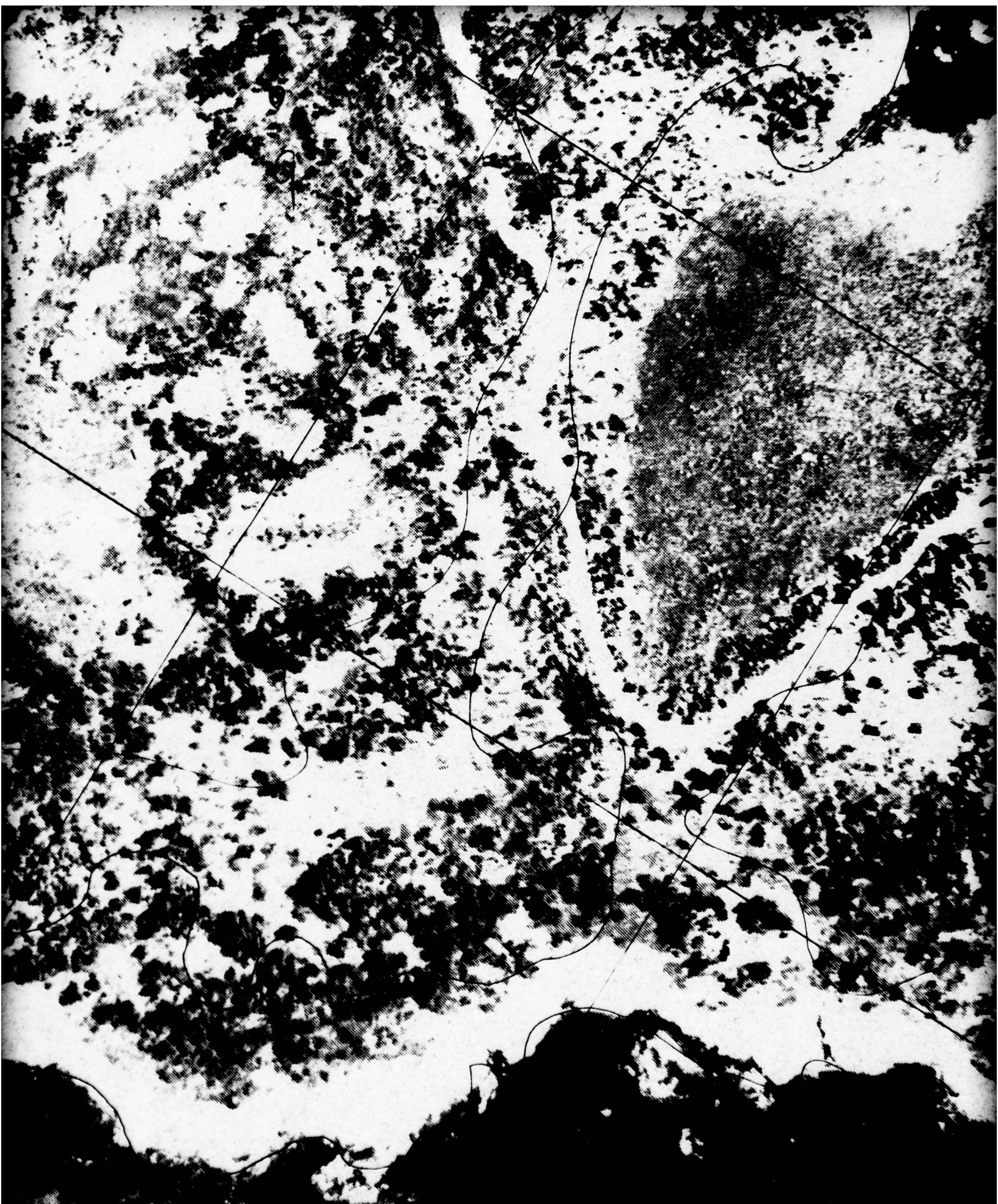








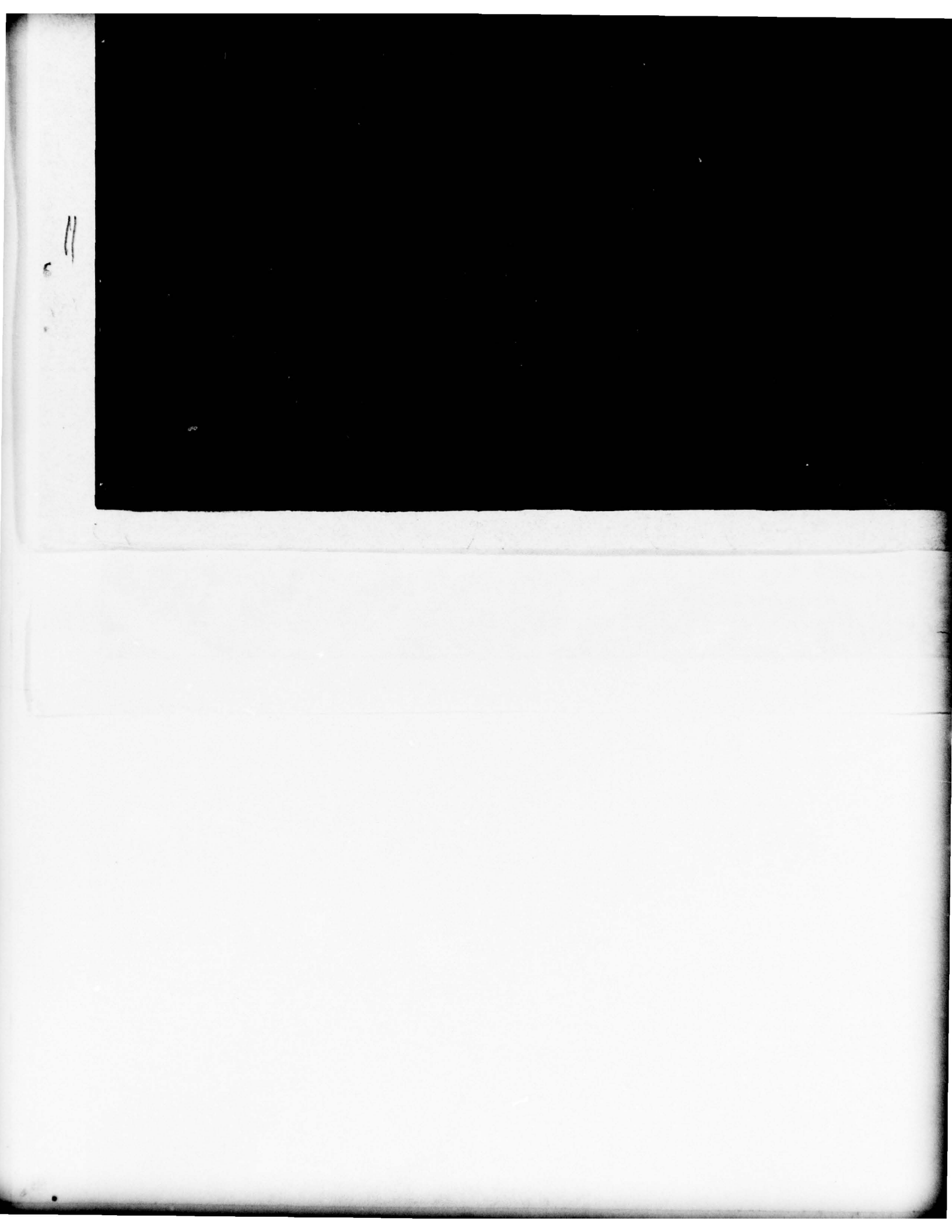












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13



14

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| DATE:<br>FEB. 2, 1977            | FB<br>PP |                                    |  |
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15

IV. DESIGN SPECIFICATIONS

1. Seawater Supply System

(a) General

Provide construction plans and specifications for a pipeline to supply cold ocean water for heat transfer for a prototype seawater air conditioning system at a U.S. Navy facility at Corea, Maine.

The pipeline shall be designed to pump seawater from the Atlantic Ocean at Prospect Harbor, Maine, through a heat transfer system and return the effluent to the bay.

Key components of the system shall be redundant for continuous operation. Prime consideration shall be given to minimizing the operational energy requirements of the system.

(b) Technical (Refer to Plates I and II at the end of this report)

(1) Route Selection

The designer shall establish an economically feasible pipeline route within the specified area (see Plate I). The route selected shall be based on the following criteria:

(1.1) Topography

- a. Landward portions of the project area include gentle slopes terminating in a 20 foot granite cliff at the water's edge. In one location the cliff is broken for a distance of about 200 feet



and a cobble beach with a well-developed berm exists. A topographic survey shall be conducted as part of the design analysis to identify and locate onshore elevation features which would adversely affect the construction or operation of the pipeline.

- b. Offshore portions of the project area exhibit a rock ledge just below sea level extending 150 to 400 feet from the shore. The sea bottom falls off rapidly at the edge of this ledge. A break in this ledge offshore of the cobble beach mentioned above appears to provide a gentle slope 1:60 to the deeper water. A bathymetric survey shall be conducted to identify and locate subaqueous elevation features which would adversely affect the construction or operation of the pipeline.

(1.2) Geology

- a. Landward portion of the project area includes soft bogs, areas of thin top soil cover and exposed ledges of granite rock. The site should be inspected to locate geological conditions which would adversely affect construction or operation of the pipeline.
- b. Offshore portions of the project area consist of rock ledges and cobble materials with soft sediment indicated in deeper water. An underwater inspection

shall be conducted to identify and locate subaqueous geological features that would affect the installation or anchoring of the pipeline.

(1.3) Environmental Impact

The selected route should minimize destruction of trees and other plants and reduce the visibility of the pipeline route (from the Bay) after completion of construction. The pipeline route should follow existing clearings and zones of less desirable trees and plants to the degree possible.

(2) Seawater Piping

A redundant piping system shall be designed to transport 280 gallons per minute from a submerged offshore intake approximately 3000 feet to a heat exchange system onshore (at an elevation of roughly 60 feet) and return the heated effluent to the bay.

(2.1) Pipe Materials

The pipeline shall be designed with continuously extruded or welded high density polyethylene pipe.

(2.2) Pipe Size

a. Ocean Intake Pipes: Ocean intakes shall be sized such that each pipe will flow 280 gallons per minute with a maximum head loss of 2 feet. The pipes shall have a minimum diameter of 10 inches, to allow for anticipated internal encrustation by marine organisms.

- b. Onshore Supply and Discharge Pipes: Onshore piping shall be sized by optimizing construction and projected pumping costs. Flow velocities should be maintained above 2 feet per second at a flow of 140 gallons per minute to retard fouling.

(2.3) Pipe Length

- a. Supply Pipe: The length of the supply piping shall be determined by the design location of the pump station and the selected pipeline route.
- b. Discharge Pipe: The length of the discharge pipe shall be determined by the selected pipeline route and the location of the point of discharge (see Seawater Discharge Section 4).
- c. Intake Pipe: The length of the intake pipe shall be determined by the design location of the pump station and the location of the seawater intake as determined by the Ocean Temperature Survey to be conducted by others.

(2.4) Embedment

- a. Onshore: All self-draining pipes, not subject to freezing, shall be buried with a minimum two feet of cover.

All piping subject to freezing will be buried with a minimum of 5 feet of cover.



- b. Tidal Zone: All pipes shall be embedded with a minimum 5 feet of cover.

All pipes shall be placed with steel conduits for protection from abrasion. The protective steel conduit shall extend offshore to an elevation of at least -12 MLW, or deeper if necessary. Conduit shall be stabilized from the high tide mark to its offshore termination by means of embedment anchors or cementing into rock ledge, or other suitable means to prevent movement and damage due to waves and currents.

- c. Offshore: Conduit shall be embedded or anchored offshore to withstand drag and lift forces produced by maximum projected local wave conditions and transverse currents of four feet per second.

Seaward of the conduit exit, pipes shall be stabilized with concrete weights, designed by the method similar to that of Lars-Eric Janson as described in his book "Plastic Pipe in Sanitary Engineering" (Celanese, 1974). The transition between conduit and concrete anchors should be designed to prevent bends and crimps. The plastic pipe should be protected from abrasion and chafing where necessary along the route.

Embedment and anchor design shall anticipate subaqueous erosion by waves and currents.

### (3) Seawater Intake

Dual seawater intakes should be located at an approximate depth of 45 feet. The exact depth of the intake shall be determined by a Temperature Survey to be conducted in the summer of 1977. Design is to follow guidelines for "best technology available for cooling water intake structures" as defined in EPA regulations 40 CFR, 401 and 402.

#### (3.1) Intake Strainer

Each suction pipe shall be capped with a strainer device designed to minimize the intake of debris and marine organisms. The strainer device shall extend from the ocean bottom, as required to eliminate the intake of sediments. Each strainer shall be designed to intake 280 gallons per minute horizontally at velocities less than .5 feet per second. Intake designs should utilize available natural current flows to remove debris from intake openings.

#### (3.2) Intake Maintenance

The intakes shall be designed to be maintainable by divers and/or surface methods. The use of flexible intake piping should be evaluated as an aid to surface maintenance.

### (4) Seawater Discharge

The effluent pipeline shall extend beyond the low tide elevation and terminate in a discharge diffuser. The diffuser

shall be designed to distribute heated effluent such that the temperature of tidal waters beyond 50 feet from the diffuser is not raised more than 1.5°F. The discharge site shall be located away from existing marine life habitats.

The design shall comply with all State and Federal regulations for thermal discharges.

#### (5) Pumping System

The pumping system shall be designed to take suction from the ocean and deliver 280 gallons of seawater per minute to a remote location at an elevation of approximately +60 feet MLW. Exact elevations shall be determined by topographic survey as part of the design.

The system shall be designed to alternately supply one-half of the design volume, based on the thermal requirements of the heat exchange system.

##### (5.1) Pumps

- a. Two or more identical pumps shall be included in the system to provide redundancy for year-round operation and parts inter-changibility.
- b. They shall be selected to supply the required volumes of water under fluctuating suction condition created by a spring tidal range of 12.1 feet at a constant delivery pressure compatible with heat exchanger requirements.



- c. Pumps and drivers shall be constructed of high quality materials suitable for continuous service with unpolluted seawater at a maximum temperature of 60°F.
- d. Pumps shall be designed for remote control from the heat exchange location.

(5.2) Pump Station

All pumps shall be installed in a suitable pump station, located at an elevation which will provide adequate positive suction head at low tide. The pumping system should be designed to provide a relatively constant total design head which would be compatible with the heat exchanger requirements throughout the tidal range during both full flow and half-flow operations.

- a. The pump station shall be well protected from flooding by ocean storm waves.
  - b. It shall provide adequate space for equipment with easy access for servicing and inspection during operation.
  - c. The pump station shall be suitably maintained to minimize corrosion and prevent freezing.
  - d. The pump station shall be designed to minimize its visual impact on the surrounding environment.
- Embedment of the pumping station is anticipated,

requiring excavation of soil and rock. Site selection of the pump station should include consideration for minimization of blasting and rock removal.

(6) Fouling Resistance

All components of the pipeline shall be designed to eliminate or minimize fouling by marine organisms.

Pipe joints shall be minimized to reduce potential fouling sites.

Components whose configuration or materials of construction are subject to fouling shall be arranged to facilitate periodic cleaning.

The design analysis shall include a specific fouling control program. Thermal, toxic and stagnation control methods should be evaluated under the design conditions.

Several options are available for the air conditioning design, depending on maximum seawater temperature. One system requires direct circulation of seawater through air conditioning coils. In this option all organisms down to the size of bacteria must be destroyed or removed, preferably without the use chemicals. One possible technique is mechanical filtration down to 50 microns and ultra-violet purification for smaller organisms.

(7) Maintenance

All system components shall be designed for ease of maintenance.

A 12-foot wide rock road should be designed to provide maintenance vehicles access to the pump house.

Pipelines shall provide access for mechanical cleaning equipment each 500 feet, both onshore and offshore. A short removable flanged section of pipe shall be provided in each intake, supply and discharge line to facilitate the introduction of hydraulic cleaning equipment. The design should consider the requirements of locally available cleaning equipment.

(8) Frost Protection

All components of the system shall be properly protected from frost damage.

(9) Corrosion Resistance

All system components shall be designed to minimize corrosion. Material selected shall be resistant to pitting during periods of stagnation.

All system components subject to electrolysis shall be well-grounded and provided with cathodic protection.

Life requirements of all components shall be specified in the design analysis.



(10) Environmental Impact

System design shall minimize adverse environmental impact during construction and operation. Feasible pipeline routes which minimize blasting for required rock removal should receive primary consideration. Design analysis should be consistent with the Environment Impact Assessment prepared for this project.

(11) Site Surveys

Design analysis shall include comprehensive site inspection and surveys as follows:

(11.1) Onshore:

- a. Soils testing for optimum route selection.
- b. Inspection of proposed routes.
- c. Topographic survey of selected pipeline route and pumping station.

(11.2) Offshore

- a. Bathymetric survey for location of intake.
- b. Visual underwater inspection for route and discharge location.

2. Air Conditioning System

(a) Mechanical Specifications

(1) Scope

This Section of Specifications covers an air conditioning system capable of providing year-round cooling for building

utilizing chilled water from the sea as the prime source. Additional cooling obtained from air cooled condensing units shall, when seawater temperature increases above desired levels, be activated to maintain dry bulb temperature and relative humidity at 75°F and 50%, respectively, throughout building.

(2) Applicable Documents

The following Performance Specifications and Standards listed and referred to form part of this Performance Specification.

Federal

- 00-A-A-374 - Air Conditioners with remote condensing units.
- WW-T-799D - Tubing, copper, seamless (for use with solder-joint or flared-tube fittings).

(3) Requirements

(3.1) General

The work includes the installation in three existing Air Handling Systems of direct expansion coils with A.R.I. nominal capacities of 7½ tons, 10 tons and 28 tons.

- a. Coils shall be of same manufacture as condensing units.
- b. Direct expansion coils shall have aluminum fins on staggered copper tubes. Maximum working pressure shall be 300 psig. Coils shall be tested in accordance with ANSI B9.1.

- c. All direct expansion coils shall be provided with condensation pans with drains.
- d. Refrigerant piping shall be installed as require between new condensing units and new DX coils. Refrigerant piping shall be K copper in accordance with Federal Specification WW-T-799D: Piping shall be installed above ceilings where possible.
- e. Condensing units shall be air cooled. All construction and ratings shall be in accordance with latest ARI Standard 590 complying with USAS B9.1 Safety Code, National Electrical Code and applicable ASME Code.
- f. Condensing units shall be provided with head pressure control to unload compressor down to  $-10^{\circ}\text{F}$ . Condensing unit controls shall be enclosed in weather-tight sheet metal box with cover. Winter start control shall be provided on unit which shall temporarily bypass system's low pressurestat to permit startup at low temperatures.
- g. One-year free service contract and one-year warranty shall be provided by Contractor for furnishing parts and all labor necessary to replace any part of condensing unit which becomes defective during normal operation from date of final acceptance of building by Owner.



(4) Seawater Chilling Air Coils

Shall be provided in existing air handling units. Cooling capacities shall be the following:

Coil #1 - 7500 cfm with air entering coil at 80.5 D.B.-

65.4 W.B. Air leaving coil at 56.4 D.B.-54.4 W.B.

500 F.P.M. maximum air velocity across face of coil.

15 ft. maximum water pressure drop.

Coil #2 - 26000 cfm with air entering coil at 75.2 D.B.-

64.0 W.B. Air leaving coil at 56.0 D.B.-54.0 W.B.

500 F.P.M. maximum air velocity across face of coil.

15 ft. maximum water pressure drop.

Coil #3 - 6000 cfm with air entering coil at 75.2 D.B.-

64.0 W.B. Air leaving coil at 60.0 D.B.-59.0 W.B.

500 F.P.M. maximum air velocity across face of coil.

15 ft. maximum water pressure drop.

Coils shall be manufactured specifically for salt water application and shall be certified by manufacturer for such use.

(5) Modifications to Ductwork

All necessary modifications shall be made to existing Ductwork System for installation of additional direct expansion and seawater coils. All ductwork modifications and new ductwork shall be fabricated following SMACNA recommendations.

(6) Modifications to Existing Air Handling Equipment

All adjustments necessary to obtain specified air quantities shall be made in existing air handling equipment. Where required, new fan motors shall be provided to obtain specified air quantities.

(7) Air Balancing

After installation of new coils in existing air handling equipment, a complete air balance of building shall be performed. Air balance shall be performed following the Associated Air Balance Council recommendations.

(8) Seawater Piping

A complete Piping System shall be provided. Piping system shall run in trenches outside of building with burial to 5 feet, and shall be of same material as piping extended to sea. All necessary water specialties shall be compatible with seawater.

(9) Automatic Temperature Controls

Furnish and install a Control System capable of maintaining 75°F Dry Bulb and 50% relative humidity year-round. All necessary interfacing with existing building control system shall be made. Control system shall be of same type and manufacture as existing control system in building.

Entire temperature control system shall be adjusted and placed in operation by manufacturer. All adjustments necessary to accomplish specified results during first year of operation shall be made at no cost to Owner.

(10) Operating Instructions

When all work is finished, Contractor shall thoroughly instruct building representative in use of all equipment.

(b) Electrical Specifications

(1) Scope

Work consists of providing all necessary feeders, panelboards, disconnects and other appurtenances necessary for a complete installation as required by mechanical work. Complete installation shall be done in accordance with National Electrical Code.



## V. IMPLEMENTATION SCHEDULE

The scheduling of work for implementation of the seawater cooling project is dominated by the severe and long winter season in Corea, Maine. Roughly six months of the year are unsuitable for efficient pipeline construction (land and sea), or for the site surveys required prior to final design of the seawater supply system. In the following chart (Figure 8), major tasks as anticipated at this time are scheduled to permit completion of the seawater system prior to the winter of 1978.

It can be seen that if construction is to be performed spring/summer of 1978, field surveys must be performed during the spring/summer of 1977 to allow sufficient time for a final design. Similarly, the development of the demonstration part of the program (monitoring and evaluation) must occur prior to the final design so that instrumentation can be integrated into the final design.

Item 6, Selection of the A&E, is a three-stage task, broken into Preparation of Specifications/Bid Package, negotiation, and selection, all to be performed prior to the fall of 1977.

Item 8, Demonstration Program, is envisioned as a joint USN/ERDA R&D project. A meeting between the two groups should be arranged as soon as possible to formalize this project.



#### REFERENCES

- (1) Hirshman, J., Whithaus, D.A., and Brooks, I.H.; "Feasibility of a District Cooling System Utilizing Cold Seawater: Phase I, Final Report." ERDA Report No. ORO 4875-A, June 1975.
- (2) Hirshman, J. and Kirklin, R.; "Feasibility of District Cooling Systems Utilizing Natural Cold Waters; Phase II and Phase III - Final Report." ERDA Report No. ORO 4875-B, March 1977.
- (3) Hirshman, J. and Rodausakis, J.; "District Cooling System Utilizing Natural Cold Waters." Proceedings, Central Chilled Water Conference, Purdue University, November 1976.
- (4) Ciani, John B. and McLaine, Andrew W.; "Seawater Cooling for Naval Facilities." Final Report. YF.57.571.999.01.002, Naval Facilities Engineering Command, August 1976.
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APPENDIX A

LIFE CYCLE COST AND ENERGY SAVINGS DETERMINATION

SUMMARY

Life Cycle Costs

|    |   |             |
|----|---|-------------|
| 1) | Seawater system                           | - \$305,449 |
| 2) | Seawater system w/enhancement             | - 380,498   |
| 3) | Seawater system with existing enhancement | - 396,554   |
| 4) | Conventional A/C system                   | - 404,044   |

Payoff Period

At the 10 percent discount rate with 7 percent differential energy escalation rate, payoff for the seawater system is between 11 and 12 years.

## SECTION 2

### OVERVIEW

#### 2.1 Introduction

This report describes the results of the Life Cycle Cost (LCC) Analyses that were conducted for the Seawater Cooling Project. The seawater Cooling Project involves the development of design alternatives for providing air conditioning and dehumidification by means of a seawater system in lieu of a conventional system.

#### 2.2 Scope

The following tasks were performed in the study:

- a. Determine the LCC's for three (3) alternate seawater cooling air conditioning system configurations.
- b. Determine the LCC for a comparative conventional air conditioning system configuration.
- c. Perform sensitivity analyses of a and b above.
- d. Determine the energy savings and discounted payoff periods for the three (3) alternate seawater cooling systems vis-a-vis the conventional system.

#### 2.3 References

1. SOW, Preliminary Design of Seawater Cooling System, undated.
2. Economic Analysis Handbook NAVFAC P-442, June 1975.
3. Energy Escalation Rates for Short Term Costing and Life Cycle Costing, NAVFAC ltr 1203/JNW, 23 August 1976.
4. DoD Instruction 7040.5, "Definitions of Expenses and Investment Costs", 1 September 1966, with Change 1, 7 September 1967.
5. DoD Instruction, 7041.3, "Economic Analysis and Program Evaluation for Resource Management", 18 October 1972.
6. SECNAVINST 7000.14B, "Economic Analysis and Program Evaluation for Navy Resource Management", 18 June 1975.



7. NAVFACINST 4100.6, "Shore Facilities Energy Conservation Survey Program", 29 March 1974.

8. NAVFACINST 11010.14L, "Project Engineering Documentation for Proposed Military Construction Projects", 11 November 1975.

9. NAVFACINST 11010.55A, "Design Economic Analysis Guidance for Naval Facilities", 1 July 1974.

## SECTION 3

### TECHNICAL DISCUSSION

#### 3.1 General

This report contains a life cycle cost analysis of several alternate seawater cooling systems and a comparison of these systems to conventional air conditioning.

#### 3.2 Methodology

The Life Cycle Costs, the energy use, and the Discounted Payoff Period due to energy savings of three seawater cooling options are compared to a conventional air conditioning system of the type presently used at the Corea Facility. The alternate systems are:

- (a) Direct Seawater Cooling
- (b) Direct Seawater Cooling with new DX enhancement
- (c) Direct Seawater Cooling with existing A/C enhancement
- (d) Existing Air Conditioning System.

##### 3.2.1 Life Cycle Costs

In order to make a meaningful comparison of Life Cycle Costs for these systems, current costs are used for all systems, R&D costs for the seawater systems are excluded, and all systems are compared at a ten-year economic life.

##### 3.2.1.1 One-Time Costs

Some R&D funds have been expended by the U.S. Navy and ERDA in Feasibility Studies and Preliminary Designs to develop the seawater concept. These are Sunk Funds and will not be considered in this analysis. An additional joint R&D program (USN and ERDA) for evaluation of the seawater system is anticipated if one of the seawater cooling options is selected. However, in order to compare these systems with conventional systems as competitive cooling systems, these costs are also excluded in this analysis.

The Facility Investment Costs for equipment, construction and modification are the only non-recurring costs used in this analysis. These are summarized in Table A1-I, and outlined in the following paragraphs.

Site-survey and design costs for all systems are included.

Current price estimates are used for all systems.

All systems contain costs for redundant components, to insure continuous operation. For example, the existing A/C system has complete duplication (100 percent redundancy) of chiller and condensor cooling systems. The seawater system designs call for complete redundancy in the seawater supply system (pipelines and pumps). This causes costs for all systems to be considerably higher than in comparable systems where some shutdown for maintenance and repair can be tolerated.

The costs for construction of the seawater supply system are given as a high and a low depending on the amount of rock excavation necessary. An average of the high and low is used in this analysis.

All systems utilize an existing air handling and distribution system in the building, therefore these costs are not included. The seawater estimates do include costs for minor modification to the air ducts.

The Future Terminal Value of all systems is considered to be zero. Other one-time cost elements commonly considered in Life Cycle Cost Analyses, such as Value of Existing Assets Employed, Value of Existing Assets Replaced, and Working Capital Changes are all zero in this analysis.

#### 3.2.1.2 Recurring Costs

In this analysis energy is separated from other Operating and Maintenance costs in order to apply a differential escalation rate to the cost of energy. Non-energy costs are discounted at 10 percent and escalated at 0 percent. Energy costs are also discounted at 10 percent; however, a 7 percent differential energy cost escalation rate is used. The actual FY 77 cost of electrical energy in Winter Harbor, Maine, of \$.024 per KWH was escalated at the recommended 16 percent short-term escalation rate to a FY 79 value of \$.032 per KWH. This value was used to calculate FY 79 energy costs after which the recommended long-term rate of 7 percent is used.

#### 3.2.1.3 Economic Life

The economic life of the conventional air conditioning system falls under Category 3, Operating Equipment, with a maximum allowable economic life of 10 years. The seawater systems fall under Category 4, Utilities, Plants and Utility Distribution Systems (electricity, gas, water, etc.), with a maximum allowable



life of 25 years. In order to compare the systems on an equal basis, a ten year economic life was used for all systems, even though the economic life of the seawater system is estimated as 20 years.

### 3.2.2 Energy Use

Energy use of the various subsystems analyzed are summarized in Table A1-II in this section. Energy use for conventional air conditioning and for enhancement is tabulated in Tables 1 and 2 in the previous section, as developed from a detailed load analysis of the building. The energy used in the existing A/C system, if it is utilized for enhancement, is based on an estimate that it can be operated at a power level of 50 percent when used in this mode.

### 3.2.3 Payoff Period

The U.S. Navy method of using discounted energy savings to calculate payoff periods was used. The savings/investment ratio (SIR) is set equal to unity and the following equation is solved for the adjustment factor,  $b_N$ .

$$\frac{\text{Energy Savings in first year} \times b_N}{\text{Total Investment}} = 1.0 = \text{SIR}$$

The adjustment factor (Project Year Inflation - Discount Factor) is then inserted into the appropriate table (Table 7, NAVFAC P-442) to determine the payoff year. At the 10 percent discount rate with 7 percent differential energy escalation rate, payoff for the seawater system is between 11 and 12 years. With no differential energy escalation, the payoff would be in the 25th year, and with 10 percent differential escalation the payoff would be in the 9th year.

Addendum A1     Life Cycle Costs

The Life Cycle Costs of three seawater cooling options and a conventional system were determined using cost and energy use data summarized in Tables A1-I and A1-II following. The methodology is discussed in the previous section.

SUMMARY

TOTAL LIFE CYCLE COSTS

|  |           |
|--|-----------|
| A. Direct Seawater Cooling                               | \$305,449 |
| B. Direct Seawater Cooling with DX Enhancement           | \$380,498 |
| C. Direct Seawater Cooling with Existing A/C Enhancement | \$396,554 |
| D. Existing Conventional A/C System                      | \$404,044 |

TABLE A1-I Cost Element Summary

| Cost Elements                          | A) Direct Seawater Cooling | B) Direct Seawater Cooling with New DX Enhancement | C) Direct Seawater Cooling with Existing A/C Enhancement | D) Conventional A/C System Existing |
|--|----------------------------|--|--|-------------------------------------|
| Materials (in building)                | \$ 27,160                  | \$ 37,460  | \$ 27,160  | \$ 94,000                           |
| Labor (in building)                    | 7,400                      | 12,700   | 7,400  | 25,000                              |
| Materials and Labor (outside building) | 130,700                    | 130,700  | 130,700  | --                                  |
| Design and Engineering                 | 25,000                     | 25,000   | 25,000   | 12,000                              |
| Survey                                 | 15,000                     | 15,000   | 15,000   | --                                  |
| Bio-fouling Prevention Equipment       | <u>24,000</u>              | <u>24,000</u>                                      | <u>24,000</u>  | <u>--</u>                           |
| Subtotal (Investment and Non-Recurring | \$229,260                  | \$244,860  | \$229,260  | \$131,000                           |
| Annual Maintenance (in building)       | 2,000                      | 5,200  | 7,000  | 5,000                               |
| Annual Maintenance (outside building)  | <u>5,000</u>               | <u>5,000</u>                                       | <u>5,000</u>   | <u>--</u>                           |
| Subtotal (Annual Maintenance)          | \$ 7,000                   | \$ 10,200  | \$ 12,000  | \$ 5,000                            |
| ANNUAL COST OF ENERGY (FY 79)          | \$ 3,555                   | \$ 7,998   | \$ 10,293  | \$ 27,562                           |



TABLE AI-II Annual Energy Use Summary

|                    | A) Direct Seawater Cooling (KWH)/yr | B) Direct Seawater Cooling with New DX Enhancement (KWH)/yr | C) Direct Seawater Cooling with Existing A/C Enhancement (KWH)/yr | D) Conventional A/C System Existing (KWH)/yr |
|--------------------|-------------------------------------|---|---|--|
| A/C Equipment      |                                     | (1) 138,440   | (2) 210,560   | (3) 861,310                                  |
| Primary SW Pumps   | 73,900                              | 73,900  | 73,900  |  |
| Secondary SW Pumps | 37,200                              | 37,200  | 37,200  |  |
| TOTAL              | 111,100                             | 249,540   | 321,660   | 861,310                                      |

(1) From Table II, Page 20

(2) 2,904 hours (from Table II) x 50 tons (estimated minimum for existing equipment) x 1.45 KW/ton

(3) From Table I, Page 9

Primary Seawater Pumps (Outside)

|        | Hours Used/Yr. | HP | Total HP Hours | Total HP-Hours Pumps 1 & 2 | Adj. Factor* | Total KWH's |
|--------|----------------|----|----------------|----------------------------|--------------|-------------|
| Pump 1 | 8,760          | 7½ | 65,700         | 98,550                     | .75          | 73,900      |
| Pump 2 | 4,380          | 7½ | 32,850         |                            |              |             |

\*The adjustment factor is 1 HP hour = .75 KWH

Secondary Seawater Pump (Inside)

|        | Hours Used/Yr. | HP  | Total HP Hours | Adj. Factor* | Total KWH's |
|--------|----------------|-----|----------------|--------------|-------------|
| Pump 1 | 8,760          | 5.7 | 49,600         | .75          | 37,200      |

\*The adjustment factor is 1 HP hour = .75 KWH

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TABLE Al-III A. Direct Seawater Cooling - Net Present Value

| Project Year | Non-Recurring Cost and Investment | Recurring Costs |          | Annual Cost | Adjustment Factors |       |              | Adjusted Annual Costs |
|--------------|-----------------------------------|-----------------|----------|-------------|--------------------|-------|--------------|-----------------------|
|              |                                   | Non-Energy      | Energy   |             | Non-Energy Mult.   | Adj.  | Energy Mult. | Adj.                  |
| 0            | FY78                              | \$229,260       | \$       | \$          |                    | \$    |              | \$229,260             |
| 1            | FY79                              |                 | 7,000    | 10,555      | .954               | 6,678 | .986         | 3,505                 |
| 2            | FY80                              |                 | 7,000    | 10,555      | .867               | 6,069 | .959         | 3,409                 |
| 3            | FY81                              |                 | 7,000    | 10,555      | .788               | 5,516 | .933         | 3,317                 |
| 4            | FY82                              |                 | 7,000    | 10,555      | .717               | 5,019 | .908         | 3,228                 |
| 5            | FY83                              |                 | 7,000    | 10,555      | .652               | 4,564 | .883         | 3,139                 |
| 6            | FY84                              |                 | 7,000    | 10,555      | .592               | 4,144 | .859         | 3,054                 |
| 7            | FY85                              |                 | 7,000    | 10,555      | .538               | 3,766 | .836         | 2,972                 |
| 8            | FY86                              |                 | 7,000    | 10,555      | .489               | 3,423 | .813         | 2,890                 |
| 9            | FY87                              |                 | 7,000    | 10,555      | .445               | 3,115 | .791         | 2,812                 |
| 10           | FY88                              |                 | 7,000    | 10,555      | .405               | 2,835 | .769         | 2,734                 |
| Subtotals    | \$229,260                         | \$70,000        | \$35,550 | \$105,550   | \$45,129           |       | \$31,060     | \$305,449             |
| TOTALS       | \$229,260                         |                 |          |             | \$45,129           |       | \$31,060     | \$305,449             |

(NPV) TOTAL LIFE CYCLE COSTS

\$305,449



TABLE A1-IV B. Direct Seawater Cooling With New DX Enhancement - Net Present Value

| Project Year |      | Non-Recurring Cost and Investment | Recurring Costs |        | Annual Cost | Adjustment Factors |       |          |       | Adjusted Annual Costs |
|--------------|------|-----------------------------------|-----------------|--------|-------------|--------------------|-------|----------|-------|-----------------------|
|              |      |                                   | Non-Energy      | Energy |             | Non-Energy         |       | Energy   |       |                       |
|              |      |                                   |                 |        |             | Mult.              | Adj.  | Mult.    | Adj.  |                       |
| 0            | FY78 | \$244,860                         | \$              | \$     | \$          |                    | \$    |          | \$    | \$244,860             |
| 1            | FY79 |                                   | 10,200          | 7,998  | 18,198      | .954               | 9,731 | .986     | 7,886 | 17,617                |
| 2            | FY80 |                                   | 10,200          | 7,998  | 18,198      | .867               | 8,843 | .959     | 7,670 | 16,513                |
| 3            | FY81 |                                   | 10,200          | 7,998  | 18,198      | .788               | 8,038 | .933     | 7,462 | 15,500                |
| 4            | FY82 |                                   | 10,200          | 7,998  | 18,198      | .717               | 7,313 | .908     | 7,262 | 14,575                |
| 5            | FY83 |                                   | 10,200          | 7,998  | 18,198      | .652               | 6,650 | .883     | 7,062 | 13,712                |
| 6            | FY84 |                                   | 10,200          | 7,998  | 18,198      | .592               | 6,038 | .859     | 6,870 | 12,908                |
| 7            | FY85 |                                   | 10,200          | 7,998  | 18,198      | .538               | 5,488 | .836     | 6,686 | 12,174                |
| 8            | FY86 |                                   | 10,200          | 7,998  | 18,198      | .489               | 4,988 | .813     | 6,502 | 11,490                |
| 9            | FY87 |                                   | 10,200          | 7,998  | 18,198      | .445               | 4,539 | .791     | 6,327 | 10,866                |
| 10           | FY88 |                                   | 10,200          | 7,998  | 18,198      | .405               | 4,131 | .769     | 6,151 | 10,282                |
| Subtotals    |      | \$244,860                         | \$102,000       | 79,980 | \$181,980   | \$65,759           |       | \$69,879 |       | \$380,497             |
| TOTALS       |      | \$244,800                         |                 |        |             | \$65,759           |       | \$69,879 |       | \$380,497             |

(NPV) TOTAL LIFE CYCLE COSTS

\$380,497

TABLE A1-V C. Direct Seawater Cooling With Existing A/C Enhancement - Net Present Value

| Project Year                 | Non-Recurring Cost and Investment | Recurring Costs |           | Annual Cost | Adjustment Factors |          |        |          | Adjusted Annual Costs |
|------------------------------|-----------------------------------|-----------------|-----------|-------------|--------------------|----------|--------|----------|-----------------------|
|                              |                                   | Non-Energy      | Energy    |             | Non-Energy         |          | Energy |          |                       |
|                              |                                   |                 |           |             | Mult.              | Adj.     | Mult.  | Adj.     |                       |
| 0                            | FY78                              | \$              | \$        | \$          |                    | \$       |        | \$       | \$229,260             |
| 1                            | FY79                              | 12,000          | 10,293    | 22,293      | .954               | 11,448   | .986   | 10,149   | 21,597                |
| 2                            | FY80                              | 12,000          | 10,293    | 22,293      | .867               | 10,404   | .959   | 9,871    | 20,275                |
| 3                            | FY81                              | 12,000          | 10,293    | 22,293      | .788               | 9,456    | .933   | 9,603    | 19,059                |
| 4                            | FY82                              | 12,000          | 10,293    | 22,293      | .717               | 8,604    | .908   | 9,346    | 17,950                |
| 5                            | FY83                              | 12,000          | 10,293    | 22,293      | .652               | 7,824    | .883   | 9,089    | 16,913                |
| 6                            | FY84                              | 12,000          | 10,293    | 22,293      | .592               | 7,104    | .859   | 8,842    | 15,946                |
| 7                            | FY85                              | 12,000          | 10,293    | 22,293      | .538               | 6,456    | .836   | 8,605    | 15,061                |
| 8                            | FY86                              | 12,000          | 10,293    | 22,293      | .489               | 5,868    | .813   | 8,368    | 14,236                |
| 9                            | FY87                              | 12,000          | 10,293    | 22,293      | .445               | 5,340    | .791   | 8,142    | 13,482                |
| 10                           | FY88                              | 12,000          | 10,293    | 22,293      | .405               | 4,860    | .769   | 7,915    | 12,775                |
| Subtotals                    |                                   | \$229,260       | \$120,000 | \$102,930   | 222,930            | \$77,364 |        | \$89,930 | \$396,554             |
| TOTALS                       |                                   | \$229,260       |           |             |                    | \$77,364 |        | \$89,930 | \$396,554             |
| (NPV) TOTAL LIFE CYCLE COSTS |                                   |                 |           |             |                    |          |        |          |                       |
| \$396,554                    |                                   |                 |           |             |                    |          |        |          |                       |

TABLE A1-VI D. Conventional A/C System (Existing) - Net Present Value

| Project Year | Non-Recurring Cost and Investment | Recurring Costs |          | Annual Cost | Adjustment Factors |       |           |        | Adjusted Annual Costs |
|--------------|-----------------------------------|-----------------|----------|-------------|--------------------|-------|-----------|--------|-----------------------|
|              |                                   | Non-Energy      | Energy   |             | Non-Energy         |       | Energy    |        |                       |
|              |                                   |                 |          |             | Mult.              | Adj.  | Mult.     | Adj.   |                       |
| 0            | FY78                              | \$131,000       | \$       |             | \$                 |       | \$        |        | \$131,000             |
| 1            | FY79                              |                 | 5,000    | 27,562      | .954               | 4,770 | .986      | 27,176 | 31,946                |
| 2            | FY80                              |                 | 5,000    | 27,562      | .867               | 4,335 | .959      | 26,432 | 30,767                |
| 3            | FY81                              |                 | 5,000    | 27,562      | .788               | 3,940 | .933      | 25,715 | 29,655                |
| 4            | FY82                              |                 | 5,000    | 27,562      | .717               | 3,585 | .908      | 25,026 | 28,611                |
| 5            | FY83                              |                 | 5,000    | 27,562      | .652               | 3,260 | .883      | 24,337 | 27,597                |
| 6            | FY84                              |                 | 5,000    | 27,562      | .592               | 2,960 | .859      | 23,676 | 26,636                |
| 7            | FY85                              |                 | 5,000    | 27,562      | .538               | 2,690 | .836      | 23,042 | 25,732                |
| 8            | FY86                              |                 | 5,000    | 27,562      | .489               | 2,445 | .813      | 22,408 | 24,853                |
| 9            | FY87                              |                 | 5,000    | 27,562      | .445               | 2,225 | .791      | 21,802 | 24,027                |
| 10           | FY88                              |                 | 5,000    | 27,562      | .405               | 2,025 | .769      | 21,195 | 23,220                |
| Subtotals    |                                   | \$131,000       | \$50,000 | \$275,620   | \$32,235           |       | \$240,809 |        | \$404,044             |
| TOTALS       |                                   | \$131,000       |          |             | \$32,235           |       | \$240,809 |        | \$404,044             |

(NPV) TOTAL LIFE CYCLE COST

\$404,044



## ADDENDUM A2

### SENSITIVITY ANALYSIS

A sensitivity analysis is traditionally divided into two types of analyses: risk analysis and uncertainty analysis. Risk analysis addresses variables which have a known or estimated probability distribution of occurrence. This type of sensitivity analysis is not appropriate for this task. Uncertainty analysis addresses situations where there is insufficient data to determine frequency distributions for the variables involved. This type of analysis is more suited for this task and has been utilized.

The cost of construction outside the building was developed by using the mean cost of the two construction options given; one for soil and one for rock. Fluctuation of this variable to either the estimated cost of soil construction (down) or rock construction (up) will have a small impact (4 percent) on the total life cycle cost.

The cost of energy of each of the systems analyzed was separated from other recurring costs and escalated at differential escalation rates of 0 percent, 7 percent, and 10 percent. Costs for each of these systems is tabulated below at the three escalation rates and the percentage change is given.

TABLE A2-I

#### Life Cycle Cost Sensitivity to Energy Cost Escalation

| Differential<br>Annual<br>Energy<br>Escalation<br>Rate | (a)<br>Direct<br>Seawater<br>Cooling |                                 | (b)<br>Direct Seawater<br>Cooling w/New<br>DX Enhancement |                                 | (c)<br>Direct Seawater<br>Cooling with<br>Existing A/C<br>Enhancement |                                 | (d)<br>Conventional<br>A/C System<br>Existing |                                 |
|--|--------------------------------------|---------------------------------|---|---------------------------------|---|---------------------------------|---|---------------------------------|
|  | %<br>Change                          | Total<br>Life<br>Cycle<br>Costs | %<br>Change   | Total<br>Life<br>Cycle<br>Costs | %<br>Change   | Total<br>Life<br>Cycle<br>Costs | %<br>Change                                   | Total<br>Life<br>Cycle<br>Costs |
| 0%   | 0                                    | \$297,308                       | 0   | \$362,182                       | 0   | \$372,983                       | 0   | \$340,927                       |
| 7%   | 2.7                                  | 305,449                         | 5.1   | 380,498                         | 6.3   | 396,554                         | 18.5  | 404,044                         |
| 10%  | 4.3                                  | 309,939                         | 7.9   | 390,599                         | 9.8   | 409,554                         | 28.7  | 438,855                         |

The seawater systems are relatively insensitive to changes in energy costs; however, the conventional system is extremely sensitive, indicating that it is indeed energy intensive.

**APPENDIX B**  
**ENVIRONMENTAL IMPACT ASSESSMENT**

ENVIRONMENTAL IMPACT ASSESSMENT

PROPOSED SEAWATER AIR CONDITIONING SYSTEM  
FOR THE U.S. NAVY SECURITY FACILITY,  
WINTER HARBOR, MAINE

Prepared by Tracor Marine, Inc. for the Energy Programs Office,  
Civil Engineering Laboratory, NCBC, Port Hueneme, California,  
in accordance with OPNAVINST 6240.3D in compliance with Section  
102(2)(c) of the National Environmental Policy Act of 1969.



Summary of Environmental Impact Assessment

(a) The action is a proposed energy conservation project using direct seawater cooling of buildings on a U.S. Navy site in Corea, Town of Gouldsboro, Maine.

(b) The long-term regional environmental impact is judged to be positive (i.e., beneficial) because the energy saved reduces power plant requirements having considerably more serious impacts. The long-term local environmental impact will take the form of minor adverse disturbance to plankton and fishes, and plant life on land. Short-term temporary local disturbance along the pipeline construction route is unavoidable.

(c) Alternate design options have been specified to reduce adverse environmental and aesthetic factors.

One possible alternative is to abandon the proposed project.

(d) Both the size of the project and the impacts anticipated are small. No significant environmental impact is anticipated. Indications are that instead of being environmentally controversial, the project will receive support from many environmentalists, who view energy conservation as a major environmental objective.

Note: The Environmental Impact Assessment was made for a 3000 gpm system. The system as presently envisioned will be less than 400 gpm.

(e) The following Federal, State, and Local Agencies have been asked to provide comments.

Federal:

U.S. Environmental Protection Agency  
U.S. Army Corps of Engineers

State of Maine:

Department of Environmental Protection  
Bureau of Water Quality Control  
Division of Licensing & Enforcement  
Division of Review and Planning

## 1. Introduction

(a) Project Description: Existing U.S. Navy buildings at the Corea site, Town of Gouldsboro, require a new air conditioning system to cool equipment and buildings on a year-round basis. Earlier ERDA and USN studies have shown that 70 to 80 percent of the electrical energy used for air conditioning can be saved in suitable locations by using natural cold water to air condition buildings directly. The Navy is examining the direct seawater cooling concept as one possible alternative to conventional vapor compression air conditioning at this site.

This project calls for the construction of a prototype seawater cooling system at the Corea site. Intake and discharge pipelines of approximately 12 inch diameter will be run 1300 feet from existing buildings to the shoreline, and the intake pipe run another 1300 feet (approximate) to about 40 foot depth (mean low tide). A pumping station will be constructed within the treeline along the shore. Cold seawater from the bottom of Prospect Harbor will be circulated through a titanium plate or Cu/Ni tube heat exchanger on land, and then discharged back into the bay through a diffuser near the surface. Mechanical filtering will be used to remove planktonic material and UV irradiation to kill bacteria before the seawater is circulated through the air conditioning coils. Plastic pipelines and other non-toxic materials will be used, and the use of toxic



chemicals in the system will be avoided. Preliminary estimates indicate a maximum flow of 3,000 GPM and a maximum increase in temperature of the bottom water before discharge of 15°F.

We believe that the system can be designed to present a minimal adverse impact on the environment with the obvious benefit of somewhat reducing the need for electricity generation and its effects, producing a net positive environmental effect in the region. Although this is a small energy conservation effort, the concept applied elsewhere on a larger scale could have significant future importance.

(b) Existing Environment of the Proposed Site

Surrounding Area: Prospect Harbor and the Corea site lie completely within the Town of Gouldsboro. The town had a population of 1310 in 1970 (U.S. Census), with a growth rate estimated at 1.6% per year.<sup>1</sup> This population is centered mostly in the small villages of Birch Harbor, Corea, Prospect Harbor, West Gouldsboro, South Gouldsboro, and Gouldsboro proper. The area has a rural residential and tourist character and the likelihood of major industrial development and rapid population growth is unlikely.<sup>2</sup> The Town of Winter Harbor abuts to the west and south and lands of the Acadia National Park are located on the Schoodic Peninsula some 2 to 3 miles from the Corea site.

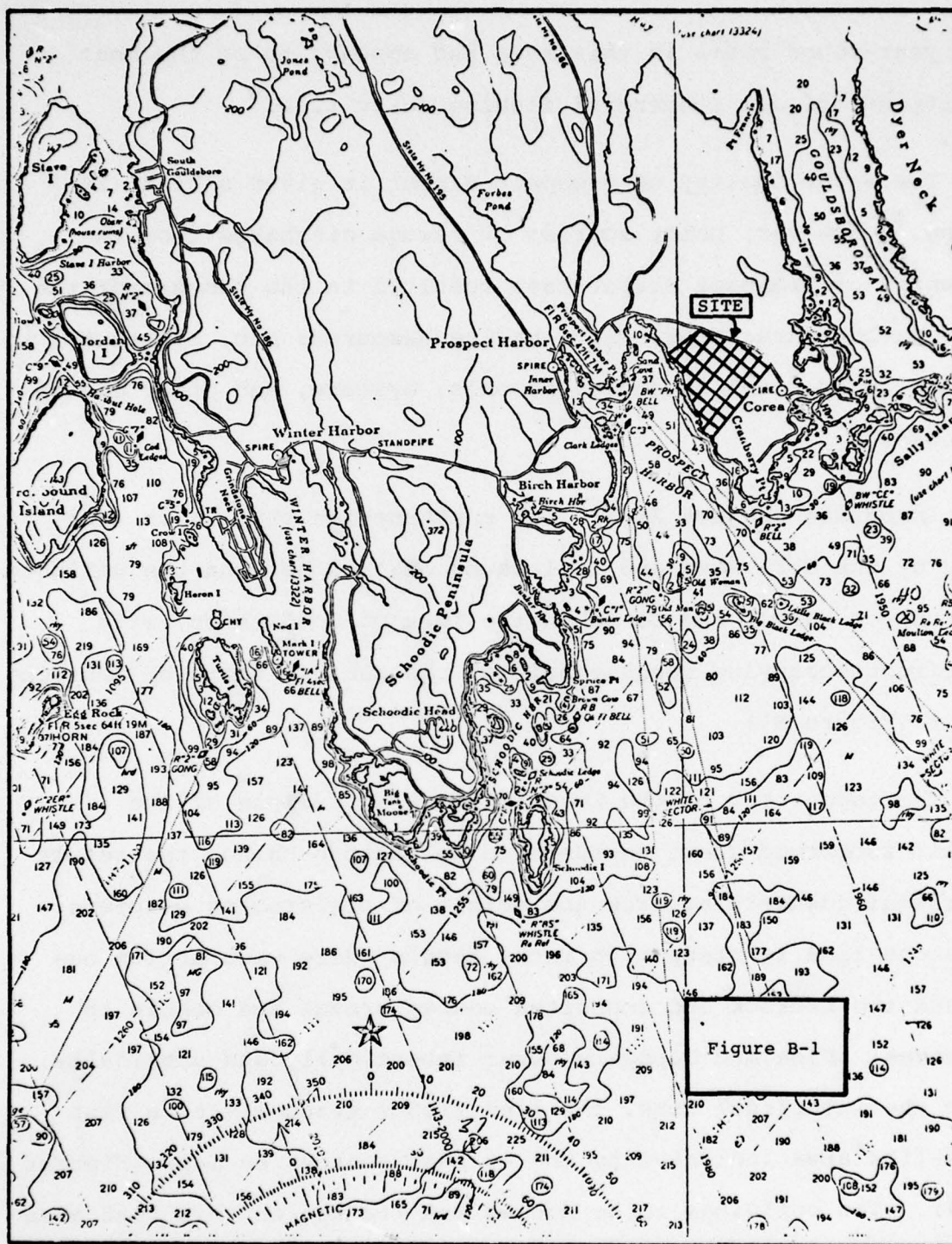
Commercial fishing (lobster, shrimp and scallop) and activities related to commercial fishing (seafood dealer, shipper, canner) are major sources of employment. The Stinson Cannery is located in Prospect Harbor village. Lobster fishing is done

on a year-round basis in this area and appears to be the most significant of all commercial fishing activities.<sup>3</sup>

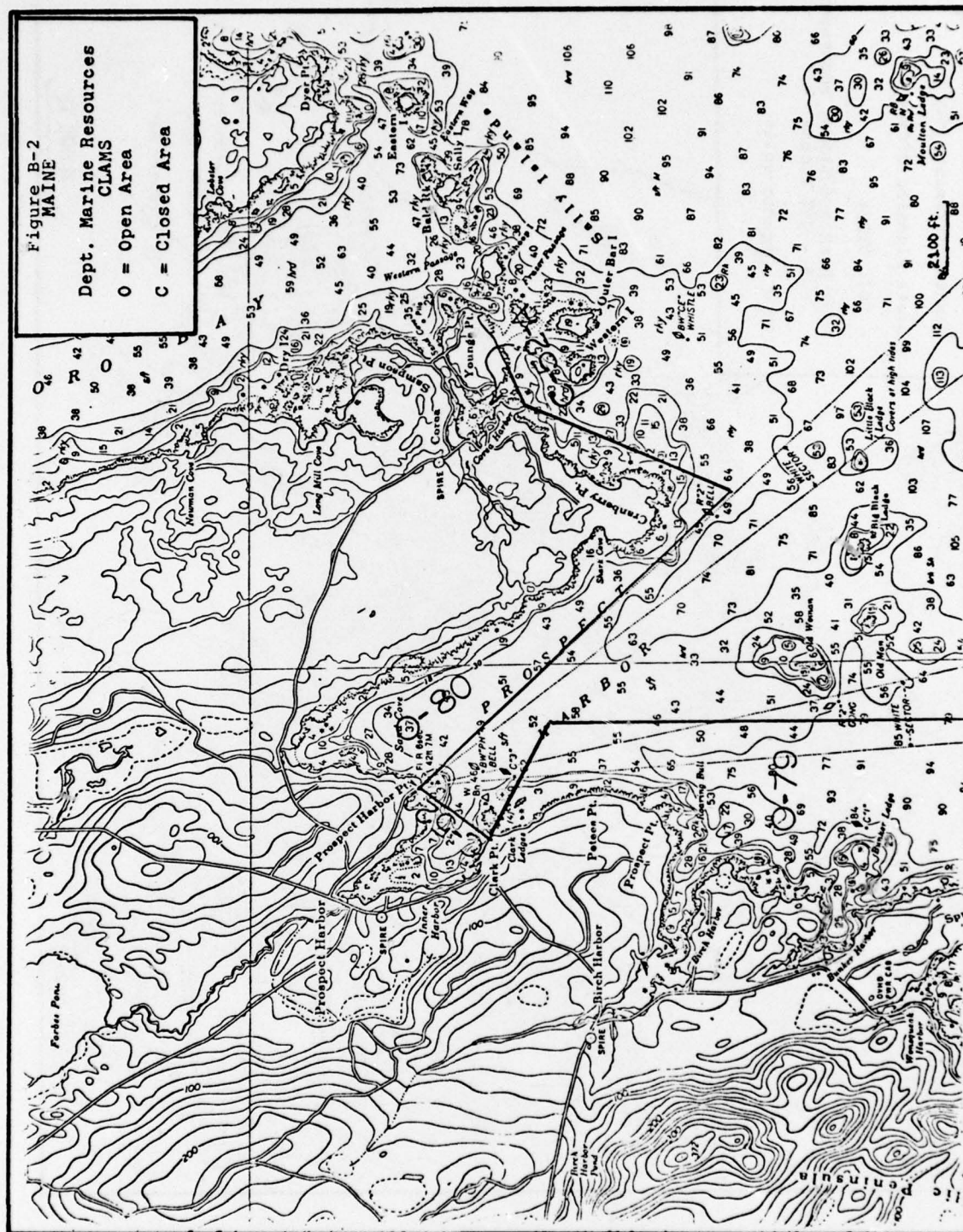
The water quality of Prospect Harbor is given a high (SB<sub>1</sub>) rating.<sup>4</sup> However, point sources of sewage discharge from the community of Prospect Harbor have resulted in the closure of the Inner Harbor (Area C-52, Dept. Marine Resources Map, Figure B2) to the taking of clams, quahogs, mussels, oysters, and other marine mollusks.<sup>5</sup>

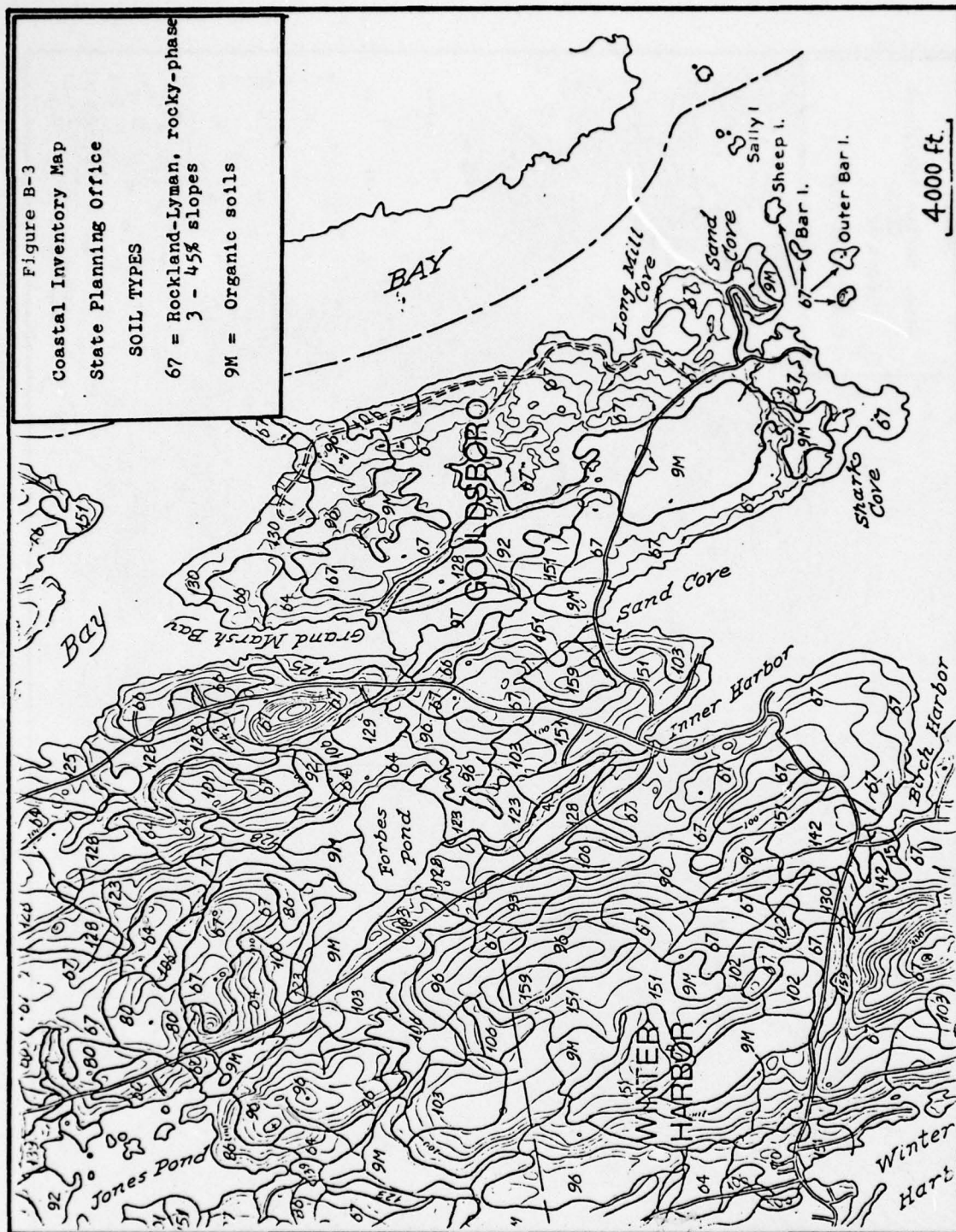
Immediate Project Area: The construction site is on land owned by the U.S. Navy and is located on land between the villages of Prospect Harbor and Corea in the Town of Gouldsboro, with waterfront occupying roughly half of the eastern shore of Prospect Harbor (Figure B1).

The topography of the Corea site is an example of the typical submerged coast encountered in eastern Maine, the result of crustal downwarping from the weight of pleistocene glaciers. The shore line is steep with rocky ledges where wave action has exposed the bedrock and deposited coarse gravel and cobble in the coves. Fine mud deposits occur intertidally and subtidally. Above the intertidal zone, the land slopes gradually to a flat table-like area indicated by the 40 foot contour on maps (Figures B2-B4). The buildings to be cooled are located on this flat area some 1300 feet from the water. There are no docks or other man-made structures along the shore line in the immediate area of the site.

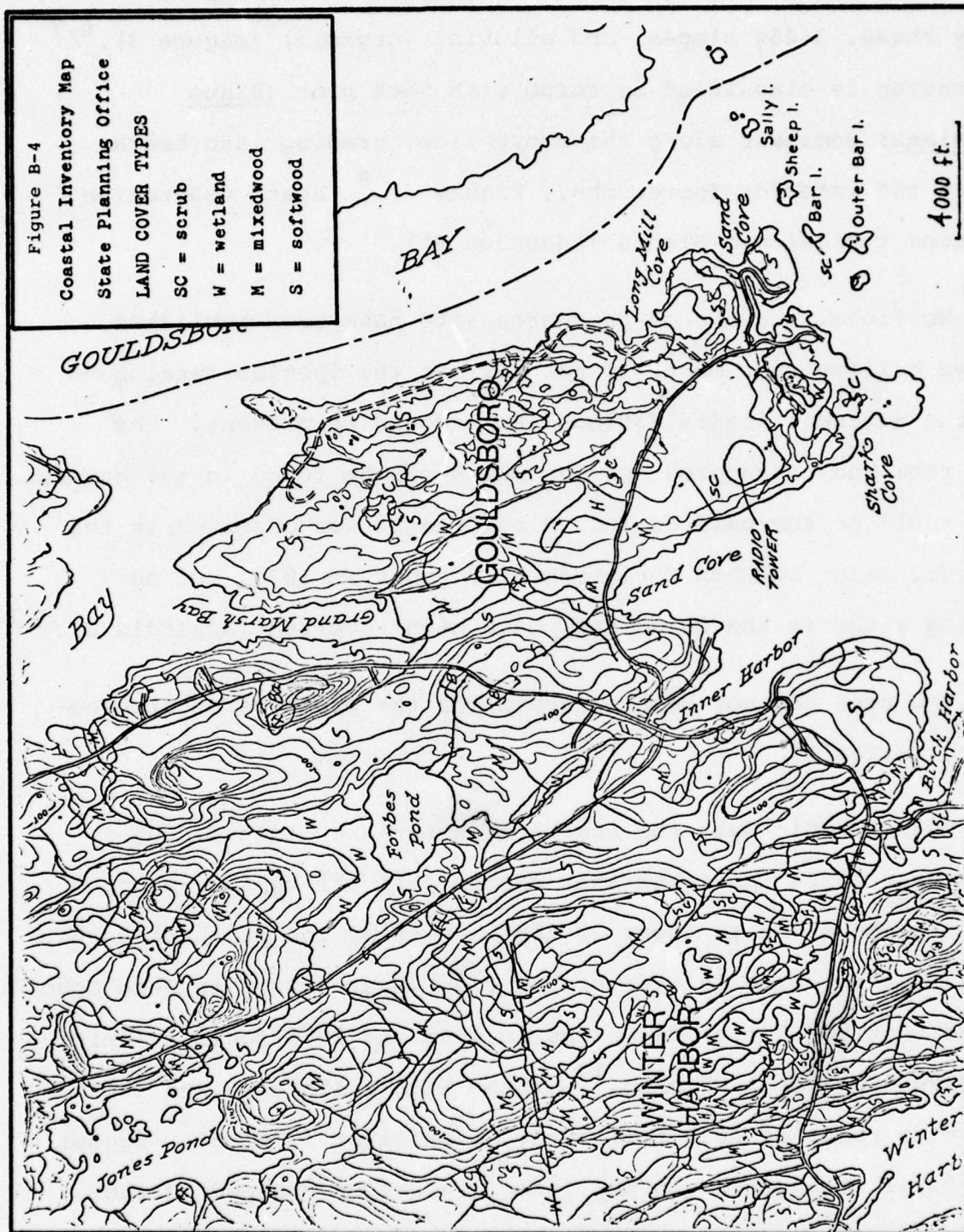














Soils are classified as glacial till (Rockland-Lyman, Rocky Phase, 3-45% slopes) and alluvial (organic) (Figure 3).<sup>6,7</sup> Vegetation is classified as scrub with jack pine (Pinus banksiana) dominant along the shore line, grading into heath toward the interior (pers. obs., Figure 4).<sup>8</sup> Heath vegetation includes typical bog plants (Addendum B1).

No faunal surveys of the Corea site have been published, but we believe that most, if not all, of the species catalogued for the adjacent Acadia National Park would be present. The only rare and endangered species which can be found in the general area would be the bald eagle. A bald eagle was observed in the Schoodic Point Audubon Christmas bird count in 1976, but no nesting sites in the Corea area have been reported (Appendix 2).<sup>9,10</sup>

The area has not been surveyed for the presence of archaeological sites.<sup>11</sup>

Hydrographic data for Prospect Harbor are limited, but NOAA chart 13324 indicates that depths fall off rapidly along the site shoreline to about 30 feet. Most of the Prospect Harbor is 50 feet in depth or greater. A clam (Mya) survey in Sand Cove by the Dept. of Marine Resources in 1966 and 1970 found salinities of 29.90 o/oo to 32.07 o/oo.<sup>12</sup> These high salinities and the mean tide range of 10.5 feet (U.S. Coast Pilot 1, p. 86) suggest good tidal mixing even in the inner reaches of Prospect Harbor.

Although there are no published data on surface and bottom temperatures in Prospect Harbor, work by Speirs, et al. (1975) at Arey Cove (Schoodic Point) some 4 miles distant, recorded surface temperatures of 0-5°C in Jan.-May, and 5-12°C in June-Dec., with a maximum recorded temperature of 13.2°C.<sup>13</sup> The 32 o/oo salinity reported for Arey Cove and the 32.07 o/oo reported by the DMR survey for Sand Cove suggests that both sites are seeing the same well-mixed water and similar temperatures can be expected in Prospect Harbor.

Graham (1970) and others have reported that upwelling is common along the western shores of the Gulf of Maine providing abundant cold bottom water which tends to move into the bays along the coast.<sup>14</sup> Dolan (1972) reports that more than 50% of the waves in this region are greater than 5 feet high.<sup>15</sup> The presence of cobble berms along the mean high tide mark in coves from Cranberry Point to Sand Cove indicate the presence of strong wave action which will contribute to mixing.

2. Relationship of Proposed Action to Land Use Plans, Policies, and Controls for the Affected Area

There are a number of regulations which apply to projects involving construction across the intertidal zone and heated discharge into tidal waters. The Shoreland Zoning Ordinance for the Town of Gouldsboro (As Amended, March, 1975) has established a Resource Protection District inland along the Corea

site, as well as a Shoreland District (lands within 250 feet of normal high tide mark) requiring Planning Board approval of uses projecting over 20 feet into water bodies (Figure B5). The same ordinance prohibits the discharge of heated liquids in those cases where such liquids are "harmful to human, animal, plant, or aquatic life," or harm the receiving waters.

The State of Maine Department of Environmental Protection regulations concerning Site Location of Development (Title 38, M.R.S.A., Sect. 481) requires approval for construction involving the reshaping of earth in excess of 60,000 sq. ft. The Alteration of Coastal Wetlands (Title 38, M.R.S.A., Ch. 12, Sect. 4701) requires approval for any project involving dredging or filling or deposition of septic sewerage. The regulations concerning Protection and Improvement of Waters (Title 38, M.R.S.A., Ch. 13, Sect. 413) require a waste discharge license. Section 582.5 of the same act requires that tidal water thermal discharges not raise monthly mean of daily maximum ambient temperatures more than 4°F, nor more than 1.5°F from June 1 to September 1, and in no case should the receiving waters outside of any mixing zone be raised to a temperature greater than 85°F.

The United States Environmental Protection Agency (EPA), in order to implement the Federal Water Pollution Control Act, as amended, 1972, has published regulations (40 CFR, Parts 401 and



TRACED FROM:

TOWN OF GOULDSBORO  
OFFICIAL SHORELAND ZONING MAP  
march 1, 1975

resource protection district  
SHORELAND DISTRICT

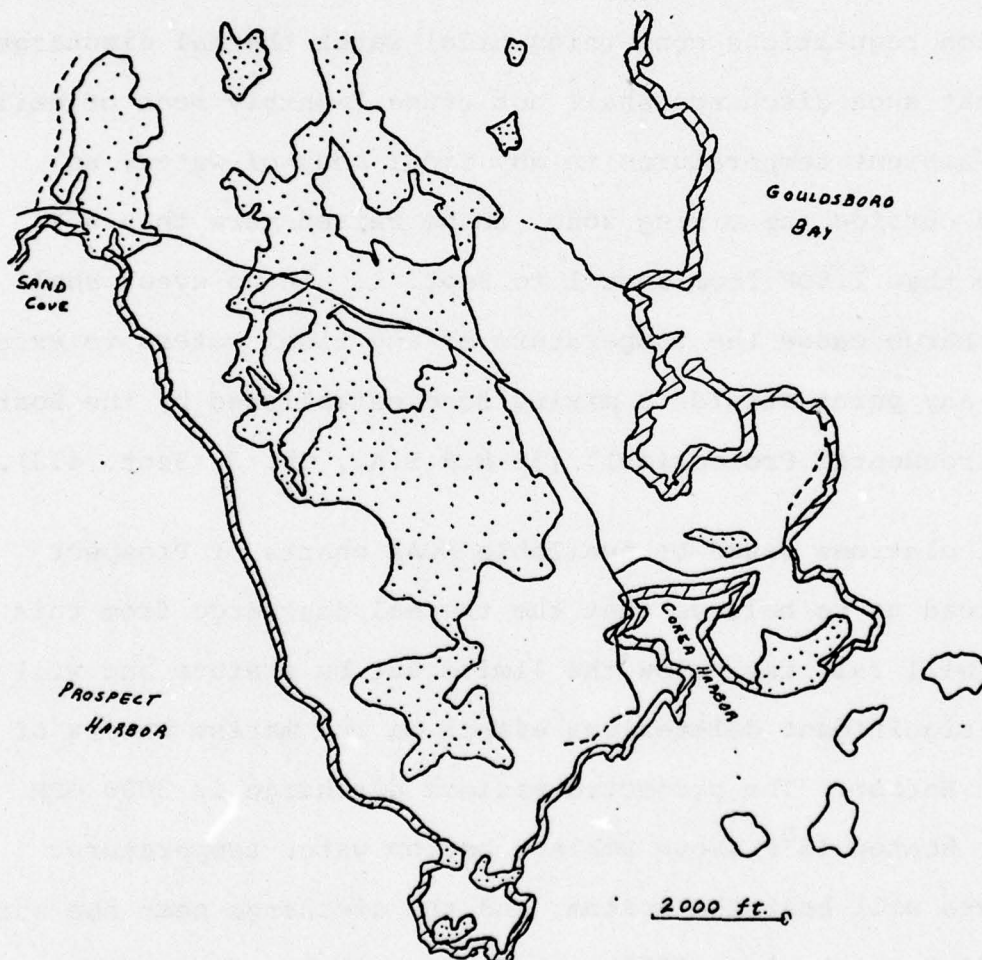


Figure B-5

### 3. Probable Impact of the Proposed Action on the Environment

(a) Direct Effects: Operational Period. The operation of the seawater cooling system should have no effect on the terrestrial biota in the area. Pipelines will be buried and the only permanent new structure will be the pump station. The impact of heated discharge into tidal waters is considered below.

Effects of Temperature: The Department of Environmental Protection regulations concerning tidal water thermal discharge state that such discharge shall not cause "monthly mean of daily maximum ambient temperatures in any tidal body of water, as measured outside the mixing zone, to be raised more than 4°F, nor more than 1.5°F from June 1 to Sept. 1. In no event shall any discharge cause the temperature of any tidal waters to exceed 85°F at any point outside a mixing zone established by the Board (of Environmental Protection)" (38 M.R.S.A., Ch. 3, Sect. 413).

Calculations based on available NOAA charts of Prospect Harbor lead us to believe that the thermal discharge from this project will fall far below the limits set by statute and will have no significant deleterious effect on the marine waters of Prospect Harbor. The projected maximum discharge is 3000 GPM of water heated 15°F above ambient bottom water temperature. The intake will heat the bottom, and the discharge near the surface. Speirs, et al., (1975) reported maximum summer surface temperatures of 55.8°F in Arey Cove, 4 miles from Prospect Harbor.

402) governing cooling water intake structures. These regulations state, "...the location, design construction and capacity of a cooling water intake structure of a point source subject to standards established under the provisions of section 306... reflect the best technology available for minimizing the adverse environmental impact." The factors set forth in the document entitled "Development Document for Proposed Best Technology Available for Minimizing Adverse Environmental Impact of Cooling Water Intake Structures" shall be used to determine the "best available technology".

The Federal Water Pollution Control act, as amended, authorizes any State to apply and enforce standards of performance relating to the discharge of heated effluents (FWPCA, Sect. 306 (2,c)). The Corps of Engineers requires a permit for construction in navigable waters (Rivers and Harbors Refuse Act of 1899, section 10) and a discharge permit (FWPCA of 1972, as amended, section 404).

Historic and archaeological sites are protected in accordance with procedures established by the Advisory Council on Historic Preservation (36 CFR, part 800) under the National Historic Preservation Act of 1966.

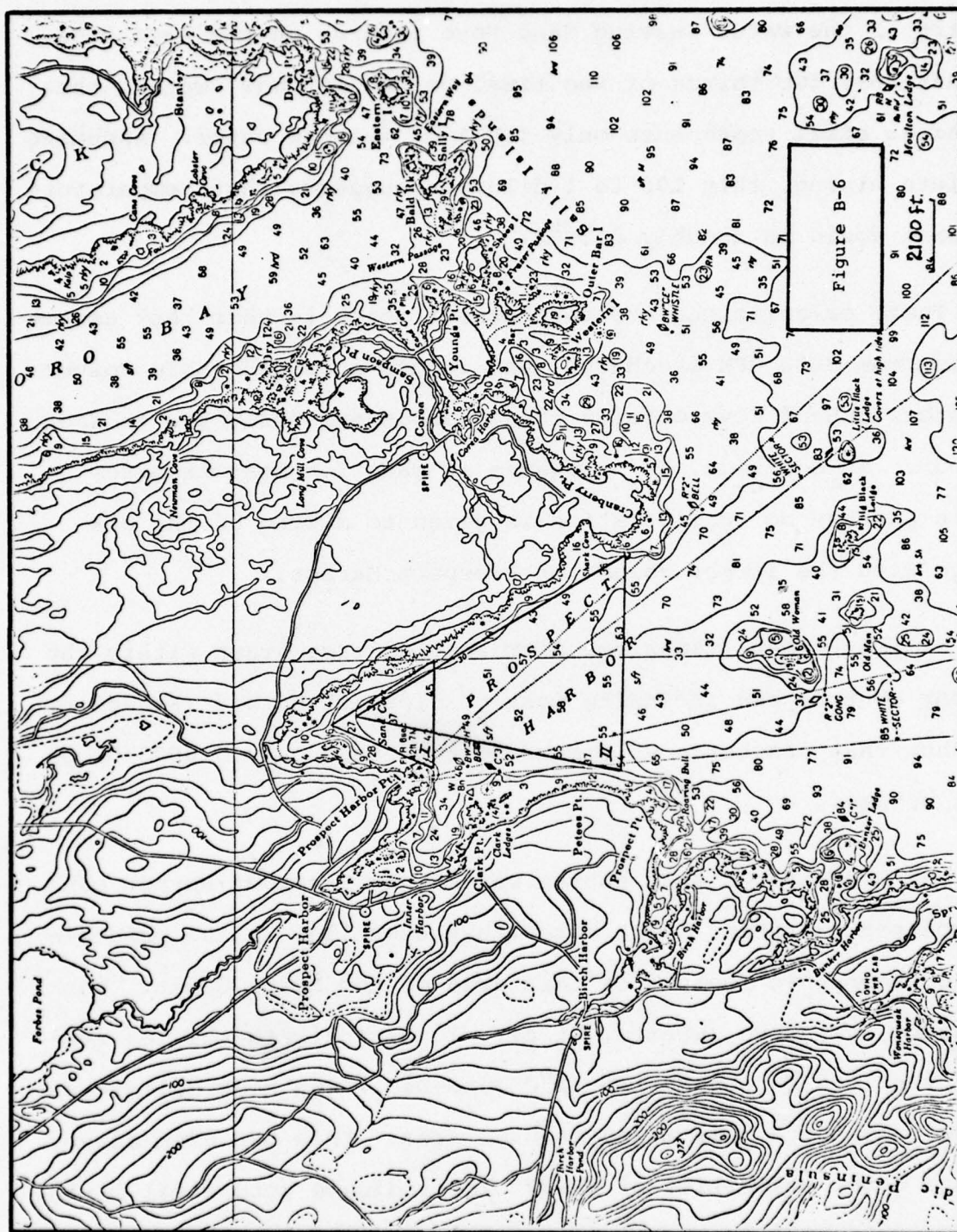
Section 7 of the Rare and Endangered Species Act establishes compliance procedures with the United States Fish and Wildlife Service.



Assuming that Prospect Harbor sees the same maximum temperature, the maximum expected discharge temperature would be less than 70°F. Discharge water will be mechanically diffused before entering the Bay.

Discharge water can be expected to mix in the Sand Cove - Prospect Harbor area. With a mean tidal range of 10.5 feet, it can be shown that the volume of heated water discharged is small compared to the volume of water entering and leaving the area on each tidal cycle, and that any heat addition to the harbor would be insignificant.

Taking the most disadvantageous assumption that the heated discharge would be confined to Sand Cove, a triangular area drawn within the confines of the 18 foot mean low tide contour (Figure B6) would contain a minimum low tide volume (assuming all water within the triangle to be only 18 feet deep) of  $5.9 \times 10^8$  gal. The same area would contain  $9.34 \times 10^8$  gal with a 10.5 foot high tide. The volume of water entering on a high tide would be the difference between these two volumes or  $3.44 \times 10^8$  gal. In the 12 hours during which one high tide volume enters and leaves Sand Cove,  $2.16 \times 10^6$  gal of heated water would be discharged. The discharge would equal 0.63% of the water entering on a tide (Calculations: Addendum B3).



The flushing rate of Sand Cove is unknown. Assuming that a third of the water leaving Sand Cove returns on the next tide, so that only two thirds of the tidal volume is "new" water, the discharge still represents only 0.95% of the new water. Assuming complete mixing, this 100 to 1 dilution suggests that temperature increase would be roughly  $0.15^{\circ}\text{F}$ .

These calculations are very conservative in that they assume the maximum 3000 GPM discharge, and ignore a considerable volume of water in Sand Cove outside the triangle and below the 18 foot contour. In addition, no allowance is made for heat transfer to the air and no consideration is given to mixing of the discharge with the larger volume of Prospect Harbor.

Similar calculations for a triangular area drawn within the 30 foot contour and including most of Prospect Harbor (Figure 6, II) show that discharge volume would represent only 0.000015% of tidal volume.

The movement of cold bottom water into Prospect Harbor can be expected. Graham (1970) notes that upwelling is the predominant hydrographic feature of this area of the Maine Coast. Work at nearby Arey Cove (Speirs, et al., 1975) indicate the low temperatures ( $0-5^{\circ}\text{C}$  Jan.-May;  $5-12^{\circ}\text{C}$  June-Dec.) and high salinities (31-33 o/oo) of a well-mixed coastal area. In a DMR clam survey in Sand Cove, salinities of 29-32 o/oo indicate good tidal mixing (DMR Survey, 1970). These observations suggest that there would



be no significant local heating of the Sand Cove - Prospect Harbor area.

Other Biological Effects: The amount of planktonic organisms removed by filters should be insignificant due to the small volume of water passing through the system compared to the tidal exchange in the harbor (see Temperature Effects). The same will be true from bacteria removed by UV irradiation. Entrapment of fish on the intake structure should also be minimal since intake design will utilize best available technology within EPA guidelines to protect the marine biota.

The use of plastic piping and titanium heat exchangers will essentially eliminate the release of metals and no anti-fouling chemicals will be released. If Cu/Ni heat exchangers are found to be necessary, a very small amount of copper will be released over a very long period of time. The amount of copper released will be diluted to the extent that the additional copper in the vicinity of the discharge will not be harmful to biota. Marine organisms will have free passage around the pipes in the Bay.

Effects on Local Fishing Activities: The pipes, inlet and outlet structures will be designed and located so as not to interfere with navigation. According to local residents, dragging operations are not routinely conducted in Prospect Harbor proper, and inconvenience to local draggers would be minimal. Lobstering, which is the major fishery in the area and is conducted year round, would not be affected by the pipe and structures since traps can be laid quite close with no danger to gear. Use of a diffuser will

minimize localized heating in the area of the discharge. Heated water tends to rise to the surface, minimizing any effect on benthic organisms.

Construction Period: The scope of the project is quite limited. Employment of local contractors for construction will be a benefit to an area reporting considerable unemployment.<sup>16</sup> The site surrounding the shoreside pipeline is already disturbed due to previous construction of existing facilities. Some trees will have to be cleared and trenching and blasting will occur. The intertidal zone is gravel and cobble beach which is highly unstable. The intertidal flora and fauna in this area is correspondingly poor. Subtidally, some trenching and blasting will probably occur. The area directly affected by these activities will be quite small. Disturbance of the area will be temporary.

(b) Secondary (Indirect) Consequences for the Environment: This is a small project which involves laying two pipelines and constructing a pumphouse to provide no more than 3000 GPM flow. The period of construction will be less than 6 months.

Construction will be done by local contractors and will not involve an influx of construction personnel from outside the area. This project will not have a direct effect on the physical size or population of the Naval facility; its operation will be neither increased nor decreased by the addition of this pilot cooling system. Therefore, we anticipate no additional demands on the surrounding communities for public services, nor will there be

any significant impact on the existing patterns of social and economic activities.

#### 4. Alternatives

A decision not to proceed with this project and to continue to use conventional air conditioning will involve the continued use of electricity for this purpose with the environmental consequences of generating that power. Decisions not to proceed with innovative projects such as this one preclude options for power conservation which may be important in the near future.

#### 5. Any Probable Adverse Environmental Effects Which Cannot Be Avoided Should Proposal Be Implemented

The seawater cooling system, while in operation, will result in the unavoidable loss of a number of plankton and possibly some finfishes due to entrainment or entrapment. The discharge of heated water might have an influence on plankton and finfishes in the mixing zone, even with discharge temperatures close to ambient. We feel that although unavoidable, these losses will not be significant because of the relatively small volume of water passing through the system compared to the tidal exchange in the harbor.

An attempt will be made to mitigate the effects of construction, which involves trenching the soil, blasting bedrock, and clearing trees, in the following ways.



It may be possible to lay a section of the pipeline (approx. 1000 feet) in an existing cleared and filled path. Also, to reduce the amount of blasting, part of the pipeline may be placed on the bedrock and covered with fill. A means of avoiding or reducing subtidal blasting, and subsequent disruption of subtidal habitat and biota, is desirable. The subtidal section of pipe may be of high density polyethylene anchored with concrete blocks if this method provides to be sufficient to protect the pipeline from wave action. If the seawater cooling system proves to be feasible, the anticipated reduction in consumption of electric power and the environmental effect of that power generation would more than offset the minimal, anticipated adverse effects.

6. Relationship Between Local Short-Term Use of Man's Environment and Maintenance and Enhancement of Long-Term Productivity

The construction phase of this project will involve the temporary disruption of a limited area. The operation of the system will involve a low-level loss of some planktonic organisms. This loss is expected to be insignificant due to the small volume of water pumped compared to the daily tidal volume. For this reason, the long-term productivity of the area in terms of fisheries activity will not be adversely affected.

The only new above-ground structure will be a pumphouse located within a screen of trees at the shoreline. The facility

will, therefore, not detract from the scenic quality of the shoreline.

The water quality classification will not be lowered by operation of the system and the water use and land use options in the area will not be affected.

7. Any Irreversible and Irretrievable Commitments of Resources That Would Be Involved in the Proposed Action if Implemented

There appears to be no irreversible curtailment of the range of potential uses of the environment in the project area.

8. Considerations That Offset Adverse Environmental Effects

We believe that any adverse environmental effects are minimal and temporary, and mostly related to the construction phase. These effects will be offset by the potential future energy savings which can be effected if this prototype cooling system proves feasible for general use.

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8. Maine Coastal Inventory Map No. 4-3; Land Cover Types. Maine State Planning Office, 1972.
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ADDENDUM B1

Bogs are best developed and most abundant in cold northern forested regions such as those of the Schoodic - Gouldsboro area.

BOG PLANTS: (Sharpe, G.W., 1968), (Deevey, 1958), (Johnston, G.S., unpublished)

|               |                                     |
|---------------|-------------------------------------|
| cranberry     | - ( <u>Vaccinium</u> sp.)           |
| leather leaf  | - ( <u>Chamaedaphne</u> sp.)        |
| labrador tea  | - ( <u>Ledum</u> sp.)               |
| bog rosemary  | - ( <u>Andromeda glaucophylla</u> ) |
| sweet gale    | - ( <u>Myrica gale</u> )            |
| bog aster     | - ( <u>Aster nemoralis</u> )        |
| cotton grass  | - ( <u>Eriophorum</u> sp.)          |
| pitcher plant | - ( <u>Sarracenia purpurea</u> )    |
| sundew        | - ( <u>Drosera</u> sp.)             |
| tamarack      | - ( <u>Larix</u> sp.)               |
| black spruce  | - ( <u>Picea mariana</u> )          |
| sphagnum moss | - ( <u>Sphagnum</u> )               |

ADDENDUM B2

76th Audubon Christmas Bird Count\* 139. Schoodic Point, Me. 44 25°N 68 06'W, center South Gouldsboro at jct Rte 186 and Summer Harbor Rd.; area and habitat coverage as described 1972.-- Jan. 28; 7 a.m. to 4 p.m. Clear, Temp. 19° to 28° F. Wind NW, 5 m.p.h. Snow cover 0 to 2 in. Fresh water frozen. Salt water open. Wild food crop poor. Four observers in two parties. Total party-hours, 15 (1 on foot, 14 by car); total party-miles, 161 (2 on foot, 159 by car).

Com. Loon 46; Red-throated Loon 6; Red-necked Grebe 4; Horned Grebe 121; Great Cormorant 12; Great Blue Heron 1; Mallard 1; Black Duck 227; Greater Scaup 14; Com. Goldeneye 417; Bufflehead 150; Oldsquaw 627; Harlequin Duck 1; Com. Eider 3150; White-winged Scoter 480; Surf Scoter 6; Red-breasted Merganser 68; Bald Eagle 2 (1a, 1i); Purple Sandpiper 46; Iceland Gull 1; Great Black-backed Gull 28; Herring Gull 838; Ringbilled Gull 2; Black Buillemot 12; Rock Dove 45; Mourning Dove 7; Short-eared Owl 1; Belted Kingfisher 1; Pileated Woodpecker 1; Hairy Woodpecker 3; Downy Woodpecker 4; Blue Jay 47; Com. Raven 9; Com. Crow 6; Black-capped Chickadee 105; Boreal Chickadee 4; White-breasted Nuthatch 1; Red-breasted Nuthatch 8; Brown Creeper 2; Am. Robin 3; Golden-crowned Kinglet 3; N. Shrike 1; Starling 57; House Sparrow 4; Red-winged Blackbird 2; Com. Crackle 11; Brown-headed Cowbird 101; Evening Grosbeak 17; Pine Grosbeak 11; Pine Siskin 3; Am. Goldfinch 25; Tree Sparrow 26; White-throated Sparrow 3.

Total, 53 species; about 6826 individuals. (In count area count week but not seen count day: Fox Sparrow.)--Connee Jellison, Helen and William Townsend (compiler--Sorrento ME 94677), Peter Vickery. (SC-1.5).

ADDENDUM B3

Calculations: Tidal Volume.

Triangle I (Figure 6) - Sand Cove

$$\text{Area} = 4380135 \text{ ft.}^2$$

$$\text{Volume (18' at low tide)} = 78842430 \text{ ft.}^3$$

$$= 5.90 \times 10^8 \text{ gal.}^*$$

$$\text{Volume (28.5' at high tide)} = 9.34 \times 10^8 \text{ gal.}$$

$$\text{Tidal Volume (High - Low)} = 3.44 \times 10^8 \text{ gal.}$$

$$\text{Discharge Volume (12 hr., 3000 gpm)} = 2.16 \times 10^6 \text{ gal.}$$

$$\text{Discharge as \% Tidal Volume} = \frac{2.16 \times 10^6 \text{ gal.}}{3.44 \times 10^8 \text{ gal.}} = 0.63\%$$

Triangle II (Figure 6) - Prospect Harbor

$$\text{Area} = 1.84 \times 10^{11} \text{ ft.}^2$$

$$\text{Volume (30' at low tide)} = 5.52 \times 10^{12} \text{ ft.}^3$$

$$= 4.13 \times 10^{13} \text{ gal.}$$

$$\text{Volume (40.5' at high tide)} = 5.57 \times 10^{13} \text{ gal.}$$

$$\text{Tidal Volume (High - Low)} = 1.44 \times 10^{13} \text{ gal.}$$

$$\text{Discharge Volume (12 hr., 3000 gpm)} = 2.16 \times 10^6 \text{ gal.}$$

$$\text{Discharge as \% Tidal Volume} = \frac{2.16 \times 10^6 \text{ gal.}}{1.44 \times 10^{13} \text{ gal.}} = .000015\%$$

\*Volume Conversion: 1 gal. = .13368 ft.<sup>3</sup>

or 7.48 gal/ft.<sup>3</sup>

Tide Range: 10.5' mean.

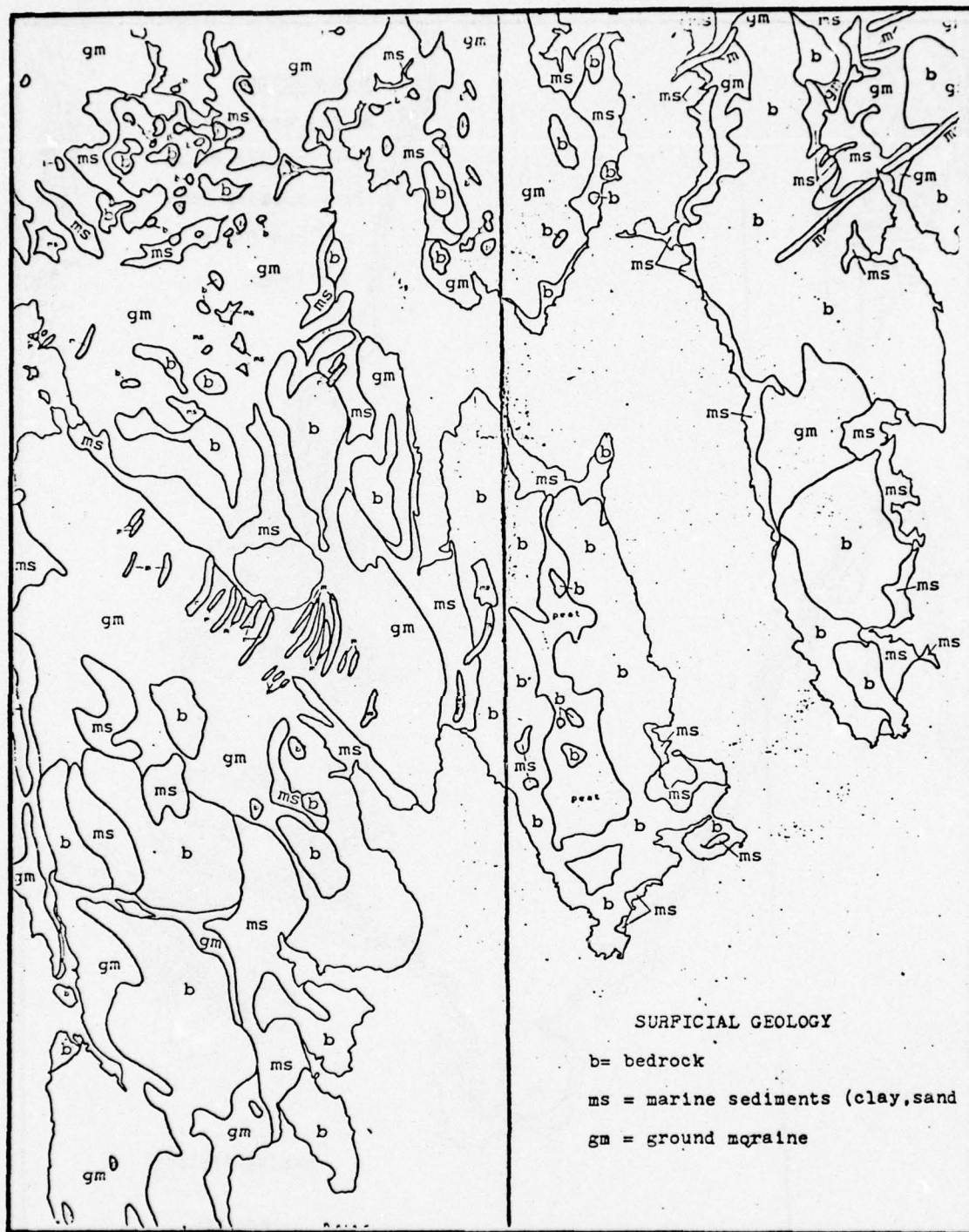
Map Scale (Figure 6): 1 cm = 1316 ft.

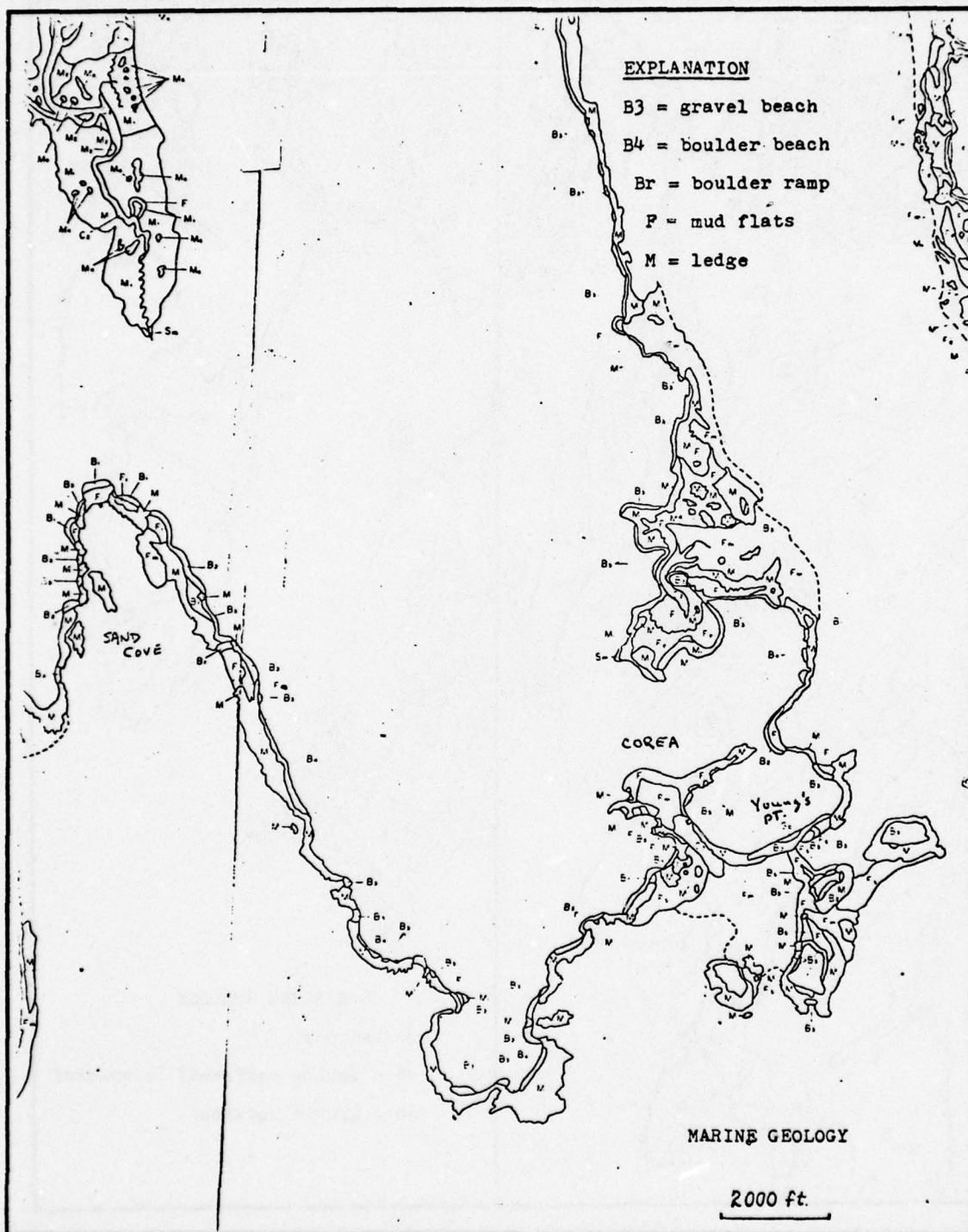


ADDENDUM B4

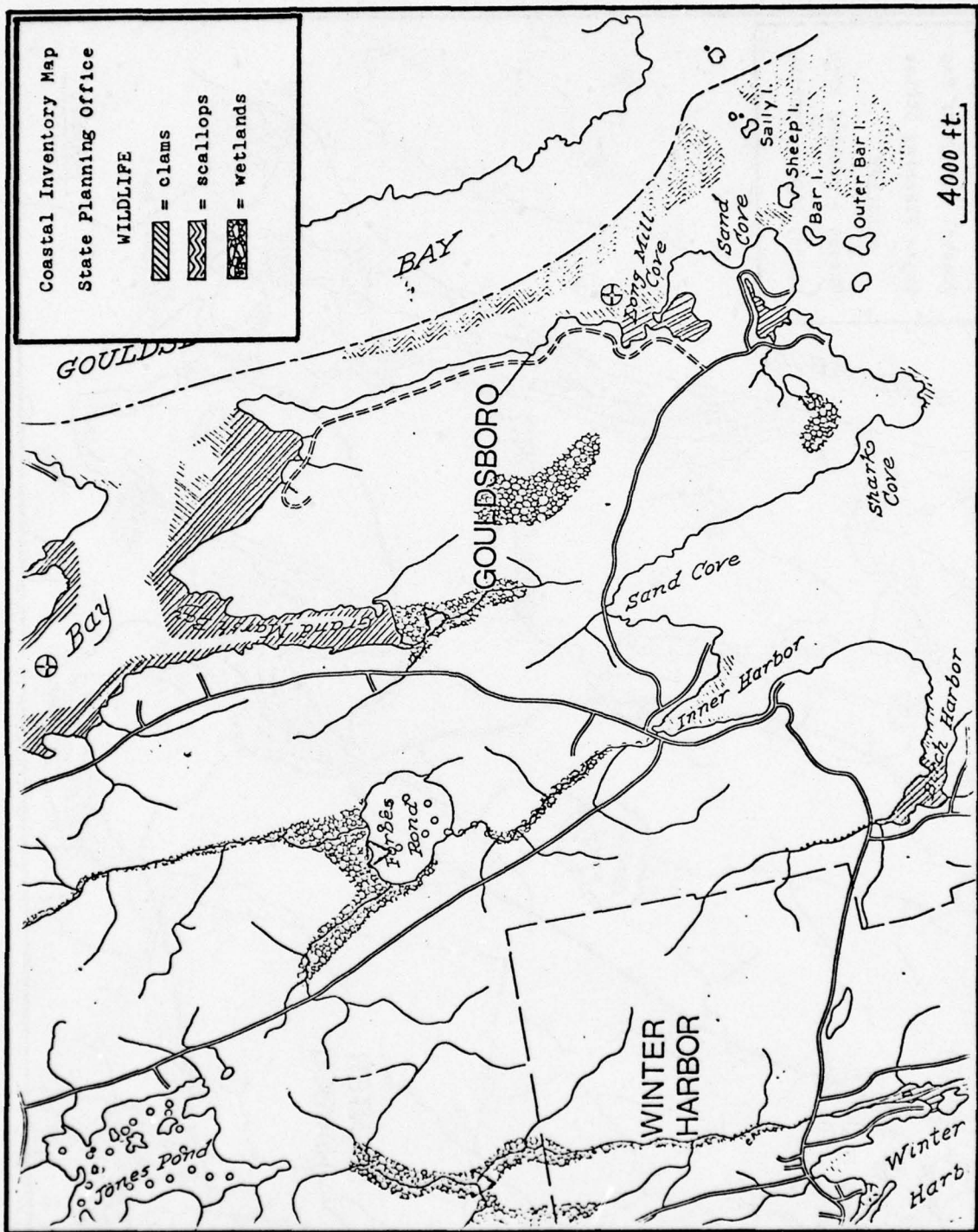
MAPS

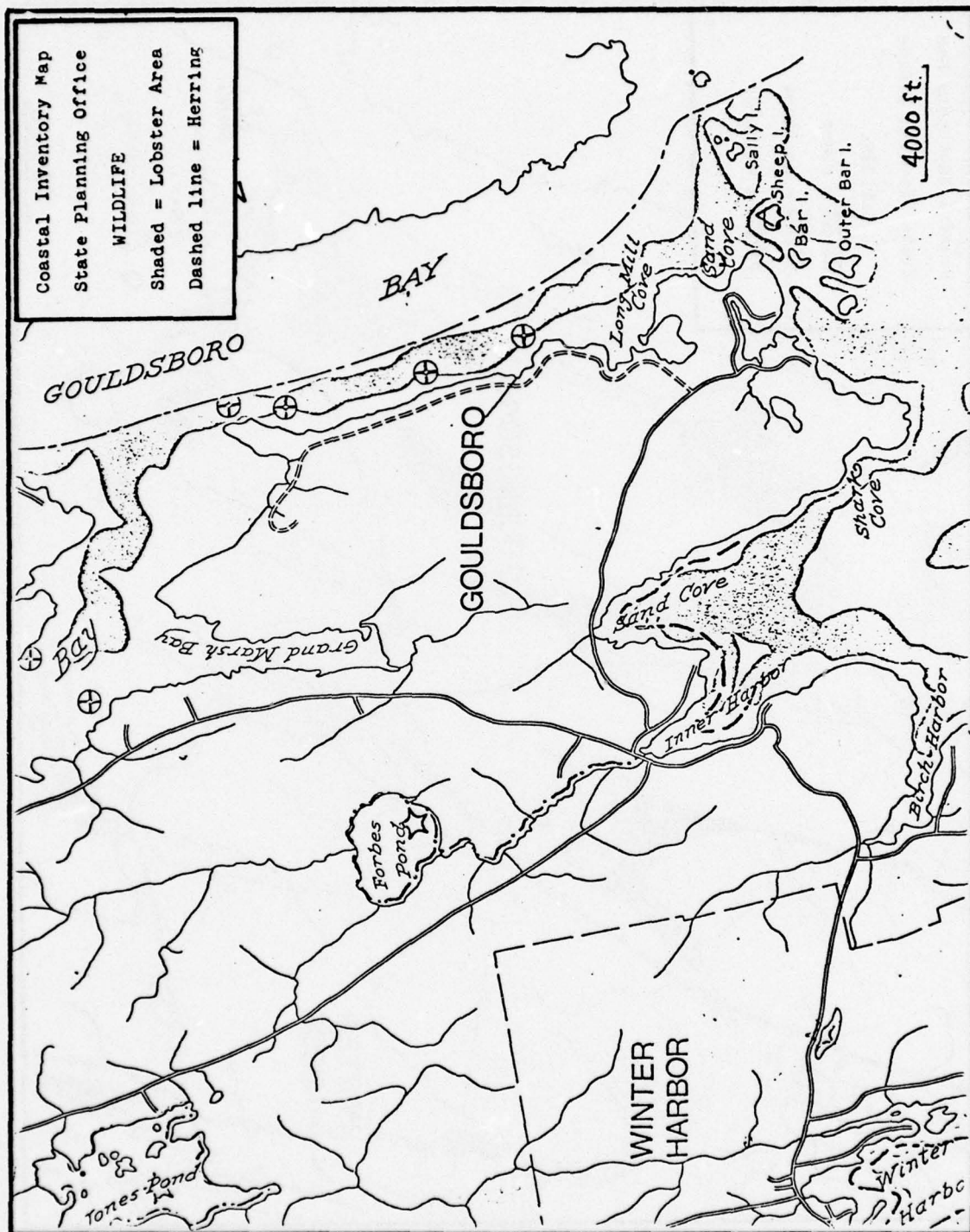
- B4-I        Surficial Geology
- B4-II       Marine Geology
- B4-III      Coastal Inventory Map - Clams, Scallops,  
Wetlands
- B4-IV       Coastal Inventory Map - Lobster Area, Herring











ADDENDUM B5

U.S. ENVIRONMENTAL PROTECTION AGENCY

COOLING WATER INTAKE STRUCTURE



THURSDAY, DECEMBER 13, 1973  
WASHINGTON, D.C.

Volume 38 ■ Number 239

PART II



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# ENVIRONMENTAL PROTECTION AGENCY

## COOLING WATER INTAKE STRUCTURES

Proposal Regarding Minimizing Adverse  
Environmental Impact

# ENVIRONMENTAL PROTECTION AGENCY

[ 40 CFR Parts 401, 402 ]

## COOLING WATER INTAKE STRUCTURES

### Proposal Regarding Minimizing Adverse Environmental Impact

Notice is hereby given of proposal of the regulations set forth below concerning determinations required to insure that the location, design, construction, and capacity of cooling water intake structures reflect the best technology available for minimizing adverse environmental impact. The regulations are intended to implement section 316(b) of the Federal Water Pollution Control Act, as amended (33 U.S.C. 1251, 1326; Pub. L. 92-500; 86 Stat. 816 et seq.) (the act).

Section 316(b) of the Act requires that any standard established pursuant to section 301 or section 306 of this Act and applicable to a point source shall require that the location, design, construction, and capacity of cooling water intake structures reflect the best technology available for minimizing adverse environmental impact. The Environmental Protection Agency (EPA) will be publishing a series of regulations establishing effluent limitations guidelines for existing sources and standards of performance for new sources pursuant to sections 301, 304(b), and 306 of the Act. These regulations will be set forth under Parts 401 et seq. of Title 40 CFR.

The regulations set forth below in tentative form provide for an amendment to 40 CFR Part 401 (General Provisions concerning effluent limitations guidelines and standards of performance) and the establishment of a new Part 402, 40 CFR. The General Provisions set forth in Part 401 were published in proposed form on August 22, 1973 (38 FR 22606, 22608). The regulations below amend Part 401 as proposed to add section 316(b) to the catalogue of applicable legal authorities set forth under 40 CFR 401.12. In addition, new § 401.14 below provides that the location, design, construction, and capacity of cooling water intake structures for any point source for which a standard is established pursuant to section 301 or 306 shall reflect the best technology available for minimizing adverse environmental impact in accordance with the provisions of 40 CFR Part 402.

New Part 402 as proposed is intended to provide a framework for the case-by-case determination of the best technology available for minimizing adverse environmental impact resulting from the location, design, construction and operation of cooling water intake structures. The provisions of Part 402 do not set forth mandatory design and operational requirements since the factors to be considered would lead to highly site-specific determinations of the best technology available for minimizing adverse environmental impact. However, when considering cooling water intake requirements in connection with application for NPDES permits pursuant to section 402

of the Act, the factors set forth in Part 402 must be examined in order to establish requirements for minimizing adverse environmental impact. The regulations of Part 402 are therefore intended to serve as an outline of the factors to be considered, and the data required, in order to arrive at an environmentally sound decision concerning cooling water intake structure, location, design, construction, and operation.

The Part 402 regulations were developed in the course of studies undertaken in support of effluent limitations guidelines and standards of performance for the steam electric power generating industry. Water withdrawal for cooling by all industrial point sources now amounts to approximately 70 trillion gallons per year. Steam electric powerplants withdraw approximately 80 percent of this, or 60 trillion gallons per year, which is roughly 15 percent of the total flow of waters in U.S. rivers and streams. The intake flow for a typical steam electric powerplant is 40 billion gallons per year.

The intake flow for typical petroleum refineries, primary metals manufacturing plants, chemical manufacturing plants, and pulp and paper mills are about one-tenth the intake flow of typical steam electric powerplants. Flows from large rubber, wood, food, stone, clay and glass products manufactures are typically about one-hundredth the flow of powerplants. Cooling water intake flows for textile mills and leather manufacturers are typically about one-thousandth the flow of powerplants. However, the maximum cooling water volumes for specific establishments will be dependent on factors such as products, processes employed, size of plant, degree of recirculation employed in the cooling water system, etc.

Adverse environmental impacts that could occur from cooling water intakes relate to the net damage or destruction of benthos, plankton and neuston organisms by external interaction with the intake structure and by internal interaction with the industrial cooling system. Important aspects of the intake which relate to adverse environmental impacts are the intake volume, the number and types of organisms which interact externally with the intake or which interact internally with the industrial cooling system, the configuration and operational characteristics of the intake and plant cooling system, the thermal characteristics of the cooling system, and the chemicals added to the cooling system for biological control.

(a) *Applicable technology.* The range of technologies corresponding to the control of the number and types of organisms which interact externally with the intake is comprised of two factors—the choice of the location of the intake relative to the location of the organisms, and the full array of process modifications including the use of recirculating cooling water systems employing off-stream means to transfer process heat directly to the atmosphere and to minimize or in some cases eliminate the use of cooling water. The technology for con-

trolling the number and types of organisms which interact internally with the cooling system is comprised of one factor in addition to location and flow volume controls as cited above for intake interactions, i.e., the degree to which the configuration and operation of the intake means prevents the entry of these organisms into the cooling system. The technology for preventing the entry of these organisms while minimizing damage due to external interactions with the organisms is diverse, including a multiplicity of physical and behavior barriers and covering various fish bypass and removal systems.

Devices which cause damage due to internal interactions with process cooling systems relate to the design and operation of these systems with respect to mechanical, thermal, and chemical characteristics. For example, the presence of a cooling tower in a nonrecirculating cooling system could affect the amount of organism damage due to the pumping, temperature changes, and possible chemical additives employed with the tower.

A document entitled "Development Document for Proposed Best Technology Available for Minimizing Adverse Environmental Impact of Cooling Water Intake Structures" further details the analysis undertaken in support of the regulations being proposed below. The draft contractor's report on the steam electric power industry circulated for comments in early July, 1973, contained the cooling water intake structures technology considered in the EPA document cited above.

A copy of the "Development Document" is available for inspection at the EPA Information Center, Room 227, West Tower, Waterside Mall, 4th & M Street, S.W., Washington, D.C., at all EPA regional offices, and at State water pollution offices. Copies of the document are being sent to persons or institutions affected by the proposed regulations, or who have placed themselves on a mailing list for this purpose (see EPA's Advance Notice of Public Review Procedures, 38 FR 21202, August 6, 1973). In this regard, all persons who have requested the Development Documents for "Steam Electric Power Plants," "Iron and Steel Manufacturing" or "Ferroalloy Manufacturing" will also receive a copy of the "Cooling Water Intake Structures" Development Document. An additional limited number of copies of the report are available. Persons wishing to obtain a copy may write the EPA Information Center, Environmental Protection Agency, Washington, D.C. 20460, Attention: Mr. Phillip B. Wisman.

(b) *Costs.* The Development Document contains information concerning the performance and costs of various technologies for minimizing environmental damage from cooling water intake structures for steam electric power plants. The analysis indicates that in general the costs associated with the choice of intake location or application of various intake devices to minimize damage due to internal interactions will



have a small economic impact on steam electric power plants.

The Agency expects the same measures necessary to minimize adverse environmental impacts from steam electric power plant cooling water intakes will be applicable to other industries utilizing cooling water in their manufacturing processes. Since the steam electric power industry utilizes the greatest volume of cooling water, the total cost which will result from applying the best technology available for cooling water intake structures will clearly be greatest in that industry. Although the Agency possesses some data with respect to the cost of the application of the cooling water intake requirements to other industries, the Agency recognizes that the Development Document for cooling water intakes was prepared with specific reference to the steam electric power industry. Therefore, the Agency requests comments, and if possible additional data, concerning the cost and economic impact of the application of the measures listed in the Development Document to industries other than the steam electric power industry. These comments should be directed toward the costs and impacts of biological studies required for assessing environmental damages as well as the costs and impacts of remedial measures. Comments which provide such additional information as to costs should include a detailed explanation of the methodology used to derive the cost estimates. Additional issues about which the Agency seeks specific comments are: The question of whether, and how, a distinction should be drawn between existing and new cooling water intake structures and the question of whether, and how, a distinction should be drawn between large and small volume cooling water intake structures.

(c) *Summary of public participation.* Prior to this publication, the agencies and groups listed below were consulted with respect to the development of the regulations below. (Members of this group were also consulted with respect to the effluent limitations guidelines and standards of performance for the steam electric power industry). A draft of the development document containing the cooling water intake structures information was sent to all participants and comments were solicited on that report.

(1) Effluent Standards and Water Quality Information Advisory Committee (established under section 515 of the Act); (2) all State Pollution Control Agencies; (3) the Edison Electric Institute; (4) American Public Power Association; (5) Atomic Industrial Forum, Inc.; (6) Tennessee Valley Public Power Association; (7) The American Society of Mechanical Engineers; (8) Hudson River Sloop Restoration, Inc.; (9) The Conservation Foundation; (10) Environmental Defense Fund, Inc.; (11) Natural Resources Defense Council, Inc.; (12) Business and Professional People for the Public Interest; (13) The American Society of Civil Engineers; (14) Water Pollution Control Federation; (15) National Wildlife Federation; (16) National As-

sociation of Electric Companies; (17) National Rural Electric Cooperative Association; (18) New England Interstate Water Pollution Control Commission; (19) Ohio River Valley Sanitation Commission; (20) Government of Guam; (21) Trust Territory of the Pacific Islands; (22) Puerto Rico; (23) Delaware River Basin Commission; (24) U.S. Department of Commerce; (25) U.S. Department of the Interior; (26) U.S. Water Resources Council; (27) U.S. Department of Treasury; (28) U.S. Atomic Energy Commission; (29) U.S. Department of Defense; (30) U.S. Department of Agriculture; (31) Tennessee Valley Authority; and (32) U.S. Department of Housing and Urban Development.

The following organizations responded with comments relative to the cooling water intake structures information: Effluent Standards and Water Quality Information Advisory Committee (established under section 515 of the Act); Honorable Mike McCormack; U.S. Department of the Treasury; Atomic Industrial Forum, Inc.; Delaware River Basin Commission; Edison Electric Institute; U.S. Atomic Energy Commission; U.S. Water Resources Council; Southern Electric Generating Company; Consumers Power Company; American Electric Power Service Corporation; Virginia Electric and Power Company; Duke Power Company; Commonwealth Edison; Southern Services, Inc.; Public Service Electric and Gas Company; Tennessee Valley Authority; Los Angeles Department of Water and Power; Bechtel Power Corporation; New York Power Pool; U.S. Department of Agriculture; Gulf Power Company; Mississippi Power Company; Consolidated Edison Company of New York, Inc.; Georgia Power Company; American Public Power Association; National Advisory Committee on Oceans and Atmosphere; Tennessee Valley Public Power Association; Detroit Edison; Southwestern Electric Power Company; City Public Service Board of San Antonio; U.S. Department of Defense; U.S. Department of Commerce; Florida Power and Light Company; Federal Power Commission; Natural Resources Defense Council, Inc.; Hudson River Fishermen's Association; Tampa Electric Company; State of Illinois Environmental Protection Agency; State of Maryland Department of Natural Resources; State of Michigan Department of Natural Resources; State of Ohio Environmental Protection Agency; State of North Carolina Department of Natural and Economic Resources; State of Texas Water Quality Board.

The primary issues raised in the development of the proposed regulations and the treatment of these issues herein are as follows. Public comments on all these suggestions are solicited.

1. Some commenters suggested the consideration of type and design of intakes on a case-by-case basis due to the high degree of site specificity involved. While this view is warranted with respect to the outcome, a certain degree of national uniformity can be prescribed relative to the factors that must be con-

sidered. Section 402.12 below is intended to fulfill this need.

2. Some commenters suggested that the evaluation of existing intake structures be concerned with their environmentally related performance rather than their location, configuration, and operation. While environmentally related performance would provide a measure of the effect desired, it must be related to control technology in order to be assured that adverse environmental impacts are minimized in any particular case.

3. Some commenters feel that location is by far the most important aspect of intake technology related to environmental impact. Furthermore, they feel that no large intake structure should be located in an estuarine water body. This would mean that all powerplants on estuaries would be required to employ closed-cycle cooling systems. While location is no doubt the most important factor involved, and estuarine sites in general would have a high potential for adverse environmental impact, no data is available to support evaluations leading to specific intake structure requirements other than on a case-by-case basis.

4. Some commenters feel that the biological data gathered to support consideration of factors related to cooling water intake structures should be obtained by the Environmental Protection Agency or under contract with independent research organizations. The qualifications of the investigator and the data obtained should stand on the merits of each case.

Interested persons may participate in this rulemaking by submitting written comments in triplicate to the EPA Information Center, Environmental Protection Agency, Washington, D.C. 20460, Attention: Mr. Philip B. Wisman. Comments on all aspects of the proposed regulations are solicited. In the event comments are in the nature of criticisms as to the adequacy of data which is available, or which may be relied upon by the Agency, comments should identify and, if possible, provide any additional data which may be available and should indicate why such data is essential to the development of the regulations. In the event comments address the approach taken by the Agency in establishing an effluent limitation guideline or standard of performance, EPA solicits suggestions as to what alternative approach should be taken and why and how this alternative better satisfies the detailed requirements of sections 301, 304(b), 306 and 307 of the Act.

A copy of all public comments will be available for inspection and copying at the EPA Information Center, Room 227, West Tower, Waterside Mall, 401 M Street, SW., Washington, D.C. A copy of preliminary draft contractor reports, the Development Document, and certain supplementary materials supporting the study of the industry concerned will also be maintained at this location for public review and copying. The EPA information regulation, 40 CFR Part 2, provides that a reasonable fee may be charged for copying.



## PROPOSED RULES

All comments received on or before January 14, 1974 will be considered. Steps previously taken by the Environmental Protection Agency to facilitate public response within this time period are outlined in the advance notice concerning public review procedures published on August 6, 1973 (38 F.R. 21202).

Dated: December 7, 1973.

JOHN QUARLES,  
Acting Administrator.

Part 401 is proposed to be amended as follows:

#### PART 401—GENERAL PROVISIONS

Sec.

##### 14 Cooling water intake structures.

401.12 Law authorizing effluent limitations guidelines, standards of performance and pretreatment standards for new sources.

(i) Section 316(b) of the Act provides that any standard established pursuant to section 301 or section 306 of the Act applicable to a point source shall require that the location, design, construction, and capacity of cooling water intake structures reflect the best technology available for minimizing adverse environmental impact.

##### 401.14 Cooling water intake structures.

The location, design, construction and capacity of cooling water intake structures of any point source for which a standard is established pursuant to section 301 or 306 of the Act shall reflect best technology available for mini-

mizing adverse environmental impact, in accordance with the provisions of Part 402 of this chapter.

#### PART 402—BEST TECHNOLOGY AVAILABLE FOR MINIMIZING ADVERSE ENVIRONMENTAL IMPACT OF COOLING WATER INTAKE STRUCTURES

Part 402 is proposed to read as follows:

Sec.

##### 402.10 Applicability.

##### 402.11 Specialized definitions.

##### 402.12 Best technology available for cooling water intake structures.

##### § 402.10 Applicability.

The provisions of this part are applicable to cooling water intake structures for point sources for which effluent limitations guidelines are established pursuant to section 301 or standards of performance are established pursuant to section 306 of the Act.

##### § 402.11 Specialized definitions.

For the purpose of this part:

(a) The term "cooling water intake structure" shall mean the total structure used to direct water from a water body into the point source subject to the provisions of this part whenever the intended use of a major fraction of the water so directed is to absorb waste heat rejected from the process or processes employed or from auxiliary operations on the premises, including air conditioning.

(b) The term "existing cooling water intake structure" shall mean any cooling water intake structure, the construction of which was commenced before the date of publication of these proposed regulations.

(c) The term "new cooling water intake structure" shall mean any cooling water intake structure, the construction of which has been commenced on or after the date of publication of these proposed regulations.

(d) The term "Development Document" shall mean the document entitled "Development Document for Proposed Best Technology Available for Minimizing Adverse Environmental Impact of Cooling Water Intake Structures", and published by the U.S. Environmental Protection Agency.

##### § 402.12 Best technology available for cooling water intake structures.

(a) The applicable factors set forth in the Development Document shall be considered to determine that the best available technology for minimizing the adverse environmental impact is reflected in an existing cooling water intake structure of a point source subject to standards established under sections 301 and 304(b) of the act.

(b) The factors set forth in the Development Document shall be used to determine that the location, design, construction and capacity of a cooling water intake structure of a point source subject to standards established under the provisions of section 306 and that the location, design, construction and capacity of a new cooling water intake structure of a point source subject to the standards established under the provisions of sections 301 and 304(b) of the Act reflect the best technology available for minimizing the adverse environmental impact.

[FR Doc. 73-26421 Filed 12-12-73; 8:45 am]

ADDENDUM B6  
STATE OF MAINE  
TIDAL WATER THERMAL DISCHARGES

**TEMPERATURE CRITERIA****582.1 Freshwater Thermal Discharges**

No discharge of pollutants shall cause the ambient temperature of any freshwater body, as measured outside a mixing zone, to be raised more than 5°F or more than 3°F in the epilimnion of any lake or pond. In no event shall any discharge cause the temperature of any freshwater body to exceed 84°F at any point outside a mixing zone established by the Board, nor shall such discharge cause the temperature of any waters which presently are designed as trout or salmon waters to exceed 68°F at any point outside a mixing zone established by the Board.

**582.2-4 Reserved****582.5 Tidal Water Thermal Discharges**

No discharge of pollutants shall cause the monthly mean of the daily maximum ambient temperatures in any tidal body of water, as measured outside the mixing zone, to be raised more than 4°F, nor more than 1.5°F from June 1 to September 1. In no event shall any discharge cause the temperature of any tidal waters to exceed 85°F at any point outside a mixing zone established by the Board.

**582.6-8 Reserved**



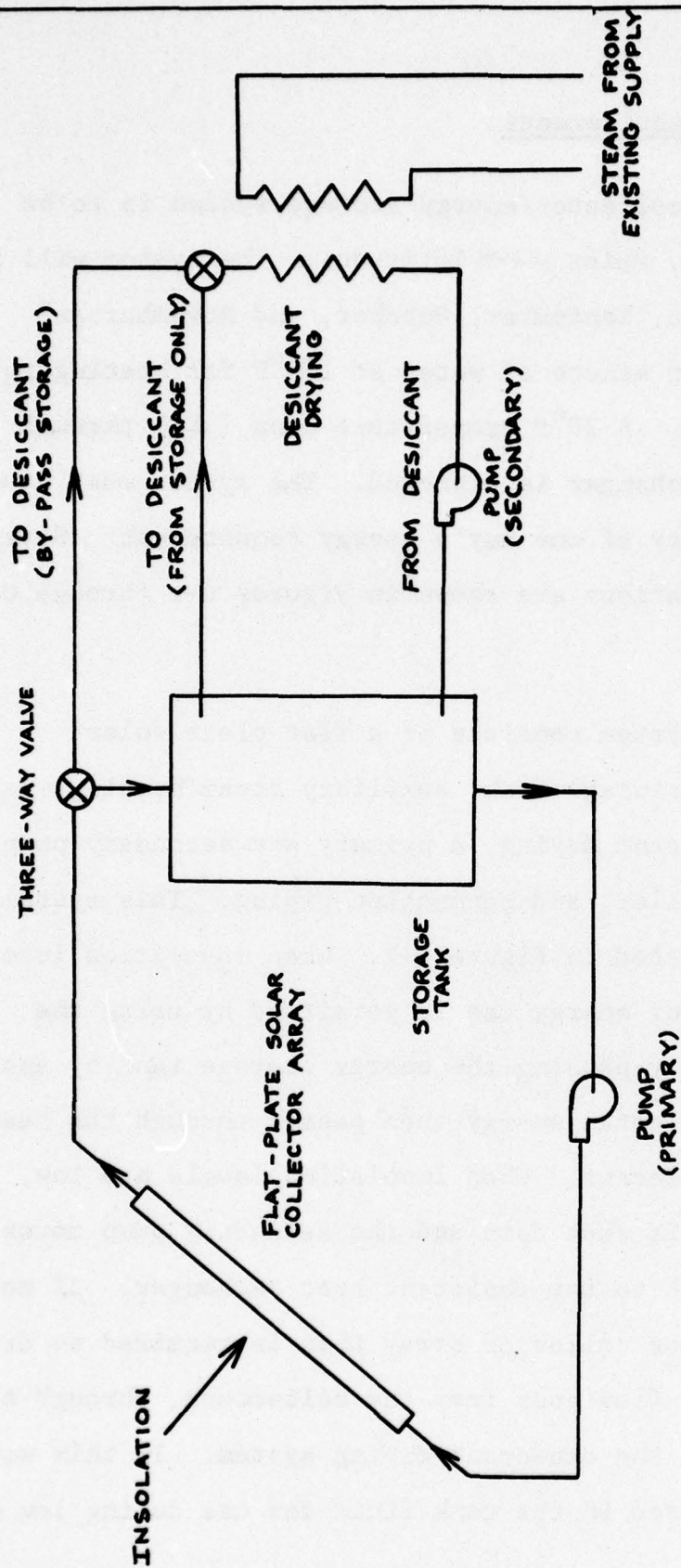
APPENDIX C

SOLAR COLLECTOR/STORAGE FOR DESICCANT DEHYDRATION

## System Description and Requirements

A solar flat plate collector/energy storage system is to be located in Winter Harbor, Maine (44°N latitude). The system will be used in the months August, September, October, and November and must supply 6 gallons per minute of water at 140°F for heating to dry a desiccant material. A 20°F temperature drop ( $\Delta T$ ) through the coils of the heat exchanger is expected. The system must have an energy storage capacity of one day's energy requirement. Several possible system configurations are shown in Figures C-1 through C-5, and are described below:

ALTERNATE S-1: The system consists of a flat-plate solar collector array, energy storage tank, auxiliary steam heating system, heat exchanger for desiccant drying, a primary and secondary pump, three-way valves, controller, and connection piping. This system is schematically illustrated in Figure C-1. When insolation levels are high, direct collector energy use is permitted by using the primary pump system and by-passing the energy storage tank by appropriate valving. The collected energy then passes through the heat exchanger to dry the desiccant. When insolation levels are low, the primary pump system is shut down and the secondary pump moves energy stored in the tank to the desiccant heat exchanger. If more energy is collected by the collector array than is required to dry the desiccant, the water flow goes from the collectors, through the storage tank and then to the desiccant drying system. In this way the excess energy is stored in the tank fluid for use during low or



C-2

FIGURE C-1. SYSTEM SCHEMATIC FOR SOLAR DEHYDRATION OF DESICCANT

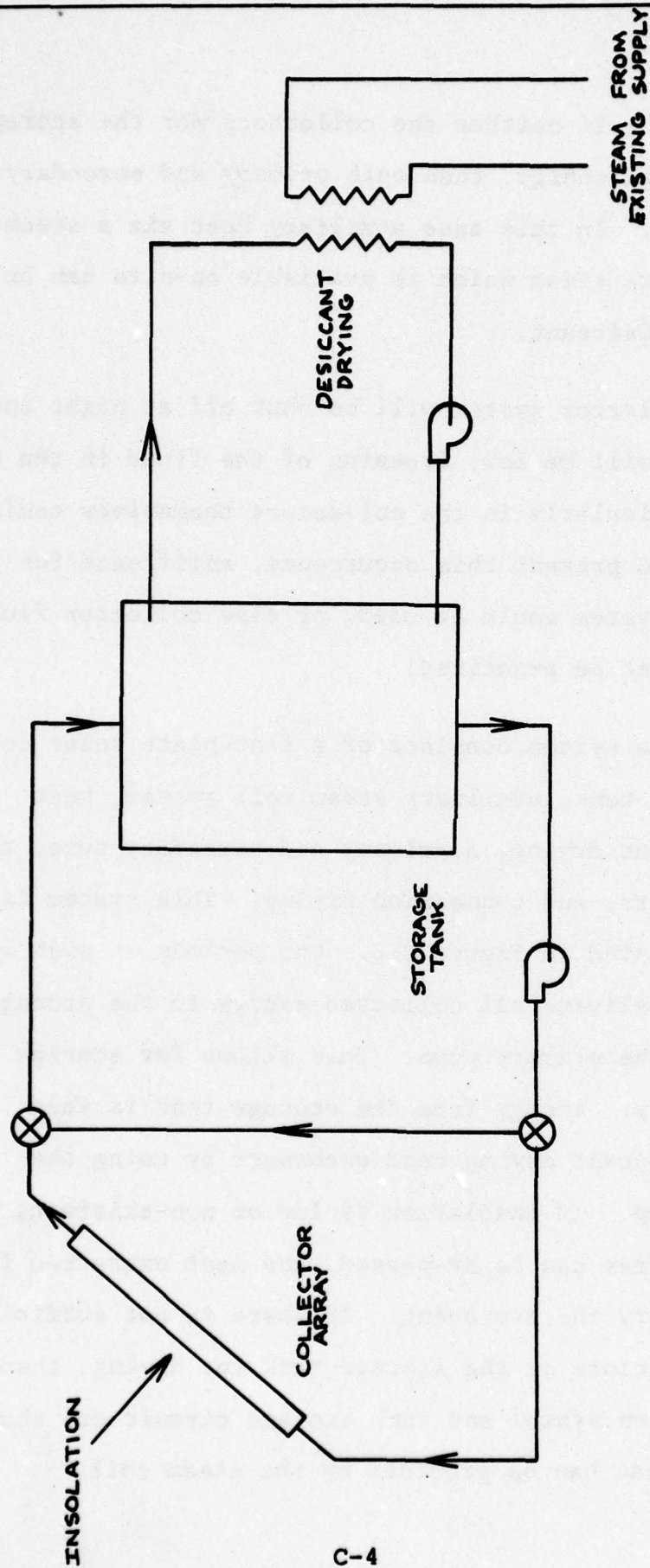
**TRACOR MARINE**  
**PORT EVERGLADES**  
**FLORIDA**



no insolation periods. If neither the collectors nor the storage tank can provide enough energy, then both primary and secondary circuits are shut off. In this case auxiliary heat via a steam coil using low pressure steam which is available on-site can be provided to dry the desiccant.

As the solar collector system will be shut off at night and ambient temperatures will be low, freezing of the fluid in the solar collector system particularly in the collectors themselves could present a problem. To prevent this occurrence, antifreeze for the fluid of the entire system could be used, or else collector fluid draindown at night must be practiced.

ALTERNATE S-2: The system consists of a flat-plate solar collector array, energy storage tank, auxiliary steam coil system, heat exchanger for desiccant drying, a primary and secondary pump, three-way valves, controllers, and connection piping. This system is schematically illustrated in Figure C-2. For periods of high insolation, this system delivers all collected energy to the storage tank through use of the primary pump. This allows for storage of excess energy capacity. Energy from the storage tank is then delivered to the desiccant drying heat exchanger by using the secondary circuit pump. If insolation is low or non-existent, then the collector array can be by-passed, and heat extracted from the storage tank to dry the desiccant. If there is not sufficient energy from the collectors or the storage tank for drying, then the entire solar collection system and tank storage circuit are shut down and auxiliary heat can be provided by the steam coil.



C-4

FIGURE C-2. SYSTEM SCHEMATIC FOR SOLAR DEHYDRATION OF DESICCANT

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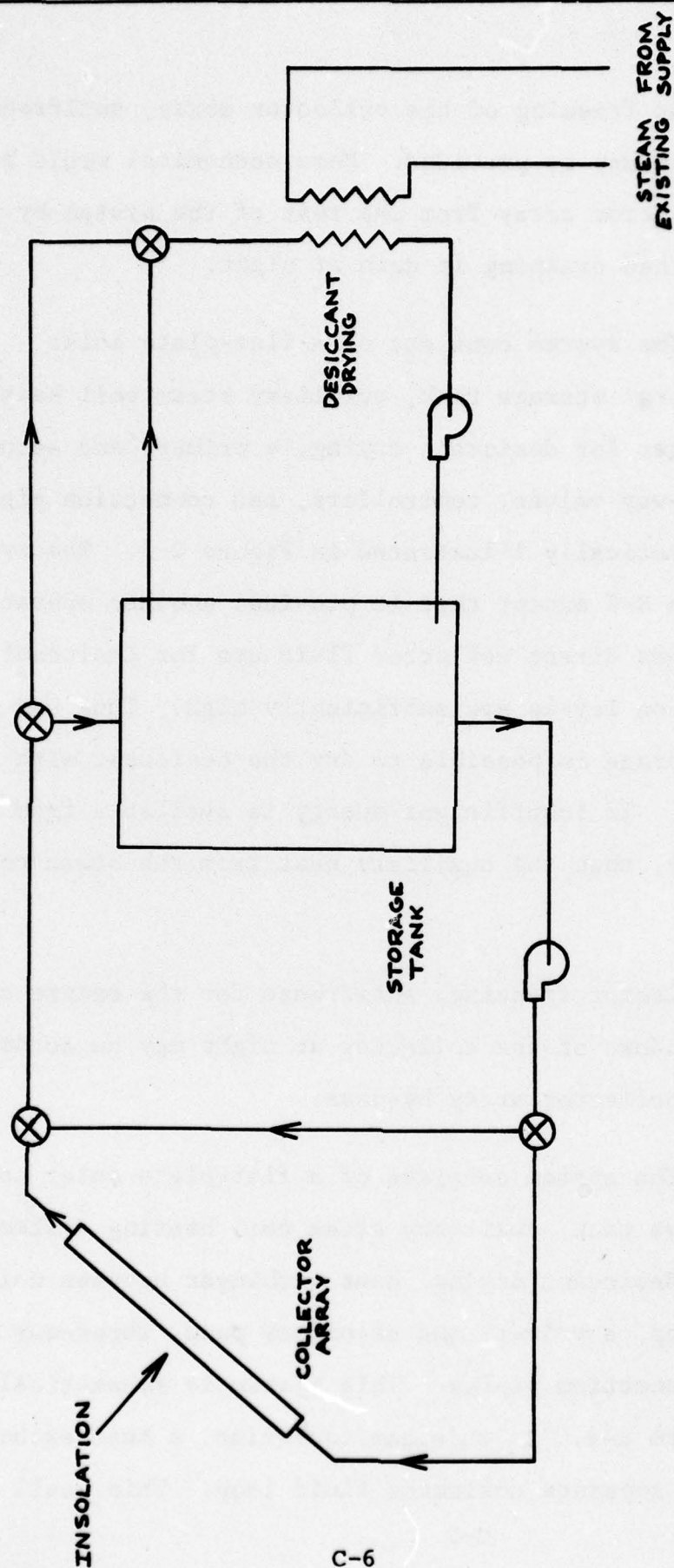
To prevent night freezing of the collector array, antifreeze for the entire system may be provided. More economical would be cutting off the collector array from the rest of the system by way of the by-pass and then draining it down at night.

ALTERNATE S-3: The system consists of a flat-plate solar collector array, energy storage tank, auxiliary steam coil heating system, heat exchanger for desiccant drying, a primary and secondary pump circuit, three-way valves, controllers, and connection piping. This system is schematically illustrated in Figure C-3. The system is similar to alternate S-2 except that it provides another operational mode, namely it allows direct collector fluid use for desiccant drying when insolation levels are sufficiently high. Thus use of collector and/or storage is possible to dry the desiccant with appropriate valving. If insufficient energy is available from the collector or storage, then the auxiliary heat from the steam coil may be used.

To prevent collector freezing, antifreeze for the entire system may be used or draindown of the collector at night may be accomplished through use of the collector array by-pass.

ALTERNATE S-4: The system consists of a flat-plate solar collector array, energy storage tank, auxiliary steam coil heating system, heat exchanger for desiccant drying, heat exchanger between collector and storage tank loop, a primary and secondary pump, three-way valves, controllers, and connection piping. This system is schematically illustrated in Figure C-4. In this configuration, a heat exchanger is provided to allow a separate collector fluid loop. This small loop





C-6

FIGURE C-3. SYSTEM SCHEMATIC FOR SOLAR DEHYDRATION OF DESICCANT

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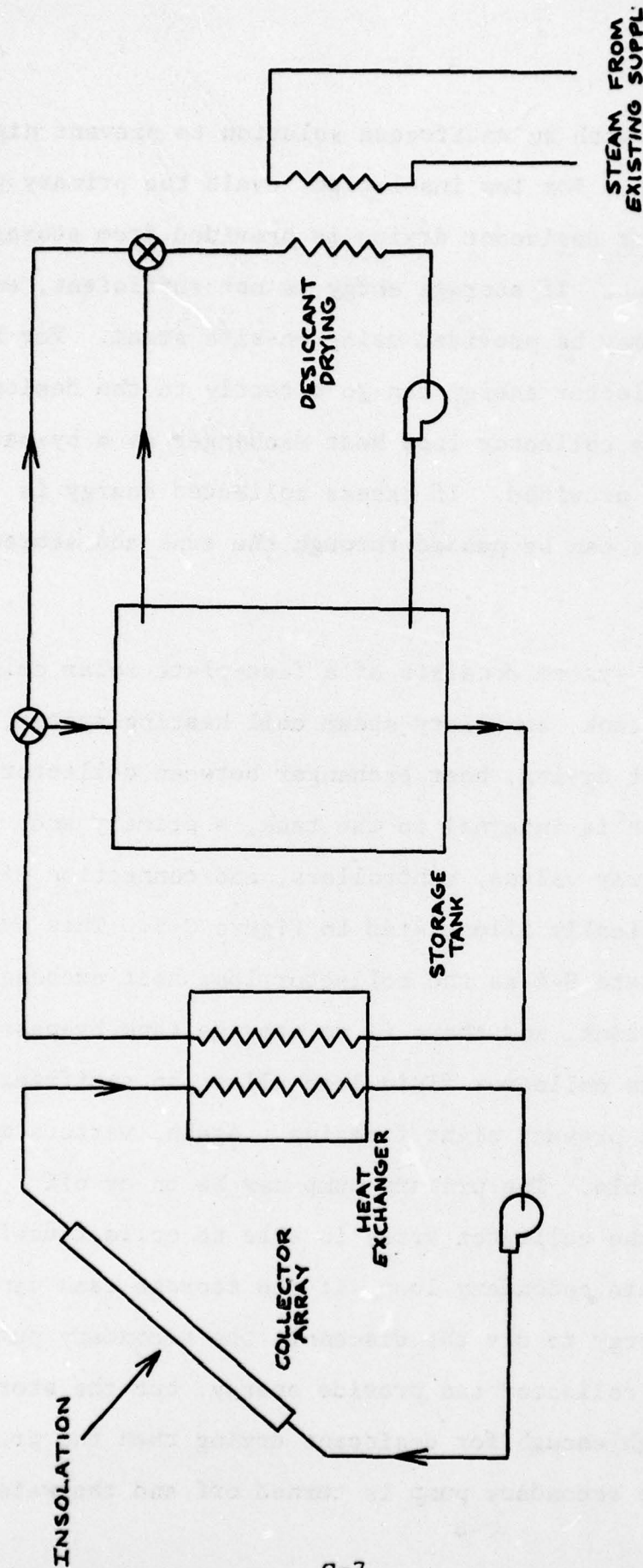


FIGURE C-4. SYSTEM SCHEMATIC FOR SOLAR DEHYDRATION OF DESICCANT

TRACOR MARINE  
PORT EVERGLADES  
FLORIDA

may easily be provided with an antifreeze solution to prevent night time collector freezing. For low insolation levels the primary pump is shut off and heat for desiccant drying is provided from storage using the secondary pump. If storage energy is not sufficient, an auxiliary heat system may be provided using on-site steam. For high insolation levels, collector energy can go directly to the desiccant heat exchanger from the collector loop heat exchanger as a by-pass of the storage tank is provided. If excess collected energy is available however, this can be passed through the tank and stored for future use.

ALTERNATE S-5: The system consists of a flat-plate solar collector array, energy storage tank, auxiliary steam coil heating system, heat exchanger for desiccant drying, heat exchanger between collector and storage tank loop which is internal to the tank, a primary and secondary pump, three-way valves, controllers, and connection piping. This system is schematically illustrated in Figure C-5. This system is simpler than alternate S-4 as the collector loop heat exchanger is inside the storage tank, and there is no storage tank by-pass provided. The separate collector fluid loop allows an antifreeze solution to be used to prevent night freezing. Again, various modes of operation are possible. The primary pump may be on or off depending on whether the collector array is able to collect useful energy. In the separate secondary loop, if the storage tank can provide sufficient energy to dry the desiccant, the secondary pump is turned on. If the collector can provide energy, but the storage temperature is not high enough for desiccant drying then the primary pump is turned on, the secondary pump is turned off and the water in



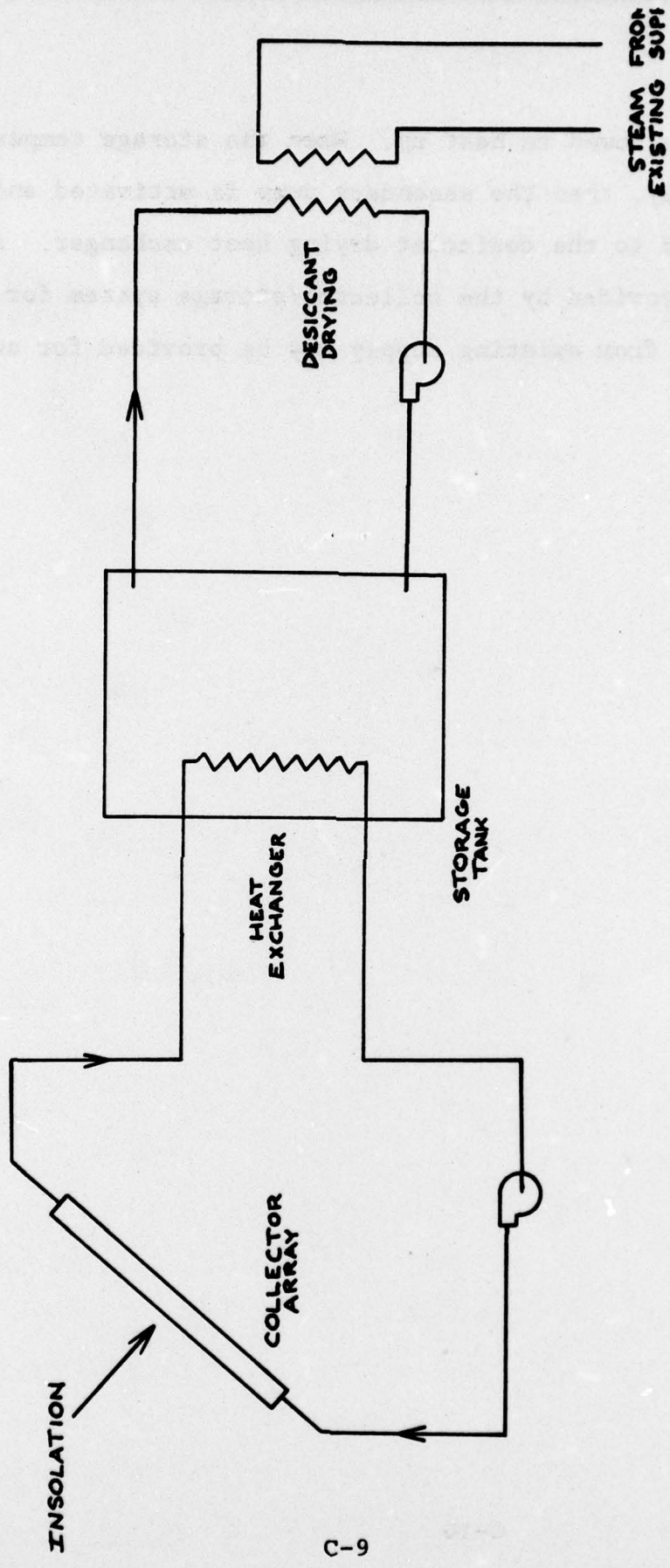


FIGURE C-5. SYSTEM SCHEMATIC FOR SOLAR DEHYDRATION OF DESICCANT

TRACOR MARINE  
PORT EVERGLADES  
FLORIDA

the storage tank is allowed to heat up. When the storage temperature increases sufficiently, then the secondary pump is activated and energy is transferred to the desiccant drying heat exchanger. At any time energy is not provided by the collector/storage system for desiccant drying, steam from existing supply may be provided for auxiliary heat.

## Weather Data

For sizing the solar collector/storage system, weather data, particularly insolation levels for August, September, October and November are necessary. General weather information and averages for the region of interest in Maine was obtained from References 1, 2, and 5. As no insolation measurements are made in Bar Harbor, the values from Portland, Maine had to be used. Portland lies approximately 110 miles SW of Bar Harbor and also is a coastal city. Table 1 outlines general weather information, Table 2 lists mean daily insolation for the four months of interest, and Table 3 gives the insolation value distribution throughout the day. The values in Tables 2 and 3 differ somewhat as they are from different sources. Figure 6 plots the data listed in Table 3 and demonstrates that for the first three months of interest, total daily insolation (area under hourly curves) is fairly constant but then drops significantly in November.



|                      |              |                                 |
|----------------------|--------------|---------------------------------|
| Sun total            | 59%          | } yearly averages<br>and totals |
| Wind Ave.            | 8.7 mph      |                                 |
| Rain, total          | 42.85 inches |                                 |
| Relative Humidity    | 7 am : 80%   |                                 |
|                      | 1 pm : 60%   |                                 |
| Precipitation        | 126 days     |                                 |
| Snow per Season      | 73.7 inches  |                                 |
| 32°F or less         | 162 days     |                                 |
| Latitude             | 44°          |                                 |
| Elevation            | 61 feet      |                                 |
| Degree days, heating | 7,511        |                                 |

TABLE 1. Weather Data, Portland, Me (Ref. 1)

| <u>Mean Daily Solar Radiation</u><br><u>on a Horizontal Surface</u> | <u>Langley's/day</u> | <u>BTU/Day sq.ft.</u> | <u>BTU/Hour sq.ft.</u> |
|---|----------------------|-----------------------|------------------------|
| August<br>daylight hours/day = 13                                   | 488                  | 1799                  | 138                    |
| September<br>daylight hours/day = 11                                | 383                  | 1412                  | 128                    |
| October<br>daylight hours/day = 11                                  | 278                  | 1025                  | 93                     |
| November<br>daylight hours/day = 9                                  | 157                  | 579                   | 64                     |

TABLE 2. Mean Daily Solar Radiation on a Horizontal Surface, Portland, Me. (Ref. 3)

|                     | SOLAR TIME           |    | BTU-HR <sup>-1</sup> -FT <sup>-2</sup> TOTAL INSOLATION ON SURFACES |                    |   |
|---------------------|----------------------|----|---|--------------------|---|
|                     | AM                   | PM | NORMAL SURFACE  | HORIZONTAL SURFACE | SOUTH FACING SURFACE<br>TILT = 44° = LATITUDE |
| AUG 21<br>(8=+12.1) | 6                    | 6  | 90  | 25                 | 9   |
|                     | 7                    | 5  | 190   | 86                 | 68  |
|                     | 8                    | 4  | 235   | 146                | 139   |
|                     | 9                    | 3  | 256   | 196                | 204   |
|                     | 10                   | 2  | 270   | 236                | 254   |
|                     | 11                   | 1  | 274   | 262                | 288   |
|                     | 12                   |    | 276   | 169                | 300   |
|                     | SURFACE DAILY TOTALS |    | 2906  | 2166/ave 166       | 2215  |
| SEPT 21<br>(8=0.0)  | 7                    | 5  | 140   | 39                 | 47  |
|                     | 8                    | 4  | 223   | 100                | 129   |
|                     | 9                    | 3  | 256   | 151                | 203   |
|                     | 10                   | 2  | 274   | 195                | 260   |
|                     | 11                   | 1  | 283   | 220                | 294   |
|                     | 12                   |    | 285   | 231                | 309   |
|                     | SURFACE DAILY TOTALS |    | 2638  | 1655/ave 150       | 2173  |
| OCT 21<br>(8=-10.7) | 7                    | 5  | 26  | 5                  | 8   |
|                     | 8                    | 4  | 185   | 56                 | 102   |
|                     | 9                    | 3  | 242   | 117                | 186   |
|                     | 10                   | 2  | 270   | 152                | 248   |
|                     | 11                   | 1  | 280   | 178                | 286   |
|                     | 12                   |    | 286   | 187                | 300   |
|                     | SURFACE DAILY TOTALS |    | 2304  | 1186/ave 107       | 1960  |
| NOV 21<br>(8=-19.9) | 8                    | 4  | 86  | 17                 | 46  |
|                     | 9                    | 3  | 206   | 64                 | 148   |
|                     | 10                   | 2  | 250   | 105                | 218   |
|                     | 11                   | 1  | 270   | 130                | 259   |
|                     | 12                   |    | 272   | 139                | 273   |
|                     | SURFACE DAILY TOTALS |    | 1898  | 769/ave 85         | 1613  |

TABLE 3. TOTAL INSOLATION ON VARIOUS SURFACES LOCATED AT 44° NORTH LATITUDE, ZERO PERCENT GROUND REFLECTANCE, CLEARNESS FACTOR OF 1.0 (REF. 2 AND 5).



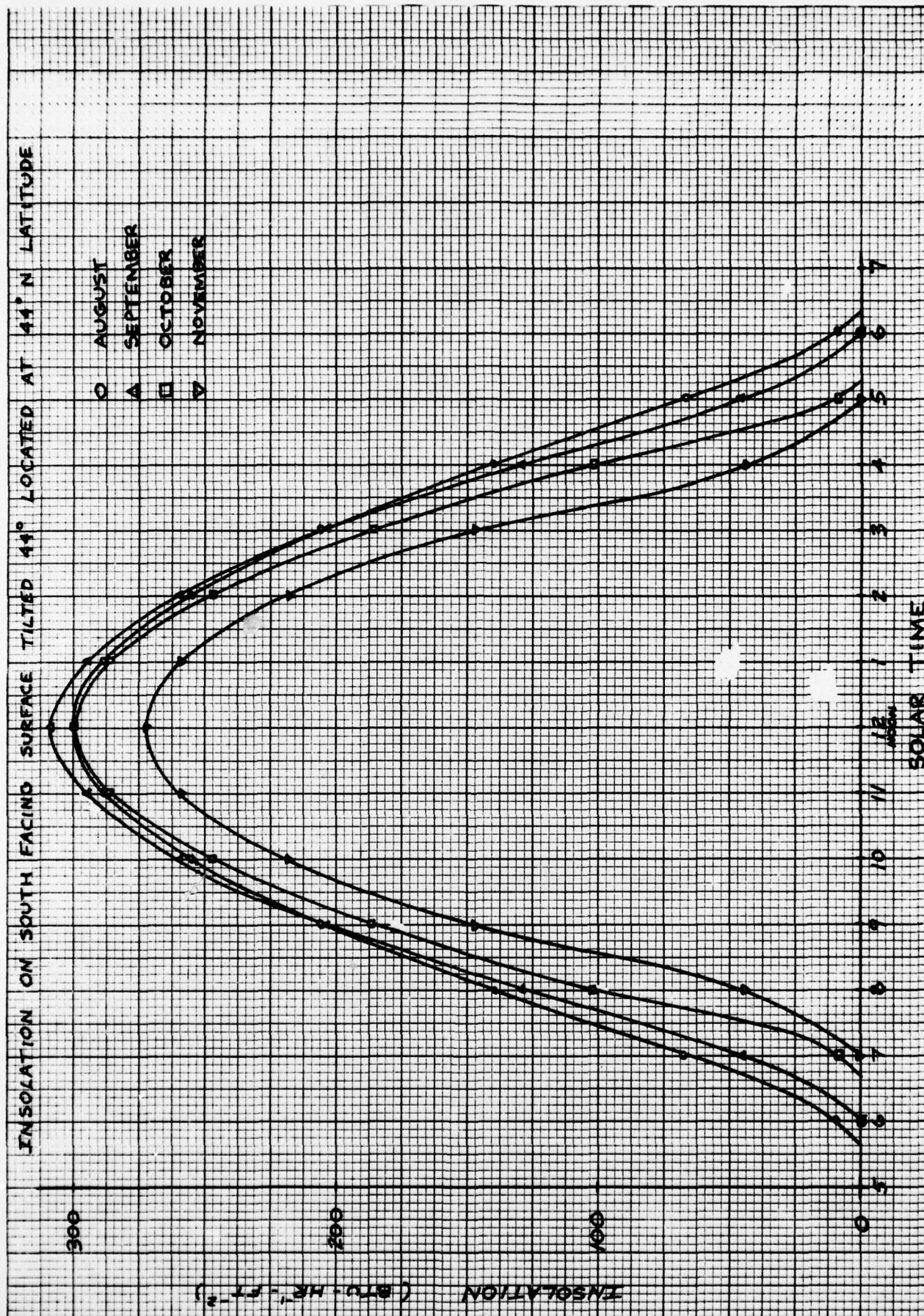


FIGURE C-6. HOURLY INSOLATION

### System Parameters

$$\text{At } 140^{\circ}\text{F} \quad C_{p_{H_2O}} = 0.998 \quad \frac{\text{BTU}}{\text{lbM-}^{\circ}\text{F}}$$

$$H_2O = 61.39 \quad \frac{\text{lbM}}{\text{FT}^3}$$

$$K_{H_2O} = 0.378 \quad \frac{\text{BTU}}{\text{HR-FT-}^{\circ}\text{F}}$$

Mass flow rate of  $H_2O$  through collector: 6 gallons/minute

$$\frac{6 \text{ gal}}{\text{min}} \quad \frac{60 \text{ min}}{\text{hr}} \quad \frac{0.1337 \text{ FT}^3}{1 \text{ gal}} \quad \frac{61.39 \text{ lbM}}{1 \text{ FT}^3} = 2995 \frac{\text{lbM}}{\text{HR}} H_2O$$

Extraction of heat (per hour) from collector must equal:

$$\begin{aligned} \text{useful from collector} &= C_p T = (2995 \frac{\text{lbM}}{\text{HR}}) (0.998 \frac{\text{BTU}}{\text{lbM-}^{\circ}\text{F}}) (20^{\circ}\text{F}) \\ &= 58,978 \frac{\text{BTU}}{\text{HR}} \end{aligned}$$

Assuming a collector overall efficiency of 50% and insulation of  $200 \frac{\text{BTU}}{\text{HR-FT}^2}$ , then

$$\text{useful from collector} = x I = (0.50) (200) = 100 \frac{\text{BTU}}{\text{HR-FT}^2}$$

Thus for the required  $60,000 \frac{\text{BTU}}{\text{HR}}$  we need

$$\frac{60,000 \frac{\text{BTU}}{\text{HR}}}{100 \frac{\text{BTU}}{\text{HR-FT}^2}} = 600 \text{ FT}^2 \text{ of collector}$$



Assuming 20 ft<sup>2</sup> / standard flat-plate collector, the system thus needs

$$\frac{600 \text{ FT}^2}{20 \text{ FT}^2/\text{collector}} \sim 30 \text{ collectors}$$

To satisfy the one-day energy storage requirement, assuming 8 to 9 hours of sunshine

$$(60,000 \frac{\text{BTU}}{\text{HR}}) (8 \frac{\text{hours}}{\text{day}}) \sim 500,000 \frac{\text{BTU}}{\text{day}} \quad \text{STORAGE}$$

Assuming that storage tank temperatures below 130°F are of no use and that tank temperatures will not be permitted to rise above 180°F, then

$$\text{ENERGY STORAGE} = M C_p \Delta T$$

or

$$M = \frac{(\text{STORAGE})}{C_p \Delta T} = \frac{500,000}{(1) (180-130)} = 10,000 \text{ lbs of H}_2\text{O}$$

which is in line with the rule of thumb of 10 to 15 lbs of water per square foot of collector area.

$$\text{SIZE OF TANK} = \frac{10,000 \text{ lbs H}_2\text{O}}{8.2 \frac{\text{lbs H}_2\text{O}}{\text{gal}}} = 1200 \sim 1000 \text{ gallon tank as it was oversized}$$



Notes:

- 1) Detailed studies by Lof and Tybout (Ref. 4), show that the optimum, i.e. least cost per BTU delivered, collector tilt for building heating is approximately latitude plus  $15^{\circ}$ . However, for hot-service water heating only, the optimum tilt is an angle equal to the latitude. Thus, in this study a collector tilt of  $44^{\circ}$  is used.
- 2) The optimum number of collector covers varies with climate, and for the Maine region, 2 covers are optimal (Ref. 4,5) and thus used in this study.
- 3) There is also an optimal amount of water storage per square foot of collector. The optimal storage volume per square foot of collector is independent of building location, of heat load and of insulation. The optimal value ranges from 10 to 15 lbs. of water per square foot of collector for nearly all locations in the conterminous United States (Ref. 5).

## System Components

### COLLECTORS

- a) 30 Flat plate collectors
- b) Double glase, flat black absorber surface,  $\eta_p=0.90$
- c) Area  $\sim 20 \text{ ft}^2$  each; total collector area =  $600 \text{ ft}^2$
- d) Top loss coefficient  $\sim 0.70 \frac{\text{BTU}}{\text{HR-FT}^2\text{-OF}}$

### STORAGE TANK

- a) Fiberglass or steel, 1000 gallon tank
- b) Cylindrical, insulated  $\sim 0.05 \frac{\text{BTU}}{\text{HR-FT}^2\text{-OF}}$

### PUMPS

Pumping rate of 6 gallons/minute @ 250 psig.

### VALVES

3-Way valves, Controlled by differential thermostat

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