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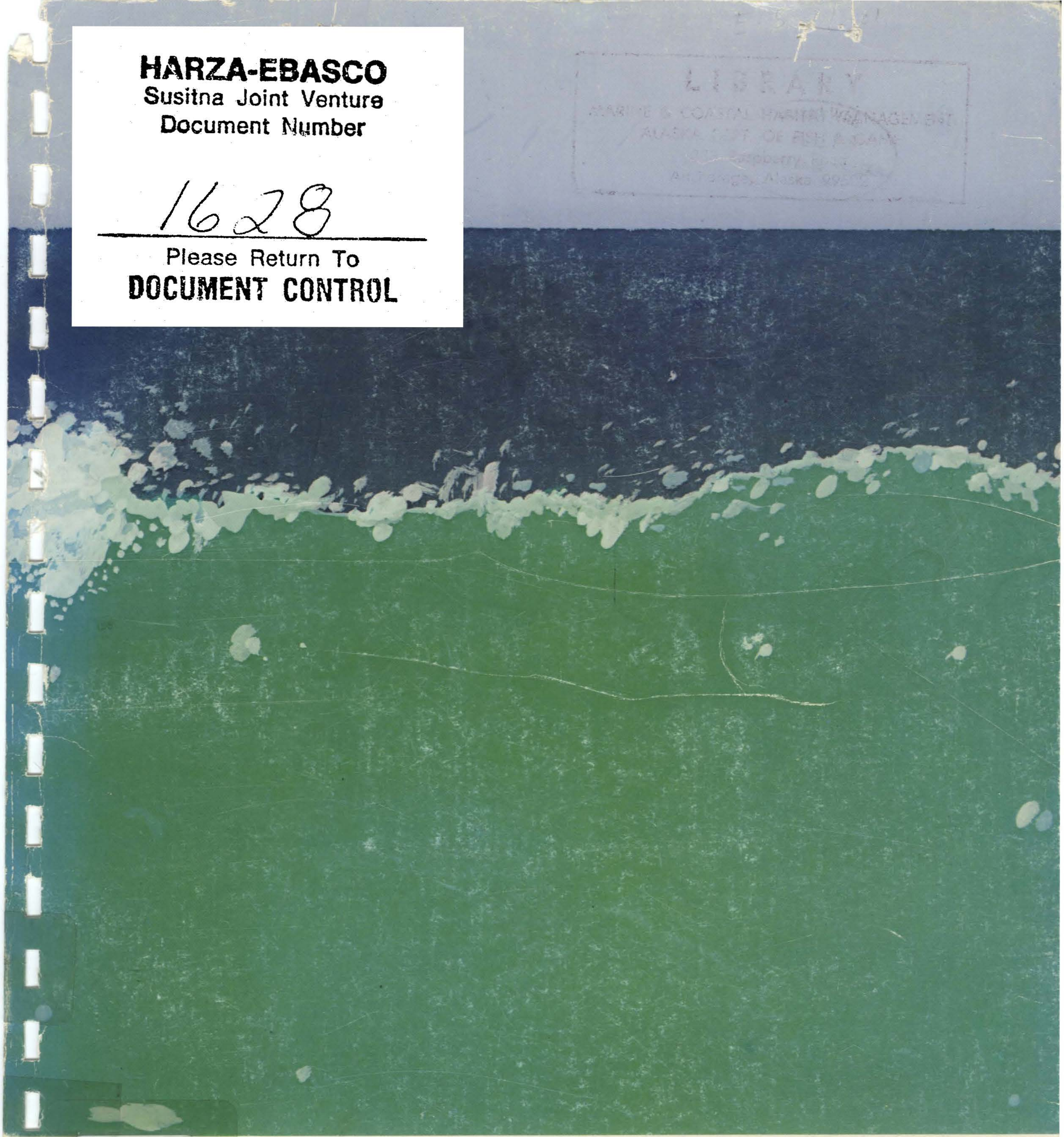

PRELIMINARY ASSESSMENT OF COOK INLET TIDAL POWER
PHASE I REPORT

VOLUME II

STATE OF ALASKA
OFFICE OF THE GOVERNOR

PRELIMINARY ASSESSMENT OF COOK INLET TIDAL POWER

PHASE I REPORT

VOLUME II

SEPTEMBER 1981

ACRES

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APPENDICES - VOLUME II

TABLE OF CONTENTS

FORWARD

1 - Task 1 Report (Submitted to the State of Alaska April 1981)

2 - Visual Reconnaissance of Selected Sites (Submitted to the State of Alaska April 1981)

3 - Parameter Selections

4 - Turbine Design

5 - Electrical Equipment

6 - Tidal Power Plant Energy Studies

7 - Closure of the Tidal Basin

8 - Tidal Power Design and Construction Methods

9 - Cost Estimates and Schedules

10 - Preliminary Environmental Assessment

11 - Socioeconomic Assessment

12 - Regulatory Evaluation

13 - System Study and Economic Evaluation

14 - Marketing and Financing

15 - Preliminary Risk Assessment

MAP - Location of Selected Sites

FOREWORD

This report was prepared by Acres American Incorporated in partial fulfillment of a contract with the Office of the Governor, State of Alaska, to conduct a study entitled "Preliminary Assessment of Cook Inlet Tidal Power."

The work described herein constitutes the first phase of a planned three phase study to determine the potentials and constraints of utilizing the tides of Cook Inlet to produce useable energy. The three phases include:

(1) Phase I: Preliminary assessment of Cook Inlet tidal power potentials and characteristics.

(2) Phase II: In-depth study of the potential industries or groups of industries that appear to have a comparative advantage in association with a Cook Inlet tidal power source.

(3) Phase III: Detailed engineering and environmental investigation of site-specific configurations, as well as the preparation of a conceptual development plan.

Conclusions and recommendations contained herein are based solely upon Phase I study efforts. Results of later phases could lead to modifications in the initial findings.

For the convenience of the reader, a fold-out map is provided as the last page in this report. Knik and Turnagain Arms at the upper end of Cook Inlet are shown thereon.

APPENDIX 1 - TASK 1 REPORT

(SUBMITTED TO THE STATE OF ALASKA APRIL 1981)

APPENDIX I - TASK 1 REPORT

TABLE OF CONTENTS

Page

SECTION I - INTRODUCTION AND SUMMARY.............................. 1-1

1.1 - Background.. 1-1
1.2 - General... 1-1
1.3 - Cook Inlet Region....................................... 1-2
1.4 - The Railbelt Electrical System.......................... 1-2
1.5 - Summary... 1-3

SECTION 2 - TIDAL POWER CONCEPT.................................. 1-5

2.1 - The Tidal Range... 1-5
2.2 - Tidal Characteristics................................... 1-7
2.3 - Conversion of Tidal Energy.............................. 1-9
2.4 - Tidal Energy Production................................. 1-9
2.5 - Retiming of Tidal Energy................................ 1-11

SECTION 3 - DATA COLLECTION...................................... 1-17

3.1 - Previous Studies on Tidal Power......................... 1-17
3.2 - Cook Inlet Tidal Studies................................ 1-18
3.3 - Study References.. 1-18

SECTION 4 - SITE SELECTION.......................................1-25

4.1 - Methodology...1-25
4.2 - Site Identification.....................................1-27
4.3 - Candidate Site Review...................................1-28
4.4 - Parametric Screening....................................1-34
4.5 - Selected Sites..1-35

LIST OF TABLES

Number Title

2.1 Possibility of Resonance in Cook Inlet 1-12
2.2 Typical Tidal Power Plant Characteristics for Single Effect Operation 1-13
2.3 Double Effect Operation 1-14
2.4 Hydraulically Linked Basins 1-15
2.5 Paired Basins 1-16
4.1 Energy and Capacity 1-39
4.2 Site Parameters 1-40
4.3 Site Parameters 1-41

LIST OF FIGURES

Number Title

1 Candidate Sites 1-6
2 Cook Inlet Tidal Ranges 1-8
3 Flow Chart Site Selection 1-26

1 - INTRODUCTION AND SUMMARY

1.1 - Background

This report was prepared by Acres American Incorporated in partial fulfillment of a contract with the Office of the Governor, State of Alaska, to conduct a study entitled "Preliminary Assessment of Cook Inlet Tidal Power."

The overall scope of the study is to provide engineering services to conduct a preliminary assessment of Cook Inlet tidal power characteristics and potentials, as well as to set forth a conceptual program for later in-depth investigations if the initial assessment indicates that such a program is warranted.

The work has been divided into the following four tasks:

Task 1 - Preliminary Field Reconnaissance and Site Selection
Task 2 - Comparative Evaluation
Task 3 - Reports
Task 4 - Project Control and Administration

This report summarizes the findings for Task 1. The objectives of this task were to gather as complete a data base as possible on the Cook Inlet Region and tidal power concerns; to review existing literature and identify potential sites; to perform a field reconnaissance of the potential sites and gain first-hand information (details will be presented in a separate report); to develop preliminary concepts for tidal power; and to select final site(s).

1.2 - General

The natural process of ebb and flow in the ocean tides entrains very large amounts of energy and offers a non-polluting, renewable source. Tidal energy is available both in kinetic form in rapidly flowing tidal currents, and as potential energy associated with the tidal waters contained behind man-made barrages. In view of the relatively low density, the cost of extracting kinetic energy from tidal currents is relatively high. There are, around the world, a few special locations where tidal ranges are particularly high, and where it is possible to tap the potential energy for economic power generation.

The fundamental approach to tidal power development involves the creation of an artifical barrier which permits one or more pools to be maintained at elevations which are lower than high tide or higher than low tide. When sufficient head differential is obtained, water at the higher pool level is allowed to flow through hydraulic turbines to the lower pool level, thereby generating power. It will be appreciated that the operating head available within even the highest available tidal ranges falls just within the lowest limit for economic hydroelectric power generation.

1.3 - Cook Inlet Region

Cook Inlet is a major tidal estuary located in the South Central Region of Alaska and characterized by its high tidal ranges. It is approximately 180 miles long and ranges in width from 80 miles near its mouth in the Northern Gulf of Alaska to approximately 20 miles not far from Anchorage where the waters divide forming the narrow Knik and Turnagain Arms.

The Inlet lies in a large structural depression between the Alaska Range to the west and the Kenai and Chugach Ranges to the east. Tertiary sedimentary formations were the foundation for later glacial activity which at one time occupied its entire length, developing the broad trough-like characteristic of the basin. The many glacial fed tributary waters have carried enormous quantities of sediment into the Inlet, forming mud flats exposed at low tides which are predominant especially in the Knik and Turnagain Arms and the Susitna River Delta.

Human activities in Cook Inlet are relatively extensive in comparison to other parts of the State. The predominant activities that share the Inlet waters include a broad based fishing industry, increasing exploration of energy and mineral resources, as well as cargo and passenger traffic to and from the ports of Anchorage, Kenai, Homer, and Seldovia.

1.4 - The Railbelt Electrical System

The electrical system which will benefit from the outputs of the Cook Inlet tidal power development in Cook Inlet is assumed to be identical with that treated in the Susitna Hydroelectric Power Study (The Susitna Study), i.e., the Railbelt area of Alaska including the urban areas of Fairbanks, Anchorage, Homer, Seward and other small communities. Demand projections adopted for load growth in this review are those developed earlier by the University of Alaska, Institute for Social and Economic Research (ISER) in connection with the Susitna Study. The ISER projections were used to estimate system capacity, and were adjusted to allow for only those potential electrical energy markets which are known to be available and to account for transmission losses on the supply side. The forecast estimates were as accurate a picture as can be obtained at present of the demand on generating resources, likely to be provided to meet Railbelt load demands.

Planning for potential tidal power generating plants will consider two load cases: (1) a constrained case, consistent with the ISER forecasts, and (2) an unconstrained case, which would permit encouragement of industrial growth, over and above the ISER forecasts, attracted by the development of a large and virtually inflation proof source of power and energy.

The mid-range and high forecasts of capacity and energy for the Railbelt used in the Susitna Study are as follows:

	Mid		High	
	Capacity (MW)	Energy (GWH)	Demand (MW)	Energy (GWH)
1990	735	4030	920	5090
2000	1170	6430	1670	9180
2010	1640	8940	2900	15,900

The planning for the constrained case will strive for consistency with these estimates. The unconstrained case will be appropriate to serve a projected load larger than even the high forecast given above and will assume energy-intensive industrial development. Even at unconstrained levels, however, developments considered must be within a conceivable range of likely demand.

1.5 - Summary

This report contains four Sections and one Appendix.

Section 2 discusses tidal power concepts and concludes that for purposes of site screening, comparisons are best made for single basin, single effect developments. In other words, each of the various possible tidal sites is to be viewed on a preliminary basis as if it would contain a single impounding basin which would be filled during flood tide. Generation through hydraulic turbines would occur at ebb tide.

Section 3 reviews the data base which has been assembled for the study. While much has been written about tidal power, few actual developments have ever been attempted. The most exhaustive studies of tidal power concepts have dealt primarily with the Bay of Fundy in Canada. The Bay of Fundy work and a number of earlier Cook Inlet studies have been found to be useful for the current effort. A list of references is provided at the end of Section 3.

Section 4 deals with the site selection process. A total of sixteen sites were considered and an initial calculation was made of capacity, energy, and certain parameters which assist in comparison of relative costs. Three sites were chosen for further analysis in Task 2:

- Rainbow. This site crosses Turnagain Arm from a point near the mouth of Rainbow Creek to a point about two miles east of Resurrection Creek.

- Point MacKenzie-Point Woronzof, crossing Knik Arm near Anchorage.

- Eagle Bay/Goose Bay, crossing Knik Arm at the narrowing of the channel above Eagle and Goose Bays.

Rainbow and Eagle Bay/Goose Bay appear to be compatible with future energy demands as forecasted by the Institute for Social and Economic Research. Thus, both are candidates for the constrained case wherein a potential development must meet Railbelt System requirements without major industrial expansion.

Point MacKenzie-Point Woronzof would provide more energy than has been forecasted as needed in the time frame during which it could be built and operated. This site meets the criteria for consideration of an unconstrained case wherein industrial growth is assumed to be encouraged.

All selected sites offer opportunities for causeway connections from the heavily populated Anchorage area to lands across Knik or Turnagain Arms.

Appendix A provides a summary data sheet for each of the sixteen sites which were included in the screening process.

A field reconnaissance was conducted for the seven most promising sites in the original list of sixteen. Data from the reconnaissance effort was an important part of the data base for final site selection. A separate report of the field reconnaissance effort amplifying the data contained in Appendix A will be prepared and published.

2 - TIDAL POWER CONCEPT

The energy potential of the tides in Cook Inlet is directly related to the high tidal ranges that occur naturally in the Inlet, and also to the volumes of water that move in and out with the changes in tidal levels. These factors can be used in fairly elementary calculations to show the tidal energy potential is very large. If only a relatively small fraction of the energy can be controlled and diverted to human use, then the contribution of this renewable (and incidentally entirely predictable) resource to the preservation of non-renewable sources could be significant.

However, to realize the energy potential of the Cook Inlet tides, it is necessary to consider carefully the characteristics of the tides and their associated energy content and to develop entirely practical methods of converting the energy into a usable form.

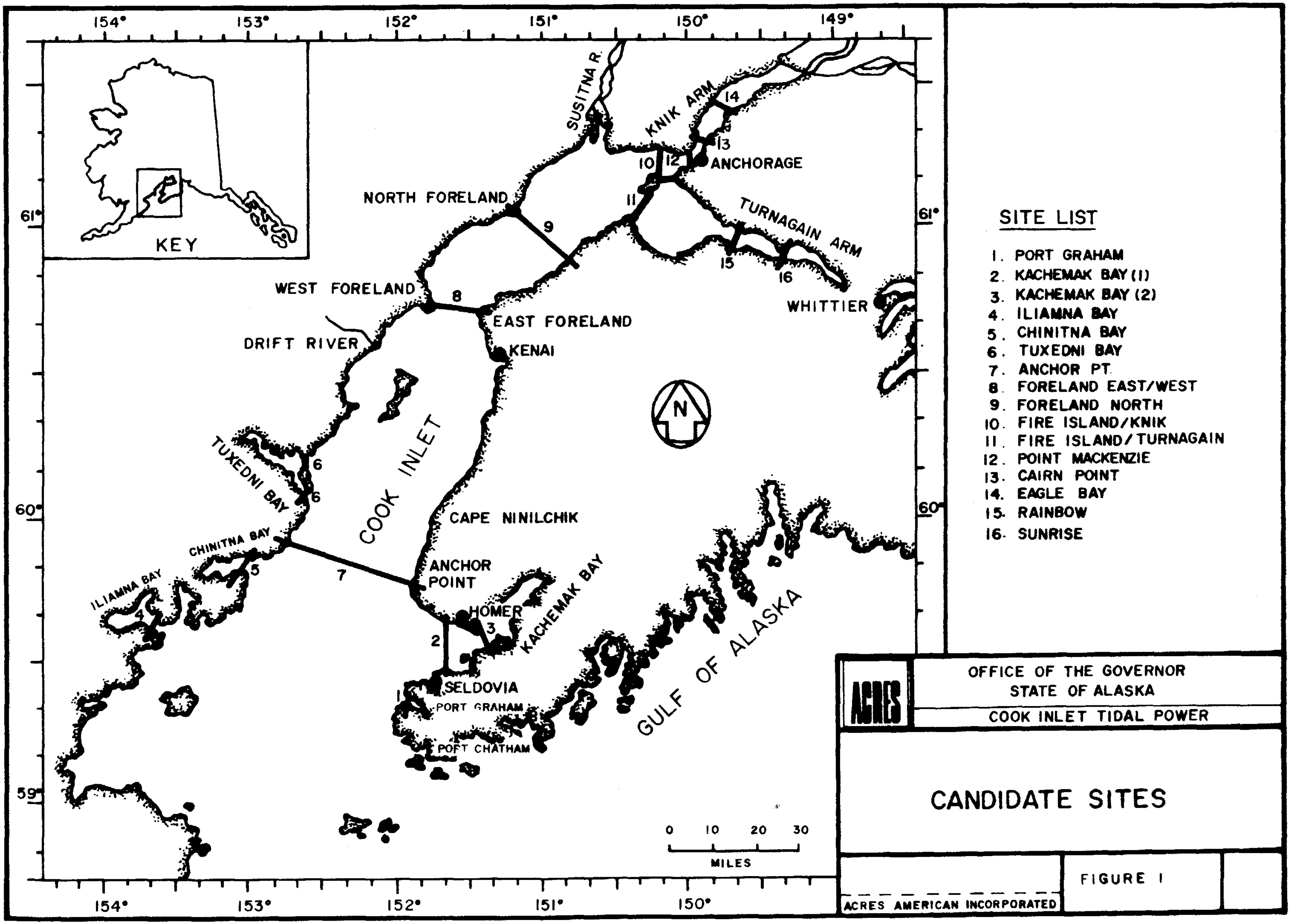
2.1 - The Tidal Range

The tides in Cook Inlet are significantly higher than those prevailing in the nearby open ocean. For example, the mean tide ranges recorded in the National Ocean Survey tide tables vary from 6.6 ft at Kodiak Harbor to 11.4 ft at the Barren Islands and to 26.1 ft at Anchorage (see Figure 1 for an overall plan of Cook Inlet and its potential tidal power sites).

The physical reasons for the amplification of tidal effect in the oceans of the world are extremely complex and the phenomenon is not amenable to simple calculation. In simplistic terms, however, it can be concluded that a particular configuration of seabed levels and channel widths tends to funnel the tides up an inlet and results in a concentration of potential energy in high tidal levels which is not dissipated in overcoming friction.

Theories have been presented supporting the view that the length of the Inlet is close to that required for perfect resonance of the tidal wave, a factor which could contribute greatly to increase in tidal levels. Analysis of the tide table predictions suggests that the shape of the Cook Inlet may not be as conducive to resonance as earlier studies supposed. These earlier studies calculated a reasonant length for the Inlet based on a simple formula which neglects friction and assumes a simple rectangular cross section for the channel. Calculations such as this show that the resonant length could be from 120 to 152 miles (see Table 2.1). This would imply that, with an actual length of about 190 miles from the Barren Islands to Fire Island, an artifical barrier across the Inlet seaward of Fire Island could bring the Inlet closer to resonance and so increase the tidal range.

In actual fact, the mean tide at the Barren Islands is already 1.7 times the mean tide at Kodiak, so that a significant amplification has already been achieved by the time the tidal wave reaches that point. In addition,



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COOK INLET TIDAL POWER

CANDIDATE SITES

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FIGURE 1

from the timing given in the tide tables, it is apparent that the velocity of the tidal wave passing up the Inlet is reduced to approximately 50 to 75 percent of its maximum after it is "throttled-down" at the Forelands. Also, the theoretical resonant length (neglecting friction) based on the tidal wave velocity seaward of the Forelands is greater than the actual length.

It is also noted, from the sparse tidal data available, that Knik Arm experiences tidal ranges increased from those at Anchorage, and the data for Turnagain Arm indicate a similar amplification relative to those at Anchorage. The changes in tidal wave velocity and levels within the Inlet suggest that a simple resonance model cannot be reasonably applied and that the overall system is not necessarily close to resonance.

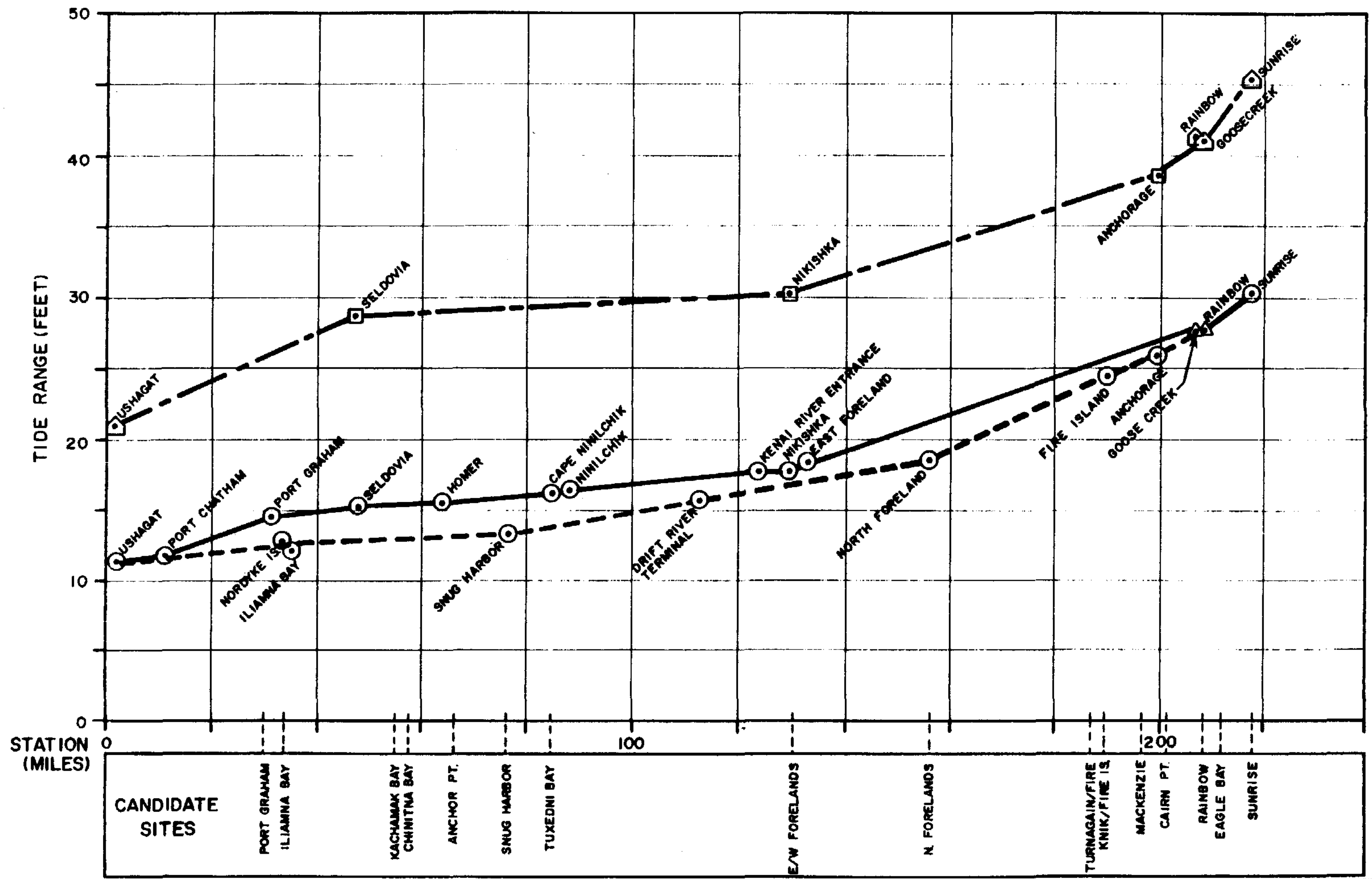
In view of this, it is concluded that it is unlikely that construction of man-made tidal barriers, in the upper Inlet particularly, will have a major impact on existing tidal levels and hence on the potential energy which can be developed. As a result, for the present studies, existing tidal levels shown on the profile on Figure 2 will be used for computing available potential energy. Further refinement of this issue may be necessary at later stages of the study.

To reproduce the existing tidal regime and to examine potential changes due to tidal barriers would require an extremely sophisticated and expensive model. This model would probably be a hybrid with computer simulation developing ocean tidal functions for input to a hydraulic laboratory model of the inner Inlet. Such a model will be required in later phases of the engineering to provide detailed input for final feasibility assessment and design.

2.2 - Tidal Characteristics

The variation in rate of energy production with the changes in tidal level is an important factor in computing the available energy from the tides. Since the available potential energy can only be realized by impounding water at high tide level and converting the head difference between the impounding basin and the ebbing tide, it is essential that the regular and predictable variations in tidal levels be included in the calculation of energy production.

The tidal variations are caused by a complex interaction of harmonic equations which reflect the gravity pull between the earth, the sun, moon, and planets. Certain of the harmonic constituents control the major variations in tidal range and tidal wave velocity. For example, the tides in Cook Inlet are designated as "mixed semidiurnal" in nature. This means that although there are two tides in a lunar day of 24 hours 50 minutes, there is a substantial difference in amplitude between the two tides in any one day.



LEGEND

——— MEAN TIDAL RANGE ON EASTERN SHORE AND TURNAGAIN ARM

– – – – MEAN TIDAL RANGE ON WESTERN SHORE AND KNIK ARM

—— – —— MAXIMUM TIDAL RANGE

⊙ MEAN TIDAL RANGE AT TIDE GAGING STATIONS BASED ON N.O.S. 1980 TIDE TABLES

△ MEAN TIDAL RANGE AT TIDE GAGING STATIONS WITH LIMITED DATA, BASED ON NATIONAL CIRCULATORY SURVEY DATA

⊡ MAXIMUM TIDAL RANGE APPROXIMATION, BASED ON N.O.S. 1981 SUPPLEMENTAL TIDAL PREDICTIONS

⌂ ESTIMATED MAXIMUM TIDAL RANGE

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FIGURE 2

The dominant constituent in the tidal equation is that due to the moon, so that the tidal waves occur essentially on a lunar cycle with slight timing differences due to other constituents that are out of phase with the moon.

Since tidal levels and timing are utterly predictable, so too is the available energy from this nondepleting resource - in perpetuity. Even so, the rate of energy production is variable albeit in phase with the various harmonic constituents that make up the tide. Since the dominant constituent originates with the moon, maximum energy output only coincides occasionally with peak demand requirements which tend to follow the normal solar working day. It is possible and practicable to provide for storage of tidal energy when it is produced out of phase with demand. Such provision may be hydroelectric pumped storage, compressed air energy storage or other advanced concepts yet to be fully developed.

2.3 - Conversion of Tidal Energy

To extract energy from the tides, it is necessary to convert the head of water in the impounding basin to a usable form of energy. This has been done historically in small installations by direct coupling of water wheels or turbines to mechanical drives. Such installations are not practical nor economic for large scale modern use. Present technology allows more efficient extraction of energy by use of low head hydraulic turbines to generate electricity following practice regularly adopted for low head hydroelectric projects. This electricity can be fed readily into existing or new transmission systems and used either as replacement for energy provided by fuel burning plants or else storage for later peak load use.

For purposes of initial site selection, the prime mode of extracting energy from the Cook Inlet tides is assumed to be by means of hydraulic turbines which generate electricity. During more detailed analysis of selected sites in Task 2, consideration will also be given to linking air compressors to hydraulic turbines. Such an arrangement could facilitate development of an energy storage system.

2.4 - Tidal Energy Production

The simplest method to generate electricity from the tides is by means of a single impounding basin. The basin is filled by open sluiceways during the rising or flood tide and power is generated by releasing the impounded water through turbines during the falling, or ebb tide. This is known as single basin, single effect ebb tide operation.

Although this arrangement produces predictable energy on a cyclical basis, its output is neither continuous nor available on demand as firm power for peaking purposes. The energy is produced in slugs in phase with the ebb tide cycle. Only minor retiming of the energy within the slugs of output is possible and this would result in lower overall energy production.

To illustrate the characteristics of typical single effect operation, data from studies for various tidal power developments around the world are given in Table 2.2. The possible application of the tabulated figures to the Cook Inlet studies will be discussed later.

A variation on the basic single basin, single effect operation is the use of double effect turbines, capable of generating power on both the ebb and flow tides. The output is again produced in slugs but the total generating time in any tidal cycle is lengthened. The double effect scheme will probably allow the production of more energy than the purely single effect operation although due to the less efficient design of a double effect turbine runner, the increase is small.

A further possibility is to equip the tidal barrage with hydroelectric plant capable not only of turbine operation in both directions but also having pumping capability. When tidal levels above and below the barrage are nearly equal, water can be pumped from one basin to another with relatively low energy. The pumped water can then be released through the turbines when a substantial tidal head differential has developed at a later time in the cycle. While the major existing tidal power plant at La Rance, France, is provided with this feature, later studies have established relatively minor benefits which are offset by some compromise in the optimum turbine efficiency and by the disadvantages arising from water levels being forced beyond natural tidal elevations.

Studies* for the Bay of Fundy Tidal Power Review Board of tidal power development in the Bay of Fundy compared single and double effect operations and showed that due to the added cost of more sophisticated equipment for double effect operation, the cost of energy generated by double effect operation was in fact higher than that for single effect (see Table 2.3). Furthermore, it was still not possible to generate significant firm power. It was possible to retime the energy to a limited extent, only, to meet peak system demand and while this increased the value of delivered energy, the benefit was offset by higher costs of output from the double effect plant.

At this stage of study, it is reasonable to assume that similar conclusions are likely to be reached for Cook Inlet. As a result, double effect operation will not be considered in detail in the present preliminary assessment studies. In later phases of work, the impact of double effect operation should be included in optimization processes.

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*As the major proportion of study effort applied to tidal power development throughout the world over the past fifteen years has been concentrated on Bay of Fundy studies repeated reference will be made to the results of this work. Application of these results to the Cook Inlet studies must take into account several major differences between the two tidal regions; e.g., Pacific vs. Atlantic tides, regional power/energy demand, etc.

2.5 - Retiming of Tidal Energy

If firm power is to be obtained from a tidal generating plant, it is necessary to retime the energy output so that it can be delivered to the system independently of the timing of the lunar cycle. To achieve this, a number of possible schemes have been proposed for at-site retiming.

(a) Single or double effect tidal power plants with hydraulically linked basins to provide dependable and firm power.

(b) Single or double effect tidal power plants with independent basins paired electrically to provide dependable and firm power.

In a number of earlier studies for tidal power developments in other areas of the world, consideration has been given to the use of linked and paired basins to retime the tidal energy. A summary of these is listed in Tables 2.4 and 2.5 together with an indication of the results of the studies.

It can be seen that, although it is possible to achieve a fair measure of retiming with power of 95 percent dependability obtainable only from linked basins, it is only achieved at the cost of reducing the annual energy production significantly, and increasing the cost of energy production. In addition, the firm power obtained is equivalent only to a relatively small proportion of the annual output which might be produced by a comparable conventional hydroelectric station. Firm power is unlikely to be obtained from independent basins unless they can be constructed at sites with sufficient naturally occurring difference in tidal phase to allow generation at one, while not at the other. This implies about a six-hour difference between the tidal effects at the two sites.

As a result, it has been concluded in studies for the Bay of Fundy in 1967 - 1969 and 1976 - 1977, and confirmed by others, that use of either linked or paired basins to retime tidal energy is not likely to be attractive. The best use of tidal energy will most likely be in its raw state, as generated by a single basin scheme operated to maximize energy production. If the receiving power system has a large capacity relative to the tidal power plant it may be able to receive the energy and assimilate it using existing storage (e.g., in hydroelectric plants), thus providing the necessary retiming capability. If the tidal power plant output is large compared with the system capacity it serves, specific provision for retiming may be necessary (e.g., pumped storage or compressed air storage plants). In general, however, the Bay of Fundy findings regarding unattractiveness of multiple basins for retiming are considered applicable to the Cook Inlet Study since conditions are favorable in the Cook Inlet area for less costly conventional off-site energy storage. Careful analysis is required of overall system requirements and existing, as well as likely future, generation modes. Consideration will be given to the need for the net economic benefits of energy storage facilities during Task 2 studies.

TABLE 2.1

POSSIBILITY OF RESONANCE IN COOK INLET

A. NEGLECTING FRICTION AND DAMPING EFFECTS

Assuming uniform, rectangular channel shape

Resonant length = $\frac{T}{4}$ gd

where T = tidal wave period = 12 hrs 25 min
= 44,700 seconds

g = acceleration due to gravity
= 32.3 ft/sec^2

average 100 ft ± at Forelands Point

Resonant length = $\frac{44{,}700}{5280 \times 4}$ 32.3 x (100 to 160) miles

= 120 to 152 miles

with theoretical tidal wave velocity
= 39 to 49 mph

Actual length - Barren Islands to Fire Island, about 190 miles

B. BASED ON ACTUAL TIDAL WAVE VELOCITIES

(a) Using timing from tide tables for tidal wave occurrence at various stations

- Overall velocity Barren Islands to Anchorage = 34 to 40 mph
- Velocity Barren Islands to Forelands = 45 mph
- Velocity Forelands to Anchorage = 21 to 34 mph

(b) Mean tide amplification

- Kodiak to Barren Islands $\frac{11.4}{6.6} = 1.7$
- Barren Island to Anchorage $\frac{26.1}{11.4} = 2.3$

TABLE 2.2

TYPICAL TIDAL POWER PLANT CHARACTERISTICS FOR SINGLE EFFECT OPERATION

This table is based on optimized developments as reported in the results of various earlier studies.

Tidal Power Development	Mean Tidal Range (ft)	Gross Energy Potential (G.E.) GWh	Installed Capacity MW	No. of Sluiceways	Net Annual Energy Production (AE) GWh	$\frac{AE}{GE}$	Load Factor $\frac{AE \times 10^3}{8,760 \times MW}$
Fundy - Site A6	33.6	22,600	1,643	30	4,533	0.2	0.31
Fundy - Site A8	34.2	15,700	1,147	24	3,423	0.22	0.34
Fundy - Site B9	39.1	57,600	4,028	60	12,563	0.22	0.36
LaRance	27.6	3,050	240	NA	554	0.18	0.26
Kislaya Guba	7.9	22	0.8	NA	2.3	0.1	0.33
Korea - Site 6B	20.0	7,300	450	NA	1,345	0.18	0.34
Korea - Site 6A	20.0	11,100	810	NA	2,229	0.2	0.31
Korea - Site 3B	18.7	5,100	330	NA	900	0.15	0.28
Korea - Site 8	15.7	5,500	330	NA	820	0.15	0.28
Cook Inlet (Swales)	24.6	34,200	2,800	NA	6,000	0.18	0.25

Notes:

1. The studies from which these figures are abstracted were carried out by different study teams, at different times and for a variety of economic and tidal conditions. Care is needed in using the information to ensure that the various study conditions are properly correlated.

TABLE 2.3

DOUBLE EFFECT OPERATION

From the Bay of Fundy studies,* typical at-site figures for single and double effect operation at two sites are:

	SITE A8		SITE B9	
	Single Effect	Double Effect	Single Effect	Double Effect
Net Capacity, MW	1,085	1,292	3,800	5,118
Annual Energy output GWh	3,423	3,617	12,653	15,179
Capacity Factor, percent	36	32	38	34
At-site energy cost** mills/kWh	21.8	25.8	17.9	20.0

The above figures represent operation in each case so as to produce maximum energy at minimum cost. To produce more energy at either site, it would be less costly to increase the installation for single effect operation. Operations to retime the energy will reduce the energy available and increase the at-site cost of energy.

*References - Reassessment of Fundy Tidal Power
Reports of the Bay of Fundy Tidal Power Review Board and Management Committee, November 1977.

**Based on cost estimates made in 1976 and on real discount rate of 5-1/2%.

TABLE 2.4

HYDRAULICALLY LINKED BASINS

A. FROM BAY OF FUNDY STUDIES 1969

(Reference-Feasibility of Tidal Power Development in the Bay of Fundy, October 1969)

Comparison of optimized single effect energy production at sites 7.1 and 7.2 with optimized double basin operation for the same sites.

	Site	Installed Capacity MW	No. of Sluices	Average Annual Energy Production GWH
Single Basins	7.1	60 @ 27 = 1,620	48	4,200
	7.2	36 @ 27 = 972	29	2,690
	Total	96 2,592	77	6,890
Double Basin	7.1 & 7.2	40 @ 27 = 1,080	164	4,621

With the double basin there is a peak power production capability with dependability of 95 percent of 712 MW.

Based on the above figures for these optimized installations the energy generated by two single basin developments is 1.5 times that for the double basin operation.

For the specific sites studied by the ATPPB in 1969, it was reported that "the unit cost of power production would be about twice such costs from other schemes" and when rough cost parameters are applied to Cook Inlet it appears likely that two single basin schemes would cost about 1.3 times the double basin scheme at Fire Island. Using the energy production rates from the Bay of Fundy, this means the energy from a double basin in Cook Inlet could cost 1.5/1.3 = 1.15 times that from the two comparable single basin schemes.

B. FROM BERNSHTEIN

(Reference "Tidal Energy for Electric Power Plants")

For a double basin scheme 13 percent of potential energy from the two basins is generated. Compared to the energy production of 20 to 22 percent calculated for the Bay of Fundy in 1976 - 1977, this gives energy production from 2 single basin schemes of

$$\frac{20}{13} \text{ to } \frac{22}{13} = 1.5 \text{ to } 1.7$$

times that from the double basin operation.

TABLE 2.5

PAIRED BASINS

A. BAY OF FUNDY STUDIES 1969

Paired basins, Sites 7.1 and 7.2, linked electrically

	Site	Capacity	Sluices	Dependable Peak Capacity MW	Net Annual Energy Production GWh
Paired	7.1	864	27		
	7.2	864	27	941	4,367

Operating independently (for maximum energy generation)

	Site	Capacity	Sluices	Dependable Peak Capacity MW	Net Annual Energy Production GWh
	7.1	1,620	48	0	4,200
	7.2	972	29	0	2,690
Total					6,890

Notes:

1. The paired basins were not optimized. From the report it appears likely that if installations are compared on the same basis, then energy production from the paired basins will be about 93 percent of that from similar single basin plants operated to generate maximum energy.
2. Dependable peak capability is defined as the level of peak output that could be maintained 90 percent of the time for peaking hours.

3 - DATA COLLECTION

The initial study effort centered on collecting and assimilating available data from other relevant studies of tidal power and on the Cook Inlet geographical region. Two types of information were sought for inclusion in the study data base: (1) information summarizing previous studies of tidal power in Cook Inlet and other regions and (2) data specific to the Cook Inlet area, including land use and status, environmental and geological conditions and tidal information.

The purpose of this section of the Task 1 report is to provide a summary of the pertinent information as well as a reference list.

3.1 - Previous Studies on Tidal Power

As there are relatively few areas in the world where tidal characteristics justify realistic consideration of the harnessing of tides for usable energy production, there are few detailed studies of tidal power potential. Indeed, only two such developed plants exist in the world: the 240 MW facility at LaRance, on the northwest coast of France, and a small Russian pilot plant off of the Arctic coastline at Kislaya Guba.

The area of the world generally accepted as having the greatest potential for tidal power within reach of market is the Bay of Fundy in the Maritime Provinces of Canada. The potential Fundy tidal power project has also been subject to the greatest amount of study. During the two past decades governmental boards in Canada have studied the matter in considerable detail and produced preliminary designs for the development of tidal power. Among other findings, the most recent study to which Acres provided engineering input concluded that Fundy tidal power is technically and economically feasible as part of the projected electrical generation supply systems in the Maritime Provinces of Canada with possible benefits arising from integration with the larger interconnected system in northeast U.S.A.

Aside from merely providing site specific data, the Fundy studies provide an established framework for conducting studies, general conceptual approaches and designs which can be applied to other tidal projects under consideration. Another tidal power possibility in the general area of the Bay of Fundy at Passamaquoddy Bay/Cobscook Bay, has been assessed several times for power potential by the U.S. Department of the Interior, the U.S. Army Corps of Engineers and the International Joint Commission. Tidal ranges are less than those occurring at the head of the Bay of Fundy and studies have indicated only marginal feasibility.

Stone and Webster Engineering Company completed a comprehensive study in 1977 of tidal power development in the United States for the Energy Research and Development Administration (now DOE). The study reviewed worldwide potentials and developed projects, conceptual methods of operation, equipment design, suitability and availability and project construction techniques.

The study also assessed the tidal potentials in the two regions believed suitable for tidal power developments in the U.S.--Passamaquoddy Bay in Maine and Cook Inlet in Alaska. Consideration was given to potential sites, energy production, socioeconomic, environmental and legal constraints to development, as well as to the assimilation of output into the electric power systems and an economic evaluation. The published findings showed that over a life-cycle analysis, given increasing costs of alternative fuels, the output of a tidal project could be competitive. It was also found that there were no overriding environmental or institutional constraints to development.

3.2 - Cook Inlet Tidal Studies

Several other small scale studies have addressed the potential of harnessing Cook Inlet tides. In 1967, a paper was published by Wilson and Swales (Ref A.4) which assessed the tidal power potential of Cook Inlet. The authors performed an energy potential analysis and outlined development plans for several site areas in the upper inlet. The study presented conceptual development methods, and addressed the cost and benefits of tidal development. The authors concluded that large quantities of energy could be generated from tidal power, possibly at rates competitive to other conventional energy sources. It was noted that energy demand forecasts for the region did not warrant full site developments at either Turnagain or Knik Arms.

R. Johnson's (Ref A.3) paper in 1975 recommended that the Cook Inlet tidal project take a two-basin form with tidal dams across the openings of both Arms, connected to Fire Island with a third structure connecting Fire Island and Pt. Campbell which would accommodate the tidal power generating plant. The report reviewed power production possibilities, and developments in other areas. A preliminary cost estimate of tidal development was also presented.

A paper published in 1976 by Behlke and Carlson (Ref A.1) reviewed the hydraulic theory behind tidal power development, cited the previous study by Wilson and Swales and proposed consideration of tidal development on a relatively small scale. The paper suggested that, until large projects became economically feasible, a few small plants could be constructed. These plants could be spaced throughout the Inlet to take advantage of the tidal lag. Energy production from the systems of plants would possibly permit production of firm power since generation would be sequential rather than concurrent.

3.3 - Study References

There have been numerous other references used during the study. Of particular value are the studies of causeway crossings of Turnagain and Knik Arms, and the submarine cable crossing of Knik Arm. Other useful data was supplied by the National Oceanic and Atmospheric Administration and the U.S. Geological Survey. A complete list of assembled reference material follows.

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4 - SITE SELECTION

The primary objective of the site selection efforts was to review available data, to consider potential sites and configurations for tidal plants throughout the Cook Inlet area and to select sites for more detailed evaluations and comparative study.

4.1 - Methodology

The site selection process proceeded essentially in three stages. Initially, an almost infinite number of potential sites were available in the Cook Inlet region. Criteria was developed to identify and screen sites to a manageable level and to identify those few which are most appropriate for further study. A flow chart representing the site selection process is provided as Figure 3.

The first step of the study was to undertake a site identification effort. Based on available NOAA (National Oceanic and Atmospheric Administration) navigation charts and USGS (United States Geological Survey) topographical maps, a survey was made of the Cook Inlet area from the entrances at the south end from Cape Douglas to the Barren Islands, to Cape Elizabeth to the deltas of Matanuska and Knik Rivers in Knik Arm, and to Portage in the Turnagain Arm.

Numerous general criteria were used in developing the initial list of sites including previous studies, bathymetry, tidal range, environmental and geotechnical considerations. This first stage effort produced sixteen potential siting areas.

The second stage was a more detailed review of these study areas. The review entailed further consideration of site development concerns including foundations, structural lengths, access, transmission line routings, environmental impact and navigation requirements. Capacity and energy estimates were made for each site. Several other parameters, which related energy yield to size of dam and to closure problems were also calculated for use in site comparison.

With this additional information available on the sixteen sites, nine of the less attractive sites were dropped from consideration leaving seven sites to be reviewed for final selection. At this final selection, primary consideration was given to geographic location and development potentials of each particular site. For preliminary assessment purposes, it was considered important to select several sites which would yield the most information on the ultimate feasibility of tidal power development in Cook Inlet. Thus it was considered undesirable to retain sites which were very similar in location, size and potential development problems.

The following pages in Section 4 discuss, in depth, the siting areas considered and the criteria used in site selection.

FLOW CHART
SITE SELECTION

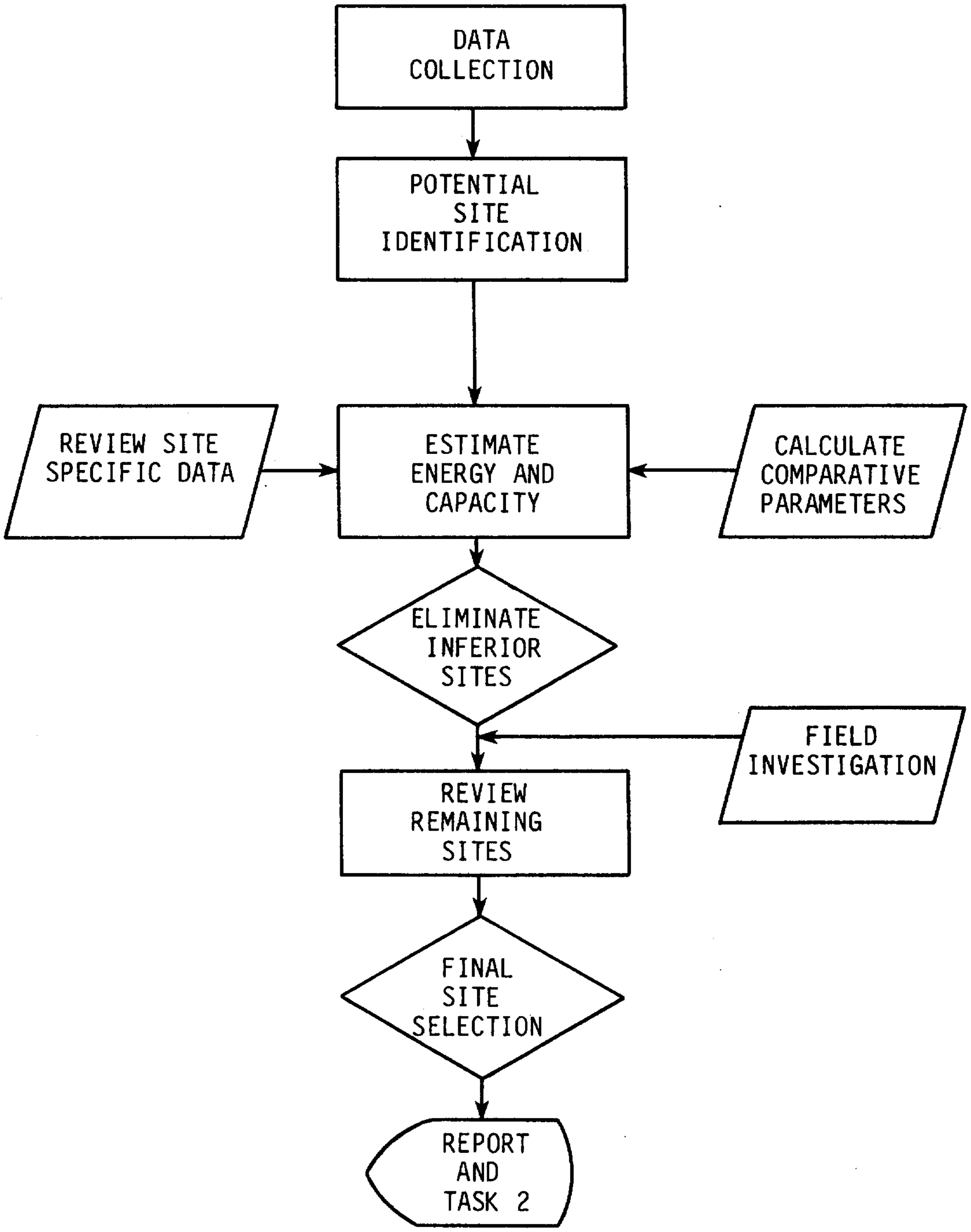

FIGURE 3

4.2 - Site Identification

The objective of the identification stage was to provide a list of potential sites for more detailed review and parametric analysis. Three major sources of data were used in this first stage of the process: (1) the Cook Inlet Northern and Southern Part Navigation Charts published by NOAA, (2) a tidal plot of Cook Inlet (developed from available tidal range information), and (3) previous studies of tidal power in Cook Inlet. Sites were considered primarily as single basin, single effect schemes.

Several criteria were followed on a general basis in selecting the initial list of sites:

- Bathymetry: The depths of water at a potential site were reviewed to make an initial comparison of the size of closure dam and the depth of powerhouse foundations which would be needed relative to the available tidal storage behind the dam. Sounding powerhouse foundation depths on the NOAA navigation charts were used to indicate depths.

- Tidal Range: Based on available data a plot was made of mean tidal range in Cook Inlet. This plot is shown as Figure 2. The plot provided a systematic estimate of tidal ranges at sites where specific data was unavailable.

- Previous Studies: Sites which were reviewed or mentioned by previous studies were given consideration and in most cases were included on the initial list of potential sites to be screened.

- Environmental and Geotechnical: In establishing the sites, these constraints were given general consideration. Sites were not rejected at this stage due to specific problems. In establishing the site areas, situations where there were poor abutment conditions and wetlands were avoided.

Applying these criteria to the analysis procedure, sixteen sites were established for further consideration. These sites are listed in Table 4.1 and shown in Figure 1.

To keep the number of siting areas to a manageable level, sites which were very similar in nature were avoided. For example, in southern Cook Inlet on the western shore there are two side bays somewhat smaller in tidal power development potential than the full estuary development sites: Iliamna Bay and Iniskin Bay. A review of the bathymetry showed that both sites are small, and the latter, Iniskin Bay, is very shallow throughout most of its reach, indicating minimal water storage potential. Thus only Iliamna Bay was included in the site list. However, during further consideration of the sites, these early decisions of location were considered to be subject to review.

Another example of the similarity trade off is a Kalgan Island crossing of Cook Inlet compared to a dam between the East and West Forelands. Since both sites have similar storage areas and tidal ranges, energy potential is approximately the same. Since the Forelands dam would be shorter in length, it was retained for further study.

Other areas were rejected due to the length (quantity) of dam structure compared to storage. Examples of the application of this criteria were the wide open bays at Kamishak, Redoubt, Chicaloon and Goose Bays. Similarly, dam sites across Cook Inlet south of Anchor Point were rejected due to sheer size of development and low tidal ranges.

One other area, partly outside of Cook Inlet, was given consideration due to previous reference to the potential for development. Development of a tidal plant at Whittier, on Prince William Sound could take advantage of the mean water level difference between the Sound and Cook Inlet arising from the phase difference in tides at these locations. To develop this potential head, which is sustained continuously, a system of undergound tunnels and overland canals about 10 miles long would need to be constructed, in addition to tidal dams and power generating equipment. These structures would need to be of very large capacity to carry enough water to generate significant power at the relatively low average head of 20 feet. It was judged that such a development would not be competitive with other more conventional tidal power arrangements or other power alternatives in the study area.

Consideration was also given to a suggestion by Behlke (Ref A.1) that several smaller plants could be constructed along the inlet to take advantage of tidal lag and avoid retiming of energy. Although sound in theory, experience in other studies has indicated that, as tidal power plants are capital intensive developments, they are likely to be economically competitive only at a relatively large scale. Thus, if energy from a plant has to be retimed, this can be accomplished more economically by building a less capital intensive retiming medium such as a pumped storage or a compressed air system. The sites mentioned by Behlke were reviewed in the site identification process.

The Stone & Webster report (Ref D.5) identified the potential for a double basin scheme which would cross both the Turnagain and Knik Arms at Fire Island with a third dam between basins from Pt. Campbell on the Anchorage Peninsula to Fire Island. This configuration was included as two individual sites in the site list.

4.3 - Candidate Site Review

The second phase involved a site specific review of available data to compare sites for the purpose of selecting those for Task 2. The phase involved four steps: (1) site review, (2) calculation of energy and capacity, (3) assessment of other comparison parameters and (4) elimination of inferior sites. Review of the sites was based on single basin single effect configuration of a tidal project.

The first step consisted of a map and literature review on a site by site basis to bring to light all available information relevant to tidal power development. Sites were located on the USGS 7.5 Minute series maps to determine land usage of adjacent areas, site access, possible routes of transmission line and potentially sensitive environmental areas. Literature from the USGS and previous studies of Cook Inlet crossings were checked for data on sub channel geology and foundation conditions. The study team's knowledge of the area was applied to note any other site development advantages or disadvantages. Barrier or dam lengths and depths were also estimated. Cross-sections of the inlet crossing were plotted.

From this review, a summary sheet which contains information for each area of concern was completed. These summary sheets are included in the end of this appendix.

The following is a brief summary of information collected for each site:

(a) Site 1 - Port Graham: The tidal dam would be located across Port Graham Bay with a structure length of 2.5 miles. Mean tidal range is about 15 feet. Abutments to shore would be in the vicinities of Dangerous Cape and Russian Point. Land access to the site would be difficult. Transmission line routing would be a major effort, possibly crossing under Kachemak Bay to Homer. Although foundations appear adequate, a fault line runs parallel to the site about 1/2 mile to the east.

(b) Site 2 - Kachemak Bay: The tidal dam would span the bay from Barbara Point to Bluff Point, a distance of about 11 miles. Mean tidal range is about 15.5 feet. Access to the site would be relatively easy from the Homer area. Likewise transmission lines would link to the system there with an uprating of the line to Anchorage. Foundation conditions appear adequate. The site is a very sensitive area environmentally and is an important spawning ground for king crabs. Development would interfere with major navigational traffic to Homer.

(c) Site 3 - Kachemak Bay: This site would be located farther up the bay from Site 2, about 4 miles east of the Homer Spit. Mean tidal range is over 15.5 feet. The structure length of the dam would be about 7 miles. Site access, transmission and environmental concerns would be about the same as Site 2 although there would be less interference with Homer traffic.

(d) Site 4 - Iliamna Bay: The tidal dam would cross the bay at the mouth of the Bay. The structure length would be about 1.3 miles at a point where the mean tidal range is 13.0 feet. Land access and transmission would have to be constructed over long and difficult terrain. Reef areas exist along the coast at the south abutment. A nearby geological fault line runs parallel to the dam center line.

(e) Site 5 - Chenetna Bay: The structural length of a tidal dam across the mouth of the bay would be over 3.5 miles long. No land access exists and it would be extremely difficult to provide. Power would possibly have to be transmitted by underwater cable across Cook Inlet. Foundations appear adequate to the south but poor to the north. Active volcanos are within 15 miles of the site.

(f) Site 6 - Tuxedini Bay/Snug Harbor: Mean tidal range at this site is 14 feet. Site development consists of 2 dams; one across the bay and one across the channel, both connecting to Chisik Island. Total length of structure would be less than 4 miles. No land access exists from any shoreline. Transmission routing would likely be under Cook Inlet. Chisik Island is a National Wildlife Refuge.

(g) Site 7 - Anchor Point: An east-west tidal dam across Cook Inlet at this point would require a structure over 30 miles long with the center depths to 240 feet. Mean tidal range at this point is nearly 16 feet. Foundations on both shores are surface glacial and delta deposits. Anadromous fish spawning and other migratory life would be affected by closure. Provisions would need to be included for navigation to Anchorage. Access to the site on the east shore exists.

(h) Site 8 - East-West Forelands: The forelands site has previously been identified in Cook Inlet tidal power studies. A tidal structure across the inlet would be about 10 miles long. Mean tidal range is nearly 18 feet. Several road corridors are in the area but no major developments are nearby. The site foundations, environmental problems and navigation conflicts are similar to Site 7.

(i) Site 9 - North Foreland: The tidal dam would run in a NW-SE alignment from North Foreland on the west shore. Tidal range at the site is about 18.3 feet. No land access is available on the west shore but small road corridors run another 10 miles on the east coast. Aside from the similar concerns as Sites 7 and 8, land areas around the dam are interspersed with wetlands.

(j) Site 10 - Knik Arm/Fire Island: Mean tidal range at the site is 24.4 feet. The dam would consist of 2 sections, one from Point Campbell to Fire Island and from Fire Island to the north to a point east of the Little Susitna River. Structure length would be about 8.5 miles. Access and transmission would not pose major problems. Foundations appear marginal in quality from available data. This site was identified by Stone & Webster. A dam would be above the major anadramous fish river, the Susitna, but would affect some smaller rivers.

(k) Site 11 - Turnagain/Fire Island: This site was identified in the Stone & Webster study as part of a double basin scheme, coupled with Site 10. The dam scheme would cross Turnagain Arm from Point Possession to Fire Island. A second dam would extend from Fire Island to the mainland at Point Campbell. Mean tidal range is about 24.5 feet. Available data on geology and foundations indicate only marginally satisfactory conditions. A dam across Turnagain Arm would have a lesser impact on migratory species and navigation. Total structural length would be about 10 miles.

(l) Site 12 - Point MacKenzie: This tidal dam would cross the Knik Arm from Point MacKenzie to Point Woronzof, a distance of about 2.5 miles. Mean tidal range is 26 feet. There are no existing roadways directly to the site but providing access and transmission would not be difficult. Provision would need to be made for Anchorage navigation. The abutment areas of the dam are deltaic deposits.

(m) Site 13 - Cairn Point: This site is located about 3 miles up from Anchorage and Knik Arm, at a point where there is a constriction in the inlet. Length of the dam would be 3 miles in this area where the mean tidal range is 25.5 feet. This site would have similar impacts as Site 10 with the exception of the Anchorage navigation conflict.

(n) Site 14 - Above Eagle Bay/Goose Bay: This site is the furthest upstream which was identified on the Knik Arm. It is situated at the narrowing of the channel above Eagle and Goose Bays. A structure nearly 4 miles in length would have to be constructed here. The mean tidal range is 23.4 feet. The site is about 5 miles from the Alaska Railroad Corridor, where a transmission link could be made. Much of the storage area above the dam forms into mud flats during low tide.

(o) Site 15 - Rainbow: This tidal dam would cross the Turnagain Arm from a point near the mouth of Rainbow Creek, southward to the shore about 2 miles east of Resurrection Creek. Structure length would be about 4 miles. The area has a mean tidal range of over 26.5 feet. Site access is very good on both sides of the Arm. There are apparently fewer environmental problems with a dam across the Turnagain Arm than anywhere else in the inlet.

(p) Site 16 - Sunrise: The mean tidal range of nearly 30 feet is higher at this site than at any other in the inlet. Structure length of a dam crossing the Turnagain Arm between Bird Point and Snipers Point is about 1.5 miles. Access and impacts of this site are similar to Site 15. Most of the storage area at the site is mud flats during low tide.

4.3.1 - Energy and Capacity

In order to compare the development potentials of the sites, it is necessary to develop an estimate of each site's energy and capacity. For the sixteen selected sites, gross potential energies were calculated using Bernshtein's formula (Ref D.2).

$$E = 0.475\ AR^2 \times 10^6 \text{ kWh/year}$$

where A = area of the basin at mean tide range in square miles.
R = Mean tidal range in feet.

This formula provides a method of obtaining a preliminary estimate for available gross energy at a tidal power site, although it does not take into account possible effects on the tide due to basin configuration. Where the length of the basin is close to the critical length for tidal resonance, then the imposition of the power plant could have a significant effect on the tidal range and therefore the energy available. The only sites where this effect could be of concern would be the main inlet crossings, Sites 8, 9 and 10.

It can be seen that at many of the sites, a significant portion of the basin is uncovered at lower tide. For this reason, at each site, the basin was planimetered on the NOAA map at both low and high tides and the average taken for use in the Bernshtein formula.

From studies conducted in other areas, it has been found that annual energy production from a tidal plant is only a fraction of the theoretical gross energy production which is calculated from the Bernshtein formula. The proportion of annual energy production related to gross energy potential, calculated at other sites varies from 0.18 at LaRance, France, to 0.22 for sites in the Upper Bay of Fundy. The factor to be applied depends on tidal characteristics, type and cost of generating plant and method of operation. Tides in Cook Inlet can be described as diurnal, meaning there are two complete tidal oscillations daily, with marked inequalities in the two daily oscillations. For Cook Inlet, the energy output factor selected was 0.20.

To date there is no definite relationship established between the type of tide and the amount of energy available from a specific installed capacity It appears likely, however, that the optimum installed generating capacity for tides with marked daily inequalities will be higher than that at a similar site with tides with little or no inequalities.

To determine the installed capacity in MW required to generate that amount of energy consideration was given to the characteristics of the mixed semidiurnal tides at Cook Inlet as opposed to the more regular semidiurnal tides in the Bay of Fundy.

The gross energy potential, and hence the factored net annual energy are related to the mean tidal range, whereas the power output in MW/turbine is based on the rated head which is proportional to the maximum tidal range. For the Bay of Fundy, the ratio of the rated head to the mean tide range is 0.62 to 0.63. Also, the ratio of the maximum tidal range to the mean tidal range in the Bay of Fundy varies from 1.28 at Site A6, to 1.29 at A8 and 1.34 at B9.

At Anchorage the ratio $\frac{\text{Max tidal range}}{\text{Mean tidal range}} = 1.49$. If the diurnal component is eliminated, then the ratio becomes 1.49/1.11 = 1.34, which compares well with Site B9 in the Bay of Fundy.

It is concluded that to obtain equivalent energy proportional to that for the Bay of Fundy, it will be necessary to increase the turbine rated head by the equivalent of the diurnal tidal component (11 percent).

Since the power output is proportional to the rated head to the power 1.5, the output for equivalent energy is $(1.11)^{1.5} = 1.17$ times that for the Bay Fundy sites. As a result, the load factor used in the site selection studies was reduced for Cook Inlet from 0.34 to 0.29.

The equation then needed to estimate installed capacity was:

$$\text{Capacity (MW)} = \frac{\text{kWh X } 10^6}{.29 \text{ X } 8760 \text{ hrs X } 10^3}$$

A complete estimate of the energies and capacity estimates for the sites is included as Table 4.1.

From the table, it is readily seen that there is a wide range of energy and capacity potential at the sites, from 50 MW to over 25,000 MW. Obviously, the larger group of sites would be unusable in the conventional electrical system in the Railbelt during the period covered by the ISER forecasts (through 2010).

4.3.2 - Parametric Calculations

To avoid producing detailed cost estimates and layouts at each of the sixteen potential sites in advance of the site selection itself, it is necessary to find some alternative parameters for comparing sites to one another. A typical parameter representing the relative capital cost of tidal power plant development at a particular site can be derived from the product of the length of the tidal barrier times the square of the height of the closure structure at the deepest point ($L \text{ X } H^2$). If this product is divided into the net annual energy in kilowatt hours, the result can provide a basis for comparison of the at-site cost of energy from the various alternatives being considered. High values for this parameter generally indicate favorable economic benefits can be achieved. For some shallow sites, a minimum depth of 65 feet was used for calculation since excavation to that depth would be necessary in any case to place the tidal power generating plant structures.

This cost parameter is based on the generalized assumption that the capital cost of the tidal power plant is proportional to the cost of civil works and that the civil costs are roughly proportional to the volume of the barrier. For comparable tidal ranges and plant outputs, however, the cost of the turbine and other mechanical and electrical generator equipment can be assumed to be constant. For lower ranges of tidal amplitude, the per megawatt cost of turbine/generators is likely to be appreciably more than that for higher tides.

One limit to be imposed on the parametric comparison concerns the requirement to effect closure across the tidal basin at a key stage during construction. A minimum area must be provided up to this stage to accommodate tidal flows past the barrage under construction. Arrangements are necessary to make an orderly closure of this diversion channel when other construction is complete. To obtain an indication of the problems to be expected, estimates were made of unit capacities, number of units and the length of the powerhouse at each of the sixteen sites. These estimates are shown on Table 4.2. The generating units assumed for screening purposes are 24.6 feet (7.5M) diameter bulb turbines, the largest ever installed in the world. The rated head at which the capacity for each of the sites would be established was estimated at .64 of the mean tidal range, based on the diurnal nature of the tides and on findings of previous studies. Although this parameter does not include the length of sluiceways also needed in the development, it should be noted that these also have a bearing on the feasibility of final closure of the structure.

At most of the sites, it appears unlikely that velocity of flow at closure will affect the feasibility of tidal power plant construction using floated in powerhouse and sluiceway structures.

For the very large sites with lower tidal ranges (numbers 7, 8 and 9) the calculated ratio of length of powerhouse to barrier length approaches one, a situation which is not feasible. Should development of these sites become desirable, substantially larger sized generating units may be necessary, or else a system of unit stacking (with one horizontal shaft turbine generating unit above another) would be necessary.

4.4 - Parametric Screening

A comparison of the sixteen sites (data on Tables 4.1 - 4.3) allows a secondary screening out of sites which are obviously inferior in tidal power development potential.

The initial observation which can be made from a comparison of capacities and energies are that Sites 7, 8 and 9 (i.e., the large crossings of Cook Inlet) provide energy potentials larger than the demand projections for the Railbelt over any reasonable study period. The smallest of these sites, North Foreland, would provide an annual energy of 32,800 GWh, over three times the total electrical demand of the highest forecast for the year 2000 used in the Susitna studies. Even with a massive influx of industrial development, generating capability would far exceed demand. These sites would always be available for ultimate development of a massive amount of power, should the need arise.

The larger sites in question would also present the possibilities of severe environmental impacts particularly during construction, most notably in regard to the large area of inlet which would be affected. Furthermore, the tide level changes could effect salmon spawning in the rivers in upper Cook Inlet and also make it necessary to pass the entire salmon run through the tidal facility. In addition, the tide level changes could have an impact on other areas influencing existing tidal patterns and on navigation. Additionally, in considering the elimination of these sites from further study, it should be noted that the "developmental parameters" were less attractive than those for other sites.

The second group of sites which do not compare favorably with other sites within the list of sixteen comprises the first six at locations in the lower Inlet. Four of these six sites are small, and would probably not justify the relatively high capital investment required for a tidal power plant. It is likely that a small hydro site could compete effectively with these developments. Two of the sites, while sufficiently large, are in extremely sensitive environmental areas. Finally, the selected parameters for all six of the sites do not compare well with those for other sites. In all probability, too high a cost in tidal dam construction would be involved in relation to the amount of annual energy which could be generated.

The following list of six sites summarizes the basic reasons for their elimination from further study:

(1) Port Graham
- excessively small
- remote

(2) Kachemak Bay (1)
- known adverse environmental conditions
- poor comparative parameters

(3) Kachemak Bay (2)
- known adverse environmental conditions
- poor comparative parameters

(4) Iliamna Bay
- excessively small
- remote

(5) Chinitna Bay
- remote
- poor comparative parameters

(6) Tuxedni Bay
- closure problems
- poor comparative parameters
- remote

At the end of this stage of selection, seven sites remained for further consideration and field reconnaissance.

4.5 - Selected Sites

In reviewing the remaining seven sites, several additional selection parameters were introduced. These were (1) specific geographic location, (2) site development potential relative to possible electrical demand growth, and (3) input from preliminary field reconnaissance.

Since all of the remaining sites were in the upper Cook Inlet area, across either the Knik or Turnagain Arms, it was concluded that the study should preferably include one site from each arm of the inlet. In this manner, the effects of icing conditions, environmental impacts, and tidal ranges and other factors can be studied to compare relative merits and problems of development of one area with another.

As for site development potential, there is merit to reviewing sites with differences in capacity to provide information such as:

- Scale of development necessary to provide cost effective output from a tidal project.
- Potential for the Railbelt electrical system to absorb different levels of output from a tidal power plant.
- Planning for a project under a "constrained" versus an "unconstrained" forecast of future electrical demands.

Given these additional criteria, it was initially considered that, in the Turnagain Arm, the Sunrise site should be included in Task 2 studies. The site has the highest mean tidal range of all those reviewed, yet in view of the limited size of the tidal basin, has the smallest estimated capacity and energy production. However, field reconnaissance at the site has indicated that the basin would be almost completely dewatered during extreme low tide. This condition could cause major problems both in construction and operation of a tidal plant and for this reason, the site at Rainbow was selected in preference to Sunrise. The Rainbow site is estimated to produce a net annual energy output of 3000 GWh, comparable to the level of the initial development of the Susitna hydroelectric alternatives under consideration. The site would also involve an installed capacity which could be conveniently associated with the Railbelt load projections for the 1995-2000 range. Rainbow also has the advantage of offering a potential causeway to the Kenai Peninsula.

The tidal power site at Turnagain Arm/Fire Island (Site 11) planned as a single basin development would possibly present some difficulty in matching capability to demand. The development of potentially over 6500 MW and 16,600 GWh would stretch the bounds of even the unconstrained electric load case. The highest forecast used for the Susitna study estimated the 2010 pool peak at 2900 MW and 15,900 GWh. Although this aspect alone is not sufficient grounds to dismiss the site, a review of the comparative parameters applicable to the site shows it to be inferior to both the others on the Turnagain Arm. The ratio of powerhouse length to barrier length also indicates the potential for closure problems.

Rainbow, a site located on Turnagain Arm, is reasonably representative of practical means of developing tidal power potential in this location and of other alternative sites nearby. A review of the sites on the Knik Arm shows that there are four from which to make a selection. Sites 10, 12 and 13 all are of similar magnitudes of development ranging from 2200 to 2900 MW. Only Site 14, above Eagle Bay, has a capacity of 1400 MW, similar to the range of the Rainbow site.

Three sites, Cairn Point (13), Point MacKenzie (12) and Knik Island/Fire Island (10) are similar in location, potential impacts and potential energy. Each could provide a causeway benefit across Knik Arm. A secondary review of the comparative parameters calculated for the sites shows the Point MacKenzie site to be superior to the other two. Due to channel configuration, it has a significantly higher AE/LH^2 parameter of

27, compared to 15 for Sites 10 and 13. Although these parameters are only indicators, this difference is large enough to indicate a real advantage for Site 12. The closure parameter, LP/L indicates that there may be significant closure problems at the Cairn Point site, requiring a system of stacking powerhouse generating units to reduce width. Even if found to be feasible, the added costs of this measure will tend to make the site less competitive. The comparison of the closure factors of .31 and .53 for Sites 10 and 12, respectively, indicates some advantage for Site 10. It is not expected, however, that the increased difficulty in closure problems would render Site 12 impracticable from the point of view of closure.

It should be noted that several problems inherent in development at Cairn Point could be mitigated by moving the site upstream. Due to the minor change in capacity and energy that would be involved, it was decided not to consider the implications of minor site relocation.

The Eagle Bay/Goose Bay, Site 14 appears to have very strong potential as a developable site. Parametrically, it compares favorably to all of the other sites on the second stage selection list. It could provide a causeway across Knik Arm without requiring navigation locks. Although very similiar to the Rainbow site in energy potential and "fit" into the generation system, and mutually exclusive to the Pt. MacKenzie site, the attractiveness of the development potential merits its inclusion in Stage 2 studies. Additionally, Site 14 can be compared directly to Site 15 in consideration for potential constrained case development, as they are of comparable size.

Finally, consideration was given to retaining Sites 10 and 11 as a hydraulically linked double basin scheme for two major reasons. Firstly, the other two sites do not provide the potential for studying a hydraulically linked scheme. Secondly, prior studies have identified the double basin site as having significant potential for development. However, several current considerations lead to the conclusion not to consider this alternative further. Firstly, the energy developed by these sites may be on the order of 20,000 GWh, well beyond the high energy forecasts made by ISER in 1980 and in any case stretching beyond the conceivable limits of even an unconstrained energy forecast. Secondly, the individual sites appear to have developmental problems. Field reconnaissance indicated that the necessary saddle dam and structures between Campbell Pt. and Fire Island, which would house generating units would be difficult to develop due to mud exposure at low tide. Thirdly, the combination of Rainbow and Pt. MacKenzie sites, which are not mutually exclusive would allow for an electrically connected scheme at sites which appear to have more development potential, should the benefits of a double basin scheme be desired. Finally, the combination of these factors, plus the indication from previous studies that double basin schemes are not particularly more attractive than single basin schemes, eliminated this scheme from further consideration.

In conclusion, configurations will be developed at the following three sites and carried forward for comparative evaluation in Task 2:

(a) Rainbow (Site 15) on the Turnagain selected due to location on the Turnagain Arm, parametric comparison with other sites and compatibility with Railbelt load projections.

(b) Point MacKenzie - Point Woronzof (Site 12) on the Knik Arm selected due to location on the Knik Arm, parametric comparison with other sites and compatibility with an unconstrained load growth in the Railbelt.

(c) Above Eagle Bay/Goose Bay (Site 14) on the Knik Arm selected due to parametric comparison with other sites, compatibility with Railbelt load projections and avoidance of some environmental conflicts of sites further down the Knik Arm.

The selection of these three sites:

(1) Provides comparable sites in each of Knik Arm and Turnagain Arm.

(2) Adopts tidal power developments which are of a scale, in capacity, which matches Railbelt System needs for both the "constrained" and "unconstrained" cases.

(3) Allows for consideration of dual purpose benefits with transportation crossings.

(4) Allows consideration of sites with sufficiently different characteristics to allow for spanning a reasonable range of alternatives.

TABLE 4.1

ENERGY AND CAPACITY

Site	Tidal Range (Ft)	Gross Annual Energy (10^6 KWh)	Net Annual Energy (10^6 KWh)	Installed Capacity (MW)
1. Port Graham	14.4	584	117	46
2. Kachemak Bay (1)	15.5	18,600	3,730	1,470
3. Kachemak Bay (2)	15.5	11,100	2,230	877
4. Iliamna Bay	12.3	590	118	46
5. Chinitna Bay	13.0	2,000	408	160
6. Tuxedni Bay/Snug Harbor	13.2	2,400	484	100
7. Anchor Point	14.5	318,000	63,700	25,100
8. Foreland East/West	17.5	198,000	39,500	15,600
9. North Forelands	19.0	164,000	32,800	12,900
10. Knik/Fire Island	24.4	37,000	7,430	2,920
11. Turnagain/Fire Island	25.0	83,000	16,600	6,530
12. Point MacKenzie	25.7	30,000	6,000	2.350
13. Cairn Point	26.3	27,000	5,470	2,150
14. Above Eagle Bay/Goose Bay	27.6	17,717	3,550	1,400
15. Rainbow	27.5	15,000	3,000	1,180
16. Sunrise	30.3	9,300	1,860	730

TABLE 4.2

SITE PARAMETERS

Site	Name	Net Energy ($kWh \times 10^6$)	Estimated Structure Height (ft)	Barrier Length (ft)	$\frac{AE^*}{LH^2}$ (kWh/ft^3)
1	Port Graham	117	122	8,000	0.98
2	Kachemak Bay (1)	3,730	400	59,300	0.39
3	Kachemak Bay (2)	2,230	340	36,500	0.53
4	Iliamna Bay	120	67	6,100	4.3
5	Chinitna Bay	408	65	18,000	5.4
6	Tuxedo Bay/Snug Harbor	484	195	20,000	0.64
7	Anchor Pt.	63,700	340	166,000	3.3
8	Foreland East/West	39,500	259	52,400	11.2
9	North Forelands	32,800	184	84,200	11.5
10	Knik/Fire Island	7,400	123	31,200	15.7
11	Turnagain/Fire Island	16,600	186	37,000	13.0
12	Pt. MacKenzie	6,000	126	13,700	27.4
13	Cairn Pt.	5,500	220	7,800	14.5
14	Above Eagle Bay	3,500	65	18,200	46.1
15	Rainbow	3,000	65	24,300	29.1
16	Sunrise	1,900	65	15,300	28.7

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* As noted in Section 4.3.2, high values for this parameter generally indicate more favorable economic benefits.

TABLE 4.3

SITE PARAMETERS

Site	Name	Capacity (MW)	Estimated Rated Head (ft)	Unit Capacity (MW)	Length of Powerhouse (ft)	Barrier Length (ft)	LP/LB*
1	Port Graham	46	9.2	8.7	320	8,000	.04
2	Kachemak Bay (1)	1,470	9.9	9.7	9,670	59,300	.16
3	Kachemak Bay (2)	880	9.9	9.7	5,800	36,500	.16
4	Iliamna Bay	47	7.9	6.9	450	6,100	0.07
5	Chinitna Bay	160	8.3	7.5	1,350	18,000	0.07
6	Tuxedo Bay/Snug Harbor	190	8.5	7.7	1,600	20,000	0.08
7	Anchor Pt.	25,100	9.3	8.8	183,000	166,000	>1
8	Foreland East/West	15,600	11.2	11.7	85,600	52,400	>1
9	North Forelands	12,900	12.2	13.2	63,000	84,200	.74
10	Knik/Fire Island	2,920	15.6	19.2	9,730	31,200	.31
11	Turnagain/Fire Island	6,530	16.0	19.8	21,000	37,000	.57
12	Pt. MacKenzie	2.350	16.5	20.9	7,300	13,700	.53
13	Cairn Pt.	2,150	16.8	21.5	6,400	7,800	.82
14	Above Eagle Bay	1,400	17.7	23.02	3,900	18,200	.21
15	Rainbow	1,180	17.6	23.	3,300	24,300	.13
16	Sunrise	730	19.4	26.6	1,700	15,300	.11

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* Values for this parameter at or near 1.0 are generally unfavorable since they indicate that closure problems may be significant or that more expensive and sophisticated approaches are necessary to develop the site. Very low values (less than .10 or so) indicate that the cost of civil features (barrages) will probably be high in comparison to the cost of power generating facilities.

SITE SUMMARY SHEETS

Site 1: PORT GRAHAM

Tidal Range: 15.0 ft

Site Description:

- tidal inlet 6-7 miles long, fed by freshwater mountain streams,
- channel is deep (80') to Port Graham

Geology/Foundations/Bottom Conditions:

- 'Border Ranges Fault' runs parallel to dam alignment approximately 4 miles to to the east of site.
- the northern, southern, and mid-channel island abutments are of volcanic rock formations
- reefs are located along all shores

Environmental Considerations:

- lower Cook Inlet fishing area

Navigation:

- deep channel navigation routes into Port Graham cross the proposed dam site

Site Access:

- site is remote from major road network
- landing strips are located at the towns of Port Graham (3 miles from site) and English Bay (1 mile)
- other access by water

Transmission Lines:

- would require routing of lines to Kachemak Bay, submarine crossing to Homer, and upgrading the existing transmission lines from Homer to Anchorage

Particular Site Advantages:

None

Site 2: KACHEMAK BAY (1)

Tidal Range: 15.4'

Site Description:

- deep channel inlet, 25 miles long
- fed by freshwater streams to north, glacial streams to the south

Geology/Foundations/Bottom Conditions:

- north abutment: sandstone, shale, and mudstone covered by moraine deposits
- south abutment: sandstone, siltstone, and conglomorate
- generally solid foundation conditions

Environmental Considerations:

- important King Crab and shrimp fisheries in Kachemak Bay as well as other anadromous, freshwater and shell fish
- extensive recreational use and esthetic importance of Homer spit and bay area
- entire Kachemak Bay is protected by Kachemak Bay State Critical Habitat Area
- Fox River Flats State Critical Habitat Area located at mouth of Fox River
- Kachemak Bay State Park located on southern coast of bay

Navigation:

- deep channel navigation routes crosses dam site
- Alaska Marine Highway Ferry System cross site to Homer
- extensive fishing uses of channel

Site Access:

- access to Homer (3 miles from site) is good, via Sterling Highway, air, or water routes
- access to north abutment good from Homer
- no road access to south abutment

Transmission Lines:

- tie in at Homer with existing transmission facilities; construct higher voltage lines to Anchorage

Particular Site Advantages:

None

Site 3: KACHEMAK BAY (2)

Tidal Range:15.7 ft

Site Description:

- deep inlet, 25 miles long, site located upstream of Homer spit,
- fed by fresh water streams to the north, glacial fed streams to the south

Geology/Foundations/Bottom Conditions:

- north abutment - glacial deposits and deltaic deposits consisting of silt and sand
- south abutment - chert and greenstone, apparently solid
- in general, poor conditions

Environmental Considerations:

- important King Crab and shrimp fisheries in Kachemak Bay as well as other anadromous, freshwater and shell fish
- extensive recreational use and esthetic importance of Homer spit and bay area
- entire Kachemak Bay is protected by Kachemak Bay State Critical Habitat Area
- Fox River Flats State Critical Habitat Area located at mouth of Fox River
- Kachemak Bay State Park located on southern coast of bay

Navigation:

- would not block ferry route to Homer, but would cross extensively used recreation and commercial fishing channels

Site Access:

- access to Homer (3 miles from site) is good, via Sterling Highway, air, or water routes
- access to north abutment good from Homer
- no road access to south abutment

Transmission Lines:

- tie in at Homer with existing transmission facilities
- construct higher voltage lines to Anchorage

Particular Site Advantages:

None

Site 4: ILIAMNA BAY

Tidal Range: 13.0 ft

Site Description:

- mountain formed inlet, fed by fresh water streams,
- relatively shallow, mostly less than 10 feet deep

Geology/Foundations/Bottom Conditions:

- north abutment - intrusive rock, dikes, and silts
- south abutment - quartz, diorite, steep cliff formations
- site centerline corresponds with Bruin Bay Fault (normal type)
- active volcanoes within 30 mile radius

Environmental Considerations:

- lower Cook Inlet Fishing area

Navigation:

- small boat access routes to Williamsport cross dam site

Site Access:

- approximately 1 mile from Williamsport
- only road access by small dirt roads interconnecting neighboring communities, no significant road network within 150-200 miles
- other access is questionable

Transmission Lines:

- long route required along western shore of Cook Inlet through difficult, virgin terrain

Particular Site Advantages:

None

Site 5: CHINITNA BAY

Tidal Range: 13.5 ft
Site Description:

-
-

Geology/Foundations/Bottom Conditions:

- south abutment - sandstone, quartz, conglomerate
- north abutment - similar, but overlain by surficial glacial deposits
- active volcanoes to north (15 miles) and to south (30 miles)
- site is roughly parallel to and closely corresponding with Bruin Bay Fault

Environmental Considerations:

- lower Cook Inlet fishing area

Navigation:

- small fishing boat access routes may be crossed

Site Access:
- no land access within 150-200 miles
- other access is questionable

Transmission Lines:

- remote from load centers, 50 miles across the inlet to Homer or 200 miles by land to Anchorage

Particular Site Advantages:

None

Site 6: TUXEDNI BAY

Tidal Range: 14 ft

Site Description:

- deep channel to the south of Chisilik Island, extends for 10-15 miles, bay is by glacial streams

Geology/Foundations/Bottom Conditions:

- steep mountainous channel with mid-channel island
- north abutment - flat river delta with glacial deposits adjacent to steep incline of volcanic rocks
- south abutment - mountain cliffs; siltstone, limestone, and sand stone
- island abutment - sandstone cliffs
- site corresponds with Bruin Bay Fault

Environmental Considerations:

- cannery at Snug Harbor
- Tuxedni National Wildlife Refuge located on Chisik Island
- major fishing area
- upper portion of bay locted in Lake Clark National Park

Navigation:

- commercial fishing vessel route to cannery crosses upstream of dam site

Site Access:

- by water only

Transmission Lines:

- remote from load centers: 50 miles across Cook Inlet to Homer or approximately 150 miles by land to Anchorage

Particular Site Advantages:

None

Site 7: ANCHOR PT.

Tidal Range:
- 15.8 ft on western shore
- 14.0 ft on eastern shore

Site Description:

- crosses main body of inlet at Anchor Pt.

Geology/Foundations/Bottom Conditions:

- east abutment - River Delta with surficial deposits
- west abutment - Red River Delta of glacial fed river, covering formation of conglomerate with sandstone, siltstone, located 15 miles from Ilimna volcano

Environmental Considerations:

- the unknown effects on extensive fisheries and wetlands north of the site would be of great magnitude
- the largest populations of red salmon, the second most abundant anadromous species, spawn in the Kenai and Kasilof River basins upstream of the sites.
- important clam diging activities along Kenai Peninsula shore north to Kasilof River, protected as Clam Gulch State Critical Area
- see also, the environmental effects for sites 8-16 for more upstream details

  Navigation:
- major shipping channels to Anchorage are crossed

Site Access:
- good, along Sterling Highway (Rt. 1) to Town of Anchor Pt.
- access by air and ferry to Homer (12 miles south of site)
- no land access from west

Transmission Lines:

- Anchor Pt. on the eastern shore is located near the Homer-Soldatna Intertie, higher voltage (345 or 500 kV) lines would be required from site to Anchorage

Particular Site Advantages:

None

Site 8: FORELAND E/W

Tidal Range: 17.7 ft

Site Description:

- crossing main body of Cook Inlet at the channel constriction between Kustatan and Nikishka

Geology/Foundations/Bottom Conditions:

- west abutment - delta area, surficial deposits with rock formation along shore
- east abutment - delta area with surfical deposits
- several drilling platforms north of the site with submerged pipelines

Environmental Considerations:

- most major conflicts associated with unknown effects of the inlet barrier
- site located just downstream of Trading Bay State Game Refuge

Navigation:

- major shipping channels to Anchorage are crossed

Site Access:
- no land access from western shore
- eastern shore access by paved roads connected with Sterling Highway

Transmission Lines:

- existing 69 kV and 115kV lines at Nikishka would need to be reconstructed to higher voltage (345 or 500 kV) to Anchorage

Particular Site Advantages:

None

Site 9: FORELAND NORTH

Tidal Range: 18.3 ft

Site Description:

- crossing main body of Cook Inlet

Geology/Foundations/Bottom Conditions:

- surficial deposits on both shores, land is interspersed with lakes and wetlands

Environmental Considerations:

- major effects associated with tidal barrage across inlet
- eastern shore abutment may conflict with Kenai National Moose Range. Eastern shore transmission lines would conflict.
- may conflict with Captain Cook recreation area
- western shore Indian lands
- western shore access may affect Kenai National Moose Range

Navigation:

- major shipping channels to Anchorage crossed

Site Access:

- improved and paved roads connect to Sterling Highway at Soldatna

Transmission Lines:

- higher voltage (345 or 500 kV) lines would need to be constructed for 20 mile route on eastern shore or 10 mile route on western shore, adjacent to (or replacing) existing lines.

Particular Site Advantages:

None

Site 10: FIRE ISLAND/KNIK

Tidal Range: 24.4 ft

Site Description:

- two-part dam crossing from Fire Island northward and westward to to Pt. Campbell, closing off Knik Arm. Significant freshwater inflow from the Matanuska River and glacial fed inflow from Knik River occurs

Geology/Foundations/Bottom Conditions:

- major feature is the continuously shifting mud flat forming the inlet bottom and shore line
- Susitna and Little Susitna River Dalta, mud flats and lowlands to the north formed by glacial outwash
- Fire Island - alluvial and glacial surficial deposits, gravel pit indicating aggregate source
- Pt. Campbell - glacial and alluvial deposits, poor data

Environmental Considerations:

- major effects associated with tidal barrage blocking Knik Arm, including Anchorage
- note that the major anadromous fish passage up the Susitna River would not be affected
- site is located upstream of Susitna Flats State Game Refuge
- significant numbers of anadromous fisheries use the Knik Arm tributaries

Navigation:

- ship channels to Anchorage terminals cross the site

Site Access:

- no direct land access to site, Pt. Campbell located 4-5 miles from Anchorage

Transmission Lines:

- intertie 5 miles to Anchorage required

Particular Site Advantages:

- causeway opportunities
- hydraulic pairing with Fire Island/Turnagain site possible
- with heat from storage system district heating opportunities (distance of 5 miles to Anchorage)

Site 11: FIRE ISLAND/TURNAGAIN

Tidal Range: 24.4 ft

Site Description:

- a two-part dam is required, connecting Pt. Possession Fire Island, and Pt. Campbell and blocking the Turnagain Arm
- no major sources of fresh water inflow, a few small streams

Geology/Foundations/Bottom Conditions:

- Fire Island and Pt. Campbell - glacial and alluvial deposits, gravel pit Susitna mud flats
- Pt. Possession - glacial deposits
- major feature is the continuously shifting mud flat forming the inlet bottom and lowlands

Environmental Considerations:

- blocks the Trunagain tributaries
- Point Possession abutment is located at the edge of a wilderness area in the Kenai National Moose Range
- the site would affect Potter Point State Game Refuge located in the mud flats southeast of Pt. Campbell

Navigation:

- no impact on Anchorage port access
- fishing access to Turnagain Arm effected

Site Access:

- if working from Campbell Pt., access by land is 5 miles to Anchorage
- barge access from Anchorage area would be possible

Transmission Lines:

- connected by tie line to Anchorage

Particular Site Advantages:

- causeway connecting to the Kenai Peninsula
- hydraulic pairing with the Fire Island/Knik Arm site would probably be planned
- district heating opportunities to Anchorage, 5 miles away

Site 12: PT. MACKENZIE

Tidal Range: 26 ft

Site Description:

- Site extends from Pt. MacKenzie to Pt. Woronzof at this constriction at the mouth of Knik Arm. The abutments are high ground upstream of the Susitna mud flat. Knik Arm is generally a shallow tidal basin with significant fresh water inflows from Matanuska and Knik Rivers. A deep shipping channel approaches Anchorage harbor.

Geology/Foundations/Bottom Conditions:

- north abutment (Pt. MacKenzie) delta and glacial deposits, overflow channel surface,
- south abutment (Pt. Woronzof) - glacial and alluvial deposits, relief of 150-175 ft
- at the crossing, depths are greater than at sections both upstream and downstream and the extension of shallow mud flats into the channel is minimal at the constriction

Environmental Considerations:

- major effects are associated with the tidal barrage blocking passage to the Knik Arm
- anadromous fish passage occurs into the Matanuska River and other tributaries
- Beluga whales sited off Anchorage

Navigation:

- shipping channels to Anchorage harbor cross the site cross-section
- fishing traffic also affected

Site Access:

- from Pt. Woronzof, land access readily available from Anchorage
- located near the Knik Arm submarine cable crossing from Beluga to Anchorage

Transmission Lines:

- close to tie in with Anchorage network

Particular Site Advantages:

- causeway opportunity to area north of Knik Arm
- electrical pairing (double basin) scheme may be possible with Turnagain Arm site
- district heating opportunities good (2-3 miles from Anchorage) if compressor drive alternative adopted

Site 13: CAIRN PT.

Tidal Range: 25.5 ft

Site Description:

- Located in Knik Arm at the Cairn Pt. constriction north of Anchorage harbor, which is the narrowest (1.5 miles) and deepest (175 ft) point in the Arm. Minimal mud deposits due primarily to high tidal velocities. Relatively high abutment relief (250' to the west, 150' to the east). Knik Arm upstream of Anchorage, is characterized with significant fresh water inflows from the Matanuska and Knik Rivers.

Geology/Foundations/Bottom Conditions:

- Elmendorf Morraine deposits approximately 170-180' to firm foundations in both abutments

Environmental Considerations:

- major effects associated with the tidal barrage blocking passage to the Knik Arm upstream tributaries
- anadromous salmon passage occurs into the upstream tributaries, including Matanuska River, Knik River, Eagle River, Cottonwood Creek
- located downstream of Goose Bay State Gam Refuge

Navigation:

- shipping channels to Anchorage NOT affected by this site

Site Access:

- land access from Cairn Pt. is less than one mile from Elmendorf AFB
- western shore access is 10 miles south of existing road network

Transmission Lines:

- close tie in with Anchorage or western shore transmission lines

Particular Site Advantages:

- causeway opportunity
- electrical pairing with a Turnagain Arm site is possible
- district heating opportunities at Elmendorf AFB and Anchorage (2 miles) if compressor drive alternative adopted

Site 14: EAGLE BAY

Tidal Range:

Site Description:

- Located at Knik Arm constriction upsteam of Eagle and Goose Bays. 50-100 ft abutment relief. Mid-channel mud flats are exposed at low tide. Upstream freshwater and glacial tributaries.

Geology/Foundations/Bottom Conditions:

- glacial alluvial deposits in both abutments

Environmental Considerations:

- major effects associated with tidal barrage blocking upstream passage
- anadromous passage to upstream tributaries, including Matanuska River, Knik River and Cottonwood Creek affected. (Eagle River and Eagle River Flats not affected) Navigation:
- no affect on ship channels to Anchorage
- may affect fishing traffic

Site Access: - land access by existing road networks is within 1-2 miles on both shores

Transmission Lines:

- transmission network tie-ins on eastern and western shores

Particular Site Advantages:

- electrical pairing with Turnagain Arm development is possible
- causeway potential still available but not quite as attractive as sites closer to Anchorage

Site 15: RAINBOW

Tidal Range: 26.6 ft

Site Description:

- shallow tidal basin fed by a few small glacial and fresh water streams (substantially smaller drainage basin than Knik Arm) mountainous rock cliff relief to north and south

Geology/Foundations/Bottom Conditions:

- exposed mud flats at low tide
- approximately 20 ft to rock foundations

Environmental Considerations:

- south abutment in Chugach National Forest
- north abutment in Chugach State Park
- generally, less abundant marine habitats in Turnagain as compared to Knik Arm

Navigation:

- no major shipping channels affected
- small craft may be affected

Site Access:

- land access good, to the north from Alaskan Highway, to the south from Hope Highway

Transmission Lines:

- existing 115 kV lines on northern shore would require reconstruction to higher voltage

Particular Site Advantages:

- causeway potential to Kenai Peninsula
- electrical pairing with Knik Arm site is possible

Site 16: SUNRISE

Tidal Range: 30 ft

Site Description:

- located upstream in Turnagain Arm, a very shallow tidal basin fed by a few small glacial and fresh water streams (smaller drainage basin than Knik Arm). High mountainous rock cliff relief to north and south.

Geology/Foundations/Bottom Conditions:

- exposed mud flats at low tide
- approximately 20 ft to rock foundations

Environmental Considerations:

- south abutment in Chugach National Forest
- north abutment in Chugach State Park
- generally, less abundant marine habitats in Turnagain as compared to Knik Arm

Navigation:

- no major shipping channels affected
- small craft usage is questionable

Site Access:

- land access good, from Alaskan Highway to the north and from Hope Highway to the south

Transmission Lines:

- existing 115 kV lines on northern shore would require reconstruction to higher voltage

Particular Site Advantages:

- causeway potential to Kenai Peninsula
- electrical pairing with Knik Arm site is possible

APPENDIX 2 - VISUAL RECONNAISSANCE OF SELECTED SITES

(SUBMITTED TO THE STATE OF ALASKA APRIL 1981)

APPENDIX 2 - VISUAL RECONNAISSANCE OF SELECTED SITES

TABLE OF CONTENTS

PAGE

1 - INTRODUCTION

1.1 - Introduction 2-1
1.2 - Purpose 2-1
1.3 - Methodology 2-1
1.4 - Summary 2-2

2 - SITE DATA

2.1 - General 2-3
2.2 - Eagle Bay/Goose Bay (Site 14) 2-3
2.3 - Cairn Point/Point No-Name (Site 13) 2-4
2.4 - Point Woronzof/Point MacKenzie (Site 12) 2-5
2.5 - Fire Island/Point MacKenzie with Fire Island/Point Campbell (Site 10) 2-6
2.6 - Fire Island/Point Possession with Fire Island/Point Campbell (Site 11) 2-7
2.7 - Sunrise (Site 16) 2-7
2.8 - Rainbow (Site 15) 2-8

LIST OF FIGURES

Number	Title
1	Candidate Sites
2.2.1	Eagle Bay/Goose Bay (Site 14)
2.2.2	Eagle Bay/Goose Bay (Site 14)
2.2.3	Eagle Bay/Goose Bay (Site 14)
2.3.1	Cairn Point/Point No-Name (Site 13)
2.3.2	Cairn Point/Point No-Name (Site 13)
2.3.3	Cairn Point/Point No-Name (Site 13)
2.3.4	Cairn Point/Point No-Name (Site 13)
2.4.1	Point Woronzof/Point MacKenzie (Site 12)
2.4.2	Point Woronzof/Point MacKenzie (Site 12)
2.4.3	Point Woronzof/Point MacKenzie (Site 12)
2.5.1	Fire Island/Point MacKenzie with Fire Island/Point Campbell (Site 10)
2.5.2	Fire Island/Point MacKenzie with Fire Island/Point Campbell (Site 10)
2.6.1	Fire Island/Point Possession with Fire Island/Point Campbell (Site 11)
2.6.2	Fire Island/Point Possession with Fire Island/Point Campbell (Site 11)
2.7.1	Sunrise (Site 16)
2.7.2	Sunrise (Site 16)
2.7.3	Sunrise (Site 16)
2.7.4	Sunrise (Site 16)
2.8.1	Rainbow (Site 15)

1 - INTRODUCTION

1.1 - Introduction

This report is the second of a series of working papers prepared by Acres American Incorporated in partial fulfillment of a contract with the Office of the Governor, State of Alaska, to conduct a study entitled "Preliminary Assessment of Cook Inlet Tidal Power."

The overall scope of the study is to provide engineering services to conduct a preliminary assessment of Cook Inlet tidal power characteristics and potentials, as well as to set forth a conceptual program for later in-depth investigations if the initial assessment indicates that such a program is warranted.

The work has been divided into the following four tasks:

Task 1 - Preliminary Field Reconnaissance and Site Selection
Task 2 - Comparative Evaluation
Task 3 - Reports
Task 4 - Project Control and Administration

Task 1 is organized into five subtasks as follows:

Subtask 1.01 - Data Collection
Subtask 1.02 - Initial Screening
Subtask 1.03 - Field Reconnaissance
Subtask 1.04 - Power Plant Configuration and Operation
Subtask 1.05 - Site Selection

A complete Task 1 Report, entitled "Preliminary Field Reconnaissance and Site Selection," was distributed as a working document on April 8, 1981.

1.2 - Purpose

The purpose of this report is to document the results of a visual reconnaissance conducted as Subtask 1.03. Seven sites which survived the initial screening (accomplished as Subtask 1.02) were physically visited and photographed to gain insights regarding suitability for tidal power development. Whereas the complete Task 1 Report summarized information gathered during the visual reconnaissance, this report provides a more detailed record of information gained in site visits.

1.3 - Methodology

In order to gather as much information as possible on surficial and to topographic conditions, on-site investigations were conducted at each potential abutment area and each barrage crossing was overflown to permit visual evaluation. This work was accomplished in February 1981. One hundred forty color slides were taken. The complete set is currently being maintained as a part of the project file. Selected photographs are reproduced in this report for illustrative purposes.

It is important to note that no subsurface investigations have been made as a part of the preliminary assessment effort. In the event that the preliminary assessment indicates a reasonable probability that tidal power development will be in the best interests of the state of Alaska, subsurface investigations of selected sites will be necessary in a later study phase.

Upon completion of the visual reconnaissance, a detailed oral presentation of the results was made to the project team. The results of the field work were taken into account in the consideration of power plant configuration and operation in Subtask 1.04 and in the final site selection process in Subtask 1.05.

1.4 - Summary

Descriptions and representative photographs for each of the sites visited on the ground are provided in Section 2 of this report. Three of the sites were ultimately selected for more detailed analysis in Task 2. The selected sites are:

(1) Rainbow (Site 15) on the Turnagain Arm

(2) Point Woronzof/Point MacKenzie (Site 12) in the Knik Arm

(3) Eagle Bay/Goose Bay (Site 14) on the Knik Arm.

The remaining four sites described in this report include:

(1) Cairn Point/Point No-Name (Site 13) on the Knik Arm

(2) Fire Island/Point MacKenzie with Fire Island/Point Campbell (Site 10) at the mouth of Knik Arm

(3) Fire Island/Point Possession with Fire Island/Point Campbell (Site 11) at the mouth of the Turnagain Arm

(4) Sunrise (Site 16) on the Turnagain Arm.

Figure 1, reproduced from the Task 1 report, locates each of these sites.

2 - SITE DATA

2.1 - General

Succeeding portions of this report provide the results of the visual reconnaissance as well as representative photographs. Knik Arm sites are presented first, beginning with the northernmost. The final three sites in the group are in Turnagain Arm.

2.2 - Eagle Bay/Goose Bay (Site 14)

This crossing is the most northerly site visited in the ground investigation. The eastern abutment is considered to be in the vicinity of Eagle Point itself. Eagle Point rises from a high bluff approximately 100 feet above the water surface and is the predominant feature in the area (see Figure 2.2.1). The relief behind the point north and southeast becomes shallower by 40 to 50 feet. The bluff has a near-vertical face and juts into the arm with the upstream northeast and downstream southeast sides receding substantially.

The exposed soil on the bluff face is light brown to grey in color, composed of a hard consolidated clay cemented with small gravel conglomerate which becomes almost a hardpan at the base. There is a definite thick band of loose coarse gravel deposit halfway up the bluff face, overlain by what appears to be the same deposit as is at the base, suggesting an outwash or erosion surface between two ages of glacial deposits (see Figure 2.2.2). An extrusion of frozen water on both the upstream and downstream bluff faces suggests a succession of pervious and impervious layers.

There is a definite indication of the erosion and gradual deterioration of the point which will continue at least until the face recedes back to the surrounding shoreline. A very swift tidal current was observed to pass the point in a channel running parallel to the upstream bluff face.

The gravel band is sufficiently high in the bluff face so as to pose no serious problem to any abutment structure.

The relative remoteness of the Eagle Point area (in an undeveloped area of Ft. Richardson), and the sheer drop to the bottom of the bluff, make site access comparatively difficult for reconnaissance purposes. A U.S. Geological Survey map (Anchorage B-8) shows the nearest road, an unimproved dirt road, to be several miles from the site.

The west abutment of this crossing would be located upstream (north) of Goose Bay, and approximately 3 1/2 miles across the Knik Arm from the Eagle Point east abutment (see Figure 2.2.3). This site is not characterized by as prominent a point as Eagle Point. It is characterized by a bluff 30 to 40 feet high with generally the same elevation upstream (north) and downstream (south) for a considerable distance. The downstream side of the bluff eventually falls to nearly sea level at Goose Bay itself, approximately one mile away.

The soil at the base of the bluff is a hard grey clay which is generally the same as found in the Eagle Point abutment, except that it appears to possess a more cohesive or clay-like characteristic. The middle third of the bluff face is made up of a band of a loose, coarse sand-gravel deposit, with intermittent lenses of fine sands to silts. This gravel band seems to correspond to the band observed at the Eagle Point abutment.

Access to the Goose Bay abutment would not be difficult to develop. The nearest road ends at an abandoned Nike missile site approximately two miles southwest of the abutment site. Adjacent to the Nike site is a 5000-foot long airstrip, which is presently closed to non-military aircraft.

2.3 - Cairn Point/Point No-Name (Site 13)

Cairn Point is on the east shore of the Knik Arm, about 1 1/2 miles north of the Port of Anchorage docks. The point is part of a bluff which is approximately 50 feet high. This elevation is uniform well upstream (north) and downstream (south) of the point for a considerable distance. Additionally, the land behind the point (to the east), is approximately the same elevation as the brow of the bluff (see Figure 2.3.1).

Cairn Point has been identified as an extension of the Elmendorf terminal moraine running roughly east to west across the Knik Arm. A somewhat mottled surface feature of the area and the presence of a very fine, consolidated, cemented deposit having a sparse mixture of 1 inch to 3 inches of cobbles supports this observation (see Figure 2.3.2). There is evidence of significant slumping or eroding at the bluff face with numerous trees and clumps of vegetation sliding down to the water's edge, (see Figure 2.3.3).

Periodic erosion gullies were noted in the bluff face, adding to the slumping condition noted above. The mouths of many of these gullies were 75 to 100 feet across.

At the time of this site visit, the tide in the area was going out, and the current in the main body of the Knik Arm was observed to be moving in a southerly direction. However, at the shoreline near Cairn Point, the water was observed to be moving northward, implying a large eddy in the area of the point.

Access to Cairn Point appears to be relatively good. The U.S. Geological Survey map of the area (Anchorage B-8) shows an unimproved dirt road running to nearly the brow of the bluff, apparently to a benchmark in the area.

Although it is not marked as such on available maps, the western abutment of this crossing is at what is known locally as Point No-Name, about 1 1/2 miles across the Knik Arm from Cairn Point.

The bluff at this site is 60 to 70 feet high, with the land behind (west) being at about the same elevation. Also, the bluff remains at about 60 to 70 feet high for a considerable distance upstream (north). In the downstream direction the bluff gradually slopes off to sea level, about 1 1/2 miles south of the point.

The soils at the base of the Point No-Name bluff were observed to be extremely fine powdery silts (likely a glacial flour) and a grey cohesive clay. This layer was about 15 feet thick. It was overlain with a layer of non-uniform sand and gravel soil. This layer contained cobbles of from 1/2 inch to 4 inches in diameter. Evidence of slumping from the brow of bluff was observed similiar to that noted at Cairn Point; trees and vegetation had slid downhill to the base of bluff in some places (see Figure 2.3.4).

The land behind the bluff contained a number of small bodies of water perched above the inlet. This was taken as an indication of an impervious subsurface layer behind the bluff. The area behind the bluff is swampy for a considerable distance west.

Point No-Name is about 10 miles south of an existing road.

A Knik Arm closure from Cairn Point to Point No-Name could alter the environmental conditions of the Goose Bay and the Eagle Flats wetlands, the important waterfowl nesting areas. These areas would not be affected by a closure from Eagle Point to Goose Bay.

2.4 - Point Woronzof/Point MacKenzie (Site 12)

For most Anchorage area residents, this crossing is the most easily identified. Point Woronzof, the southern abutment of this crossing, is approximately one mile west of the municipality's Earthquake Park. The point itself is a promontory 60 to 70 feet high. The land on both sides of the point decreases somewhat in elevation. The area inland of the point is generally slightly rising.

The soils observed at Point Woronzof were a layer from the base of the bluff up to about 15 feet, composed of a sandy silt and gravel mixture. The remainder of the bluff appeared to be of a coarser sandy gravel (see Figure 2.4.1).

Access to Point Woronzof is good. A paved road runs within 100 yards of the brow of the bluff and a bulldozer trail has been cleared from the brow to the waterline, less than 1/2 mile west of the point.

The northern abutment of this crossing is located at Point MacKenzie, about 2 1/2 miles northeast of Point Woronzof.

The Point MacKenzie bluff is 50 to 60 feet high. The land behind (north) the point is at about the same elevation as the point itself. The bluff elevation decreases slowly both upstream (north) and downstream (west) of the point. On the upstream side, the bluff recedes to sea level at the same point as the Point No-Name bluff which comes from the north. In the downstream direction, the bluff recedes slowly over a distance of about 2 miles to the Susitna Flats.

At the point, the soils observed were predominantly a thick glacial lacustrine clay intermingled with small cobbles of 1 to 3 inches in diameter and is probably a source of "bootlegger" clay. Evidence of mud flows in the bluff face were noted, probably occurring in the previous summer (see Figure 2.4.2). Evidence of active bluff recession was noted and the face of the bluff appears to be unstable (see Figure 2.4.3). The bluff is topped with a 10 foot thick layer of brown sandy (and possibly organic) material which supports the vegetation cover on top of the bluff.

The clay layer was observed to dip in a westerly direction until it disappeared under the sandy layer approximately 1 1/2 miles from the point.

There is no developed land access to Point MacKenzie.

The same environmental concerns noted for the Cairn Point/Point No-Name closure would apply to a Point Woronzof/Point MacKenzie closure. Additionally, if the Woronzof/MacKenzie closure were constructed, some means of navigational access to the Port of Anchorage would be a necessary consideration.

2.5 - Fire Island/Point MacKenzie with Fire Island/Campbell Point (Site 10)

An effective closure of the Knik Arm as far downstream as Fire Island requires that the channel between Fire Island and the mainland would be closed also. Fire Island is a small island, 5 miles long and 2 miles wide, lying 3 miles offshore of the extreme western tip of the Anchorage area mainland. Geologic observations have led to the conclusion that at one time the island and the mainland were connected by an isthmus which was gradually eroded by the action of tidal currents. The former isthmus is now a very shallow sand bar, which is completely exposed at low tide (see Figure 2.5.1). Even at high tide, it is suspected that the water at this crossing is very shallow.

The Island rises approximately 40 to 70 feet above the water of Cook Inlet, with very steep banks in most locations. The terrain on the top of the islands is a rolling hilly area.

The island is composed of gray and brown silty clays with sufficient cohesion to form steep banks and to withstand tidal action which eroded the isthmus to the mainland. It has successive bands of sandy gravel, indicating successive glacier outwashes (see Figure 2.5.2).

The U.S. Geological Survey map which shows the island (Tyonek A-1) notes a gravel pit, but there is apparently no activity at this facility presently. The quality and quantity of material removed from this gravel pit is unknown. The island is presently unused, except for a number of small fishing cabins on the western side and an FAA navigational facility. There are at least two unimproved "bush" airstrips on the island, one at each end on lower ground. There is no land access to the Island.

Environmental constraints on development of Knik Arm/Fire Island and associated closure would be similar to those of any other closure of Knik Arm. Additionally, the island itself is a federal wildlife range. what? years ago

The Point MacKenzie abutment of this closure was discussed under the Point Woronzof/Point MacKenzie closure. Point MacKenzie is approximately 7 miles northeast of the northern tip of Fire Island.

2.6 - Fire Island/Point Possession with Fire Island/Point Campbell (Site 11)

Turnagain Arm lies between two distinctive mountain formations. Both generally extend to the water's edge, except as otherwise indicated at a specific site. The northern formation is the more massive, having steep faces dropping to the water's edge. The southern face slopes more gently. Both are composed of massive rock outcropping, consisting of fractured, weathered surface rock. The rock formation appears to be of igneous origin, subjected to enormous pressures and metamorphic action creating the highly fractured, jointed conditions of the surface rock (see Figure 2.6.1).

A closure of the entire Turnagain Arm would require construction of a closure from Point Possession to Fire Island, and the closure of Fire Island to Point Campbell, discussed above.

Since the composition of Fire Island is quite uniform from end to end, a detailed discussion of its structure will not be repeated.

Point Possession is the most northern point of the Kenai Peninsula and is about seven miles southwest of Fire Island.

The soils at Point Possession were observed to represent a very wide variety of soils which are common to the area. These ranged from bootlegger clays to sandy silts, to sandy gravels, to gravels which can totally change in consistency within 10 to 15 feet (see Figure 2.6.2).

There is no land access to Point Possession, but barge access from Anchorage would be possible.

2.7 - Sunrise (Site 16)

The northernmost abutment area of this site (Bird Point) lies in an area of lowlands extending from the base of the mountain. Intermittent marsh/stream beds behind the point are clearly engineering problems to be dealt with if this site were used. The presence of dead birch trees in the marsh/swamp indicates that previously the land was at a higher elevation. It is known that the area dropped in elevation about 8 feet as a result of the 1964 earthquake (see Figure 2.7.1).

A major road/railroad system follows along the base of the mountain between the mountain and Bird Point. The Point extends about 1500 feet from the road/railroad (see Figure 2.7.2).

There is a definite outcropping of rock at the Point indicating a subsurface rock foundation at the abutment. The rock structure is similar in composition to the existing mountains (see Figure 2.7.3).

The southern abutment area slopes gently to the water and has rock outcropping at the water's edge with about an 8 to 10 foot elevation from the water. It appears to have excellent abutment characteristics.

An undesirable feature of the Sunrise/Bird Point alternative is the exposure of tidal flats well before low tide arrives. This limits the usefulness of this crossing as a tidal power producer (see Figure 2.7.2).

Land access could be developed without great difficulty from the Alaskan Highway to the north and from Hope Highway to the south.

2.8 - Rainbow (Site 15)

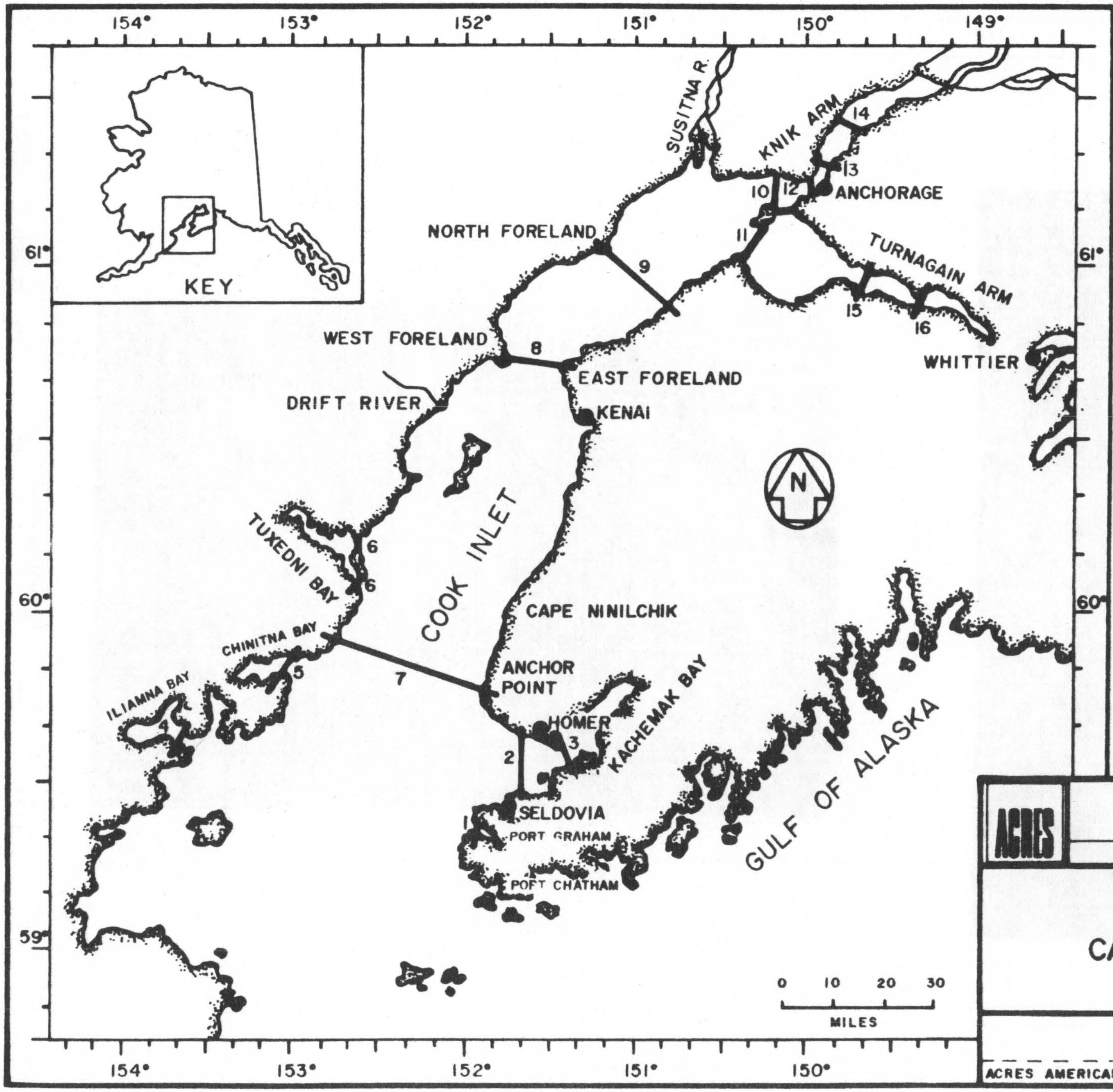
The northernmost abutment area of this site (Rainbow) lies at the foot of a mountain formation and presents an excellent choice for an abutment area. The same road/railroad system lies between the mountain and the site. The site is about 50 to 100 yards from the road (see Figure 2.8.1).

Massive outcrop formations about 50 feet from the shore suggest bedrock extending into the Arm.

The southernmost abutment, which has no known name, is relatively flat, rising about 10 feet above the high water line. Massive rock outcropping on the shoreline extending into the water suggests exposed bedrock into the Inlet. There is a beach shoreline adjacent to the site having an abundance of gravel material up to 1 inch to 1 1/2 inches in size.

There is no land access to the site from the south. The closest known road is in Hope, Alaska, a small village upstream of the site.

This crossing has an environmental impact greater than that of the Bird Point site as it is located downstream of several major creeks in Turnagain area (Resurrection, Sixmile, Bird and Indian Creeks).



SITE LIST

1. PORT GRAHAM
2. KACHEMAK BAY (1)
3. KACHEMAK BAY (2)
4. ILIAMNA BAY
5. CHINITNA BAY
6. TUXEDNI BAY
7. ANCHOR PT
8. FORELAND EAST/WEST
9. FORELAND NORTH
10. FIRE ISLAND/KNIK
11. FIRE ISLAND/TURNAGAIN
12. POINT MACKENZIE
13. CAIRN POINT
14. EAGLE BAY
15. RAINBOW
16. SUNRISE

ACRES

OFFICE OF THE GOVERNOR
STATE OF ALASKA

COOK INLET TIDAL POWER

CANDIDATE SITES

ACRES AMERICAN INCORPORATED

FIGURE 1

FIGURE 2.2.1

FIGURE 2.2.2

EAGLE BAY
SITE 14

FIGURE 2.2.3

EAGLE BAY
SITE 14

FIGURE 2.3.1

FIGURE 2.3.2

CAIRN POINT
SITE 13

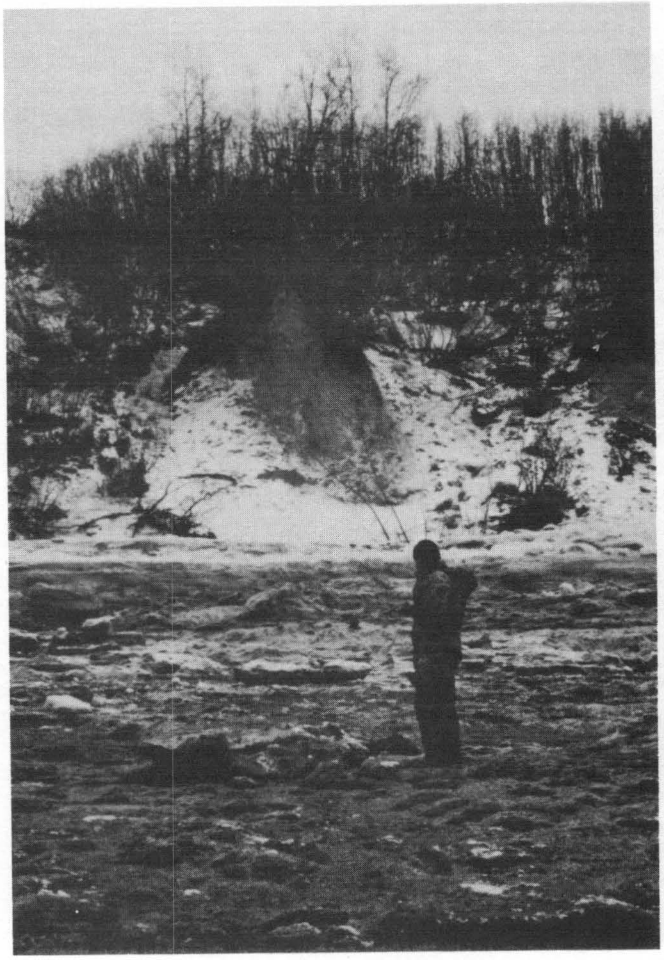


FIGURE 2.3.3

FIGURE 2.3.4

CAIRN POINT
SITE 13

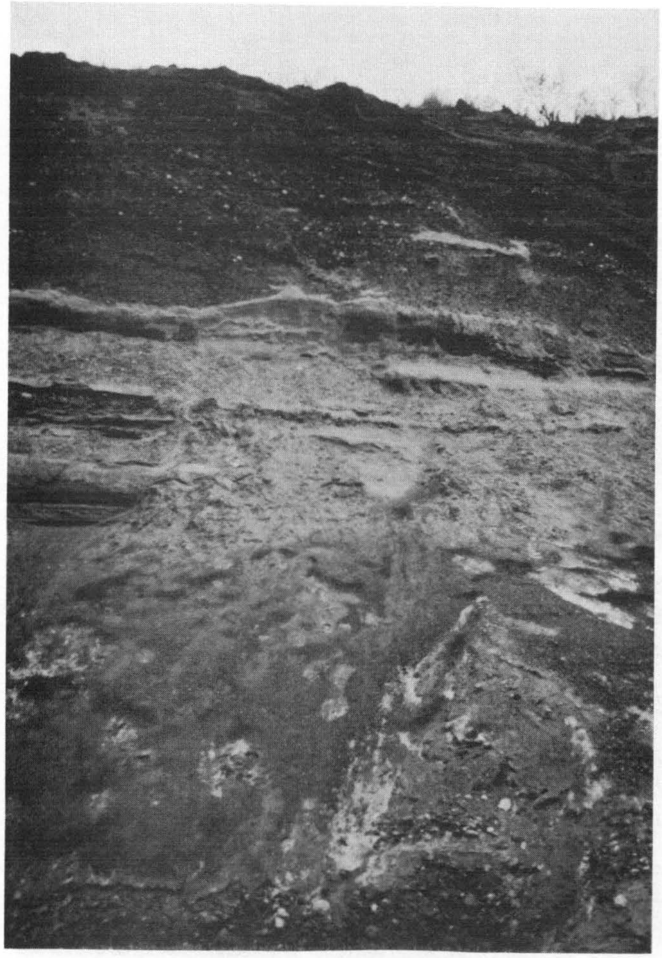


FIGURE 2.4.1

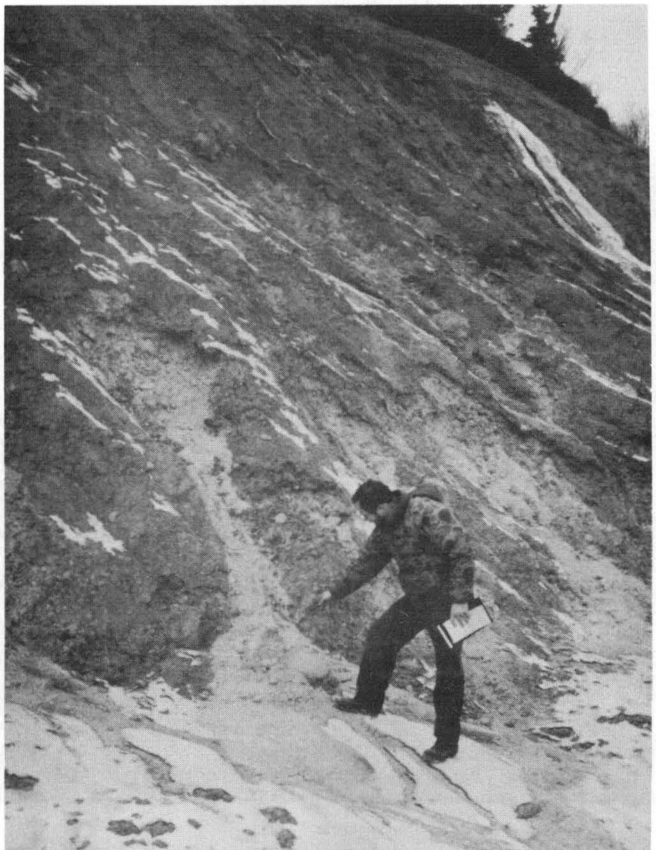


FIGURE 2.4.2

POINT MACKENZIE
SITE 12

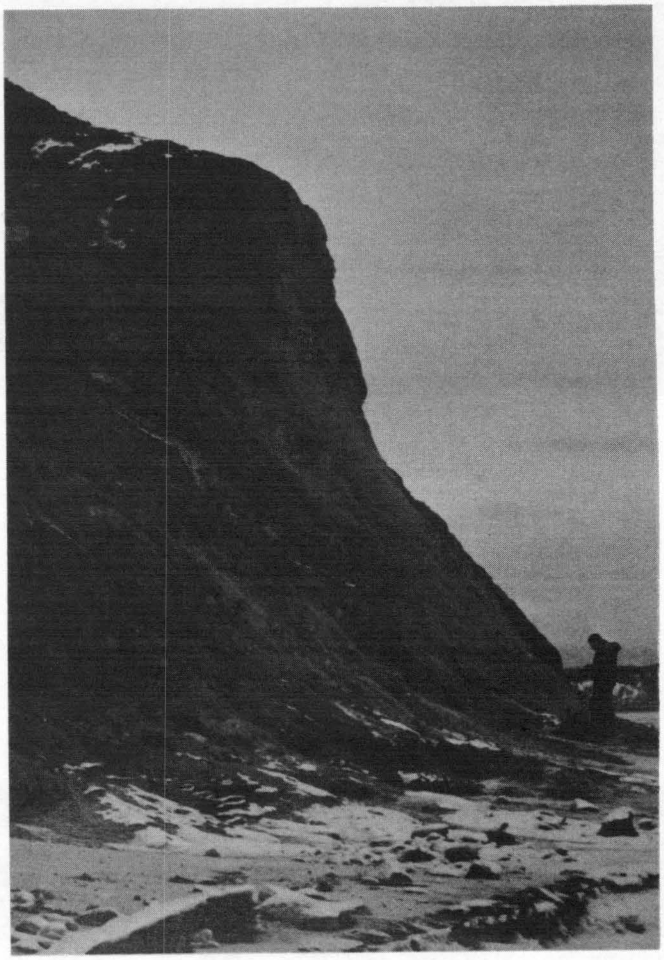


FIGURE 2.4.3

POINT MACKENZIE
SITE 12

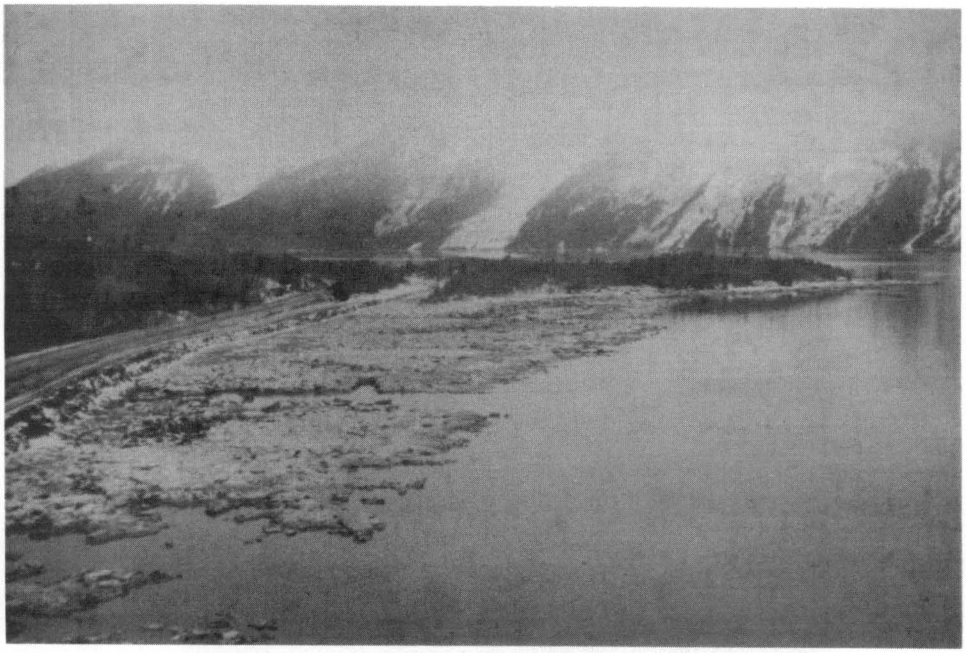


FIGURE 2.7.1

FIGURE 2.7.2

SUNRISE
SITE 16

FIGURE 2.7.3

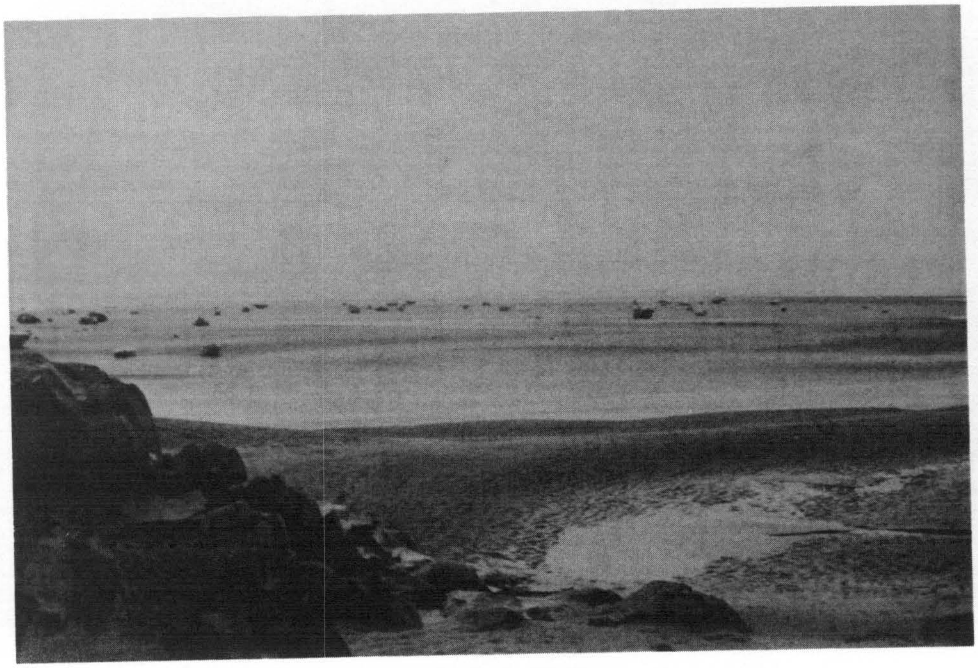


FIGURE 2.7.4

SUNRISE
SITE 16

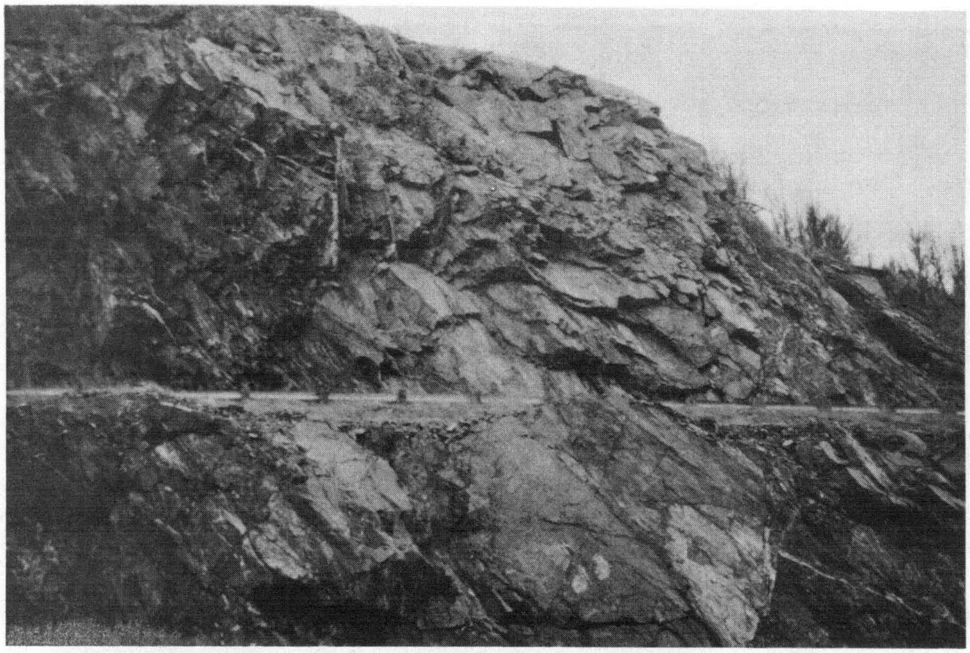


FIGURE 2.6.1

FIGURE 2.6.2

FIRE ISLAND/
POINT POSSESSION
SITE II

FIGURE 2.5.1

FIGURE 2.5.2

FIRE ISLAND/
POINT MACKENZIE
SITE 10

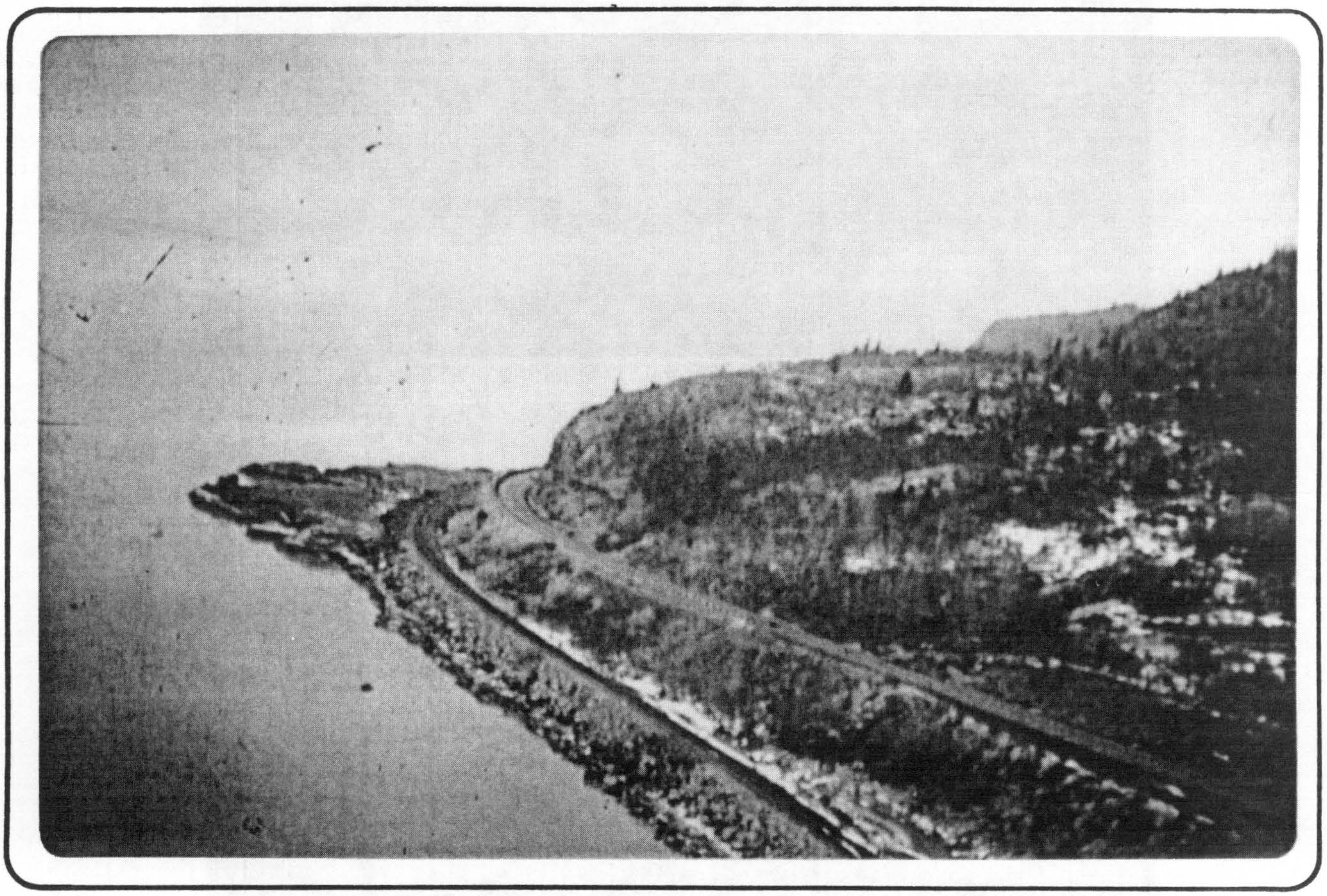


FIGURE 2.8.1

RAINBOW
SITE 15

APPENDIX 3 - PARAMETER SELECTIONS

APPENDIX 3 - PARAMETER SELECTIONS

TABLE OF CONTENTS

Page

3.1 - Objective 3-1
3.2 - Approach 3-1
3.3 - Geotechnical Conditions 3-1
3.4 - Bathymetry 3-2
3.5 - Construction Material Availability 3-3
3.6 - Tidal Levels and Currents 3-3
3.7 - Meteorological and Hydraulic Conditions 3-5
3.8 - Seismic Conditions 3-7
3.9 - Barrier Effect 3-8

LIST OF TABLES

Number	Title
3-1	Published Tidal Data
3-2	Tidal Levels, Currents, and Meteorological Conditions

3 - PARAMETER SELECTIONS

3.1 - Objective

To select parameters in order to provide a basis of comparison for the three sites selected under Task I (Appendix 1) and to allow development of layouts for costing purposes.

3.2 - Approach

Site specific parameters for the development of layouts have been selected on the basis of data resulting from the study of geotechnical conditions, bathymetry, construction materials, tidal levels and currents, meteorological and hydraulic conditions, seismicity, and barrier effects. These parameters also became a basis of comparison for the three selected sites.

3.3 - Geotechnical Conditions

The information has been largely derived from the review of published and unpublished geological data, study of available boring records, and a brief visual reconnaissance of Turnagain Arm and Knik Arm area. Neither detailed geological mapping nor subsurface investigations have been performed at this time.

Geologically the upper Cook Inlet area can be divided into two major regions: the first region includes the major river channels and lowland areas where igneous and metamorphic bedrock is overlain by glacial fluvial sediments of various thickness; the second region includes the upland and mountain areas where igneous, metamorphic, and, to a lesser degree, sedimentary bedrock is found at or near the ground surface.

In the upper Cook Inlet area near Anchorage, unconsolidated sediments are typically greater than 500 feet thick and approach maximum thickness of 4300 feet at the mouth of the Susitna River. These sediments primarily consist of glacial-fluvial sediments and, to a lesser degree, eolian deposits. The glacial-fluvial sediments consist of both well sorted deposits such as glacial outwash, valley train, or alluvial deposits, and poorly sorted deposits such as moraine and other types of glacial drift. Eolian deposits consist of accumulations of well-sorted fine-grained sediments. Throughout the areas, unconsolidated sediments are found as a complex interlayering of both sorted and poorly sorted materials.

The upland and mountain areas surrounding the upper Cook Inlet have sedimentary, metamorphic, and igneous rocks exposed at or near the ground surface. Along the upper portions of the Turnagain Arm, bedrock is exposed at or near the ground surface and primarily consists of metamorphic rock.

Site specific geological conditions are described in Appendix 2.

A preliminary review of geological information revealed that the dense till in the vicinity of Turnagain and Knik Arms would provide excellent foundation support for abutments and other civil structures on land. Along the sea bed, at least 20 feet of soft sediments are assumed to be dredged and replaced by a controlled fill of compact granular material in order to provide adequate foundation support for the powerhouse, sluiceway, and the proposed embankment sections.

3.4 - Bathymetry

Bathymetric conditions vary considerably within Knik and Turnagain Arms. West of the Point MacKenzie-Point Woronzof tidal power site, the waters are shallow while the intertidal areas are wide. During extreme low water, mudflats extend from the mainland westward to Fire Island. From Point MacKenzie to Cairn Point, there are well established channel depths ranging to 160 feet below MLLW. The intertidal areas are less than one-half mile wide and are covered with fine glacial silt. The deeper channel areas are composed of gravel and cobble or rock.

Several miles north of Cairn Point, Knik Arm widens to a broad shallow area. During low water, extensive mudflats are exposed for many miles and are criss-crossed by numerous channels. This is the condition of the bathymetry at the Eagle Bay site.

The bathymetry in the vicinity of the Rainbow site is similar to that of the Eagle Bay site. At low tide, about two-thirds of Turnagain Arm is bare tidal flats. Comparison of early charts of Turnagain Arm indicates the area has been stable for many years.

Detailed hydrographic survey data exists for the Eagle Bay and Point MacKenzie sites.*

A bottom profile of the Rainbow site was obtained from the Turnagain Arm Crossing report.** For future detailed studies and design, it will be necessary to confirm bathymetry at each site with field measurements.

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* National Ocean Survey - Hydrographic surveys 9441 and 9443.

** Turnagain Arm Crossing - Causeway Studies - Profile #3. Armstrong Associates, Engineers and Consultants, January 1969.

3.5 - Construction Material Availability

Sand and gravel deposits probably are the most abundant nonmetallic mineral resource within the lowland regions, including the Knik and Turnagain Arms of the upper Cook Inlet. Some of these sand and gravel deposits have already been developed for use in construction in the area; others show a great potential for further development as construction material.

The Chugach mountains, located just east of Anchorage, would provide an excellent source of rock for construction. These mountains consist of hard, crystalline metavolcanics and greywackes which are adequately competent and durable for use in dike construction. Several quarries are already under operation in the area. If required, the bedrock present in the mountains can be developed into more quarries which should provide adequate supplies of the rock material for construction.

3.6 - Tidal Levels and Currents

3.6.1 - Tidal Levels

Tides in Turnagain Arm and Knik Arm are among the highest in the world, being mixed and possessing large diurnal and semidiurnal components. Tidal information exists for Anchorage, Fire Island, and to a lesser extent Goose Creek and Rainbow. The data is summarized in Table 3-1 from Fire Island and Anchorage tidal data. Tidal levels for the Point MacKenzie site were interpolated. Because of the proximity of Goose Creek to the Eagle Bay site (approximately one mile) and because of the lack of upstream tide data, Goose Creek data was selected as being representative of Eagle Bay. The Rainbow tidal data was chosen as being representative of the Rainbow site.

Extreme high water data for Eagle Bay and Rainbow were obtained by a correlation with Anchorage data. The ratio of the extreme high water to the mean high water at Anchorage was multiplied by the mean high water at the sites in question. The resulting value for each site was then compared with a second value obtained by taking the ratio of the diurnal high water inequalities at Anchorage and the site, multiplying by the difference between the extreme high water and mean high water at Anchorage and adding this value to the mean high water at the site. Both methods yielded similar results.

For the extreme low water determination, only the second method, using the diurnal inequality comparisons, were used.

Personal communication with NOAA cast some doubt on the estimated extreme high water. Based on a long term correlation with the Sitkin tidal gauge, the extreme water level at Anchorage might be closer to 40 feet. A comparison of the 1976 actual and predicted high water data showed that the difference was always less than one foot. Based on the NOS/NOAA tidal datum information, communication with NOAA, and the 1976 comparison, the estimated extreme high water at Anchorage was estimated as 36.5 feet (2 feet above the highest astronomical tide).* This yielded extreme high water elevations of 36, 39, and 37 feet at Point MacKenzie, Eagle Bay, and Rainbow respectively. The recommended tidal elevation data for design is illustrated in Table 3-2.

Neither the barrier effect nor long term changes in mean water levels were considered in deriving the listed tidal elevations for the base case. Preliminary calculations in Task 1 (Appendix 1) indicated that the effect of a tidal barrage on tidal ranges is not likely to be significant at the selected sites. A sensitivity analysis conducted using the simulation program showed that a one foot decrease in tidal levels resulting from a barrier effect would reduce energy production by 5 to 6 percent (see Appendix 6).

3.6.2 - Tidal Currents

Natural tidal currents in Knik Arm and Turnagain Arm are fast. This is the result of the high tidal fluctuations in combination with the bathymetric features and shoreline configurations. Tidal bores have been observed in upper Knik Arm.

Current measurements in Knik Arm were recorded as early as 1914, during a hydrographic survey. In 1964 and 1965 the U.S. Army Corps of Engineers measured tidal velocities as part of a sedimentation study and again in 1972. The 1972 area of study extended from the Point MacKenzie site to the Eagle Bay site. From 1973 - 1975, NOS/NOAA conducted an Oceanographic Circulatory Survey of Cook Inlet.

In the vicinity of Point MacKenzie-Point Woronzof, maximum flood velocities have been recorded up to 11.2 feet per second (fps). Normal flood tide maximum currents in the main channel typically range between 5 to 6 fps. On the ebb tide normal maximum velocities are on the order of 5.5 to 7 fps and are strongest on the western side. Flood current maximums occur 2 to 3 hours after low tide and last only a short time. The main channel flood currents then usually level off to a velocity of 3 to 5 fps for several hours depending on the location, depth and tidal range. Ebb tide begins about 5.5 to 6.5 hours after low tide. Maximum ebb current occurs 2 to 3 hours after the start of the ebb tide and then reduces to a steady current of 3 to 6 fps. During flood tide and to a lesser extent during ebb tide, eddy currents are present off Point Woronzof.

Just above Goose Creek, a maximum velocity of 11.8 fps was recorded in 1914, thus indicating velocities similar to those near Point MacKenzie at the Eagle Bay site. Maximum current velocities at Eagle Bay in the range of 7 to 9 fps are not uncommon. Bottom velocities of 2 to 3 fps have been estimated.

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* This condition involves joint probabilities; i.e., obtaining the highest tides at the same time as a 2 foot storm surge. Further studies should consider this in more detail.

In Turnagain Arm, a maximum flood velocity of 12.6 fps was measured with a tide range of 37 feet in October 1962. Armstrong Associates calculated the maximum average velocity at 10 to 11 feet per second. With an average range of 28.5 feet, the maximum velocity recorded was 9 fps at a depth of 8.7 feet below the surface. The average velocity over the full depth was 5.2 fps.

In summary, the currents at the three sites are strong, with maximum velocity measurements of over 11 fps at each site. All three sites appear to have natural currents of similar magnitude, as shown in Table 3-2.

3.7 - Meteorological and Hydraulic Conditions

3.7.1 - Wind

Wind records from Elmendorf Air Force Base and the Anchorage Airport were examined for the period 1960 - 1978. Elmendorf Wind Velocity extremes taken from the "Knik Arm Highway Crossing" report for the period 1941 - 1959 were then compared with those from 1961 - 1978. The wind extremes from the earlier period were found to be greater. Extreme velocities from the NNW, N, NE and SE were 52, 49, 59 and 47 miles per hour (mph) respectively. To obtain a reasonable probability of occurrence for wind speeds when combined with extreme high tidal water levels, a maximum wind speed with a recurrence interval of approximately 50 years is required. Since the available data are based on 37 years of records, it was considered that they are acceptable for preliminary design. In accordance with this, 60 mph and 45 mph were selected as the design wind speeds for the computation of wave heights from the north and south respectively. These wind speeds are consistent with the "Knik Arm Crossing" report.

Use of Anchorage wind data for Turnagain Arm is not strictly valid. However, wind data for Turnagain Arm are lacking. Armstrong Associates used a wind velocity of 85 mph from the south to generate maximum wave action. While this wind speed may be attainable, there is some doubt as to whether its duration will be large enough to generate maximum waves. It is also equally doubtful that the maximum tide level will occur simultaneously with the maximum wind speed. With this in mind the selection of a 60 mile per hour wind from the north seemed reasonable (Table 3-2).

3.7.2 - Waves

Wind generated waves at all three sites are fetch limited. The effective fetch was determined with methods consistent with the U.S. Army Corps of Engineers Shore Protection Manual (1973). With the exception of the basin side of Eagle Bay and Rainbow, significant wave heights were determined assuming deepwater waves (i.e., d/Lo > 0.5; where d = average depth) (Table 3-2). With shallower depths such as those that occur at low tide deepwater wave heights will not be generated. Significant waves are used to select the crest of the dike powerhouse and sluiceways and sizing of the dike armour units. Using deepwater wave heights leads to conservative results and these will require refinement in later more detailed studies.

It should be noted that if the effects of shoaling and diffraction are taken into account design wave heights are likely to be reduced accordingly.

Probable maximum waves were calculated assuming a storm duration of three hours and a significant wave period of 6 seconds.

3.7.3 - Freshwater Inflows

The watershed area north of Point MacKenzie is 4570 square miles. The associated mean annual discharge is approximately 14,000 cubic feet per second (cfs) and the flood peak with a 50 year recurrence interval is 130,000 cfs. Even with occasional Lake George peakouts with discharges of as much as 360,000 cfs, the freshwater flows are minor compared to the volume displaced difference between the water in each tidal cycle. Conditions are similar for the Eagle Bay site.

The basin area for Turnagain Arm is 1160 square miles. The mean annual discharge is 3500 cfs, with a flood peak maximum estimated at 60,000 cfs. This flow is minor relative to the associated tidal discharges.

3.7.4 - Ice

Ice on Turnagain and Knik Arms lasts about seven months of every year. From December to February, Turnagain and Knik Arms are usually ice clogged. Ice occurs as floe ice or shore fast ice. Floe ice (or sheet ice) thickness is governed by the degree days of freezing. It varies in thickness from 2 to 4 feet depending on the severity of the winter. Because of the extreme tidal currents, sheet ice rarely occurs as a continuous cover.

Shorefast ice is formed by successive flooding and draining of the tidal flats. In this way, ice with thicknesses up to 15 feet is formed on shoals and the shore. This type of ice may well be expected to be less severe on the basin side if a tidal plant were developed because some of the tidal flats will no longer be exposed at low tide since basin low water would approximate mean tide level.

Twenty to thirty foot bergs are sometimes caused by seepage of freshwater flow on top of the sea ice.

Designs have to take account of static and dynamic ice loads on the structures, ice pile ups on the dike slopes and riprap removal by shore ice.

3.7.5 - Sediment Transport and Erosion

Average total suspended sediment carried into Knik Arm is 16 million tons from April to September. During the remainder of the year it is reduced to 135,000 tons. Maximum daily transport rates have been measured as 1.3 million tons (August 15, 1959) and 2 million tons (July 10, 1965) in the Matanuska and Knik Rivers respectively. Particle sizes vary from 0.002-1mm in the suspended load and up to 32mm in the bed load.

With the volume of sediment transported in every tidal cycle it will be necessary in later studies to make a detailed assessment of the impact of the tidal power plant on sedimentation and erosion patterns. For the preliminary studies it is assumed that since the plant changes flow patterns, the sedimentation and erosion patterns are likely to be affected but not to an extent that would impair the effective operation of the plant over its useful life.

3.7.6 - Scour Protection

During closure care will have to be taken to ensure the seabed is protected from scour adjacent to the dike and structures. Permanent scour protection will also be needed upstream and downstream of the sluiceway and powerhouse structures.

3.8 - Seismic Conditions

The Cook Inlet region is located in an area of intense seismic activity and recent (geologic time) orogenic activity. Between 1898 and 1965, seven earthquakes have occurred in the area, equaling or exceeding Richter magnitude 8, and more than 60 have equaled or exceeded magnitude 7. Most of these earthquakes originated at shallow to intermediate depths and had their epicenters located within the Cook Inlet region.

One of the greatest seismic events in southern Alaska occurred March 27, 1964, with a computed magnitude of 8.3 - 8.4 on the Richter scale. The earthquake was accompanied by crustal deformation of more than 110,000 square miles of land and sea bottom caused by direct seismic vibration, by ground cracks, and by landslides.

The Cook Inlet region falls within seismic Zone 4 which is characterized as an area of major damage corresponding to earthquake intensity VIII and higher on the Modified Mercalli Scale. The value of the maximum design ground acceleration for this region should be taken as 0.5 g.

3.9 - Barrier Effect

As described in Appendix 1, on the basis of the tidal data available it seems unlikely that construction of man-made tidal barriers in the upper Inlet will have a major impact on tidal levels. However, to assess the sensitivity of energy generation to changes in tidal level, a very preliminary calculation was made of possible changes in level due to imposition of barriers at the three selected sites.

Neglecting the flows through the tidal power plant in generating and sluicing cycles and based on a simplistic calculation using formulae described by Ippen and Hanleman in Chapter 10 of "Tidal Dynamics in Estuaries," an Engineering Society Monograph on Estuary and Coastal Hydrodynamics, maximum possible changes in tidal levels due to barriers at the three sites are estimated to be as follows:

Eagle Bay and Rainbow - less than 0.2 foot difference

Point MacKenzie - reduction of 2.8 feet

Resulting changes in energy generation were assessed in Appendix 6 by assuming reductions in tidal level of 1 foot at Eagle Bay and Rainbow and 2 and 3 feet at Point MacKenzie.

TABLE 3-1

PUBLISHED TIDAL DATA

	Anchorage[1]	Fire Island[2]	Goose Creek	Rainbow
Estimated extreme HW	35.5	33	-	-
Highest astronomical tide*	34.4	-	-	-
Mean Higher Highwater (MHHW)	29.0	-	-	-
Mean High Water (MHW)	28.3	27.5	30.5	29.7
Mean Sea Level (MSL)	16.4	26.8	29.8	29.1
National Geodetic Vertical Datum (NGVD)	15.7			
Mean Tide Level (MTL)	15.2	14.5	16.0	15.3
Mean Low Water (MLW)	2.2	2.2	2.3	1.6
Mean Lower Low Water (MLLW)	0	0	0	0
Lowest astronomical tide*	-4.8	-	-	-
Estimated extreme LW	-6.4	-6	-	-
Estimated extreme range	42	39	-	-
Estimated astronomical range*	39.2	-	-	-
Mean tide range	26.1	24.6	27.6	27.5

1/ U.S. Department of Commerce April 17, 1970, "Tidal Bench Marks"
2/ 1973 - 1975 N.O.S. Circulating Survey

* Tides predicted in 1976 Tide Tables. Maximum predicted tide in 1980 was 39.0 feet. Maximum range for astronomical tide derived from 1970 - 1974 predicted tide levels 38.4 feet.

NOTE: Datum in feet relative to mean lower low water (MLLW)

TABLE 3-2

TIDAL LEVELS, CURRENTS, AND METEOROLOGICAL CONDITIONS

	Point MacKenzie	Eagle Bay	Rainbow
Tide Levels (in feet relative to MLLW)			
Mean Tide Range	25.7	27.6	27.5
Extreme High Water (EHW)	36	39	37
Mean Higher High Water (MHHW)	28.6	30.5	29.7
Mean High Water (MHW)	27.9	29.8	29.1
Mean Tide Level (MTL)	15.1	16.0	15.3
Mean Low Water (MLW)	2.2	2.2	1.6
Mean Lower Low Water (MLLW)	0	0	0
Extreme Low Water (ELW)	-6.4	-6.5	-6
Current Velocities (Natural) (in feet per second)			
Maximum recorded	11.2	11.8	12.6
Average Maximum flood/ebb	5-7	-	5
Design Wind Speeds (mph)			
Ocean side	45 S	45 S	60 N
Basin side	60 N	60 N	45 S
Waves (ft)*			
Ocean side			
Effective fetch (miles)	20	6	17
Significant wave height (Hs)	7.8	4.8	10
H_{10}	9.9	6.1	12.7
H_{max}	15.1	9.3	19.4
Basin side			
Effective fetch (miles)	3	8.5	
Significant Wave height (Hs)	4.8	6.9	5.0*
H_{10}	6.1	8.8	6.4
H_{max}	9.3	1.34	9.7

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* computed based on average depth of 50 feet

NOTES:

Hs is approximately the 50 year significant wave height.
H_{10} is average of highest 10 percent of the wave.
H_{max} is maximum probable wave.

APPENDIX 4 - TURBINE DESIGN

APPENDIX 4 - TURBINE DESIGN

TABLE OF CONTENTS

Page

4.1 - Objective 4-1
4.2 - Approach 4-1
4.3 - Choice of Type of Turbine 4-1
4.4 - Turbine Characteristics 4-3
4.5 - Conclusions 4-8

LIST OF FIGURES

Number	Title
4.1	Bulb Unit Compared to Vertical Unit - Sections
4.2	Typical Bulb Installation
4.3	Typical Straflo Installation
4.4	Eagle Bay Turbine-Generator Performance Characteristics

4 - TURBINE DESIGN

4.1 - Objective

To select the hydraulic turbine after a review of the applicable types for tidal power plants; namely, bulb, Straflo, and vertical turbines; and establish the turbine characteristics, data, and dimensions for use in the energy studies and design of the power plant.

4.2 - Approach

During the studies performed for the Bay of Fundy tidal plant assessment, a reasonably thorough review and optimization program was carried out for bulb turbo-generator units. The turbine characteristics established during these studies were therefore used as the basis of the turbine design for the Cook Inlet studies, supplemented by experience on other low-head hydroelectric installations, and by discussions with leading manufacturers of turbine equipment related to recent design developments for proposed tidal plants at Annapolis Royal, on the Severn Estuary and in Korea.

4.3 - Choice of Type of Turbine

4.3.1 - Vertical or Horizontal Axis Units

In selecting the type of hydraulic turbine to be used at a particular site, the key parameter is the operating head. For low-head applications, below 100-feet head, axial flow, horizontal shaft turbines using propeller-shaped runners provide significant economy and are normally selected. At the higher end of this head range, vertical shaft units have proven most effective.

For Cook Inlet, the operating head is low, varying from 5 to 35 feet, and horizontal shaft units would normally prove most effective primarily because of the lower civil construction costs. Although horizontal units require a longer structure in the direction of the flow, the unit blocks are narrower and of lower overall height resulting in lower total volume of excavation and concrete (Figure 4.1). The shape of the structure for the horizontal unit is much more suitable for the float-in caisson type construction which is proposed for Cook Inlet. In addition, studies for Cook Inlet, where the powerhouse will be founded on overburden, indicate that the full length of the horizontal unit intake and draft tube is required to provide structural stability. Hence a vertical turbine arrangement would not permit advantage to be taken of the shorter upstream/downstream dimensions of its powerhouse block. Moreover, because of the deeper excavation required for vertical units, stability criteria may dictate an even longer upstream/downstream dimension than with horizontal units. All factors indicate that for Cook Inlet horizontal units will be even more favored than at conventional sites of similar head. As a result, no further consideration has been given to vertical units.

4.3.2 - Bulb, Tube or Straflo Turbine

There are three main types of horizontal axial-flow units depending on the location of the generator relative to the turbine and to the water passages.

At present, for runner diameters greater than 20 feet the most popular is the bulb unit (Figure 4.2) in which the generator is located in a bulb shaped watertight enclosure immediately upstream from the turbine runner. The water passes around the outside of the generator; and in order to minimize its diameter, compromises are required in the generator design as described in Appendix 5.

The tube turbine is popular for smaller diameter runners. The generator is located outside the water passage and connected to the turbine by a long shaft. This arrangement has not proven successful for large runner diameters, and it has, therefore, not been considered for Cook Inlet.

The third type is the Straflo in which the generator is mounted around the outside of the turbine runner. There is no shaft, and the runner acts as the hub of the generator rotor spider (Figure 4.3). Special seals are required to keep the generator dry, but there are no other constraints, as in the bulb unit, on the generator design. The Straflo design is a revitalization of an old concept, made feasible for larger turbines by the development of new hydrostatic seals. The first large Straflo unit is now under construction for the Annapolis tidal power demonstration project in Nova Scotia, Canada. This unit, rated at 17.8 MW at 18 feet net head, has a runner diameter of 25 feet, only slightly smaller than the world's largest bulb units now being installed at the Racine project in Ohio. The Racine bulb turbines have a runner diameter of 25.3 feet and a rating of 24.6 MW at 23 feet net head. The Annapolis unit is scheduled to go into operation in mid-1983.

The power and efficiency characteristics for the Straflo and bulb designs are very similar, and the difference in energy production would be small. The selection between the two designs must be made primarily on the basis of capital costs of a complete powerhouse caisson.

The Straflo design has a clear advantage over the bulb design in that it is possible to provide a greater generator inertia, should this be necessary for reasons of electrical system or governing stability. However, for bulb units rated at low heads such as at Cook Inlet, and with the modern trend to make the bulb diameter greater than the runner diameter, it is possible to achieve better inertia constants than with the older, higher head designs. For the St. Mary's Redevelopment Project now under construction, in Ontario, Canada, studies indicate that the bulb units, rated 18 MW at 18.7 feet net head, will be capable of stable, isolated operation with special features on the electronic governor. The requirement for higher generator inertia should be studied in greater depth in any future detailed studies. Due to the lack of costing and operating experience for the Straflo design, some speculation is required for a comparative evaluation of its design. It is particularly difficult to verify a single manufacturer's claim as to the lower cost of the Straflo design due to the present lack of back-up data. However, the potential cost reduction could be in the range of 10 to 15 percent for the Straflo units, which would translate into an energy cost reduction of about 3 to 4 percent.

For the more recent Straflo design with an overhung runner supported by a single concrete pier it would appear that the cost could be lower; however, a detailed study would be required to establish this trend in relation to competitive turbine designs.

The Straflo unit also has a potential for reduced civil costs since the inlet water passages can be shorter without the generator enclosure of the bulb design. The full advantage of this feature cannot be taken in Cook Inlet, since structural calculations indicate that the full length of the bulb design water passages is required for stability of the caisson when supported on soft foundations.

Because of present uncertainty related to the Straflo data, layout and costing studies have been based on the use of the bulb designs. The energy calculation would be applicable to either design, but the potential cost savings of the Straflo design should be given further consideration in detailed studies.

It is expected that alternative plans for both bulb and Straflo designs would be developed through the feasibility and licensing phases. The final decision on which type of unit is selected need not be made until the later detailed design and procurement phase of the project.

4.4 - Turbine Characteristics

4.4.1 - Characteristics Used for Energy Calculations

Leading turbine manufacturers were contacted to obtain information on the latest developments of turbine design for tidal plants. Detailed information on manufacturers' turbine characteristics was obtained very late in the study. Therefore, the turbine characteristics developed for the 1976 Fundy studies were used; these later proved to be very similar to manufacturers' recommended characteristics for fixed-blade turbines.

The power/discharge characteristics of an axial flow turbine depend on whether the unit is single-regulated or double-regulated. Traditionally single-regulated referred to variable distributor (wicket gates) and fixed pitch runner blades and is commonly referred to as a fixed-blade design. The double-regulated arrangement in which both distributor and blade pitch are variable is also referred to as a Kaplan design. Recently, single-regulated designs have been developed in which the wicket gate (distributor) is fixed and the pitch of the runner blades can be varied; these are referred to as variable-blade turbines.

For varying heads, the double-regulated design provides much higher efficiency when operating at heads above or below rated and is usually selected for conventional plants with a significant head variation. However, the actual power output capability of a fixed-blade turbine is the same as for the double-regulated design at varying heads, but the discharge is higher at heads other than rated.

For single effect tidal applications, where output and low cost are more important than efficiency, fixed-blade designs are usually proposed. Optimization with the double-regulated design is somewhat more difficult, and the Fundy studies indicated there would be little difference in the cost of energy for fixed-blade (single-regulated) or double-regulated designs. For Cook Inlet, therefore, it was decided to use the Fundy fixed-blade characteristics for the energy calculations. More extensive development of low head turbines by the manufacturers now suggest a fairly substantial increase in energy output so that this aspect would require more detailed consideration in further Cook Inlet studies.

The turbine characteristics were expressed as two functions, the generator output against head and turbine discharge against head. The unitized curves are shown in Figure 6.3 of Appendix 6. These are based on operation at a gate position midway between best efficiency and maximum output (saturation) conditions. Operation at saturation conditions would theoretically give a higher energy output but is not recommended because of possible rough operation.

For a given site and installation there is a very wide variation in the head available for generation. The power output capability of a given turbine varies as the three-halves power of the head, and it is not economic to provide a generator capable of accepting the maximum turbine power output at the highest heads, which occur only on the highest tides. The head at which the maximum turbine output equals the generator capability is referred to as the rated head. At heads higher than the rated head, the turbine gate opening must be reduced to avoid overloading the generator. This is also necessary to avoid possible cavitation of the turbine at the higher heads; otherwise deeper settings and higher civil costs would be incurred.

The Fundy studies indicated that the cost of energy was not very sensitive to the rated turbine head. For the sites studied at Fundy the ratio of optimum rated head to mean tidal range varied from 0.62 to 0.69. For Cook Inlet optimums of 0.64 to 0.65 were obtained. The unit rated output was factored from Fundy as a three-halves power of the rated head, and the rated discharge as the one-half power of the rated head.

Sluicing through the turbines during basin filling was modeled by assuming orifice characteristics. The discharge coefficient used was the same as for the Fundy studies. The maximum sluicing head and the minimum generating head are very close to the same, one-third of the rated head. At this head, the sluice discharge is 70 percent of the generating discharge. The sluice discharge decreases as the one-half power of the head becoming zero at zero head.

4.4.2 - Information from Manufacturers

Following completion of preliminary optimization studies, inquiries for specific proposals for the Point MacKenzie, Eagle Bay and Rainbow sites were sent to three manufacturers as follows:

(a) Allis-Chalmers Corporation, the principal U.S. hydraulic turbine manufacturer, who is at present providing large bulb units for two conventional projects

(b) Combustion Engineering/Neyrpic, the U.S. affiliate of the French firm Neyrpic, who had prime responsibility for the supply of bulb turbines for the La Rance tidal power project and who has produced more bulb units than any other manufacturer

(c) Dominion Bridge-Sulzer, who is supplying the large diameter Straflo unit for the Annapolis demonstration project, and who is the North American representative of the Straflo Group and of Escher Wyss Ltd. of Switzerland, a major supplier of bulb units.

Both Neyrpic and Sulzer provided estimated data and prices for bulb units and Sulzer also provided data for the Straflo designs. Neyrpic suggested runner diameters of 28 to 28.4 feet for bulb units and Sulzer suggested a diameter of 26.9 feet for both bulb and Straflo units.

4.4.3 - Fixed-Blade Turbine Characteristics

Neyrpic provided efficiency curves for their recommended turbine design for the Eagle Bay site. In addition to the fixed-blade characteristics requested they also provided performance data for a single-regulated, variable-blade bulb design. They strongly recommended this for tidal applications.

Sulzer provided some Straflo model test data both for the Annapolis arrangement with a downstream bearing support and for the overhung runner design developed for the Severn tidal studies. Appropriate efficiency curves for Eagle Bay were developed from the Straflo overhung model data. In order to achieve the required rated output of 24 MW at 18 feet it was necessary to increase the speed from 51.4 rpm proposed by Sulzer to 58.1 rpm.

Figure 4.4 shows the comparative performance of the fixed-blade characteristics used for energy calculations for Eagle Bay, the Neyrpic fixed-blade and variable-blade characteristics, and the Straflo fixed-blade characteristics. In estimating prototype performance from the model the following assumptions were made:

(a) Prototype exit loss is equivalent to normal model-to-prototype step-up

(b) Generator losses are 3 percent in bulb units and 2 percent in Straflo

(c) Straflo rim and seal losses are 1 percent.

Note that the power versus head curve is virtually identical for all four alternatives.

There are differences in the discharge versus head curve resulting from the differences in efficiency. The fixed-blade characteristics used in the energy calculations, are the highest, indicating a lower efficiency as discussed previously. Hence, the energy estimates are conservative.

The Neyrpic bulb and Straflo fixed-blade curves are very similar, confirming that the hydraulic performance of the Straflo is very similar to that of the bulb.

4.4.4 - Performance of Variable-Blade Bulb Turbines

The Neyrpic variable-blade bulb design has a much lower discharge than the fixed-blade design when operating at low or high heads. This means that the basin level will not be drawn down as much during the generating cycle and the average operating head will be higher, thus increasing the power output.

The turbine characteristic curves for variable-blade bulb units shown in Figure 4.4 were derived from the maximum recommended power output line shown on the variable-blade characteristic provided by Neyrpic.

Previous studies for the Bay of Fundy did not include variable-blade characteristics. The studies using turbine characteristics have shown that the maximum energy generation is achieved by operation at best efficiency while the head is increasing and at maximum power while the head is decreasing. For fixed-blade turbines, the characteristics for maximum efficiency and maximum power conditions are so close that there is little to be gained by operating the turbine differently during increasing and decreasing head.

The variable-blade characteristic shows considerable difference between maximum power and maximum efficiency. It will be noted from the Neyrpic curve for the Eagle Bay turbine design that at best efficiency the maximum generator rating is reached at 26 feet head compared with 18 feet rated head at maximum power. It is likely that future studies will show that greater increases in energy can be achieved by the variable-blade characteristics when operated at best efficiency during increasing head.

As discussed in Appendix 6, energy calculations done for the variable-blade characteristic indicated increased annual generation on the order of 5 to 11 percent depending on the site. The increase in energy for the variable-blade design is not uniform for all tides and has a greater effect on the smaller tides.

The energy production increments would be even greater with a double-regulated turbine, although the increment in capital costs would also be higher.

Both the variable-blade and double-regulated bulb turbine alternatives must be given more attention in future studies.

There is not a great deal of experience available with the variable-blade bulb design. Since the blades cannot be used to shut off the flow completely, a hydraulic operated downstream gate is used for shutdown and starting purposes. Synchronizing will be done by opening the gate partially to provide a reduced head across the turbine. The speed is then regulated by varying the runner blade pitch. Once sychronized, the gate is opened and output is regulated by varying blade pitch. For tidal applications, where the unit is started at low head in any case, it may not be necessary to throttle the head with the downstream gate for synchronizing. An additional benefit for tidal application is that it may be possible to have a higher turbine setting since the pressure on the runner could be increased at extreme low tide levels by partially closing the gate to avoid cavitation.

One potential problem with the downstream gate is that its operation at high heads may cause erosion in the tailrace downstream of the draft tube outlet. This possibility must be examined in future studies.

The variable-blade arrangement would also simplify the civil design since there is no need to provide space for the servomotor and wicket gate operating mechanism around the outside of the turbine distributor. It would be possible to completely encase the turbine-generator unit except for access passages and hatches.

At present Straflo units are limited to fixed-blade designs, and the Straflo group is at present concentrating on developing fixed-blade designs for heads greater than 60 feet. However, there is one small full double-regulated unit being installed in Switzerland, and it is planned to continue the development of such units in larger diameters. Presumably both double-regulated and variable-blade Straflo turbogenerator units will be available in the future.

4.4.5 - Operation of Fixed Blade-Units at Low Head

In accordance with previous tidal power studies, the energy calculations assume that at the end of each tidal generating cycle, the turbines will continue to generate as the head reduces until the output drops to zero. Sulzer confirms that the Annapolis fixed-blade Straflo is designed to operate in this manner and they would expect no difficulty with either Straflo or bulb fixed-blade designs.

Neyrpic, on the other hand, states that this mode of operation will be very rough and excessive vibrations will develop which will require shutting down the units whenever the efficiency drops less than 50 percent. They have confirmed this with tests at La Rance.

The effect on energy production of such a restriction on operation is expected to be small, but should be considered further in future studies.

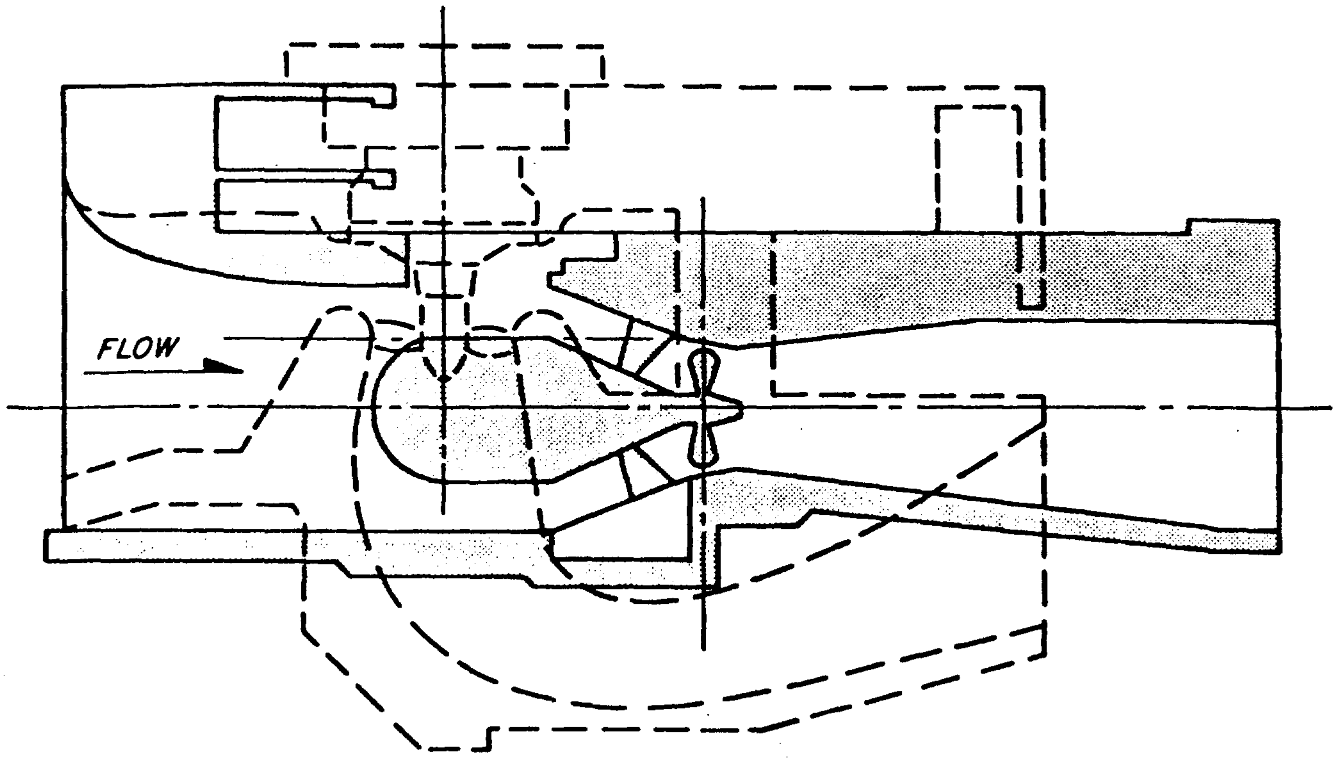
4.5 - Conclusions

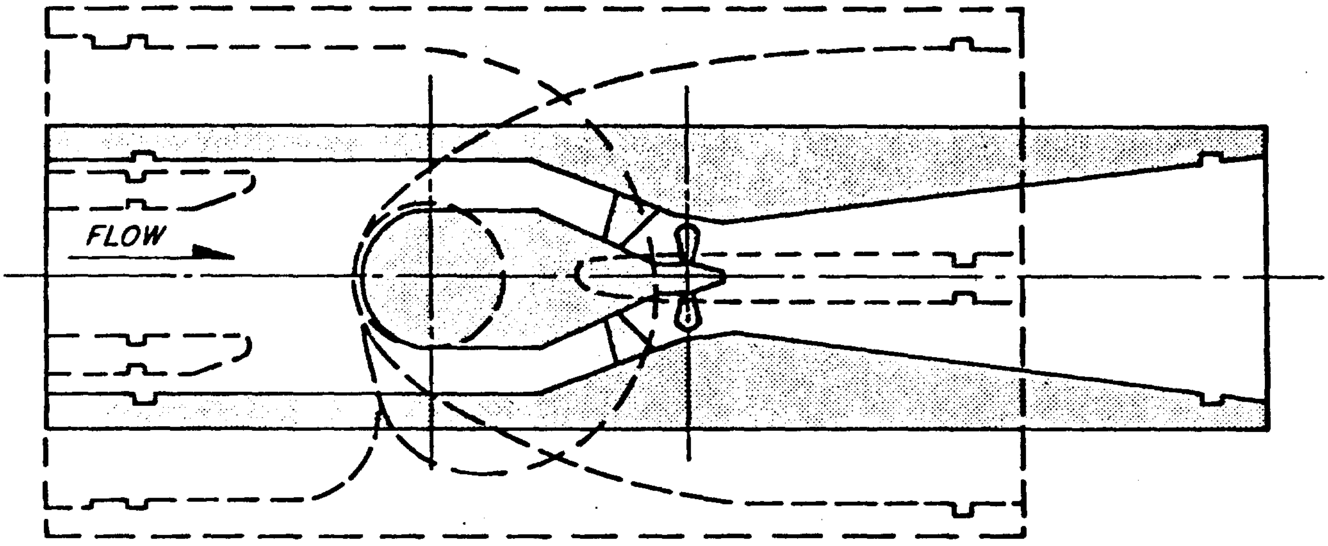
(a) Horizontal bulb units with fixed-blade characteristics have been used in the study.

(b) Variable-blade, single-regulated bulb turbines show improved discharge and efficiency characteristics and should be included in future studies. Double-regulated turbines should also be further studied.

(c) Straflo turbines have similar characteristics to the fixed-blade bulb units. They have potential cost reductions and should be included in further studies.

(d) The final decision on which type of unit is most suitable need not be made until a later detailed design and procurement phase. Adoption of the horizontal bulb units with fixed-blade characteristics for the study would, in the meantime, provide a conservative assessment of the project.





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COOK INLET TIDAL POWER

BULB UNIT COMPARED TO VERTICAL UNIT - SECTIONS

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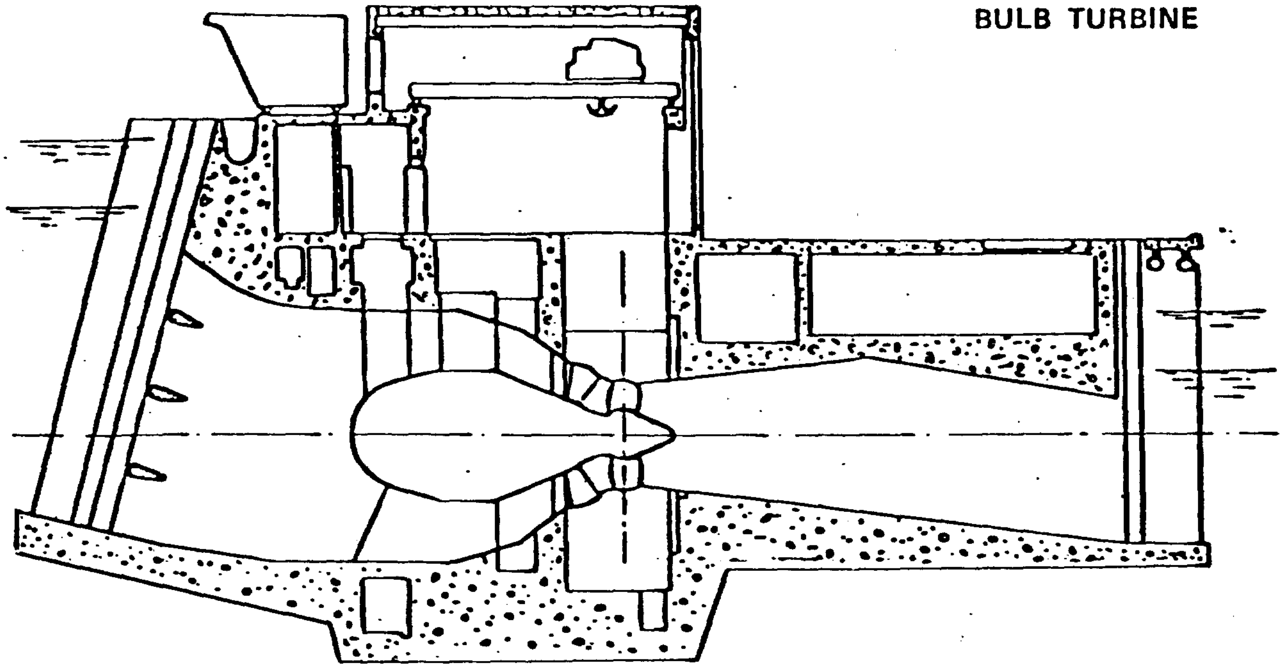
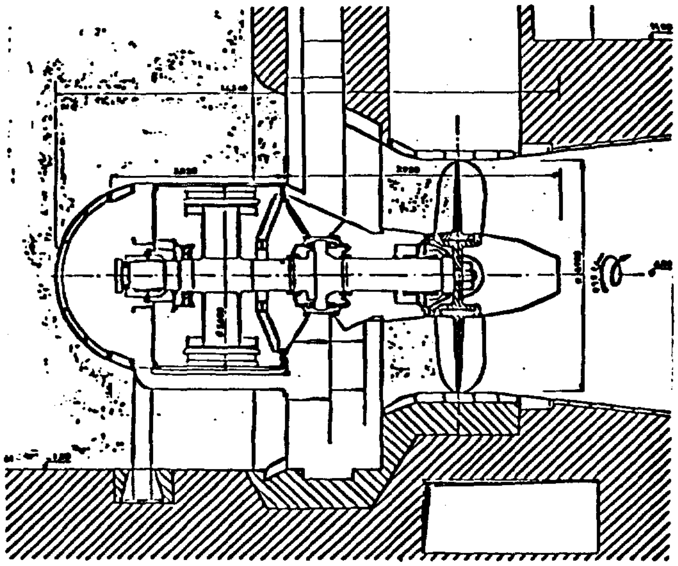
FIGURE 4.1

BULB TURBINE



CROSS-SECTION OF POWERHOUSE WITH BULB UNIT

SOURCE ESCHER WYSS



DETAILS OF (FIXED BLADE/FIXED DISTRIBUTOR) BULB TURBINE

SOURCE NEIRPIC

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TYPICAL BULB INSTALLATION

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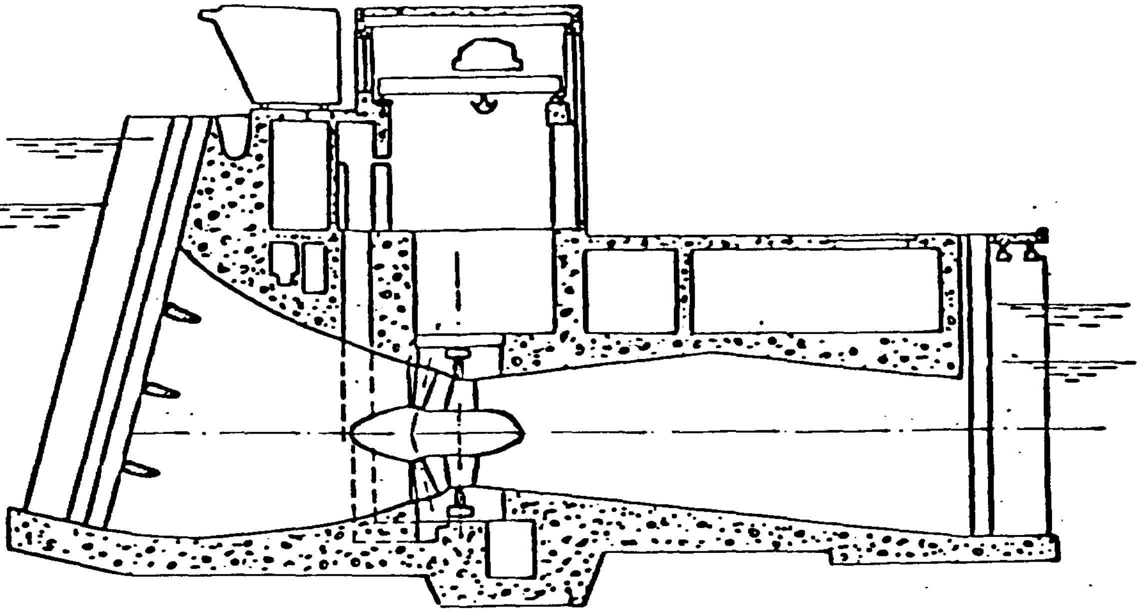
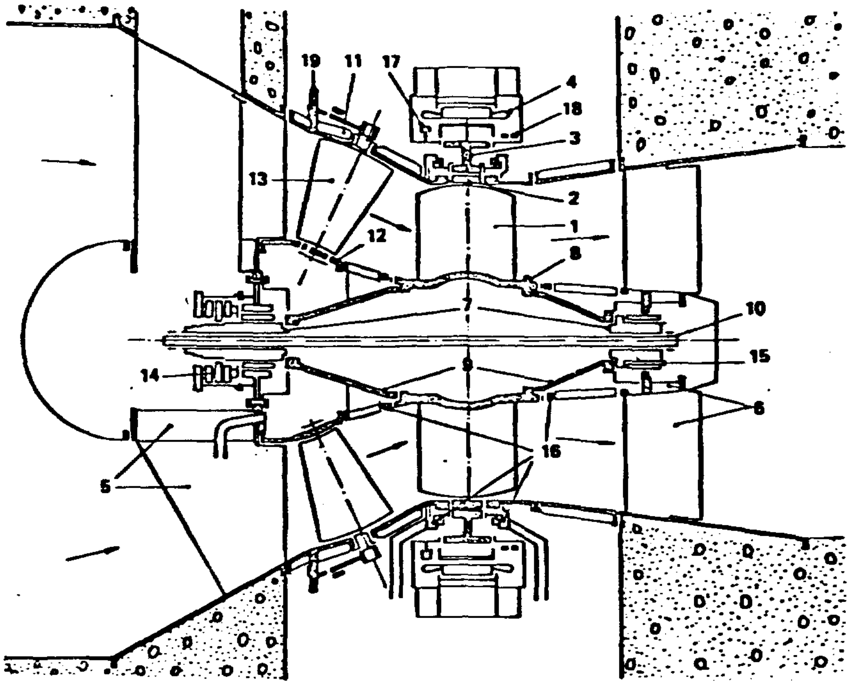
FIGURE 4.2



CROSS SECTION OF POWERHOUSE WITH STRAFLO UNIT

General arrangement of a 5300 kW Polar wheel unit working under 7.9 m head, and running at 120 rev/min where: 1 indicates the turbine runner; 2, the runner crown; 3, the generator rim (shrink fitted on runner crown); 4, the generator stator; 5, the upstream stayring; 6, the downstream stayring; 7, the shaft trunnions; 8, the runner hub; 9, the shaft coned webs; 10, the prestressed bar; 11, the distributor outer ring; 12, the distributor inner ring; 13, the guide vanes; 14, the combined thrust and guide bearing (upstream side); 15, the downstream guide bearing; 16, the sealing boxes; 17, the unit brakes; 18, the excitation rings; and 19, the regulating ring.



DETAILS OF STRAFLO UNIT

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TYPICAL STRAFLO
INSTALLATION

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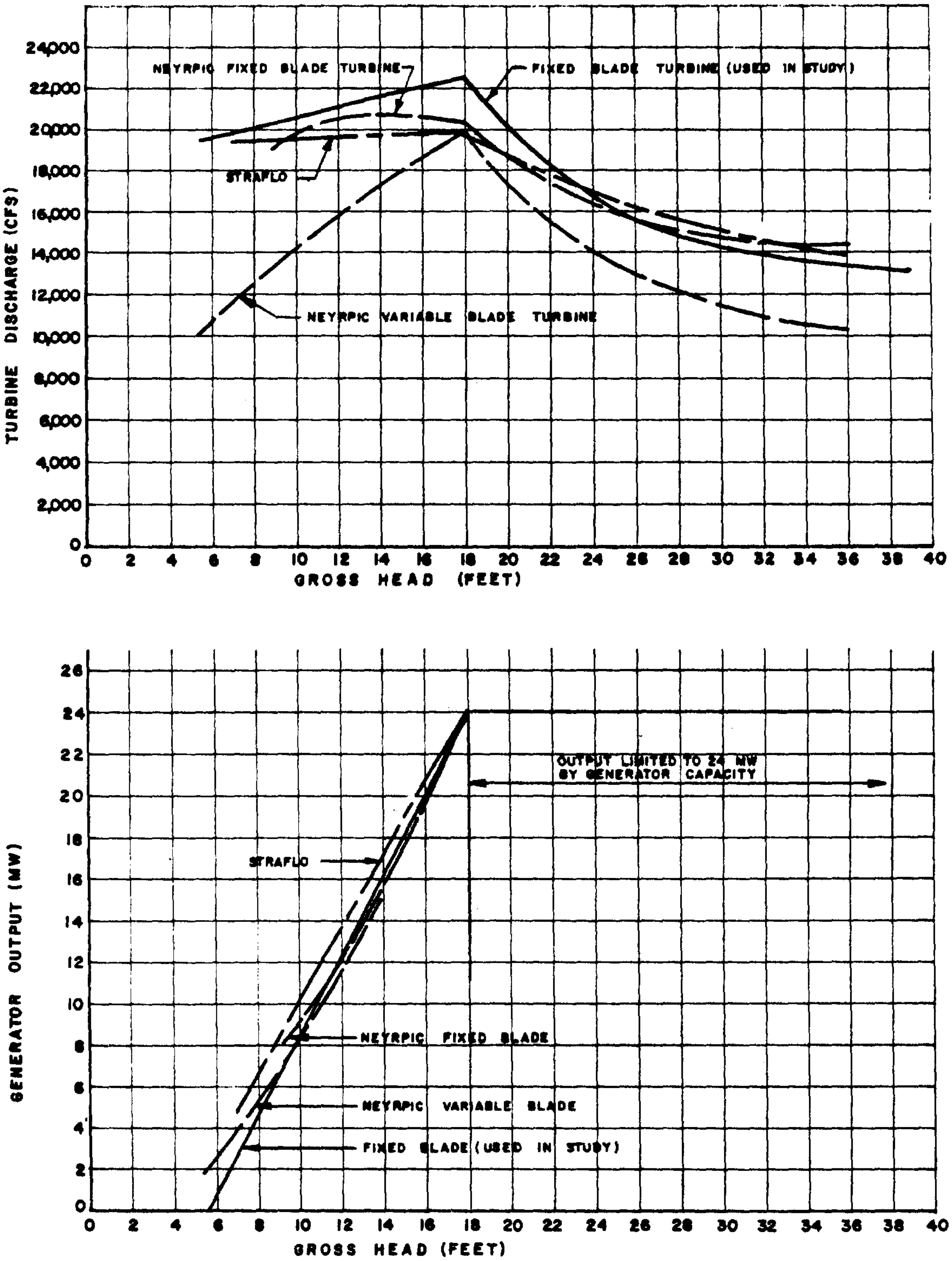
FIGURE 4.3

SOURCE ESCHER-WYSS-SULZER
WATERPOWER AND DAM
CONSTRACTION, MAY 1981.



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COOK INLET TIDAL POWER

EAGLE BAY
TURBINE — GENERATOR
PERFORMANCE CHARACTERISTICS

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FIGURE 4. 4

APPENDIX 5 - ELECTRICAL EQUIPMENT

APPENDIX 5 - ELECTRICAL EQUIPMENT

TABLE OF CONTENTS

Page

5.1 - Objective 5-1
5.2 - Approach 5-1
5.3 - Generators 5-1
5.4 - Arrangement of Units and Connections 5-2
5.5 - Auxiliary Electrical System 5-3
5.6 - Transmission System 5-3

LIST OF FIGURES

Number	Title
5.1	Electrical Single Line Diagram

5 - ELECTRICAL EQUIPMENT

5.1 - Objective

To present the principal generator and electrical equipment considerations for the design, arrangement, and connections of such equipment in the power plants; and to discuss the impact of bulb and Straflo generators in the performance of the tidal plant on the electrical power system.

5.2 - Approach

Information obtained from detailed studies carried out in the Bay of Fundy tidal plant project was used in the basic development of the electrical design and arrangement of equipment in the power plant and alternatives at Cook Inlet. Discussions were held with manufacturers to obtain pertinent technical data and estimated costs of the electrical equipment.

5.3 - Generators

Generator designs for bulb-type units and Straflo units are each considerably different from the other, and in many respects different from generators utilized in conventional hydro units.

In the bulb units, the diameter of the generator stator is limited by the turbine design requirements for optimum flow configuration. Hence, given the low speed of the turbine, there are several constraints in optimizing the electrical and mechanical design of the generators. These features in turn affect the performance of the generator and, therefore, the design of the electrical power system and include:

- MVA output limitations for a given MW output, with power factors on the order of 0.975 and above
- low generator voltages, 6 to 9 kV
- low inertia of the rotor with an H constant of 0.8 to 1.0
- special cooling designs

High power factor generators mean that heavy reactive power compensation would be required. Low inertia machines require consideration of the stability of the system.

As discussed in Appendix 4, the generator continuous maximum rating (CMR) consistutes the main limitation on the turbine output power at heads greater than the rated head. For the generators at all three sites, an 80°C temperature rise of windings above 40°C inlet cooling air with Class B insulation windings has been assumed for the maximum generator rating. Detailed optimization studies should investigate the potential overload capacity possible with Class F insulation generator windings for generation during the periods of high tides. Modern generators use thermoelastic epoxy Class F insulation as standard.

A substantial potential cost saving has been indicated by manufacturers (Neyrpic) in the use of a speed increaser to couple the turbine and generator, in the bulb unit leading to a higher speed and more economically designed generator. Higher inertia is also obtained. However, further detailed investigations need to be made regarding overall technical and economic evaluation of generators with speed increasers, taking into consideration also that higher operating and maintenance costs will be associated with their use.

The Straflo unit uses a rim-generator design, with the outer rim of the turbine runner supporting the generator rotor. Ratings will be the same as for the bulb generators as described above. Advantages of the Straflo generator over the bulb generator include greater rotational inertia due to the larger rotor diameter. Also cooling does not impose unusual problems. However, a special sealing system is required to prevent water from entering the generator. Several new designs of hydrostatic seals have been developed to overcome the problems of sealing. Although the Straflo generator would appear to be more suitable than the bulb generator, when considering solely the electrical system performance of the two types, in the absence of detailed electrical power system studies for stability and load/voltage regulation, the bulb unit has been selected for the machinery studies primarily from turbine design considerations as discussed in Appendix 4. Detailed studies would be required to further investigate and compare actual system performance of the two types of generators.

A static excitation system is considered to be best for the tidal plants, particularly for bulb units with restricted space. One static exciter can be used for a group of four units, with some cost savings resulting thereby.

5.4 - Arrangement of Units and Connections

With the large number of generators in a tidal power plant, ranging from 30 to 60 or more at each of the three sites, multiple-unit grouping, interconnection of units, and bus systems merit special consideration.

For generator ratings of 20 to 24 MW, the use of a standard short-circuit rating air circuit breaker for each generator is possible for groupings of four units. Groupings of eight units would require higher rupturing capacity circuit breakers of the isolated phase bus type. Alternatively, if disconnecting switches only are used, in each generator branch, a fault in one unit would result in an outage of all eight units. The overall savings in the eight-unit grouping scheme represent a negligible amount, about 0.2 to 0.3 percent, of the project cost in optimization studies. Hence, four-unit groupings of generators have been adopted from overall design and reliability considerations.

The single-line electrical diagram for the tidal power plant is shown in Figure 5.1.

A review of the different methods of transmission connections from the powerhouse to the shore was made. This length of connection is considerable and varies from 500 feet at Rainbow to 7000 feet at Point MacKenzie. Alternative methods include low- or high-pressure oil-filled cables, single- or 3-phase, overhead transmission lines and SF6 gas insulated bus ducts. The SF6 bus has several distinct advantages for transmitting power of 1000 to 2000 MW at 230 or 345 kV and has therefore been adopted. These advantages include:

- Limited space requirements in the powerhouse and dike structures

- Minimal maintenance and short repair times

- Integrated SF6 installations with SF6 circuit breakers, which are most cost effective at 345 or 230 kV voltage levels

- Costs comparable to the cheapest alternative (a newer development with corrugated aluminum enclosure, SF6 bus is expected to cost less, by about a third to half the presently estimated price).

A problem associated with SF6 gas switchgear is that at pressures of 70 psig, the gas liquifies at subzero temperatures below -35°C. The problem has been overcome at several installations in Canada, Sweden, Finland and elsewhere at temperatures down to -70°C by the use of a mixture of SF6 gas and nitrogen.

5.5 - Auxiliary Electrical System

Auxiliary systems required for the tidal plant are similar to those in conventional hydroplants. The auxiliary systems at the three sites are designed for a four-unit group powerhouse, except for the central control room which would include a computer controlled supervisory system for the whole tidal plant.

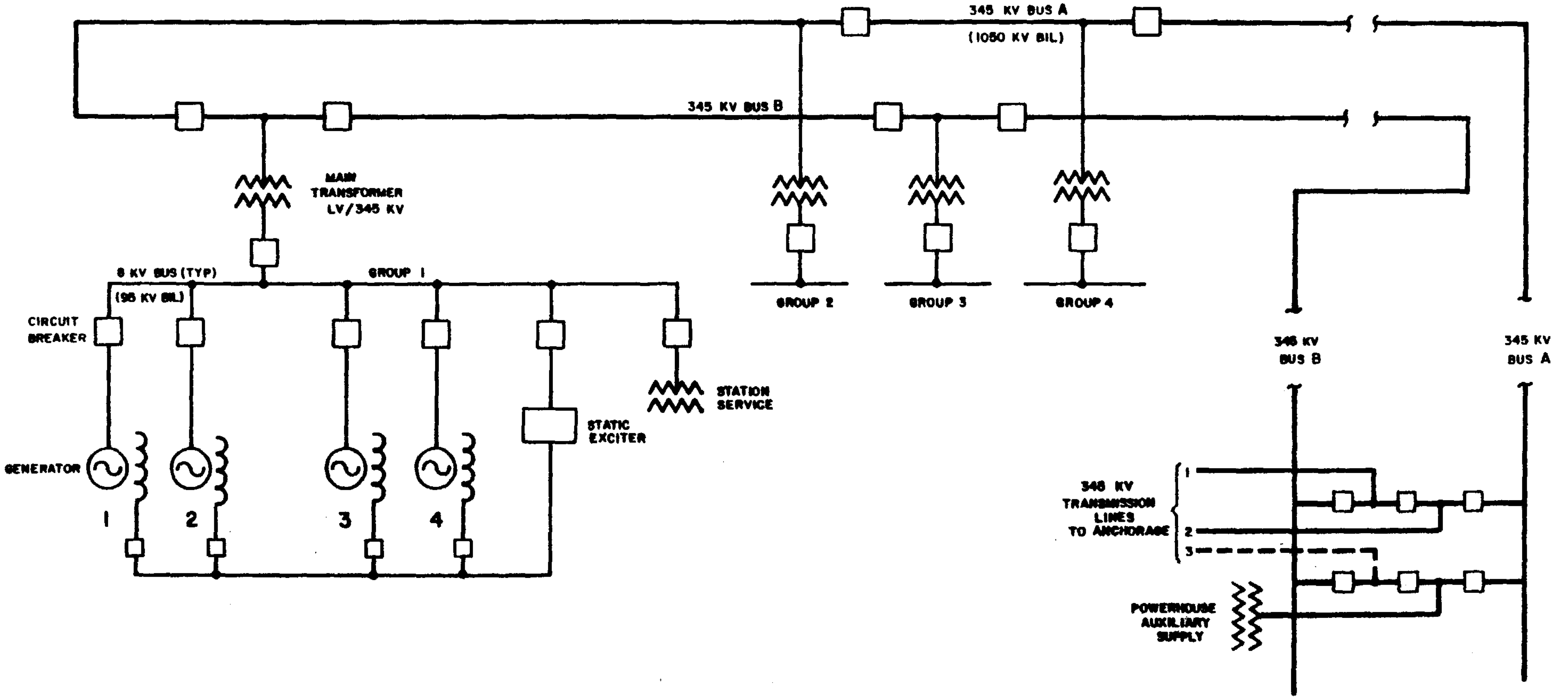
5.6 - Transmission System

The design of the transmission system is not within the scope of this preliminary feasibility study. Any future detailed studies should address the following design issues related to the integrated operation of the tidal plant in the Railbelt area power system:

- System stability
- Load flow, voltage regulation and VAR control
- System switching over-voltages during energizing or de-energizing
- EHV substation configuration
- Transmission line design including selection of the most suitable voltage for transmission, (230 kV or 345 kV).

For the purpose of the preliminary feasibility study, the transmission voltage is selected to be 345 kV, which may not prove to be the most economical voltage when considering the relatively short transmission lines (within 20 miles) from the tidal plant sites to the main load center at Anchorage.

In the cost estimates for the transmission system (Appendix 10), costs for reactive power support required at or near the load centers arising from the high power factor of the tidal plant generators have also been included.



	NO. OF GROUPS	GENERATORS
POINT MACKENZIE	15	60 X 21 MW
EAGLE BAY	15	60 X 24 MW
RAINBOW	10	40 X 23.2 MW

NOTES:

ALL GROUPS ARE IDENTICALLY EQUIPPED. ONLY 4 GROUPS ARE SHOWN TYPICALLY.

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COOK INLET TIDAL POWER

ELECTRICAL
SINGLE LINE DIAGRAM

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FIGURE 8.1

APPENDIX 6 - TIDAL POWER PLANT ENERGY STUDIES

APPENDIX 6 - TIDAL POWER PLANT ENERGY STUDIES

TABLE OF CONTENTS

Page

6.1 - Objective 6-1
6.2 - Approach 6-1
6.3 - Computer Simulation Model 6-1
6.4 - Tidal Simulation 6-2
6.5 - Turbine Characteristics 6-3
6.6 - Basin Characteristics 6-4
6.7 - Integration Routines 6-4
6.8 - Simulation Results 6-5
6.9 - "Sensitivity" Studies of Barrier Effect 6-6
6.10 - Studies with Variable Blade Turbine Characteristics 6-7
6.11 - Power Plant Optimization 6-7
6.12 - Results 6-8

LIST OF TABLES

Number	Title
6-1	Harmonic Constants of Tidal Wave Equation
6-2	One Year Simulation - Eagle Bay Site
6-3	Sensitivity Studies for Barrier Effect
6-4	Comparison of Plant Studies with Variable-Blade and Fixed-Blade Turbines
6-5	Cost Coefficients for Optimization Studies
6-6	One Year Simulation Runs for Optimum Plant Designs
6-7	Optimum Plant and Turbine-Generator Data

LIST OF FIGURES

Number	Title
6.1	Block Diagram Computer Simulation Model
6.2	Typical Plot of Tidal Simulation at Point MacKenzie
6.3	Performance Curves for Fixed-Blade Bulb Turbine
6.4	Performance Curves for Variable-Blades Bulb Turbine
6.5	Basin Filling/Discharging Characteristics
6.6	Typical Tidal Plant Operation (Single Effect)
6.7	Point MacKenzie Tidal Plant Simulation
6.8	Eagle Bay Tidal Plant Simulation
6.9	Rainbow Tidal Plant Simulation
6.10	Point MacKenzie Plant Optimization
6.11	Eagle Bay Plant Optimization
6.12	Rainbow Plant Optimization

6 - TIDAL POWER PLANT ENERGY STUDIES

6.1 - Objective

To obtain the energy generated for a single-basin, single-effect plant configuration at each of the three sites at Point MacKenzie, Eagle Bay and Rainbow; to establish optimum plant and turbine-generator equipment characteristics for each site; and to prepare plant optimization curves of energy (GWh) against cost for each site.

6.2 - Approach

To achieve the stated objectives, a computer simulation model was developed to simulate the tidal power plant operation. Plant optimization led to the selection of the optimum turbine/sluice combinations using a cost equation which provided for the number of turbines, sluices and dike length, based on incremental costs derived from the base case estimates developed in Appendix 9.

6.3 - Computer Simulation Model

A computer model was developed to simulate the operation of the tidal power plant for a single basin-single effect configuration. Each of the three sites at Point MacKenzie, Eagle Bay and Rainbow were studied for continuous simulation periods of 30 days, the optimum plant configuration being studied over a 364-day period simulation.

The program was developed with the Acres in-house D.E.C. Model VAX11/780 computer installation. A high-level simulation language, CSMP III, was used for the program.

The model includes the following principal features:

- Simulation of the time variable height of the tide using harmonic tide constituents
- Turbine characteristics for flow and power as a function of the head, for both fixed-blade and variable-blade turbines
- Tidal basin filling/discharging characteristics as a function of the basin elevation
- Sluicing characteristics of sluiceways and turbines.

The block diagram for the computer simulation model is shown in Figure 6.1. The diagram shows the algorithm whereby the instantaneous net head on the turbine, and therefore the power and energy, are continuously calculated during the period of the study. Integration of the integrable variables are carried out using the Fourth Order Runge Kutta routine or Simpson's integration routine. The latter routine was used for all long runs (30 days and above) with an integration time interval of 2.8 minutes.

The computer model allows the following variables to be easily modified during the studies:

- Number of turbines in power plant
- Number of sluices in power plant
- Rated head of turbine
- "Starting" and "stopping" heads during turbining
- Sluicing through turbines
- Basin starting level, at start of the study

Adjustable time periods include:

- Time period of simulation (7 days, 30 days or 364 days)
- Time interval of integration
- Time interval for plotting and numerical printouts (hourly printout)

The output includes the following:

- Time plot of tide height above MLLWL (Mean Low Low Water Level)
- Time plot of basin elevation above MLLWL
- Time plot of turbine-generator power
- Numerical print-out of tide height, basin elevation, and turbine-generator power, and also turbine head, discharge, basin volume, plant power and plant energy.

The operating features of the computer model, which includes ease of modification of model parameters, and plotting of results, as well as the rapid video scanning of results and plots, allows fast and efficient optimization of the tidal power plant design and performance.

The principal features of the model are discussed in detail in the following sections.

6.4 - Tidal Simulation

The general equation for the height of the tide (h) at any time (t) is calculated using the following cosine summation harmonic equation:

$$h = Ho + A\cdot\cos(at+\alpha) + B\cdot\cos(bt+\beta) + C\cdot\cos(ct+\gamma) + \ldots\ldots\ldots\ldots$$

where

- Ho is the height of the mean water level above datum (MLLWL)
- A,B,C,... are the amplitudes of the harmonic constituent terms

- a,b,c,... are the speeds of the harmonic constituents
- α, β, γ,... are the initial phase angles at time t equals zero.

The values of the harmonic constituent terms used in the simulation model are given in Table 6.1.

The principal constituents are defined below:

K_1, O_1 = lunar declination diurnal constituents

P_1 = solar diurnal constituent

μ_2 = minor semi-diurnal lunar component

S_2 = principal solar semi-diurnal constituent

M_2 = principal lunar semi-diurnal constituent (the largest tidal component)

M_4, M_6 = lunar constituents of double and triple the speed of the M_2 constituent

N_2 = lunar elliptic semi-diurnal constituent

In the model, the independent variable, time, was unitized to a solar day basis. This facilitates comparison of the tidal data with hourly tide tables, also the power output can be compared easily with daily load duration curves for energy storage studies.

The harmonic data was obtained from the U.S. Department of Commerce, Coast and Geodetic Survey, for the Anchorage station in the Cook Inlet (369-day series). Appropriate multipliers were used for the harmonic amplitude constants to achieve the mean tide ranges given in Table 3-1 of Appendix 3 for each of the sites.

A typical Calcomp computer plot of the tidal simulation is shown in Figure 6.2.

6.5 - Turbine Characteristics

The turbine characteristic curves used in the simulation are given in Figure 6.3 for the fixed-blade bulb turbines and Figure 6.4 for the variable-pitch-blade bulb turbines. These curves have been computed from turbine hill charts along predetermined operating conditions as described in Appendix 4, and are normalized to unit head, flow and power. The power characteristics include allowances for generator efficiency and hydraulic intake losses. It will be noted that the continuous maximum rating of the generator imposes the maximum limits on the unit rating at heads greater than rated head.

The data from the curves are stored in the computer model in per-unit normalized form, and are calculated for each site in dimensions of feet, cfs, and kW for head, flow and power, respectively, in terms of the rated head at each site. Intermediate data points during program execution time are interpolated by the program.

6.6 - Basin Characteristics

The basin filling and discharging characteristics for the three sites are shown in Figure 6.5. Data for these characteristics were obtained from NOAA navigational charts and are considered therefore to be essentially preliminary in nature. The characteristics of the basin showed considerable impact on the simulations, hence this is an area where any future studies should be based on more accurate data.

6.7 - Integration Routines

The two integration routines used for the solution of the differential equations were the Runge Kutta Fourth Order method and the Simpson's method.

The Runge Kutta Fourth Order method uses the following equations:

$$Y_{(t + dt)} = Y_t + \frac{1}{6} \left[K_1 + 2K_2 + 2K_3 + K_4\right]$$

where

$$K_1 = dt \cdot f\left(t, Y_t\right)$$

$$K_2 = dt \cdot f\left(t + \frac{dt}{2}, Y_t + \frac{K1}{2}\right)$$

$$K_3 = dt \cdot f\left(t + \frac{dt}{2}, Y_t + \frac{K2}{2}\right)$$

$$K_4 = dt \cdot f\left(t + dt, Y_t + K_3\right)$$

$$f(t) = \dot{Y}_t$$

The step-size or integration interval is automatically adjusted to specified error-bounds during the problem execution.

The Simpson's method uses the following equations:

$$\text{Predictor:}\quad Y^p_{\left(t + \frac{dt}{2}\right)} = Y_t + \frac{dt}{2} \cdot X_t$$

$$Y^p_{(t + dt)} = Y^p_{\left(t + \frac{dt}{2}\right)} + \frac{dt}{2} \cdot X_{\left(t + \frac{dt}{2}\right)}$$

$$\text{Corrector:}\quad Y^c_{(t + dt)} = Y_t + \frac{dt}{6} \cdot \left[X_t + 4X_{\left(t + \frac{dt}{2}\right)} + X_{(t + dt)}\right]$$

$$\text{where}\quad X_t = \dot{Y}_t$$

Although the Runge-Kutta method gives a somewhat higher accuracy (about one percent) because of the variable time-step, in problems such as the tidal power simulation, where sudden changes or discontinuities occur, as in starting or stopping turbining, the run is sometimes terminated (especially for the 364-day runs) when the integration step becomes smaller than the minimum specified. The Simpson's method was therefore used for all long runs of 30 days and more.

6.8 - Simulation Results

Simulations were done in two basic parts:

(1) Preliminary simulations for optimizing the power plant turbines/sluices configurations and design at each site using preliminary cost values for turbine-, sluice-, and dike-dependent costs

(2) Final optimization of the selected power plant configuration at each site, using more accurately determined cost data.

The object of the preliminary simulation studies was to achieve optimum operation of the tidal plant for maximum energy, by maintaining the basin level at its highest possible level at the start of each turbining cycle, cutting off generation at an appropriate head, and refilling the reservoir to its optimum level.

The turbine characteristics used for all preliminary runs were for the fixed-blade bulb turbine. The turbine rated head, "starting" head and "stopping" head during turbining were determined for each site by a series of optimizing runs of 7-day periods. Further optimization of the turbine "starting" and "stopping" heads was not performed during the execution of the long simulation runs; optimization of these parameters would increase the energy output of the plant even further.

Figure 6.6 shows schematically the effect of varying the number of turbines and sluices at a typical site. If the "starting" and "stopping" heads are maintained constant, increasing the number of turbines would decrease the generating time and vice versa. For each turbine simulation "path", a number of sluice combinations are possible for optimization.

Although the number of simulation variables are not few, it was found, in practice, that an optimum, or near optimum, plant design was very quickly achieved with a number of preliminary 7-day runs. These optimum designs were confirmed with a limited series of 30-day runs.

A preliminary 364-day run was performed for the Eagle Bay plant. Results of 30-day period energy outputs are shown in Table 6-2 and indicate that the energy computation on the basis of 30-day runs (i.e., approximately a lunar month of 54 tides) gives a fairly accurate estimate of the annual energy. Estimates based on 7-day or 14-day runs give a higher degree of deviation from their mean values.

Typical computer printouts for each of the three sites are shown in Figures 6.7 through 6.9, with plots for tidal heights, basin elevations, and power outputs.

The simulation studies indicated that the principal input characteristics to the tidal plant model, namely tidal simulation, turbine characteristics and basin filling/discharging characteristics, each have significant impacts on the results. Each site behaves quite differently from another, being influenced significantly by its basin filling/discharging characteristics apart from tidal range differences.

Resulting from these observations, a limited number of simulation studies were performed to analyze the potential impact of any barrier effect that might be predicted on the tidal energy, and the impact of variable pitch blade turbine characteristics on power and energy production of the optimum tidal power plant at each site.

6.9 - "Sensitivity" Studies of Barrier Effect

The potential impact of a reduction in the tidal ranges at each of the three sites due to the tidal barrier was studied to provide a "sensitivity" analysis of the energy output for the optimum plant configurations. A "reduction" in the tidal range, rather than an "increase" was adopted. Furthermore, no attempt at plant optimization was made, hence the results are considered to be a conservative estimate of the sensitivity analysis for tidal barrier effect.

The results of the studies are given in Table 6-3.

6.10 - Studies with Variable-Blade Turbine Characteristics

A limited number of simulations were performed with bulb-turbine characteristics for the variable-blade design. These simulations were done for the optimum plant configuration for each site obtained with fixed-blade turbine characteristics. No further optimization was done for the variable-blade turbine plants.

A comparison between the energy outputs of variable-blade and fixed-blade bulb turbines is presented in Table 6-4. Although the increase in the total annual energy output is on the order of 5 percent at Point MacKenzie, 8 percent at Eagle Bay and 10 percent at Rainbow, considerably greater percentage increases in both power and energy outputs were noticed for the low tides. An energy cost reduction of about 2.6 to 4.6 mills/kWh is achieved, depending on the site. These results indicate that a significant impact could result in the selection and sizing of energy storage plants with the use of turbines with variable-blade characteristics, and should be included in any detailed future studies.

6.11 - Power Plant Optimization

As stated earlier, the final optimum plant configuration for turbines and sluices was selected after detailed cost estimates were prepared for each site. Fixed-blade characteristics were assumed for the turbines for all final optimization runs. The cost equation used for optimization was of the following form:

$$\text{Direct Cost (\$)} = A\,.N_T + B.N_S + C.\,(\text{Length of dike in feet}) + D$$

Where A = Cost coefficient per turbine

B = Cost coefficient per sluice

C = Cost coefficient per foot of dike

D = Constant cost factor

N_T = Number of turbines

N_S = Number of sluices

The cost coefficients used for each site are given in Table 6-5.

It should be noted that the cost equation is basically a method of applying incremental costs and is only applicable to installations fairly close to those used for the base case estimates.

The following factors were used in the cost evaluation and optimization studies. (Description and rationale for the choice of these factors are given in Appendix 13.)

- Indirect costs of 13 percent are included in the direct cost coefficients given in Table 6-4.

- Engineering, management and contract administration costs are assumed to be 12-1/2 percent of total direct costs.

- Contingency is 25 percent of direct costs plus engineering, management and administrative costs.

- Interest during construction is not taken for the plant optimization studies (See Appendix 14).

- Annualized costs include:

  - Finance Cost: 3.0 percent
  - Operation and maintenance: 0.6 percent
  - Amortization: 0.89 percent
  - Insurance: 0.10 percent

Resulting from the above, total annual costs of 6.45 percent of the total direct cost for each site were taken for the plant optimization studies.

The results of the plant optimization studies are shown in Figures 6.10 through 6.12. All optimization studies were performed using fixed-blade turbine characteristics for bulb turbines. These characteristics are also very similar to the Straflo turbine curves and the energy outputs can be considered to be equally applicable for the Straflo units for this preliminary feasibility study.

A final 364-day run was performed for each of the three sites for the optimum plant configuration. The results of these year-long runs are shown in Table 6-6.

At Point MacKenzie, the optimum plant configuration of 80 turbines and 60 sluices, for an installed capacity of 1680 MW, may not be realized due to closure velocity limitations, as discussed in Appendix 7. Hence, a plant of 60 turbines and 46 sluices was considered to be a more practical and economical configuration at Point MacKenzie, and has been designated "optimum."

As a result of the plant optimization studies, the optimum turbine-generator and plant data are obtained for each of the sites and are given in Table 6-7.

6.12 - Results

(a) Plant optimization curves of energy against cost of energy for single basin, single effect operation were obtained for each site. Turbines with fixed-blade characteristics were used for these studies. These showed Eagle Bay to be the most promising site with the lowest at-site energy cost levels.

(b) The optimum plant configuration at Eagle Bay would have 60 turbines and 36 sluices with an installed capacity of 1440 MW, producing energy of 4037 GWh per annum at a cost of 43 mills/kWh. However, the plant optimization curves are very flat, and show that a smaller plant of 720 MW installed capacity produces 2300 GWh per annum at a cost of only 7.5 mills/kWh more than the optimum plant.

(c) The use of variable-blade turbines improves the annual energy output by about 6 to 11 percent depending on the site. In the case of Eagle Bay, for the 1440 MW installation, an energy increase of about 9 percent per annum is achieved at a unit energy cost reduction of about 3.3 mills/kWh. These are conservative values because no detailed optimization studies were done for the variable-blade turbine simulations.

(d) Results of the sensitivity analysis of the potential impact caused by the imposition of the tidal barrier show that if a reduction in tidal levels of 1 foot were to be taken at Eagle Bay and Rainbow, then energy production would be reduced by about 6.2 percent and 4.8 percent respectively. Reductions of 2 and 3 feet in the tidal level at Point MacKenzie would reduce energy production by 10.3 percent and 14.2 percent, respectively.

TABLE 6-1

HARMONIC CONSTANTS OF TIDAL WAVE EQUATION

Station: Anchorage, Cook Inlet, Alaska

Constituent	Amplitude (feet)	Phase (Degrees)	Speed (Degrees/hour)
K_1	2.26	191	15.0411
O_1	1.25	185	13.9430
P_1	0.63	197	14.9589
μ_2	0.66	319	27.9680
S_2	3.20	207	30.0000
M_2	11.54	175	28.9841
M_4	0.93	218	57.9682
M_6	0.53	229	86.9523
N_2	1.95	152	28.4397

NOTES: 1. Calculated Mean Tide Range is 25.1 feet.

2. Series is for 369 days, beginning July 1, 1964.

TABLE 6-2

ONE YEAR SIMULATION - EAGLE BAY SITE

	Energy GWh	% Annual Energy
1st 30 days	341	8.45
2nd 30 days	343	8.49
3rd 30 days	339	8.39
4th 30 days	333	8.25
5th 30 days	326	8.07
6th 30 days	324	8.03
7th 30 days	326	8.07
8th 30 days	329	8.15
9th 30 days	331	8.20
10th 30 days	322	7.98
11th 30 days	332	8.22
12th 30 days	334	8.27

NOTES: 1. 364 days total energy = 4037 GWh.

2. Average energy per 30 days = 333 GWh.

TABLE 6-3

SENSITIVITY STUDIES FOR BARRIER EFFECT

	Equivalent Mean Tidal Range (feet)	Annual Energy (GWh)	Annual Energy (%)
Point MacKenzie (60 Turbines, 1260 MW, 46 sluices)	25.7 23.7 22.7	3937 3560 3405	100.0 89.7 85.8
Eagle Bay (60 Turbines, 1440 MW, 36 sluices)	27.6 26.6	4037 3788	100.0 93.8
Rainbow (40 Turbines, 930 MW, 24 sluices)	27.5 26.5	2664 2535	100.0 95.2

NOTE: Turbines with fixed-blade charactertics were used for both comparative runs.

TABLE 6-4

COMPARISON OF PLANT STUDIES WITH VARIABLE-BLADE AND FIXED-BLADE TURBINES

	Annual Energy		Performance at Lowest Tides	
	(GWh)	(%)	Peak MW (% Plant MW) increase	Energy per Tide, GWh (% increase)
Point MacKenzie (60 Turbines, 1260 MW, 46 sluices)				
- Fixed-Blade Turbines	3937	100.0	13.2	2.93
- Variable-Blade Turbines	4167	105.8	14.7 (+7%)	3.31 (+13%)
Eagle Bay (60 Turbines, 1440 MW, 36 sluices)				
- Fixed-Blade Turbines	4037	100.0	12.7	2.58
- Variable-Blade Turbines	4368	108.2	14.9 (+9%)	3.24 (+26%)
Rainbow (40 Turbines, 930 MW, 24 sluices)				
- Fixed-Blade Turbines	2664	100.0	7.9	1.2
- Variable-Blade Turbines	2955	110.9	10.8 (+12%)	2.1 (+90%)

TABLE 6-5

COST COEFFICIENTS FOR OPTIMIZATION STUDIES
(Million Dollars)

Site	A	B	C	D
Point MacKenzie	27.873	12.407	0.03380	424.880
Eagle Bay	27.685	12.023	0.02796	222.600
Rainbow	28.702	12.288	0.02070	206.790

TABLE 6-6

ONE YEAR SIMULATION RUNS FOR OPTIMUM PLANT DESIGNS

	Point MacKenzie[1/] Energy (GWh)	Eagle Bay[2/] Energy (GWh)	Rainbow[3/] Energy (GWh)
1st 30 days	331	341	224
2nd 30 days	334	343	226
3rd 30 days	328	339	222
4th 30 days	324	333	221
5th 30 days	320	326	217
6th 30 days	318	323	214
7th 30 days	318	326	215
8th 30 days	323	329	218
9th 30 days	323	331	219
10th 30 days	325	323	220
11th 30 days	322	332	217
12th 30 days	325	334	220
364 days Total energy	3,937	4,037	2,664
Average energy per 30 days	324	333	219

[1/] 60 X 21 MW, 46 sluices

[2/] 60 X 24 MW, 36 sluices

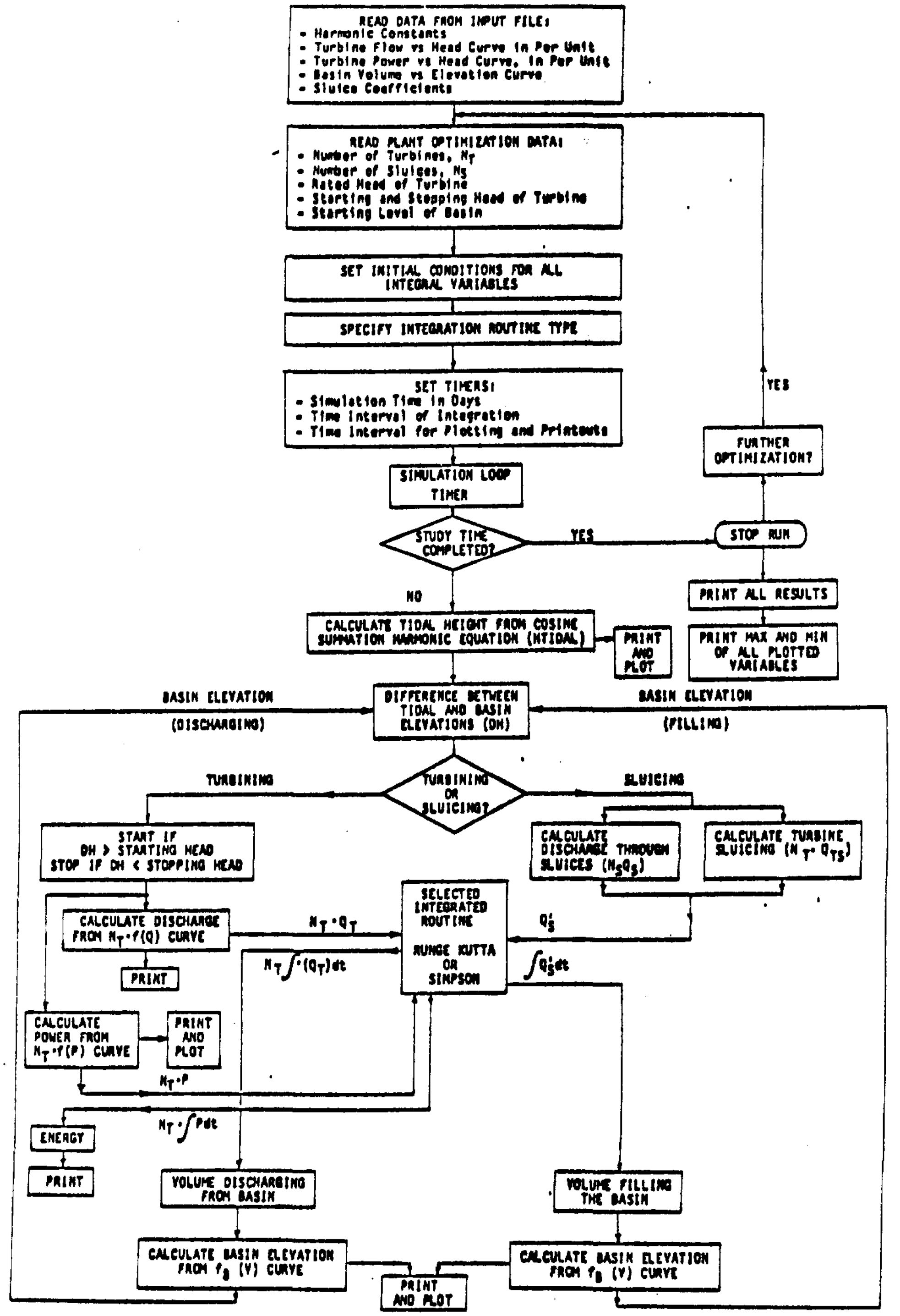
[3/] 40 X 23.2 MW, 24 sluices

TABLE 6-7

OPTIMUM PLANT AND TURBINE-GENERATOR DATA

	Point MacKenzie	Eagle Bay	Rainbow
Mean Tide Range, feet	25.7	27.6	27.5
Rated head of turbine, feet	16.5	18.0	17.6
Maximum head, feet	30.8	32.0	32.2
Minimum head, feet	4.95	5.3	5.3
Rated discharge, cfs of turbine	21,560	22,520	22,270
Type of turbine	Fixed blade bulb	Fixed blade bulb	Fixed blade bulb
Rated MW per unit, MW	21.00	24.04	23.24
Number of turbines	60	60	40
Number of sluices	46	36	24
Plant capacity, MW	1260	1440	930
Annual plant energy output, GWh	3937	4037	2664
Direct Costs, $ million	2908	2690	1969
Cost of energy,1/ mills/kWh	47.65	42.98	47.68

1/ Mill rates in this tabulation differ from those in Appendix 14 since the economic analysis also considered interest during construction.



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COOK INLET TIDAL POWER

BLOCK DIAGRAM COMPUTER SIMULATION MODEL

FIGURE 6-1

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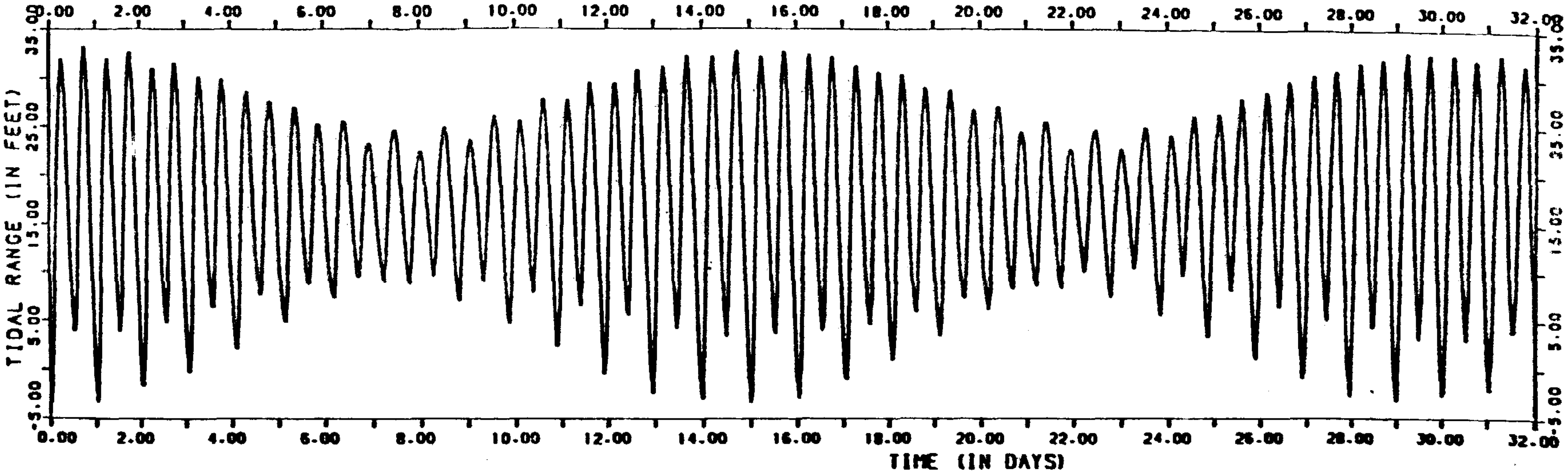
TIDAL RANGE AT ANCHORAGE COOK INLET, ALASKA

PROJECT SITE AT PT. MACKENZIE

MARCH 6. 1981



LEGEND: - TIDAL RANGE AT ANCHO

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TYPICAL PLOT OF TIDAL
SIMULATION AT POINT MACKENZIE

FIGURE 6.2

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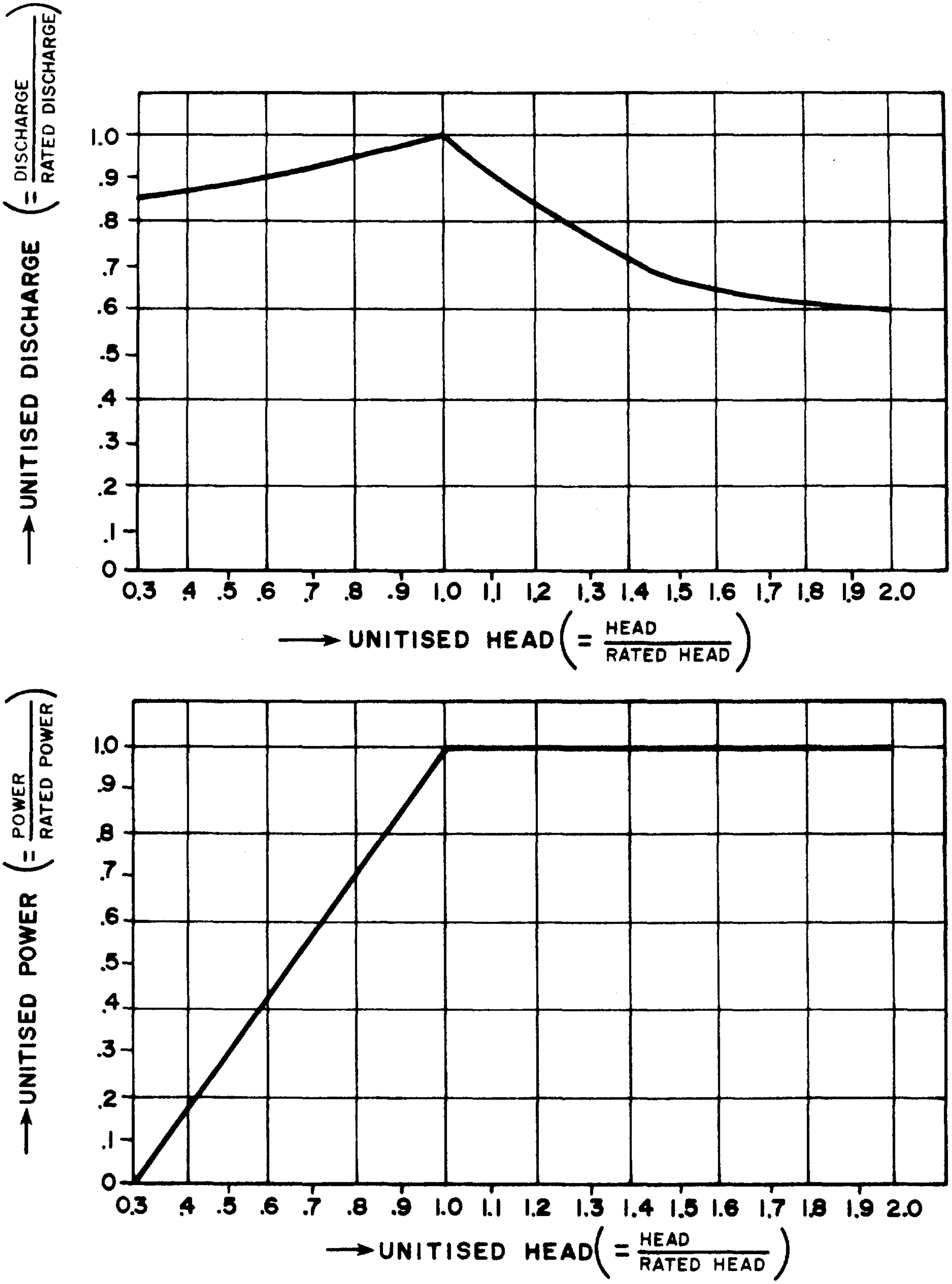

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COOK INLET TIDAL POWER

PERFORMANCE CURVES
FOR
FIXED BLADE
BULB TURBINE

FIGURE 6.3

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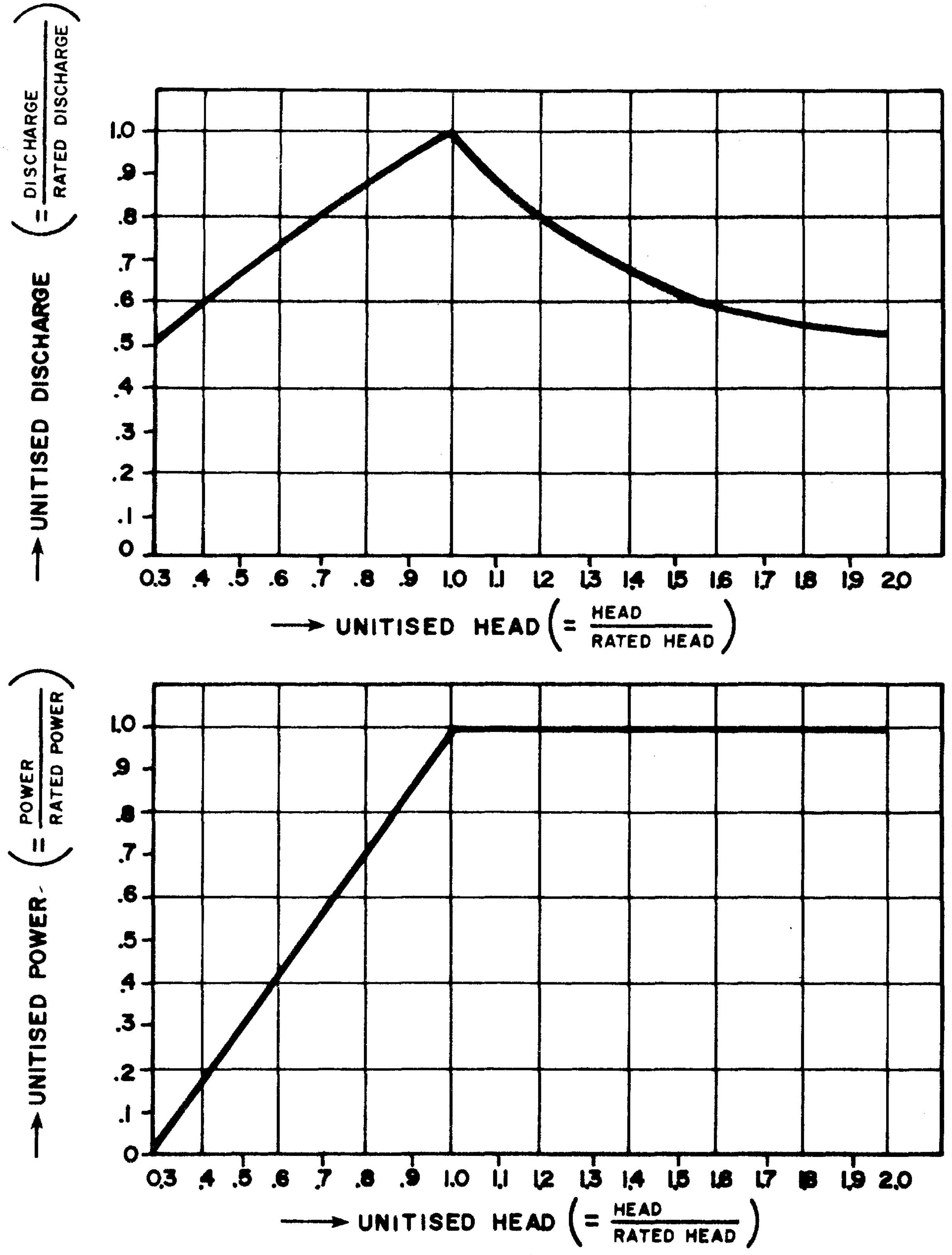

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PERFORMANCE CURVES FOR VARIABLE BLADES BULB TURBINE

FIGURE 6.4

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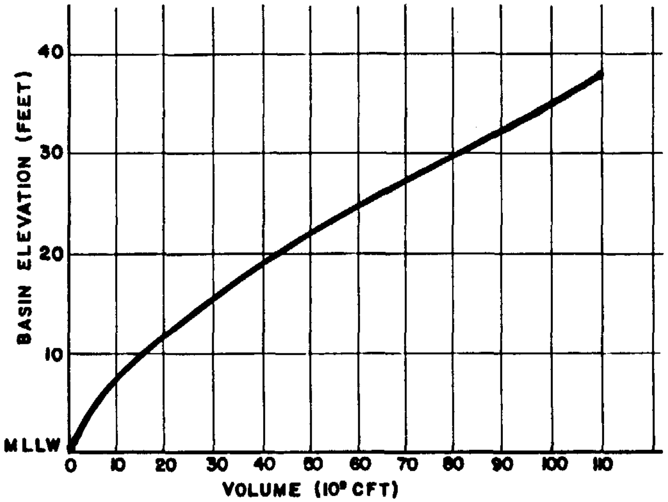
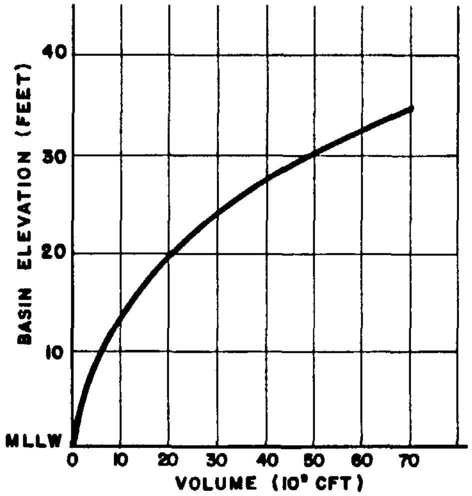
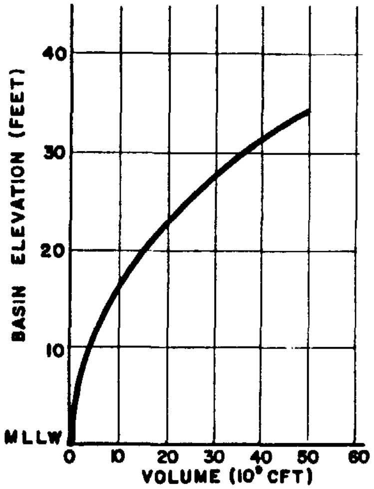


BASIN CURVE
FOR POINT MACKENZIE



BASIN CURVE
FOR EAGLE BAY



BASIN CURVE
FOR RAINBOW

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BASIN FILLING/DISCHARGING
CHARACTERISTICS

FIGURE 6.8

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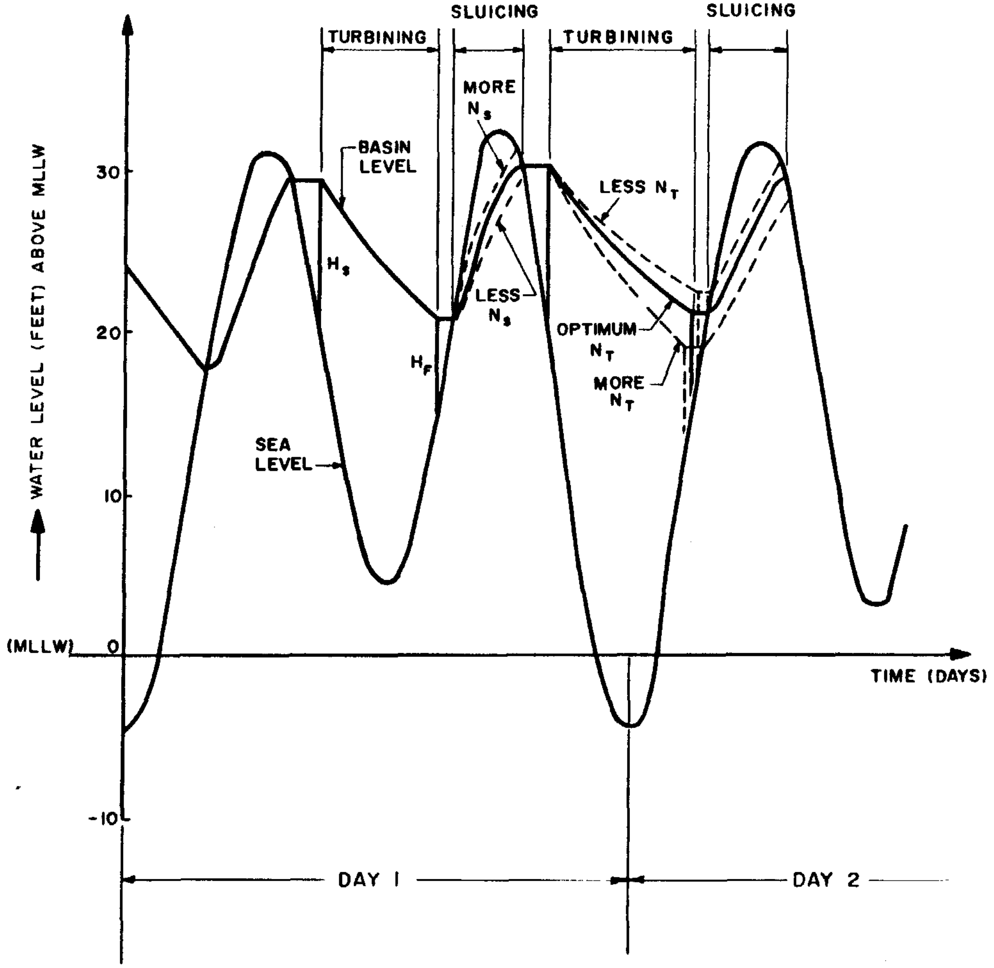

LEGEND

N_T - NUMBER OF TURBINES

N_S - NUMBER OF SLUICES

MLLW - MEAN LOW LOW WATER LEVEL

H_S - STARTING HEAD OF TURBINE

H_F - STOPPING HEAD OF TURBINE

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TYPICAL TIDAL PLANT
OPERATION (SINGLE EFFECT)

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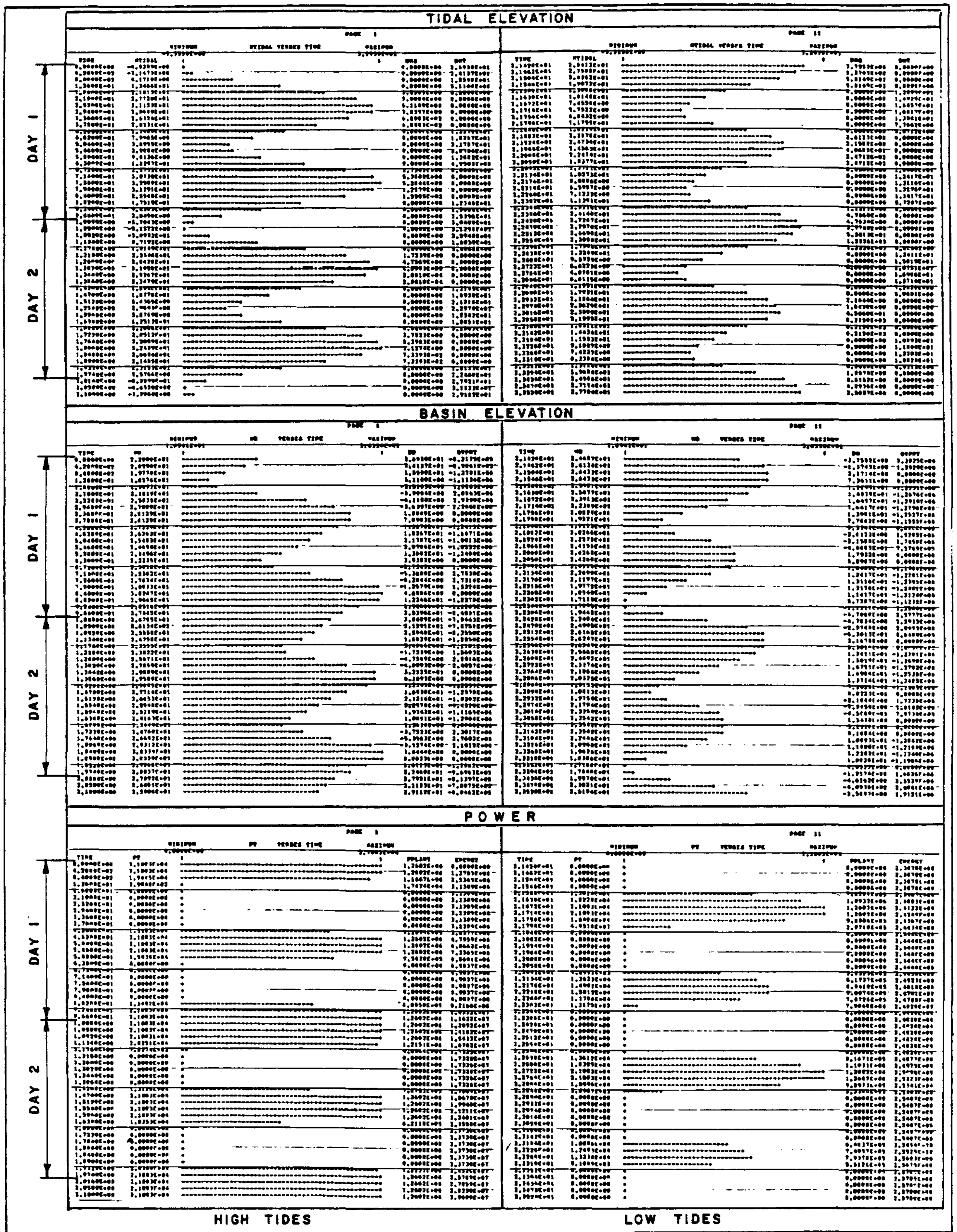
FIGURE 6.6



NUMBER OF TURBINES = 60 X 21 MW
NUMBER OF SLUICES = 46

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POINT MACKENZIE
TIDAL PLANT SIMULATION

FIGURE 6.7

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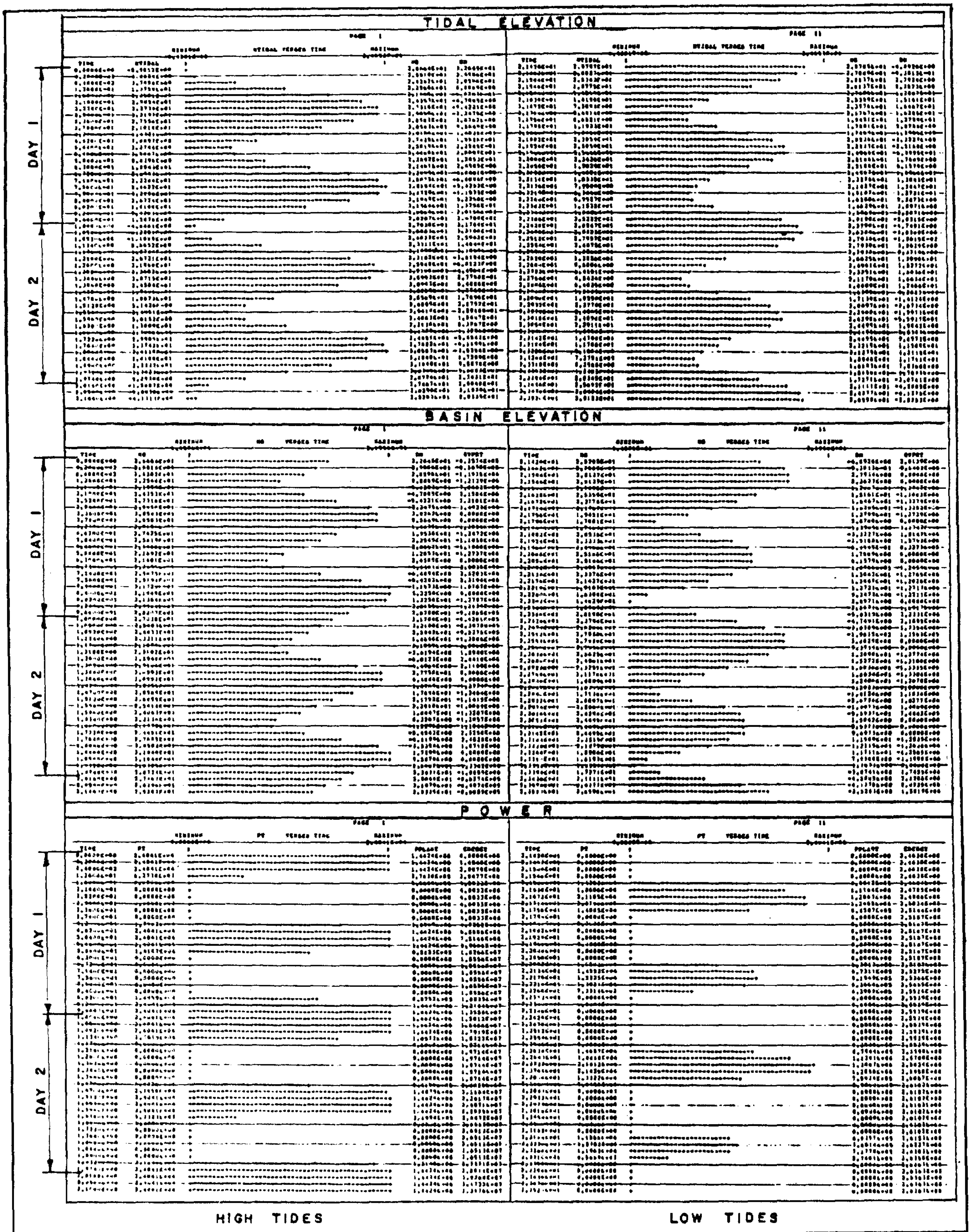

NUMBER OF TURBINES = 60 X 24 MW
NUMBER OF SLUICES = 36

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COOK INLET TIDAL POWER

EAGLE BAY
TIDAL PLANT SIMULATION

FIGURE 6.8

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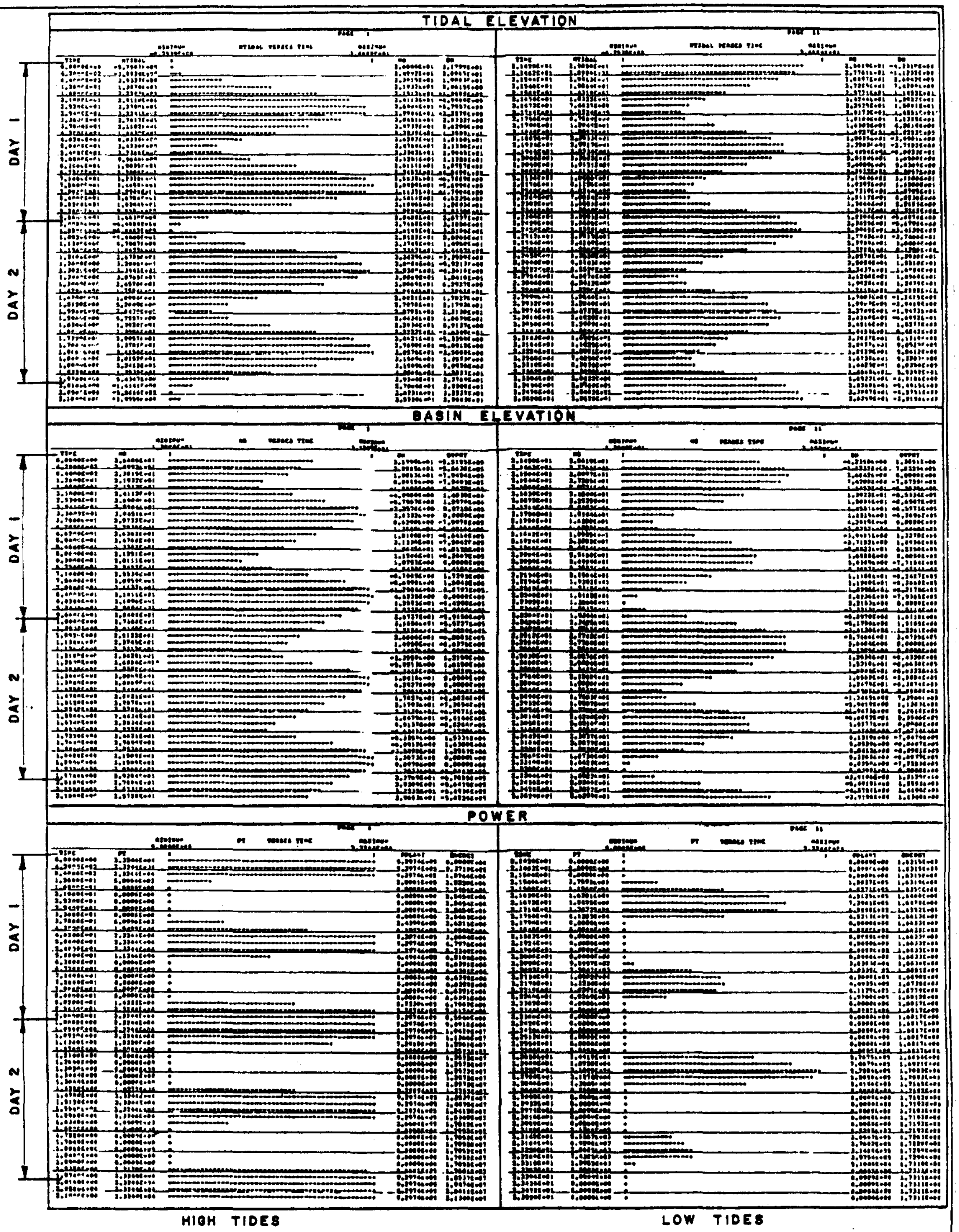

NUMBER OF TURBINS = 40 X 23.2 MW
NUMBER OF SLUICES = 24

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RAINBOW
TIDAL PLANT SIMULATION

FIGURE 6.9

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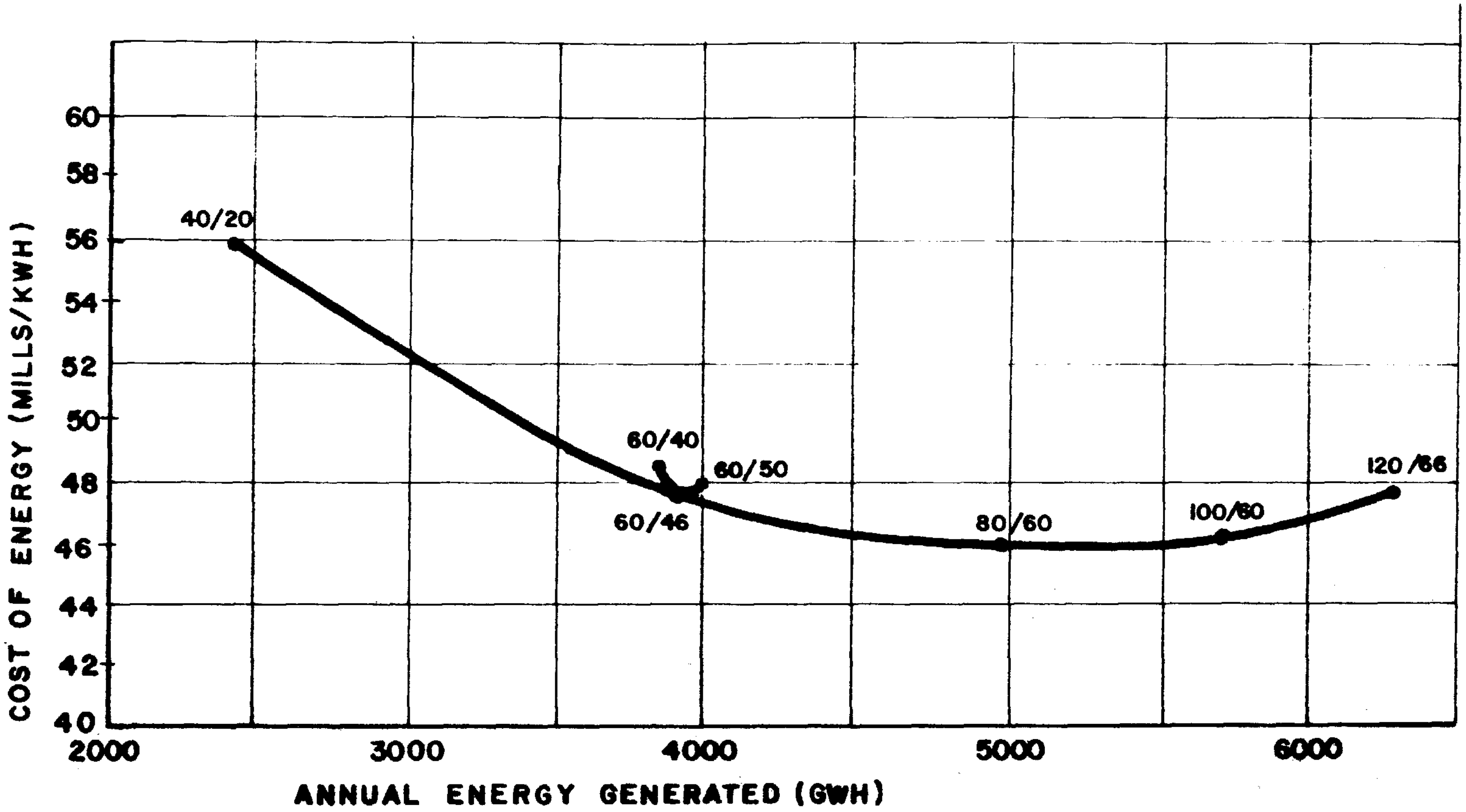

LEGEND

60/46 TYPICALLY DENOTES
"60 TURBINES/46 SLUICES

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POINT MACKENZIE
PLANT OPTIMIZATION

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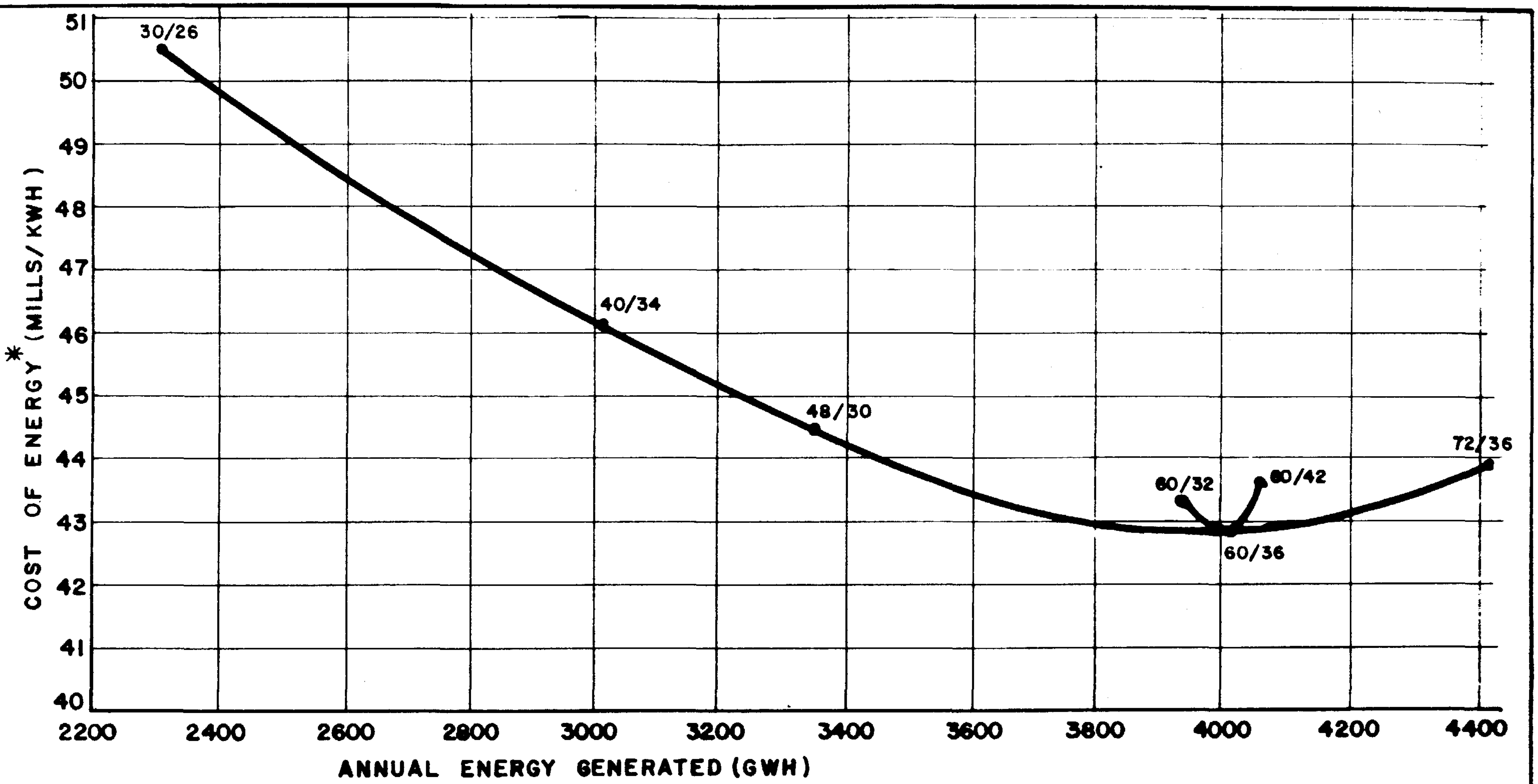
FIGURE 6.10



LEGEND

60/36 TYPICALLY DENOTES
"60 TURBINES / 36 SLUICES"

* EXCLUDING INTEREST
DURING CONSTRUCTION

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EAGLE BAY

PLANT OPTIMIZATION

FIGURE 6.11

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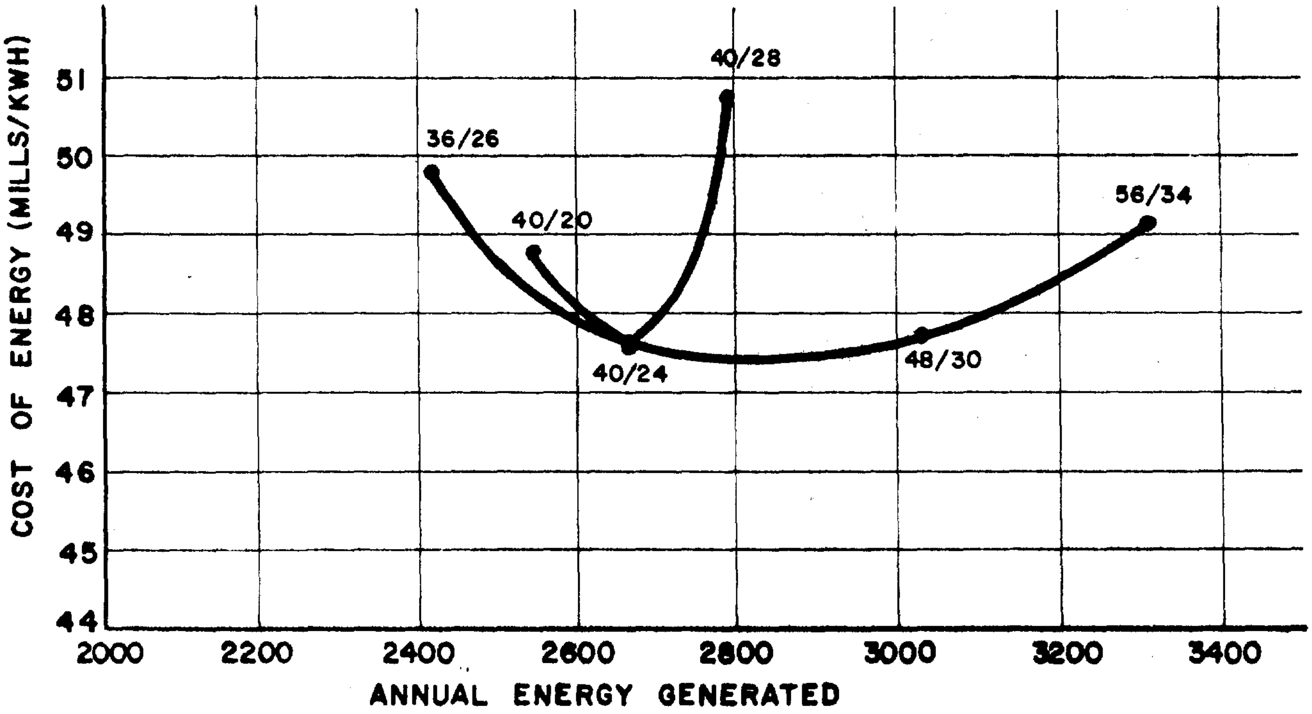

LEGEND

40/24 (TYPICALLY) DENOTES
"40 TURBINES/24 SLUICES"

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RAINBOW
PLANT OPTIMIZATION

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FIGURE 6.12

APPENDIX 7 - CLOSURE OF THE TIDAL BASIN

APPENDIX 7 - CLOSURE OF THE TIDAL BASIN

TABLE OF CONTENTS

Page

7.1 - Objective 7-1
7.2 - Approach 7-1
7.3 - Computer Model 7-1
7.4 - Natural Velocities 7-2
7.5 - Velocities during Placement of Powerhouse and Sluiceway Units 7-2
7.6 - Dike Closure 7-3

LIST OF TABLES

Number	Title
7-1	Maximum Computed Flow Velocities

LIST OF FIGURES

Number	Title
7.1	Point MacKenzie Maximum Velocities for a 5000-Foot Closure Section
7.2	Tide Range Exceedence
7.3	Typical Example of Water Surface and Velocities Through a Tide Cycle During Closure

7 - CLOSURE OF THE TIDAL BASIN

7.1 - Objective

To predict water velocities through the gap during closure of the tidal basin in order to determine the construction sequence and the feasibility and method of closure.

7.2 - Approach

As the barrier enclosing a tidal basin is constructed, the area of tidal flow is gradually decreased and a corresponding reduction in total discharge into and out of the tidal basin occurs. The basin water level is no longer able to change as fast as the seaside tide. The resulting water level differential causes dramatic increases in flow velocity which can have a major effect on the construction and resultant cost of a tidal power plant. Completion of construction requires special design provisions and construction procedure to take into account the increased tidal velocity.

Consideration of seabed conditions at three sites and the order-of-magnitude velocities expected during closure led to the conclusion that the only method of closure likely to be successful and economical is that which relies on construction of a core dike using rocks or blocks massive enough to resist displacement, prior to placement of finer material. When detailed field investigations have been completed in later studies, consideration may then be given to alternative closure methods.

Based upon a computer model which predicts water velocities as a tidal basin is closed, preliminary dike designs and construction sequences were developed at each of the three potential tidal power sites in Cook Inlet. To begin with, natural velocities were computed and compared to measured velocities. The velocity after placement of the last powerhouse unit and sluiceway unit was calculated for each site to determine the degree of difficulty in placing the units. The maximum permissible velocity during floating in and placement of the powerhouse units was established at 13 feet per second (fps). (Placement of units would be extremely difficult in greater velocities.) Dike closure sequences were then determined based on the resulting tidal velocities from various combinations of barrage length and barrage height.

7.3 - Computer Model

The important parameters in determining closure velocities are tidal range*, closure width, barrage height and basin storage area. Along with

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* Based on 1981 tide tables.

the effective number of sluices, they comprised the input parameters into the computer analysis.

The computer model determines an average velocity based on a given opening and constant barrage height. Flow is simulated over a full tidal cyle which is repeated until an equilibrium condition is obtained. The ocean tide is assumed to be sinusoidal and unaffected by the barrage. The basin water level is assumed to be horizontal so that the velocity of the tidal wave and backwater effects are not allowed for. Also no allowance is included for friction losses over the crest of the closure dike. If these effects were included, then closure velocities would be somewhat less than the calculated values. This should be assessed in later, more detailed, studies.

7.4 - Natural Velocities

Under a nominal 30-foot tidal range, natural average velocities were computed to be 7 fps at Point MacKenzie and 8 fps at Rainbow and Eagle Bay. Local velocities could be expected to be higher in some areas. The average velocities compare favorably with measured tidal currents mentioned earlier in this report. Velocities measured in the vicinity of the Rainbow site at a depth of 10 feet and at a tidal range of 28.5 feet yield the same value of 8 fps as the model.* For larger tidal ranges of 35 and 40 feet, natural velocities would increase to 8 and 9 1/2 fps at Point MacKenzie. Velocities at Eagle Bay and Rainbow were computed to be 10 fps for a 35 foot tidal range and 12 fps with a 40 foot tidal range.**

7.5 - Velocities During Placement of Powerhouse and Sluiceway Units

It is considered that it is reasonable to tow powerhouse and sluiceway caissons into place and ballast them down in water velocities up to 13 fps. This means that when the opening is at its narrowest when the last sluice caisson is placed, the flow velocity must not exceed 13 fps. To investigate this, a 30-foot tidal range was selected for velocity computations during placement of units. Based on 1981 Tide Table data for Anchorage, a 30-foot tidal range is exceeded 25 percent of the time (See Figure 7.1). Tides of this magnitude or less are required for placement of powerhouse and sluiceway units, so that there will be minimal impact on the construction schedule. It is assumed units can be placed in two working days (four tides). Since there are no great differences in tidal ranges amongst the

---

* Turnagain Arm Crossing Report - Sta 72100

** The computer mode assumes a drawdown across the barrage which may not be present before construction is started. Consequently, natural velocities tend to be overestimated.

three potential sites, a 30-foot tidal range was used for all sites. Velocities at each site were computed with all units in place and with the assumption that sluices were in operation. The velocities calculated for each site are given in Table 7-1.

The velocities at Rainbow and Eagle Bay showed almost no appreciable change from the natural condition. By sluicing through the sluiceways and turbines it is possible to control velocities to less than 13 fps. Even the largest tides should not prohibit placement of units, although it would seem to be prudent to plan to take advantage of the smaller tides and therefore reduced tidal velocities.

At Point MacKenzie, with all 60 units placed and with sluicing through turbines and sluiceways, a velocity of 15.6 fps was computed for the 30 foot tidal range, which exceeds the maximum permissible velocity of 13 fps. This would mean that no more than approximately 40 units can be placed with this tidal range. To have acceptable velocities for larger numbers of units, they must be placed when the tidal range is 25 feet or less. (About 40 percent of the tidal ranges are less than 25 feet.) Because four consecutive tides are required, placement opportunity becomes more constrained, although impact on costs can only be assessed in the light of the predicted construction schedule.

7.6 - Dike Closure

Sequences of dike closure were examined at each of the three potential tidal power sites. There are two methods of closure: end dumping and barge dumping. End tipping is easier and probably less expensive than marine placement but generally leads to higher velocities and therefore large rock sizes.

A maximum range of 39 feet was used for the Point MacKenzie runs and a 40 foot tidal range was used for the Eagle Bay - Rainbow runs. While these tides do not occur too often, they can be used to determine the maximum rock size required. During most of the closure, the rock sizes can be substantially reduced for economical savings. Such an analysis was not warranted for this preliminary assessment.

Maximum computed velocities for various stages of closure for the three sites are illustrated in Table 7-1. At Point MacKenzie end tipping is recommended until a barrage length of 5000 feet is achieved. Vertical closure (barge dumping) would then be effected. Comparison with end dumping to 3000 feet shows maximum velocities will be increased from 24.5 to 27.0, or about 2 1/2 fps. Above a sill elevation of -10 feet maximum closure velocities are the same for both a 3000-foot and a 5000-foot closure. The maximum velocities for the vertical closure are shown in Figure 7.2. A typical example of water surface elevations for the basin and seaside and flow velocity for a barrage height of -20 feet is illustrated in Figure 7.3.

Maximum required rock sizes for each site, based upon the maximum computed dike closure velocities are: Point MacKenzie 2.7 tons, Eagle Bay and Rainbow, 1 ton.

TABLE 7-1

MAXIMUM COMPUTED FLOW VELOCITIES

A. POINT MACKENZIE

Natural Velocity for Tide Ranges:

R = 30 ft	7 fps
R = 35 ft	8 fps
R = 40 ft	9.5 fps

Velocity After Placement of Last Caisson:

R = 30 ft	15.6 fps
R = 25 ft	13.0 fps

Barrage Elevation Relative to MTL:

	Width of Open Channel			
	10600 Ft	7000 Ft	5000 Ft	
			Flood	Ebb
-39.3 ft	13.97 fps	18.21 fps	18.7 fps	-21.6 fps
-30.0 ft			20.5 fps	-23.6 fps
-20.0 ft			22.8 fps	-24.2 fps
-10.0 ft			24.5 fps	-21.4 fps
- 5.0 ft			22.9 fps	-19.4 fps
0 ft			20.5 fps	-17.0 fps
5.0 ft			17.6 fps	-14.7 fps
10.0 ft			14.3 fps	-11.4 fps

TABLE 7-1 (CONTINUED)

MAXIMUM COMPUTED FLOW VELOCITIES

B. RAINBOW

Natural Velocity for Tide Ranges:

R = 30 ft	8 fps
R = 35 ft	10 fps
R = 40 ft	12 fps

Velocity After Placement of Last Caisson:

R = 30 ft	8.5 fps

Barrage Elevation Relative to MTL:

	Width of Open Channel		
	15000 Ft	1000 Ft	5000 Ft
-27.0 ft	13.4 fps	10.9 fps	17.1 fps
-20.0 ft			19.2 fps
-15.0 ft			20.7 fps
-10.0 ft			20.4 fps
- 5.0 ft			21.5 fps
0 ft			20.4 fps
5.0 ft			17.9 fps
10.0 ft			14.7 fps

TABLE 7-1 (CONTINUED)

MAXIMUM COMPUTED FLOW VELOCITIES

C. EAGLE BAY

Natural Velocity for Tide Ranges:

R = 30 ft	8 fps
R = 35 ft	10 fps
R = 40 ft	12 fps

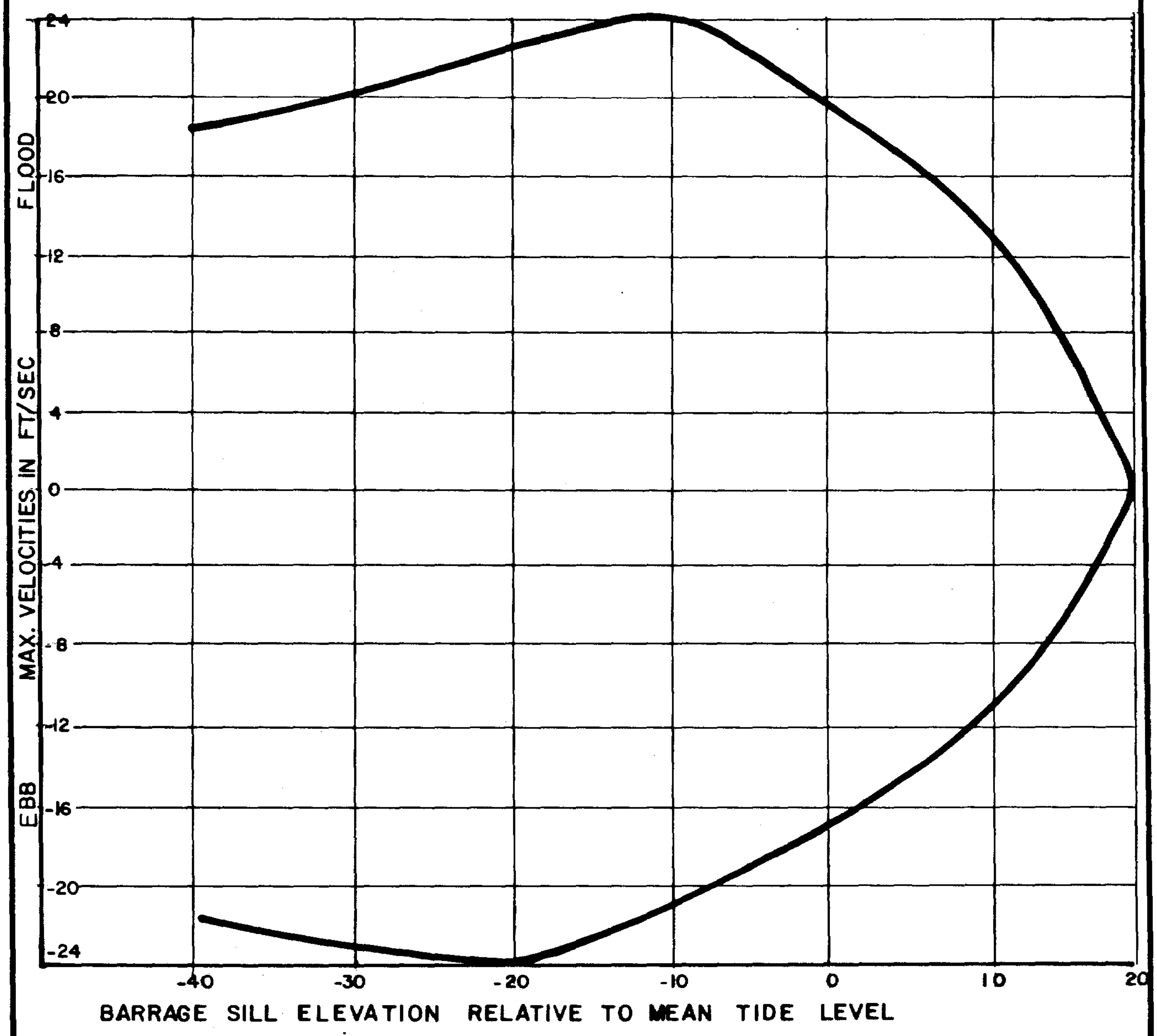
Velocity After Placement of Last Caisson:

R = 30 ft	8.3 fps

Barrage Elevation Relative to MTL:

	Width of Open Channel		
	15000 Ft	10000 Ft	5000 Ft
-21.0 ft	9.9 fps	13.04 fps	18.8 fps
-15.0 ft			20.4 fps
-10.0 ft			20.2 fps
- 5.0 ft			20.4 fps
0 ft			19.9 fps
5.0 ft			17.8 fps
10.0 ft			14.6 fps

NOTE: Recommended dike closure based on an extreme 40 ft tide range at each site.



TIDE RANGE = 39 FT
EQUIVALENT NO. OF SLUICEWAYS = 60

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COOK INLET TIDAL POWER

POINT MACKENZIE

MAXIMUM VELOCITIES FOR A 5000 FT
CLOSURE SECTION

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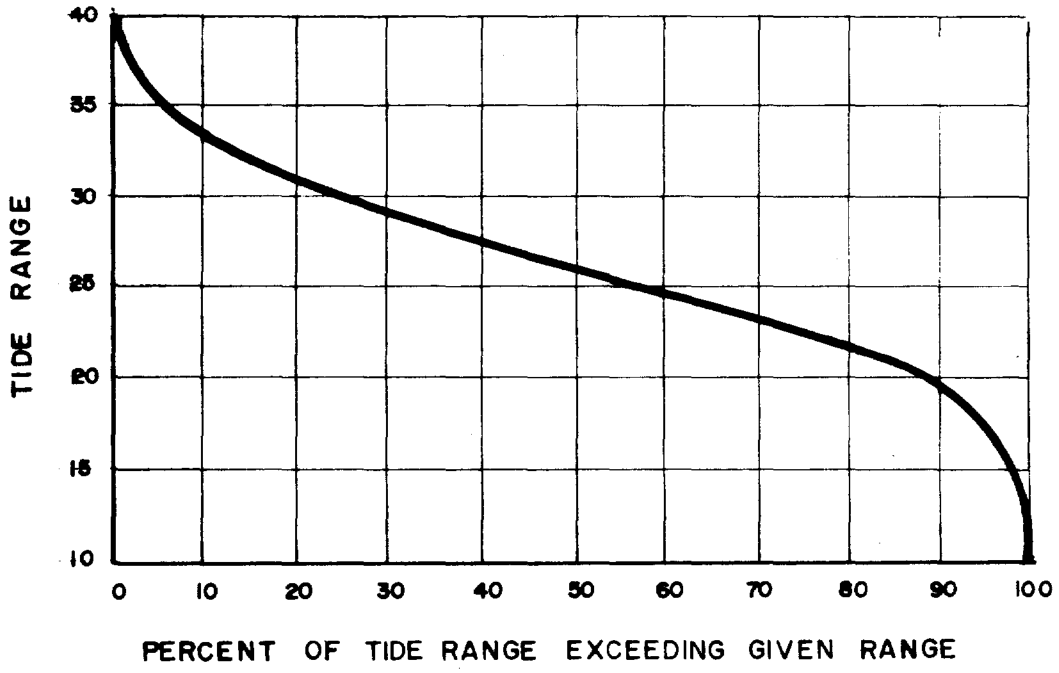
FIGURE 7.1



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TIDE RANGE EXCEEDENCE

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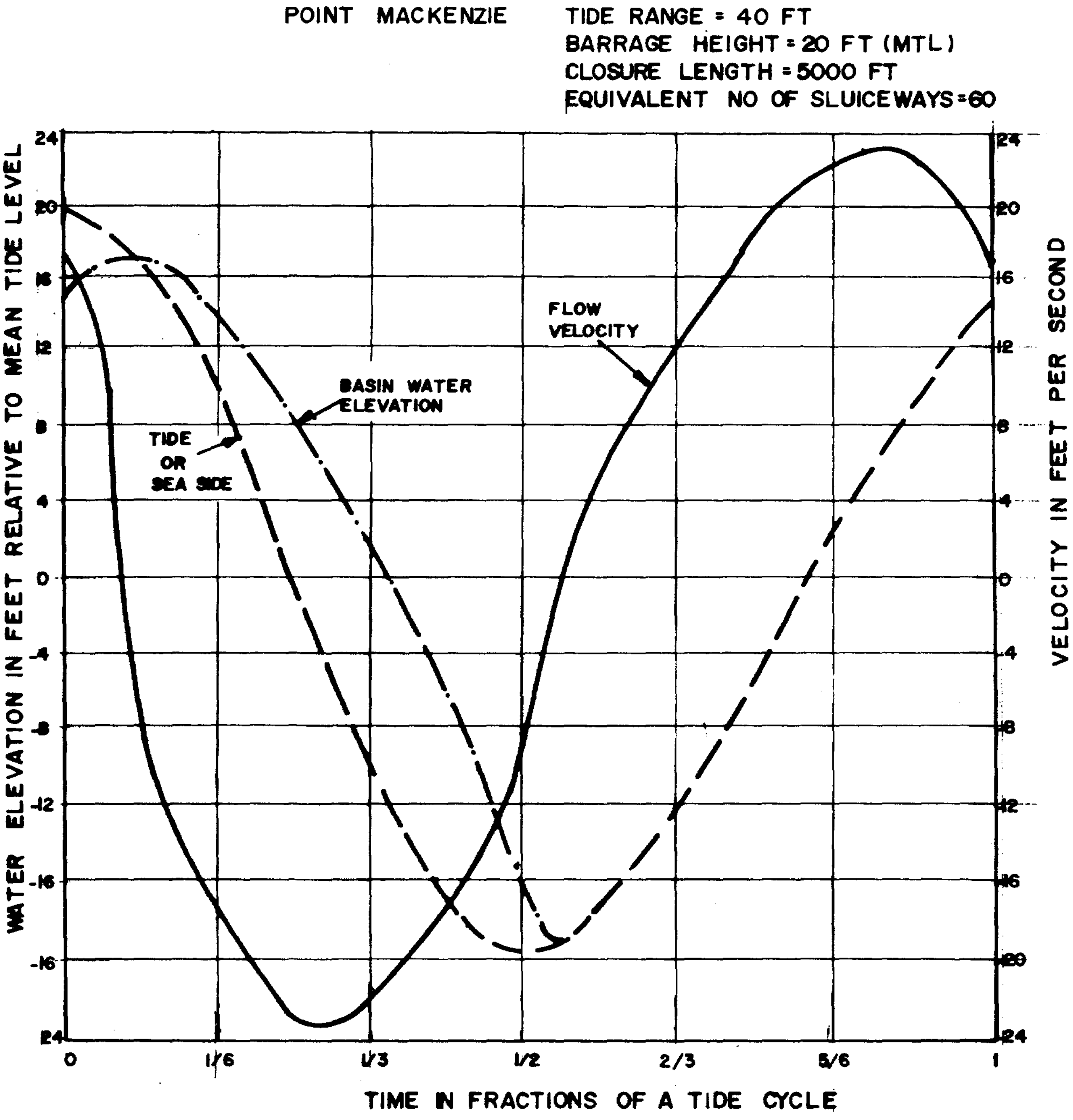
FIGURE 7.2



OFFICE OF THE GOVERNOR
STATE OF ALASKA

COOK INLET TIDAL POWER

TYPICAL EXAMPLE OF WATER SURFACE & VELOCITIES THROUGH A TIDE CYCLE DURING CLOSURE

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FIGURE 7.3

APPENDIX 8 - TIDAL POWER FACILITY DESIGN AND CONSTRUCTION METHODS

APPENDIX 8 - TIDAL POWER FACILITY DESIGN AND CONSTRUCTION METHODS

TABLE OF CONTENTS

Page

8.1 - Objective 8-1
8.2 - Approach 8-1
8.3 - Development Layouts 8-1
8.4 - Facility Design 8-2
8.5 - Construction Methods 8-6
8.6 Bridge and Causeway Crossing 8-11
8.7 - Recommendations for Future Work 8-11

LIST OF TABLES

Number	Title
8-1	Crest Elevations of Dike and Powerhouse

LIST OF FIGURES

Number	Title
8.1	Point MacKenzie Site Plan and Profile
8.2	Eagle Bay Site Plan and Profile
8.3	Rainbow Site Plan and Profile
8.4	Powerhouse Structure
8.5	Sluiceway Structure
8.6	Powerhouse and Sluiceway Stability
8.7	Access/Closure Dike Typical Cross Section
8.8	Bridge and Causeway Crossing

8 - TIDAL POWER FACILITY DESIGN AND CONSTRUCTION METHODS

8.1 - Objective

To develop site and facility layouts of a tidal power plant for each of the three selected sites. The activity further involves consideration of probable construction methods to suit foundation and other site conditions prevailing in the Cook Inlet area.

8.2 - Approach

Overall layouts of developments were made based on consideration of various factors related to design and construction of the tidal power plant.

The construction methods described in this section which address the main components for constructing a single-effect tidal power plant, are based on a general approach most applicable to all the three sites. However, special consideration has been given to site specific conditions.

The construction methods for the three selected sites involve consideration of: the foundation material, the number of powerhouse and sluiceway units, the minimum length of the access dike, the minimum length for dike closure, the location of construction materials and the location of the tie-in to the transmission line.

8.3 - Development Layouts

Layouts for the developments at each of the three selected sites were based on the following:

(a) Single-effect generation using bulb turbines with 28 feet diameter runner, installed in floated-in caissons

(b) Submerged semi venturi sluiceways with gate openings 40 feet square, installed in floated-in caissons

(c) Access dikes designed for rare overtopping by waves

(d) Closure dikes with armored vents to resist severe overtapping

(e) Land based facilities including switchyard, transmission line and construction facilities.

The numbers of turbine-generator powerhouse units and sluiceway units were set by the optimization studies described in Appendix 6.

The layout at each site was designed to take maximum advantage of the bathymetry at the selected alignment, subject to consideration of the preferred location of transmission facilities (which is on the Anchorage side at each site) and construction considerations. The resulting layouts are shown on Figure 8.1 through 8.3.

The length of the access dike was reduced to a minimum at each site, so that the length of SFG bus duct along the dike is also kept to the minimum and the time to set the first caisson is as early as possible.

A major factor in determining the location of the elements of the development is the need to achieve adequate foundation conditions and yet minimize the volume of deep dredging. The dredging is required primarily to remove soft surficial deposits from foundation areas, but also to achieve acceptable approach and discharge channel configurations, and at Rainbow in particular to obtain sufficient draft for movement of powerhouse and sluiceway caissons during construction.

In view of the geotechnical conditions at each site, and based on previous studies of the cost of cofferdams, construction-in-the-wet, using floated-in caissons was selected. The caissons are constructed in dry docks, located as shown on the layouts, and then floated into position. The floated-in concept has been used over many years for marine projects including wharfs, breakwaters, and offshore structures; therefore, it can be regarded as a normal marine construction procedure.

8.4 - Facility Design

8.4.1 - Powerhouse - Mechanical and Electrical Concepts

The powerhouse layout was developed to accommodate a bulb turbine generator with a runner diameter of 28 feet. Arrangements were developed specifically for the floated-in powerhouse using latest available information on mechanical and electrical equipment from manufacturers.

For maintenance of the turbine and generator, one access bay is provided leading through a removable hatch from the upper access level. A traveling gantry crane is provided at the access level.

Interconnection between the powerhouse units is through a service gallery paralleling the SF6 bus duct above the transformer deck.

A service area is provided every 16 units, to provide adequate facilities for routine maintenance on a scheduled basis plus emergency repairs. The service area is located on a special caisson over an operating powerhouse unit.

In addition to the turbine it has been assumed that the following mechanical equipment will be required for the operation and maintenance of the powerhouse and layouts have been developed accordingly.

(a) Service Gantry Cranes - 150-ton capacity crane operating on rails over turbine access shafts and sluice gates with 35-ton capacity auxiliary hoist over sea side stop-log guides. One crane every 16 powerhouse units.

(b) Basin Side Stop-Log Gantry Crane - 35-ton capacity crane operating on rails over basin side stop-log guides.

(c) Powerhouse Stop Logs - Three sections on basin side, 2 sections on sea side, for dewatering unit. One set every 8 units.

(d) Auxiliary Equipment - Separate governor pressure system, cooling water, compressed air, heating and ventilating, drainage and unwatering system for each pair of units installed in one caisson.

In view of the short periods of operation and the fact that the head goes to zero and reverses every tidal cycle, no provision is made for trash racks or for emergency closure of flow to turbine should the wicket gates fail to close or in the case of a variable-blade design the downstream gate fails to close. Stop logs can be placed during the low head period in order to isolate a unit. If one unit is taken out of operation for an emergency, it only represents a small percentage of the total generating capacity.

The turbine units have been set with the top of the draft tube outlet 3 feet above extra low water level. At this water level, the net head on the turbines will be considerably greater than the rated head; and, since it will happen only occasionally for a short period while the tide turns, it is considered that risk of cavitation damage will be very low.

Water passage dimensions have been set in accordance with experience on bulb unit hydroelectric installations and after discussions with turbine manufacturers.

8.4.2 - Sluiceway - Mechanical Concepts

Under the conditions of operation anticipated for the sluiceways during the winter at Cook Inlet, it is considered that a submerged gate is preferred. By this means the gate can be protected from damage due to ice and functional problems due to icing. Also, for ease of replacement and operation a vertical lift gate is preferred. To achieve the most efficient discharge capacity for all basin and sea levels, the gate is installed in a semi venturi sluiceway, with a discharge coefficient of 1.5.

Gate Sizes are based on normal practice for hydroelectric spillways.

Structural design concepts for the sluiceway are the same as those decribed for the powerhouse.

8.4.3 - Powerhouse/Sluiceway - Structural Concepts

The powerhouse and sluiceway shown respectively in Figures 8.4 and 8.5 are typical layouts proposed for any of the three sites. The foundation conditions at each of the three sites were assumed to provide adequate bearing capacity and frictional resistance for the structural stability. However, further site investigation will be required to obtain foundation data in order to confirm engineering feasibility.

The major considerations for the structural stability of the powerhouse/sluiceway are the stability against sliding, overturning, and seepage. Refer to Figure 8.6 for powerhouse and sluiceway stability diagram. The minimum length of the structure is governed by seepage, i.e., Lmin = 5H, where H is the differential head. The maximum length of the structure is governed by the factor of safety of the structure against sliding and overturning and the allowable bearing capacity of the mattress and overburden, assumed at 8KSF. The structure and/or mattress can be designed to satisfy the actual allowable soil properties. Within these limits, sufficient space is available in the powerhouse for equipment arrangement.

The other design considerations consist of seismic, ice, wind, waves, salt water attack and extreme temperatures. Although each of these present special design considerations, none of them are beyond the capability of state of the art for structural analysis and design methods. The structure may require local design features to mitigate the consequences from ice thrusts, wave action, extreme temperature and marine environment. The structures can be adequately sized to provide resistance to seismic and wind forces. These design parameters will provide the design basis for developing a conceptual engineering plan.

The minimum crest elevation of the powerhouse and sluiceway has been determined from the height of a wave equivalent to rare overtopping. The elevation of the structures has been raised to coincide with the crest elevation of the access dike. A deck-leg gantry crane is provided on the powerhouse deck for equipment installation. Hoists are provided for servicing or removing the operating gates and stoplogs.

The foundation for the powerhouse and sluiceway consists of a sand and gravel mattress designed to provide safety against piping failure. The advantage of this type of prepared foundation is that it may be used both over acceptable overburden or rock. The mattress serves as an inverted filter and the material must be filter-graded accordingly. The material must also provide an intergranular coefficient of friction, u, equal to tan 30° between the structure and the mattress and tan 20° between the mattress and the overburden. The factors of safety against sliding are given in Figure 8.6. These factors of safety should be reviewed with respect to probability of occurrence with tidal levels and wave heights.

The powerhouse and sluiceway elements are designed to be built in a dry dock and floated into place, and sunk on the prepared foundation bed. It is, therefore, essential that they should be of cellular construction, with all concrete elements made as thin as possible, so as to have a minimum draft during floating into position. This will minimize dry dock requirements and tidal current forces during placing. After placement, the required weight necessary to provide stability against sliding can be achieved by filling the cellular spaces with sand.

Protection against corrosion in the steel reinforcement shall be provided by adequate concrete cover. A concrete mix design with low heat of hydration and sulfate resistant cement should be provided and with good quality control. Further consideration and research is required in future studies to investigate protection of concrete and reinforcing against corrosion, salt water and extreme temperatures.

Longitudinally, the powerhouse element is a twin box of rectangular cross section, enclosing concrete conduits which form the draft-tubes. Cross diaphragms supply the transverse rigidity for the structure. At the stop logs, the large bearing reactions resulting from pump-out of the central turbine chambers, are transmitted by longitudinal shear walls which extend down directly to the base slab. The structure has been designed to be stable under the condition whereby the draft-tube may be pumped out in sections and its condition examined in the dry, during the course of maintenance after many years of service.

For floating-in, the optimum width of the structures is found to be that of a twin turbine/sluice unit. A single unit would be too narrow and unstable during flotation; whereas, if more than two units are used, the unit is too wide and would attract too much current force, resulting in anchorage forces too large to be handled practically.

8.4.4 - Dike Design

Major considerations in design of the dike are the seabed sediment characteristics, velocities during construction, stability and integrity of the dike, seepage control, protection against wave damage and erosion, construction materials, and construction sequence. Significant requirements of the dike sections are that they can be built under the extreme tidal conditions in the Cook Inlet, and that seepage through the section is controlled to a safe limit. The dike section is developed to resist the tidal currents predicted in Appendix 7. At this stage, one typical section, as shown in Figure 8-7, is developed for both access dike (which is intended to provide access from the powerhouse and sluiceway sections to the shore) and closure dike (which must be constructed after the powerhouse and sluiceway structures are in place). The proposed dike section is applicable to the single-effect generation scheme.

Detailed definitive information regarding the properties of the overburden are lacking at this time. However, it has been assumed that the dike will rest on a competent foundation surface. The dike slopes are designed on the premise that surficial deposits of weak mud and silts are dredged and a dense, consolidated, and relatively incompressible material has displaced the soft sediments under the foundations.

The closure section of the dike is developed as a purely rock-fill section capable of withstanding large reversible water velocities until full closure is achieved. The rock-fill section is composed of rock fragment sizes compatible with water velocities estimated for a vertical closure section. With the closure fill above elevation MHHW, the water velocity begins to decrease rapidly with increasing height of fill, thus allowing the use of quarry run in Zone 3. With the completion of the rock-fill closure section, the velocity of flow is reduced considerably. At this time, placement of finer-grained materials in the sealing zone would be feasible. A sealing zone is provided (Zones 1 and 2) on the basin side in order to provide a means of ensuring a head differential across the dike during the generating cycle. Armor is provided for slope protection first to resist highwater velocities before closure is accomplished, and then as a permanent protection of the dike against waves and currents.

8.5 - Construction Methods

The following construction sequence will be suitable for developing the tidal power facility in the Cook Inlet region: construct the access dike and dry dock facilities; dredge channel and prepare foundation base; construct the prefabricated powerhouse and sluiceway units, and float into position; complete construction of powerhouse and sluiceways, and install equipment; and construct the closure dike.

8.5.1 - Access Dike

The typical cross section of the access dike is shown in Figure 8.7. For the Rainbow and Eagle Bay sites, the access dike will be constructed at the outset whereas the access dike for Point MacKenzie will be constructed after the powerhouse and sluiceway elements are in place and closure is ready to begin. A bridge will provide temporary access to the powerhouse. The limitation on closure velocities to 13 fps requires that the structures are floated into position before any closure of the barrage begins. For more discussion, refer to Appendix 7.

The bottom of the channel at the access dike is prepared by removing the overburden such that the dike cross section will key into competent natural material. The rockfill for the access dike is placed by end dumping from trucks. The access dike is retained at the end by concrete crib structures filled with rock. The first powerhouse element is placed adjacent to the dike retaining cribs.

8.5.2 - Dry Dock and Wharf Facility

The dry dock is assumed to be constructed of a rock filled cellular steel sheet piling and a floating structural steel gate. The construction of two dry docks is required based on the time allowed in the schedule and is concurrent with the construction of the access dike. The dry docks are tentatively located on the site plan within reasonable proximity to the barrage and are located in the Anchorage area for possible use after construction. Because of the shallow channel at each of the three sites, a channel would have to be dredged from the dry dock to the powerhouse and sluiceway location. To maintain stability while floating, two powerhouse units would be paired together to form a single element measuring 178 feet by 128 feet. The sluiceways are also built in pairs. The approximate draft of the powerhouse is 60 feet whereas, that of the the sluiceway caisson is less.

The wharf facility is constructed next to the dry dock for completing the superstructure and for temporarily storing two prefabricated units until the units are ready to be floated into position. The storage at the wharf is required to minimize the time in the dry dock and to allow the construction in the dry dock to continue during the winter months even though the other construction activities are in a winter shutdown.

8.5.3 - Dredging

Dredging is required to remove the soft sediments which are unsuitable as a foundation material. This occurs at the Eagle Bay and Rainbow sites in large quantities at depths below MLLW of 30 to 70 feet. These depths present problems for existing equipment capability and availability and require further investigation with local and international dredging contractors to establish future equipment availability. At these depths, approximately 20 feet of material will be dredged from Eagle Bay and Rainbow; however, only 5 feet of material is assumed to be removed from Point MacKenzie because of anticipated underlying shallow rock surface.

The dredging can be completed either by means of a trailing suction hopper dredge or by special cutter suction equipment mounted on a walking platform. A trailer dredger is usually designed as a self-contained ship equipped with a suction pipe or pipes trailing along the sea bed while the dredger is moving forward under its own propulsion. The dredged material is taken into a suction head and passed through the pipe and pumped into the hopper.

In order to minimize the environmental problems and reduce costs associated with disposal of dredged material, the following three methods have been considered: (1) marine dumping, (2) enclosed landfill area and (3) use of the dredged material, if suitable, for construction materials.

A disposal area contained by dikes or cellular cofferdams has been assumed to be located near the site or adjoining the access dike along the shore. This requires further consideration in later studies.

8.5.4 - Powerhouse and Sluiceway Elements

The construction of the powerhouse and sluiceway elements can be accomplished by using sliding forms for the diaphragm walls with block-out rings for forming the draft tube. To save time from dismantling and reassembling forms, hydraulic jacks mounted on a stationary platform above the caisson could lift the sliding form. The powerhouse water passageways would be constructed of precast concrete. The units are cast in lower and upper halves and in widths approximately equal to the clear distance between diaphragm walls. They are fabricated under factory conditions using mass production methods reasonably close to the site. They are cast as walls, that is, oriented 90 degrees to their final position within the element, with preassembly of reinforcing, steam curing, quick stripping and other time saving methods.

The precast units are transported by float to the dry dock where they are lowered and moved into place. Later they are joined to one another and to the vertical diaphragm walls by grouting. This method reduces the construction time in the dry dock and results in a reduction in the number of dry docks that would otherwise be required.

Precast slabs are used as formwork for the top slab over the water passageways. The lower half of the slab may be precast and act as a form for the other half. Reinforcing tying the two halves together provides for composite action.

On completion of construction, the dry dock would be flooded and the gate removed. This would be followed by floating the draft tube closure bulkheads into place. The interior of the element would then be pumped out and the floating element towed out of the dry dock. It would be towed a short distance to a fitting-out wharf alongside the dike, where it would temporarily be sunk on a prepared bottom. In order to minimize the length of time the element is in the dry dock, the powerhouse superstructure would be built outside the dry dock at the wharf facility.

The powerhouse and sluiceway elements are set on a prepared foundation base of sand and gravel. The sand and gravel mattress consists of two layers. Both upper and lower layers are composed of suitably graded material with an angle of internal friction of 30 degrees or more, and designed as a filter. The material must be well graded, specially selected material for piping stability. Placement of the material shall be done to preclude segregation and shall be carefully screeded to a uniform level.

The method of placing both layers is done by a walking platform. The platform is divided into halves, each of which can be independently supported by a set of hydraulically operated legs. To move the platform, one half is kept stationary while the second half is slid over it. The second half is then secured on its supporting legs, while the first half is released and slid under it.

Both layers, each consisting of sand and gravel, are placed on the sea bottom through large tremie pipes served by hoppers on the platforms. The hopper is fed by a self-unloading ship. The tremie pipes can be raised or lowered by hydraulic jacks. At the base of the tremie pipes the gravel spreads out into a screed and a uniform layer of gravel is placed on the ocean floor. As the gravel is being placed the walking platform and screed would be moving forward to match the rate of discharge of the self-unloading ship.

After completion of each pass, the sand and gravel would be compacted by vibration. Compaction of granular fill under water is rarely required and there are only a few projects on which it has been done.

One important precedent was at the Aswan High Dam* where approximately 30 m of dune sandfill was vibrated under water in two layers of about 15 m thickness. The total quantity vibrated amounted to 3.4 million cubic meters. On each of three floating rigs, six vibrators spaced in two rows at 4 m centers were used. Use of gang vibrators is believed to yield better and more uniform compaction than single vibrators working separately.

Another interesting test program** was carried out in the United States where vibroflotation was compared with the Terra-Probe method in compacting a submerged fill. In the Terra-Probe method a vibratory pile driving hammer is used together with a pipe pile probe. With both methods satisfactory results were obtained.

Following placing and compaction of the sand and gravel fill, the walking platform would be used for placing a layer of scour protection.

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* "Aswan High Dam: Rockfill Built Under Water," Civil Engineering ASCE, August 1971.

** "Vibroflotation and Terra-Probe Comparison," Journal of the Geotechnical Engineering Division ASCE, October 1976.

The towing operation for the loated element would be carried out during the nearly slack water period at high tide. The tugs tow the element close to its permanent location and connect it both upstream and downstream to large refloatable anchors. The element can then be safely anchored against maximum tidal current forces in either direction.

The refloatable anchors are constructed of reinforced concrete designed so that when flooded they have sufficient capacity in friction to resist the maximum current pressure on the floating element. When the water is blown out of the interior, the anchor is practically buoyant and can be repositioned at the next location. One such anchor is required upstream and another downstream of the element to be placed. Two pennant cables are connected to each anchor and the opposite end of the cable is supported above water level by a float.

A pair of jacking frames are positioned and anchored on top of the powerhouse structure and the cables are stored on large reels on the powerhouse. These steel frames are equipped with cable grips and hydraulic jacks, and normally replace winches when the forces involved are large. The tugs tow the elements to the location where the two cables of the jacking frames could be pin connected to the two cables of the refloatable anchors. Once the floating element is connected to upstream and downstream anchors, it is now securely held and capable of withstanding pressure from maximum current flow.

The next step is to increase the draft of the element and move it over to its final resting place just before low tide, so that it will come to rest on the bottom at low tide. Tugs pushing laterally can assist in placing the element in contact with the one already placed. Once it has been accurately placed on the bottom, the element would be completely flooded.

This would be followed by removal of the bulkheads closing the water passageways and filling the interior cells of the element with sand. The final operation would be to grout the interstices of the scour protection material at the base of the elements.

To place the rip-rap protecting the gravel mattress from scour and wave action, it is visualized that "stone dumper" vessels would be used. They are self-propelled and are equipped with special propulsion units at both bow and stern which permit them to remain stationary in a current when dumping. Dumping is accomplished by pushing the rock over the side by means of hydraulically operated blades. Loading of the vessels would have to be carried out at the wharf facility.

8.5.5 - Closure Dike

The closure dike is built by placing the rock fill in horizontal layers assuming self-propelled bottom-dump vessels. After a certain level is reached, there is insufficient draft for the vessel. It is proposed that when this stage is reached, the walking platform be provided with a large crane to place the major portion of the remaining rock fill. The rock fill would be supplied to the crane by marine plant. Finally, the uppermost part of the rock fill would be placed by end dumping.

An alternative method is to place the rock fill by cableway. This method was not fully considered at this time, but it may have some economic advantage based on Dutch experience.

Once the closure rock fill is completed the relatively thin layer of crushed rock transitional zone material is placed by pushing it over the side using stone dumper vessels. Subsequent layers are placed in the same manner. It is assumed most of the armor units cannot be reached from the dike and are placed individually from floating plant. The remaining units are placed by crane from the crest of the dike. It should be noted that in lieu of the typical clay core used for storage dams, a sand and gravel core is provided. This is acceptable as the amount of leakage through the core is of no consequence provided it does not impair the stability of the dike.

8.6 - Bridge and Causeway Crossing

A conceptual plan and profile of a bridge and causeway crossing is shown in Figure 8.8. The bridge and causeway crossing consists of a bridge structure over the powerhouses and sluiceways, a transition bridge and approach ramps to the dikes. The bridge structure is constructed of a reinforced concrete deck supported by six precast prestressed I-beams spanning approximately 65 feet. The I-beams are supported at each end by a concrete cap and two concrete columns. The columns are supported by the powerhouse and sluiceway structure. The transition bridge is identical in construction to the span over the powerhouses and sluiceways except that the foundations are anchored into the dike. The approach ramp to each transition bridge is constructed of an elevated crest for each dike. The grade of the transition bridge and the approach ramp is 37 percent. Where the access dike is shorter than the approach distance, the transition bridge will continue to the grade along the shoreline.

The bridge over the structures provides a nominal clearance of 20 feet for operating and maintenance access on the deck of the powerhouse and sluiceway. The crest of the dike would be widened at the approach ramp and the transition bridge to provide access to the powerhouse/sluiceway deck.

8.7 - Recommendations for Future Work

Future studies should include:

- Site investigation program to determine foundation conditions sufficiently accurate to predict dredging quantities and design foundation mattress and structures
- Assessment of structural loading conditions (tidal variation, seismic, wave action, ice formation and extreme temperatures) for individual and combined probability of occurrence to determine loading combinations and factors of safety
- Further study of stability of structures against probable loading combinations and seepage to minimize the length of structures
- Construction methods and placement of elements to determine in more detail the feasibility of wet versus dry construction
- Corrosion of materials at low temperatures.

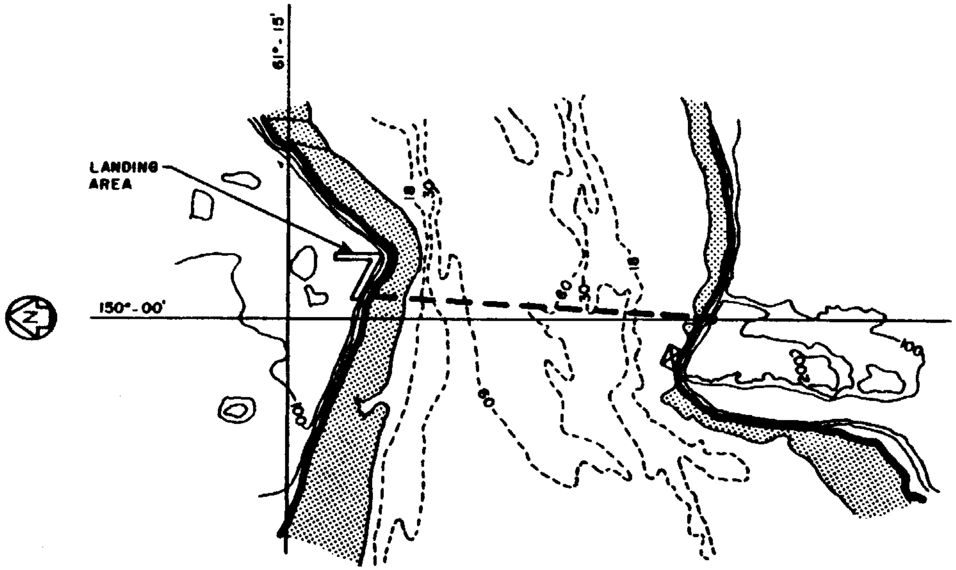
TABLE 8-1

CREST ELEVATIONS OF DIKE AND POWERHOUSE

	Point MacKenzie	Eagle Bay	Rainbow
DIKE			
No Causeway	45 ft	45 ft	49 ft
With Causeway	53 ft	50 ft	59 ft
POWERHOUSE			
No Causeway	50 ft	48 ft	55 ft
With Causeway	50 ft	48 ft	55 ft

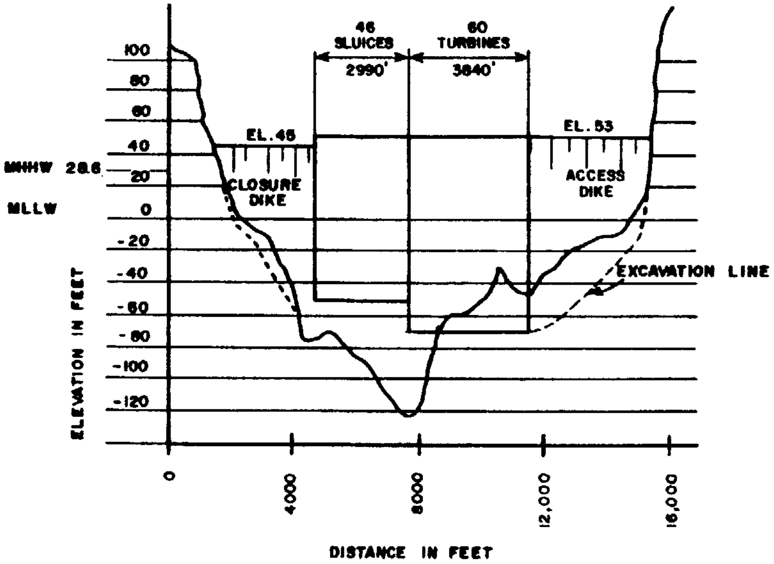
Note: The following assumptions were made in calculating the crest elevations:

1. 50-year return period
2. Design based on significant wave height
3. Dike designed for severe overtopping and shorter return period to minimize costs
4. Crest elevation = EHW + A.H_S where A is 1.2 for dike without causeway, 2.2 for dike with causeway, 1.75 for powerhouse without causeway.
5. H_S is equal to 7.8 for Point MacKenzie, 4.8 for Eagle Bay, and 10 for Rainbow.
6. Powerhouse crest elevation does not change with addition of a causeway since a bridge will be constructed over powerhouse and sluiceway caissons.



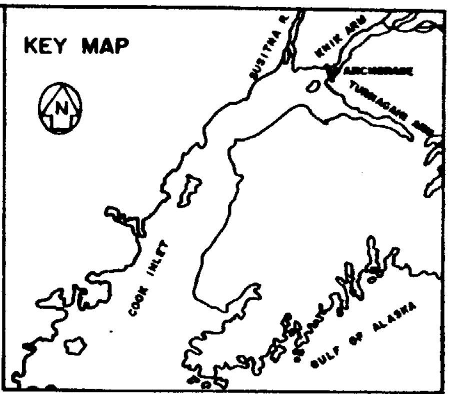
PLAN

SCALE: 1" = 1 MILE
1: 63360



DOWNSTREAM ELEVATION (LOOKING TOWARDS BASIN)

HORIZONTAL SCALE: 1" = 4000'
VERTICAL SCALE: 1" = 80'



NOTES

1. PROFILE DERIVED FOR NOS HYDROGRAPHIC SURVEY RA-10-5-74, H9441.
2. PLAN FROM USGS 7 1/2 MINUTE MAPS ANCHORAGE (A-8) QUADRANGLE.
3. LAND CONTOUR LINES ARE REFERENCED TO MSL IN FEET.
4. UNDERWATER CONTOUR LINES ARE REFERENCED TO MLLW IN FEET.

LEGEND

- ━ SHORELINE AND MEAN HIGH WATER (MHW)
- ▨ MUDFLATS
- MEAN LOWER LOW WATER (MLLW)
- — — BARRAGE CENTERLINE
- ⊠ DRY DOCK AND WHARF FACILITY
- ● SWITCHYARD

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POINT MACKENZIE SITE PLAN AND PROFILE

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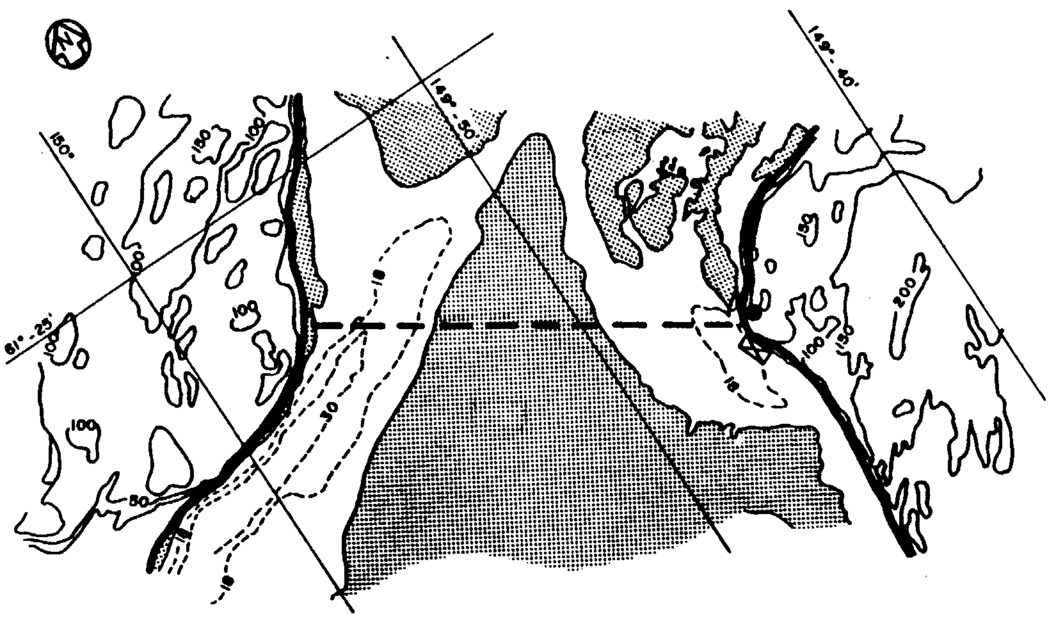
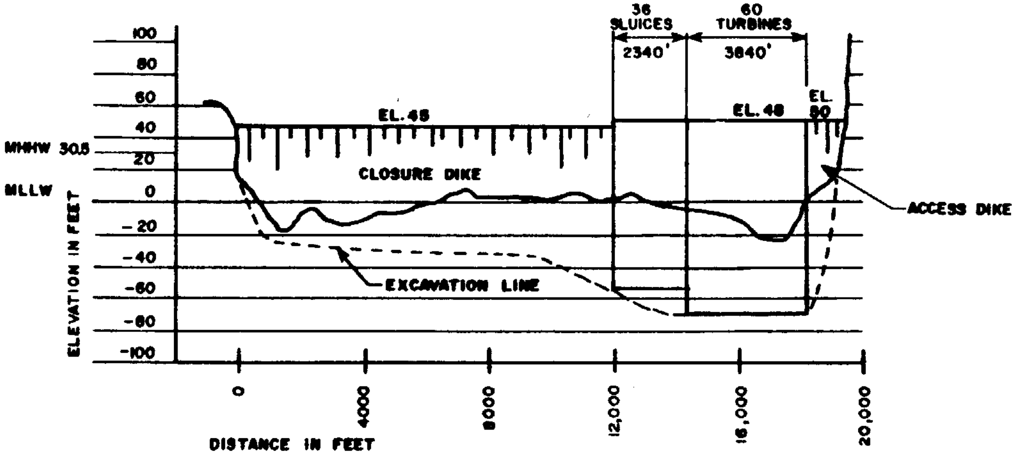
FIGURE 8.1



PLAN

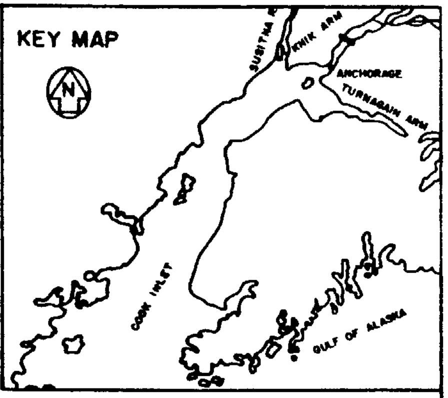
SCALE: 1" = 1 MILE
1: 63,360



DOWNSTREAM ELEVATION (LOOKING TOWARDS BASIN)

HORIZONTAL SCALE: 1" = 4000'
VERTICAL SCALE: 1" = 80'

KEY MAP



NOTES

1. PROFILE DERIVED FROM N.O.S. HYDROGRAPHIC SURVEY RA-20-1-74, H 9443.
2. PLAN FROM U.S.G.S. 7 1/2 MINUTE MAPS ANCHORAGE (B-8) QUADRANGE.
3. LAND CONTOUR LINES ARE REFERENCED TO MSL IN FEET.
4. UNDERWATER CONTOUR LINES ARE REFERENCED TO MLLW IN FEET.

LEGEND

- SHORELINE AND MEAN HIGH WATER (MHW)
- ▨ MUDFLATS
- MEAN LOWER LOW WATER (MLLW)
- BARRAGE CENTERLINE
- ☒ DRY DOCK AND WHARF FACILITY
- ● SWITCHYARD

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EAGLE BAY
SITE PLAN AND PROFILE

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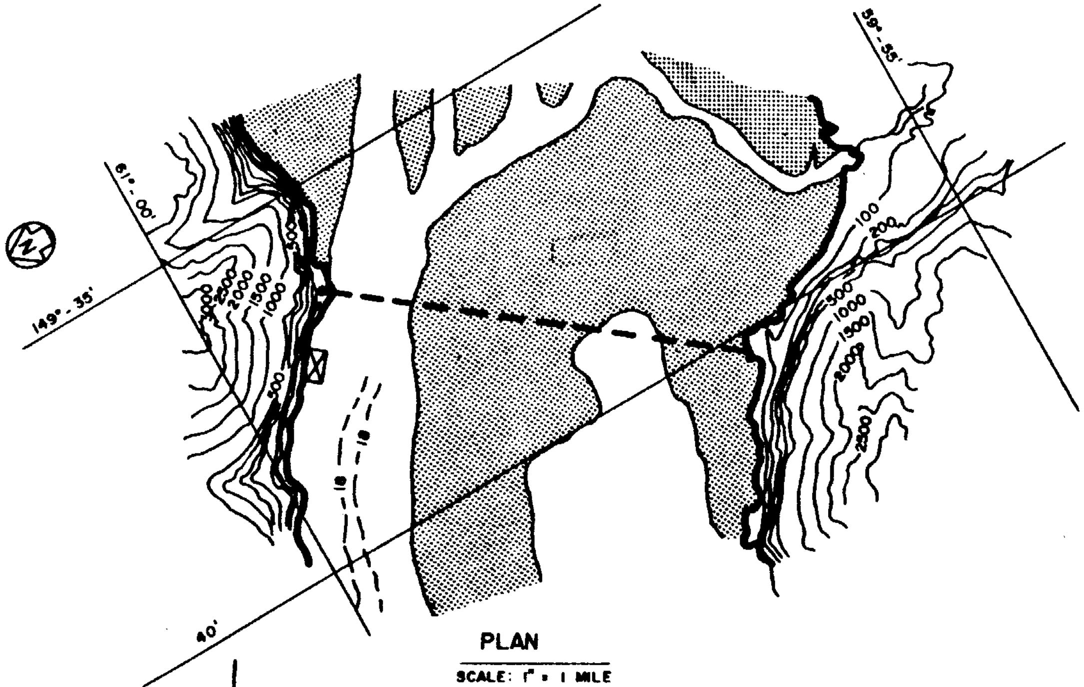
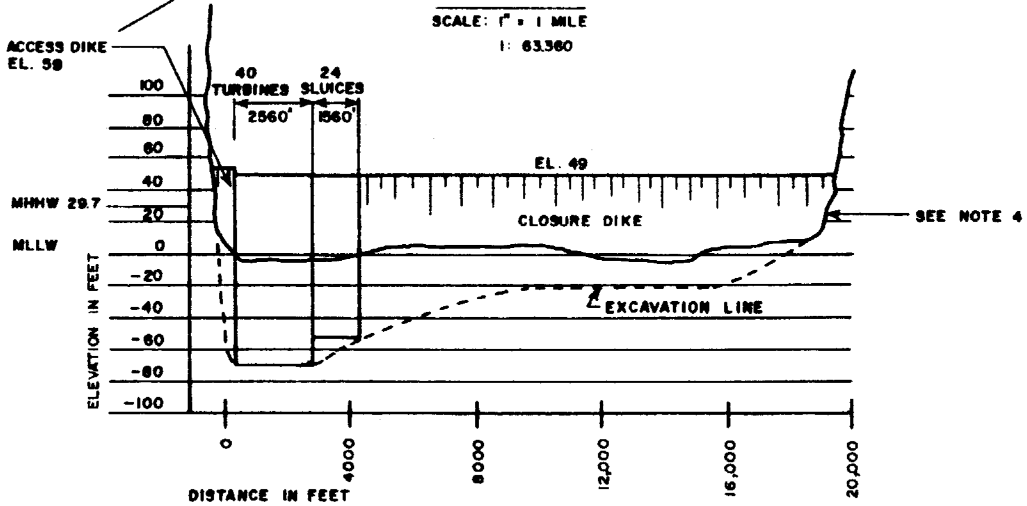
FIGURE 8.2



PLAN

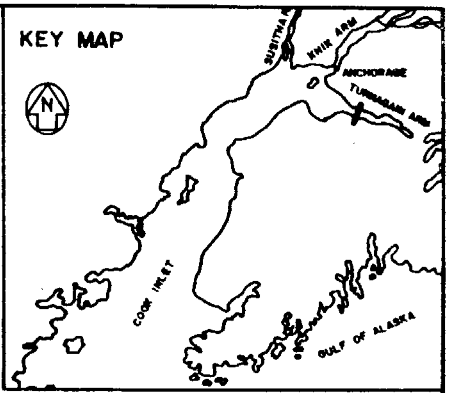
SCALE: 1" = 1 MILE
1: 63,360



DOWNSTREAM ELEVATION (LOOKING TOWARDS BASIN)

HORIZONTAL SCALE: 1" = 4000'
VERTICAL SCALE: 1" = 80'

KEY MAP



NOTES

1. PLAN AND PROFILE FROM U.S.G.S. 7 1/2 MINUTE MAPS SEWARD (D-7) AND (D-8) QUADRANGLES.
2. LAND CONTOUR LINES ARE REFERENCED TO MSL IN FEET.
3. UNDERWATER CONTOUR LINES ARE REFERENCED TO MLLW IN FEET.
4. CHANNEL PROFILE MAY BE DEEPER AS SHOWN IN TURNAGAIN ARM CROSSING STUDY, JANUARY, 1969.

LEGEND

— SHORELINE AND MEAN HIGH WATER (MHW)
▨ MUDFLATS
MEAN LOWER LOW WATER (MLLW)
— — BARRAGE CENTERLINE
☒ DRY DOCK AND WHARF FACILITY
● SWITCHYARD

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COOK INLET TIDAL POWER

RAINBOW
SITE PLAN AND PROFILE

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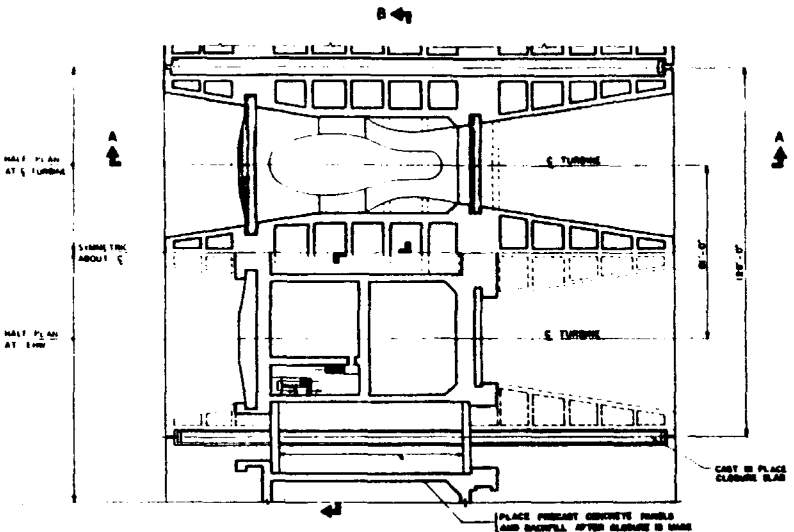
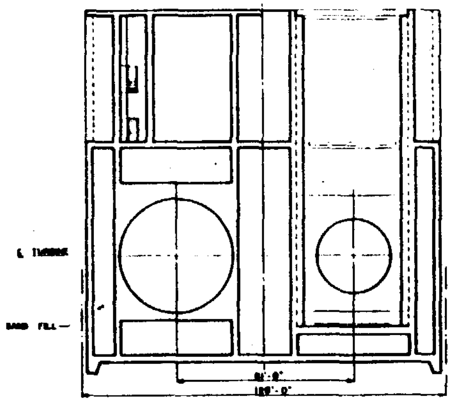
FIGURE 8.3



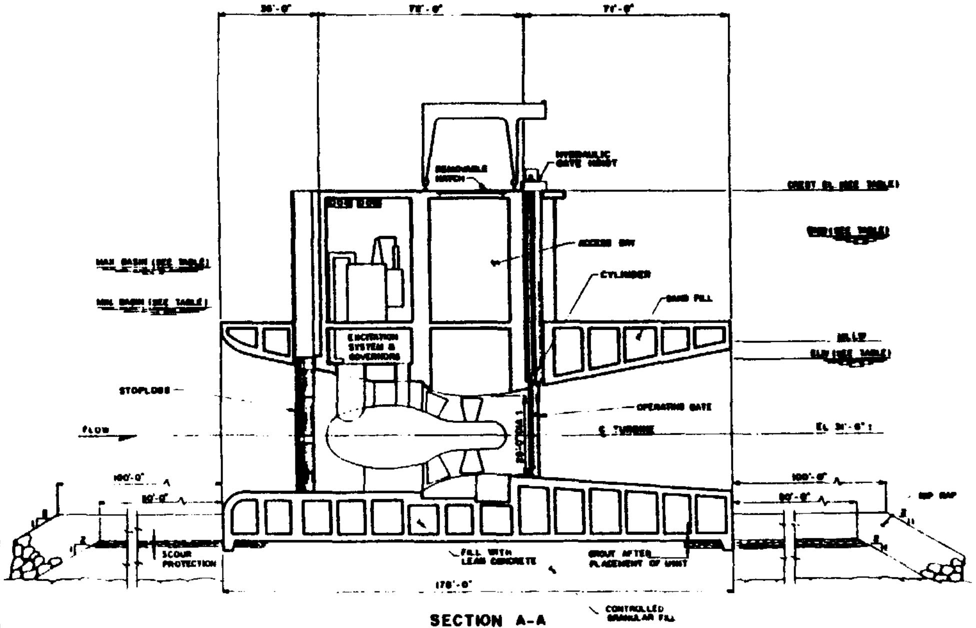
PLAN



SECTION B-B

NOTES

1 ALL ELEVATIONS ARE REFERENCED TO MLLW ELEVATION 0 AND ARE IN FEET
2 SERVICE BAY WILL BE PROVIDED AT EVERY 10th POWERHOUSE UNIT



SECTION A-A

SITE	MAX. BASIN	MIN. BASIN	ELW *	EHW *	CREST
PT. MACKENZIE	28.7	10.6	-6.4	36	50
EAGLE BAY	31.0	14.6	-6.8	37	46
RAINBOW	32.1	12.6	-6.9	34	56

* ELW - EXTREME LOW WATER
* EHW - EXTREME HIGH WATER

0 16 32 48 64

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COOK INLET TIDAL POWER

POWERHOUSE STRUCTURE

FIGURE 8-4

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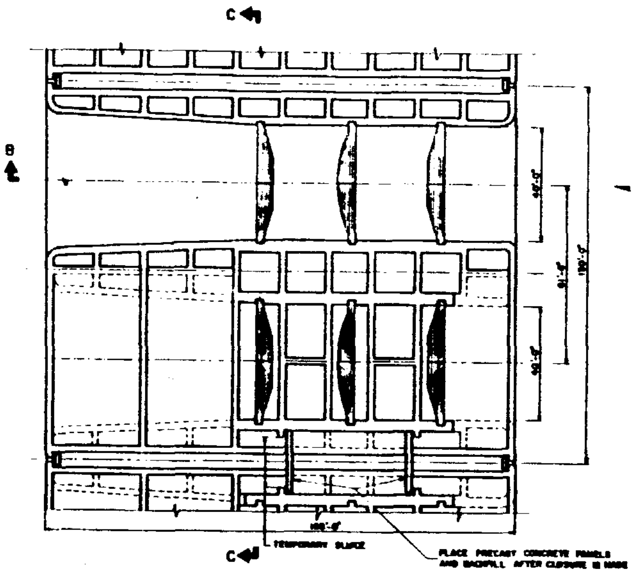
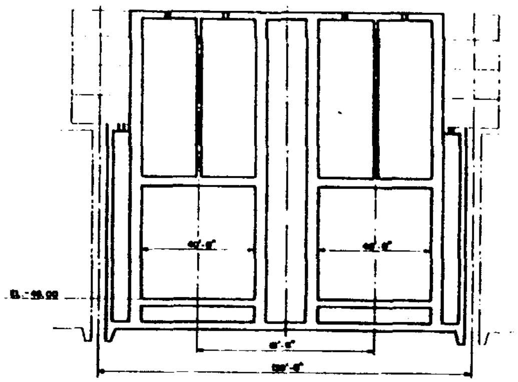


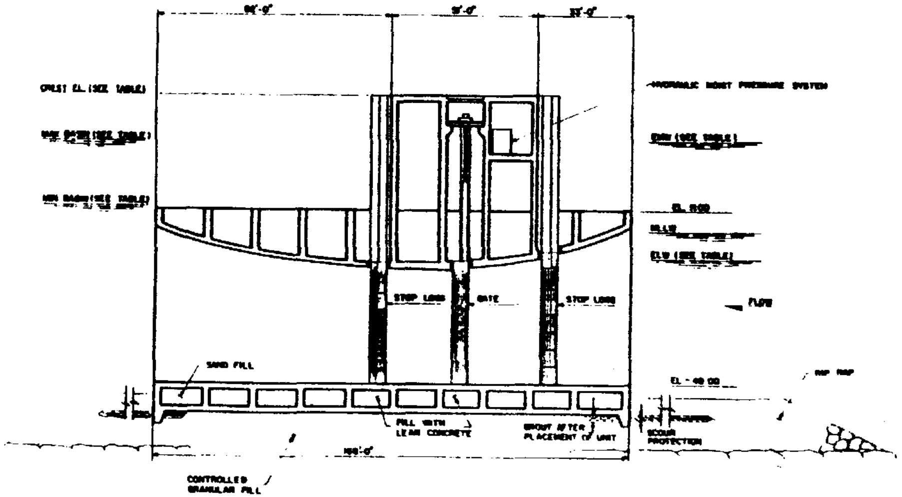
PLAN AT SLUICE



SECTION C-C

NOTES

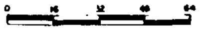
1 ALL ELEVATIONS ARE REFERENCED TO MLLW DATUM AND ARE IN FEET



SECTION B-B

SITE	MAX BASIN	MIN BASIN	ELW *	EHW *	CREST
PT MACKENZIE	30.7	8.0	-4.4	36	50
EAGLE BAY	31.0	14.6	-6.0	37	40
RAINBOW	32.1	12.0	-6.0	38	50

* ELW - EXTREME LOW WATER
* EHW - EXTREME HIGH WATER



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SLUICEWAY STRUCTURE

FIGURE 8.5

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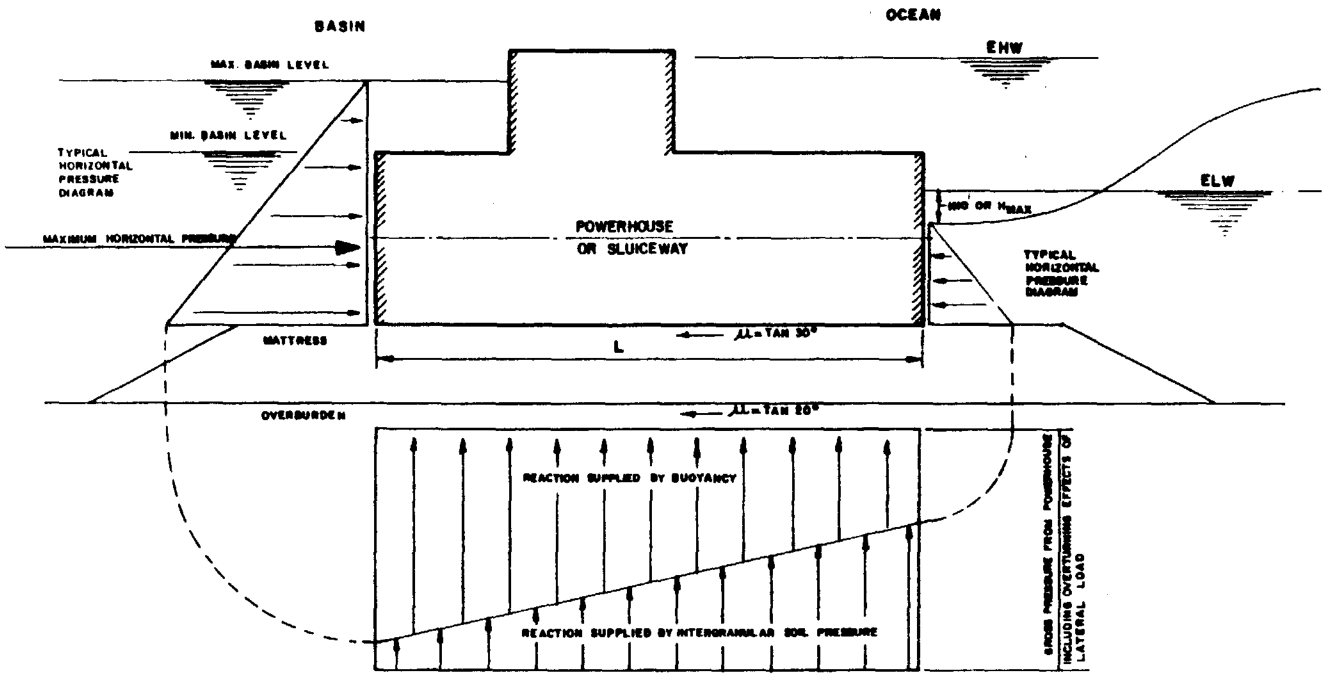

NOTES

1. VALUES FOR MAXIMUM BASIN AND EXTREME LOW WATER (ELW) ARE TAKEN FROM TIDAL SIMULATION.
2. H_S = SIGNIFICANT WAVE HEIGHT
   H_{10} = 1.27 H_S
   H_{MAX} = 1.86 H_S
3. THE MINIMUM LENGTH OF STRUCTURE, L, IS GOVERNED BY SEEPAGE BENEATH THE STRUCTURE WHERE L_{MIN} = 3.0H
4. COEFFICIENT OF FRICTION, μ, AS SHOWN AND MINIMUM SOIL BEARING VALUES ARE ASSUMED AT 6.0KSF

CRITICAL LOADING CASES CONSIDERED

LOADING CASE	DIFFERENTIAL HEAD, H	FACTORS OF SAFETY
HORIZONTAL	(MAX BASIN - ELW) + H_{10}	1.5
HORIZONTAL	(MAX BASIN - ELW) + H_{MAX}	1.25
VERTICAL	SEE DIAGRAM	1.5
SEEPAGE	(MAX BASIN - ELW)	3.0

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POWERHOUSE AND SLUICEWAY STABILITY

FIGURE 8.6

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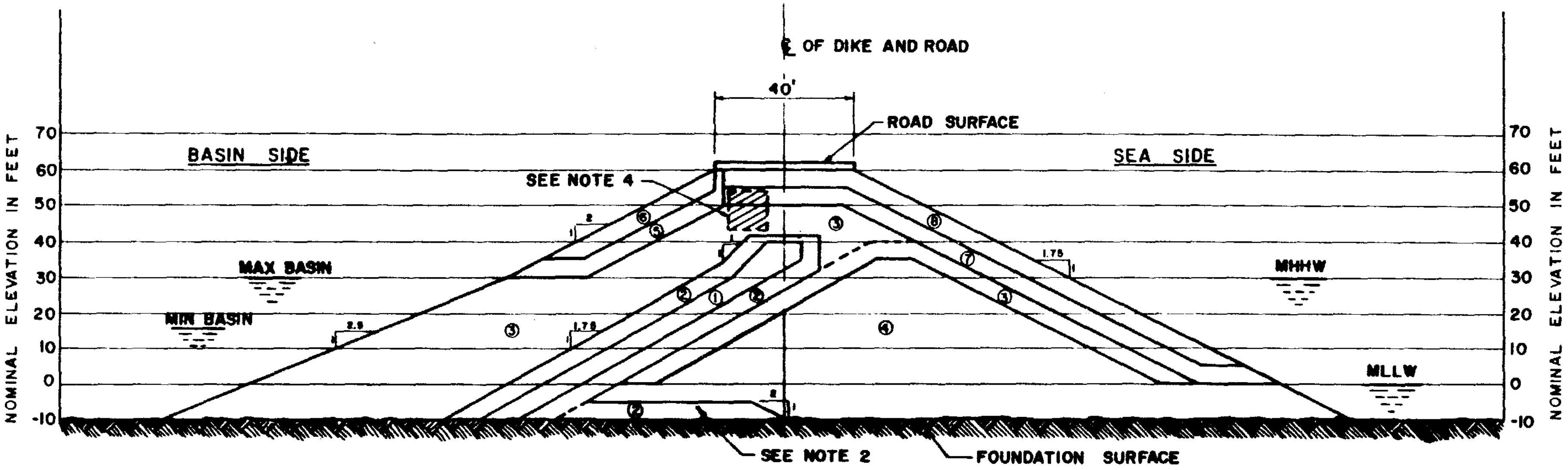

LEGEND	
①	CORE ZONE (SAND & GRAVEL)
②	TRANSITION ZONE (CRUSHED ROCK OR EQUIVALENT)
③	ROCK FILL ZONE (QUARRY RUN)
④	ROCK FILL ZONE (BOULDERS UP TO 5-11 DIAMETER)
⑤	ARMOR BEDDING ZONE: BASIN SIDE
⑥	ARMOR ZONE: BASIN SIDE
⑦	ARMOR BEDDING ZONE: SEA SIDE
⑧	ARMOR ZONE: SEA SIDE

SITE NAME	MAX BASIN	MIN BASIN	MHHW	MLLW	CREST EL. OF CLOSURE DIKE (FEET)	CREST EL. OF ACCESS DIKE (FEET)
PT. MACKENZIE	28.7	18.5	28.6	0	45	53
EAGLE BAY	31.9	14.6	30.5	0	45	60
RAINBOW	32.1	12.6	29.7	0	49	59

NOTES:

1. PROPOSED DIKE SECTION ASSUMES A COMPETENT FOUNDATION SURFACE.
2. AN INVERTED FILTER WILL BE REQUIRED UNDER THE ROCK FILL TO CONTROL PIPING WHERE THE DIKE FOUNDATION IS COMPOSED OF FINE SEDIMENTS.
3. PLACEMENT OF THE BACKFILL WILL BE BY THE VERTICAL CLOSURE METHOD.
4. PROPOSED SF_6 BUS TUNNEL FROM POWERHOUSE TO SWITCHYARD IN ACCESS DIKE ONLY.

30 0 30 60

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ACCESS/CLOSURE DIKE TYPICAL CROSS SECTION

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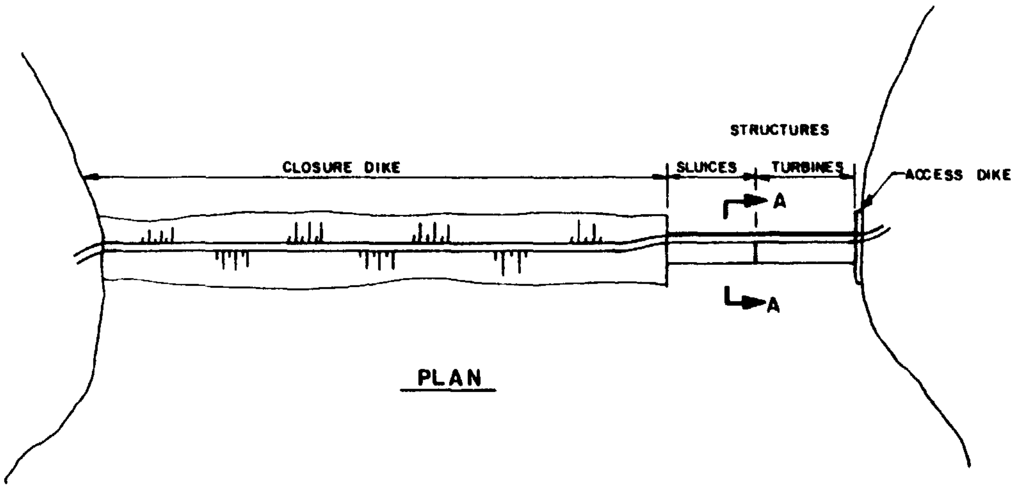
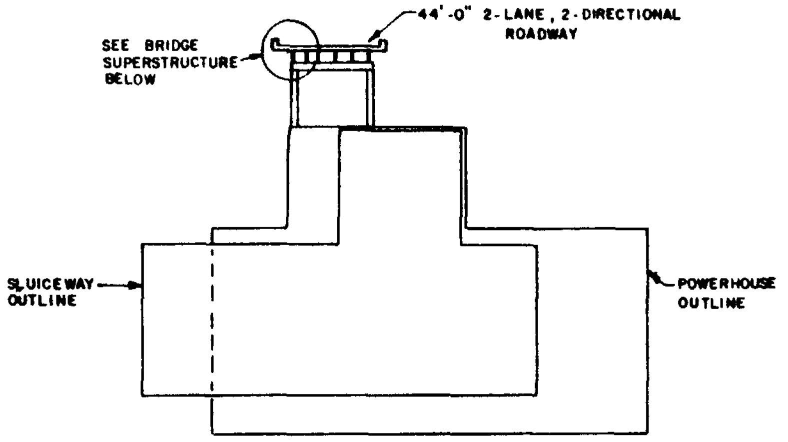
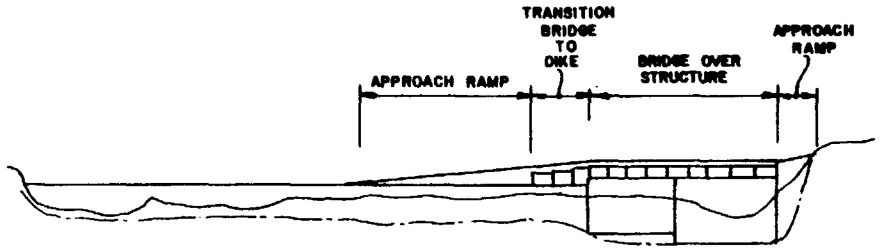
FIGURE 6.7



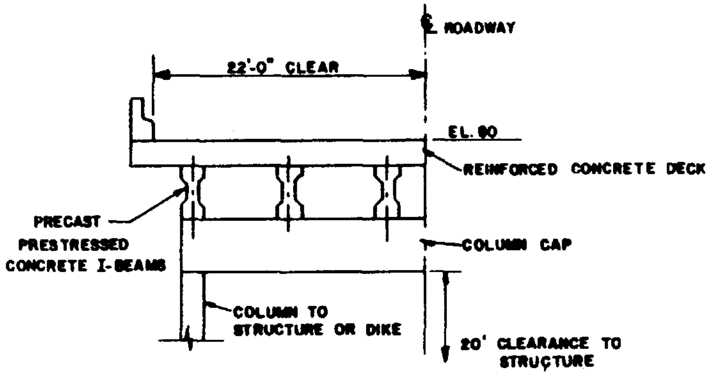
PLAN



SECTION A-A



PROFILE



BRIDGE SUPERSTRUCTURE

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COOK INLET TIDAL POWER

BRIDGE AND CAUSEWAY CROSSING

ACRES AMERICAN INCORPORATED

FIGURE 6.8

APPENDIX 9 - COST ESTIMATES SCHEDULES

APPENDIX 9 - COST ESTIMATES AND SCHEDULES

TABLE OF CONTENTS

Page

9.1 - Objective 9-1
9.2 - Approach 9-1
9.3 - Order of Magnitude Estimates 9-2
9.4 - Basis of the Order of Magnitude Estimates 9-3
9.5 - Project Schedules 9-5
9.6 - Staging of Developments 9-6

9 - COST ESTIMATES AND SCHEDULES

9.1 - Objective

To assist in site selection, i.e., reducing the number of possible sites to a manageable study level of three; provide estimating input to assist in optimizing the installed capacity; and prepare order of magnitude estimates and preliminary schedules for the three sites based on the optimized arrangements.

9.2 - Approach

The estimating input to help with the reduction of the number of possible sites to three consisted of escalating the estimated unit costs of the Fundy Tidal Power Study to 1981 values and using an adjustment factor to represent the site location. This method provided valid information for comparisons among candidate sites because it was consistently applied and was adjusted for site specific conditions. It did not yield valid absolute cost data for any site. While this approach was appropriate for site screening purposes (see Appendix I), further detail was required to develop estimates for the three selected sites.

In order to optimize the installed capacity for the three selected sites, unit costs were supplied for the various possible arrangements. This called for unit costs to be adjusted as the factors such as number of units and length of dikes, varied.

That is, quantity variations were considered in relation to their impact on the construction procedure and were accounted for in the unit prices for a particular site arrangement.

Order of magnitude estimates were prepared for the final arrangement of the three sites. These estimates were based on built-up unit prices which were developed considering the schedule and the quantity of work involved. These estimates are described as being order of magnitude estimates and as such have a ± 25 percent accuracy range.

To provide consistency with the Railbelt Alternative Study undertaken by Battelle, it was desirable to escalate cost estimates into the future to January 1982. To arrive at this level, the June 1981 estimates were escalated an additional 3.5 percent, one half year of escalation at a 7 percent rate.

9.3 - Order of Magnitude Estimates

9.3.1 - Unit Costs

The unit costs utilized in the estimates were developed based on information obtained during the study. The various sources of information are described below.

The services of the local Anchorage office of Hanscomb Associates Inc. were utilized to provide input regarding site conditions, labor supply, labor rates, logistics, equipment availability, and other such factors. This information was combined with that from other contacts of the Acres American Anchorage office to arrive at an appraisal of site conditions and present and future contracting procedures and cost levels.

Site visits were carried out to have a good overall perspective of the project and the surrounding terrains and existing infrastructure. These visits combined with the information supplied above and research on large size projects being carried out or completed in Alaska allowed for the building up of applicable unit prices for the works.

The unit cost for dredging was obtained from an international marine contractor and the necessary works for containment of the dredged material were added to the contractor's price. The price indicated allows for dredging and transporting the material upwards of 20 miles and disposal behind a retaining dike on the foreshore.

The turbine-generator costs were obtained by discussions with the leading manufacturers in this field. They supplied order of magnitude prices for the supply, transport and installation of the units.

The costs for the electrical services systems, bus duct and transformers were obtained by contacting the manufactuers of this equipment for preliminary estimating costs.

9.3.2 - Quantities

The quantities utilized in the estimates were developed from the sketches prepared for the study report. The quantities were cross checked to assure that they were accurate. The basic information available for such important items as sea bed contours, site foreshore elevations, and type and availability of construction material are described elsewhere in the study. Also, the borrow area locations and quality of material are not well defined but gathered information has been sufficient to allow reasonable assumptions to be made in order to produce the quantities.

9.3.3 - Construction Methodology and Unit Costs

The unit costs reflect the construction methodology described in Appendix 8 of this report. The methods reflect the local conditions with regard to various factors such as weather, tide, and sea bed conditions. The problems of placing the units and building closure dikes are also reflected in the unit costs.

9.3.4 - Material Sources

(a) Local Sources

The materials to construct the dikes and for concrete aggregate are all local. The coarse aggregate for concrete is crushed in the rock quarry areas. The fine aggregate (sand) is transported from the Palmer area.

Rock borrow areas are as follows:

Rainbow:	North and South side of Turnagain Arm - 5 mile haul
Point MacKenzie:	North side of Turnagain area near Rainbow site - 30 mile haul
Eagle Point:	Mount Magnificent - 15 mile haul

(b) Outside Sources

The permanent and construction equipment are from sources outside of Alaska. The marine equipment and dredging equipment, depending on market conditions at the time would be either U.S.A. or European. The turbine generators would likely be from North America or Europe, once again depending on market conditions.

9.3.5 - Labor

The labor to develop a tidal power project in the Anchorage area would come from the area, the State of Alaska, and from the south. The technical people required for turbine installation and electrical services would come from Europe or North America and would be supplied largely by the fabricators of those items.

9.4 - Basis of the Order of Magnitude Estimates

9.4.1 - Date Line of the Estimates

The estimates have a date line of June 1981 and do not reflect any escalation or interest during construction beyond that date line.

9.4.2 - Items Included

(a) Site Preparation

This item includes the costs for site access by new roads or upgrading existing roads. It includes site specific costs where there are particular problems. They are identified as follows:

Point MacKenzie:	Adjustments near airport
Eagle Point:	Nothing
Rainbow:	Viaduct off highway over existing railroad tracks (North side)
	Storage and work area along shore (North side)

(b) Direct Cost Items and Subtotal

These are the charges by a general contractor to construct the facilities. The costs are all inclusive in that they include labor, material, construction equipment rentals, the contractor's overhead and markup. Factors such as taxes, duties, and royalties are also included.

(c) Indirect Contractor Facilities

This is the cost to provide the camp site and maintenance of temporary facilities. It includes temporary offices, road maintenance, services maintenance, and other such items. In accordance with normal practice for a project of this magnitude, the indirect contractor facilities' cost is assumed to be 13 percent of the direct cost subtotal.

(d) Engineering, Project Management and Owner Cost

These include design engineering, construction supervision for quality and quantity control, project management to monitor schedule, cost control and the cost of the Owner's staff assigned to the project. To cover these, a 12.5 percent factor has been applied to direct costs. This could be reduced due to the magnitude and repetitive nature of the work, but at this stage, 12.5 percent is felt to be reasonable.

(e) Contingency

Because of uncertainties in such parameters as geotechnical, sedimentation, and construction materials, a high contingency value of 25 percent on civil work as well as on the mechanical and electrical equipment was considered appropriate to allow for lack of data on site conditions and other unknown factors.

Elsewhere in the study, it has been asserted that costs could vary by 25 percent in either direction. The potential for cost savings stems from the use of certain conservative assumptions (viz: Dredged disposal would be less costly with ocean dumping rather that assumed containment; Variable blade turbine developments may offer cost advantages as addressed in Appendix 4; foundation conditions may be better than assumed, etc.).

Charges for such items as standby on marine plant and mobilization of same, weather delays and overtime charges are included in the direct costs.

9.4.3 - Items Excluded

All work beyond the limits of the dikes other than that required for the transmission line to the nearest existing connection point to the Alaska power system and temporary facilities are excluded.

There are also no costs included for improvement on the basin side for recreational facilities. The cost of highway access across the tidal power plants and dikes are not included in the cost estimates. The following costs are estimated to be the additional costs to incorporate a highway crossing at each site:

	Cost in Million Dollars	
Site	June 1981	January 1982
Point MacKenzie	41	42
Eagle Bay	28	29
Rainbow	21	22

9.4.4 - Closure at Point MacKenzie

Due to the high velocity of flow during closure at Point MacKenzie as described in Appendix 7, it has been necessary to restrict the size of development to 60 turbines and 46 sluiceways. Detailed consideration of the construction cycles and rate of manufacture of turbine-generator equipment in later studies will probably allow an increase in this installation to 80 or 100 turbines without cost penalty, so that a full development of the site potential may be achieved.

9.5 - Project Schedules

The project schedules presented in bar chart form incorporate the construction productivities and quantities on which the unit costs are based.

The durations utilized were arrived at by discussion with suppliers of the major equipment and input from marine contractors regarding productivity, construction methods, and site and weather restraints.

The schedules represent a reasonable appraisal of the time required for project construction based on the information available at this time.

The critical path of work activities is through the structural units and the closure dikes. The number of drydocks required is based on the completion of the project in a realistic time frame and within the manufacturing capability of the turbine-generator fabricators.

9.6 - Staging of Developments

To facilitate the introduction of tidal energy into the power system as described in Appendix 13, it is necessary to consider staging of the development. This allows installed capacity and hence annual energy generated to be reduced below the at-site optimum values calculated in Appendix 6.

For the purposes of this study staging has been considered only for the Eagle Bay site, although the concepts to be applied are similar for the other sites.

Instead of the optimum installation of 60 turbines and 32 sluiceways, the initial development was restricted to 30 turbines and 26 sluiceways. Cost estimates for this development were obtained by applying the incremental cost formula described in Appendix 6. This means that when the plant is expanded later to include more turbines and sluices the structures can be floated into place behind the completed tidal barrier so reducing construction problems due to exposure to full marine conditions and high, uncontrolled velocities.

A detailed cost estimate was not developed for the 30-turbine Eagle Bay installation, although the energy costs derived for this scaled-down project are considered valid for purposes of prelimianry assessment and comparison.

Other alternatives for later expansion to be considered in later more detailed studies could include cofferdam and in-the-dry construction although geotechnical conditions do not appear favorable. Staged installation of powerhouse units without turbines installed or double decker structures do not appear to have any economic advantages.

RAINBOW (60 PH/24 SL)

COST ESTIMATE

	Items	Cost (Million Dollars)
1.	Land Acquisition	20
2.	Site Preparation	18
3.	Access Dike: (a) Dredging 0.57 cy x 10^6 x $ 6.25/cy	4
	(b) Fill 0.20 cy x 10^6 x $31.50/cy	6
4.	Units: Powerhouses	
	(a) Dredging 15.92 cy x 10^6 x $ 6.25/cy	100
	(b) Mattress 0.64 cy x 10^6 x $42.50/cy	27
	(c) Caissons:	
	- Civil $ 7,908	
	- Mechanical $ 818 $22,236 x 10^3/unit x 40 PH	889
	- Electrical $13,510	
	Sluices	
	(a) Dredging 7.87 cy x 10^6 x $ 6.25/cy	49
	(b) Mattress 0.40 cy x 10^6 x $42.50/cy	17
	(c) Caissons:	
	- Civil $6,196	
	- Mechanical $1,896 $8,122 x 10^3/unit x 24 SL	195
	- Electrical $ 30	
5.	Sluice Extension, Cribs and fishways	25
6.	Closure Dike (a) Dredging 5.30 cy x 10^6 x $ 6.25/cy	33
	(b) Fill 6.14 cy x 10^6 x $40.70/cy	250
7.	Transmission Line	120
8.	Subtotal	1,753
9.	Indirect Contractors Facilities 13% of #8	228
10.	TOTAL DIRECT COSTS	1,981
11.	Engineering Project Management & Owners Cost 12.5% of #10	248
12.	Contingency Allowance 25% of #10	495
	JUNE 1981 CAPITAL COST TOTAL (Million Dollars)	2,724
	JANUARY 1982 CAPITAL COST TOTAL (Million Dollars) (Based on 7% Annual Escalation)	2,819

EAGLE BAY (60 PH/36 SL)

COST ESTIMATE

	Items			Cost (Million Dollars)
1.	Land Acquisition			20
2.	Site Preparation			32
3.	Access Dike:	(a) Dredging	0.78 cy x 10^6 x $ 6.25/cy	5
		(b) Fill	0.32 cy x 10^6 x $36.84/cy	12
4.	Units: Powerhouses			
		(a) Dredging	16.57 cy x 10^6 x $ 6.25/cy	104
		(b) Mattress	0.96 cy x 10^6 x $39.38/cy	37
		(c) Caissons:		
		- Civil	$ 7,908	
		- Mechanical	$ 797 $22,157 x 10^3/unit x 60 PH	1,329
		- Electrical	$13,452	
	Sluices			
		(a) Dredging	10.84 cy x 10^6 x $ 6.25/cy	68
		(b) Mattress	0.58 cy x 10^6 x $39.38/cy	23
		(c) Caissons:		
		- Civil	$6,196	
		- Mechanical	$1,896 $8,122 x 10^3/unit x 36 SL	292
		- Electrical	$ 30	
5.	Sluice Extension, Cribs, and fishways			25
6.	Closure Dike	(a) Dredging	4.38 cy x 10^6 x $ 6.25/cy	27
		(b) Fill	5.83 cy x 10^6 x $48.81/cy	285
7.	Transmission Line			120
8.	Subtotal			2,379
9.	Indirect Contractors Facilities 13% of #8			309
10.	TOTAL DIRECT COSTS			2,688
11.	Engineering Project Management & Owners Cost 12.5% of #10			337
12.	Contingency Allowance 25% of #10			672
	JUNE 1981 CAPITAL COST TOTAL (Million Dollars)			3,696
	JANUARY 1982 CAPITAL COST TOTAL (Million Dollars) (Based on 7% Annual Escalation)			3,825

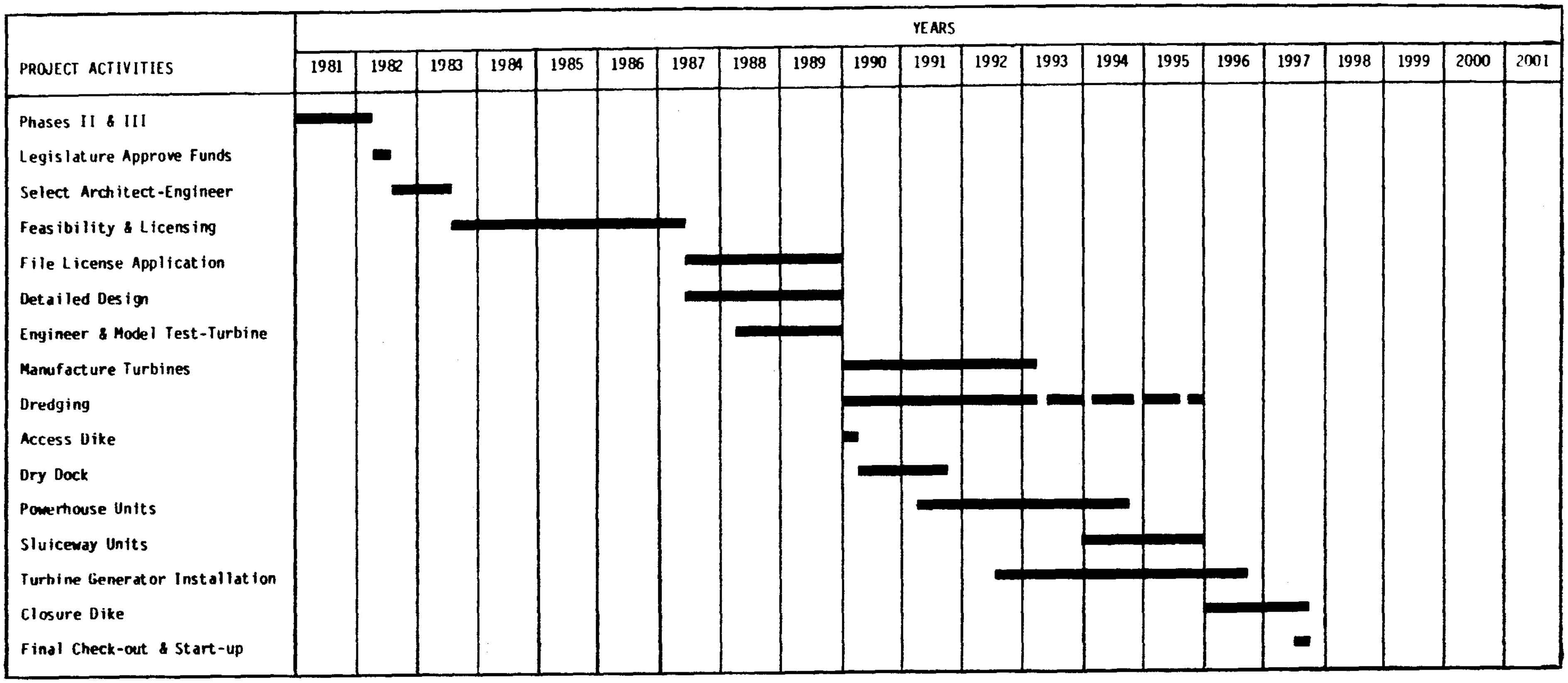
POINT MACKENZIE (60 PH/46 SL)

COST ESTIMATE

	Items	Cost (Million Dollars)
1.	Land Acquisition	20
2.	Site Preparation	29
3.	Access Dike: (a) Dredging 0.27 cy x 10^6 x \$10.35/cy	3
	(b) Fill 2.21 cy x 10^6 x \$54.50/cy	120
4.	Units: Powerhouses	
	(a) Dredging 2.0 cy x 10^6 x \$10.35/cy	21
	(b) Rock Ex. 1.71 cy x 10^6 x \$50.00/cy	86
	(c) Mattress 0.96 cy x 10^6 x \$43.85/cy	42
	(d) Caissons:	
	- Civil \$ 7,908	
	- Mechanical \$ 800 \$22,187 x 10^3/unit x 60 PH	1,331
	- Electrical \$13,479	
	Sluices	
	(a) Dredging 2.0 cy x 10^6 x \$10.35/cy	21
	(b) Fill 2.18 cy x 10^6 x \$39.30/cy	86
	(c) Mattress 0.81 cy x 10^6 x \$43.85/cy	36
	(d) Caissons:	
	- Civil \$6,196	
	- Mechanical \$1,896 \$8,122 x 10^3/unit x 46 SL	374
	- Electrical \$ 30	
5.	Sluice Extension, Cribs, and fishways	25
6.	Closure Dike (a) Dredging 0.24 cy x 10^6 x \$10.35/cy	2
	(b) Fill 1.46 cy x 10^6 x \$55.04/cy	80
7.	Transmission Line	101
8.	Lock	191
9.	Subtotal	2,568
10.	Indirect Contractors Facilities 13% of #9	334
11.	TOTAL DIRECT COSTS	2,902
12.	Engineering Project Management & Owners Cost 12.5% of #11	363
13.	Contingency Allowance 25% of #11	726
	JUNE 1981 CAPITAL COST TOTAL (Million Dollars)	3,991
	JANUARY 1982 CAPITAL COST TOTAL (Million Dollars) (Based on 7% Annual Escalation)	4,131

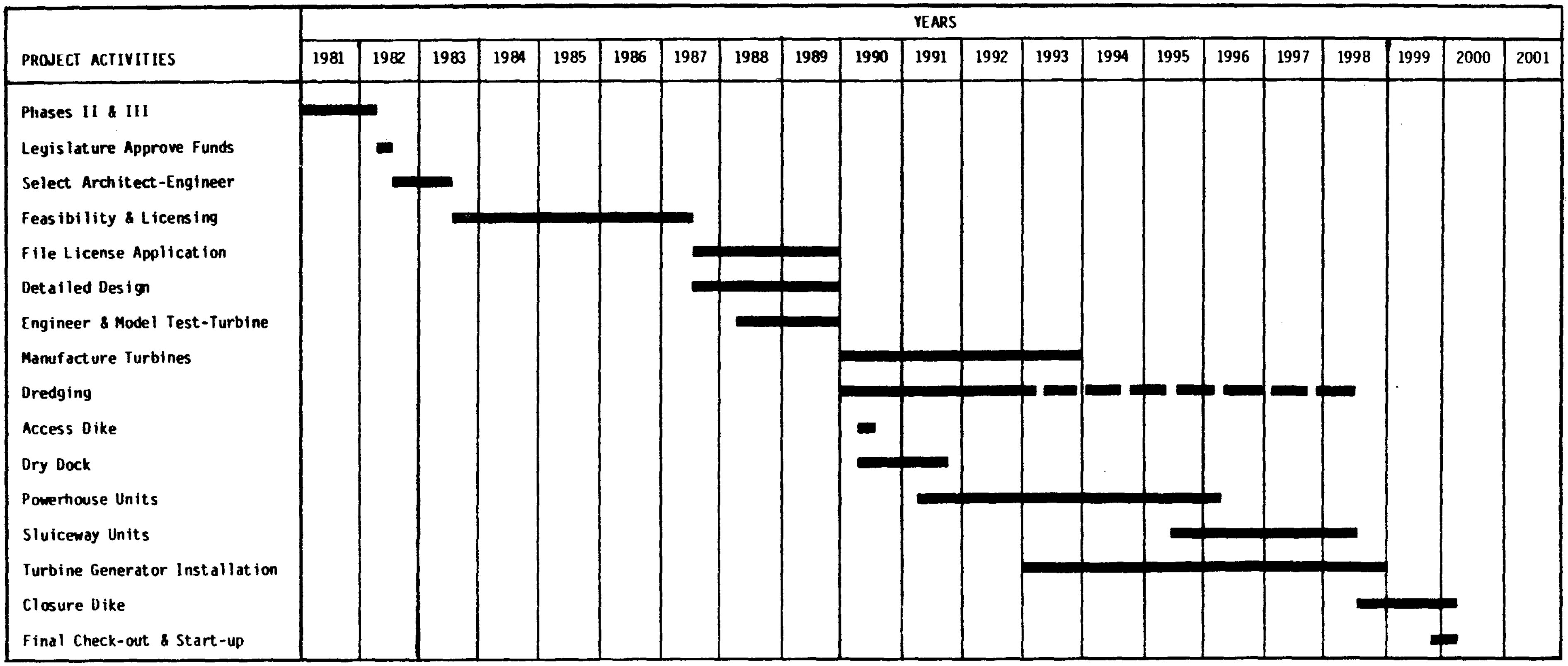
RAINBOW

PRELIMINARY SCHEDULE



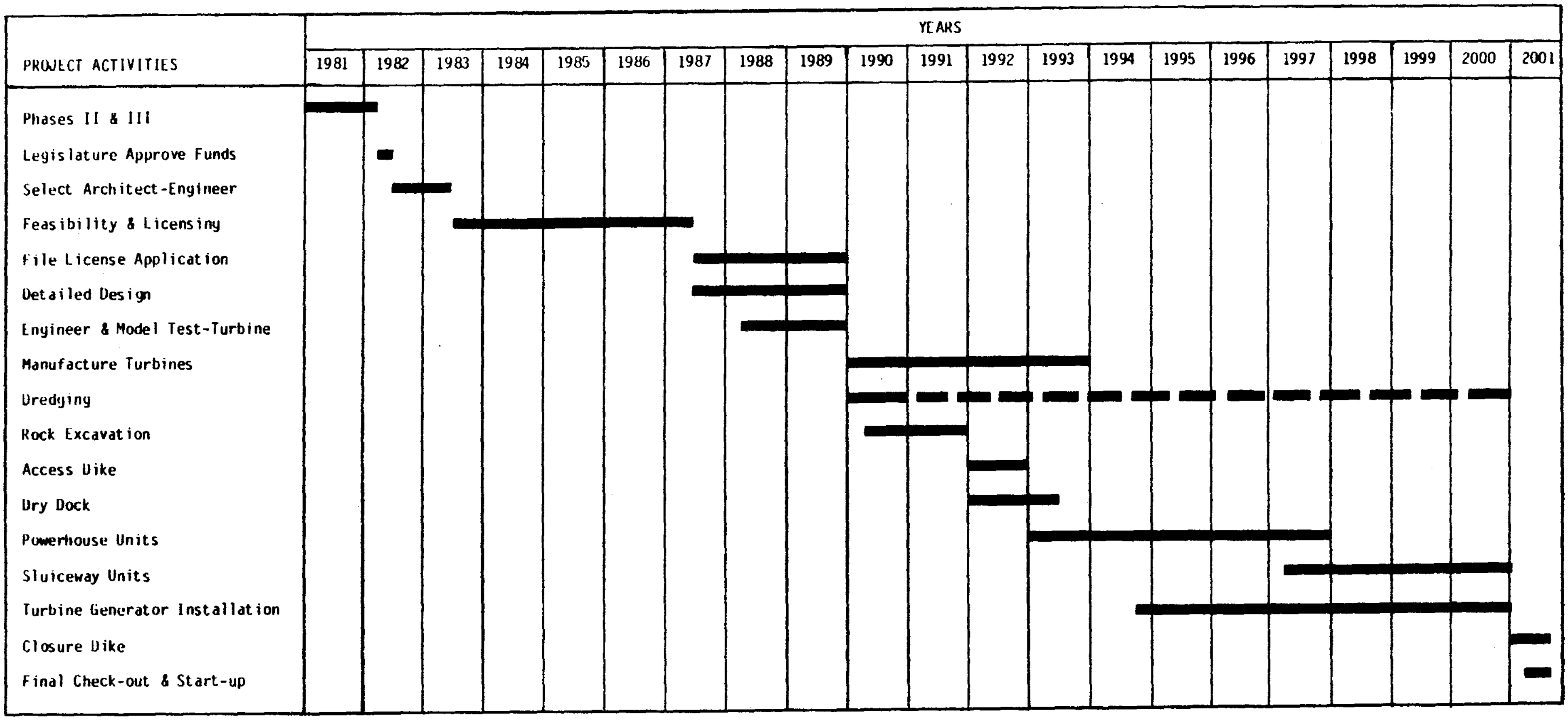
EAGLE BAY

PRELIMINARY SCHEDULE



POINT MACKENZIE

PRELIMINARY SCHEDULE



APPENDIX 10 - PRELIMINARY ENVIRONMENTAL ASSESSMENT

APPENDIX 10 - PRELIMINARY ENVIRONMENTAL ASSESSMENT

TABLE OF CONTENTS

Page

10.1 - Objective 10-1
10.2 - Approach 10-1
10.3 - Physical Setting 10-1
10.4 - Summary of Anticipated Effects 10-5
10.5 - Effects on Resources 10-10
10.6 - Summary 10-14

LIST OF TABLES

Number	Title
10-1	Potential Interaction Between the Tidal Plant and Elements of the Environment

10 - PRELIMINARY ENVIRONMENTAL ASSESSMENT

10.1 - Objective

To gather information and identify preliminary environmental impacts associated with tidal power development on Cook Inlet.

10.2 - Approach

The biological environment of Cook Inlet can be analyzed in terms of the physical processes which contribute to its unique characteristics. The local climate and geomorphic processes act upon the geologic structure and create a physical context. Evolutionary processes work within this context to create a unique, interdependent ecosystem. The presence of the biota, in turn, alters the physical setting.

It is in light of the interactions between the physical and biological components of Cook Inlet that an environmental assessment should be made. The construction and operation of a tidal power plant would have some direct effects on the environment local to the plant itself. In addition, it would result in long term changes to physical processes, such as tidal movement, sedimentation, and erosion, which may alter the physical characteristics of existing habitats.

The assessment has been made through a series of steps as follows:

1. Gain a macroscopic understanding of the interaction of physical processes in the Inlet
2. Identify the most sensitive and important components of the natural environment
3. Forecast the change in the natural environment that may result from the physical effects of the tidal plant
4. Determine the requirements for future study.

10.3 - Physical Setting

Several major characteristics of Knik and Turnagain Arms in Cook Inlet are relevant to an understanding of the processes and the potential for change in the estuarine environment. These are the tidal regime, hydrology, hydraulics, sediment load, and climate.

The characteristic which is most obvious to the casual observer is the extreme daily fluctuation of water levels; the mean tide range varies from 25 to 30 feet in the Knik and Turnagain Arms. In addition, both arms are shallow in relation to the tide range. Upstream of Fire Island, the tide range on the average is greater than the depth of the water at mean low tide. The result of a high tide in a very shallow basin is a well mixed, turbulent body of water. The energy of the tides acting within the basin results in high velocity currents, turbulence, and entrainment and transport of large volumes of sediment. Little vertical stratification of salinity, temperature or other parameters has been observed in the arms, with the exception of areas at the mouths of major tributaries. These fresh water inputs are quickly mixed by tidal actions.

The presence of glaciers as a source of tributary flows is significant in two respects. Streamflows of glacier fed tributaries vary widely throughout the year as the glaciers alternately melt in the long summer days and freeze in the winter. The effect of glacier melt serves to magnify the highs and lows of the annual hydrograph in which the high spring and summer flows result from snowmelt and runoff of precipitation and the low winter flows are fed mainly by an effluent ground water table since precipitation stored as snow cover does not contribute to stream flows. The result is that the freshwater flow into Knik and Turnagain Arms in the winter may be as little as 2 percent of the mean monthly flow in the summer. This is important to the view of the Inlet as a marine/freshwater transition zone.

The second influence of glacial flows is the large volume of silts and sediments frozen in the ice that are released as the glaciers melt. Because many of these sediments are fine grained, they remain entrained; thus, the sediment load of tributaries as they enter the Arms is high. Deposition of hundreds of feet of post glacial deposits have filled the formerly deep fiord and is a main cause of the formation of the lowlands and mudflats. The mudflats are prevalent in both Knik and Turnagain Arms, especially in the upper reaches, and are predominantly exposed at low tide.

Although the equilibrium conditions between freshwater inflows, marine influences and sediment transport are not clearly determined, the long-term trends indicate a net deposition of sediments in braided river deltas and mudflats, and high concentrations of sediments in the waters of both Arms.

Cook Inlet is an important transition zone between ocean saltwater and freshwater influences where the tides act to cause mixing at the interface. Although vertical stratification occurs in the seaward reaches of the Inlet, the absence of vertical stratification of salinities and the absence of a clearly defined thermocline is characteristic of the Arms. Temporal variations in these parameters are a function of the random mixing of waves and currents, the cyclical rise and ebb flow of the tides, and the mass flow balance between fresh and salt water. Parameters also vary with distance from the ocean influences; moving upstream, salinities decrease steadily while suspended sediment concentrations increase.

Seasonal variations also occur. In the summer when freshwater flows are high, the salt water in the estuary is forced seaward. During this time salinities drop substantially while suspended sediment load increases. In the winter as streamflows diminish, the salinities increase dramatically. This large seasonal variation is a factor in the creation of a high stress environment.

A high stress environment is one in which there is significant variation in parameters integral to the support of life forms. Salinities in Knik Arm have been observed to vary seasonally by more than 200 percent, from 6 to 20 parts per thousand. Temperatures may vary seasonally by 13°C or more. These extreme conditions create hardships for organisms living in the water. Added to this picture is a high suspended sediment concentration which both lowers the quality of the water for growth of zooplankton and severely limits the penetration of light necessary for primary production of phytoplankton, the basis of the estuarine food chain. As a result, the planktonic and benthic environments are characterized by low biological productivity.

The intertidal regions are also stressed. Added to the temperature and salinity variations are the large tidal ranges, waves, and alternating currents which continuously inundate and drain the land at the waters edge, and scour, erode, and deposit the transitional sediments. The mudflats, visible at low tide but submerged at high tide, are devoid of surficial vegetation with the exception of periodic algal growth. Organisms able to survive in this turbulent and transitional environment are severely stressed; indeed few life forms have been found in the mud.

Moving inland from the mudflats, increasing varieties and populations of organisms are found in the lowlands and wetlands. A correlation between the frequency and duration of tidal inundations and the distribution of plant communities has been made for Cook Inlet coastal marshes. Tolerance of salt water appears to affect plant communities in the coastal marshes. These lowlands and marshlands provide habitats for a variety of ducks, geese, shore birds and other birds such as terns, gulls and swallows.

It is useful at this point to summarize the components of the estuarine environment as they are found in the Upper Cook Inlet.

(a) Estuarine Environment:

This refers to the waters of the estuary and the biological communities living within it. In Knik and Turnagain Arms, high turbidity and limited light penetration result in low biological producitvity. Although the waters are not totally devoid of microscopic life, the lower trophic levels do not support any significant resident fisheries or shellfish. Anadromous fish use the turbid waters for passage between the lower Inlet and their natal streams. It should be noted that the waters are relatively free from pollution.

(b) Benthic Environment:

The benthos is that portion of the estuary floor that is always submerged. The sandy and silty bottom is highly mobile as tides and currents move and redeposit the sediments. Benthic organisms are the bottom dwellers of the estuary. Because they partially depend on organics derived from biological productivity of the water column above, food sources are scarce. Few organisms and none of commercial or recreational significance are found in the benthos. Benthic plants are virtually nonexistent due to the low degree of light penetration.

(c) Intertidal Mudflats:

The mudflats extend toward the Inlet from the mean high tideline. They are submerged at high tide and appear as a broad expanse of mud contoured by drainage rivulets as the tide recedes. No surface vegetation is present, with the exception of algae. Some worms inhabit the lower mudflats. It is a highly stressed environment, with water levels, winds, waves, ice and sun interacting to prevent the establishment of diverse life forms.

(d) Intertidal Lowlands:

Inland of the mean high tide line, the frequency and duration of tidal inundations decrease. Many areas in Knik Arm and the lower portion of Turnagain Arm are characterized by extended lowlands that are only occasionally inundated by tidal extremes. These lowlands or marshlands are highly productive; a great variety of vegetation types support extensive habitats for waterfowl and shorebirds. This productivity indicates that the marshland communities are a potential source of nutrients and organics for primary planktonic production and for zooplankton as well as benthic organisms.

Tolerance of salt water affects plant communities in the coastal marshes. Five broad types of plant communities have been defined as common to three Knik Arm marshes (this classification includes the mudflats as marshland). Above the mean high tide level, vegetation types range from the alkali and seaside arrow grasses, algae, and glasswort found in the Puccinellia-Trigochin Community, to the shrub-bog community which is least affected by tidal flooding and is poorly drained and thickly vegetated. Grasses, emergents, submergents, and shrubs predominate in these areas. Further inland, elevation and drainage facilitate the transition to upland vegetation.

(e) Uplands:

Beyond the reach of the tidal fluctuations, the drainage conditions permit the growth of upland vegetation. A wide variety of vegetation types are found in the vicinity of the upper Cook Inlet. In some cases, the upland border may be several miles from the edge of the Inlet waters. This is the case in many parts of Knik Arm where the marshlands are extensive and grades are small, as exemplified by the Eagle Bay site. In other places, bluffs formed from glacial morraines rise quickly from the waters edge to a height of several hundred feet, as is typical of the Point MacKenzie site. In this area, the intertidal lowland takes little space. A third upland configuration can be viewed at the Rainbow site in Turnagain Arm where steep mountain walls plunge sharply into the Arm and the various tide levels can be viewed as waterlines on a vertical rock face.

10.4 - Summary of Anticipated Effects

The construction and operation of a tidal power plant in either Knik or Turnagain Arm will affect the physical setting and cause changes that may directly or indirectly influence the natural environment. Tidal power development must be examined in order to identify those activities and operational characteristics which are likely to cause changes. These potential changes must then be assessed in order to identify the potential for impacts to the environment, both positive and negative.

Several types of changes will have the most far reaching potential for impact. These can be divided into short-term effects and long-term effects. Table 10.1 presents a chart of the short- and long-term interactions between components of the tidal plant and components of the environment.

10.4.1 - Short-Term and Local Effects

Short-term effects are those normally associated with construction activities:

- site development and construction/land environment
- site development and construction/marine environment
- site access and traffic
- operation of equipment
- dredging and spoil disposal
- development of construction material sources.

These short-term activities will affect, for the most part, only the environment in the vicinity of the site, and will extend for the construction period. Some permanent changes will occur in the environment, such as placement of permanent facilities, but the effects will be site specific. It should be noted that many of the negative impacts normally associated with construction can be eliminated by comprehensive construction management. Proper waste water facilities, erosion control methods, and well managed marine operations would be the rule.

(a) Dredge and Fill

The activities associated with dredging and filling may cause the most significant construction effect, due to the quantities of materials being moved and the necessary use of remote sites for spoil disposal and acquisition of construction materials.

The Eagle Bay and Rainbow sites will both require dredging of 30 million cubic yards of sediments from the inlet bottom. Most of this will not be useful as a construction material, and will need to be transported from the site for disposal. Acceptable sites for marine dumping can be found downstream where the Inlet broadens, but care must be taken to avoid commercial fisheries located in the Fire Island vicinity. The spoil itself is not polluted or chemically contaminated. The physical constituents of the spoil are likely to be similar to the bottom sediments found further downstream, although more biological activity may be found downstream. Disposal of spoil may temporarily disturb bottom organisms, but habitats would soon be reestablished. Careful planning in the timing and choice of disposal sites can ensure minimal impacts.

Because little of the dredge material at either the Eagle Bay or Rainbow sites would be suitable as construction material, upwards of seven million cubic yards of fill material must be procured from off-site sources. This would cause disturbance of upland habitats due to the activities of excavation and transport. Impact of these unavoidable activities is possibly reduced by avoiding development in sensitive environments.

It should be noted that the Point MacKenzie site is most attractive from the standpoint of dredge/fill operations. Less than one quarter of the dredging required for either Rainbow or Eagle Bay will be necessary for Point MacKenzie. Additionally, a substantial portion of the material removed will be rock, gravel and sand that may be appropriate for dam construction. This further diminishes the volumes required for acquisition and disposal.

(b) Site Access and Traffic

Establishing access to the site by land and by sea and providing for the high volume of traffic that will occur during the construction period will affect the environment. Roads and marine docking facilities will be constructed. Marine traffic for construction purposes, delivery of equipment and dredging operations will occur in areas where little or no shipping or boating of any type has occurred. Access roads will be established in previously undeveloped areas.

Access associated with construction is unavoidable. However, land routes can be chosen to avoid sensitive areas such as waterfowl habitat, and the high volumes of traffic can be limited to construction periods. Marine traffic is not likely to affect the few resident species nor block the mobile anadromous species as they migrate up and downstream. The marshlands, waterfowl habitats and upland game reserves would be most affected by development, noise and traffic activities.

(c) Site Development and Construction

The preparation of the site for construction, as well as the activities associated with construction, will have its greatest impacts on the site itself. Alterations of topography and existing habitats will occur. The presence of large, noise-producing equipment and human activity will be disruptive to habitats.

Site development can proceed in a manner that will minimize impacts. Conservation of land use, implementation of plans for erosion control and landscaping, development of permanently useful facilities such as dry docks may aid in enhancement of the site area. Certainly, more site specific details must be reviewed to determine the full scope of negative impacts versus the potential for enhancement.

Noise factors are potentially most significant at the Eagle Bay site which is located only a few miles upstream of Goose Bay State Game Refuge. The noise levels and the actual reaction of waterfowl to the noise must be investigated further.

The marine construction activities will affect the aquatic environment to some degree. Dredging, fill placement, dry dock construction, caisson construction and installation will be taking place in the water. There are few resident species to be disurbed. Migration of anadromous fish may be affected. It is likely that measures to ensure fish passage will be required during all stages of construction.

10.4.2 - Long-Term Effects

Certain aspects of plant operation may have far reaching effects on the physical regime of the estuary. It is necessary to quantify these changes and to determine the extent of their impact on the environment.

The following physical changes will be discussed in terms of their environmental implications:

- the altered tidal regime and estuarine hydrology
- the alteration of hydraulic characteristics: currents/velocities, erosion/sedimentation.

Additionally, the following long-term impacts will be considered:

- impacts added by the causeway alternative.

(a) Effects of an Altered Tidal Regime

The process of capturing the tide in a basin behind the barrier and regulating the flows through it has two important consequences. First, the mean tide level in the newly formed basin will be raised by several feet. Secondly, the mean tide range will be substantially decreased. Mean high tide levels will probably be slightly lower and mean low tide levels will be higher than what presently exist. A higher mean water level will result, but the periodic inundations will not reach as high a level. Extreme highs and lows will also be diminished.

The result of these changes can be conceptualized as follows. The extent of the mudflats will likely be somewhat diminished. The lowest reaches of the mudflats will remain totally submerged as the tide will never reach its previous low levels. At the upper limits of the mudflats, marshland vegetation may encroach seaward as the frequency of inundations decreases at the edges of the marshland, and the marsh grasses grow on the former edges of the mudflats, increasing the extent of the wetland habitats.

Other changes may alter the distribution of plant types on the lands affected by the tides. A net increase in the mean water level may alter the water table and hence runoff and other hydrologic characteristcs of adjacent marshlands. Also significant is the effect of altered salinities that may occur as tidal waters are stored in the basin. There is some potential that intrusion of salt water may have harmful effects on the ground water table. It should be noted that the Cook Inlet marshlands are high stress environments, characterized by large seasonal variation of salines. Therefore, changes in seasonal variation of salinities will probably not be detrimental to marshland vegetation; however, further investigation of these effects is necessary.

Other hydrologic characteristics would be affected, such as backwater and flooding. The raised water table could affect lowland drainage and vegetation. It appears at this time that although the potential for alteration or loss of marshland vegetation is great, it is also possible that only slight changes in populations will occur which will not greatly alter the nature of the environment as a habitat for waterfowl, shorebirds and furbearing species.

The tidal regime may also be altered downstream of the barrier. However, the impoundment of a portion of high tide water behind the barrier will not greatly alter existing water levels or tidal fluctuation downstream. Possible effects due to resonance of tidal waves will have to be studied in detail but it appears likely that the effects of the barrier will have much greater potential for impact upstream of the dam.

(b) Hydraulic Characteristics of the Basin

Regulation of flow in the basin will affect hydraulics local to the dam itself as well as having more widespread impacts. Existing current patterns and velocities throughout the basin would be altered. The most noticeable change will occur near the dam where the concentration of flow velocities through turbines and sluiceways would alter local flow patterns. These local high velocities will be dissipated with increasing distance from the dam. The decreased tidal range may result in an overall decrease in turbulence and mixing, although the tide range will still be substantial in relation to the depth of water so that the regime of total mixing may not be altered.

The effect of siltation on the environment and on the operation of the tidal power plant is one of the processes that will require more thorough investigation. Investigations of sedimentation in the Bay of Fundy, La Rance and other construction (1978) reported that siltation due to construction within the tidal flow is a function of 1) the degree of flow reduction caused by construction, 2) the availability of appropriate sized sediment in the water, and 3) the continued supply of material to site. Knowledge of the origin of sediments and the existing transport mechanism is necessary to analysis of the latter.

Sedimentation and erosion processes may be affected in the silt laden estuary. The mudflats and bottom conditions of the Arms are highly mobile. Changes can result from a net increase or a net decrease in velocities and from redistribution of wave energy on the shoreline. These will have the greatest potential for harmful impacts to the natural environment on the shorelines of marshlands, where erosion of the outlying mudflats could result in eventual erosion of the marshland and loss of habitat. It is possible, however, that a net decrease in energy in the basin (lower tide range, decreased mixing, decreased tide range) will result in higher sedimentation rates. If this is the case, it may cause decreased storage in the basin, and correspondingly, a buildup of mudflats and an extension of marshlands.

The effects of sedimentation may also be significant downstream of a barrier in Cook Inlet. Observation of recently constructed causeways at Windsor, Nova Scotia, and on the Petitcodiac estuary in New Brunswick reveal the development of large, mid-channel mudflats seawards of the barrier due to local flow reductions. This could result in a reduction of sediments which are normally deposited further downstream in the estuary. Effects on navigation may be significant, in the Knik Arm where shoaling is already a problem in the approaches to Anchorage harbor.

Another factor related to sediment load in the Inlet waters is that of penetration of light as required for biological productivity. At present, high turbidities limit light penetration. This may be the limiting factor for growth of the aquatic food chains. It is possible that along with a decrease in sediment load, an increase in food production could result in a habitat more amenable to aquatic species.

(c) Causeway Development

The addition of a causeway to the tidal power project would not create any additional impacts to the upstream and shoreline environment. The most significant impacts would result from development of a permanent road through previously undeveloped areas and from the residential and commercial growth that would occur due to the new access. Other impacts to the Inlet include increased noise due to traffic across the causeway and increased human access to the wetlands for recreational purposes.

10.5 - Effects on Resources

Certain resources of the upper Cook Inlet environment warrant discussion in light of their importance to the economy and to the lifestyle of the area and in light of their sensitivity to the tidal power development.

(a) Fisheries

Fisheries have an important role in the Alaskan economy. Subsistence, recreational and commercial harvesting is significant throughout the Cook Inlet region. Five species of Pacific salmon, as well as smelt and certain resident species are found in the tributaries to the Knik and Turnagain Arms.

Resident species are not found in the waters of the Arms. Recreational fishing of resident fish is significant in several of the tributaries to both Arms. It is not likely that the retiming of tides will affect the hydrology upstream of the reach of tidal fluctuations.

but how far up is this? esp. in Turnagain area.

Anadromous fish, which live most of their adult lives in salt water and return to their natal streams to spawn and die, utilize the water of Knik and Turnagain Arms for passage only. The loss of a passageway and disturbance of the fish as they migrate are the important considerations in respect to this resource. Further study on the use of sluiceways for passage of fish is required. It is likely that fishways for passage both upstream and downstream will be required.

Twenty-mile River?

Placer River!

Comparatively, the Knik Arm tributaries appear to sustain a more significant anadromous fishery than the Turnagain Arm. The important salmon rivers in Turnagain are Chickaloon River, Bird Creek, Indian Creek, Portage Creek, Resurrection Creek and Six Mile Creek. Of these, the largest salmon runs have been identified in the Chickaloon River. It is located approximately 10 miles downstream of the Rainbow site so that migration would not be directly affected. In the Knik Arm, the most important salmon tributary by far is the Little Susitna River, which is ten miles downstream of the Point MacKenzie site. Other important streams are Fish Creek, Wasilla Creek, Cottonwood Creek, Knik River system and Matanuska River.

These tributaries comprise only a small percentage of the total salmon run of the Inlet. However, commercial anadromous fisheries in the vicinity of Fire Island and downstream, as well as the recreational fisheries on the Knik and Turnagain tributaries would also be affected by loss of fish populations. It should also be noted that the fish, as they approach their natal streams, may wander as far as 10 miles past the mouth before turning back to their ultimate goal. In this manner, the Point MacKenzie and Rainbow sites may affect migration to the Little Su and Chickaloon, respectively, although the dam sites appear to be the limits of the interaction zone. The presence of the dams, as well as increased marine traffic and construction activities, may affect the normal migration patterns. Mitigation may be possible by means of fishways and fish ladders.

20-mile R. smelt fishing is a major sport fishing. How [illegible] pass [illegible] small? Turnagain catches were 107,000 in '79 + 82,000 in '80

(b) Wetlands and Waterfowl Habitat

The coastal marshes of upper Cook Inlet provide important resting and staging areas for hundreds of thousands of waterbirds during their spring and fall migrations. In addition to waterfowl habitat, the marshlands offer extensive recreational hunting opportunities to Alaska's most heavily populated area. During the years from 1971 to 1976, approximately 30 percent of the state duck harvest occurred in Cook Inlet. In terms of biological productivity, these coastal marshes are the most important area that may be within the reach of the direct effects of the tidal power project.

Of the five coastal marshes in the Cook Inlet that are protected as State Game Refuges, four may be potentially affected by one or more of the proposed sites (no site would disturb all four). These marshes are: Potter Point, located just south of Anchorage at the mouth of Turnagain Arm; Palmer Hayflats, located in the upper reaches of Knik Arm; Goose Bay, located on the Knik Arm ten miles north of Anchorage; and Susitna Flats, located west of Point MacKenzie at the mouth of the Susitna and Little Su Rivers. Other important marshlands not protected as refuges are Eagle River Flats, across Knik Arm from Goose Bay, and Chickaloon Flats, across Turnagain Arm from Potter Point. Construction and operation phases of each of the proposed sites will have varying degrees of interaction with some of these marshlands.

Part of federal refuge

There are three primary mechanisms by which the tidal plant could directly cause impacts to marshlands. These are due to (1) interaction along the shores of the impounded basin; (2) interaction with the construction site, noise, activity and equipment; and (3) interaction with an altered flow regime downstream of the dam.

Of these three primary impacts, the potentially most significant would be the effects of the altered tidal regime on the stability and productivity of the marshland ecosystems within the impoundment basin. Altered sedimentation patterns could result in eroded shorelines. A raised water table could result in a more saline ground water table. Altered surface hydrology may affect filtering and transport of nutrients and organics within the marsh. A loss of marsh area and a loss of vegetation types required for support of bird populations can be envisioned, thus diminishing productivity and resulting in degradation of the waterfowl habitat.

Alternatively, sedimentation may result in an enlargement of marshlands. Effects of changes in hydrology, inundations, and nutrient supplies could produce an environment more attractive to waterfowl and other species. Somewhere between the best case and the worst case lie any number of variations where, for example, vegetation or land areas may be altered but have little impact on bird populations. The conclusion, at this point, is that the interactions between hydrology, hydraulics and the wetland ecosystem must be better understood in order to predict effects with more reliability. This should be the main focus of future environmental studies.

The second impact of a tidal power plant on marshlands would occur if the site is located in or near a marsh. None of the proposed sites is located in marshlands. A few may be close enough that effects of construction, especially noise, should be investigated.

Finally, operation of the tidal project may affect the hydraulics of the Inlet downstream of the dam. These effects should be studied in greater detail for their impacts on coastal marshlands. Later phases of engineering studies should include modelling the effects of the dam on downstream hydraulics and water levels. This information will be required to determine ecological impacts.

(c) Marine Mammals

Superficial / Turnagain area is probably an important feeding spring area.

Although the upper Inlet is not known as an important habitat area for marine mammals, a few species do occasionally migrate to the area. ? For example, Beluga whales are sometimes spotted cavorting in the waters offshore from Anchorage. Construction of a dam at Point MacKenzie would restrict this movement. Care must be taken in design of intake structures and dam approaches to prevent harm to these animals in the event of their interaction with the structure. Other mammals may also be involved, and the extent of their movements may reach the other dam sites. This question should be more thoroughly investigated in later studies.

(d) Rare and Endangered Species

? not in AK

Several species of raptors which occur in Alaska are classified as rare and endangered. These include the Bald Eagle and the Arctic Peregrine Falcon. They are not known to nest in the upper Cook Inlet region. They have been known to utilize coastal areas during their spring and fall migration periods, though these routes are predominant seaward of the proposed project.

again superficial use of Turnagain Flats in spring is well known.

No endangered waterfowl species have been verified in the Cook Inlet-Kodiak Region. Habitat for the Aleutian Canada goose may occur in the southern reaches of the Inlet but is unlikely in the upper arms.

Investigative studies must be included in later phases of the project, as the occurrence of endangered species in the project area would impact the project implementation.

(e) Water Quality

Present water quality is characterized by extremely high turbidity, relatively high dissolved oxygen content, variable salinity and nutrient concentrations and low levels of primary biological productivity. Several activities associated with the tidal project may affect water quality. These include the excavation and construction of the dam, increased ship traffic and operation of marine equipment, as well as the regulation of flows to and from the basin.

Dredging, excavation, and placement of materials for dam construction in the submarine and intertidal environments may temporarily increase suspended sediment concentrations near the dam. Given the existing turbulence and turbidity of the water, this should not be a problem. Additionally, the introduction of new materials (sand, rock gravel) from other sources may result in leaching of some chemical constituents not normally found in the waters. The possibility of serious chemical problems is very small.

The presence of construction equipment, tugs, barges and human activity indicates an increased possibility for such accidents as oil spills, fires, dumping of debris, and disposal of untreated sewage into the water. Adherence to health and safety plans and control of construction areas can minimize most undesirable effects.

The presence of the dam and the resultant flow patterns may act as a physical barrier which limits exchange of salt, nutrients, sediments, etc., between the freshwater inflows and the saltwater influence from the ocean. Although the total flow of water may be reduced by the dam, large volumes of water will still be exchanged. A well mixed basin would result, although local flow patterns and water quality may be affected.

It appears that, though there are many potentials for impact to water quality, the associated risks are low.

(f) Land Use

Management of land within the coastal zone is under the jurisdiction of the Alaskan Coastal Management Program. Recently, plans have been developed by the Anchorage District describing present land uses and classifying lands for future development. Further studies should include coordination with State and District planners to ensure best use of the coastal resources and sufficient areas for wildlife habitat, recreation, residential and commercial development, agriculture and other uses.

(g) Climatology

Short- and long-term changes in the climate of the region may occur as a result of tidal power development. changes in ice formation, for example, could alter air temperatures in basin vicinity. The potential changes due to such effects should be investigated in later phases.

10.6 - Summary

In summary, a large number of potential impacts are associated with any construction project of this magnitude. Certain short-term and local effects cannot be eliminated--such as dredging, construction activities, traffic, noise and installation of permanent facilities. In addition, some widespread changes in the natural regime would result from operation of the plant; namely, changes in tidal fluctuations, water levels, and sedimentation patterns. All of these changes will affect the natural environment. Further engineering and environmental studies should identify in greater detail the impact of change on the resources of Cook Inlet. Indeed, the environment may prove resilient enough to assimilate long-term changes without a net deleterious effect on resources. Enhancement potentials also exist. The State must weigh the importance of any impact on these resources against the need for growth and development.

TABLE 10-1-POTENTIAL INTERACTION BETWEEN THE TIDAL PLANT AND ELEMENTS OF THE ENVIRONMENT

TIDAL PLANT FACILITIES AND CONSTRUCTION ACTIVITIES	ELEMENTS OF THE ENVIRONMENT																						
	TOPOGRAPHY/BATHYMETRY	MINERAL RESOURCES	SOIL	DRAINAGE & SURFACE RUNOFF	GROUND WATER	TIDAL REGIME	FRESH/SALT WATER INTERFACE	PHYSICAL OCEANOGRAPHY	SEDIMENTATION/EROSION	WATER CHEMISTRY	AQUATIC ECOSYSTEMS	MIGRATING AQUATIC SPECIES	BENTHIC ECOSYSTEMS	INTERTIDAL ZONE PRODUCTIVITY	WETLAND VEGETATION	WETLAND WILDLIFE HABITAT	UPLAND VEGETATION	UPLAND WILDLIFE HABITAT	CLIMATE	AIR QUALITY	NOISE AND VIBRATION	ICE FORMATION	SURFACE WATER HYDROLOGY
CONSTRUCTION ACTIVITIES																							
SITE DEVELOPMENT - LAND BASED																							
CLEARING, GRADING, SURFACE EXCAVATION, BUILDING STRUCTURES, MATERIAL STORAGE	●		●	●	●				●	●	●				●	●	●	●		●	●		●
ROAD, RAIL SPUR CONSTRUCTION	●		●	●	●				●	●							●	●		●	●		
EXCAVATION FOR ABUTTMENTS	●		●	●	●				●	●				●	●	●	●	●		●	●		
MATERIAL PLACEMENT	●		●	●	●				●	●				●	●	●	●	●		●	●		
OPERATE LAND BASED MARINE EQUIPMENT	●		●	●	●			●			●		●	●	●	●	●	●			●	●	
WORKER FACILITIES AND USE	●		●	●	●					●						●	●	●					
SITE DEVELOPMENT - MARINE																							
PILE DRIVING	●		●					●	●		●	●	●	●	●	●		●			●	●	
INTERTIDAL CONSTRUCTION ZONE	●		●	●				●	●	●	●	●	●	●	●	●	●	●		●	●	●	
DREDGING	●		●					●	●	●	●	●	●	●	●	●					●	●	
MATTRESS/DIKE PLACEMENT	●		●					●	●	●	●	●	●	●	●	●					●		
TUG AND BARGE OPERATION	●									●	●	●								●	●	●	
CAISSON STORAGE AND TRANSPORT	●							●	●		●	●	●	●							●	●	
CAISSON INSTALLATION	●							●	●		●	●	●								●	●	
STATIONARY MARINE EQUIPMENT	●							●	●	●	●	●	●	●							●	●	
MECHANICAL/ELECTRICAL EQUIPMENT INSTALLATION																				●	●		
SITE ACCESSIBILITY																							
ROAD, RAIL TRANSPORT OF PERSONNEL, MATERIALS, OR EQUIPMENT			●														●	●		●	●		
MARINE TRANSPORT OF PERSONNEL, MATERIALS, OR EQUIPMENT								●		●	●			●	●	●					●	●	
REMOTE CONSTRUCTION FACILITIES																							
CONSTRUCTION MATERIAL SOURCE AREAS	●	●	●	●	●												●	●		●	●		
DREDGE DISPOSAL SITES - UPLAND	●		●	●	●												●	●		●	●		
DREDGE DISPOSAL SITES - MARINE	●							●	●	●	●	●	●	●									
OPERATION OF PERMANENT FACILITIES																							
ACCESS AND CLOSURE DIKE (PRESENCE)	●			●	●	●	●	●	●	●	●	●	●	●	●	●	●	●				●	●
PHYSICAL ESTUARY BARRIER	●				●	●	●	●	●	●	●	●	●	●	●	●			●			●	●
POWERHOUSE AND SLUICEWAY (PRESENCE)						●	●	●				●	●									●	
TURBINE OPERATION						●	●	●	●	●		●									●	●	●
SLUICEWAY OPERATION	●					●	●	●	●	●		●									●	●	●
POWER FACILITIES (PRESENCE)	●			●													●	●				●	
SWITCHYARD OPERATION																					●		
DRYDOCK AND DOCK FACILITIES (PRESENCE)	●			●					●	●	●		●	●	●	●						●	
LONG-TERM OPERATION										●	●			●		●			●		●	●	
IMPOUNDMENT (PRESENCE)	●			●	●	●	●	●	●	●	●	●	●	●	●	●			●			●	●
WATER LEVEL FLUCTUATION	●		●	●	●	●	●	●	●	●			●	●	●	●			●			●	●
LOCKS (PRESENCE)													●									●	
OPERATION								●	●			●	●								●	●	
SITE ACCESS (PRESENCE)	●			●										●	●	●	●	●					●
ROAD, RAIL SPUR USE																	●	●		●	●		
MARINE USE								●		●	●			●	●	●				●	●	●	
WORKER FACILITIES (PRESENCE)	●			●								●					●	●					
USE OF WORKERS					●							●									●		

● INDICATES POTENTIAL FOR INTERACTION BETWEEN ENVIRONMENTAL ELEMENT AND PLANT COMPONENT.

APPENDIX 11 - SOCIOECONOMIC ASSESSMENT

APPENDIX 11 - SOCIOECONOMIC ASSESSMENT

TABLE OF CONTENTS

Page

11.1 - Objective 11-1
11.2 - Approach 11-1
11.3 - Impact on Adjacent Land Uses 11-2
11.4 - Materials Origin Supply Study 11-2
11.5 - Labor Supply and Limitations 11-3
11.6 - Community Impact 11-4
11.7 - Cultural Resources 11-5
11.8 - Impacts of Causeway 11-5

LIST OF FIGURES

Number	Title
11.1	Unemployed Rate for Anchorage and Alaska
11.2	Anchorage Population Growth

11 - SOCIOECONOMIC ASSESSMENT

11.1 - Objective

To identify the significant socioeconomic issues, on a regional basis, related to tidal power development in the Cook Inlet Region.

11.2 - Approach

The socioeconomic issues of a tidal development would be similar to those of other capital intensive developments, particularly to those of a large hydropower project. The investment period, characterized by very high levels of activity and expenditure, would be followed by a long operational period during which these levels would become quite low. Annual costs of operation consist mainly of capital charges. The costs of maintenance and replacement would be quite small compared to these capital charges and the other costs of operating the facility would be negligible.

A tidal project presents, however, certain aspects and options that are very different from more conventional power modes and which may yield distinctly different social and economic results. The following examples will illustrate the characteristics in the tidal power development that may make it unique from the socioeconomic viewpoint:

(i) Storage and generation will take place in the sea. Consequently, very few, if any, relocations of people will be required and very little reallocation of land and water resources.

(ii) One of the more likely construction options will be floating in huge prefabricated caissons and sinking them on location as components of the structure. If this method is adopted, a significant amount of the work may be done off the site.

(iii) Depending upon final design and the site selected for development, a tidal project in the Cook Inlet will require from 30 to 60 turbine-generating units. Such a large number may be sufficient to justify establishment of a local industry for their manufacture and overhaul.

(iv) Tidal power will be generated in surges lasting from four to six hours followed by interruptions of approximately 8-1/2 to 6-1/2 hours duration (adding up to lunar cycle of 12 hours and 25 minutes). Energy-intensive industries that could work on the rhythm of power availability might find the general region of tidal power plants to be an attractive location.

The socioeconomic issues would arise primarily from the influx of construction and operation work force. The regional economic, community, employment and societal issues of the Cook Inlet Region were reviewed to identify existing socioeconomic issues and to determine changes that may occur with the development of tidal power in the region.

11.3 - Impact on Adjacent Land Uses

The major impacts from tidal development in the Cook Inlet would occur in the Greater Anchorage Area Borough located in the Southcentral portion of Alaska at the head of Cook Inlet on a roughly triangular area of land between the two estuarine drainages, Knik and Turnagain Arms.

Of the three sites, Point MacKenzie site would have the most effects on adjacent land. The tidal dam would be built across the Knik Arm from Point MacKenzie to Point Woronzof. The Anchorage navigation system would be affected. The shipping channels to Anchorage harbor cross the site cross-section. The fishing traffic would also be affected. The Eagle Bay site located further upstream on the Knik Arm would have no effect on ship channels to Anchorage. It may, however, affect fishing traffic. For the Rainbow site the tidal dam would be built across the Turnagain Arm. There would be no effect on major shipping channels. All three sites would offer causeway potential. The Rainbow site would not be quite as attractive as sites closer to Anchorage.

The areas within the boundaries of Municipality of Anchorage suitable for urban development are to the west of Chugach State Park, south and east including Alyeska-Girdwood, and north and east to Eagle River-Birchwood. A development of tidal power at any of the three selected sites should be checked with the Comprehensive Development Plan proposed for these areas.

11.4 - Materials Origin Supply Study

The raw materials, intermediate goods and equipment required for a tidal project can be grouped into three main categories:

(i) Raw materials such as aggregate, rock, cement and lumber. It is expected that aggregate and rock can be supplied locally. The fine aggregate (sand) will be transported from the Palmer area. The coarse aggregate for concrete wil be crushed in the rock quarry areas nearby the selected sites:

Rainbow:	North and south side of Turnagain Arm, 5-mile haul
Pt. MacKenzie:	North side of Turnagain area near Rainbow site, 30-mile haul
Eagle Bay:	Mount Magnificant, 15-mile haul.

A very preliminary estimate of direct labor required for the production of these items indicates that about 300 to 400 jobs may be involved during construction period.

(ii) Steel products, including reinforcement and fabricated gates. It is likely that these supplies would be from sources outside of Alaska.

(iii) Hydroelectric and electrical equipment, including, as main items, the turbines, generators, transformers and switchgear. This equipment would be supplied from North America or Europe depending on market conditions.

11.5 - Labor Supply and Limitations

A preliminary estimate indicates that the direct, on-site, labor requirements for the three sites considered would be approximately as follows:

Site	Rainbow	Eagle Bay	Pt. MacKenzie
Average man-years per year			
Over 7.5 years	1,875		
10.5 years		2,000	
11.5 years			2,500
Peak demand man-years per year	2,000	2,200	2,750

The peak labor requirements for any site development are not much higher than the average requirement and it is likely that careful scheduling of the work will make it possible to arrange for a relatively steady level of employment throughout the construction period.

For each of the sites, the total demand amounts to less than 3 percent of the total labor force and about 50 percent of the construction labor force in the impact region (Anchorage-Matsu) as of March 1981. It seems likely, therefore, that a large part of the labor that would be required during the 1990's could be recruited in the surrounding region.

In 1980, the unemployment rate was about 8 percent in Anchorage-Matsu Region immediately around and north of the project sites, 12 percent in the Gulf Coast Region and 10 percent in the State of Alaska. It is possible the rate of employment would be lower during the 1990's than at present, but it seems unlikely it will have become very low. Figure 11.1 shows graphically monthly unemployment rates in Anchorage and Alaska for the period 1975 - 1981. Anchorage's unemployment rates remained high by U.S. standards, and absolute levels of unemployment rates increased in every year. Statewide the unemployment rates remained about 10 percent. Most probably, sufficient labor will be available in the region around the project sites and construction of one of the projects would likely offer a welcome contribution to reduction of unemployment in the area during the years of construction.

Supplementary labor requirements in addition to the direct on-site requirements, are of two types. The first consists of labor employed in the production of supplies, such as cement, concrete, lumber, aggregate, steel products, turbines, generators and other electrical products. Parts of these activities will not be located in the impact region, or even in the State of Alaska. A preliminary estimate indicated that possibly up to 300 or 400 additional jobs in the production of raw materials could be created in the Anchorage Region during the construction period if in-state manufacuring facilities are developed.

Another type of supplementary labor requirement consists of additional jobs to supply the demand for services by the labor employed on-site and in supply activities.

11.6 - Community Impact

Direct, on-site employment would reach, in the peak years, about 2000 to 2750. The impact region would be the Municipality of Anchorage. A socioeconomic study by the Bureau of Land Management* indicates that population growth in Anchorage was responsive to the growth in economic activities: Kenai oil, Prudhoe Lease and Trans Alaska pipeline construction, as illustrated in Figure 11.2. The population of the Municipality of Anchorage was estimated in that study at 195,654 as of July 1, 1979. It is likely that Anchorage could supply labor and services of sufficient variety to accommodate a project of this size.

The temporary construction activities may provide opportunities to strengthen the local infrastructure and provide lasting benefits. Transport facilities, for example, would have to be improved to facilitate construction. For site access new roads or upgrading of existing roads would have to be done except at Eagle Point. Adjustments near the military airport would be necessary at Point Mackenzie. Viaduct off highway over existing railroad tracks (north side) would be built at Rainbow as well as road to storage and work area along shore (north side). Whenever possible, expansion of the transport facilities as required for construction should take into account opportunities to create lasting beneficial effects but at the same time should not unnecessarily interfere with existing communities. It will be desirable, if and when a decision is made to build one of the projects, to initiate joint planning with municipal authority as early as possible to minimize the unavoidable strains on the communities and to maximize the benefits that can be obtained from the temporary increase in activity in the area.

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* "Alaska OCS Socioeconomic Studies Program," Technical Report Number 48, Volume 1, Gulf of Alaska and Lower Cook Inlet, Petroleum Development Scenarios, by Peat, Marwick, Mitchell and Co.; for Bureau of Land Management, Anchorage, Alaska, January 1980.

11.7 - Cultural Resources

Anchorage has always been characterized by a large transient population. Fifty percent of the existing population has resided in Anchorage 6 years or less. While 19.8 percent have been here less than 2 years, only 8 percent are residents of 25 years or more.*

The racial composition of the community has been relatively stable in recent years. Its distribution is shown below. The Alaskan native population has stabilized at about four percent of the non-military population.

Race	Nonmilitary 1977†	Total 1977†	Nonmilitary 1977††	Military 1970††	Total 1970††
White	89.5%	90.6%	91.3%	87.7%	92.4%
Black	3.0	4.3	2.9	10.2	4.4
Native	4.2	3.8	5.8	2.1	3.2
Other	3.3	1.3			

It is more likely that the construction of a tidal power project at any site under consideration would not affect much the native population in the area.

11.8 - Impacts of a Causeway

As discussed earlier, construction of a tidal power project at any site considered in this study could be planned to provide a causeway. At Rainbow, a crossing of Turnagain Arm could be built as an integrated part of the tidal power project, and, therefore, its cost would be reduced. Turnagain Arm Crossing between the Anchorage area and the Kenai Peninsula has been considered in various studies** over the past 30 years. In all

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* Source: "Alaska OCS Socioeconomic Program; Technical Report Number 48, Volume 1, January 1980.

** U. S. Public Roads Administration:
- "Preliminary Report on Turnagain Arm Crossing," July 1945.

Alaska Department of Highways:
- "Feasibility Study for Turnagain Arm Crossing, Phase I Research of Existing Data," March 1963.
- "Feasibility Study for Turnagain Arm Crossing, Phase II, Alternative Crossing Studies," January 1964.
- "Route Study, Turnagain Arm Crossing," January 1965.
- "Financing Studies, Turnagain Arm Crossing," January 1968.
- "Causeway Studies, Turnagain Arm Crossing," January 1969.

those studies and in this study, it has been recognized that a major improvement such as a crossing of Turnagain Arm would have a great impact on the area which it serves or through which it passes.

Tourism plays a major role in the regional economics of the Anchorage-Kenai area. The opening up of territory heretofore unserved by a highway becomes of major importance.

Alaska with its almost unlimited scenary has likewise unlimited potential for recreation. Good transportation makes realization of these potentials possible as well as being one of the basic ingredients of commerce and industry. The improvement of the basic network of transportation within the Anchorage-Kenai area will produce favorable results with all of these activities.

A crossing of Turnagain Arm would bring the city of Kenai, the center of a rapidly growing petroleum industry, to the existing highway system. The 1968 study by the Alaska Department of Highways indicated that the distance between the city of Kenai and Anchorage through the crossing would be 94 miles by way of a low-level highway, whereas the distance over existing roads is 154 miles over mountain roads with long grades and passes subject to heavy snowfall.

The construction of a tidal power project at either site, Point MacKenzie or Eagle Bay, could also be planned jointly with a Knik Arm crossing. A causeway crossing joining the two sides of Knik Arm near Anchorage would provide civil benefits as well as defense benefits. The 1972 study by the State of Alaska Department of Highways* indicated that the crossing will allow future economic development of the west side of Knik Arm which would certainly add to the potential of the metropolitan area of Anchorage. It would shorten the Anchorage-Fairbanks highway and also would provide the necessary access for a new international airport on the west side of the arm. Such a facility presents an interesting stimulus for the future economic development of the west side of Knik Arm. In addition, the causeway crossing would provide means for development access of lands north of Knik Arm. The geographic position of Anchorage, being presently surrounded by water, mountains and military facilities, makes the development of the lands north and west of Knik Arm very desirable. A crossing of Knik Arm would give access to the Beluga area and the Alaska Peninsula with its mineral and recreation potential.

A Knik Arm crossing utilizing a ferry system was studied in 1975 by the state of Alaska, Department of Public Works.** The system proposed would consist initially of two ferry vessels operating on a 40-minute turnaround

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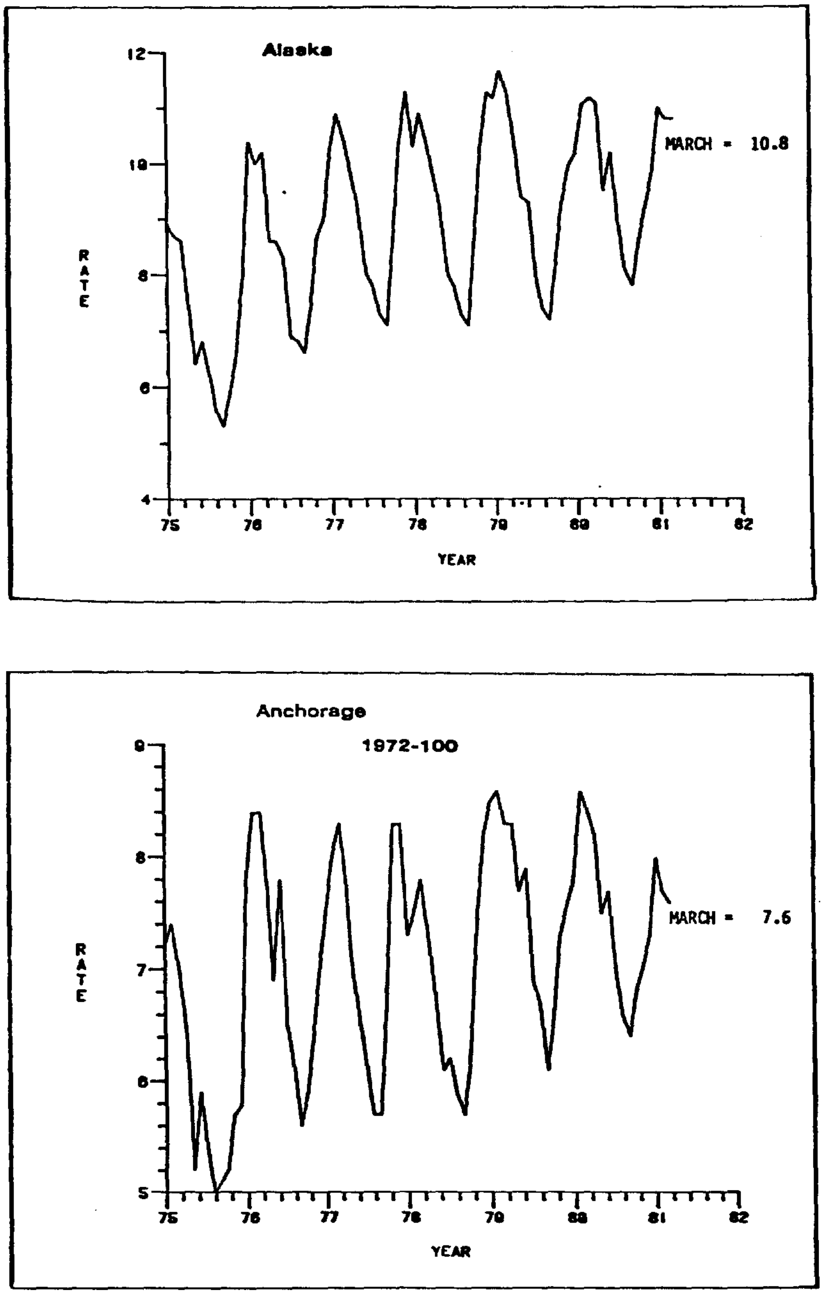
* "Knik Arm Highway Crossing," State of Alaska, Department of Highways, Anchorage, Alaska, January 1972.

** Phase I Feasibility Study, "Proposed Knik Arm Crossing Utilizing a Ferry System," State of Alaska, Department of Public Works, May 1975.

time, two ferry terminals and approximately 43 miles of new access roads. Additional ferries would be added to the system as required by the traffic. A permanent causeway crossing planned jointly with a tidal power project would seem to provide a better alternative to the proposed ferry system; therefore, it should be considered.



SOURCE: "ALASKA ECONOMIC TRENDS", ALASKA DEPARTMENT OF LABOR, RESEARCH AND ANALYSIS SECTION, MAY 1981

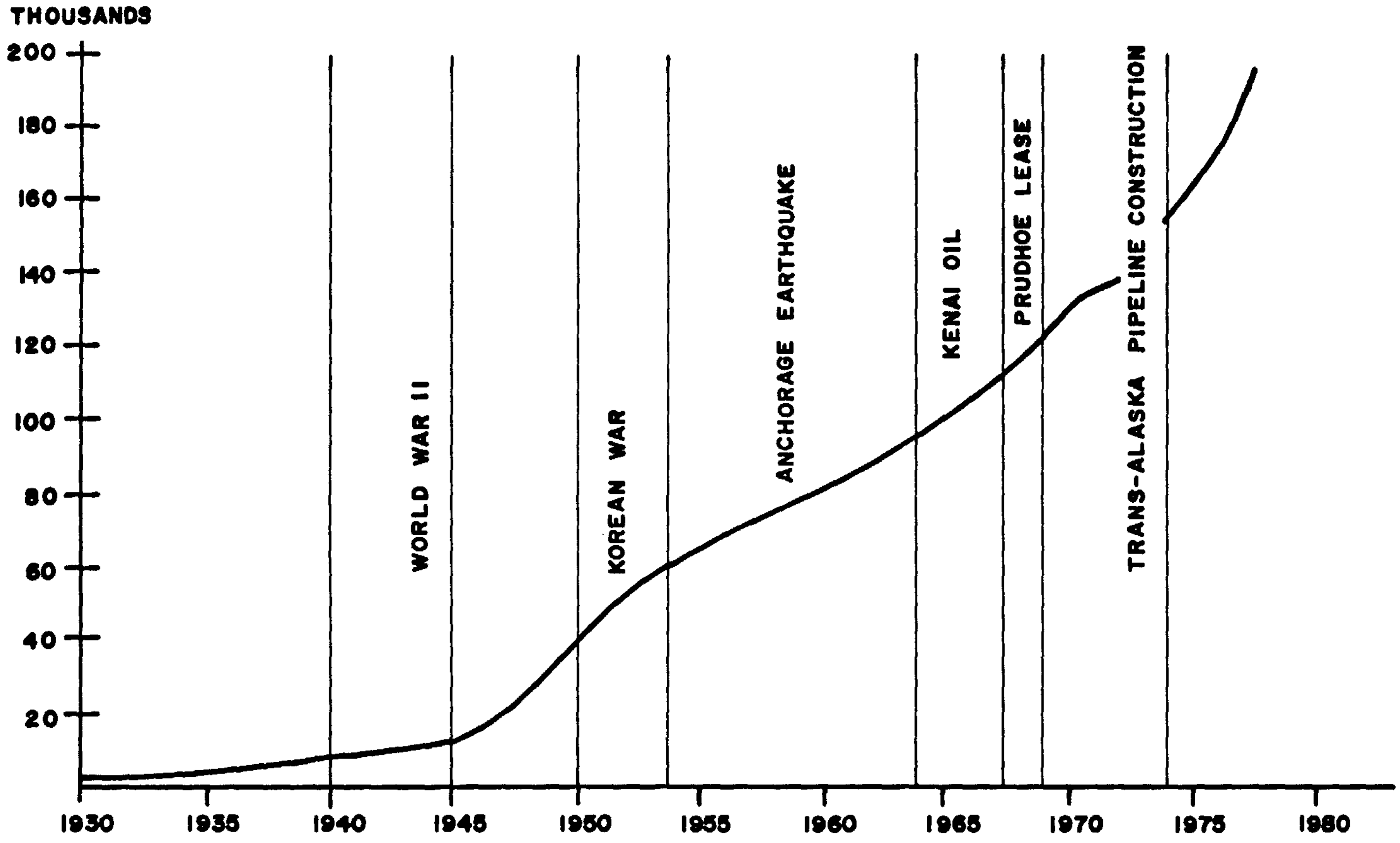
OFFICE OF THE GOVERNOR
STATE OF ALASKA

COOK INLET TIDAL POWER

UNEMPLOYED RATE FOR ANCHORAGE AND ALASKA

ACRES AMERICAN INCORPORATED

FIGURE II. I



SOURCE: "ALASKA OCS SOCIOECONOMIC STUDIES PROGRAM", TECHNICAL REPORT NUMBER 48, VOLUME 1, GULF OF ALASKA AND LOWER COOK INLET, PETROLEUM DEVELOPMENT SCENARIOS, BUREAU OF LAND MANAGEMENT, ANCHORAGE, ALASKA, JANUARY 1980.

ACRES

OFFICE OF THE GOVERNOR
STATE OF ALASKA

COOK INLET TIDAL POWER

ANCHORAGE POPULATION GROWTH

ACRES AMERICAN INCORPORATED

FIGURE II. 2

APPENDIX 12 - REGULATORY EVALUATION

APPENDIX 12 - REGULATORY EVALUATION

TABLE OF CONTENTS

Page

12.1 - Objective 12-1
12.2 - Approach 12-1
12.3 - FERC License 12-2
12.4 - Application Content 12-3
12.5 - Coordination 12-4
12.6 - Alaska Master Application 12-6
12.7 - Water Use Permits 12-7
12.8 - Coastal Zone Management Program (CMP) 12-9
12.9 - Water Rights 12-10
12.10 - Water Quality Permits 12-10
12.11 - Land Use 12-12
12.12 - Fish and Wildlife Permits 12-14
12.13 - Air Quality Permits 12-15
12.14 - Building Permits 12-16
12.15 - Navigation 12-17
12.16 - Other Permits 12-18

LIST OF TABLES

Number	Title
12-1	Cook Inlet Tidal Power Major Required Permits for Project Development
12-2	FERC Exhibit Contents

LIST OF FIGURES

Number	Title
12.1	FERC Licensing
12.2	Master Permit Application Process

12 - REGULATORY EVALUATION

12.1 - Objective

To identify and evaluate Federal, State, and local institutional considerations, including licensing, legal, and regulatory requirements associated with tidal power development in Cook Inlet region.

12.2 - Approach

Meeting regulatory requirements of the federal and state governments will be a critical aspect of the development of any tidal project at Cook Inlet. The licensing and permitting stage will occupy two to three years of the critical path towards project implementation and will have a major impact on the project plans and feasibility study schedule during the first years of project study.

The evaluation indicates that the project would undergo regulatory scrutiny similiar to that of a large low-head hydropower plant on a major river. It does not appear that the tidal plant, a unique project, would cause any major jurisdictional problems in the existing regulatory framework.

The major federal action will be the FERC licensing. The application for this license will be extensive, covering nearly every aspect of the project, with particular emphasis on environmental analysis. Development of the FERC application will have a significant upset on conduct of project feasibility studies.

Numerous state permits will be required on various aspects of the project. None of the permits are comprehensive in nature. The Master Application process of the State of Alaska allows for a simplified method of one filing for most of the permits. Critical areas of concern by the state regulatory body will be water quality, project safety and impact on anadromous fish and wetland ecology.

Local government will probably play a minor role in regulating the project, due to its location and the nature of the project. This role will vary slightly from site to site as jurisdictions change. Proper coordination during project planning stages should eliminate any problems in obtaining these permits.

The major permits required for the project are listed on Table 12.1. This list includes only those permits which would definitely be needed for project development. It does not include those which would be needed for a specific construction process (such as blasting) or which may be needed for a minor project aspect which will not affect project feasibility (air quality during construction). These type of permits are addressed in the following text.

12.3 - FERC License

The Federal Energy Regulatory Commission (FERC) is charged with the regulation of non-federal hydroelectric projects over which the Federal government has jurisdiction. The authorization for FERC's activities in this regard was made by the Federal Water Power Act of 1920, now included as Part I of the Federal Power Act of 1935. FERC's responsibilities are very similiar to those charged to the old Federal Power Commission, which was abolished in 1978 when the Department of Energy was organized. Tidal power will be classified as hydroelectric power under the Federal Power Act as it will include dams, powerhouses and other structures for the purpose of developing power.

FERC regulates hydropower projects by means of their licensing program, which was mandated in the laws. The program also ensures compliance with numerous other Federal statutes including but not limited to:

National Environmental Policy Act
Federal Water Pollution Control Act
Fish and Wildlife Coordination Act
National Historic Preservation Act
National Trails System Act
Wilderness Act
Anadromous Fish Act
Coastal Zone Management Act
Endangered Species Act.

None of these acts, in themselves, require that a permit action be taken. However, the FERC application, and specifically the exhibits to that application, have requirements that document proof of compliance with these acts. During the preparation of the application document, it is required that coordination be maintained with certain interested government agencies. For example, the Fish and Wildlife Coordination Act requires that study of the impact of the proposed project on fish and wildlife be conducted after consultation with and in cooperation with the U.S. Fish and Wildlife Service, National Marine Fisheries Service and appropriate state and local agencies, in this case the Alaska Department of Fish and Game. Evidence of this coordination and any cooperative agreements must be provided in the license application.

The jurisdiction by FERC extends to hydroelectric projects involving U.S. Government land and/or facilities, projects on navigable waterways and projects connected to interstate market grids. FERC jurisdiction is expected to apply to Cook Inlet in the first two areas mentioned. Cook Inlet certainly is considered to be a navigable waterway, and lands of the U.S. Government may be needed to develop any of the three projects.

At this time, a small tidal development in Maine is under a FERC preliminary permit for study by an Indian tribe. This is the first action regarding a tidal plant ever considered by the Commission.

Licensing regulations relevant to the Cook Inlet project are found in Title 18, Chapter 1, Subchapter B - Regulations of the Federal Power Act.

Specific parts of interest are:

Part 1 Rules of Practice and Procedure
Part 2 General Policy and Interpretations
Part 4 License, Permits and Determination of Project Costs
Part 24 Declaration of Intention

There are three categories of action before FERC relative to hydroelectric projects: Declaration of Intention, Preliminary Permit, and License.

The regulations of Part 24 define the submittal of a Declaration of Intention which must identify the application and the site, describe the project facilities and present hydrologic and system load data. FERC will use the data to make a determination of the applicable basis of law for exerting jurisdiction over the project. Although it is virtually certain that FERC will exercise jurisdiction, it may be worthwhile to submit a declaration to get a formal opinion.

A preliminary permit is for the sole purpose of securing priority of application for a license for a water power project while the permittee obtains data and performs the acts required to determine the feasibility of the project and support an application for a license. Thus, an application for license for a site may not be filed by anyone other than the permittee. It is important to note however, that the permit is a voluntary action, designed to protect the permittee and is unnecessary if there is no conceivable competition for development of a site. It is not necessary that such a permit be procured for Cook Inlet tidal power.

The major activity of the project regulatory process will be procuring a license from FERC. The requirements for an "Application for License for Major Unconstructed Project" are found in Part 4, Sections 4.40 and 4.41 of the code of Federal Regulation. The existing requirements are, however, currently under revision. It is expected that final rules, which will supersede the existing rules, will be issued imminently. It is further expected that the final rules will be substantially the same as the proposed rules, issued on January 23, 1981. For this reason, the proposed rules will be addressed in the following discussion on application content.

12.4 - Application Content

The FERC application must take the form of an initial statement with seven lettered exhibits. The contents of the exhibits are summarized in Table 12.2. The application document will include coverage on essentially every aspect of the project. The most rigorous of the exhibits will be Exhibit E, the Environmental Report, which will include eleven sub-reports on individual environmental aspects.

12.5 - Coordination

In several of the sub-reports listed under Exhibit E on Table 12.2 is a requirement for coordination. This requirement is a result of several Federal laws previously listed, that Federal actions must be coordinated with resource agencies at all levels of government. In developing the regulations for implementing their programs, FERC has included requirements and evidence of coordination in several of the reports of Exhibit E.

The regulations state that for these areas the reports must be prepared in consultation with the agencies with responsibility for the specific resource. The coordination includes an opportunity for the agency to comment on sufficiency of studies, areas of concern regarding the proposed project and recommendation for mitigating or avoiding problems. The areas specified for consideration and the law agencies for coordination are:

Water Use and Quality	Alaska Department of Natural Resources Alaska Department of Environmental Conservation Alaska Department of Fish and Game U.S. Environmental Protection Agency
Fish Wildlife and Botanical Resources	U.S. Fish and Wildlife Service U.S. National Marine Fisheries Service Alaska Department of Fish and Game
Historic and Archeological Resources	Alaska Historic Preservation Officer Alaska State Archeologist U.S. Heritage Conservation and Recreation Service
Recreational Resources	U.S. Heritage Conservation and Recreation Service U.S. Bureau of Land Management Alaska Department of Natural Resources (Parks) Greater Anchorage Area Borough (Municipality)
Aesthetic Resources	National Forest Service Alaska Department of Natural Resources
Land Use	U.S. Department of Transportation Alaska Department of Transportation and Public Facilities Alaska Department of Natural Resources National Forest Service

In the interest of arriving at the best possible plan for a project the size of Cook Inlet tidal power, it is prudent to coordinate studies and plans not only with required agencies, but all interested groups to assure ease in permitting prior to project development. A coordination and public involvement program should be part of any detailed studies for development of Cook Inlet tidal power.

12.5.1 - FERC Process

After completion of feasibility and environmental studies, the application will be filed with FERC. The following paragraphs discuss the post-application FERC process. The Figure 12.1 is a diagram of the process described.

After the application is filed, the FERC issues a filing number and begins a review of the documents for completeness. If the application is incomplete, FERC issues a deficiency letter to the applicant. When the application is deemed complete, the public notice is issued and the public comment and interagency review process begins. Also at this time, the environmental impact statement is initiated and FERC staff analysis of the project application begins. At the end of the public comment and review period, potential intervenors must submit materials. The Commission will grant intervenor status as appropriate.

If no intervenors submit petitions or none of the petitions are allowed, the process proceeds to Commission consideration at the end of staff review. If there are intervenors, the hearing process is initiated. At the time of completion of the hearing process, an order is drafted and the licensing issue is scheduled to go before the commission for action. At that time, FERC can issue the license with standard and special conditions as warranted. The applicant then has 30 days to accept the conditions or file for rehearing. The license provides authority to the licensee to operate and maintain the project for the licensing period of up to 50 years, under specified conditions and gives the licensee the right to exercise power of eminent domain in acquiring project land and water rights.

For a major license action, FERC licensing time is targeted to take from 18 to 24 months. The addition of the hearing process would add about one year to the processing time. Since a hearing can be expected on a project of the interest and magnitude of Cook Inlet tidal power, the expected time for licensing would be 30 to 36 months.

Experience with the licensing process has shown that processing can frequently be delayed for extended periods due to inadequate exhibit preparation or interventions. Thus, the environmental plan of study for pre-application studies should be carefully scoped and coordinated with appropriate agencies.

12.6 - Alaska Master Application

The State of Alaska's Master Application process was established by AS 46.35, the Environmental Procedure Coordination Act. Under the Act, a 'one stop' permitting process was established in order to clarify and simplify the state permitting program.

Under this program, if the decision is made after a feasiblity study to develop the tidal project, a Master Application form is filed with the DEC, who administers the program. The Master Application serves as a notice of intent to the state to develop a proposed project. Upon receipt, the DEC Permit Information and Referral Center sends copies of the project description for the Master Application to all state departments and any municipality where the project is located.

Agencies which claim jurisdiction over the project must respond to the permit center within 15 days specifying the permit required, a copy of the application form and a statement whether a hearing is required. The collection of responses from all agencies is returned to the applicant for completion. At this time the Permit Center will arrange a preapplication conference where the applicant may meet with the agencies who have jurisdiction. Completed applications and fees are returned to the Permit Center where they are disbursed to the proper agencies. The Permit Center also arranges for a public meeting, if one is required. Within 30 days after receipt of the last application, the Permit Center will have a notice published once a week in an appropriate periodical for three weeks. The public hearing will be held within 20 to 30 days after the last public notice.

Public hearings are conducted for the purpose of obtaining information for the assistance of state agencies and not as a trial or adversary proceeding. The hearing will be electronically recorded with transcribed copies made available to agencies upon request. Upon completion of the hearing, a date will be established by which all state agencies will forward final decisions on applications within their jurisdiction. The date will be within 90 days of completion of the hearing.

Provisions are included in the act for an appeals process for a person aggrieved by a final decision. A notice of appeal must be filed within 30 days of transmittal of the decision. If a reasonable issue of fact or law is found, a hearing officer will be provided for an adjudicatory hearing. Appeals shall be heard jointly by the commissioners of each agency. The commissioner of each agency shall decide on the portion of the appeal which involves his agency. A person aggrieved by the appeals decision may appeal to the superior court.

Prior to submission of the completed Master Application, the local government must provide a certification that the project is in compliance with the local government statutes and regulations regarding the project.

The maximum time from the submittal of the completed application to the permit issuance is about six months, as established by law. Including one month for completing application forms, the total time from filing the

Master Application to permit issuance is eight months. A diagram of the process is shown in Figure 12.2.

12.7 - Water Use Permits

The issues surrounding water use, appropriation, supply and quality are subject to regulation at both state and federal levels. Although for all practical purposes water quality issues cannot be separated from quantity and appropriation issues, those permits dealing strictly with quality are covered in the following subsection. The three actions discussed in this section will be critical to project implementation, since, as in the FERC process, the project will be considered in its entirety rather than from the point of view of one particular aspect. The Coastal Zone Management Program and the Water Rights Permit are administered by the State. A permit for dams, dikes and discharges into navigable waters of the United States is administered by the Corps of Engineers.

12.7.1 - Corps of Engineers Permits

The Corps permitting program is authorized by Sections 9 and 10 of the Rivers and Harbors Acts of 1899 and Section 404 of the Federal Water Pollution Control Act Amendments of 1972 (P.L. 92-500). Regulations covering the Corps permitting program are found in Title 33 of the Code of Federal Regulations, Part 320 through 329. Activities requiring permits fall typically under three categories:

(1) Dams and dikes in navigable waters of the United States

(2) Structures or work in or affecting navigable waters of the United States

(3) Discharge of dredged or fill materials into waters of the United States

The Project will come under more than one of these areas of jurisdiction, but only one permit action is required.

All projects within the State of Alaska lie within the jurisdiction of the Alaska District Engineer. Acting under the authority delegated by the Secretary of the Army, he may issue a permit authorizing the work unless it is found to have an adverse impact on the public interest. The public interest is determined by a proposal's consistency with state plans and interests, by its effect on navigation, fish and wildlife, water quality, economics, conservation, aesthetics, recreation, water supply, flood damage prevention, impacts on the ecosystem and, in general, the needs and welfare of the people.

The Corps jurisdiction within the permitting program is defined as the "waters of the United States" which includes isolated wetlands and lakes, intermittent streams and other U.S. waters which could affect interstate commerce. Obviously, the Corps would have jurisdiction over the navigable waters in Cook Inlet.

At the present time, the Corps of Enginers permitting jurisdiction over a project which is regulated by FERC is subject to question. There are two ongoing activities which may make it possible to avoid the Corps permitting process when a FERC license is obtained. The first is the Corps program of "nationwide permits" which may grant blanket permits to certain activities regulated by other Federal regulatory actions. The second is court litigation over a project where FERC granted a license but the Corps denied discharge permit. Even if these developments delete the need for a Corps permit, the Corps will still participate in the FERC process by providing formal comments on the license application.

The following outlines the Corps application process. Prior to submission of an application, a meeting will be be held with the Corps to discuss its specific contents whereupon a complete application would be submitted to the Corps District office. Upon receipt of the application, the District assigns a number and review for completeness. When all information is received and the application is considered complete, a public notice is issued. All comments relating to matters of special expertise of another agency, will be referred to that agency by the District. The applicant will be given the opportunity to rebut all adverse comments.

After the public comment period, the District Engineer will determine the need for an Environmental Impact Statement, based on an environmental assessment. The Corps will prepare an EIS only if it considers itself the lead federal agency (highly unlikely for this project since FERC would probably assume the lead). It is expected that the Corps will withhold permit approval until the federal EIS is final. The District Engineer also will determine the need for a public hearing on the application. If a hearing is needed, it could possibly be held simultaneously with the joint hearing of the state agencies. Scheduling of the state and Corps actions makes this unlikely.

When all actions are completed, the District Engineer prepares the Finding of Fact and makes the final decision as to whether to grant or deny the permit. The draft permit is sent to the applicant for acceptance, signature and submission of fees. Prior to permit issuance, the District Engineer requires evidence of State Water Quality Certification and the Coastal Zone Management Certificate of Consistency.

The application for the Corps permit must contain a detailed description of the proposed activities including location, purpose, types of structure, facilities for handling waste and the type, composition and quantity of dredge or fill material. The names and addresses of all adjoining property owners with direct interest in or affected by the project also need to be included.

12.8 - Coastal Zone Management Program (CMP)

The Coastal Zone Management Act was signed into law on October 27, 1972. The Act, which was substantially amended in 1976, stated a national interest in protection and development of the Coastal Zone of U.S. by providing assistance and encourgement to coastal states to develop and implement programs for managing their coastal areas. In response to these laws and the Alaska Coastal Management Act of 1977, the State of Alaska Coastal Management Program (CMP) was developed. The program document was published jointly with the final environmental impact statement (FEIS) published on the action on May 30, 1979.

In order to receive federal licenses and permits, a project must be reviewed for consistency with CMP guidelines. This applies to both the FERC and Corps permits. When an application is filed with FERC, a certification of compliance with the Alaska CMP must be included. At the same time, a copy of the certification with necessary data on the development should be filed with the state. The state will review the activity and initiate a public notice and hearing as necessary. Within six months from the receipt of consistency certification and required information, the state will notify the federal agency and applicant whether the state concurs or objects to a consistency certification.

The CMP is administered in Alaska by the Office of Coastal Management, Division of Policy and Development and Planning (DPDP), Office of the Governor. The CPM certification procedure is not included within the Alaska Master Application Program. Federal regulations covering the program are 15 CFR 930, "Federal Consistency with Approved Coastal Management Programs." State regulations pertaining to the potential Cook Inlet project are the following:

6AAC	80.040	Coastal Development
6AAC	80.070	Energy Facilities
6AAC	80.080	Transportation, Utility Route
6AAC	80.130	Habitats
16AAC	80.140	Air, Land, Water Quality
6AAC	80.150	Historic, Prehistoric, Archeologic Sites.

Under the Alaska Coastal Management Act in 1976, the state coastal lands were divided among nine district offices. Each district office established a more site specific management plan for the area under its jurisdiction. It is in the Anchorage Coastal Management District where the three study sites are located.

The Point MacKenzie and Rainbow sites encroach upon areas which are designated as Areas Meriting Special Attention (AMSA) under the Anchorage CMP.

Point Woronzof Bluffs, the southern shore of the Point MacKenzie site has been classified as a scientific and educational area with associated scenic and open spaces. This area is to be accessible only with bike paths. The Seward highway running along the northeastern edge of the Turnagain Arm is classified as a scenic and important transportation route. Because of this land designation, a complete environmental impact statement would be required along with Public Hearings for input on the proposed use. At that point there would need to be a change of land use issued by the Coastal Policy Council.

12.9 - Water Rights

A water rights application must be submitted to the Department of Natural Resources, Division of Forest Land and Waste Management. A significant amount of information must go into this application which requires both the dam construction permit, preliminary plans and proof of land entitlements to construct.

Four criteria are used to determine whether the water rights permit should be issued.

(1) Rights of prior appropriator

(2) Adequacy of the proposed means of diversion

(3) Benefits of proposed water use

(4) Public interest

The last category, public interest, includes the economic, environmental, health and navigational impacts.

After submission of the application to DNR, a public notice and review process will follow. A hearing is not required but may be held if public objections are received. If the rights are to be allowed, a permit will be issued authorizing the construction of the necessary works for appropriating the water and to commence appropriations. This permit does not secure water rights. Only when the appropriation process has commenced will DNR, upon notification, issue a Certificate of Appropriation. This certificate secures the holder's rights.

12.10 - Water Quality Permits

Regulations concerning water quality impacts of a tidal power development can best be understood by separating the permitting action into two groups: those required for the barrage and powerhouse and those required for construction, operation and maintenance of the project.

Only one water quality permit is anticipated for the barrage and powerhouse: the Water Quality Certificate. The certification requirement was established under Section 401 of Public Law 92-500, the Federal Water Pollution Control Act Amendments of 1972. Regulations governing the certification process are referenced 18ACC 15.130-180. This certification will be required prior to issuance of permits by any federal entity.

Application for the certificate is made by submitting a letter requesting certification along with a copy of the permit application to the federal agency, in this case the FERC license application. The certification is valid for five years; thus, it may need to be reserved prior to the operation of the project if other federal permits are needed.

The second set of permits deals with discharges from a waste water handling system which may or may not be necessary for support aspects of the project. These permits will not be critical actions regarding project development. On the federal level, a permit may be required under the Environmental Protection Agency's (EPA) National Pollutant Discharge Elimination System (NPDES). The purpose of this system is to prevent water pollution by monitoring and controlling the discharge of waste. The owner and/or operator of any activity or wastewater system which discharges from one or more "point sources" into a waterway must obtain a permit. The definition of "point source" includes a wastewater treatment facility for facilities used by operation personnel and those making use of recreational opportunities.

A NPDES permit could be required for the project as well as the treatment facilities. Currently, there is litigation regarding the classification of dams as "point sources." Court cases are pending regarding specific projects and dams in general. At this time, the EPA posture is that until these court cases are settled, a NPDES permit will not be required for dam construction. Should this permit be required, this would become a major project permit.

Dredged or fill material discharges do not require a NPDES permit. If construction/operation activities warrant the need for a NPDES permit, the short Form A application applies. The application must be filed 180 days prior to commencing the discharge. There is a 30-day review by the state for certification. A public hearing may be held if it is in the public interest.

Three additional permits relating to appurtenant project service facilities may be required by the State: the "Plan Review for Water and Sewer"; "Wastewater Disposal" and "Solid Waste Disposal." These three permit processes would be followed under the master application process.

The Wastewater Disposal permit is similar to the EPA-NPDES permit. Where the NPDES permit is required for project service facilities, DEC will adopt it as the required state permit. The process for reviewing the application is similar to that for NPDES.

The Solid Waste Disposal permit is to control or eliminate the detrimental health, environmental and nuisance effects of improper solid waste disposal practices. This permit will likely be required for project construction and service facilities. The application includes detailed plans and specifications for the facility, certification of compliance with local ordinances, and a report on the characteristics of the waste to be processed.

12.11 - Land Use

Several types of land use permits may be necessary to the project. Unlike many energy projects, a small amount of 'dry land' will be affected; however, some significant tidal lands will be affected.

12.11.1 - Federal Lands

It appears that each of the proposed sites encroaches on Federal lands. The Rainbow site borders the Chugath National Forest along the southern shore of Turnagain Arm. The national forest is under the jurisdiction of the National Forest Service, U.S. Department of Agriculture. The FERC license constitutes the authority to use the Federal lands and establishes the amount of annual payment appropriate for use of public lands.

The Forest Service has published regulations under authority of the Federal Land Policy and Management Act which require applicants for hydroelectric projects to obtain permits for development on National Forest Lands. The extent of jurisdiction that the Forest Service may have over project operations is questionable from two standpoints: (1) the extent to which the project encroaches on forest land is not at this point determined and (2) the legality of the regulations themselves are a subject of controversy. In any case, the Forest Service will have authority over any access roads or rights-of-way crossing land. It is not expected that encroachment of National Forest Land will be a project deterrent.

The Point MacKenzie and Eagle Bay sites each abut on military reservations on the Anchorage side of the inlet. Coordination with the Department of Defense would be necessary for establishing access roads, transmission right of way, and project lands for the projects. The impact of the use of lands for tidal power development on the military purposes is unknown at this time. This issue should be researched early on further site development studies.

Other potential land use permits which are not currently expected to be required are the U.S. Fish and Wildlife Service (DOI) permit for use of the Natural Wildlife Refuge Lands and the Bureau of Indian Affairs (BIA) permit for Indian Land Lease Authorization. Additionally, it does not appear that the Bureau of Land Management, a large land manager in Alaska, will be involved.

12.11.2 - State Lands

A major activity within the state permitting process will be obtaining approval to impact on the tidelands affected by the process. Tidelands refer to lands which are permanently or periodically covered by tidal waters from the MHW line, extending seaward three miles. These lands are considered state owned and are managed by the DNR. The right or use of these lands must be obtained through a permitting action administered by the Division of Lands of DNR. As part of the regulations promulgating this action, notification of land approved from the ADF&G must be obtained prior to any construction and development.

The application form covering the Tidelands Permit includes a designation of the lands involved and reasons for preference use rights. It is expected that this permit will be part of the Master Application process.

It is also possible that a Disturbance of Natural Material Permit would be needed from DNR if borrow materials are needed from the Chugach State Parklands. This is typically a short-term permit for small activities and may not be applicable for large-scale quarry activity.

Construction access roads and transmission lines will undoubtedly at some point encroach on existing highways for any of the sites. This action will require a Utility Permit for Encroachment Within Highway Right-of-Way. The purpose of this permit is to allow the Alaska Department of Transportation and Public Facilities (DOTPF) to maintain an accurate record of all facilities located in highway right-of-way.

A standard application form must be submitted accompanied by plans, specifications, descriptions of work, methods to be employed and other pertinent data to allow DOTPF to review the design and location of proposed facilities. DOTPF coordinates this review with that of other agencies of the Alaska State Government. This permit may be obtained as part of the Master Application process as discussed in Section 12.6.

A Right-of-Way or Easement Permit may also be required from the DNR. The permit is required for the construction of routed projects such as roads, pipelines, telephone and transmission lines. Since some of the forest or potential lands in the abutment areas are part of the state land withdrawals, this permit may be needed. The permitting process is a two-step function. The applicant submits the completed Form 10-112 to the DNR, Division of Forest, Land and Water Management. The form must include a preliminary plan. If the proposed construction is approved, a letter of entry is issued authorizing the construction. The Right-of-Way permit is not issued until construction has been completed and the as-built plans are approved by the department. The initial phase of application submission would take place under the Master Application process.

DNR has three other land use permits within its jurisdiction which may be needed, depending upon lands involved. These are Special, Conditional, and Miscellaneous Land Use Permits. These permits are typically for short-term land uses or for use of specially designated lands. The need of for these permits for the project is unknown at this time.

The ADF&G has two permitting actions regarding use of designated Game Refuge and Game Sanctuary Lands. The use of any of these lands for the project is not expectd at this time.

12.11.3 - Local Permitting

It is not expected that local permitting would play a major part in regulation of a Cook Inlet tidal plant. Permits which would be required, if any, would deal with specific parts of project such as building codes and trade licensing. Discussion with the local borough and Anchorage Municipal governments should be initiated during further study to identify jurisdictional interests.

12.12 - Fish and Wildlife Permits

As discussed in the section on FERC licensing, an extensive amount of coordination is required with the federal and state fish and wildlife agencies. In addition, several permits will be required by the Alaska Department of Fish and Game (ADF&G). These permits are for the purpose of protecting important fish and wildlife habitats.

An Anadromous Fish Protection Permit under the administration of ADF&G will be required, since the tidal project would affect the natural flow of a river that contains anadromous fish. This would be a particularly sensitive issue on the Knik Arm. The impacts are discussed in the environmental section of the report.

The application for this permit includes a completed "Waterway/Waterbody Use Request" and additional items as follows:

(a) Full plans and specifications for the proper protection of fish and game in connection with the proposed project

(b) The project schedule

(c) An outline of materials, methods and equipment

(d) A map and description of the project site.

ADF&G also regulates fishways which would be included in the project if necessary. The permit application requirements are similar to those for an Anadromous Fish Protection permit.

A third permit which may be necessary is the Critical Habitat permit. The Eagle Bay site abutment on the Goose Bay side of the inlet is very close to the designated Goose Bay Critical Habitat area. Should construction activities impact on that habitat, the permit, valid for a period of one year, would be required. The purpose of the permit is to ensure compatibility with perpetuation of fish and wildlife resources. The Critical Habitat Area permit application requirements are similar to those previously discussed. The permit is temporary with a one-year period.

12.13 - Air Quality Permits

Since the operation of a Cook Inlet project will not have a direct effect on air quality as regulated by existing programs, air quality permits will be a relatively small consideration in the overall licensing of the project.

Should on-site power from small diesels or gas turbines be necessary, a State Air Quality Permit to Operate will be necessary. The regulations governing the permit are in 18AAC 50, Air Quality Control. No air contamination emissions are allowed in the State without this permit as granted by the DEC. The permit is required for all fuel burning electric generating equipment of greater than 250 kW capacity.

Application requirements include the following:

(a) Project layout and construction

(b) Maps and aerial photographs indicating land use and zoning local to the facility

(c) An engineering report on the process causing the emission including estimated types and quantities of contaminants emitted

(d) Description of air quality control devices

(e) Effects on surrounding ambient air quality

(f) Plans for emission reduction during an air episode (not applicable).

This permit may be obtained under the Master Application process. The permit duration is specified case by case, not to exceed five years.

A permit to open burn also may be required from DEC during the construction process. As this permit has a short lead time (about five days) it will not be a critical consideration to project development.

Additionally, the Environmental Protection Agency (EPA) regulates construction and operation of air pollution sources. The Cook Inlet projects would only come under EPA jurisdiction if the construction process created 250 tons/year of emissions. Further coordination of this issue should be undertaken with Region 10 of the EPA during the feasibility studies.

12.14 - Building Permits

There may be several local building codes guarding construction of the project. These are not expected to pose any obstacle to project development. There are several state activities which are more significant.

12.14.1 - Dam Safety

The most significant state review of the structural aspects of the project will take place under the permit to construct a dam administered by DNR. The permit is required by the DNR in conjunction with the water rights permit. The purpose of the permit is to provide for a state review of the proposed structure to assure that its construction plan and design are adequate. There are apparently no public hearings associated with the permit. Since the dam associated with the project is not a high safety hazard, this review should not create any significant structral integrity issues. The permit application requires general information about the dam and the site. Also to be included are plans in sufficient detail and of sufficient scale to allow for a complete review and analysis of the project. The plans must include the following information:

(a) Plans for a gage to monitor flow released from the pool, if necessary

(b) Detailed maps of the closure/access dike site including location, sluiceway, outlet works, borings, test pits and material pits

(c) Profile of the dam axis

(d) Maximum cross section of the dam.

Since the dam construction permit is a key requirement to securing the water rights for the project, preliminary discussions should be held with DNR staff to determine the level of detail needed in the dam design data for review. These discussions should begin after alternatives for development are selected. Should the feasibility level design (adequate for FERC) be considered insufficient to issue a construction permit, the water rights permit would also be held up until sufficiently detailed design was completed and approved. This could cause a construction delay. Coordination with DNR may resolve the problem by assuring that the feasibility level of design includes adequate detail. Subsequent review of advanced project designs may be expected as a permit condition.

12.14.2 - Building Check

The Department of Public Safety (DPS) will perform a review of the buildings (other than single family residences) associated with the project to insure compliance with state fire safety regulations. There are no building permits issued by DPS; rather, the plans are approved or disapproved for occupancy or use.

To initiate review, plans and specifications must be taken or mailed to the regional office of the DPS Division/Fire Protection. There is no specified application form.

12.14.3 - Transmission Line Towers

Should any towers exceed 200 feet in height or be located within 20,000 feet of a runway, the Federal Aviation Administration must determine interference with local aircraft traffic patterns. Due to the volume of aircraft in the Anchorage area, the routing and design of transmission facilities should be coordinated with the FAA.

12.15 - Navigation

Navigable waters are under the jurisdiction of both the Army Corps of Engineers and the U.S. Coast Guard. Since all the Corps permits have been discussed in Section 12.7.1, we will look only at the role of the Coast Guard here.

The U.S. Coast Guard patrols the navigable waterways and is responsible for their safety. Lighting, marking of obstructions, coordination of traffic and construction are all under their domain. No permits should be required by the Coast Guard; however, it is important that a close working relationship be developed with them. During the actual construction phase the Captain of the Port would need to be informed of all activities so the traffic into Port could be coordinated. Certain portions of construction will require that navigation in the area be stopped. For example, when floating and anchoring the powerhouse caissons ship traffic will not be tolerable because of the impact of their wakes. It is the job of the Captain of the Port to notify the navigators and the public of such interruptions. The Coast Guard will also act as a consultant for proper lighting at the construction.

Development of the Point MacKenzie site would require much time and assistance from the Coast Guard. Construction in this area would infringe upon all navigation into the Anchorage port; navigation scheduling would be tricky and adequate lighting essential.

The Rainbow and Eagle Bay sites would not create problems of the same magnitude. These waters are classified as navigable, but few boats travel in these areas and certainly large ships would not venture close to the sites due to the shallowness of the arms at these points and the lack of a useful destination.

In any case, further studies should be coordinated with the Coast Guard Unit in Anchorage.

12.16 - Other Permits

The purpose of this section is to document briefly those permits which at this time are not expected to be a requirement for development of the project, or are of minor impact and which would be expected to be procured by specific contractors performing a job.

The following list of state permits and regulations comprises those which may appear to be applicable but, at this time, are not expected to be required or would be procured by a contractor with responsibility for the job.

(a) Public Utilities Certificate of Public Convenience and Need (Alaska Public Utilities Commission): According to AS Chapter 56, Section 44.56.090(b) the state as a developer is not subject to the jurisdiction of the PUC. Should private or utility interests develop the project, PUC approval may be necessary.

(b) Permit to Drill or Deepen (DNR): Although there will be exploratory drilling for foundation exploration at the site, this permit is intended to regulate those exploring for oil and gas.

(c) Burning Permit (DNR): This differs from similar DEC permits in that its purpose is to regulate the fire hazard rather than the air quality. The application would be made by a contractor doing the burning.

(d) Conditional Use Permits and Variances (DNR): The purpose of this permit is to allow activities that may be incompatible with State zoning requirements.

(e) State Game Sanctuary Permit (DF&G): The purpose of this permit is to ensure the protection of wildlife resources within designated State Game sanctuaries. No sanctuaries as designated at this time will be affected by the project.

(f) Permit for Oversize/Overweight Vehicles (DPS): The purpose is to regulate the movement of these vehicles to ensure the safety of the public and the integrity of the highway system. This would be the responsibility of the contractor moving the equipment.

(g) Fired and Unfired Pressure Vessels, Inspection Certificate (DOL): Inspections are made to ensure compliance with applicable standards. This would be the responsibility of an individual supplier/contractor.

(h) Prevention of Accident and Health Hazards (Inspections-DOL): The purpose of these Division of Occupational Safety and Health inspections are to ensure compliance with standards. All individual employers are compelled to comply with the standards. There are no permit requirements unless an exception from standards is needed.

(i) Water Well Authorization (DNR): The purpose is to regulate the use of abandoned oil and gas wells to be used for water supply. This is not applicable to the tidal project.

(j) Food Service Permit (DH&SS): This is a regulatory action of all food service operations to assure maintenance standards. It would be the responsibility of the individual camp suppliers to procure the permit.

(k) Surface Oiling Permit (DEC): The permit would be needed if it was proposed to oil construction roads or similar operations. Its procurement would be the responsibility of the individual contractors.

TABLE 12-1

COOK INLET TIDAL POWER
MAJOR REQUIRED PERMITS FOR PROJECT DEVELOPMENT

FEDERAL

- FERC License
- Corps of Engineers

STATE

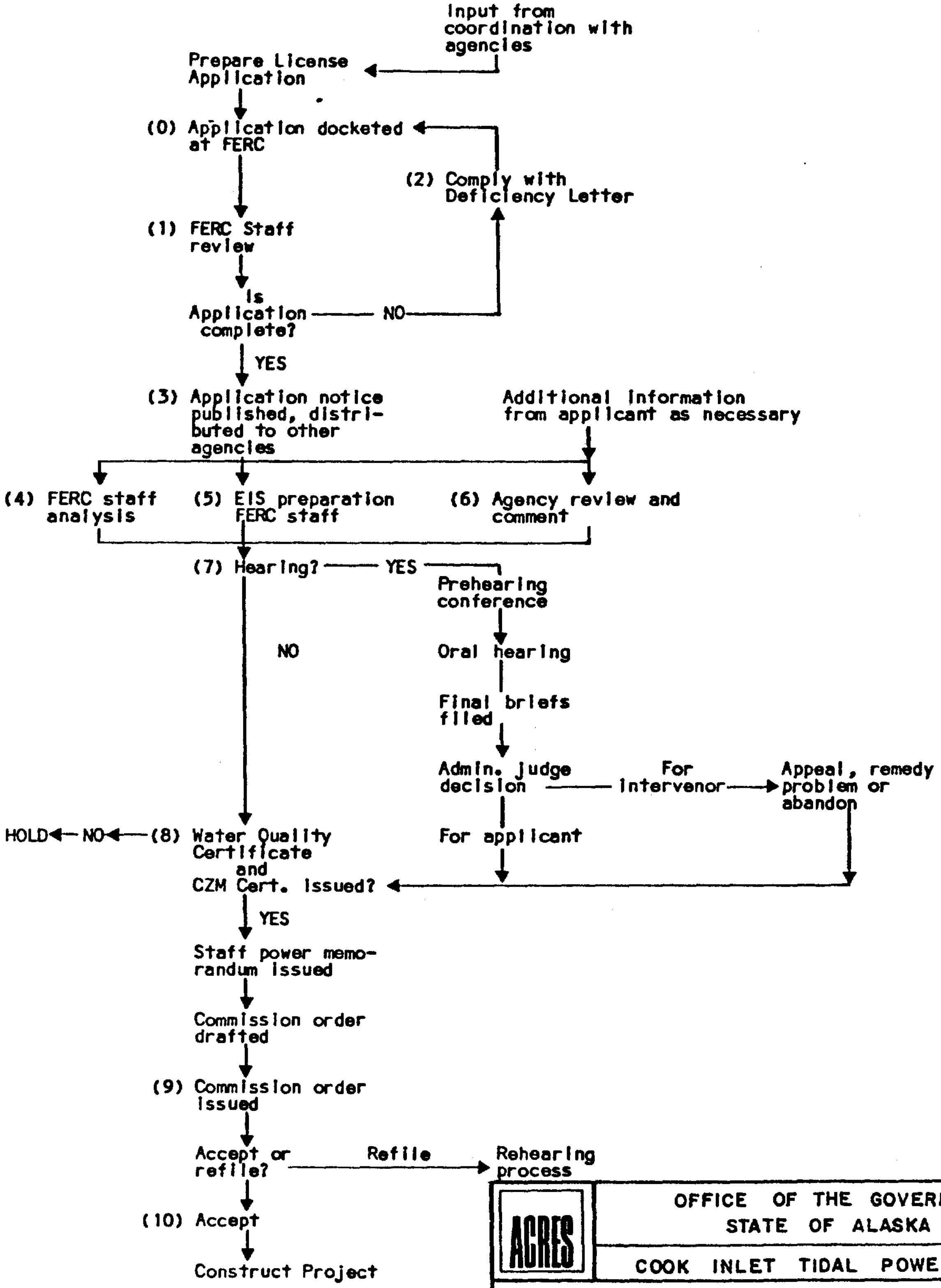
- Department of Commerce
  - Coastal Zone Certificate of Compliance
- Department of Environmental Conservation
  - Water Quality Certification
- Department of Natural Resources
  - Water Rights
  - Water Quality Certification
  - Tideland Submerged Land Use
  - Right-of-Way or Easement
  - Dam Safety
- Department of Transportation and Public Facilities
  - Encroachment with Highway Right-of-Way
- Department of Fish and Game
  - Anadromous Fish Protection
  - Critical Habitat1/
  - Fishwarp1/
- Department of Public Safety
  - Building Plan Check

1/ May not be needed at some sites

TABLE 12-2

FERC EXHIBIT CONTENTS

Exhibit	Title	Contents
A	Description of the Project	Physical descriptions of all dams, penstocks, power houses, turbines, generators, transmission lines. Identification of project lands belonging to the U.S.
B	Project Operation and Resource Utilization	Report on alternative sites. Facilities and operations considered, discussion of project optimizations, estimate of dependable capacity and average annual energy production, hydrologic (tidal) data, area-capacity data, powerplant generating characteristics, power system supply, plans for future development.
C	Construction Schedule	Commencement and completion dates of construction. Commencement of operation.
D	Costs and Financing	Estimated cost of construction, land, total costs. Estimated average annual costs of total project and financing. Sources and extent of financing. Other electric energy alternatives.
E	Environmental Report	Information must be oganized into the following eleven detailed sub-reports. (1) General description of the locale. (2) Water Quality and Use-flow Data; impacts of construction, proposed mitigation, instream flow uses, groundwater impacts, coordination. (3) Fish, Wildlife and Botanical Resources; description, expected impacts, mitigation, enhancement or protection proposed, coordination.



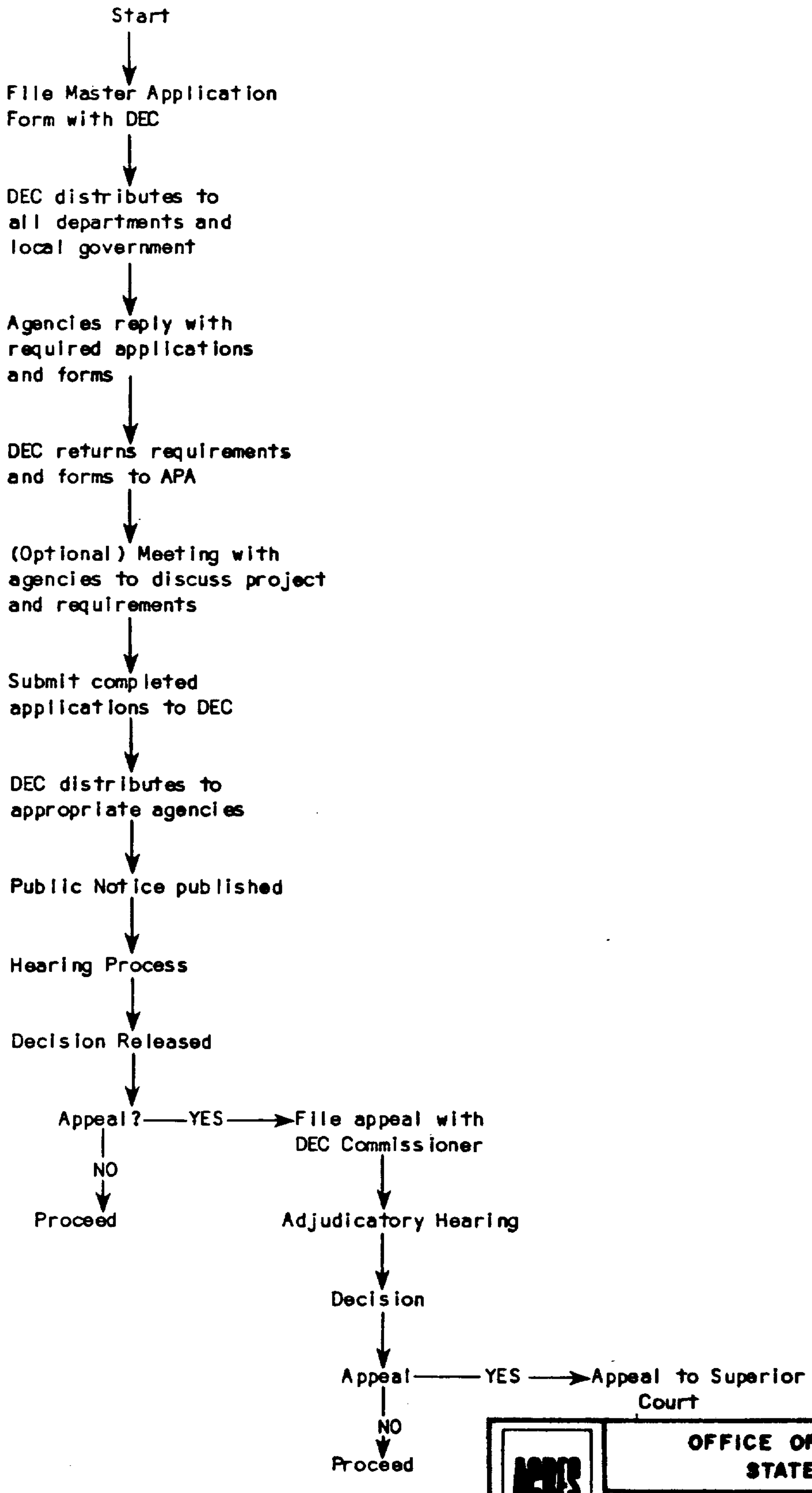
OFFICE OF THE GOVERNOR
STATE OF ALASKA

COOK INLET TIDAL POWER

FERC LICENSING

ACRES AMERICAN INCORPORATED

FIGURE 12.1



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COOK INLET TIDAL POWER

MASTER PERMIT APPLICATION PROCESS

ACRES AMERICAN INCORPORATED

FIGURE 12.2

APPENDIX 13 - SYSTEM STUDY AND ECONOMIC EVALUATION

APPENDIX 13 - SYSTEM STUDY AND ECONOMIC EVALUATION

TABLE OF CONTENTS

Page

13.1 - Objective 13-1
13.2 - Approach 13-1
13.3 - Existing Electric System 13-2
13.4 - System Compatibility 13-4
13.5 - Electrical Energy Storage 13-6
13.6 - Other System Retiming Possibilities 13-12
13.7 - Tidal Power Comparisons with Alternatives 13-15
13.8 - Project Economics 13-16
13.9 - Further Studies 13-20

LIST OF TABLES

Number	Title
13-1	Economic Evaluation Parameters
13-2	Railbelt Region Load and Energy Forecasts Used for System Studies
13-3	Cost of Energy Storage for Retiming
13-4	Levelized Cost of Power Base Load Coal-Fired Plant 200 MW Unit, First Year 1995
13-5	Cost of Power Per KWh Tidal Power Plant
13-6	Tidal Energy Costs with Retiming
13-7	Tidal Energy Costs Mills/KWh Compared with Alternative
13-8	Effect of Causeway Addition on Tidal Energy Costs

LIST OF FIGURES

Number	Title
13.1	1995 April Medium Load Forecasts
13.2	1995 August Medium Load Forecasts
13.3	1995 December Medium Load Forecasts
13.4	Eagle Bay Generation Compared to 1995 August Medium Load Forecast
13.5	Eagle Bay Generation Compared to 1995 December Medium Load Forecast

13 - SYSTEM STUDY AND ECONOMIC EVALUATION

13.1 - Objectives

To compile information regarding the existing generating system; determine the fixed and variable operating and maintenance costs of the project; review methods of retiming energy, as necessary; estimate at-site and deliverable cost of power to Railbelt customers, over the economic life of the plant; and prepare preliminary economic assessment of selected facilities.

13.2 - Approach

To fulfill the objectives, the work was divided into four sections: a system comparison, consideration of energy retiming, review of alternatives to the project, and evaluation of project economics. Due to the level of study, it was determined that for system comparison, data would be analyzed in detail on one site only with assessments of the other sites based upon the conclusions of the first analysis.

The purpose of the initial system analysis was to determine the amount of electrical energy produced by the tidal plant which would be directly usable in the electrical system. For this analysis a target year for full operation of the projects was selected. For representative months of the year, the energy output from the tidal plant was compared to chronologic hourly load forecasts to determine the percentage of directly usable tidal generated energy.

The resulting characteristics of the unusable portion of the tidal energy provide information necessary to consider alternatives for retiming the energy. Several energy retiming methods were considered and a cost estimate for retiming the energy was made, based on historical costs for electrical energy storage. Other possibilities which would not require conversion to electricity for retiming were also addressed.

Alternatives to the project, both for fuel displacement and new capacity were reviewed from the output of system studies already made by Acres American for the Susitna Hydroelectric Project. The costs of these alternatives were derived for use in estimating the value of tidal power development compared to the alternative costs of electrical energy.

The cost analyses were done, using a real cost of capital in a non-inflationary scenario of 3 percent (i.e., inflation equal to zero). This rate is consistent with the rate used in the Susitna studies and the Alaska Power Authority guidelines.

Comparisons were then made of tidal energy costs and those from alternative electrical generation sources.

In order to achieve the desirable level of consistency, the planning parameters selected for this study are identical to those used in the Susitna Hydroelectric Power Feasibility Study. The parameters include rates of escalation, cost of capital, amortization period and alternative fuel costs. These economic evaluation parameters are shown in Table 13-1.

The target year for economic analysis of the tidal plant has been selected as 1995. This year was adopted as the earliest conceivable on-line date for the project, based on a reasonable allowance of time for feasibility study, licensing, design and construction. Although selection of 1995 may lead to an optimistic development schedule, that year presents a critical point in future planning scenarios at which additional generation facilities will be needed. Should development of tidal power be delayed further into the future, other significant generating resources would need to be added to the Railbelt system.

As will be seen from schedules derived for the "most likely" case, 1997 is the earliest completion year for a project sized to meet demand without unusual industrial growth. From a conservative standpoint, it was reasoned that if a tidal plant meets demand constraints in 1995, it will more easily meet them thereafter.

13.3 - Existing Electric System

The characteristics of energy output from a tidal plant are unusual compared to conventional forms of electrical power generation. There are two primary distinguishing features, as shown in other parts of the report: the periodic nature of the power and energy output generated at the plant, and the predictability of operation, due to the unalterable pattern of the tides coupled with the dependable nature of hydraulic turbo-generating equipment. The periodic nature of the tidal plant's generation cycle and the very substantial output of energy in comparison to the Railbelt demand provides a unique problem in fitting the supply to match the pattern of the demand.

It has been estimated in previous tidal power studies that, in theory, the energy output from a tidal plant must be less than 10 percent of the total system requirements in order that it can be directly absorbed without retiming of energy. In the case of the Cook Inlet, the 2300-5000 GWh produced at the tidal power plants which have been selected for study would be as much as 40 to 80 percent of total system energy need. Thus, some type of retiming or storage is necessary if the tidal power plant output is to be absorbed effectively.

The following sections of the report discuss the energy demand and load forecasts used in the study and define the generating system as it will likely exist when tidal power from Cook Inlet could become available.

The forecasts used in the systems studies are based on Acres analysis of an energy forecast to 2010 developed by the Institute for Social and Economic Research (ISER) in Alaska. This forecast, which was made as input to the Susitna study, developed a total electrical end-use pattern for Railbelt consumers. The energy forecast provided the basis for a total electrical demand forecast, including load shapes and capacity projections made by Woodward-Clyde Consultants (WCC).

Since the energy and load forecasts developed by ISER and WCC include demand from non-system market sectors, such as industrial plants and military establishments with their own generating facilities, the forecasts were modified to exclude these loads.

Additionally, the ISER Low-Medium-High forecasts were extended to provide an even higher and even lower forecast to bracket the range of demand possibilities in the future. The modified Low-Medium-High forecasts for electrical generation in the Railbelt are shown in Table 13.2. These forecasts assume that a transmission intertie will be made between the Anchorage and Fairbanks utility systems so that economy exchange of capacity and energy can be conveniently arranged.

The medium forecast of energy demand has been used for planning purposes in this study, as it is the one considered most likely by ISER. Adoption of the higher forecast would allow for earlier absorption of the output of a tidal power plant into the interconnected system. The energy delivered would then be more of an alternative to the output from new generating capacity than displacement of relatively expensive energy from existing oil, gas, and coal burning thermal plants.

13.3.1 - Existing Generating System

System studies for the Susitna Project determined that the existing generating resources in the Railbelt include 53 units with a total capacity of 943.6 MW. The generating plant consists primarily of natural gas and oil-fired combustion turbines. Additionally, two currently planned plants are expected to be added to the system in the 1980's, one a combined-cycle unit being installed by Chugach Electric Association and the other the Bradley Lake hydropower project planned by the Corps of Engineers.

13.3.2 - System Evaluation

The Susitna system studies have concluded that, with the addition of an intertie (allowing for capacity exchange) and the planned projects identified in the previous paragraph, the Railbelt will have sufficient capacity to meet load and generating system reliability criteria under the medium load forecast well into the 1990's.

The assumption has been made that, for this study, no other capacity will be added to the system prior to the tidal power project. This assumes that should such a plant be committed to construction, existing generating capacity would be temporarily over-taxed rather than be provided with relief by other costly plants built to meet increasing loads in the early 1990's. Some relief could be afforded by staged construction of the tidal plant, with some units on line earlier than full project commissioning date.

13.4 - System Compatibility

A study has been made to determine the usefulness of the tidal plant as it might function in the Railbelt electrical system in 1995. The objective was to determine how much energy would be directly absorbed by the system and how much would be not usable or would need to be retimed to match demand.

At this level of study, it was concluded that only one of the three tidal power plant alternatives selected could be analyzed in detail and it was assumed that the conclusions could be applied to the other two. Eagle Bay on Knik Arm was selected for the detailed energy analysis as it appeared to be the most economically attractive site, based on the preliminary results of the technical evaluation.

13.4.1 - Energy and Capacity Analysis

The energy computer program developed in Subtask 2.02 provided predictions of capacity and energy applicable to the Eagle Bay Site over time for a one-month generation cycle. (As explained in Appendix 6, the 30-day run is valid to capture the variability of the tidal resource.) By comparing this output to the electrical demand over the same period, an estimate of usable energy was made.

For this analysis, chronological load curves for six daily load shapes were developed. The load shapes were representative of weekday and weekend loads in April, August and December 1995. The basic information for these curves was collected by WCC for the Susitna study from data filed with FERC by Railbelt utilities. Data for the months has never been collected and would require a significant effort, beyond the scope of these studies. The daily shapes are shown on Figures 13.1, 13.2 and 13.3.

The Railbelt peak load estimated for 1995 is 944 MW and total annual energy demand is about 5200 GWh. The potential Eagle Bay tidal plant would have an installed capacity of 1440 MW and would produce about 4000 GWh. Thus, its output when in full operation, would necessarily displace a large portion of existing generating resources, as well as postpone the need for new capacity, if energy is retimed to meet peak demand.

By processing the daily load shapes manually through the monthly power output curves for the tidal power site it was possible to estimate the amount of usable and non-usable energy throughout the three sample months. Figures 13-4 and 13-5 illustrate the superposition of the tidal plant capacity on the system load curves.

Figures 13-4 and 13-5 clearly illustrate that, in the Railbelt system, the value of the installed capacity of a tidal power plant operating strictly on tidal cycles cannot be fully realized. In order to attract a proper capacity benefit, the tidal plant will definitely need to have its energy deliveries retimed to meet system loads during the low output phases of the tidal cycle.

Even in this theoretical evaluation of the practicability of operating a tidal plant on the Railbelt system, it can be seen that the 4000 GWh from the Eagle Bay plant would not be sufficient to meet the entire energy demand or load and that some existing generating plant would still have to be operated on a regular basis. It was determined that approximately 150 MW of plant on the existing system could not be effectively cycled with the tidal plant, yet could generate inexpensive energy operating on low opportunity cost fuels, or on no fuel or at high efficiency. This capacity is made up of coal-fired steam plants, gas-fired combined cycle plants and existing hydro plants. It was therefore assumed that 150 MW capacity would operate on a baseload schedule, contributing annually 1300 GWh of the system load.

To convert the monthly results into an annual estimate, an assumption of similarity was made. It was assumed that winter months of November to February had identical load characteristics to December, summer months of July to September had identical characteristics to August and the remaining "transition" months were similar to April.

13.4.2 - Usable Energy

The energy usable in the system is defined as that portion of the tidal power plant production which falls on a time basis within system demand or under the load curve illustrated in Figures 13.4 and 13.5. The usable portion varies from about 30 percent of the total energy produced in summer months to about 35 percent in the spring and fall months and to over 50 percent in the winter months. Over all, it was found that about 1600 GWh, or 40 percent of the Eagle Bay plant total of 4000 GWh would be directly usable in the system. Obviously this portion of tidal plant energy output does not require to be retimed.

13.4.3 - Energy for Retiming

The direct system absorption of 1600 GWh of the tidal plant energy output leaves about 2400 GWh which must be retimed to be of effective use. The directly usable tidal output of 1600 GWh together with the 1300 GWh from baseload plants leaves 2200 GWh of the 5200 GWh of annual demand to be met. Thus, 2400 GWh of available energy is available to meet 2200 GWh of energy demand. It must be realized, however, that conventional electrical energy storage devices such as pumped storage impose significant losses on the retimed energy amounting perhaps to as much or more than one third. This would leave about 700 GWh of energy demand to be met by hydroelectric or standby gas turbine units which have been displaced from regular usage.

Several significant assumptions which have been made in this assessment should be clearly noted:

- Many existing generating units serving the Railbelt power needs would be operated and maintained past their normally accepted "useful life." This could result in several interim years of higher cost to consumers prior to operation of the tidal plant due to greater reliance on gas and oil. It also assumed that most of these units would be taken out of service, after commissioning the tidal project.

- Several of the generating units and plants displaced may not be fully amortized by the owner utilities by the time the tidal plant is commissioned. This could impact the rate base structure of Railbelt utilities and affect their tariffs unfavorably.

- It is assumed that the Railbelt utilities who currently generate their own power, would be called on to purchase 70-100 percent of their energy demand from the tidal power plant (augmented by other baseload supply). This transition to such an arrangement over a period of several years could cause institutional problems.

- The tidal plant is assumed to be "block loaded" into the system in 1995. In actual fact, the plant would likely be phased into operation over a period of several years, which could be expected to mitigate the above problems.

13.5 - Electrical Energy Storage

In Section 13.3 it was shown that, on an average, a tidal power generation system operates at a capacity factor of about 30 - 35 percent. If the system to which the plant supplies energy is relatively small, as is the case of substantial tidal power plant addition to the Railbelt, the impact of reliance on tidal energy supply can be considerable. The intermittent phased pulses of tidal power output will require other generating plants on the system to balance the supply and load demand with a varying or cycling operation. This type of operation would inevitably result in shortened plant life for coal- and gas-fired plants due to the adverse effect of thermal stresses during repeated start ups and shut downs. Cyclical loading of generator and other electric equipment may also be expected to have adverse effects.

It should be noted, however, that the generating plant most commonly used on the Railbelt system, i.e., gas-fired combustion turbines, is more capable of cycling operation than that used for base and intermediate load generation over most utility systems.

The alternative to balancing tidal power output with cycling of other generation units is to install an energy storage system designed to balance the tidal fluctuations and provide a load-following power supply source. In all probability the optimum arrangement will involve both cycling of other plant and energy storage.

13.5.1 - Potential for Retiming Energy Delivered to System

It is possible to devise tidal power plant configurations, plant designs and modes of operation which allow energy outputs to be scheduled to meet system needs more precisely and to have a degree of firm capacity. Prior studies have generally concluded, however, that single ebb tide generation is usually most cost effective and that retiming should be accomplished externally on the system being supplied.

Large scale retiming of electricity can be achieved with available technologies which have been proved over many years of operation. In order to meet the balancing needs of a tidal power plant the storage system and associated charging and generation equipment have to be capable of rapid response to meet the variations in both energy supply and the demands of the utility consumers. Most energy storage plants are designed for between 5 and 30 hours of storage and require to be capable of switching from full charging to full generation in a matter of minutes. The storage system should also be sufficiently flexible to allow a wide range of regulatable output when generating and sufficient step loading during the charging cycle. It sould also have the ability to change load at as rapid a rate as necessary to act in harmony with other generating units supplying the system.

From the system study, it appears that for retiming the Eagle Bay site, a capacity of up to 1200 MW would be necessary to absorb tidal power output in the storage cycle. Interestingly, only one half of that capacity would be needed for the generation cycle when the retimed energy would be fed into the system. This is due to the fact that the tidal project capacity is large compared to the Railbelt load. It was also estimated from an energy/supply/balance that energy storage of about 20 hours at full load generation from the storage plants would be desirable.

The efficiency of energy storage has substantial impact on the economics of an electrical supply system. Commercially acceptable modes of storage systems operate up to 76 percent efficiency (energy output divided by energy input).

The loss is compensated in economic (and revenue) terms by the transfer of energy available at the time that it could be excess to system requirements to a time when the energy has high value in contributing to load demand. Systems with substantial amounts of low cost energy available at periods when demand is low can benefit appreciably from a storage facility. With a tidal power plant of a capacity which is large in comparison to the system, retiming or storage is almost essential.

13.5.2 - Alternative Concepts for System Retiming

(1) Pumped Storage

Only one energy storage system has been accepted and widely implemented by U.S. electric utilities-hydroelectric pumped storage. About 40 plants are in operation or under construction with installed capacities ranging from 30 MW to 2000 MW. Pumped storage is achieved by pumping water from a lower reservoir to a higher elevation for storage during off-peak periods. During peak load periods, the water is made to flow back to the lower reservoir through turbines to generate power.

Modern installations usually are based on pump/turbine units which can operate in either direction and which are directly connected to reversible motor generators. Capital cost of a pumped storage plant is heavily dependent on operating head and the construction problems associated with operation of the two reservoirs required. Recent environmental limitations have curtailed the number of acceptable sites for pumped storage plants with the result that electric utilities have actively sought feasible alternative systems.

It does appear however, that with the proximity of mountainous terrain around Cook Inlet, that there should be several sites with high head and good development potential, possibly using Cook Inlet as an afterbay. A siting study would be required to identify these.

(2) Underground Pumped Storage

One possible alternative to pumped storage with reservoir sites dependent on topographic feataures is the construction of a man-made lower reservoir underground at a depth below the surface selected to minimize overall plant costs. The concept is heavily dependent on good geological conditions at depth. If these do exist, siting problems are greatly reduced as the surface reservoir can either be a man-made reservoir on flat land or a natural water body (such as Cook Inlet). Furthermore, site selection close to the load center or to a major transmission line, results in cost savings and avoidance of environmental impact on wild, scenic or sensitive areas.

Applicability of this alternative to the needs of a tidal power plant and the Railbelt would depend on geological conditions at depth in the region.

(3) Compressed Air Energy Storage

The principle of compressing air and the generation of shaft power by firing fuel into the compressed medium is employed in most internal combustion engines and gas turbines. If the air can be compressed by off-peak power, stored and later released for power generation with fuel injection during peak periods, a productive energy storage system is created. In 1977 a utility in Huntorf, West Germany, commissioned the first plant of this type. The plant has a generating capacity of 290 MW and storage capability of 2 hours at full load. The compressing time required to pump the storage caverns to maximum pressure is 8 hours. At the Huntorf plant the two air storage caverns were created in a salt dome by solution mining.

This first-of-a-kind plant has triggered strong interest in compressed air energy storage (CAES) and many deriviations of the Huntorf design have been proposed including:

- recovery of exhaust heat from the stored air prior to storage
- coal firing by pressurized fluidized bed burning of the fuel
- coal firing by coal gasification
- storage of air in caverns excavated in rock
- storage of air in abandoned mines
- use of water compensation to maintain cavern air pressure
- storage of air in porous media (aquifer)
- adiabatic (no fuel) operation, where the heat of compression is stored and returned to the air flow during generation
- utilization of compression heat for district heating or industrial process.

Most of the CAES variants exhibit favorable electric energy output/input ratios; that is, more electric energy is generated in the form of off-peak power than supplied to storage. The difference is contributed by the fuel burned during the generating cycle. The siting of a CAES plant is limited by availability of a suitable geologic medium at depth. As in the case of underground pumped storage, applicability to Cook Inlet tidal power retiming could only be determined when subsurface conditions have been properly evaluated.

(4) Batteries

Electro-chemical systems are currently widely used for relatively small energy storage applications, such as transportation, switchgear operation, emergency power, lighting and other traditional uses. When considered for large-scale energy storage, batteries are found to have relatively low storage efficiency and high capital cost.

Development work to improve the storage efficiency and cost per kWh is progressing but the ultimate use of batteries will probably be confined to local substations and transport.

(5) Retiming at Site

A certain amount of energy retiming can be achieved by use of double effect turbines, or twin tidal power plants linked electrically, such as at Rainbow and Eagle Bay. Neither of these allow the generation of firm power which means a significant investment in off-site energy storage or retiming facilities.

By means of a double-basin scheme linked hydraulically it is possible to achieve a small amount of firm power, or rather more dependable peak capacity.

The most likely site with an appropriate configuration of bathymetry for a double-basin scheme is at Fire Island with barriers across Knik and Turnagain Arms. Optimum installed capacity at that location is likely to be about 4000 MW with annual energy production of about 16,000 GWH. This is obviously too large for consideration in the present studies, and since the parametric comparison has already indicated energy costs well in excess of those predicted for Eagle Bay, it has not been considered further.

Construction of a double-basin scheme at Eagle Bay will obviously require a lot more dike than the single-basin scheme. Preliminary calculation based on gross extrapolations from double-basin studies for the Bay of Fundy suggest that the energy available from a double-basin scheme at Eagle Bay will be reduce to about 2700 GWH/year with an installed capacity of about 600 MW giving a "dependable peaking capacity" (95 percent reliable) of about 400 MW.

Energy costs would be of the order of 100 mills/kWH. Assuming that no excess energy needs retiming firm power obtained from the double-basin scheme is likely to be considerably less than the dependable peaking capacity.

Table 13-3 supplies estimates of the types of energy storage discussed. For simplicity in presentation and due to the presence of potential sites, pumped storage has been used to estimate the costs of retiming energy. Further study should be done prior to rejecting any type of energy storage.

13.5.3 - Characteristics of Retiming Needs

Either compressed air or pumped storage energy storage systems can be suitably adapted to meet the retiming needs of a Cook Inlet tidal power plant. The present level of study has dealt only with generation/storage needs in a general sense. In view of the several cyclical influences of the tides on power and energy output (daily, monthly, seasonal, annual, etc.) a rigorous examination will be necessary of power plant, storage facility and system interaction on a yearly basis.

In considering the relative merits of one storage system to another it should be noted that pumped storage and the non-fueled adiabatic compressed air storage systems have turnaround losses of about 25 percent and thus less energy is returned to the system, cycle by cycle, than is taken from the tidal power plant. The fueled compressed air energy storage system adds energy in the form of gas or oil and can deliver 1.4 times the energy taken from the tidal power plant. This ability may have particular significance when retiming a tidal power plant as it can be used to partially offset shortfall in energy output during low tide phases.

A further important consideration involves the ratios between charging and generating power capacities and the time duration of these two cycles. It has been noted that where the tidal power plant capacity is large in relation to the system the retiming cycle is used to "spread" the energy output over a time significantly longer than the generating cycle which is tide dependent. From the generalized overview of storage/retiming needs made at this point of study it appears that pumping capacity may have to be twice that of generation with the latter cycle being correspondingly lengthened as required by tidal conditions and system used.

With a fueled compressed air energy storage plant, capacity requirements may lead to installation of a bank of motor driven compressors with no turbine generation capability in addition to the dual function machines which could adequately meet system needs with their 1.4 output/input characteristics. This consideration has a substantial bearing on a retiming concept described in the following section under "Other System Retiming Possibilities."

13.6 - Other System Retiming Possibilities

In this preliminary study it is appropriate to base findings on established technology and practice. However, in view of some special features of tidal power development prospects in Cook Inlet, certain alternative concepts are recorded here as providing other system retiming possibilities.

13.6.1 - Direct Compression by Tidal Turbines

In 1971 studies of tidal power potential in the Bay of Fundy, Acres proposed an arrangement with air compressors directly driven by tidal power water turbines. The compressed air was to be stored in the same manner as for the energy storage systems described in 13.5.2 - 3 and used to power, with added fuel, combustion turbine generators.

Application of this concept to Cook Inlet would require equipping tidal power turbines of 20 to 40 MW capacity at about 50 rpm with compressors directly driven through speed increasers. Various arrangements may be considered with a single turbine driving low, intermediate, and high pressure compressor units or with a bank of three turbines each driving a single compressor stage. Although the original direct driven air compressor arrangement was developed on the basis of a slant axis tube type tidal turbine (as proposed in U.S. Corps of Engineers studies of Passamaquoddy), the concept is applicable to bulb type turbines with step-up planetary gears housed in the bulb and to Straflo machines with the generator rotor replaced by a large gear wheel. In order to accommodate torque and output reduction as the tidal head falls during the cycle, paired compressor units have been proposed. The two units would match the higher tidal power output; a single unit only would operate at the lower head phase of the cycle.

In all probability a tidal power plant equipped for direct air compression would also have a proportion of its installed capacity driving generators directly supplying the system without storage.

The compression cycle develops substantial heat losses which must be removed for efficient operation and storage by means of intercoolers and aftercoolers transferring the heat to water as a cooling medium.

13.6.2 - Combination Compressed Air Retiming and District Heating

The useful heat energy available from the intercoolers and aftercoolers of a compressor train amounts to about 60 percent of the heat equivalent of the compressor shaft power. Therefore for every 100 MWh of energy used for compression about 200 million Btu's would be available for district heating and/or industrial process heating. Since with the tidal power plant as proposed compression power is only available in phase with the tides, a thermal storage facility would be necessary to provide a continuous supply.

Most district or facility heating systems in the U.S. utilize steam as the heat fluid. Various pressures are employed - 250 psig in Washington, D.C.; 50 psig in Fairbanks and 90 psig at Fort Wainwright. However, experience in Europe since the 1950's indicates that hot water (as would be produced by the intercoolers and aftercoolers) is a superior fluid for the following reasons:

(a) Less corrosion and maintenance problems.

(b) Heat can be distributed at lower temperatures with consequently lower losses.

(c) Heat can be transmitted greater distances for the same cost.

(d) The higher heat capacity of water means smaller diameter pipes and less expensive distribution systems.

(e) Hot water provides a simpler system distribution.

(f) Hot water is an ideal fluid for extraction of heat from compressor air coolers due to its high heat transmission characteristics and high specific heat.

(g) System heat storage can be achieved in semi-buried water tanks located at strategic points and backed up by peak load and emergency boiler plants.

The economic transmission distance for hot water varies with the scale of the district heating facility, but 10 to 15 miles should be economic for a system matched to a tidal power plant on Cook Inlet. The selected sites are reasonably well placed in relation to Anchorage to justify consideration of a "cogeneration" application of tidal power and district heating. It will be appreciated that either the direct driven compressor concept or the electrically linked compressed air energy storage offers the benefit of heat extraction from intercooler/aftercooler flows.

13.6.3 - Fuels

Compressed air energy storage enhances the capacity of a tidal plant by increasing the energy available through the use of fuel--probably distillate oil or natural gas. These fuels may be scarce and high priced by the time the tidal plant is in operation and for this reason alternative fuels should be considered.

Several studies have been performed to determine the feasibility of coal-fired compressed air energy storage systems. Concepts have included atmospheric and pressurized fluidized bed firing, and coal gasification. The feasibiity of all concepts suffer from the lack of user experience with conventional gas turbines fired with coal conversion systems. Until planned demonstration facilities (such as the Southern California Edison Cool Water project) are in operation, no firm position regarding coal-fired compressed air energy storage can be taken. However, within the next 5 years experience data should be available and more objective comparisons may then be made.

13.6.4 - Hydrogen Production

Of the chemical energy storage systems other than batteries (i.e., systems that store energy in the chemical potential of compounds) hydrogen energy has received the most attention. The basic system entails the production of hydrogen, storage under pressure or in liquid form, and recovery of the stored hydrogen for conversion to electricity during peak loads. Several approaches are possible for each stage of the hydrogen energy storage system.

The combination of subsystems which appears to lead to the lowest estimated capital costs and highest turnaround efficiencies for a hydrogen-based energy storage system are (a) electrolysis of water, (b) storage of compressed gas, and (c) use of hydrogen in a fuel cell or in a combined-cycle plant for electricity generation.

The electrolysis of water to produce hydrogen and oxygen is an industrially mature and commercially feasible process available for hydrogen production. This is the process that would be generally used in areas where low-cost electricity is available.

Hydrogen can be stored in four basic ways: as a compressed gas contained in fabricated vessels, as a cryogenic liquid in highly insulated containers or in a metal hydride, and as a compressed gas in underground storage reservoirs of both natural and man-made types. The first two of these, compressed hydrogen vessel and cryogenic liquid vessel storage, are presently in commercial use, with the former most practical for projected electric load leveling applications. The major disadvantages of high pressure storage are the cost of the pressure vessels and the compressors, and unresolved questions concerning hydrogen embrittlement and fatigue cracking due to cyclic thermal and mechanical stresses as the storage vessel is regularly filled and emptied.

Conversion of hydrogen to electric energy can be done either in fuel cells or in combustion devices (such as a boiler in a steam plant or a gas turbine). The fuel cell approach offers potential for high efficiency and low air emissions. However, no commercial fuel cell technology is yet available.

The gas turbine would be readily adaptable to operation on hydrogen, but overall system efficiency would be relatively low. In addition to electrical utility load-leveling, other potential end uses for hydrogen include vehicle transportation, chemical feedstocks, and supplementation to natural gas fuel.

In general, the projected costs of a hydrogen/electrical conversion system for use as a load leveling device prohibits system implementation in the short-term future. In the case of fuel cell electricity generation, the concept is only technically viable pending the development of a commercial fuel cell. Until the performance characteristics and costs of commercial electrolyzers and fuel cells are better known, the economics of hydrogen electric energy storage appears marginal at current fuel prices, and given the status of competing energy storage technologies such as pumped storage, either surface or underground, compressed air energy storage, and batteries. It is anticipated that initial introduction of utility generated hydrogen will be in the non-electric sectors first with electric generation via hydrogen occurring at a later date.

13.7 - Tidal Power Comparisons with Alternatives

Implementation of the tidal project of 2000-4000 GWh in the mid-1990's would have a major impact on the way the Railbelt electrical supply system would operate. A project of this magnitude producing energy without firm capacity would have a marked effect both on the way in which existing plant would be used and the need for other generating resources.

If the project were added without retiming of energy, there would be simply a saving in fuels resulting from a decreased use of existing plant. Estimates previously discussed indicate that 40 - 50 percent of the tidal power production could be directly used in this manner. It should be noted, however, that the severe cycling of the other units, off-to-full load and off again, twice a day every day would probably result in severe equipment problems, particularly in the relatively cold operating climate. Although this type of operation theoretically sounds plausible, practically it is not likely to be acceptable.

It is possible to design new generating resources around operation of the tidal plant, but the need for capacity to meet increased loads would be the same as without the tidal plant. Instead of a large base load facility to meet needs, the new capacity would need to have a cycling capability, such as a gas turbine or large capacity hydroelectric plant with adequate storage.

System studies for the Susitna project were performed with parameters set in Table 13-1 of this appendix and project the "running rate" for a non-Susitna 1995 Railbelt system to be at about 35 mills/kWh. This total includes the incremental fuel and costs of operating the plants to meet system demands. The approximate value of the tidal plant output without retiming would approximate this value of 35 mills/kWh or match the savings in not operating other plants.

If the energy were retimed, with the storage system designed to handle the needed cycling, the project would take on a role of providing dependable capacity as well as becoming the primary source of energy for the system. This scenario would allow the tidal plant to displace the more expensive energy producing units which would be dispatched to meet load and offset the need for additional capacity. Again, using the output from Susitna studies, it is estimated that the value of energy with dependable power which would be displaced by the tidal power plant is 47 mills/kWh. This estimate was made by removing from the previously mentioned total rate of 35 mills/kwh the component due to efficient baseload units, which would continue to operate.

Additionally, the project would offset the need for other new capacity. As identified in the Susitna studies, the non-Susitna system alternative would likely be a coal-fired plant. Using the parameters discussed in Section 1 and the costs developed in the Susitna study, Table 13-4 provides estimated costs for a coal plant (i.e. 3 percent cost of money.) The coal-fired generating plant would include 200 MW units, and be located in an area to use the Beluga coal. The total rate for new coal capacity is about 44 mills/kWh, (including capital charges based on 3 percent money). This cost is levelized for the project life, with zero general escalation and 1.5 percent annual escalation of coal prices.

It should be noted that the coal-fired plant costs reflect the assumption of commercial development of the Beluga fields for a large export market. Should this market not develop, higher costs would be associated with energy supplied from the coal-fired alternative, either at Beluga or another site, say in the Healy area.

It is reasonable then to attribute to the output of the tidal power plant with retimed energy deliveries, a value in the range of 44 mills/kWh.

13.8 - Project Economics

Based on the costs estimated in other sections of the report, the economics of the project have been assessed. It should be noted that demonstrating the true value of output from the tidal power plant would be an extremely complex study, requiring the aid of a system model as well as detailed information on potential retiming schemes. The following estimates approximate the costs and values based on a mid 1990's date of initial project operation. General inflation is neglected in the study, but incremental fuel escalation is taken into consideration. Cost of capital has been taken as 3 percent.

13.8.1 - Cost of Power

Table 13-5 provides the total costs in mills/kWh calculated for each of the three sites studied. These are purely production costs, regardless of the need for the energy. These costs contain an allowance for amortization based on a 50-year project life. Insurance rates are consistent with those used for hydroelectric plants.

Operation and maintenance costs have been estimated as being fixed (.60) at an annual percentage of the original project investment cost. A similiar estimate for O & M was used in the Bay of Fundy studies. Calculated O & M for the LaRance plant is about .50 percent of total costs, on an annual basis.

An allowance for engineering, project management and owners costs has been included at 12.5 percent. A contingency allowance of 25 percent has been made which should be compared with 20 percent used for the Susitna evaluations. The larger unknowns associated with this level of study for a tidal plant justify the higher contingency. Interest during construction was calculated based on a 3 percent rate with investment weighted towards the early years of the scheduled 8 years to power.

The costs should also be considered in light of what could contribute usefully to the system. Studies of the Eagle Bay site indicated that approximately 40 percent of the energy would be directly usable in 1995. This amount is probably an optimistic estimate, due to some assumptions necessary in developing the estimate. The major inaccuracy may be in assuming that, in an un-retimed situation, the existing and added generating plants could effectively and efficiently cycle in harmony with the generation output of the tidal plant. The same usable energy estimate can be extended to the Point MacKenzie site, based on a review of the production curves developed in Subtask 2.02. For the Rainbow site, the estimate of usable energy may be increased to about 50 percent, this being justified by the smaller capacity of the site fitting a higher proportion of energy demand area.

If the value of the unretimed and directly unusable energy is zero, the cost of the usable energy goes up by a factor of 2.5 at Eagle Bay and Point MacKenzie and 2 at Rainbow. Thus the cost for usable kWh to the system, is 121 mills/kWh at Eagle Bay, 133 mills/kWh at Point MacKenzie and 105 at Rainbow. This condition indicates that for an un-retimed project, the project tidal power plant should be of smaller size. It will also be seen that it is more cost effective to retime the energy than to allow it to go unused.

13.8.2 - Cost of Retimed Energy

Study indicates that in the absence of industrial demand for low cost intermittent energy, retiming will be necessary to make the major portion of energy produced by the tidal power plant useful to the system. As discussed in Section 13.4, there are many variables and issues which need to be addressed prior to selection and assessment of a storage system. For the purposes of this study, it is assumed that this will be conventional hydroelectric pumped storage at a site in the upper Cook Inlet region. The pumped storage efficiency has been conservatively estimated at 67 percent (i.e., two kWh returned for three put in.)

It has been estimated that 1200 MW of pumped storage capacity would be needed to store all the excess energy from Eagle Bay as from time to time this would be the tidal power output surplus to system requirements. However, only about 600 MW of generation output would be needed to be used to retime the energy. This does not lead to any significant savings in cost as there is little difference between pumps and reversible pump turbines.

As the system studies which estimated usable and unusable energy and storage needs were based on the Eagle Bay site, it was necessary to make estimates for the other sites. While many of the characteristics of the storage system remained the same, it was evident that less storage was needed at Point MacKenzie or at Rainbow.

Extrapolating the 1200 MW capacity determined for the Eagle Bay site, it is estimated that Point MacKenzie would need to have 1000 MW of storage and the Rainbow site 700 MW. Table 13-6 shows the increase in the cost of energy resulting from the retiming.

13.8.3 - Comparison with an Alternative Coal Fired Power Plant

Table 13-7 summarizes the cost of power at the three selected sites as compared with an alternative coal-fired power plant and with the avoided costs applicable to existing capacity.

It will be seen that the full output of energy from a tidal plant in a raw or unretimed state is competitive with the cost of new alternative forms of generation, although more expensive than the aggregate of existing capacity. When system considerations are taken into account and the usable energy only is considered, the cost of tidal power substanitally exceeds that of the alternatives. When the energy is retimed into the system, it appears to be about 50 percent more expensive than the energy it would displace.

In making these comparisons it should be made clear that they are in economic terms. The cost of capital of 3 percent and a zero rate of inflation used in the study minimizes the estimated cost of power. If the cost of capital was 10 percent, the levelized alternative costs of energy produced in a new coal-fired plant would rise to about 80-85 mills/kWh while the tidal plant costs without retiming would be of the order of 100-110 mills. The costs of retimed tidal energy would increase to about 170 mills/kWh or over 2 times the cost of energy from the coal plant alternative.

13.8.4 - Effects of Addition of Causeway on Power Costs

A further economic analysis was performed using capital costs for the tidal plant with due allowance for combination with a causeway project. The purpose of this calculation was to estimate the incremental cost of power, from a causeway superimposed on a tidal power plant. To make this estimate, the costs of the tidal plant and the incremental cost of a facility required for a causeway were summed. From this total, the costs of a separate causeway crossing were subtracted. The separate causeway costs were estimated by updating costs from previous studies at similar crossing sites. The results are shown in Table 13-8. This analysis established that from 5 - 10 percent could be saved on the cost of tidal power, depending on the site.

13.8.5 - Effect of Higher Load Forecast

The primary analysis for this study has been carried out on the basis of the medium forecast of the ISER study. Should a higher rate of growth occur, the considerations of tidal power as a component of future systems generation would be different. Of primary importance is the issue of whether the Railbelt system, with the addition of an intertie, could "struggle through" to 1995 with no system additions. The system would need significant additional generating capacity, on the order of 250-400 MW, prior to the commissioning of the tidal project in 1995.

If the added capacity were baseload coal-fired units, considered the least expensive thermal alternative, no change in cycling capacity would occur. As previously discussed, then the tidal plant, when it came on line would have the same amount of usable and unusable energy as in the treatment already applied using the medium load forecast. However, if this new capacity were planned for cycling compatibility with the tidal plant, a higher percentage of the tidal energy (perhaps up to two-thirds) could be directly usable. A higher growth pattern would also allow for further absorption of the unused tidal energy, potentially making retiming unnecessary. One method of matching the cycling energy would be through the use of small to medium sized hydro plants with storage in their headponds or reservoirs. These could operate as baseload plants until the time the tidal plant came on line. Once tidal power was added to the system the hydro plant's installed capacity could be increased to permit cycling of the units to match the output of the tidal plant.

Potentially, the tidal plant could operate quite compatibly with a major hydroelectric plant of similar capacity, such as an element of the Susitna Project. However, in the absence of major industrialization, the large amount of energy provided by these two developments together would not be needed until after the turn of the century, even under high load forecasts.

13.8.6 - Implications of a Smaller Scale Tidal Project

The system and economic study results presented have indicated that given either the high cost penalty arising from the need to retime energy or the large amount of unusable energy, a smaller tidal power plant may be more acceptable. Although the actual unit production costs of a smaller project may be higher, the economics of the entire project may be more favorable when viewed in a system context.

For this reason, a smaller development at Eagle Bay site was selected for studies. This development would have 720 MW of installed capacity consisting of only 30 powerhouse units (26 sluices) and producing 2300 GWh annual energy output. Total investment costs for this development were estimated at $2,901,000,000 (January 1982, price level). With annual costs equal to 4.59 percent of investment costs (as shown in Table 13-5), the production cost of power is 57.8 mills/kWh. This cost is about 20 percent higher than the cost of energy from the larger Eagle Bay development.

A system study identical in methodology to that of Section 13.4 of this appendix was carried out on the basis of the 720 MW project. It was found that about two-thirds of the energy produced was directly usable in the system, resulting in an un-retimed cost for the tidal project energy of 86.8 mills/kWh. This value compares favorably with that of the larger projects with their significant amounts of unusable energy.

The smaller project also allows for a much smaller amount of retiming to make the tidal energy fully usable. It is estimated that 450 MW of capacity would be needed to retime the energy from the project. It should be noted that the retiming capability is much more important in the summer than in the winter where about 85 percent of the tidal energy would be directly usable as produced.

The savings, arising from dual use of the causeway with a transportation crossing, have a higher impact on the smaller sized project due to the larger percentage of total costs charged to the secondary use. Using the methodology set out as in Table 13-8, the added costs to the tidal project are $28 million while the share of the cost equivalent to the estimated crossing investment is $365 million. The net tidal power capital cost would be $2,551,000,000. This cost relates to an energy production cost without retiming of 50.9 mills, i.e., a saving of 12 percent over that from a single purpose tidal project.

In general, the economics of partial site development were less favorable than expected. Although there were savings in energy costs if excess energy is not used or retimed, there is a corresponding penalty to partial development in pure production costs. The actual market for the power to be considered in Phase II will provide important input to settling sizing questions. Smaller developments at alternative sites within the Cook Inlet area were not reconsidered in the economic analysis for the same reasons that they were rejected in site selection; namely, loss of economy of scale, technical infeasibility, and remoteness of site relative to project site.

13.9 - Further Studies

The brief system study and economic analysis carried out in this Phase I task have been limited in detail commensurate with the overall level and scope of the assignment. It will be readily seen that the many simplifying assumptions made to estimate the value and predict the mode of operation of a large tidal project in the system will need to be reviewed and strengthened in later phases of work.

To allow a better estimate of the benefits of the tidal plant a system simulation and production cost model should be used. Although there are numerous models available, it does not appear that in their present form any would handle properly predictable yet irregular energy production of a tidal plant. It would therefore be necessary to modify an existing model somewhat for this purpose.

It is also clear that detailed investigation into suitable sites for energy storage is necessary. It is readily seen that the tidal project will need to incorporate a significant retiming system if its output is to be absorbed into the Railbelt electrical system. This study would identify the proper type of storage and would also select potential sites as well as develop a preliminary design.

Finally, the system and storage studies would need to be combined to optimize the tidal power project components on a cost basis. The optimization process should take into account the size versus cost relationships, size versus storage needed, cost of storage, value of energy without retiming and variable load forecasting. The analysis may be best handled by constructing a linear optimization program, once adequate information to provide reliable input has been developed. The complexity of tidal power plant output and operation with a relatively small system will demand most careful study.

TABLE 13-1

ECONOMIC EVALUATION PARAMETERS

Fuel Prices - Base Period:		January 1981
Natural Gas[1]		$2.32/MMBtu
Coal[2]		$1.19/MMBtu
Oil[2]		$4.62/MMBtu
General Price Inflation (Percent)		
Discount & Capital Rates Per Year		3.0
Energy Price Escalation Per Year		
Natural Gas	1981-2005	4.0
	2006-2010	0
Coal[3]	1981-2005	1.5, 3.0
	2006-2010	0
Oil	1981-2005	3.5
	2006-2010	0
Economic Life (Years)		
Steam Turbine		30
Hydroelectric Plant		50
Diesel and Gas Turbine (gas-fired)		30
Tidal Power Plant		50
Energy Storage		50

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[1] These are based on the values used for planning in the Susitna Hydroelectric Power Study, increased by the amount of escalation from 1980 to 1981.

[2] Based on Comment Draft Working Paper 1.2 "Alaska Coal Future Availability and Price Forecasts," May 1981.

[3] The escalation rate of 1.5 percent was chosen for base case analysis for consistency with the ongoing alternatives study being conducted by Battelle. A 3 percent rate was also tested to determine the sensitivity of results to fuel escalation.

TABLE 13-2

RAILBELT REGION LOAD AND ENERGY FORECASTS USED FOR SYSTEM STUDIES

	GROWTH LOAD CASE								
	Low			Medium			High		
Year	MW	GWh	Load Factor	MW	GWh	Load Factor	MW	GWh	Load Factor
1980	510	2790	62.4	510	2790	62.4	510	2790	62.4
1985	580	3160	62.4	650	3570	62.6	695	3860	63.4
1990	640	3505	62.4	735	4030	62.6	920	5090	63.1
1995	795	4350	62.3	945	5170	62.5	1295	7120	62.8
2000	950	5210	62.3	1175	6430	62.4	1670	9170	62.6
2005	1045	5700	62.3	1380	7530	62.3	2285	12540	62.6
2010	1140	6220	62.3	1635	8940	62.4	2900	15930	62.7

Source: ISER forecasts of Electrical Energy Demand in the Railbelt region of Alaska 1980, modified to exclude military establishment and industrial demand met with separate generating plants.

TABLE 13-3

COST OF ENERGY STORAGE FOR RETIMING

Storage Alternative Characteristics	Pumped Storage	UPH	Fueled CAES*	Adiabatic CAES*
Pumping capacity MW	1200	1200	800	1200
Generating capacity MW	600	600	600	600
Storage MWh	12000	12000	12000	12000
Period of generation output (at full load) hours	20	20	20	20
Period of full load pumping hours	6.6	6.6	5.35	6.9
Direct cost$/kW Based on pumping capacity	400	720	500	720
Eng., Proj. Mgt. 12.5%	50	90	63	90
Subtotal	450	810	563	810
Contingency 25%	113	203	141	203
Project cost$/kW	563	1013	703	1013
Interest during construction $/kW	51	101	70	101
Total cost $/kW	614	1114	773	1114
Total Cost adjusted for Alaska Factor (1.5)$/kW	760	1671	1125	1671
Rounded $/kW of pumping capacity	760	1700	1100	1700
TOTAL COST - Millions $	912	2040	880	2040

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* Compressed air energy storage plant.

TABLE 13-4

LEVELIZED COST OF POWER BASE LOAD COAL-FIRED PLANT

200 MW Unit, First Year 1995

Fixed		Variable	
Unit Capital Cost[1] (1980-$)	$2,100/kW	Heat Rate = 10,500 Btu/kWh	
Unit Capital Cost[2] (1982-$)	$2,505/kW	Fuel Cost (1980-$)[6]	$1.10 MMBtu
Transmission Cost[3]	$ 143/kW	Fuel Cost (1982-$)[2]	$1.31 MMBtu
Subtotal	$2,648/kW	Fuel Cost (1995-$)[7]	$1.64 MMBtu
Allowance for Funds During Construction (3%, 6 years, 9.32%)	247	Levelized Fuel Cost Project Life 30 Years	= $2.00 MMBtu
	$2,895/kW		
Fixed Charge Rate[4]	0.0535	Fuel Cost	= 21.0 mills
		Variable Cost	= 2.0 mills
			23.0 mills
Annual Investment Cost	$ 155/kW		
Fixed O & M	1		
	156/kW		

Fixed Energy Cost[5] $\frac{\$156}{7358} = 21.2$ mills/kWh

TOTAL COST = Fixed + Variable = 21.2 mills/kWh + 23.0 mills = 44.2 mills
Say 44 mills

---

[1] Preliminary estimate by Battelle, 1st Quarter 1980 dollars.

[2] Escalation at 11.5% - 1980, 7% - 1981.

[3] Estimated at $57.2 million (1982), Beluga to Anchorage--allocated between 2 units or 400,000 kW.

[4] Includes debt service, amortization, insurance.

[5] Annual estimated production of unit per kW installed.

[6] Battelle Railbelt Alternative Study, Working Paper 1.2.

[7] Fuel escalation set at real rate of 1.5%.

TABLE 13-5

COST OF POWER PER KWH

TIDAL POWER PLANT

	(million $) Eagle Bay	Point MacKenzie	Rainbow
Total Direct Cost	$2,627	$2,902	$1,981
Engineering, Project Management 12.5%	337	363	248
Contingency 25%	672	726	495
Total Construction Cost (June 1981)	$3,696	$3,991	$2,724
Escalation to January 1982 (3.5%)	129	140	95
TOTAL CONSTRUCTION COST (January 1982)	$3,825	$4,131	$2,819
Interest During Construction 10%	383	413	282
Total Investment Cost	$4,208	$4,544	$3,101
Annual cost	193	208	142
Annual Energy (GWH)	4000	3900	2700
Production Cost mills/kWh	48.3	53.5	52.7

(1) Based on cost of capital at 3%
(2) Annual Costs (as % of Investment Costs)

Interest	3.00
Amortization	.89
O & M	.60
Insurance	.10
	4.59

TABLE 13-6

TIDAL ENERGY COSTS WITH RETIMING

	Eagle Bay	Point MacKenzie	Rainbow
Cost of Storage	1100$/kW	1100$/kW	1100$/kW
Storage needed	1200MW	1000MW	700MW
Total Cost of Storage ($\$X10^6$)	1320	1100	700
Total Project Cost ($\$X10^6$)	5528	5644	3801
Annual Cost (4.59%) ($\$X10^6$)	254	259	174
Directly Usable Energy (GWh)	1600	1560	1350
Retimed Energy (GWh)	1600	1560	900
Total GWh	3200	3120	2250
Retimed energy cost mills/kWh	79.3	83.0	77.3

TABLE 13-7

TIDAL ENERGY COSTS MILLS/KWH COMPARED WITH ALTERNATIVE

	MILLS/KWH		
	Raw Energy Production Costs	Cost if "excess" energy is wasted Usable Energy	Cost if "excess" energy is Retimed
Eagle Bay	48	121	79
Point MacKenzie	54	133	83
Rainbow	53	105	77
New Coal-Fired Plant	44	44	44
Avoided Costs of energy from existing capacity	35	47	47

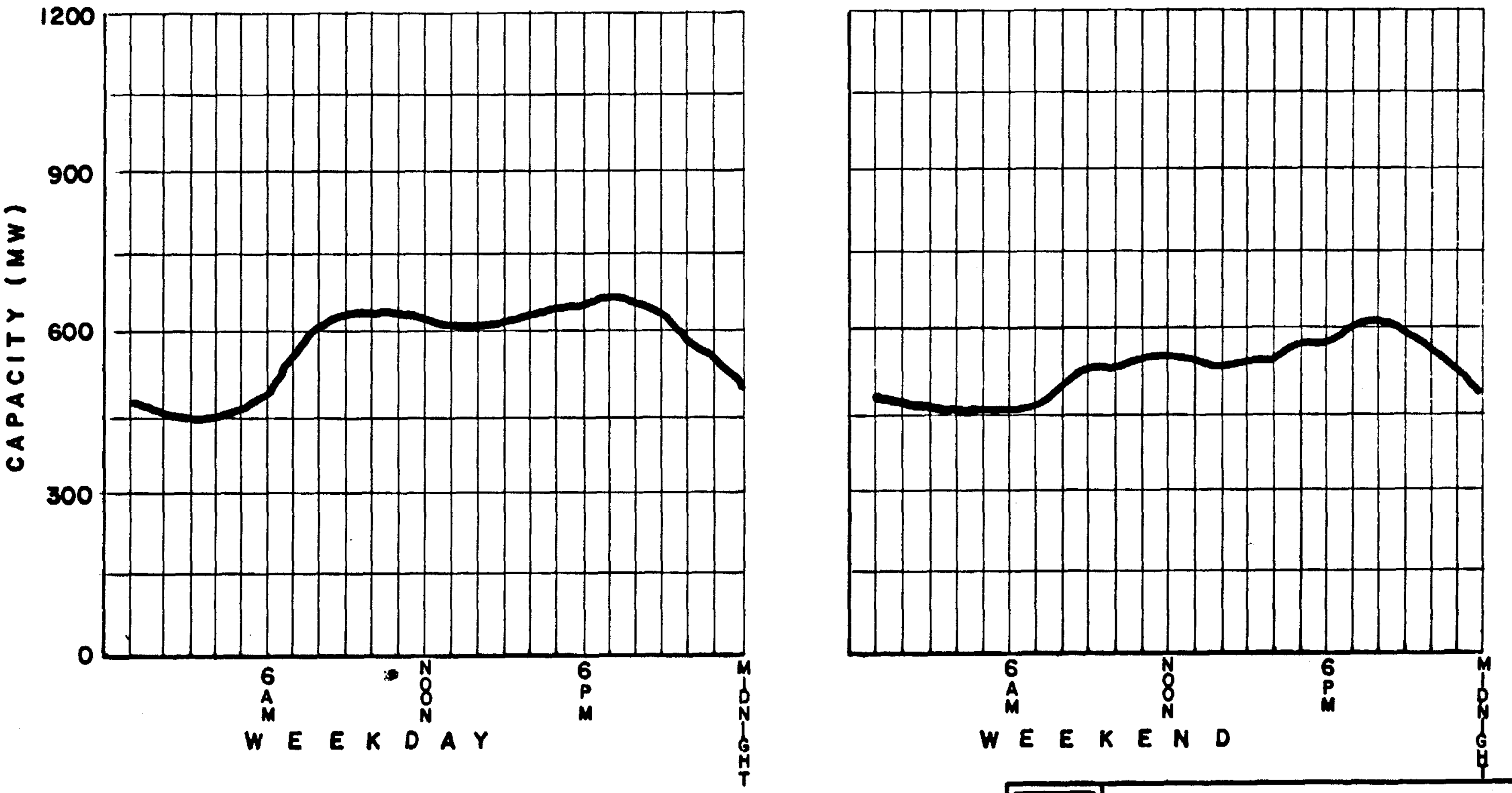
Based on cost of capital = 3%

TABLE 13-8

EFFECT OF CAUSEWAY ADDITION ON TIDAL ENERGY COSTS

	Eagle Bay	($ millions) Pt. MacKenzie	Rainbow
Tidal Project Cost ($X10^6)	4208	4544	3101
Incremental Causeway Costs ($X10^6)	29	42	22
Subtotal	4237	4586	3123
Project cost for Stand Alone Causeway [1/]	(378)	(378)	(176)
TOTAL NET COST FOR TIDAL PROJECT	3859	4208	2947
Annual Cost (4.59%)	177	193	135
Annual Energy (GWh)	4000	3900	2700
Production Cost mills/kWh	44.2	49.5	50.1
Savings in % - compared to energy from single purpose tidal plant	8	8	5
Cost with retiming	74	77	74

[1/] Estimated from prior reports-lowest cost alternatives, updated by ENR Highway cost rise index.

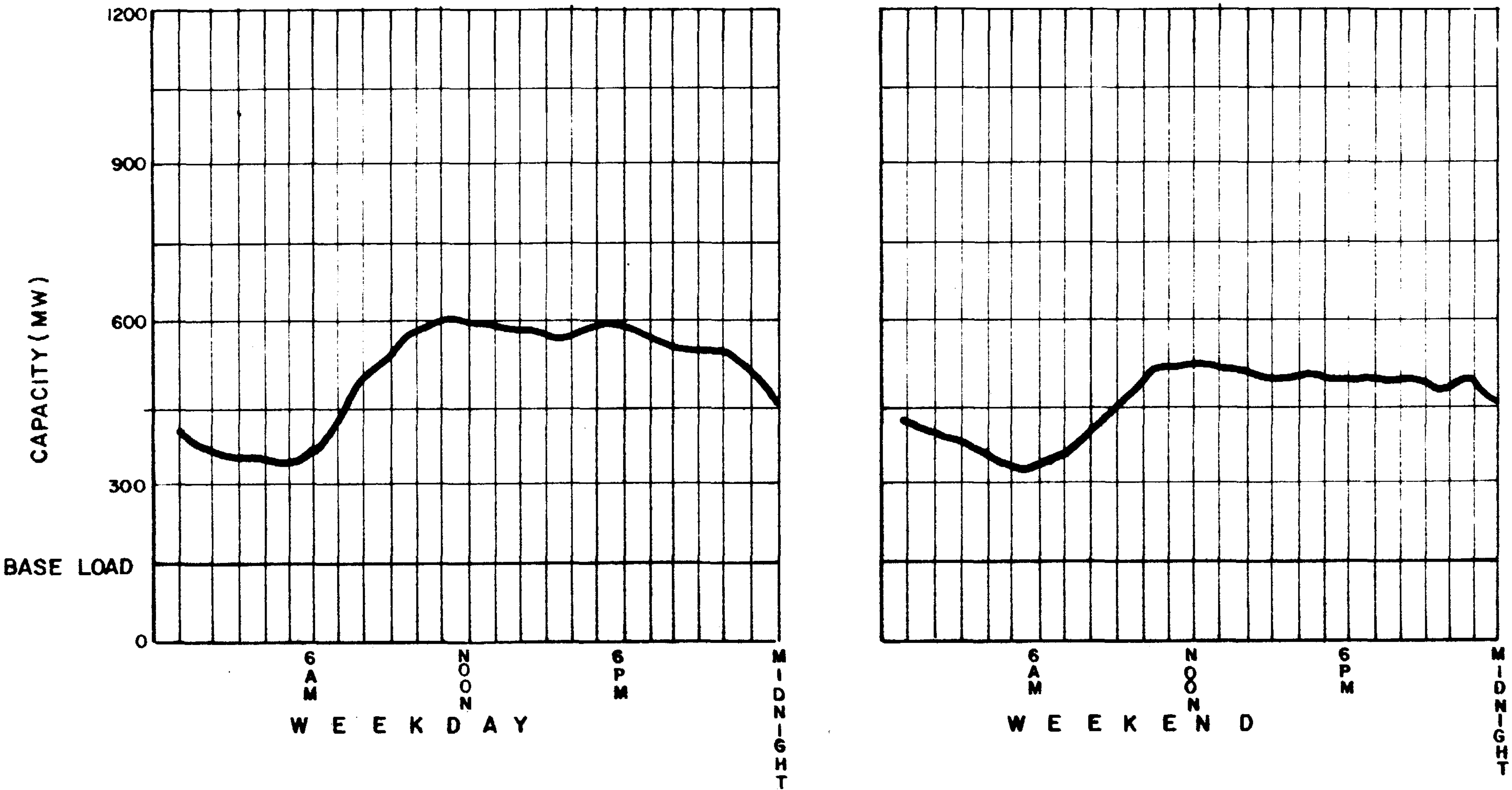


OFFICE OF THE GOVERNOR
STATE OF ALASKA
COOK INLET TIDAL POWER

1995 APRIL MEDIUM LOAD FORECASTS

FIGURE 13.1

ACRES AMERICAN INCORPORATED



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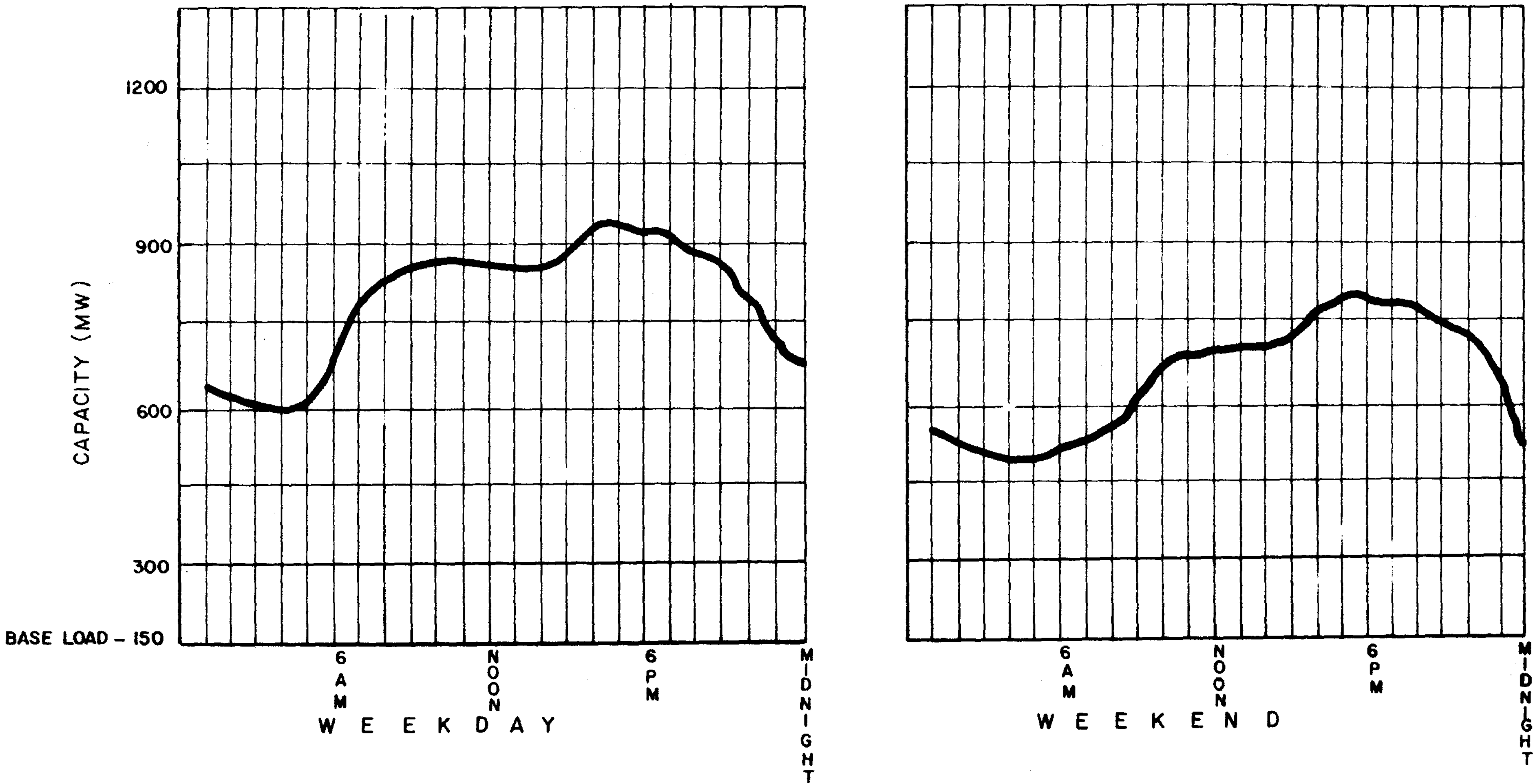
STATE OF ALASKA

COOK INLET TIDAL POWER

1995 AUGUST MEDIUM LOAD FORECASTS

ACRES AMERICAN INCORPORATED

FIGURE 13.2



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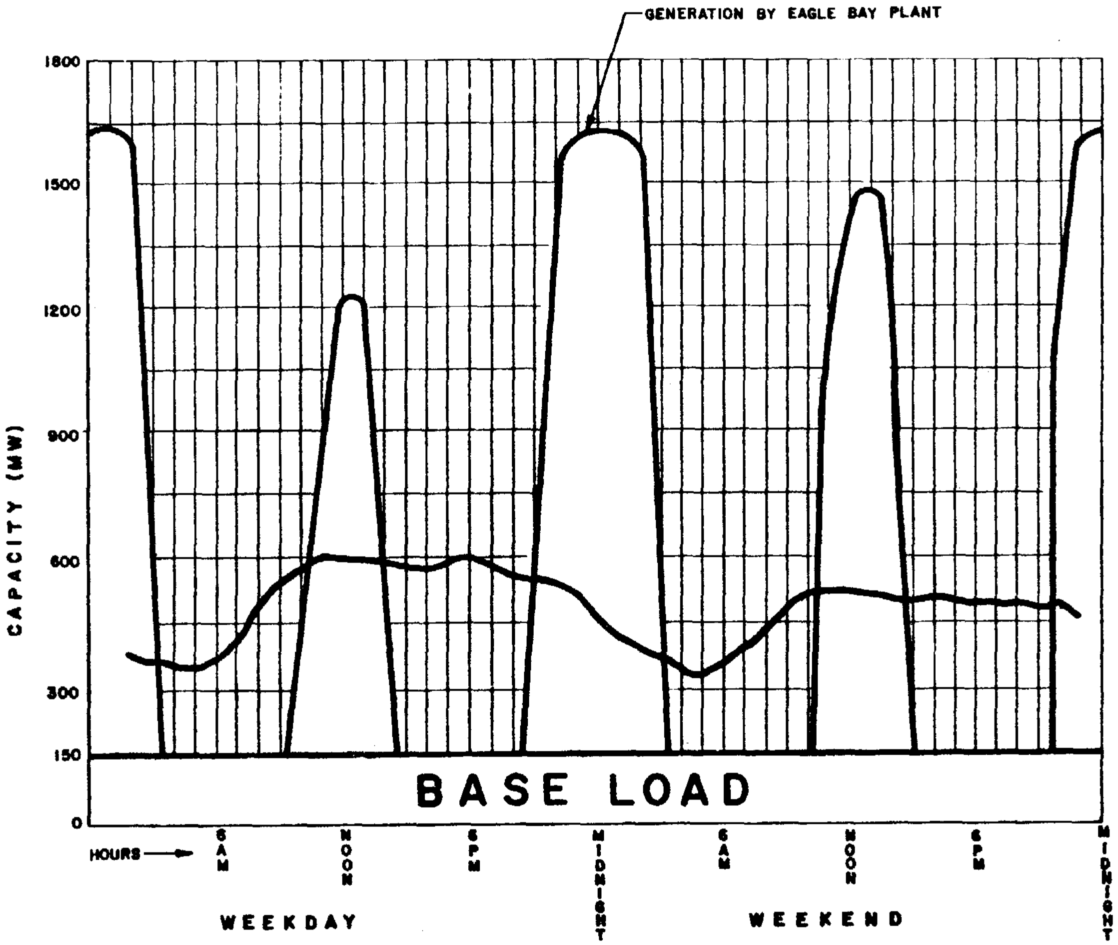
STATE OF ALASKA
COOK INLET TIDAL POWER

1995 DECEMBER MEDIUM LOAD FORECASTS

FIGURE 13.3

ACRES AMERICAN INCORPORATED



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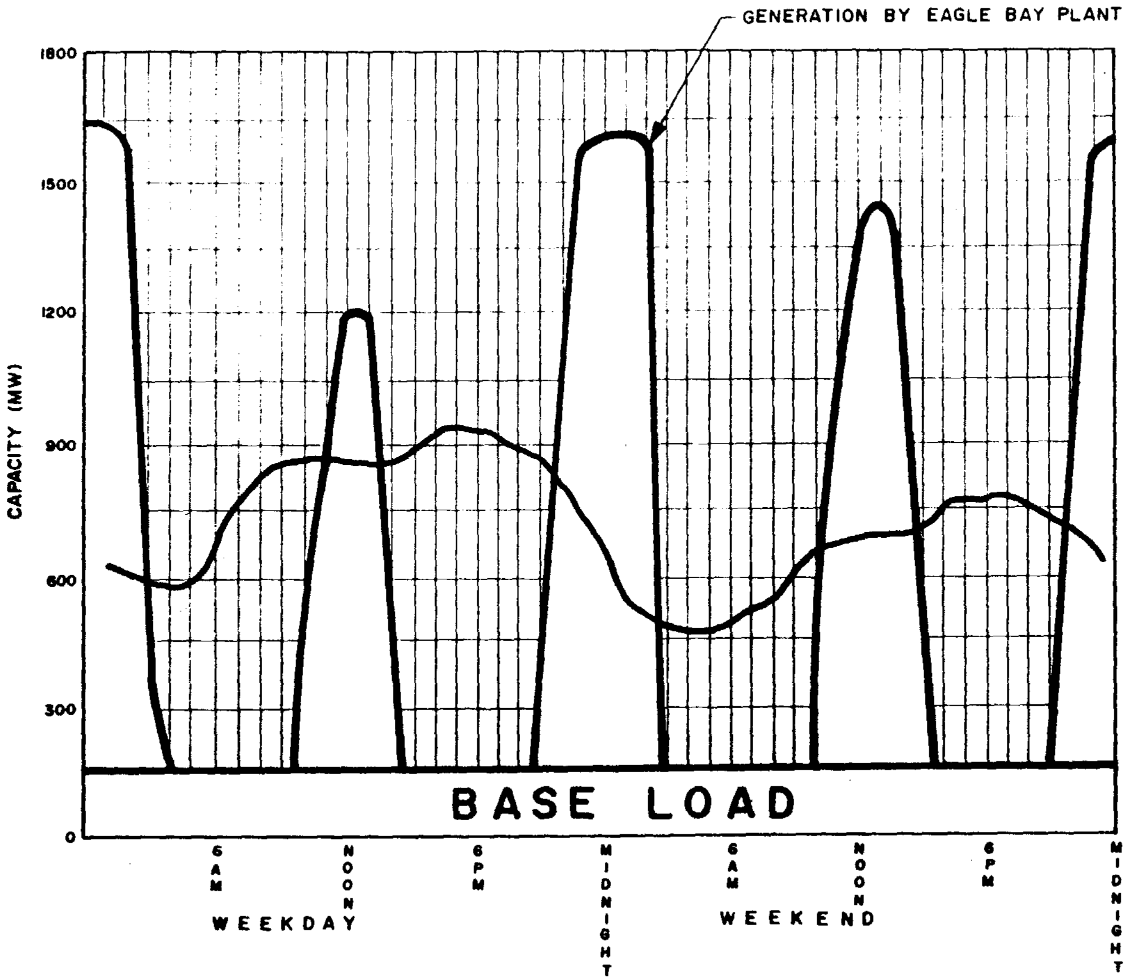
COOK INLET TIDAL POWER

EAGLE BAY GENERATION COMPARED TO
1995 AUGUST MEDIUM LOAD FORECAST

FIGURE 13.4

ACRES AMERICAN INCORPORATED



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STATE OF ALASKA
COOK INLET TIDAL POWER

EAGLE BAY GENERATION
COMPARED TO 1995 DECEMBER
MEDIUM LOAD FORCAST

ACRES AMERICAN INCORPORATED

FIGURE 13.5

APPENDIX 14 - MARKETING AND FINANCING

APPENDIX 14 - MARKETING AND FINANCING

TABLE OF CONTENTS

Page

14.1 - Objective 14-1
14.2 - Approach 14-1
14.3 - Marketing 14-2
14.4 - Financing 14-7
14.5 - Marketing and Financing Constraints 14-10

14 - MARKETING AND FINANCING

14.1 - Objective

To provide a preliminary evaluation of marketing and financing opportunities and constraints.

14.2 - Approach

Cook Inlet Tidal Power Project is being assessed as a potential source for providing electrical power supply to the Railbelt Region of Central Alaska. Any selected tidal scheme under consideration in this preliminary assessment would have an installed capacity and energy output which are large in comparison to the Railbelt Electrical System as a whole; including the eight electrical utilities, the Alaska Power Administration, defense agencies of the Federal Government, and existing industries. The marketing area for tidal power in this study is taken to encompass the two major urban areas of Alaska, Anchorage and Fairbanks, and a number of other communities with smaller, but significant demand. Military installations in the Railbelt represent an appreciable proportion of potential demand and growth as consumers of electrical energy but meet much of this from on-base generating capacity, some linked with district heating facilities in a cogeneration mode. The region would be one of the preferred locations of new industries to be established in Alaska during the rest of this century. Certain current industrial users of electrical power have their own generating plant and it is likely that this practice will continue and apply to at least some new industrial consumers. Table 13-2 presents forecasts of electrical load demand and energy consumption from 1980 to 2010 based on low, medium and high rates of growth as estimated by ISER in their studies of the likely needs of the Railbelt Region.

The potential for utilizing the output of a tidal power development in Cook Inlet to meet growing demand was examined in the previous section. This appendix now presents a preliminary evaluation of some of the marketing and financing implications of this energy source bearing in mind the inherent characteristics of:

- High capital costs of development
- Risks and uncertainties
- Intermittent and cyclical energy delivery
- Large scale of development necessary to achieve economic viability.

The first part of the appendix covers a review of the financing arrangements and marketing strategies pursued and explored at other tidal power sites, namely Passamaquoddy Bay in New England, Bay of Fundy, Canada, and La Rance, France. The second part includes a summary of marketing and financing constraints and recommendations for further detailed investigations.

14.3 - Marketing

It should be appreciated at the outset that those tidal power sites so far subjected to detailed study for potential development have been limited to those with electrical power systems having an interconnected load and system need large in comparison with plant output. This relationship requires particular consideration in relation to marketing of the tidal energy resource. It is, however, useful to review briefly the approaches used in other tidal power development studies in order to derive possible benefit from the evolution of the financing approaches and marketing strategies found appropriate over the past 60 years. As the mode of operation has a considerable bearing on the marketable output, a description of this is included for each case.

14.3.1 - Passamaquoddy

A plan for harnessing the high tides in the Passamaquoddy area to develop electric power was put forward by an eminent American engineer, Dexter P. Cooper, as early as 1919. The plan was to build dams and sluiceways in the openings into the Bay of Fundy and a powerhouse between Passamaquoddy Bay (New Brunswick, Canada) and Cobscook Bay (Maine, United States). The International Joint Commission (IJC)* selected a design arrangement that included the 101 square miles of Passamaquoddy Bay as the high pool and the 41 square miles of Cobscook Bay as the low pool, with a powerhouse located at Carryingplace Cove. The IJC plan would have provided an installed generating capacity of 300 MW, a dependable capacity** of 95 MW, and an average annual generation of about 1,843 GWh. In order to supplement the varying output from the tidal power project,

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* The International Passamaquoddy Engineering Board was appointed by the International Joint Commission to carry out the necessary investigation to answer the reference of August 2, 1956, made by the governments of Canada and the United States with the Boundary Water Treaty of 1909.

** The load-carrying ability of a system under adverse conditions for the time interval and period specified.

Rankin Rapids on the Upper St. John River in Maine was selected by the Board as the best source of firming power. The combined project would provide 555 MW of dependable capacity and 3,063 GWh of average annual generation. This plan was found by the International Joint Commission (April 1961) to be not economically feasible under the economic conditions then pertaining.

President Kennedy, by letter of May 20, 1961, requested the Department of the Interior to review the International Joint Commission's report on the International Passamaquoddy Tidal Project and the Upper Saint John River Hydroelectric Power Development.* A load and resources study made in the New Burnswick, Canada-New England areas, indicated that the Passamaquoddy Tidal Power Project would be economically feasible if developed as a peaking power plant in the magnitude of 1,000 MW instead of 300 MW as studied in the earlier IJC Report. This development would fit into the predicted future load requirements of the areas.

The plan envisioned a tidal power development at Passamaquoddy Bay and a major storage and power project at the Dickey site instead of Rankin Rapid on the Upper Saint John River. The Passamaquoddy Tidal Project would have had an ultimate installed capacity of 1,000 MW and the Dickey project an ultimate installed capacity of 750 MW. The coordinated and integrated operation of these two plants would produce 1,000 MW of dependable peaking capacity and 250 MW of dependable capacity at 60 percent load factor delivered to the load centers. The power requirements in the market areas at the anticipated time of commissioning were estimated to be 36,000 MW of which 23,000 MW would be new capacity.

The original plan was generally directed toward obtaining the greatest amount of energy from the tides. It was proposed to use two tidal pools, a high pool and a low pool. The method of operation entailed filling the high pool during high tides and emptying the low pool during low tides, the energy being generated by continuously passing water from the high to the low pool through a 300 MW power plant. The generation of the greatest amount of energy severely limits the peaking capability of the project since at times minimum generation is produced during maximum energy demands. This results from the fact that the 24-hour and 50-minute tidal cycle is out of phase with the 24-hour solar day which governs energy demand.

The two-pool plan is adaptable to a peaking method of operation. The primary consideration is that the two pools be operated to provide the maximum amount of head on the power plant turbines at the start of each peaking period. During the high tide prior to a

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* "The International Passamaquoddy Tidal Power Project and Upper Saint John River Hydroelectric Power Development," Report to President John F. Kennedy, Stewart L. Udall, Secretary, Department of the Interior, July 1963.

peaking period, the high pool is filled to the highest possible elevation. Similarly, during the low tide prior to a peaking period, the low pool is emptied to the lowest possible elevation. These pool elevations are then maintained until the start of the peaking period. Following the peaking period, off-peak or secondary energy can then be produced until the time and tides are such that the pools must be filled or emptied in preparation for the next peaking period. A similar mode of development has been considered for a Cook Inlet tidal power plant involving barrages across Knik and Turnagain Arms to Fire Island with a third structure incorporating a tidal power plant.

The basic operating plan for Passamaquoddy as a "peaking" power plant would have involved the following basic steps:

(a) Filling the Upper Pool through the filling gates to the maximum height possible from the tide

(b) Holding the water in the Upper Pool until power output is desired; then, releasing the water through the power plant to the Lower Pool

(c) Releasing the water in the Lower Pool to the ocean through the emptying gates whenever the tide is below the level in this pool.

This plan differs from the IJC plan only in the fact that water would be released as required to meet "peaks" rather than continuously to supply the base load.

The marketing area for the potential power and energy from the Passamaquoddy Tidal Power Project was extended to cover the New England States, Upper New York State, and the Canadian Provinces of New Brunswick and Nova Scotia. The proposed plan would have included development of power at Passamaquoddy Tidal project integrated with the Dickey and modified Lincoln School projects on the Upper Saint John River. The Passamaquoddy Tidal development with a two-pool arrangement would have provided substantial peaking capacity.

14.3.2 - The Bay of Fundy

A comprehensive investigation of feasibility of large-scale tidal power developments in the Bay of Fundy was initiated in 1966 jointly by the Government of Canada and the Provinces of New Brunswick and Nova Scotia. Through the Atlantic Tidal Power Programming Board it was concluded, in 1969, that tidal generation was technically feasible but uncompetitive economically with energy from alternative sources. Emphasis in that study was on dependable peak operation so as to determine the maximum power generation which could be guaranteed between 4:00 p.m. and 6:00 p.m. on weekdays during the maximum peak-demand months of December, January, and February.

The two-pool or two-basin concept was considered in the 1971 technical and economic appraisal of the Bay of Fundy, and found to provide dependable plant capacity. However, the combination of high cost of construction and reduced head available for generation rendered the concept economically unattractive at that time. Two subsequent studies by Acres Consulting Services (1971) and Tidal Power Consultants (1972) led to a better understanding of the role that tidal energy can play in an electrical system.

The significant rises in fossil-fuel prices in 1973 and later years changed the economic position of tidal energy appreciably and new studies on the Bay of Fundy were initiated in December 1975. The priority markets to be served by the Fundy Tidal Power Project were to be those served by the Maritime Integrated System (MIS) comprising the electrical utilities of New Brunswick, Nova Scotia and Prince Edward Island. Surplus tidal energy available in the short and intermediate term could be transmitted to contiguous systems of Quebec and the Northeastern United States.

The reports of the Bay of Fundy Tidal Power Review Board November 1977*, concluded that the sites in Cumberland Basin (Site A8, 1085 MW), Cobequid Bay (Site B9, 3800 MW) and Shepody Bay (Site A6, 1550 MW) would provide the best projects for development of tidal power. These were sites which would be capable of producing significant amounts of energy. Sites with potentials smaller than that for A8 were found to be uneconomical. Moreover, sites having capacities significantly less than 1000 MW was considered by the Review Board to be of limited interest to the Maritime Utilities within the time frame of the utility expansion planning programs.

It was found that single basin schemes operated for maximum energy output would offer the lowest unit costs of energy, and the primary role for tidal power in this instance was foreseen as displacemnt of energy generated by thermal plants. It would not decrease materially the role of thermal plants or of nuclear plants in meeting base load, although it would result in a net elimination in the Maritime Integrated System of oil-fired thermal generation of some 350 MW if a project at Site B9 was constructed.

The evolution of tidal power generation approaches in the Bay of Fundy region (embracing Passamaquoddy) has been influenced by the trend to consider in particular substantial sites with the highest heads available. As time has gone on, the emphasis has shifted from relatively complex arrangements and operation to justification for development based on simple single ebb flow generation with energy

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* "Reassessment of Fundy Tidal Power," Reports of the Bay of Fundy Tidal Power Review Board and Management Committee, November 1977.

output replacing fossil fuel generation on an interconnected system large enough to accommodate a tidal power addition without retiming.

14.3.3 - La Rance

In the case of La Rance in France, tidal power development proceeded in the mid-1960's with no dedicated retiming facilities, but with a plant capable of generation with ebb and flow tides. It involves a single- basin scheme with an installed capacity of 240 MW and a yearly output of 500 GWh. The powerhouse has twenty-four 10 MW reversible bulb units. Each unit is a horizontal shaft Kaplan turbine, with adjustable blades and movable guide vanes, directly connected to a generator housed in a metal bulb-shaped casing. The units can operate as turbines or pumps in either direction.

The installed capacity and the yearly output are small compared with those of other conventional hydroelectric plants in France. In 1978 La Rance ranked twenty-fifth and thirteenth in terms of output and installed capacity respectively.* The rating and energy output are small compared with those of tidal projects planned for the Bay of Fundy, Passamaquoddy and Cook Inlet.

La Rance tidal power station is operated in conjunction with hydroelectric plants having substantive storage capacity, and provides peak load generation or energy depending on tide phase and system demand relationships for peaking capacity or energy. In the French electric power system, there has been persistent demand for energy to allow replenishment of storage in hydroelectric reservoirs and pumped storage plants to enable their installed capacity to contribute reliability system requirements. With La Rance operating it this way, one fourth of the installed capacity can be considered as increasing the firm power of the system between 8 a.m. and 10 p.m. on a daily basis. The plant maintains an annual capacity factor of about 30 percent.

Viewing past tidal power experience from the perspective of Cook Inlet and Alaska, it appears that a tidal project which only offers intermittent output governed by the lunar cycle and not the demand may not be economically attractive. While the nature of generating capacity in the Railbelt Region would permit operation in close conjunction with a tidal power plant with continuously varying pulses of energy output, the saving in fuel costs of existing stations, which are capable of being off-loaded on a cyclic basis

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* "La Rance Tidal Power Station, Review and Comments," J. Cotillon, Proceedings of the Thirtieth Symposium of the Colston Research Society on Tidal Power and Estuary Management, held in the University of Bristol, April 1978.

for some hours, has to be high enough to counterbalance the relatively high investment cost for tidal power. The savings will, in all probability, have to be supplemented by a credit for firm capacity. Design and operation modes considered for Cook Inlet tidal power should therefore aim at producing at least some firm power either by retiming at site or at facilities some distance away.

Market needs will probably best be met by a combination of full replacement energy supply from the tidal power plant with the capacity value derived from:

- Linkage with a pumped storage plant
- Linkage with a compressed air energy storage plant
- Operation in conjunction with hydroelectric facilities with large reservoir storage

In regard to the latter, it should be noted that some benefit accrues from storage which can accommodate the monthly, seasonal and annual cycles inherent in tidal fluctuations.

14.4 - Financing

The development of financing and marketing strategies for tidal power development on Cook Inlet is a subject for later phases of study. At this juncture, however, it is appropriate to provide a brief summary of financing approaches suggested for tidal power project in the past, if only to identify the potential constraint that this issue implies. It should be recognized that earlier studies on Passamaquoddy and the Bay of Fundy were conducted prior to 1973 and the period of rapid price escalation in fossil fuel costs. Furthermore, studies in the 1967 - 1972 period were made at a time when substantial addition of relatively low cost nuclear capacity appeared a likely future for New England. On the other hand, the financial viability of developments dealt with in the earlier studies benefitted from the lower discount rates and longer debt repayment terms then available.

At this time, an updating of the most recent Bay of Fundy analysis (made in 1975 - 1977) is underway with the expectation that, when current financing parameters are introduced and likely future fuel cost escalation taken into account, an even more favorable benefit/cost relationship will be presented. Should this be so, then the prospects that sufficiently long-term debt financing supported by U.S. purchase power contracts may allow the Maritime Provinces in Canada to seriously consider major development.

Dealing then with past potential development, and subsequently with Cook Inlet, the following brief commentary may assist in placing tidal power project financing in its proper perspective.

14.4.1 - Passamaquoddy

The Passamaquoddy - Upper St. John project was found to be financially feasible for development in a study conducted by the U.S. Department of the Interior. Repayment of the cost allocated to power was assumed to be accomplished, with interest at 2-7/8 percent on the unpaid balance, within a period of 50 years after each power unit begins producing revenue. The cost allocated to recreation and area development would be nonreimbursable. The 2-7/8 percent interest rate was prescribed for project formulation, by the Bureau of the Budget, July 26, 1962. The financial feasibility was clearly dependent on favorable low cost government financing.

14.4.2 - Bay of Fundy

A financial analysis was undertaken in the 1976-77 reassessment of Bay of Fundy tidal power development to identify the impact of the project on cash requirements and on the annual costs which must be covered by revenues from the customers of the utilities involved in developing and purchasing energy from the project. Two methods of financing were assumed (supported by the Provinces of New Brunswick, Nova Scotia and Prince Edward Island): in one case the Maritime Integrated System (MIS) would own and operate the tidal plant, in the other, ownership and operation would be through a "stand-alone" company. Key financial parameters used in the study to calculate the cost of service of tidal power were as follows:

• Rate of interest on bonds	10 percent
• General rate of inflation as defined by the Consumer Price Index	7 percent before 1980 and 6 percent thereafter

The period of analysis extended from 1980 to 2010, covering a construction schedule for the plant of about 10 years together with the first 20 years of operation. This was considered to be the longest bond issue term likely to be acceptable to financial institutions. Major findings from the financial analysis of the Bay of Fundy Project may be summarized as follows.

The inclusion of a tidal development in the MIS generation program would create very high capital expenditure requirements during the period of construction from 1980 to 1990. This would result in very significant increases in the cost of service and the corresponding electricity rates on the system in the period starting from the commissioning of the tidal plant in 1990 throughout the first seven to nine years of plant operation.

The large costs incurred during the period of construction of a tidal development, or "front-end" costs would place a severe strain on the utilities' financing capability, and would make a tidal project unsuitable as an undertaking solely as a utility-developed energy resource. It was recognized that there would have to be an effective involvement of Federal and Provincial governments, along with the utilities, possibly through a "regional power supply agency" in developing the potential of the renewable tidal resource. The Board suggested that consideration must also be given to arrangements that would shift part of the financial burden from the years of construction and initial operation to a later period when benefits would become greater by virtue of increasing utilization and cost escalation of fossil fuels.

14.4.3 - Cook Inlet

In considering the financing of a tidal power development as an alternative means of contributions to Alaska's Railbelt electrical requirements by the end of the century, it is important to recognize several significant factors which have not been present in strong measure in earlier studies reviewed above. These are:

(a) The commitment of the State of Alaska to development, for the long-term future, of renewable energy resources

(b) The financial capability of the State of Alaska to support the undertaking in a fashion which could lessen the impact of high capital investment costs on cost of power in the earlier years of operation

(c) The potential for joint funding of a vehicular crossing of Knik or Turnagain Arms and a tidal power generating facility

(d) The possibility of coincidence of potential development of a major hydroelectric resource on the Susitna River, having substantial energy storage capacity, and a tidal power energy producing plant with a comparable output

(e) The potential for energy production, power generation, energy storage and provision of standby capacity, which would be available for hydroelectric and tidal power, interacting with the substantial amount of existing generating plant capable of cycling operation on the Railbelt system

(f) The possibility that a large-scale industrial process plant or groups of industries may have a competitive advantage in association with a Cook Inlet tidal power source.

The influence of these factors on the economic and financial viability of tidal power development in Cook Inlet deserve careful consideration in any future planning study which the State of Alaska may determine to be worthwhile. It should be observed that a major consideration will be the extent to which the existing or future

Railbelt generation system and/or industrial load reduces (or even eliminates) the need for retiming of tidal power output, particularly in the early years of its availability.

14.5 - Marketing and Financing Constraints

While constraints to marketing and financing of tidal power development should not be overemphasized, it is desirable that they be clearly identified in order that later phases of study, which may be undertaken, address the particular issues involved.

At this stage of study and for some time into the future, before detailed investigation are completed, the construction costs and demand for capital funds for a Cook Inlet tidal power plant are far from being deterministic. Investment in a facility of the type required will, furthermore, be construed to be exposed to some (or possibly substantial) risk until construction is complete and closure of the tidal barrage structure made. In this regard it should be acknowledged that risks on a tidal power project will in all probability exceed those on a large hydroelectric facility. Appropriate provisions for contingencies and for completion funds to be applied to cover those residual exposures, remaining at the project implementation phase, must be factored in to the analysis of financial viability. With this need in mind, Section 15 presents a listing of potential risks and indicated sensitivity of the project to these, both in respect of cost and operation.

Summarized here are several issues which will have a bearing, if not a constraining influence, on tidal power development in the Cook Inlet.

(a) Issues arising from cost and schedule performance on the project construction and operation.

- Relatively high capital cost of major tidal power facilities
- Impact of the relatively long schedule prior to initial power output from the project's first stage
- Risks of overrun in cost and schedule
- Staging of the project to meet an optimum construction schedule and/or optimum overall cost
- Reliability of power and energy delivery to points of load demand.

(b) Issues arising from the capital intensive nature of the project and demand on investors.

- Impacts of initially high debt service costs on costs of power

- Availability of initial and senior debt funding at reasonable rates and at terms acceptable to institutional lenders
- Conditions and convenants embedded in bond agreements which may affect minimum revenue or interest coverage
- Impact and the method of handling project cost overruns or other aberations in the base plan for its development
- Influence of tax legislation, particularly as it relates to tax exempt status of potential purchasers of energy and output.

(c) Issues arising from outside influences.

- Regulatory influences including required rate of return for utility purchasers of the output
- Influence of cost escalation on operating, maintenance and replacement costs
- Possibilities of lessened cost escalation, both in fuel charges and capital costs of construction in Alaska, of alternative energy generation sources
- Possibility of significant change in power and energy demand from that assumed in the planning scenarios.

These issues deserve careful consideration in later stages of study should the State of Alaska decide to proceed with further investigations of tidal power development in the Cook Inlet.

APPENDIX 15 - PRELIMINARY RISK ASSESSMENT

APPENDIX 15 - PRELIMINARY RISK ASSESSMENT

TABLE OF CONTENTS

Page

15.1 - Objective 15-1
15.2 - Approach 15-1
15.3 - Risk Analysis 15-2

LIST OF TABLES

Number	Title
15-1	Cook Inlet Tidal Power Risk Analysis
15-2	Cook Inlet Tidal Power Risk Analysis Proposed Investigation Programs

15 - PRELIMINARY RISK ASSESSMENT

15.1 - Objective

To identify, assess and summarize the major technical, environmental, operational, and economic uncertainties and risks associated with tidal power development on the Cook Inlet.

15.2 - Approach

The risks dealt with in this section are identified in terms of uncertainties associated with the engineering and other assumptions made in the course of the study. These uncertainties are mainly attributed to the limited preliminary information available in the several elements of the project. The effect of these uncertainties depends on the extent and the accuracy of the available information and on the relative importance of the assumptions made to the outcome of the overall project study. Other uncertainties or risks are of a "residual" nature in that they may have an impact on the ultimate operation and performance of a tidal power project.

A listing of possible risk items has been developed which covers both those risks which diminish as more and more data become available through investigatory programs and those which remain more or less undiminished but recognized by special provisions or mitigating response. The listing also identifies the consequences resulting from an incorrect assumption. The sensitivity of particular risks is identified as being either major or minor in regard to their effect on the overall project development.

The risk areas considered are:

- Regulatory Evaluation
- Geotechnical Conditions
- Civil/Structural Design Approach
- Construction Methods
- Hydraulic Evaluation - Environmental Evaluation
- System Study
- Economical Evaluation

Risk associated with mechanical/electrical design and the resulting equipment is considered minor in its effect on the project due to the fact that variation in the assumptions made for the design of such equipment would more likely lead to cost reductions and/or performance improvement, than to the opposite effects. Furthermore, low-head hydroelectric equipment has demonstrated satisfactory performance in similar hydroelectric power stations even though tidal power applications are limited.

While risks, in a negative sense, are low, the overall impact of influences arising from variation in equipment design and construction approach deserves careful study in the optimization phase of any future studies.

15.3 - Risk Analysis

Since most of the identified risk items result from insufficient preliminary information, it should be noted that further investigation of the variables affecting an assumption could in some cases lead to elimination of the risk either by verifying the correctness of the assumption or by providing sufficient backup information for more certain basis to be used at the final design stage.

Table 15-1 presents the identified risks along with the consequences, responses and sensitivity associated with each.

Table 15-2 summarizes a program proposed for further investigation required to mitigate as far as possible the adverse effects of the risk items. A brief description for each element of this program is also provided.

Risk associated with the estimated cost and schedule for the project is established based on evaluation of the sensitivity of the risk items presented in Table 15-1. Both cost and schedule are mainly affected by factors associated with construction methods, material availability, labor and equipment performance, and, to a lesser extent, by modifications to the original design resulting from updating of preliminary assumptions of hydraulic and geotechnical conditions. Factors of major effect on the total cost and schedules of this project were assigned probability risk values having, at this stage of study, a level of accuracy which must be regarded as preliminary. The values were based on the importance of the factor to the overall project development and on engineering judgment. These probability values were combined using a mathematical technique to compute the combined effect on the cost and schedule of all the factors involved. This evaluation did not take into consideration the effect of escalation, nor interest rate variation, nor any additional cost resulting from changes in licensing requirements. The estimated cost and schedule overrun resulting from the approximate probability values provisionally assigned indicate the possibility of a 25 percent variation from the base estimates.

Project economic studies have been based on a very simplified system study, commensurate with the level of this Phase I investigation. The assumptions which have been made regarding interaction with the electrical supply system, potential for energy storage and industrial demand will require careful review at the feasibility study stage. In particular, economic parameters will require updating from time to time, particularly in relation to discount rates and fuel cost escalation for alternative generating modes.

To evaluate the economics of the project, a real discount rate of 3 percent has been used consistent with Susitna hydropower studies and in line with the evaluation guidelines of the Alaska Power Authority. Caution is necessary to avoid an overoptimistic view of the attractiveness of a capital intensive energy project at this discount rate. At 3 percent real cost of capital, the energy output from a tidal project is competitive with that from alternative coal-fired plants and is also close to that applicable to the generating sources it would displace. If higher interest rates were to apply, the balance shifts fairly rapidly in favor of the existing installation and new coal-fired plants, where, furthermore, risks are substantially lessened.

TABLE 15-1

COOK INLET TIDAL POWER RISK ANALYSIS

Potential Risk Item	Preliminary Assumptions	Possible Consequences if Assumptions Not Met	Response	Potential Impact on Project Development	
				Major	Minor
Area: Regulatory Evaluation					
FERC License	Feasibility study level can adequately address key issues in project development.	Limited level of study may result in delays in FERC licensing process. Unknown environmental issues and possible changes in regulations represent largest risk.	Conduct comprehensive study to back up licensing application.	X	
Area: Geotechnical Conditions					
Geology and Geotechnical conditions	Competent foundation surface 20 ft below existing sea bed.	Revised quantity estimates for dredging. Revised foundation design of civil structures.	Detailed exploration program to determine geotechnical and geological conditions.	X	
Seismicity	Ground acceleration of 0.5g. No active fault in vicinity.	Requires improved design for earthquake safety.	In-depth analysis of fault system and seismic conditions.	X	

TABLE 15-1 (Continued)

COOK INLET TIDAL POWER RISK ANALYSIS

Potential Risk Item	Preliminary Assumptions	Possible Consequences if Assumptions Not Met	Response	Potential Impact on Project Development	
				Major	Minor
Area: Civil/Structural Design Approach					
Subsurface conditions	Assumed bearing capacity of 8 kSF.	Lower actual value could result in: -increased size of caisson and/or increased thickness of structural subbase. -increased dredging.	Detailed subsurface drilling program required.	X	
Tidal and wave variation	Differential head of 32 ft.	Higher water head would decrease stability, i.e., factor of safety. Redesign for larger caisson.	Probability analysis of tidal and wave data to determine critical conditions.		X
Seismic Conditions	Ground acceleration of 0.5 g.	Could lead to structural failure requiring major repair and reconstruction effort. Requires improved design for earthquake safety.	Seismological investigation is warranted to determine a most severe seismic event for design basis.	X	
Ice Formation	Limited consideration	Affect structural integrity and plant operation difficulty.	Initiate detailed investigation of ice formation intensity in the region and design for ice forces and impacts.	X	
Temperature effect	Limited consideration	May result in harmful stress concentrations in critical parts of the structure.	Collect and evaluate data of air and water temperature and design for temperature variations.		X

TABLE 15-1 (Continued)

COOK INLET TIDAL POWER RISK ANALYSIS

Potential Risk Item	Preliminary Assumptions	Possible Consequences if Assumptions Not Met	Response	Potential Impact on Project Development Major	Minor
Area: Construction Methods					
Construction in the wet	Established and accepted marine construction method	Could result in major changes in design and construction approach if dry construction is required.	Investigate local conditions and application of wet construction techniques and equipment in Cook Inlet.	X	
Availability of construction material	Assumed local quarries can supply material requirements	Inadequate supplies will require hauling material for longer distance thereby affecting cost and schedule.	Investigate local material sources and suitability to properly plan for cost and schedule.	X	
Winter shutdown	Asssumed four months	Longer shutdown results in longer equipment and manpower idle time. Increased cost and schedule.	Investigate and adopt suitable construction sequence.	X	
Tidal and wave variation	Differential head of 32 ft	Extreme low tide may require dredging a deeper channel to float in caissons.	Collect and review tidal records to determine extreme conditions and modify planned construction method accordingly.		X

TABLE 15-1 (Continued)

COOK INLET TIDAL POWER RISK ANALYSIS

Potential Risk Item	Preliminary Assumptions	Possible Consequences if Assumptions Not Met	Response	Potential Impact on Project Development	
				Major	Minor
Area: Hydraulic Conditions					
Bathymetry	Data Source: -Preliminary Hydraulic Survey -Turnagain Arm Report	Possible increased sedimentation. Increase frequency of dredging.	Perform additional hydrographic survey.		X
Tsunamis	Not considered at this stage. Lack of data for the region	Possibly catastrophic. Potential failure of dike.	Perform probability analysis, modify dike design.	X	
Maximum Tide	Interpolated from published NOAA data	Modification of design of major components.	Additional field data required to better define tide magnitude.	X	
Storm Surge	Used historical data to predict water level	Failure of structures due to dynamic effect of storm surge.	Collect data, determine critical storm surge magnitude, and design for the dynamic effect of the surge.	X	
Tide Current	-Assumed uniform enclosure analysis and unit placement	Fluctuation and high local velocities could complicate construction procedure.	Perform hydraulic model study.	X	

TABLE 15-1 Continued)

COOK INLET TIDAL POWER
RISK ANALYSIS

Area: Hydraulic Conditions (Continued)

Potential Risk Item	Preliminary Assumptions	Possible Consequences if Assumptions Not Met	Response	Potential Impact on Project Development	
				Major	Minor
Wave Height	Hindcasted using fetch length, unlimited duration and design wind velocity -Shoaling and refraction ignored -Deepwater behavior assumed for seaside -Non-breaking waves assumed	Adjusting height of dike and powerhouse and modify the structural design.	Shoaling and refraction analysis should be performed. Actual wave height measurement should be recorded.		X
Ice	Thickness assumed to be less because of reduced basin water level	May affect movement of individual dike armour units and hinder sluiceway and turbine operation.			X
Sediment Transport	Annual volume assumed to settle uniformly in basin	Could affect life of power plant	Perform hydraulic model analysis of sedimentation.		X
Erosion	Scour protection provided at dike and powerhouse	Dike powerhouse could fail if undermined by scour.	Scour velocities could be determined with hydraulic model.		X

TABLE 15-1 (Continued)

COOK INLET TIDAL POWER
RISK ANALYSIS

Potential Risk Item	Preliminary Assumptions	Possible Consequences if Assumptions Not Met	Response	Potential Impact on Project Development	
				Major	Minor
Area: Environmental Evaluation					
Effects of altered shoreline erosion patterns.	The alteration of the sedimentation and erosion processes may affect shoreline habitats, but - changes will occur slowly and equal amounts of land will be created and eroded - The gradual process will allow time for the biota to adapt	Large areas of biologically important shoreline could be lost.	Investigate shoreline erosion and sedimentation patterns using hydraulic model.		X
Marine disposal of dredge spoil resulting in benthic habitat destruction.	- The dredge spoil is not polluted - The dredge spoil is not chemically or biologically incompatible with the disposal area - Few habitats presently exist in either the spoil or the disposal area	Benthic habitat destruction could be locally significant.	Perform chemical and biological testing on samples from areas to be dredged		X

TABLE 15-1 (Continued)

COOK INLET TIDAL POWER RISK ANALYSIS

Potential Risk Item	Preliminary Assumptions	Possible Consequences if Assumptions Not Met	Response	Potential Impact on Project Development	
				Major	Minor
Area: Environmental Evaluation (continued)					
Decrease in aquatic/benthic productivity.	Cook Inlet presently has low productivity of resident aquatic and benthic organisms.	Cook Inlet may have a higher productivity than originally assumed, thus increasing the potential for damage due to changes.	Determine, to a greater degree of confidence, the status of the aquatic and benthic biota.		X
Environmental impacts of construction.	- Most construction impacts will be short term or local - Habitat alteration will occur in areas local to construction site - Noise and traffic effects will be limited to the construction period	Impacts could be longer term or more widespread. Habitat alteration could be permanent.	Ensure careful interface of environmental considerations with construction plans.		X
Loss of marine mammals.	- Interaction between mammals and operating equipment will be avoided by proper design of intakes, sluices, and tailraces	Damage to marine mammals could result if design is not adequate.	Ensure that design of dam structure and equipment incorporate these criteria.		X
Disturbance of endangered species habitats.	Endangered species habitats have not been identified in project area	Endangered species habitats could be disturbed if some are located within the bounds of project effects.	Field investigation of habitat types in the project area.	X	

TABLE 15-1 (Continued)

COOK INLET TIDAL POWER RISK ANALYSIS

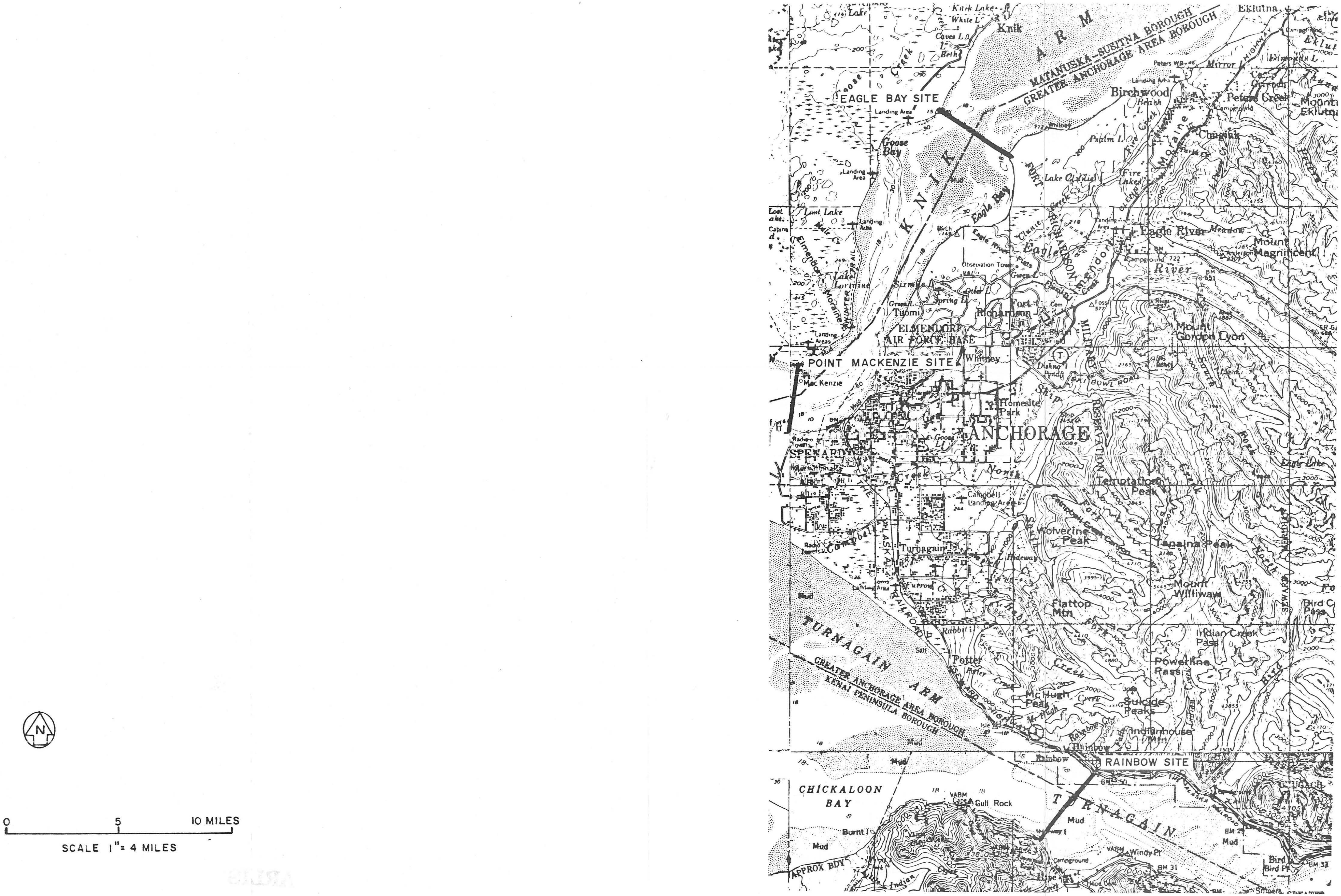
Potential Risk Item	Preliminary Assumptions	Possible Consequences if Assumptions Not Met	Response	Potential Impact on Project Development	
				Major	Minor
Area: System Study					
Impact of large project in the system.	Existing system units would go into 'moth-ball' condition or be retired with advent of large tidal project with retimed energy	Existing units would still need to be paid off, burdening rate payer with excess capacity. Utilities may be unwilling or unable to buy tidal power.	Problems need to be addressed in system study. Coordination with customer utilities should be extensive during this portion of the study.	X	
Operation of tidal plant in system.	Existing gas turbines could be cycled around tidal plant without energy storage	This could be damaging to the existing units not designed for rapid periodic cycling.	Problem should be addressed during feasibility studies. Conclusion may be that even less than 40-50% of tidal plant energy may be usable in system.	X	
Energy storage	Reasonably good sites for conventional	If sites are unaccessible, more expensive retiming	A detailed study of energy storage possibilities is necessary, including site selection studies for the most promising storage types.		
Area: Econonomical Evaluation					
Interest rates	Project has been evaluated on a real discount rate of 3%	Higher real costs of capital make project less attractive compared to using existing capacity.	Potential developer should review developmental objectives in setting interest rates.		

TABLE 15-2

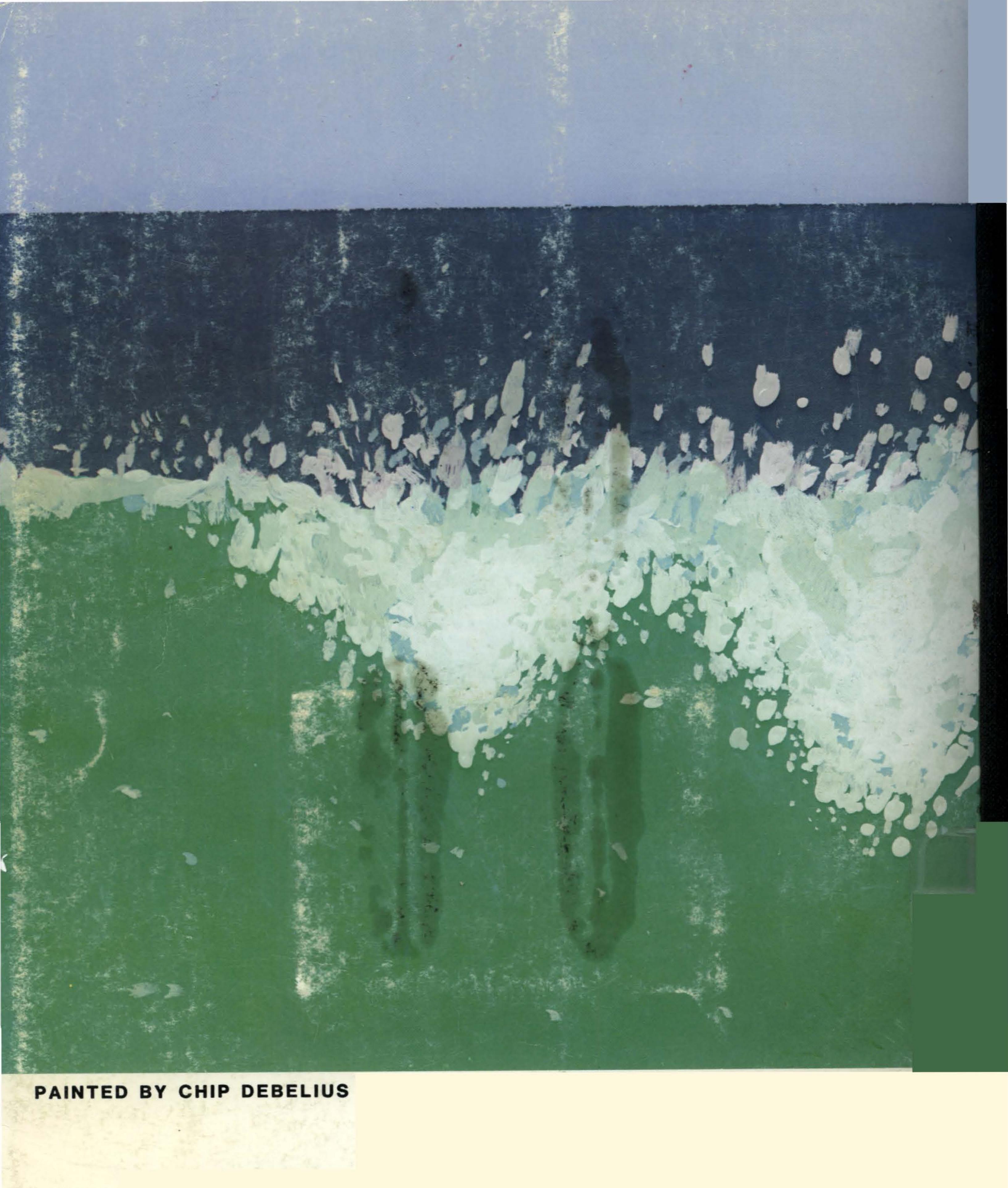
COOK INLET TIDAL POWER
RISK ANALYSIS
PROPOSED INVESTIGATION PROGRAMS

Proposed Investigation	Description of Items to be Investigated
1. Investigation of Regulatory Licensing Requirements	- Continued updating of the preliminary application - Preparation of required backup reports
2. Subsurface Exploration	- Geological conditions - Geotechnical conditions - Foundation physical parameters
3. Seismological Investigation	- Fault system - Seismic activity
4. Probability Analysis	- Maximum and minimum tides - Maximum wave height - Seismic event frequency and magnitude - Tsunami wave occurrence and magnitude
5. Investigation of Construction Approach	- Site conditions - Material sources and availability - Construction methods
6. Hydraulic Survey	- Tidal variations - Tide mode shape - Storm surge - Wave height - Shoaling and Refraction - Water temperatures
7. Hydraulic Model Studies	- Barrier effect and impact on tides - Tide current - Sedimentation - Erosion
8. Chemical and Biological Testing	- Identification of harmful chemical composition of existing material when moved to new areas - Determine presence and identify types of biological organisms - Determine presence or absence of endangered species
9. Energy Storage Study	- Storage sites - Storage type
10. System Model Study	- Capital cost - Interest rate - Escalation rates - Operation requirements

LOCATION OF SELECTED SITES



SELECTED SITES IN UPPER
COOK INLET AREA



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