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AN INVESTIGATION OF SELECTED ALASKA GEOTHERMAL SPRING SOURCES AS POSSIBLE SALMON HATCHERY SITES

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The study investigated seven thermal sites in Alaska as possible locations for a salmon hatchery to test and demonstrate geothermal energy potential in aquaculture. Each site was evaluated for physical, chemical and biological suitability. Remoteness of most of Alaska's geothermal springs complicates the application of energy/cost saving techniques, and impacts their economy. Hatcheries are seen as a key to restoring the state's dwindling salmon catches. Reducing the high costs of constructing and operating these facilities are seen as vital to a successful rehabilitation program. One site, Bell Island (located 40 miles north of Ketchikan), in Southeastern Alaska is seen as the most promising site for a demonstration salmon hatchery utilizing geothermal energy. Economic, climatological and biological considerations favor this Southeastern Alaska location.

Recent concern over possible worldwide energy shortages has generated considerable interest in developing energy resources alternative to traditional fossil fuel supplies. Geothermal energy has been identified as an alternative energy source with significant potential. Geothermal areas in the United States are found primarily in the western states associated with the circum-Pacific belt of young volcanism and mountain building (Goodwin, et al., 1971).

The nation's geothermal base is large. The potential for recoverable heat is estimated to be in the order of 4.4×10^5 Quads; an amount equal to the entire energy consumption of the United States for 50 to 100 years (ERDA, 1975). However, with present technology, only a small fraction of that total is considered recoverable. Implementation of a national geothermal energy research, development and demonstration program by the Energy Research and Development Administration (ERDA) is expected to produce 4.4 Quads annually by the year 2000 (ERDA, 1975).

The hydrothermal convective resources have thus far received the greatest actual use in the United States. These systems result from ground waters infiltrating heated rock formations, and represent a relatively small portion of the total geothermal resource base. Present uses of geothermal energy consist of electric power production (via steam turbine) and non-electric applications, mainly space heating.

Alaska contains numerous and widely scattered geothermal resources. The occurance and characteristics of more than 94 Alaskan thermal springs have been documented since 1917.

However, the utilization of these thermal springs has been quite limited. Early prospectors and settlers in the Alaskan interior used some of these hot springs for bathing, space heating, hot tap water, and agriculture. Most of these early settlements have since been abandoned.

The purpose of our study was to investigate selected thermal spring sites in Alaska as possible locations for the construction of a salmon hatchery to test and demonstrate the potential applications of geothermal energy in salmon aquaculture. The study, a joint project of the Alaska Division of Energy and Power Development and the Department of Fish and Game, was conducted from January 1977 to September 1977.

A complete review of existing information on Alaskan thermal springs attempted to identify candidates for hatchery sites. Limited funding precluded a survey of all geothermal sites. The location of candidate springs relative to existing common property fisheries, accessibility, land availability, logistical considerations, availability of construction material, fisheries management requirements, "existence of adjacent non-thermal water supplies", and suitability of release areas are factors that were used to further evaluate the potential of candidate springs as hatchery sites.

Seven sites were investigated by biologists from the Alaska Department of Fish and Game (ADFG) and engineers contracted from Dames and Moore (Map 1). The sites finally selected for evaluation are: (1) Akutan, in the Aleutian Islands; (2) False Pass, on the Alaska Peninsula; (3) Port Moller, on the Alaska Peninsula; (4) Mother Goose Lake, on the Alaska Peninsula; (5) Ophir Creek, in the Kilbuck Mountains northeast of Bethel; (6) Bailey, North of Ketchikan in southeastern Alaska and (7) Bell Island, also north of Ketchikan. The Bell Island location appears to be the best candidate for a pilot hatchery program utilizing geothermal energy. (Map 2).

Near term utilization of Alaska's geothermal springs is dependent to a large degree on developing non-electrical applications which produce usable commodities at remote sites.

Alaska's salmon fisheries have historically been an extremely valuable resource representing a major segment of the State's economy. In recent years the total value of salmon landings to commercial fishermen varied from $24.6 to $67.9 million annually (Table 1).

However, the total catch of salmon in Alaska has undergone drastic reduction the last 5 to 6 years. The reasons for this decline are complex but related mainly to past over fishing, recent severe climatic conditions, and habitat alternation. This decline in salmon abundance has stimulated major efforts towards rehabilitation and enhancement of these fisheries by the State of Alaska.

Hatcheries and other artifical propogation techniques will play key roles in the restoration effort. Current plans call for the expenditure of upwards of $500 million of public and private funds through 1990 for hatchery construction in Alaska.

The rationale behind this expenditure is the greater overall survival rate of early freshwater life history stages of salmon in hatcheries as opposed to corresponding survival in the natural environment. Except for certain isolated land-locked populations of red or sockeye salmon, all five species of Pacific salmon are anadromous. The salmon's early life history stages are spent in fresh water, with a subsequent migration to the ocean where they mature. Completion of the life cycle occurs with a return to natal streams to spawn.

Alaska's harsh climate severly restricts survival of the early life history stages of salmon. Estimates of mortality from the egg to fry stage of development in the natural environment versus hatcheries are variable but generally indicate that hatchery survival is 5 to 8 times greater than corresponding natural rates. This is the direct result of the ability to control the hatchery environment. Natural variables (For example,freezing, predation, dewatering, flooding, siltation, low oxygen levels) are responsible for the mortality of salmon eggs. Higher survival rates of salmon in hatcheries necessitates fewer spawners and corresponding greater numbers of fish are available for commercial harvest.

The process of propagating salmon in hatcheries, release to graze at sea, and harvesting either in an ocean fishery or upon return to their natal stream has been termed ocean ranching. It is an efficient method to produce large amounts of high quality, low cost animal protein.

Heating water solely for hatchery use is expensive, utilizes valuable fossil fuel resources, and increases the cost of fish production. Fuel costs in rural Alaska range from $1.00 to $2.75 per gallon with fuel transportation logistics often complicated by early freeze-up and late spring thaws. For example, the Crystal Lake hatchery near Petersburg in Southeast Alaska heats hatchery waters using heating fuel. Annual heating costs exceed $80,000 per year. Economical heat sources are available as waste industrial heat and thermal springs. Industrial cooling water is now used to produce coho and king salmon in Alaska. There is limited potential for use of this concept, however, since many future hatcheries must be located in remote areas of the State. To date, the application of geothermal energy to salmon aquaculture has not been demonstrated in the State.

Geothermal energy could play a major role in developing Alaska's hatchery program for coho and king salmon. Natural water temperatures in most of Alaska are too low during long winter periods to successfully operate hatcheries where overwinter rearing is required. Optimal growth and conversion efficiency for coho salmon occur when water temperatures are in the 10-15^{o}C range. Growth is negligible below 4.5^{o}C.

A viable hatchery program for coho and king salmon is dependent upon producing smolt in a single growing season. Subjecting fish to longer periods of hatchery residency increases their susceptibility to disease-related mortality. The greater food conversion efficiencies associated with increased survival to smolt size are instrumental factors in developing a salmon hatchery operation having favorable cost/benefit ratios.

Another potential use of geothermal energy for salmon production is the use of thermal spring water to operate less costly hatcheries producing non-rearing pink (O.gorbuscha) and chum salmon (O. keta) species.

Construction costs in Alaska are high. Current construction costs of an 80 X 96 foot hatchery building designed to produce 10 million salmon fry from substrate incubators in a remote area of Alaska are in excess of two million dollars. Building maintenance and heat costs associated with this type of operation substantially increase the cost of salmon produced. Direct or indirect application of thermal spring water could result in the development of a more cost effective system producing large number of pink or chum salmon.

The joint investigation was divided into three phases. The major objective of the Phase I portion was to determine the potential of Alaskan geothermal resources for salmon aquaculture. Phase II would be the construction of a demonstration salmon hatchery; and Phase III is operation and evaluation of the facility.

Phase I tasks included:

> A survey of selected thermal springs to determine those producing sufficient quantities of water and heat to permit hatchery operations with favorable cost/benefit ratios;
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> Analysis of water quality to determine suitability of direct heat transfer or the necessity of heat exchangers and identify availability of non-thermal water supplies of sufficient quantity and quality;
>
> Determination of the suitability of promising thermal sites for hatchery construction by evaluating physical site characteristics, accessibility, engineering, economic, and environmental considerations, and;
>
> Categorization of potential sites by evaluating type of aquaculture operation in relation to the quality and quantity of fish production potential, and maximum anticipated economic, social and environmental benefits.

Because of unusually good weather conditions during the field work portion of the study, unused funding has been earmarked for further engineering and biological investigations at Ball Island.

Initial analyses included a topographic evaluation of the sites. Aerial photographs were available for only the False Pass, Port Moller, Bailey, and Bell Island sites. Topographic information is lacking for much of the Akutan and False Pass sites. These two areas are only partially covered by U.S. Geological Survey topographic maps and U.S. Coast and Geodetic Survey nautical charts.

Field surveys were conducted at selected sites to collect physical, chemical, and biological data during the period of 19 May 1977 to 8 June 1977. Field investigations were conducted by a hydrologist/engineer and fisheries biologists. The following tasks were performed at each site:

1. Inspection of the hot spring(s)including measurement of flow and temperature.

2. Assessment of surface and subsurface water supplies and gauging of freshwater streams with a current meter.

3. Manual excavation of test pits to investigate subsurface soil conditions.

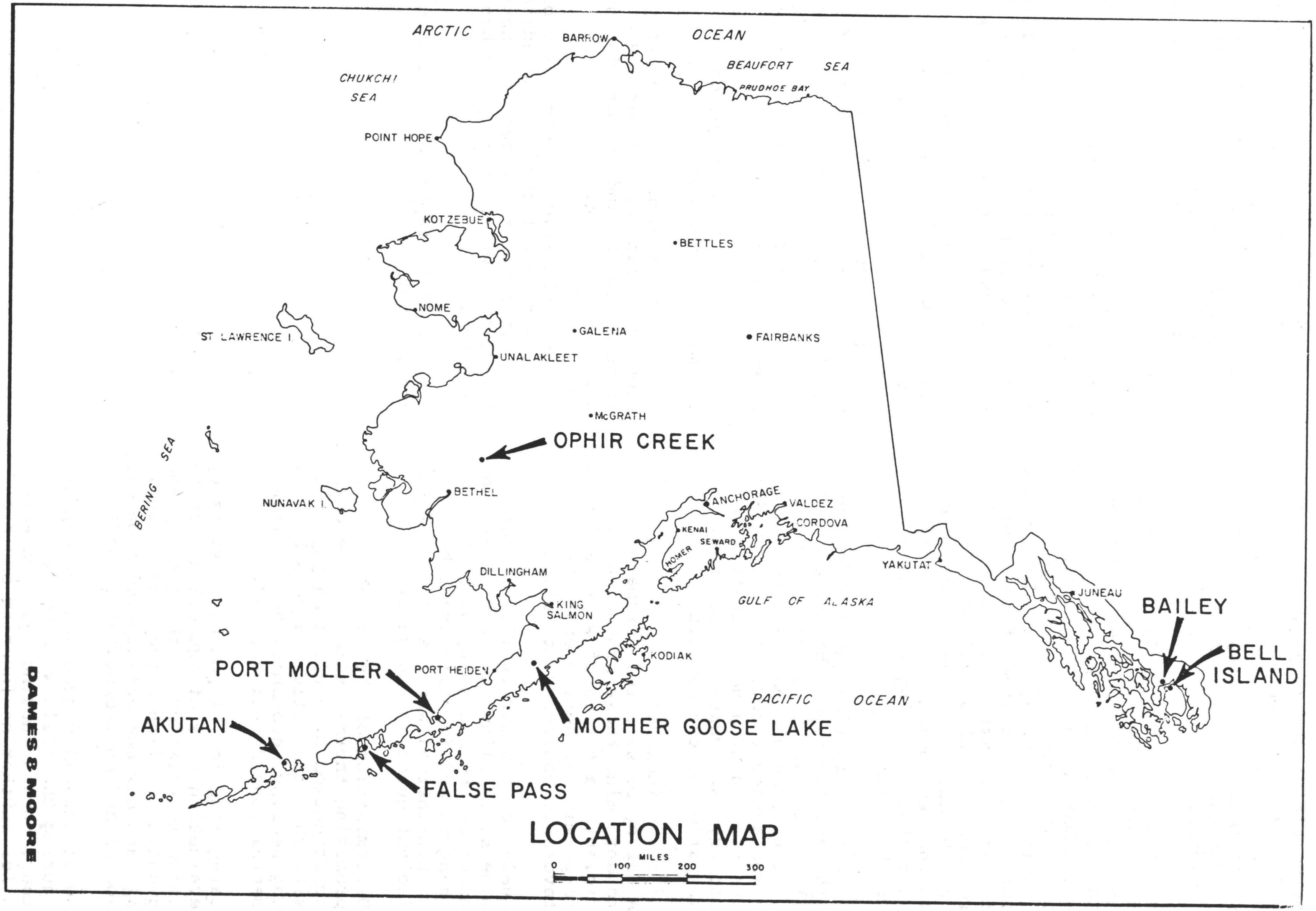
4. Identification of potential building material sources.

5. Estimation of engineering factors such as surface and subsurface drainage, slope steepness and aspect, and depth of soil over bedrock.

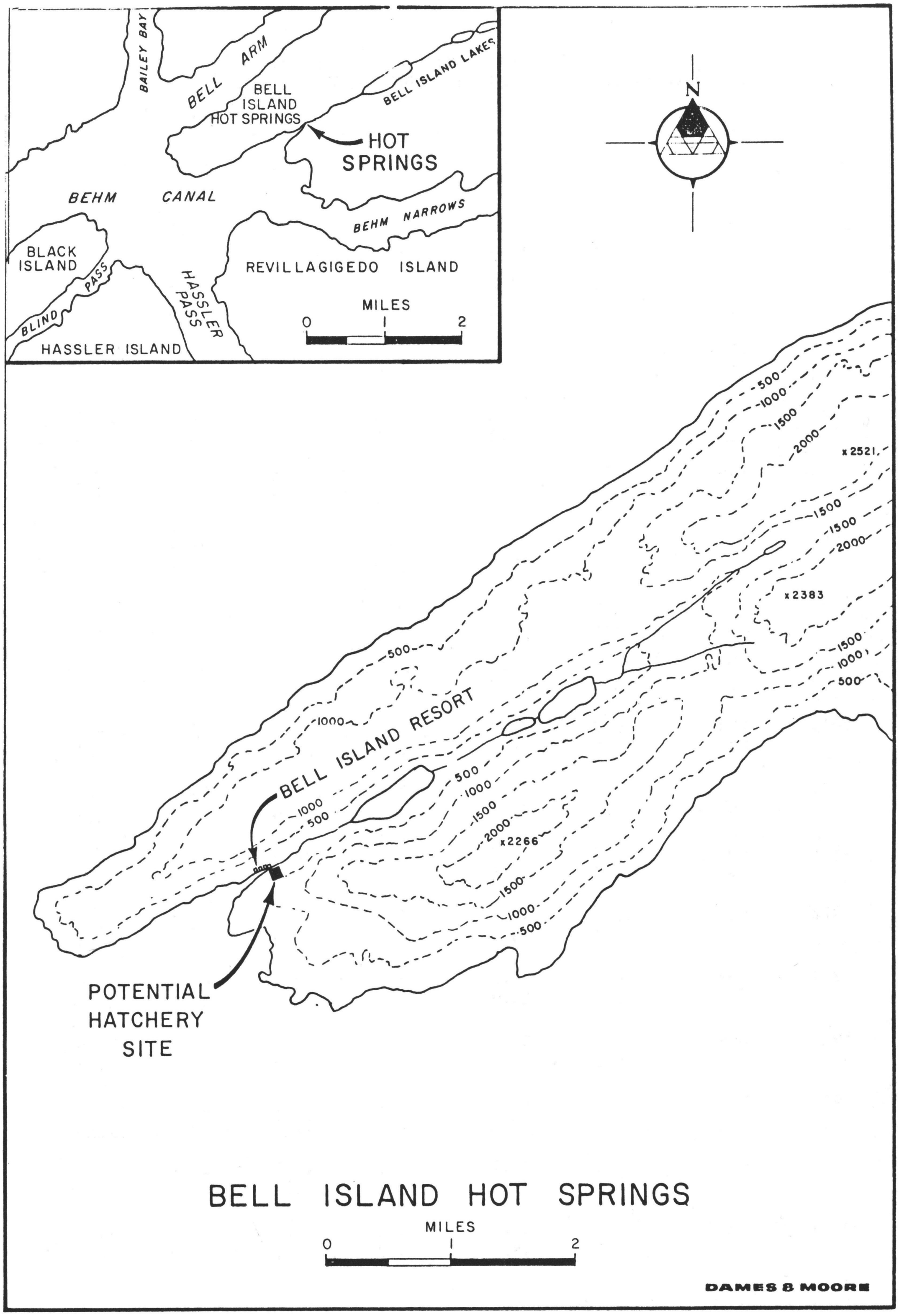
6. Collection of eater and biological samples from hot springs and adjacent surface fresh water sources for laboratory analysis of water quality and habitat assessment.

7. Photographic documentation of site conditions.

MAP NO. 1



LOCATION MAP


BAILEY BAY
BELL ARM
BELL ISLAND HOT SPRINGS
BELL ISLAND LAKES
HOT SPRINGS
BEHM CANAL
BEHM NARROWS
BLACK ISLAND
BLIND PASS
HASSLER PASS
REVILLAGIGEDO ISLAND
HASSLER ISLAND
MILES
0
1
2
N
500
1000
1500
2000
x 2521
x 2383
x 2266
BELL ISLAND RESORT
BELL
POTENTIAL HATCHERY SITE
BELL ISLAND HOT SPRINGS
MILES
0
1
2
DAMES & MOORE

MAP NO. 2

Table 1. Fifteen year comparative salmon catch summary, Alaska, 1961-1975. Data are reported in millions (ADFG 1975).

Date	Item	Kings	Reds	Cohos	Pinks	Chums	Total
1961	Lbs.	8.5	95.2	11.4	103.5	46.1	264.7
	$	2.2	17.5	2.0	10.1	3.8	35.6
1962	Lbs.	8.7	52.9	15.3	143.3	57.7	277.9
	$	2.7	11.1	3.2	20.3	4.8	42.1
1963	Lbs.	9.2	35.5	17.6	125.1	35.7	223.1
	$	3.1	7.6	3.0	14.5	3.0	31.2
1964	Lbs.	11.6	54.1	21.0	162.3	62.7	311.7
	$	3.7	12.2	3.6	17.2	4.7	41.4
1965	Lbs.	11.0	142.0	17.7	74.9	29.3	274.9
	$	3.0	30.8	4.4	7.7	2.4	48.3
1966	Lbs.	9.4	92.8	16.1	162.9	52.2	333.4
	$	2.9	19.7	3.7	22.1	5.7	54.1
1967	Lbs.	11.6	53.5	13.0	28.8	31.5	138.4
	$	3.1	11.9	3.3	3.2	3.1	24.6
1968	Lbs.	11.2	48.7	21.0	148.4	55.9	285.2
	$	3.9	12.7	5.4	20.5	7.0	49.5
1969	Lbs.	10.7	71.7	8.0	106.0	22.7	219.1
	$	3.5	18.0	2.2	15.7	2.9	42.3
1970	Lbs.	11.5	150.8	11.9	117.7	54.5	346.4
	$	5.0	37.2	3.5	15.6	6.6	67.9
1971	Lbs.	12.0	87.3	11.5	86.3	54.7	251.8
	$	4.7	22.8	2.8	13.5	7.5	51.3
1972	Lbs.	10.0	42.0	13.0	60.0	64.8	189.8
	$	3.7	13.2	5.6	10.9	11.9	45.3
1973	Lbs.	8.9	35.2	9.8	36.6	45.9	136.4
	$	7.9	15.3	7.5	11.7	17.7	60.1
1974	Lbs.	9.3	32.2	12.8	40.1	37.2	131.6
	$	6.9	22.1	8.7	13.9	14.0	65.6
1975	Lbs.	6.9	42.8	7.1	50.0	30.8	137.6
	$	5.3	19.2	4.2	16.0	10.5	55.2
Total	Lbs.	150.5	1036.7	207.2	1445.9	681.7	3522.0
	$	61.6	271.3	63.1	212.9	105.6	714.5
Mean	Lbs.	10.0	69.1	13.8	96.4	45.5	234.8
	$	4.1	18.1	4.2	14.2	7.0	47.6

TABLE NO. 1